US Army Corps
of Engineers
Chicago District

INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING
AND
DISPOSAL ACTIVITIES

EPA

INH 4.00

Argonne National Laboratory
FUSRAP Project Document
Indiana Harbor
P-98017

COMPREHENSIVE MANAGEMENT PLAN

VOLUME 2 OF 2

TECHNICAL APPENDICES

SEPTEMBER 1998

COMPREHENSIVE MANAGEMENT PLAN
INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES

VOLUME 2 OF 2
TECHNICAL APPENDICES

List of Appendices

INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL

APPENDIX A

COORDINATION LETTERS SINCE JANUARY 1990

U.S. ARMY CORPS OF ENGINEERS
CHICAGO DISTRICT
111 NORTH CANAL STREET
CHICAGO, ILLINOIS 60606-7206

APPENDIX A
INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL

COORDINATION LETTERS SINCE JANUARY 1990

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TELEPHONE OR VERBAL CONVERSATION RECORD

For use of this form, see AR 340-15; the proponent agency is The Adjutant General's Office.

DATE 3/2/90

JECT OF CONVERSATION IDNR Comments on Indiana Harbor Dredging

INCOMING CALL

PERSON CALLING Steve Josy	**ADDRESS** IDNR, Env. Review Coord.	**PHONE NUMBER AND EXTENSION** 317-232-4070
PERSON CALLED Paul Whitman	**OFFICE** CENCC-PD-S	**PHONE NUMBER AND EXTENSION** 353-7795

OUTGOING CALL

PERSON CALLING	**OFFICE**	**PHONE NUMBER AND EXTENSION**
PERSON CALLED	**ADDRESS**	**PHONE NUMBER AND EXTENSION**

SUMMARY OF CONVERSATION: Mr. Josy called me in response to a phone conversation on 3/1/90, regarding their agencies' comments on the Indiana Harbor dredging project. He stated he was unable to locate the file and requested I send him copies of previous correspondence. He also said he would talk to Roger Hedge about the project. I stated I would send him copies of all pertinent correspondence today. I put this in the mail immediately after getting off the phone.

Paul Whitman
Ecologist, CENCC-PD-S

DA FORM 1 APR 66 751 REPLACES EDITION OF 1 FEB 58 WHICH WILL BE USED.

☆U.S. G.P.O. 1983-381-546/8225

INDIANA DEPARTMENT OF NATURAL RESOURCES **PATRICK R. RALSTON, DIRECTOR**

Division of Outdoor Recreation
605 State Office Building
Indianapolis, Indiana 46204
317-232-4070

September 12, 1990

Mr. Philip R. Bernstein, Acting Chief
Planning Division
Chicago District Corps of Engineers
219 South Dearborn Street
Chicago, Illinois 60604

Re: Energy Cooperative, Inc. disposal site for the Indiana Harbor dredging and confined disposal facility project; Lake County

Dear Mr. Bernstein:

The above referenced proposal has been reviewed by the Indiana Department of Natural Resources and the following comments are offered for your information.

In general, the IDNR has received no scientific data to change its basic position outlined in our response the Draft Environmental Impact Statement. Considering the toxicity of the material and valid concerns about the long term structural integrity of a confined disposal facility located in Lake Michigan, our agency still prefers an upland site.

The proposed site appears to be a favorable alternative. Its close proximity to the dredging site would help minimize the hazard of moving contaminated sediment over a long distance. Since it is an abandoned refinery, however, it should be investigated for possible contamination. Any further approval will depend upon the results of that investigation.

The IDNR has no objection to the dredging of the canal system outside of the Federal navigation channel, provided adequate sediment testing occurs. We would recommend that extensive sampling take place due to the occurrence of hot spots of polychlorinated biphenyls (PCBs) in the canal. Their toxicity justifies more stringent sampling procedures than what would normally be required.

Our agency recognizes the problem with the Calumet River/Indiana Harbor and Canal System and is willing to work with the Corps to develop a method for removal of the contaminated sediments with minimal environmental risk.

We appreciate this opportunity to be of service and apologize for not being able to respond to your inquiries sooner on this matter. If we can be of further assistance, please do not hesitate to contact me.

Sincerely,

for Patrick R. Ralston, Director
Department of Natural Resources

PRR:SHJ

cc: IDEM, Division of Water Management, Indianapolis, IN
U.S. EPA, Region 5, Aquatic Resources Section, Chicago, IL
U.S. Fish and Wildlife Service, Bloomington, IN

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

REPLY TO ATTENTION OF:

JAN 29 1991

Mr. Richard Carlson, Chief
Planning Section
Department of the Army
Chicago District, Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

Dear Mr. Carlson:

We have reviewed the Preliminary Draft Environmental Impact Statement (EIS) for Indiana Harbor, Indiana. The purpose of the EIS is to evaluate several options on the disposal of contaminated dredge material from the Federal navigation channel. The amount of material to be dredged is approximately one million cubic yards. In terms of disposal sites the following locations have been identified as possibilities: Inland Steel Landfill, 141st Street in Hammond, Indiana, J-pit site in Gary, Indiana, and ECI in East Chicago, Indiana. A series of advanced technologies were investigated in connection with the disposal of dredged material. These advanced technologies were ranked through the use of a series of criteria. Four of these alternatives were discussed in detail. These alternatives are solidification and stabilization, solvent extraction, incineration, and wet air oxidation. The dredging options that would be used consist of mechanical and/or hopper dredging. Our Agency has several concerns with the proposed project. These concerns are the volatilization of contaminants, uncovering of contaminants, alternative site selection, presents of polychlorinated biphenyls (PBC's), and classification of dredge material. Our recommendations include deeper dredging, dredging outside the navigation channel, and post project monitoring.

Our concerns regarding air quality impacts center on the release of organics to the atmosphere. Any alternative selected will increase or enhance the concentrations of organic, and inorganic compounds in the air. This increase in concentration could create potential health impacts. This concern is greater for specific actions or activities associated with dredging and incineration. In terms of dredging, increased concentrations will occur with intermediate stage prior to disposal. The intermediate stage is considered to be the exposure of dredge material during operations, transportation, and storage in the Confined Disposal Facility, until permanently covered. If these types of alternatives are chosen, we suggest that some type of screening level analysis be performed. In addition, the use of thermal treatment (incineration) can cause organic compounds, particulate matter, dioxin, and furans to be emitted into the air pathway.

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If this option is pursued, we recommend that a more detailed evaluation of impacts to the public health, the Great Lakes, and the environment be assessed.

Regarding the concentration levels of sediment that will be exposed, the EIS must provide further discussions on post project monitoring, alternative of deeper dredging, and dredging of side channels. The increase in depth and/or additional dredging would expose the clay layer and/or remove side channel sediment. The environmental benefits would include the reduction of pollutant loadings to the Great Lakes, improved sediment and water quality, and could possibly increase in the diversity of aquatic wildlife. Therefore, overall these alternatives would increase the environmental benefits for the project area. If additional dredging is not pursued, post project sampling should be performed. This post sampling of the channel should be done quarterly after dredging operations have stopped. This sampling would investigate whether the newly exposed contaminated sediment is being covered by a cleaner layer. This study would also require the knowledge of the rate of sedimentation. The goal of the study would be to determine whether the cleaner material was moving downstream to cover contaminated sediments.

On page 17, the EIS identifies the ECI site as a former petroleum refinery. This refinery has Resource Conservation and Recovery Act (RCRA) interim status for the storage and treatment of hazardous waste. The closure plans for the hazardous waste units at the facility were never submitted. Therefore, these units were not formally closed under RCRA. This site is still technically subject to corrective action authority under RCRA. The RCRA corrective action would require the cleanup of any residual wastes or hazardous constituents that were released during routine operations, systematic releases during production and/or hazardous or solid waste management. The environmental impact statement must address the measures that will be taken to assure proper cleanup and compliance with RCRA.

Pages 9, and 10 of the EIS addresses pollutants or contaminants in the sediment. Section 40 CFR 262.11 requires the testing of generated wastes if the generator has reason to believe the wastes could be hazardous. The sediments should be analyzed for the possible demonstration of RCRA characteristics. The sediments should be evaluated using Toxicity Characteristic Leaching Procedure (TCLP) and also compared to the RCRA lists of wastes being subject to it. Furthermore, if any of the technology alternatives that would alter the characteristics of the sediment are chosen, then those sediments would have to undergo TCLP testing. This testing would determine whether their character has been altered to make them subject to RCRA.

The EIS needs to provide additional discussion on the migration of PCBs. This discussion should provide concentrated focus on the impacts that would be caused by dredging and storage of dredge material that has PCBs present. This dialogue must address in detail the controls that will be used to contain the PCBs. The potential impacts to surface and groundwater quality, from dredge plumes, and storage of material need to be included in this dialogue. In addition, a risk assessment should be conducted to determine the potential impacts to human health in relationship to the environment from all sources.

Our Agency has taken six sediments samples from the Indiana Harbor Canal. The preliminary results show that one of these samples has failed the TCLP test. At this time, we are currently completing our evaluation. We understand that your agency's regulations do not consider dredge material to be solid waste. The Federal Code of Regulations definition of solid waste includes dredge material. Therefore, depending on the results of these tests, our Agency may consider this dredge matter as RCRA material. If this is the case, the disposal of the material will have to meet RCRA guidelines.

Your agency has made a request of our Agency to become co-lead agency on the proposed project. Our Agency is interested in this possibility. We would appreciate a meeting with your agency to discuss the merits of this request. We will be contacting you to arrange for a meeting.

Thank you for the opportunity to comment on the Preliminary Draft EIS for Indiana Harbor. If you have any questions or comments, please contact Al Fenedick at 886-6872.

Sincerely yours,

William D. Franz

William D. Franz, Chief
Environmental Review Branch
Planning and Management Division

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, CORPS OF ENGINEERS
111 NORTH CANAL STREET
CHICAGO, ILLINOIS 60606-7206

REPLY TO
ATTENTION OF

CENCC-PP-PM (1165)

31 May 1991

MEMORANDUM THRU U.S. Army Corps of Engineers, North Central
Division, ATTN: CENCD-OC, 536 S. Clark St.,
Chicago, IL 60605-1592

FOR Department of the Army, HQ, U.S. Army Corps of Engineers,
ATTN: CECG-OC (John J. Mahon), Washington, DC 20314-1000

SUBJECT: Indiana Harbor and Canal CDF Study, Environmental Laws/Regs and Policy Issues

1. References.

a. Federal Register, 24 March 1986, p. 10168.

b. Federal Register, 2 April 1991.

2. Background.

a. The Indiana Harbor and Canal navigation project was authorized by the River and Harbor Act of June 25, 1910 and subsequent acts. No local sponsor is required for the maintenance of this project. This project has not been maintained since 1972, due primarily to the siting problem associated with polluted dredge material disposal.

b. Since June 1990, the district has participated in over 25 coordination meetings in an effort to resolve the Indiana Harbor dredging and CDF siting issues. There has been direct participation in this coordination by U.S. Representative Peter J. Visclosky, the United States Environmental Protection Agency (USEPA) Region V administrator Valdas J. Adamkus, and the commissioner of the Indiana Department of Environmental Management (IDEM), Kathy Prosser.

c. As a result of this coordination with Federal, state, locals, and industry, an enormous amount of energy is focused upon resolving the harbor's sediment pollution problem. The district and USEPA Region V are preparing to sign a memorandum of understanding to facilitate a cooperatively prepared National Environmental Policy Act (NEPA) documentation with an intent on the part of USEPA to expand the project toward environmental dredging in addition to navigation maintenance. The USEPA, IDEM, locals, and industry are united in their intent to begin the remediation of this International Joint Commission area of concern.

d. Due to this increased project awareness and spirit of partnership, a number of questions are being asked that current COE policy does not adequately address. Some of these questions are formulated later in this memo.

3. Indiana Harbor Sediments.

a. The sediments in the harbor and canal have been classified nearly 100 percent "heavily polluted" IAW Section 404 guidelines. About 70,000 cubic yards of the in-place navigation sediments are classified by the USEPA as **TSCA-regulated** because of PCBs that range from over 50 to about 100 ppm in concentration. Under **TSCA**, there are three alternatives for managing a waste:

(1) incineration;

(2) disposal in an approved **TSCA** facility; or

(3) other disposal method approved by the USEPA regional administrator as defined by **TSCA** in 40 CFR Section 761.75(b)(5). The district has designed a facility which we believe would meet the requirements of the third alternative. This design consists of a CDF constructed with a soil/bentonite slurry trench down to clay till around the site perimeter tied into a 3 foot thick layer of compacted clay along the inside dike slopes, and burial of the **TSCA** material completely surrounded by other sediments from the maintenance dredging.

b. Region V USEPA's **TSCA** staff have reviewed this proposal and have indicated that it would be workable. Further, in response to questions per our telephone conversation with HQUSACE in March, the district has coordinated the concern about a "landfill ban" and the expected permanence of a **TSCA** landfill. USEPA's response was that the "landfill ban" did not affect **TSCA** and that once a material is landfilled it would be very unlikely that it would ever be required to be removed. The only historical remedial activity at any **TSCA** facility has occurred because of facility malfunction or failure. Even then, the remedy has generally not been removal because of health implications associated with rehandling of this type of material.

c. The sediments from some reaches of the canal also contain oil and associated petroleum hydrocarbons. The USEPA has collected a total of six samples of sediments expected to contain high concentrations of organics where the **RCRA TCLP** test of one sample has failed for benzene. Knowing the COE position on sediment not being a **RCRA** waste, the USEPA is pursuing a sampling program to clarify the situation. Based upon the location of the sample that failed, it is highly unlikely that the bulk of the Indiana Harbor and Canal sediments would be classified as **RCRA**. The district's position, thus far, has been that if a sediment reach were classified by the USEPA as **RCRA**, the COE would no longer consider dredging that reach under navigation authority. The USEPA staff frequently remind the district of the **RCRA "Of course" rule**, described in the 24 March 1986 <u>Federal Register</u>, (p. 10168), suggesting that treatment of dilute benzene waste would be relatively easy within 90 days in tanks and could be rendered non-**RCRA** for CDF disposal. The district remains optimistic that the **RCRA** sediment problem will be either insignificant or non-existent once USEPA exhausts its testing.

d. The major **RCRA** sediment issue will be with the State of Indiana since their program specifically includes sediment as **Solid Waste**. The district has apprised the IDEM of our policy not to apply for solid waste permits for dredge material and has sent them an example of a past dispute with their program. The IDEM is now considering the issue. A list of permits that the State of Indiana may require in association with ECI site remediation and/or eventual CDF siting/dredging is at enclosure 1.

4. ECI Site.

a. The leading candidate CDF location is an abandoned refinery called the ECI site (Energy Cooperative, Inc.; the last owner/operator of the refinery facility). ECI filed Chapter 11 in 1981; all operations ceased in 1983; and ECI filed Chapter 7 in June 1984. The appointed trustee attempted to abandon the site but the USEPA objected. The ECI facility was dismantled and the site was remediated by the bankruptcy court during 1986 through 1989. Based upon IDEM memos (enclosure 2), court approved closure was not necessarily in compliance with **RCRA** procedures. The USEPA and IDEM are currently investigating what will be required for formal closure of the no longer existing **RCRA** facilities that were permitted. At least one problem area, lead waste pits, is already underneath a new roadway and the Indiana DOT has verified that adequate closure procedures had been adhered to. The State of Indiana will probably move soon to execute formal closure paperwork for this one facility.

b. The ECI site has been nominated and scored under **Superfund**, but has never scored into the NPL. The USEPA is rescoring the site now and they anticipate that it will not score at NPL rating. The primary problem remaining on-site is petroleum hydrocarbon contamination from spills occurring over the period of refinery operation (1919 to 1983). The entire area surrounding the site and much of the land adjacent to the Indiana Harbor and Canal is part of a major refinery complex and the area's groundwater is heavily burdened with petroleum hydrocarbon product. A site inspection report has been completed and is at enclosure 3.

c. The soils on-site have the potential to contain some organo-lead and other metals along with petroleum hydrocarbon residues. A key compound from a **RCRA** standpoint with regard to ECI site soils is benzene. If petroleum residues are of sufficient concentration as to render the site soils a **RCRA** managed waste (after testing under the new **TCLP** standard), it could be very costly to manipulate the ground surface. This, ironically, holds true for oil recovery operations that require trenching as well as for the types of construction activities that would be associated with the site preparation for a CDF. In the 2 April 1991 Federal Register, this problem has surfaced as an appeal by three states for regulatory relief as the benzene issue affects ongoing oil recovery programs.

d. The City of East Chicago has taken deed (Dec 89) to the ECI site. The city has appealed to and is receiving assistance from the ARCO petroleum company, a previous owner/operator of the refinery at the ECI site. ARCO and the city are signing an agreement aimed at remediating the site to a final quality that could allow COE use as a CDF site. ARCO and the city are jointly entering into an agreed order with the IDEM to remediate the site. The USEPA and the IDEM both have emergency response capability to protect the canal from oil discharges. The site discharged a significant quantity of oil into the canal during a rainstorm in the spring of 1990. Under the **Oil Pollution Act of 1990**, the USEPA can remediate and recover up to triple damages from the responsible parties.

e. ARCO has been very proactive in the matter of coordinating with the district on the development of site remediation and CDF utilization plans that are compatible with each other.

5. The ECI site is the leading candidate because of a number of factors. Of the three other sites under study, two have specific resolutions by the local communities prohibiting their use as CDFs. The third site, the Inland Steel lakefill would be the most expensive CDF location (about $100 million as opposed to $20 million to $40 million for the other sites) because of the requirements for both a water impermeable liner and massive stone dikes to prevent wave erosion and overtopping.

6. 141st St. This site is very close to the ECI site and is surrounded by petroleum refineries and contains wetlands. The last time the district attempted to sample the 141st Street site in the mid 80s, it was denied permission by the owner, AMOCO. The district feels that this site is just as suspect as ECI for environmental problems and further, there is no site data.

At a recent meeting a representative from AMOCO was questioned on this site and his first response was that he thought it was in an area of significant unregulated dumping during the early part of the century. He also felt that RCRA waste would likely be found on-site. The district has requested the results of a recent audit of this site by AMOCO.

7. J-Pit Site. The other site, J-Pit, is scheduled by Waste Management, Inc. as a municipal landfill. A permit has been applied for and designs are complete. The district is reviewing the land value at this location and we suspect that it will be much higher than previously thought due to the enormous revenues that this sort of landfill would generate in the future.

8. Inland Site. Finally, the Inland Steel lakefill has a long industrial history and may have environmental problems as well. The company is auditing the site now under USEPA request.

9. USEPA/Corps Cooperative Project: The USEPA has reviewed a preliminary version of a DEIS with all recommendation language deleted (enclosure 4). Based upon coordination following this review, the USEPA and the district are about to sign a memorandum of understanding that would allow for a cooperative approach to navigation and environmental remedial dredging of the Indiana Harbor and Canal and the upstream Grand Calumet River. The USEPA has a number of enforcement actions along the river and canal that will likely require the responsible parties to dredge or remediate near-channel/river soils. The USEPA anticipates having private material that would need disposal and would like to purchase space or contract the COE to build and presumably manage a CDF cell to contain these dredgings/soils. Also, the USEPA appears to be interested in expanding dredging to create a sediment trap in the navigation channel to prevent further, the migration of contaminated sediment out to Lake Michigan. The USEPA is very uncertain at this point about the degree and method of their cooperative project effort, but they are serious.

10. Questions: Given the complex situation described above, a few basic questions need to be addressed regarding the environmental laws and COE policy involved in this project.

(a) Given that **TSCA** material exists in the navigation project, would the COE dredge and dispose of it under a USEPA permit?

(b) Given that some **RCRA** material may exist in the navigation project according to USEPA standards, would the COE dredge and dispose of these sediments under permit; or alternatively under the "Of course rule" without permit; or not dredge this sediment?

(c) Given that the sediments are likely to be classified by the State of Indiana as **Solid Waste**, should the COE dredge and dispose of the sediments under permit; without permit? Should the COE apply for a permit; or should it comply with a permit issued without application by the COE if one were given by the IDEM?

(d) Given the complex environmental situation with an expectation that the USEPA, the IDEM, the City of East Chicago and ARCO will be able to prepare this site for CDF use, will the COE accept some liability associated with its use? While the preliminary design was to contain the CDF at the ground surface and the underground problems together behind a single slurry wall, the design could be altered to separate the underground problems from the CDF material by placing a seal at the ground surface. Given also, that it would be unlikely to find any site in the harbor and canal area without similar environmental problems, should the COE purchase the site; lease the site; require a sponsor; or recommend "no action"?

(e) Given a cooperative COE/USEPA project beyond the maintenance dredging project, would the COE manage a facility constructed for private materials brokered to the COE by the USEPA? Would the COE build and manage a **RCRA** facility for private material disposal on a reimbursable basis in connection with its CDF construction? Under what policy and liability constraints could the COE participate in such a joint program?

11. I realize that in order for some of the above questions to be answered coordination with operations or policy staff and a meeting between Washington and the Chicago District may be required. Please coordinate with appropriate Washington staff and contact Mr. John Dorkin, CENCC-PP-PM of my staff at 312/886-5193 to arrange a meeting.

12. To further assist you, recent fact sheets and project maps are at enclosures 5 and 6.

Randall

6 Encls

RANDALL R. INOUYE
LTC, EN
Commanding

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

JUN - 3 1991

REPLY TO ATTENTION OF:
5HR-13

Greta Hawvermale, Chief
Environmental Response Branch (OER)
Indiana Department of Environmental Management
105 S. Meridian Street
Indianapolis, Indiana 46206

Re: Supplement TCLP Sampling Plan for
Indiana Harbor

Dear Ms. Hawvermale:

On November 6, 1990, representatives of the Office of RCRA, in cooperation with the Large Lakes ORD Office and ARCS Program, obtained six sediment samples from six different locations scattered throughout the Federal Navigation Project at Indiana Harbor. The purpose of the sampling program was to determine if the sediments within the Federal channel exhibited the hazardous waste characteristic defined by the Toxicity Characteristic Leaching Procedure (TCLP). These samples were composited from the most visibly contaminated portions of the sediment cores and were subsequently analyzed via the TCLP. The analytical results obtained included one regulatory exceedance (1,100 ppb) for benzene at what was labeled Location 1 in the outer harbor. Note, the regulatory threshold for benzene is 500 ppb. The other TC benzene concentrations associated with the sediments from the other five locations sampled ranged from 3 to 5 ppb. In contrast to Location 1, all of these sediments were collected from the channel portions of the Federal Navigation Project.

The Office of RCRA is planning to conduct a supplementary sampling program during the week of June 3, 1991. The purpose of the supplemental effort is to ensure an adequate sample coverage within the Federal channel and assess the significance of the exceedance in the outer harbor.

My staff has decided to collect additional samples from two locations within the channel portions of the project and seven locations within the outer harbor. This sampling effort will include the resampling of the approximate location of the November exceedance. See Attachment I for the November sampling locations and the slated June sampling locations. This sampling scenario is predicated upon the potential existence of two TCLP populations within the Federal project (one in the channel and one in the outer harbor), and is an inference based upon the November TCLP data. The two samples to be collected from the channel will provide TCLP results from all channel portions slated to be dredged. A statistical procedure provided in SW-846, Chapter 9, and discussed in Attachment II, has indicated the need to collect no less than eight samples in the outer harbor. Please note that this is an estimate only, and that the accuracy of the result is subject to the assumptions discussed in Attachment II. This method was used to approximate a minimum sample density using the population variance of the November data, assumed population means and the regulatory threshold. The provision for seven sampling locations (with two samples per location, if feasible) as compared to the calculated minimum of eight samples is a precaution against the variance estimate and/or the estimate of the mean being too low, and therefore the predicted need for eight samples being too conservative.

At each of the "June sampling locations" identified in Attachment I, a 4-inch sediment core will be collected via a "vibricoring unit" provided by the Rossfelder Corporation. The sediments cored will consist of those materials within the Federal channel from the sediment-water interface down to 2 feet below the project depth. This will be determined by a review of the most recent Corps of Engineers (COE) bathymetric survey maps. Given 10 feet or more of sediment, two 5-foot composite samples will be collected from each of the seven sites. If there are less than 10 feet of sediments in the interval defined above, one 5-foot composite will be collected. Each composite sample will consist of material/sediment scraped from the 5-foot interval of the core selected for sampling. Each composite will be analyzed separately for all TCLP constituents, except the pesticides, by an approved Contract Laboratory Program (CLP) facility. The core barrel of the Rossfelder unit will be rinsed with water after each sampling event and subsequently lined with a Polyethylene bag to prevent cross contamination. Sampling vessels will be provided ~~by~~ Region V or an approved contractor. No field blanks will be taken as sediments are a nonaqueous medium. Duplicate samples will be taken from at least one of the 5-foot sampling intervals.

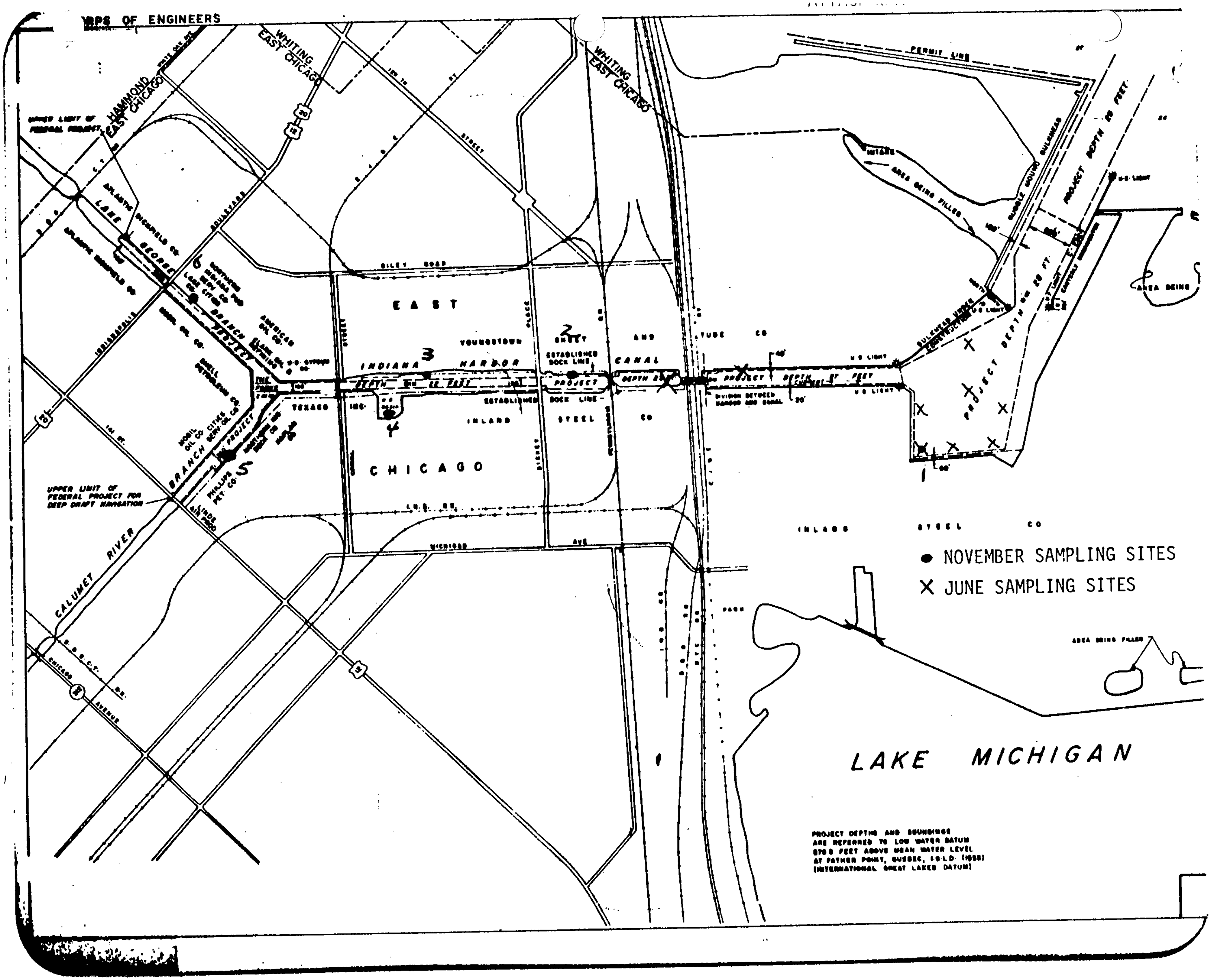
If an IDEM representative would like to accompany Agency personnel on the June 3rd sampling visit, or if you have any questions or comments regarding these issues/sampling procedures, please contact Dave Petrovski at 886-0997.

Sincerely,

Karl E. Bremer

Karl E. Bremer, Chief
RCRA Permitting Branch

cc: J. Dorkin, COE
J. Filkins, ORD
D. Anderson, IDEM
R. Koelpin, IDEM
B. Muno, OR
J. Boyle, REB
B. Franz. PMD
H. Zar, WD
A. Lubin, ESD
M. Mikulka, WD
T. Slaughter, REB
M. Tuchman, WD
R. Traub, RPB
D. Petrovski, RPB


RPS OF ENGINEERS
WHITING
EAST CHICAGO
HAMMOND
EAST CHICAGO
UPPER LIMIT OF FEDERAL PROJECT
LAKE GEORGE BRANCH PROJECT
ATLANTIC RICHFIELD CO.
SINCLAIR OIL CO.
AMERICAN OIL CO.
MOBIL OIL CO.
SHELL PETROLEUM CO.
CITIES SERV. OIL CO.
TEXACO INC.
PHILLIPS PET CO.
INDIANA HARBOR CANAL
PROJECT DEPTH 22 FEET
ESTABLISHED DOCK LINE
EAST
CHICAGO
YOUNGSTOWN SHEET AND TUBE CO
INLAND STEEL CO
RILEY ROAD
MICHIGAN AVE
CALUMET RIVER
BRANCH PROJECT
UPPER LIMIT OF FEDERAL PROJECT FOR DEEP DRAFT NAVIGATION
PERMIT LINE
INTAKE
AREA BEING FILLED
RUBBLE MOUND BULKHEAD
PROJECT DEPTH 28 FEET
BULKHEAD UNDER CONSTRUCTION
U.S. LIGHT
DIVISION BETWEEN HARBOR AND CANAL
PROJECT DEPTH 27 FEET
AREA BEING
AREA BEING FILLED
1
2
3
4
5
6
● NOVEMBER SAMPLING SITES
X JUNE SAMPLING SITES
LAKE MICHIGAN
PROJECT DEPTHS AND SOUNDINGS ARE REFERRED TO LOW WATER DATUM 576.8 FEET ABOVE MEAN WATER LEVEL AT FATHER POINT, QUEBEC, I.G.L.D. (1955) (INTERNATIONAL GREAT LAKES DATUM)

ATTACHMENT II

November 6, 1990, TCLP Benzene Data for Indiana Harbor

Location	Concentration (ppb)
1	1,100
2	3
3	5
4	5
5	4
6	5

TCLP regulatory threshold (RT) for benzene is 500 ppb

Sample 1 - Outer Harbor sediment inferred to represent a TCLP population with a potentially higher mean and variance due to less sediment re-working

Samples 2, 3, 4, 5, and 6 - Channel sediment, inferred to represent a TCLP population with a potentially lower mean and variance due to more sediment re-working.

Estimated minimum number of sampling locations in the outer harbor used the procedures provided in SW-846.

> This procedure is being used only to estimate a minimum number of sampling locations given the potential presence of a separate TCLP benzene population in the outer harbor. All data and all assumptions will be re-evaluated upon receipt of the June TCLP results. The existence of only one TCLP benzene datum in the outer harbor makes the estimation of outer harbor TCLP benzene population statistics problematic. An estimation of the outer harbor benzene mean and variance was needed to use the procedure provided in SW-846 and outlined below. In the absence of additional outer harbor data, the variance exhibited by the channel data (locations 2 through 6) was used as an estimation of the outer harbor variance. As the population mean approaches the regulatory threshold, the number of samples required increases. Consequently, the calculation was completed using 2 relatively high population means (400 ppb and 450 ppb). The use of these assumptions allowed the procedures provided in SW-846 to be used giving some minimal guesstimation of the required sampling density for the outer harbor. Please note however, that upon receipt of the June sampling results, the assumed mean values and the use of the November data as an estimate of outer harbor population characteristics may prove inappropriate.

Scenario I

Mean X = 400 ppb

Variance S^2 = 6,625

Scenario II

Mean X = 450 ppb

Variance S^2 = 8,323

Location	Concentration (ppb)	Concentration @ X=400	Concentration @ X=450
2	3	273	306
3	5	455	510
4	5	455	510
5	4	364	408
6	5	455	510

For the November channel data the mean X = 4.4

NOTE: Concentrations @ X = 400 and X = 450 were calculated by dividing the assumed X by the calculated X for the November data and multiplying by the location concentration, e.g., For Scenario I/Location 2

$$\frac{(400)\ (3)}{(4.4)} = 273$$

Scenario I: Appropriate number of samples

$$N = \frac{(t_{0.20})^2\ S^2}{(RT - X)^2} = \frac{(1.533)^2\ (6,625)}{(500-400)^2} < 2 \text{ samples}$$

Scenario II: Appropriate number of samples

$$N = \frac{(t_{0.20})^2\ S^2}{(RT - X)^2} = \frac{(1.533)^2\ (8,323)}{(500-450)^2} < 8 \text{ samples}$$

Assuming a variance similar to the variance exhibited by the channel sediments and a mean concentration not exceeding 450 ppb, no more than 8 samples would be needed to characterize the outer harbor sediments. Upon review, if the outer harbor data are associated with a higher mean and/or variance than provided by the assumptions given above, this procedure could underestimate the required sampling density. Given the costs associated with sediment sampling effort, the potential that the assumed population characteristics could prove incorrect, it was decided to collect samples from 6 new locations in the outer harbor as well as re-sampling the approximate location of the November exceedance. Given sufficient sediment thickness, 2 five foot composites will be collected at each sampling site. This procedure should ensure that at least 8 sediment data points will be obtained in the outer harbor.

Amoco Oil Company

Whiting Refinery
2815 Indianapolis Boulevard
Whiting, Indiana 46394
219-473-7700

Frank J. Citek
Refinery Manager

June 11, 1991

Mr. D. Wallin
Economist, Chicago District
U. S. Army Corp of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

Incentive to Dredge Indiana Harbor Ship Canal - Amoco Oil Company

Per your request, Amoco Oil Company - Whiting Refinery, has updated a 1989 study of the economic impact of failure to conduct maintenance dredging at Indiana Harbor and Canal. Whiting is not currently experiencing restrictions on barge loading for petroleum products on the Indiana Harbor Ship Canal, but could incur significant penalties if barge movements were suddenly terminated. The option of continued use of the Ship Canal is clearly of key importance to the refinery.

In 1990, the refinery shipped approximately 525 million gallons via the canal. Just under two-thirds of this volume was lighter transportation fuels such as gasoline and distillate fuels. Included in this volume currently is about 34 million gallons of JP-4 fuel sold to the military. For these products, the refinery is not totally dependent on the Indiana Harbor and Ship Canal for distribution to most of our markets. Our industry requires and utilizes a combination of rail, pipeline, trucking, and marine transportation systems. But flexibility is very important in supplying cost competitive products to our customers, so it is imperative that all alternative transportation options be maintained. Assuming all of our markets could be supplied by other options, the total closing of the canal would force us to spend an estimated $3 million annually to use alternatives to marine transportation.

The other one-third of our 1990 marine shipments (about 175 million gallons) were of various asphalt products. The Whiting Refinery is the largest supplier of asphalt in the Midwest, and here the impact of closing the canal would be more significant. About 50 million gallons, or about 30% of the asphalt moved via barge in 1990, could be shipped by rail or truck instead. However, this switch to alternative modes of transportation would be limited by the capacity of our truck and rail facilities and even then assumes we could increase the size of our rail fleet several-fold. The other 70% of barged asphalt could not be supplied at all without access to the canal. Important terminals could not be reached, forcing us to withdraw from markets and resulting in Midwest shortages of asphalt in some areas. The cost to the Whiting Refinery would be substantial. The total cost to Amoco Oil in asphalt products of losing the canal option would exceed $15 million annually. The resulting total cost to Amoco Oil of closing the canal could approach $18 million annually.

If the canal were closed, our capital assets at the Ship Canal, valued at $2.1 million at the end of 1990, would likely be abandoned. The net book value of these assets is $972,000. This abandonment could result in a one-time tax write-off of $265,000 and a loss of ten Amoco jobs. Additional tankerman and barge jobs might be lost if the lack of Whiting shipments forced the barge companies we do business with to trim operations.

This assessment of costs to Amoco Oil has not included the impact of a lack of dredging on other industries dependent on the canal. These industries and their employees are important consumers of our products. Since the canal is important to the economic viability of all of Northwest Indiana, lower total demand for our products could increase our penalties even more.

I hope you find the Amoco potential penalties provided here useful in developing the economic impact of not dredging the canal. Please call me if you need additional information.

Sincerely,

F. J. Citek

Amoco Oil Company
P.O. Box 710
Whiting, Indiana 46394

June 13, 1991

Randall R. Inouye, P.E.
Lieutenant Colonel, U. S. Army
District Engineer
Department of the Army
Chicago District, Corps of Engineers
111 North Canal Street
Chicago, IL 60606-7206

Dear Lieutenant Colonel Inouye:

We have reviewed the information concerning the two sites near 141st Street in Hammond per your request of May 10, 1991. Our review of Lake County Tax records has shown that the property does not belong to Amoco, but instead the parcels are owned by Clark Oil, Mobil Oil, D&I Meyers, and the City of Hammond.

Please advise me if you have any further questions.

Sincerely,

D. C. Kloeckner

D. C. Kloeckner
Manager, Environmental Control

DCK/nb

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, CORPS OF ENGINEERS
111 NORTH CANAL STREET
CHICAGO, ILLINOIS 60606-7206

REPLY TO
ATTENTION OF

June 28, 1991

Executive Office

Honorable Peter J. Visclosky
House of Representatives
330 Cannon House Office Building
Washington, DC 20515-1401

Dear Mr. Visclosky:

I am writing to advise you that I cannot release the Draft Environmental Impact Statement (DEIS) to the public on the Indiana Harbor and Canal Navigation Maintenance project this summer. The previously scheduled July 1991 public release date was based upon an assumption that the USEPA-initiated ECI site study would provide conclusive hazardous waste liability documentation upon which I could base a confined disposal facility siting decision.

A final report on the USEPA study was received by the Chicago District in March 1991. The study justifiably focused upon establishing the need for an emergency response to the ECI site oil problem. However, the report does not contain sufficient data upon which to base a siting decision. The study established a need for further field tests to characterize the limits of the unknown hazardous/toxic condition of the ECI site soils. The City of East Chicago and ARCO are initiating action to remediate the oil problem and to characterize the soils. These data are required before I can make a site recommendation on the DEIS.

I met with Mayor Pasterick on June 10 to discuss the intentions of the City of East Chicago and ARCO and how they impact on the schedule for the DEIS. Based upon this discussion, it appears that the necessary data will not be collected until later this year and that the earliest possible date for the public release of the DEIS would be February 1992. However, this data is based upon a very optimistic schedule from ARCO. There is a strong possibility that the complete data may not be available until the summer of 1992. I will have my staff re-evaluate the overall project schedule to determine if some of the lost time can be made up in later project phases in an attempt to hold the scheduled start of dredging to 1996.

We are continuing to work on the DEIS and will be about as far as we can proceed by the end of July without the additional data needed on the ECI site. We should then be in a position to complete the DEIS in a relatively short period of time once the remaining information on the ECI site becomes available.

If you or your staff has any questions regarding the Indiana Harbor and Canal Navigation Maintenance project, please contact me at 312/353-6400.

Sincerely,

Randall

Randall R. Inouye, P.E.
Lieutenant Colonel, U.S. Army
District Engineer

Copy Furnished:

Honorable Peter J. Visclosky
Representative in Congress
215 West 35th Avenue
Gary, Indiana 46408-1506

PETER J. VISCLOSKY
1ST DISTRICT, INDIANA

COMMITTEES:
PUBLIC WORKS AND TRANSPORTATION
INTERIOR AND INSULAR AFFAIRS
CONGRESSIONAL STEEL CAUCUS
WHIP-AT-LARGE

Congress of the United States
House of Representatives
Washington, DC 20515

420 CANNON BUILDING
WASHINGTON, DC 20515
(202) 225-2461

215 WEST 35TH AVENUE
GARY, IN 46408
TTY-TDD SERVICE AVAILABLE
(219) 884-1177

CITY HALL LOWER LEVEL
100 EAST MICHIGAN BOULEVARD
MICHIGAN CITY, IN 46360
(219) 873-1435
(219) 873-1436

July 3, 1991

Lt. Col. Randall R. Inouye
Chicago District Engineer
Army Corps Of Engineers
111 North Canal Street
Chicago, Indiana 60606-7206

Dear Colonel Inouye:

I write to express my extreme displeasure upon learning that you do not intend to release the Draft Environmental Impact Statement (DEIS) on the Indiana Harbor and Canal Navigation Maintenance project this summer.

I am particularly disappointed because during the past eight months I have made this a top priority in my office. Since September 1990 my staff and I have held numerous meetings with the United States Environmental Protection Agency, the Indiana Department of Environmental Management, and the City of East Chicago to expedite this project.

I had been encouraged by the outcome at each of these meetings and truly felt after the March 1991 meeting at Region V headquarters that progress was finally being made and that all agencies were cooperating to see that this project finally came to fruition.

While I do not doubt the sincerity of the Army Corps of Engineers in the dredging of the ship canal, I cannot accept any further delays. It has been nearly twenty years since the canal has been dredged, resulting in severe economic and environmental impacts for Northwest Indiana. I want to see some action taken toward the dredging of this canal.

While I do understand your concern regarding the liability issue of unidentified contaminants on the ECI site, it was my impression from our March 1991 meeting that all identifiable on site contaminants were assessed and that future steps to remediate the site would be taken. Additionally, a remediation agreement has been signed by all parties involved in the ECI cleanup and remediation will begin soon.

I find unacceptable any further delays in this already long and drawn out process. Your reference to a possible summer 1992 release of a DEIS is not conducive to my schedule for this project. It appears that it is necessary for me to take a stronger role in overseeing this process and ensuring that each agency, including the Army Corps of Engineers follows through on their committed time frames.

Sincerely,

Peter J. Visclosky
Member of Congress

PJV:ehl

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

REPLY TO ATTENTION OF:

AUG 15 1991

Mr. Richard Carlson, Chief
Planning Section
Department of the Army
Chicago District, Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

Dear Mr. Carlson:

We have completed our review of the Preliminary Draft Environmental Impact Statement (PEIS) for the Federal Navigation Channel for Indiana Harbor and Canal. In January of 1991, our Agency provided you with comments on the proposed project. In further discussions with your staff, we agreed to provide additional review comments on the project. In the spirit of our Agencies' proposed Memorandum of Understanding (MOU) for this project, a meeting has been scheduled between our staffs to address our Agency's comments, concerns, and recommendations. The date for this meeting on the PEIS is August 28, 1991 at 10:00 A.M. at your office.

As you know, the U. S. Environmental Protection Agency Region 5 is currently focusing its efforts and is committing resources to the Northwest Indiana region. The Federal navigation project holds a high priority status for us. Our Agency has a genuine interest in the completion and implementation of this project. With the signing of the MOU, we will be providing your Agency with an additional commitment for technical assistance and support in the undertaking of the National Environmental Policy Act process.

Our point of contact for this project is Al Fenedick, of the Environmental Review Branch, Planning and Management Division. Mr. Fenedick can be reached at 886-6872, FAX number 353-4135.

Sincerely yours,

Edward P. Watter

for Dale Bryson, Director
Water Division

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

105 South Meridian Street
P.O. Box 6015
Indianapolis 46206-6015
Telephone 317/232-8603

September 3, 1991

Philip R. Bernstein, Chief
Planning Division
Department of the Army
Chicago District, Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

Re: Section 1135(6)
Demonstration Projects

Dear Mr. Bernstein:

This is in response to your letter of August 2, 1991, regarding possible coordination with this agency on proposed Section 1135(6) projects.

A review of those project descriptions which you included with your letter disclosed that they all had required sponsorship. However, we are looking into the possibility of submitting a proposal that would involve modification of the Corps' plan to dredge the Indiana Harbor Ship Canal to include contaminated sediments outside of the navigation channel.

Before such a proposal can be prepared and submitted, there are several questions that must be answered. These include:

1. Would modification of the Indiana Harbor Ship Canal dredging plan to include additional sediments likely be eligible for Section 1135(6) funding?
2. What is the deadline for submitting FY 92 proposals and is it too early to propose modifications of the Corps dredging plan?
3. Will the 1135(6) program likely continue into FY 93 and FY 94?
4. Part 5 of the guidance is not clear on what portion of the modification project costs require a nonfederal match. We understand that there may be additional information forthcoming on this section.
5. How detailed do the cost estimates need to be in the preliminary proposal?

We would appreciate your early response to these questions so we can determine if we should submit a proposal at this time. Please send the information to John Winters, Chief, Water Quality Branch, Office of Water Management, at the above address, or contact him by phone at 517/243-5028.

Sincerely,

Kathy Prosser

Kathy Prosser
Commissioner

CLEVELAND TANKERS, INC

55 PUBLIC SQUARE
P. O. BOX 6479
CLEVELAND, OHIO 44101
216/771-1999

October 18, 1991

Kim Bloomquist
Chief, Economics Branch
Department of the Army
Chicago District, Corps of Engineers
111 North Canal Street
Chicago, IL 60606-7206

Dear Mr. Bloomquist:

SUBJECT: **INDIANA HARBOR & CANAL NAVIGATION**

Please be advised that Cleveland Tankers has been in the Marine Transportation business for many years. We are the only U.S. company operating tankships on the Great Lakes.

Cleveland Tankers currently operates two self-propelled tank vessels on the Great Lakes for the total capacity of 124,000 barrels. Our vessels have been navigating throughout the Indiana Harbor and Canal for a very long time; however, navigation via the waterway has deteriorated the last few years. The major obstacles facing the waterway and the commerce of the area are water depth and bridge width restrictions.

As an example, the Elgin, Joliet & Easter Ry Bridge (bridge #15, U.S. Coast Pilot data) has deteriorated abutments creating a clearance of approximately 60 feet in width primarily underwater. The underwater concrete pylons of the bridge have become a hazard to navigation. Current depths create great navigating restrictions for our vessel Saturn, the only Cleveland Tankers vessel presently transiting via the waterway at a loaded draft of 19'6". In addition to the draft, bridge's restrictions have eliminated our vessel Gemini's (65' beam, 23'00" draft loaded) ability to trade via the canal.

During the year of 1990 Cleveland Tankers vessels (Saturn and Jupiter) transported approximately 2,500,000 barrels of petroleum products through the waterway. As of today, during 1991 the vessel Saturn has transported approximately 210,000 barrels.

These navigational restrictions have created a burden to our Company where our vessel Gemini cannot trade and the very bleak possibility that the Saturn can also be restricted from transiting via the waterway.

A/BLOOMQUI.GG:wg

Water transportation has been the least expensive method of transporting petroleum products in bulk, has created jobs not just for our vessel's crew, but for the local communities. The local refineries can comparatively export refined products to other regions in the U.S. and Canada.

Therefore, we urge the Corp to establish a program where the waterway can be improved for the benefit of all interested parties.

Your help in this matter will be greatly appreciated.

Very truly yours,

CLEVELAND TANKERS SHIP MANAGEMENT

Gerry Grammenos
Vice President, Operations
& Administration

cc: George Ryan, Lake Carriers Association

A/BLOOMQUI.GG:wg

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN STREET
CHICAGO, IL 60604

REPLY TO THE ATTENTION OF:

October 18, 1991

John Dorkin, Project Manager
U.S. Army Corps of Engineers
Chicago District
6th Floor
111 North Canal Street
Chicago, Illinois 60606

Dear Mr. Dorkin:

Thank you for the time you recently spent meeting with Tim Brown of ICF, Inc.

As he explained to you, the U.S. Environmental Protection Agency (EPA) is seeking to augment its many environmental initiatives in northwest Indiana by creating a comprehensive public information and outreach program. Our goal is to keep northwest Indiana citizens apprised of our actions, and to provide the most appropriate opportunities for public involvement. The ideas and suggestions you have provided will be most helpful to us in developing such a program.

I will be sure that you receive a copy of our information/outreach plan when it is complete, and that you are kept up to date with EPA's progress in northwest Indiana. We expect to finish our plan by the end of November 1991.

If you have any questions about this or other EPA activities in northwest Indiana, you may contact either Phillippa Cannon, at (312) 353-6218, or Karen Martin, at (312) 886-6128 of my staff.

Thank you again for your efforts on behalf of our environment.

Yours sincerely,

Margaret McCue

Margaret McCue
Director, Office of Public Affairs

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN STREET
CHICAGO, IL 60604

REPLY TO THE ATTENTION OF:

October 18, 1991

Major Steve Smith, Deputy District
Engineer
U.S. Army Corps of Engineers
Chicago District
6th Floor
111 North Canal Street
Chicago, Illinois 60606

Dear Mr. Smith:

Thank you for the time you recently spent meeting with Tim Brown of ICF, Inc.

As he explained to you, the U.S. Environmental Protection Agency (EPA) is seeking to augment its many environmental initiatives in northwest Indiana by creating a comprehensive public information and outreach program. Our goal is to keep northwest Indiana citizens apprised of our actions, and to provide the most appropriate opportunities for public involvement. The ideas and suggestions you have provided will be most helpful to us in developing such a program.

I will be sure that you receive a copy of our information/outreach plan when it is complete, and that you are kept up to date with EPA's progress in northwest Indiana. We expect to finish our plan by the end of November 1991.

If you have any questions about this or other EPA activities in northwest Indiana, you may contact either Phillippa Cannon, at (312) 353-6218, or Karen Martin, at (312) 886-6128 of my staff.

Thank you again for your efforts on behalf of our environment.

Yours sincerely,

Margaret McCue

Margaret McCue
Director, Office of Public Affairs

GEORGE J. RYAN, *President*
GORDON D. HALL, *Vice President / Treasurer*
CAROL ANN LANE, *Secretary*

THOMAS O. MURPHY, *General Counsel*
HAROLD W. HENDERSON, *Associate Counsel*
GLEN NEKVASIL, *Communications Director*

LAKE CARRIERS' ASSOCIATION
614 Superior Avenue, West
915 Rockefeller Building
Cleveland, Ohio 44113-1383
Telephone: (216) 621-1107 / Fax: (216) 241-8262

October 22, 1991

Lieutenant Colonel Randall R. Inouye
Commander, Chicago District
U.S. Army Corps of Engineers
111 N. Canal Street
Chicago, IL 60606

Dear Colonel Inouye:

Reference is made to Cleveland Tankers, Inc. letter dated October 18, 1991, (copy enclosed) regarding restrictions which are affecting the economic viability of their operations out of Indiana Harbor. Since this is without question the most important tanker port on the U.S. side of the Great Lakes, and since Congresss has shown great concern over tanker operations, on behalf of its members whose vessels transit the waters leading to both the Calumet River and Lake George Branches of the Indiana Harbor Canal, the Association would like to express its concern over existing channel conditions.

I understand the environmental parameters which, for lack of a suitable dredge spoils disposal area, have held up dredging in the area for 20 years. However, it seems that obstructions from bridge protective cells and foundations should be subject to removal if they are restricting channel width and channel depth.

Other Corps Districts provide periodic up-to-date sounding information to be cut out and replace tabular soundings on charts, but our members have no such information on the Indiana Harbor Canal.

It would be very helpful if you could provide me with the most recent sounding charts of the waterway for office use here and a tabular depiction that I could provide for use by member companies transiting the area.

Please furnish the requested sounding data if it is available and advise if it is feasible to remove any "strikes" which reflect more than long term shoaling. If removal is feasible, in what time frame could removal be expected?

Continuing viability of Indiana Harbor is of importance not only to the locale but to the ports to which petroleum products move and the end users of those products. I believe it is essential environmentally to continue the ability to move petroleum products by water instead of other more costly and riskier modes of transport.

Your assistance will be greatly appreciated.

Sincerely,

George J. Ryan

George J. Ryan
President

GJR:GDH:emh

cc: Mr. Gerald Grammenos - Cleveland Tankers Ship Management Inc.
Mr. Daniel L. Gorrell - Coastwise Trading Company

American Steamship Company • Bethlehem Steel Corporation • Cement Transit Company • Cleveland Tankers (1991), Inc. • Coastwise Trading Company
Erie Sand Steamship Co. • Inland Lakes Management, Inc. • Inland Steel Company • The Interlake Steamship Company • Lakes Shipping Co., Inc.
Litton Great Lakes Corp. • M.A. Hanna Company • Oglebay Norton Company • Pringle Transit Company • USS Great Lakes Fleet, Inc.

EPA Environmental NEWS RELEASE

United States
Environmental
Protection
Agency
Region 5
230 S. Dearborn St.
Chicago, IL 60604

Technical Contact: Al Fenedick
(312) 886-6872

Media Contact: Don de Blasio
(312) 886-4360

U.S. Army Corps of Engineers
Technical Contact: Lydia Benda
(312) 353-6401

For Immediate Release: October 28, 1991

No. 91-M187

EPA, CORPS OF ENGINEERS SIGN AGREEMENT ON INDIANA HARBOR DREDGING

U.S. Environmental Protection Agency (EPA) Region 5 and the U.S. Army Corps of Engineers, Chicago District, said today they have signed an agreement to develop an environmental impact statement (EIS) in preparation for dredging of the Indiana Harbor and Canal, Lake County, IN.

The EIS, required by Federal law, is a written document that fully describes the environmental consequences of Federal actions. The public will have an opportunity to comment and make recommendations on the EIS. Under the agreement, EPA will contribute its special expertise to assist the Corps to fully assess and describe the environmental impacts of the project.

The Corps proposes to remove sediments that have built up over the last 18 years in the harbor and the canal. The buildup has reduced channel depth, which restricts shipping.

In addition, these sediments and sediments from the Grand Calumet River are saturated with contaminants from industrial and municipal sources, which pollute the waters.

- more -

"Two Federal agencies working on this project means a significant restoration of the environment," said EPA Regional Administrator Valdas V. Adamkus. "I look forward to working with the Corps on this crucial project to address the navigational hazards and restore the environmental damage caused by contaminated sediments in the Indiana Harbor and Canal."

Lt. Col. Randall R. Inouye, Chicago District engineer, said: "The signing of this agreement is the result of much coordination between the Corps of Engineers and EPA. It is this continued cooperation that will make the completion of the environmental impact statement a reality."

The Corps plans to complete a draft EIS by early 1992 for public comment. The date for public review of the final EIS will depend on the complexity and the number of comments the Corps receives on the draft.

# # #

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, CORPS OF ENGINEERS
111 NORTH CANAL STREET
CHICAGO, ILLINOIS 60606-7206

REPLY TO
ATTENTION OF

18 NOV 1991

Environmental and Social
Analysis Branch

Mr. David Hudak
Field Supervisor
U.S. Fish and Wildlife Service
Bloomington Field Office (ES)
718 North Walnut Street
Bloomington, Indiana 47401

Dear Mr. Hudak:

The purpose of this letter is to update you on the status of our Environmental Impact Statement (EIS) for Indiana Harbor dredging and disposal. The alternative disposal sites are the same as those evaluated in your draft Fish and Wildlife Coordination Act report of January 30, 1989. We are still considering four sites for the confined disposal facility (CDF): 141st Street Site; J-Pit Site; Inland Steel Site (with CDF construction within the existing lakefill area); and the ECI Site. The locations of these sites are shown on the enclosed map (Enclosure 1).

We have encountered some potential problems with the ECI site due to the pollution left from past refinery operations. Operating permits, required under the Resource Conservation and Recovery Act (RCRA), were applied for by the last operator, Energy Cooperative Incorporated, but due to the bankruptcy of the corporation, no RCRA closure was implemented. The site was also the source of a substantial oil spill into Lake George Canal during the summer of 1990. The site owner and a previous owner are currently working with the Indiana Department of Environmental Management (IDEM) to remediate the site. We are trying to resolve these issues with the IDEM and US Environmental Protection Agency (USEPA) and hope to be able to continue to consider this site for confined disposal.

We recently signed a Memorandum of Understanding with USEPA Region 5 for preparation of the EIS (Enclosure 2). Under the agreement, USEPA is a cooperating agency and the Chicago District maintains lead agency responsibilities for the documentation. One reason for the MOU is to expand the scope of the EIS to include dredging beyond the federal navigation channel. An option under consideration is expanding our disposal facility by adding cells in the future to accommodate some of this additional dredged material.

The EIS is scheduled to be distributed to the public in early 1992. If you desire any additional information or have any comments, please contact Lydia Benda (312-353-8574) or Rose Austin (312/886-0451).

Sincerely,

ORIGINAL SIGNED

Philip Bernstein
Chief, Planning Division

CF:
IDEM, Indianapolis, IN (D. Anderson)
IDEM, Gary, IN (D. Dabertin)
USEPA Region 5, Chicago, IL (A. Fenedick)

AUSTIN/ef/3-7795

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CENCC-PD-S

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, CORPS OF ENGINEERS
111 NORTH CANAL STREET
CHICAGO, ILLINOIS 60606-7206

REPLY TO
ATTENTION OF

18 NOV 1991

Environmental and Social
Analysis Branch

Mr. Patrick R. Ralston, Director
Indiana Department of Natural Resources
Environmental Review Coordinator
Division of Outdoor Recreation
ATTN: Steve Jose
402 W. Washington, Room 271
Indianapolis, IN 46204

Dear Mr. Ralston:

The purpose of this letter is to update you on the status of our Environmental Impact Statement (EIS) for Indiana Harbor dredging and disposal. The alternative disposal sites have not changed since our previous letters (dated November 28, 1988 and April 11, 1989). Your agency provided comments in a letter dated September 12, 1990. We are still considering four sites for the confined disposal facility (CDF): 141st Street Site; J-Pit Site; Inland Steel Site (with CDF construction within the existing lakefill area); and the ECI Site. The locations of these sites are shown on the enclosed map (Enclosure 1).

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The EIS is scheduled to be distributed to the public in early 1992. If you desire any additional information or have any comments, please contact Lydia Benda (312-353-8574) or Rose Austin (312/886-0451).

Sincerely,

ORIGINAL SIGNED

Philip Bernstein
Chief, Planning Division

CF:
IDEM, Indianapolis, IN (D. Anderson)
IDEM, Gary, IN (D. Dabertin)
USEPA Region 5, Chicago, IL (A. Fenedick)

AUSTIN/ef/3-7795

CENCC-PD-S

CENCC-PD

CENCC-PD-S

55

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, CORPS OF ENGINEERS
111 NORTH CANAL STREET
CHICAGO, ILLINOIS 60606-7206

REPLY TO
ATTENTION OF

November 25, 1991

Mr. Gerry Grammenos
Vice President, Operations &
Administration
Cleveland Tankers, Incorporated
55 Public Square
P.O. Box 6479
Cleveland, Ohio 44101

Dear Mr. Grammenos:

The Chicago District is preparing a Draft Environmental Impact Statement in cooperation with Region V of the U.S. Environmental Protection Agency that will address the dredging of the Indiana Harbor and Canal. The information you provided to us on October 18 will help in the preparation of this document.

There is additional information that would greatly assist us in completing our dredging study. That information involves additional detail on your operations in Indiana Harbor. I would appreciate your assistance in sharing this information with us.

a. What products do you carry into and out of Indiana Harbor? What are the origin and destination of that product?

b. How many trips per year do you make to Indiana Harbor?

c. What is the average number of barrels carried per trip?

d. What are your approximate transport costs per barrel?

If your information is proprietary and needs to be held in confidence we can and have done this in the past. This information will assist us in determining the economic impacts on current operations in the harbor. Before any dredging can occur, the costs and benefits of the project must be evaluated.

Thank you for your assistance. We are working on a very tight schedule and would appreciate your response as soon as possible. Our Project Manager is Ms. Lydia Benda, (312) 353-8674. She can answer any questions you or your staff may have.

Sincerely,

Randall

Randall R. Inouye, P.E.
Lieutenant Colonel, U.S. Army
District Engineer

LTV Steel Company

LTV

INDIANA HARBOR WORKS

Date: 27-NOV-1991

US ARMY CORPS OF ENGINEERS
CHICAGO DISTRICT
111 NO. CANAL STREET - SUITE 600
CHICAGO, IL 60606-7206

Attention: MS LYDIA BENDA

Subject: INDIANA HARBOR SHIP CANAL

Attached are the documents listed below as requested.

DREDGING HISTORY - DATED SEPTEMBER 26, 1977 (3 PAGES)

CALCULATIONS FOR CANAL DREDGING - DATED MARCH 1990 (2 PAGES)

R. E. Rupnow
R. E. Rupnow
Works Civil Engineer

cc: T. WOOD

September 26, 1977

TO: T. J. Lynch

INDIANA HARBOR WORKS
STEEL PLANT GENERAL
INDIANA HARBOR SHIP CANAL
DREDGING HISTORY

The following is a summary of the dredging history for the Indiana Harbor Ship canal for the years 1920 through 1975, with the exception of the years 1929 through 1948, for which we can find no data except for a letter to Mr. R. C. Stevenson dated Nov. 18, 1954, which states we were unable to find any figures for those years.

The data we have available for the years 1920 through 1928 is from a Construction Department record dated Feb. 18, 1949. We can find no other information for these years.

Total dredging figures for the years 1950, 1951, 1952 and 1953 were taken from a Corps of Engineers' tabulation dated August 22, 1956. The remaining figures are from records in our files.

There are no records of costs incurred for dredging along the face of the dock for the years 1972 and 1973. Dredging was accomplished by using our Ore Unloader.

The above is per phone request of J. L. Reitzel July 7, 1977

W. B. Watkins

ENCL
CAO/cs

NG-638 7-54

LTV Steel Company
ENGINEERING DEPT.
Indiana Harbor Works

ATE March 1990
REPARED BY R.E. Rupnow
UBJECT Canal Dredging
SKETCH NO.
SCALE
Sh. 1of 2

Calculations for Canal Dredging

Rough Calculations based on soundings 4-8-88

Required Depth Determined by Meeting with C. Wimmer, R. Rupnow, and P. Lopes (Neptune Marine) on 3-7-90

Required Depth (from Datum) is 28 ft. Sta. 2+00 to Sta. 24+00
30 ft. Sta 24+00 to Sta 34+00

Depth before dredging calculated as follows:
Subtract water elev. from depth of soundings.
Subtract additional 0.25' for siltation.
Use ave depth of 10'E & 25'E. (ignore wall & 50E readings)
Result is existing depth below datum

Results are as follows:

Sta.	Depth	Sta.	Depth	Sta.	Depth
2+00	18.0'	13+00	23.5'	24+00	24.5
3+00	24.5'	14+00	25.0'	25+00	27.0
4+00	23.5'	15+00	24.0'	26+00	26.5'
5+00	23.0'	16+00	26.5'	27+00	25.5'
6+00	23.5'	17+00	26.0'	28+00	26.0'
7+00	23.0'	18+00	26.0'	29+00	25.5'
8+00	21.5'	19+00	24.5'	30+00	26.0'
9+00	21.5'	20+00	25.5'	31+00	25.0'
10+00	24.0'	21+00	26.5'	32+00	23.5'
11+00	25.0	22+00	25.0'	33+00	24.0'
12+00	24.0	23+00	23.5'	34+00	24.5'

Width of area to be dredged is 40'
Depth to be dredged is Required depth minus Existing Depth.
Volume is calculated based on ave. end area method

(CONT.)

..6 7-84

LTV Steel Company
ENGINEERING DEPT.
Indiana Harbor Works

E March 1990
REPARED BY R.E. Rupnow
UBJECT Canal Dredging
SKETCH NO.
SCALE
Sh. 2 of 2

Calculations for Canal Dredging (cont.)

Sta.	End Area		Ave End Area	x	Length	= Vol (ft³)
2+00	(28 - 18.0) x 40 =	400	270	x	100	27,000
3+00	(28 - 24.5) x 40 =	140	160	x	100	16,000
4+00	(28 - 23.5) x 40 =	180	190	x	100	19,000
5+00	(28 - 23.0) x 40 =	200	190	x	100	19,000
6+00	(28 - 23.5) x 40 =	180	190	x	100	19,000
7+00	(28 - 23.0) x 40 =	200	230	x	100	23,000
8+00	(28 - 21.5) x 40 =	260	260	x	100	26,000
9+00	(28 - 21.5) x 40 =	260	210	x	100	21,000
10+00	(28 - 24.0) x 40 =	160	180	x	100	18,000
11+00	(28 - 25.0) x 40 =	200	180	x	100	18,000
12+00	(28 - 24.0) x 40 =	160	170	x	100	17,000
13+00	(28 - 23.5) x 40 =	180	190	x	100	19,000
14+00	(28 - 25.0) x 40 =	200	180	x	100	18,000
15+00	(28 - 24.0) x 40 =	160	110	x	100	11,000
16+00	(28 - 26.5) x 40 =	60	90	x	100	9000
17+00	(28 - 26.0) x 40 =	120	120	x	100	12,000
18+00	(28 - 26.0) x 40 =	120	130	x	100	13,000
19+00	(28 - 24.5) x 40 =	140	120	x	100	12,000
20+00	(28 - 25.5) x 40 =	100	80	x	100	8,000
21+00	(28 - 26.5) x 40 =	60	130	x	100	13,000
22+00	(28 - 25.0) x 40 =	200	190	x	100	19,000
23+00	(28 - 23.5) x 40 =	180	160	x	100	16,000
24+00	(28 - 24.5) x 40 = (30 - 24.5) x 40 =	140 220	180	x	100	18,000
25+00	(30 - 27.0) x 40 =	120	170	x	100	17,000
26+00	(30 - 26.5) x 40 =	140	130	x	100	13,000
27+00	(30 - 25.5) x 40 =	180	160	x	100	16,000
28+00	(30 - 26.0) x 40 =	160	170	x	100	17,000
29+00	(30 - 25.5) x 40 =	180	170	x	100	17,000
30+00	(30 - 26.0) x 40 =	160	170	x	100	17,000
31+00	(30 - 25.0) x 40 =	200	180	x	100	18,000
32+00	(30 - 23.5) x 40 =	260	230	x	100	23,000
33+00	(30 - 24.0) x 40 =	240	250	x	100	25,000
34+00	(30 - 24.5) x 40 =	220	230	x	100	23,000

TOTAL VOL. =

577,000 ft³

$\frac{577,000}{27}$ =

21,370 cu. yds.

YEAR	CU. YDS. DREDGED		COST/CU. YD.	PUR. ORD.	Y.S. & T. COST	REMARKS
	TOTAL	Y.S. & T. SIDE				
1959	141,444	103,108	1.02	F-2758 F-10370	107,513(5)	Inland Contracted for Dredging to be Done
1960	62,825	36,302	1.05	F-46656	40,170(5)	"
1961	66,410	43,550	1.07	F-85654	46,599	"
1962	180,712	72,297	1.115	16-2-28524 16-2-41084 16-2-41085	93,680(7)	Inland Obtained Canal Bids Corps Contracted Work for Outer Harbor
1963	86,005	59,927	1.15	16-3-33524	73,020	Y.S. & T. & Inland Stl. Co. Dredged Canal Jointly
1965	170,147	108,757	1.19	16-5-8797	125,510(8)	"
1966	88,393	68,266	1.23	16-6-20974	77,951(8)	"
1967	87,797	57,021	1.25	16-7-15548	68,963(8)	"
1970	239,064	239,064	Outer Harbor 1.70 Canal 3.25	16-0-16301	659,613(3)	Y.S. & T. Contracted for Dredging-Y.S.&T. Side Only
1972	6,200	6,200	No Record	None		Y.S. & T. Dredged Along Face of Dock Using Ore Unloader
1975	7,500 Approx.	7,500 Approx.	No Record	None		Y.S. & T. Dredged Along Face of Dock using Ore Unloader

(1) Taken from Const. Dept. Record dated 2/18/49 No Other Data Available
(2) Total Dredging Taken from Corps of Engr's Tabulation Dated 8/22/56
(3) Y.S. & T. Cost Includes $9,608 for Chimical Additives - Flocculent and Dike Repairs
NOTE: (4) Y.S. & T. Cost Based On Unit Cost per Cu. Yd.
(5) Y.S. & T. Cost not Compatible with Unit Cost Probably due to Engr., Stores or other Intangibles
(6) No Record of Large Difference Between Actual Cost and Cost if Unit Prices were used
(7) Y.S. & T. Costs Incl. Engr. Costs
(8) Y.S. & T. Costs Incl. Engr. and Stores Costs. No Record as to why Actual Cost is Below Cost if Unit Prices are Used

EAR	CU. YDS. DREDGED TOTAL	CU. YDS. DREDGED Y.S.& T. SIDE	COST/CU. YD.	PUR. ORD.	Y.S.& T. COST	REMARKS
920 (1)		19,897	.25	No Record	4,974 (4)	Mark Co. Contracted for Dredging to be Done
924 (1)	73,826	44,926 (60%)	.42	" "	18,869 (4)	Dredged Canal Jointly with Inland Steel
925 (1)		22,576	.42	" "	9,482 (4)	Y.S. & T. Contracted for Dredging to be done
926 (1)	99,210	50,275	.30	" "	15,083 (4)	Y.S. & T. & Inland Stl. Co. Dredge Canal Jointly
27 (1)	46,817		.29	" "		Dredged Canal Jointly-No Record of Vol. on Y.S. & T. Side
928 (1)	37,494	20,030	.29	" "	7,912 (5)	Dredged Canal Jointly
949		42,883	.75	G-86129	32,162	Did not Dredge Jointly with Inland
950		Turning Basin 130,000	.76	H-14279	36,182 (6)	Dredged Canal Jointly with Inland Have No Copy of Purchase Ord. to Substantiate Cost with Unit Price
950	73,500 (2)	50,642	.808	H-42456	32,818	Inland Contracted for Dredging to be Done
951	85,531 (2)	41,225	.60	H-69684	24,736	"
952	85,064 (2)	46,998	.7175	K-34470	33,721	"
953	77,000 (2)	37,752	.915	Req'n IST-3069	36,712 (5)	"
954	93,865	42,052	.7175	A-24958	31,536 (5)	"
955	94,040	66,392	.775	A-83624	52,445 (5)	"
956	177,525	90,183	.82	B-26914	73,995	"
957	77,930	54,693	.93	C-2734	53,133 (5)	"
958	122,572	72,268	.99	C-49751	74,389 (5)	"

5 DEC 1991

Environmental and Social
Analysis Branch

Mr. John Winters, Chief
Water Quality Branch
Office of Water Management
Indiana Department of Environmental Management
105 South Meridian Street
P.O. Box 6015
Indianapolis, IN 46206-6015

Dear Mr. Winters:

This letter has been prepared to answer your questions regarding potential projects funded under Section 1135 of the Water Resources Development Act of 1986 (letter dated September 3, 1991). Your suggestion for dredging and disposal of contaminated sediments outside of the Federal navigation channel at Indiana Harbor would probably not qualify as a project modification under Section 1135. The current policy guidance for this authority requires fish or wildlife habitat improvement via a structural or operational change to an existing Corps project. Although the proposed dredging would improve area water quality, it would do little to improve the overall structural component of the fishery habitat of the river system. In addition, the proposed modification is outside the boundaries of the Federal navigation project.

However, Section 312 of the Water Resources Development Act of 1990 gave the Corps a new environmental authority to dredge outside of the Federal channel for environmental reasons. A local sponsor must pay 50% of the dredging costs and 100% of the disposal costs. In addition, Section 307 of the Aquatic Nuisance Act of 1990 gave the Corps authority to carry out projects for the protection, restoration, or enhancement of aquatic and associated systems. These new authorities are probably a more appropriate means of pursuing your proposal than Section 1135.

I would like to respond to some of your other questions so that you will have a better understanding of the Section 1135 program and therefore be able to submit other proposals in the future. The Section 1135 program will continue into the foreseeable future and will be managed like the Corps' Continuing Authorities Program. The annual program funding is 15 million dollars with a two million dollar per project spending ceiling.

Sponsorship requirements include paying for 25% of the initial construction costs and 100% of all future operation and maintenance costs. The cost estimate for Section 1135 proposals need not be very detailed, but they should be based on the best available information that you have.

If you wish to pursue this dredging outside the navigation channel, I would suggest that appropriate representatives from your office, U.S. EPA, and our office meet sometime in the near future to discuss what authority would be the best avenue to pursue. We will contact you by telephone in early December to discuss a potential meeting.

Please contact Mr. Paul Whitman at 312-353-8901 if you need any more information.

Sincerely,

ORIGINAL SIGNED

Philip R. Bernstein
Chief, Planning Division

Copy Furnished:

CENCC-PP-PM
Cody Fleece, IDEM

WHITMAN/bj/3-8901

CENCC-PD-S

CENCC-PD

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

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Governor
Kathy Prosser
Commissioner

105 South Meridian Street
P.O. Box 6015
Indianapolis, Indiana 46206-6015
Telephone 317-232-8603
Environmental Helpline 1-800-451-6027

Mr. Richard Carlson
U.S. Army Corp of Engineers
111 North Canal Street
Suite 600
Chicago, Illinois 60606

Dear Mr. Carlson:

Re: ECI Site
East Chicago, Indiana

In response to a verbal request from your office, I am sending you information pertaining to the position of Indiana Department of Environmental Management (IDEM) in regard to the Energy Cooperative, Inc. (ECI), site in East Chicago, Indiana. Specifically, you are seeking guidance on the minimum technical requirements that would be imposed, under IDEM's interpretation of RCRA requirements, in the event that a confined disposal facility (CDF) is constructed at this location.

As you are aware, the ECI site had hazardous waste management units which have not yet been through the closure process pursuant to 329 IAC 3.1. Due to soil and ground water contamination which may have come from these units, the site is also subject to post-closure permitting requirements. The responsibility for closure and post-closure activities at this facility rest with the owner/operator of the site.

The U.S. Army Corp of Engineers (U.S. ACE) interest in the site is in regard to a new CDF for the placement of dredged sediments from local waterways, particularly the Indiana Harbour. There have been numerous meetings between this agency, the U.S. ACE, the U.S. Environmental Protection Agency (U.S. EPA), the City of East Chicago, and other interested parties regarding the integration of the construction of a CDF with closure activities at this site. It is believed that such a concept, properly conceived and executed, will allow for closure to occur and enhance environmental protection.

For the purpose of delineating what the IDEM considers the minimum technical requirements for the construction of a CDF at this site, please consider the following:

Enclosure 9

67

- The establishment and maintenance of a ground water gradient control system that will prevent contamination from leaving the site. The use of a full or partial slurry wall is not an IDEM requirement, although slurry wall construction has been proposed. The maintenance of an adequate negative gradient within the site should be accomplished through the pumping of strategically placed wells. Any slurry wall construction, however, should be as close as possible to the property bounderies of the area referred to as the "main parcel". Contaminated ground water could be treated on-site at a treatment plant or stored for transportation to an off-site facility.

  Active or passive gradient control strategies are possible. The preferred approach is the pumping and treating of the groundwater, which is then reinjected into the ground. This approach may be combined with passive methods such as french drains and slurry walls. Comments on these are as follows:

  Pump and treat. Pump and treat includes high long-term energy and maintenance costs and generates large volumes of water that must be treated. The benefits of this system are: 1) intergrates well with corrective action; 2) small adaptable foot print on site, least likely to interfere with design of CDF, or be affected by remaining footers and refinery debris; 3) most likely to succeed in altering and maintaining groundwater flow in desireable if treated water is reinjected on site; 4) will generate the least contaminated soil to be dealt with.

  French drain. Configuration of drains may be difficult without affecting the CDF design. The excavated soils for construction will be a significant volume, that will potentially need to be treated as RCRA characteristic hazardous wastes due to organic contamination. The benefits are: 1) little or no long term energy or maintenance costs; 2) preliminary testing to evaluate this approach for proposed product recovery is currently being conducted.

  Slurry wall. Excavation will be required to cut off pipelines/plumbing that cross the path of slurry wall. A great deal of possibly RCRA hazardous soil could be generated, depending on the method of construction chosen. Construction delays due to excavation and cutting of pipelines increases the planned construction time of slurry walls around refineries. Compatibility of slurry with contaminants must be demonstrated. The benefits are: 1) only have construction costs; 2) can be built at site boundary.

- A cap meeting the requirements of 329 IAC 3.1-21 must be placed on top of that area where the regulated hazardous waste units were located. The remainder of the site would then be capped as the CDF reaches final design capacity. This final cap must meet hazardous waste land disposal facility requirements.

- Provided that the regulated hazardous waste management units are capped during the initial construction of the CDF, the IDEM will defer final capping until the CDF has reached design capacity for each cell. Upon final capping, the owner/operator of the site must begin post-closure activities and seek to obtain a post-closure permit. Post-closure will require monitoring and maintenance activities at the site for as long as necessary to provide environmental protection.

- Berms would be constructed around the entire CDF. The interior side of the berms would be lined with sufficiently impermeable synthetic, clay or composite liners.

- The CDF may be constructed with or without physical separation/drainage layer between the existing site and the new disposal cells. The U.S. ACE maintains that the sediment desicates to a very impermiable material, thus negating any benefit of an underlying system. In any case, design proposals should include surface liquid collection systems to accomodate storms, heavy rains, and other periods during which normal evaporation is not adequate.

Closure activities may be partially or fully (excepting post-closure) completed before CDF construction begins. Partial activities would be construction of the gradient control systems and capping of the hazardous waste management unit areas only. Full activities would be gradient control with complete capping of the main refinery parcel.

Regarding permitting issues, the facility will need two types: A closure/post-closure permit and a solid waste disposal facility permit. These could be combined into one permit to expedite issuance. The technical design specifications for a solid waste permit for the CDF should not exceed the previously discussed minimum requirements.

Please understand that these comments are not intended to be all-inclusive, but merely touching on some of the major issues brought to light thus far. The IDEM supports the dredging of the Indiana Harbor in an environmentally sound manner and believes that the use of the ECI site could result in multiple environmental benefits for this area.

Thank you for continuing to work closely with the IDEM on these important issues. Please contact Mr. Thomas Linson of my staff at 317/232-3292 if you have further questions on this matter.

Sincerely,

Timothy J. Method

Timothy J. Method
Assistant Commissioner
Solid and Hazardous Waste Management

TEL/kaw

cc: Mr. Karyl Bremer, U.S. EPA, Region V

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
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Commissioner

105 South Meridian Street
P.O. Box 6015
Indianapolis, Indiana 46206-6015
Telephone 317-232-8603
Environmental Helpline 1-800-451-6027

January 27, 1992

Mr. William Muno
Associate Division Director
U.S. EPA, Region V
77 West Jackson
Chicago, Illinois 60604

Dear Mr. Muno:

The purpose of this letter is to set forth the position of the Indiana Department of Environmental Management (IDEM) on closure/post-closure requirements for the ECI site in East Chicago, Indiana. This site obtained interim status for both tank storage and incineration in 1980. Through a bankruptcy court order in 1984, all above-ground buildings and equipment were removed, but closure was not conducted. Closure/post-closure of the site is required in accordance with 329 IAC 3-21.

The ECI property is composed of several parcels of land which are adjacent to and, in some cases, contiguous with, the main refinery parcel. For the purposes of closure/post-closure (excluding the corrective action requirements of the post-closure permit) the requirements will be limited to the area within and including the boundaries of the main refinery parcel. Any contamination from contiguous property solid waste management units (SWMU's) or off-site contamination from SWMU's or regulated units will be dealt with in the post-closure permit through corrective action requirements.

Closure/post-closure requirements focus on two main systems. These are (1) the ground water monitoring/gradient control system, and (2) the in-place closure cap system. The IDEM will consider and provide timely comment on any and all proposals for closure/post-closure which meet the minimum requirements in 329 IAC 3-21. This rule also requires that the owner/operator of the site be able to demonstrate adequate financial assurance for closure/post-closure activities. At this time, there does not appear to be an owner/operator entity who can meet these requirements. Until the problem of the existance of a viable owner/operator can be addressed, it is impossible to further address liability issues regarding the future of this site.

The IDEM will continue to take an active role in focusing on and recommending the elimination of duplicative regulatory requirements in proposed closure and confined disposal facility (CDF) designs. We will work to ensure that the closure and CDF design meets environmental protection requirements, but does not result in inflated or unnecessary costs. All requirements imposed will be identical to those that would be required of any other regulated facility in a similar situation. Please also note that CDF or no CDF, any future use of this site will be affected by the same closure/post-closure requirements.

Several different closure design options have been discussed up to this point. The one which has received the most attention to date involves placing a 2-3 foot thick slurry wall around the entire site at or very near the property line. A ground water gradient control system would be installed within the slurry wall to ensure maintenance of an inward flow and meet the ground water monitoring requirements for post-closure. The entire site would then be capped to the slurry walls. The cap would be constructed of materials to meet or exceed regulatory permeability requirements of 10-7 cm/sec. The CDF could either be constructed on this cap, or the liner of the CDF could actually serve as the cap. This opition, given proper design and adequate implementation, could certainly suffice to meet the necessary requirements.

In accordance with U.S. Environmental Protection Agency (U.S. EPA) policy and previous agreements between the IDEM and the U.S. EPA, the sediments are considered a solid waste upon removal from water's surface. As such, the disposal facility will be required to meet IDEM's solid waste landfill design requirements pursuant to 329 IAC 2 and applicable technical policies. For further information on the solid waste management program, please contact Mr. Bruce Palin of this office at 317/232-8892.

All of the above issues have been discussed at length with your various staff, so this serves as a summary rather than a revelation of any new issues. If you require additional information, please contact me at 317/232-3210 or Mr. Thomas Linson of my staff at 317/232-3292.

Sincerely,

Timothy J Method

Timothy J. Method
Assistant Commissioner
Solid and Hazardous Waste Management

TEL/kaw

cc: Hon. Peter Visclosky, U.S. Congressman
Mr. Dick Chapman, Arco Petroleum
Ms. Lydia Benda, U.S. Army Corps of Engineers
Mr. Richard Carlson, U.S. Army Corps of Engineers
Ms. Kay Nelson, City of East Chicago
Mr. Al Fenedick, U.S. EPA, Region V

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT, CORPS OF ENGINEERS
111 NORTH CANAL STREET
CHICAGO, ILLINOIS 60606-7206

REPLY TO
ATTENTION OF

2 2 JUN 1995

Environmental and Social
Analysis Branch

U.S. Fish and Wildlife Service
620 S. Walker St.
BLoomington, Indiana 47403
ATTN: Dave Hudak

Dear Mr. Hudak:

The Chicago District would appreciate your agency's comments on the impacts of the Indiana Harbor and Canal project on peregrine falcons nesting in the vicinity of the proposed dredging and confined disposal facility at East Chicago in Lake County, Indiana.

Chicago District staff discussed the falcons with Dan Sparks of your office on 19 August 1994, 16 November 1994, and 1 December 1994. Mr. Sparks said that he would schedule a meeting of USFWS, USEPA, and Chicago District staff to discuss the project's impacts on the falcons and the need for interagency coordination; he also said that USFWS planned to conduct a natural resource damage assessment. Mr. Sparks expressed concern over the potential for short-term increases in contaminant uptake by the falcons and their prey, but also said that such an increase would be insignificant compared to the environmental benefits of dredging and confinement. Copies of pertinent correspondence are attached.

The falcons nest on the underside of the eastbound ramp of the Cline Avenue (Route 912) high-rise bridge over railroad tracks. The bridge stands 2.5 miles southwest of the harbor and 3000' north of the canal, at the northwest corner of the proposed disposal site. The falcons (like diving ducks and wading birds in the vicinity) suffer from accumulation of PAHs and PCBs (contaminants present in their prey; in oil-stressed diving ducks, for example).

The proposed project will involve several episodes of dredging in Indiana Harbor and Canal, and construction and filling of a confined dispoal facility adjacent to the canal, over a period of several years. The confined disposal area will be fenced and screened (according to plans developed in consultation with USDA animal damage control staff in Indianapolis) before capping, to prevent uptake of contaminants by wildlife.

Because the falcon nesting site is from 3000' to 12,000' from dredging zones, adverse impacts due to increases in noise during dredging will be minimal.

Increases in noise during disposal or CDF construction would be greater due to the proximity of the bridge to the northwest corner of the disposal area, but would not be a significant adverse impact. The nesting site is already subjected to considerable noise from road and rail traffic.

It is my staff's opinion that no "incidental taking" (of peregrine falcons) will result from the proposed Indiana Harbor project.

I would prefer to resolve the question of "peregrine impacts" before the draft EIS is released for public review. If no response if provided by 1 August 1995, I will assume that you have no comments or objections. Please mark your reply to the attention of Mr. Keith Ryder, CENCC-PD-S; questions should be directed to Mr. Ryder at 312/353-7795. Thank you for your assistance.

Sincerely,

Philip R. Bernstein
Chief of Planning Division

Attachments

Copy Furnished:

USEPA (R. Tolpa, WQC-15J)
USEPA (A. Fenedick, 5ME-14)
USEPA (C. Alexander, 5ME-14)
CENCC-PP-PM (R. Carlson)
IDNR, Mitchell (J. Castrale)
IDNR, Indianapolis (W. Faatz)
USDA, Indianapolis (J. Loven, West Lafayette)
IDEM (J. Smith, OER)

United States Department of the Interior

FISH AND WILDLIFE SERVICE
BLOOMINGTON FIELD OFFICE (ES)
620 South Walker Street
Bloomington, Indiana 47403-2121
(812) 334-4261 FAX 334-4273

IN REPLY REFER TO:

July 14, 1994

Mr. Keith Ryder
U.S. Army Corps of Engineers
111 N. Canal St.
Chicago, Illinois 60606-7206

Dear Mr. Ryder:

This regards the March 14, 1994 Federal Register notice concerning the intent to prepare a Draft Environmental Impact Statement (DEIS) in conjunction with proposed maintenance dredging of Indiana Harbor and Canal, and the construction of a Confined Disposal Facility (CDF) at East Chicago, in Lake County, Indiana.

This letter has been prepared under the authority of the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) and is consistent with the intent of the National Environmental Policy Act of 1969, the Endangered Species Act of 1973, and the U.S. Fish and Wildlife Service's Mitigation Policy.

We believe this project is a vital component for restoring the Area of Concern (AOC) and look forward to its implementation. However, due to the presence of the federally endangered peregrine falcon (*Peregrinus falco*) nest within the project area, and likely year-round usage of this area by peregrine falcons, we need to address Endangered Species Act of 1973 issues relating to this at your earliest convenience. This is not a request for a "formal consultation" as defined at (50 CFR 402.14), rather an effort to fulfill the requirements of Section 7 of the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.) via early coordination.

We are willing to meet with you to discuss this issue, and to provide technical assistance regarding the planning of the proposed project. Please contact Dan Sparks of my staff at (812) 334-4261, extension 219 to arrange a meeting at your convenience.

Sincerely yours,

Daniel W. Sparks, acting

for David C. Hudak
Supervisor

cc: Regional Director, FWS, Twin Cities, MN (AES) - J. Blankenship
U.S. EPA, Environmental Review Branch, Chicago, IL - C. Alexander (5ME-14)
U.S. EPA, Water Division, Special Projects Section, Chicago, IL - R.Tolpa(WQC-15J)
Indiana Department of Natural Resources, Indianapolis, IN - W. Faatz
Indiana Department of Natural Resources, Mitchell, IN - J. Castrale
Indiana Department of Environmental Management, OER, Indianapolis, IN - J. Smith

MARCH 3, 1849

IN REPLY REFER TO:

United States Department of the Interior

TAKE PRIDE IN AMERICA

FISH AND WILDLIFE SERVICE
BLOOMINGTON FIELD OFFICE (ES)
620 South Walker Street
Bloomington, Indiana 47403-2121
(812) 334-4261 FAX 334-4273

July 27, 1995

Mr. Philip R. Bernstein
Planning Division
U.S. Army Corps of Engineers
111 N. Canal St.
Chicago, Illinois 60606-7206

Dear Mr. Bernstein:

This regards your June 22, 1995 letter concerning peregrine falcon impacts related to the maintenance dredging of Indiana Harbor and Canal, and the construction of a Confined Disposal Facility (CDF) at East Chicago, in Lake County, Indiana.

This letter has been prepared under the authority of the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) and is consistent with the intent of the National Environmental Policy Act of 1969, the Endangered Species Act of 1973, and the U.S. Fish and Wildlife Service's Mitigation Policy.

We believe this project is a vital component for restoring the Area of Concern (AOC) and look forward to its implementation. However, due to the presence of the federally endangered peregrine falcon (*Peregrinus falco*) nest within the project area, and likely year-round usage of this area by peregrine falcons, we need to address Endangered Species Act of 1973 issues relating to this at your earliest convenience. Pursuant to Section 7 of the Endangered Species Act of 1973, as amended, federal agencies are required to ensure their actions do not jeopardize the continued existence of federally listed species. In order to ensure compliance with this mandate, consultation with the FWS is required for any action that may affect listed species. Based on the information we have shared with your staff, we believe that this action "may affect" these peregrine falcons. The Corps should initiate formal consultation, so that we can address the endangered species permitting requirements for this project in a timely fashion.

This does not preclude the need for further consultation on this project as required under Section 7 of the Endangered Species Act of 1973, as amended.

If you have any questions regarding these comments, or require further technical assistance, please contact Dan Sparks of my staff at (812) 334-4261, extension 219.

Sincerely Yours,

David C Hudak

David C. Hudak
Supervisor

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INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

We make Indiana a cleaner, healthier place to live

Evan Bayh
Governor
Kathy Prosser
Commissioner

100 North Senate Avenue
P.O. Box 6015
Indianapolis, Indiana 46206-6015
Telephone 317-232-8603
Environmental Helpline 1-800-451-6027

August 16, 1995

Joe Malek
USEPA Region V
77 W. Jackson Blvd.
Chicago, IL 60604

Dear Mr. Malek:

On August 8, 1995 IDEM received a copy of the USACE's calculation for air emissions for open air storage of sediments from the Indiana Harbor Ship Canal. Various people in the Office of Air Management reviewed this calculation and it is deemed satisfactory.

On another related note, it does not appear that the USACE project will need VOC emissions offsets because, based on the estimate, the 25 ton/year threshold will not be surpassed. IDEM is still looking into this matter and will keep you advised.

Thank you for your cooperation.

Sincerely,

William Cody Fleece

Cody Fleece
Sediment Remediation Program Coordinator
Office of Water Management

cc: Jay Koch
Robert Ondrusek
Ed Stressino
Dave Wersan
Beth Admire
Rich Carlson
Kay Nelson

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
CHICAGO DISTRICT. CORPS OF ENGINEERS
111 NORTH CANAL STREET
CHICAGO. ILLINOIS 60606-7206

REPLY TO
ATTENTION OF

August 16, 1995

Environmental and Social
Analysis Branch

U.S. Fish and Wildlife Service
620 S. Walker Street
Bloomington, IN 47403
ATTN: Mr. David C. Hudak, Supervisor

Dear Mr. Hudak:

In response to your letter of July 27, 1995, the Chicago District is requesting a formal consultation with your office on the potential impacts of the Indiana Harbor and Canal project to the Peregrine Falcons (***Peregrinus falco***) nesting near the proposed Confined Disposal Facility (CDF) at East Chicago, Lake County, Indiana.

This formal consultation request is in accordance with Part 402, Subpart B, Section 402.15 of the Endangered Species Act of 1973, as amended. The enclosed Biological Assessment includes a description of (1) the action, (2) the specific area affected, (3) the listed species which may be adversely affected, (4) how the action impacts the listed species, and (5) the other federal agencies with jurisdiction in the project area.

We look forward to working with your office on this important matter. We suggest a meeting here in Chicago, at your earliest convenience, to visit the project site and nesting site of the Peregrines in question It is our understanding that a biological opinion is to be rendered, by your office, within 90 days of the initiation of this formal consultation.

Please send your reply to the attention of Dr. Ken Derickson, CENCC-PD-S; questions should be directed to Dr. Derickson at 312/353-6475. Thank you for your assistance.

Sincerely,

Philip R. Bernstein
Chief of Planning Division

Attachment

United States Department of the Interior

FISH AND WILDLIFE SERVICE
BLOOMINGTON FIELD OFFICE (ES)
620 South Walker Street
Bloomington, Indiana 47403-2121
(812) 334-4261 FAX (812) 334-4273

IN REPLY REFER TO:

September 16, 1996

Lt. Colonel Robert E. Slockbower
District Engineer
U.S. Army Engineer District
Chicago
111 North Canal Street
Chicago, Illinois 60606-7206

Dear Lt. Colonel Slockbower:

This constitutes our Final Fish and Wildlife Coordination Act report for the Indiana Harbor and Ship Canal Maintenance Dredging and Disposal Project at East Chicago in Lake County, Indiana. This report has been prepared under the authority of the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq) and are consistent with the intent of the National Environmental Policy Act of 1969, the Endangered Species Act of 1973, and the U.S. Fish and Wildlife Service's Mitigation Policy.

The U.S. Army Corps of Engineers (Corps) proposes to maintenance dredge the entire Indiana Harbor and Ship Canal (IHC) Federal navigation channel to authorized project depths, plus an average 0.5 foot overdredge. The dredged materials would be deposited in a confined disposal facility (CDF), constructed on the former Energy Cooperative, Inc. (ECI) site in East Chicago.

As described in the Draft Environmental Impact Statement (DEIS), the Recommended Plan, also called the Cooperative Dredging Program, includes dredging of the Federal channel and polychlorinated biphenyl (PCB) "hot spots" by the Corps, dredging of all navigation berthing areas by their owners, and dredging of the dockfaces owned by Inland Steel, which are covered in a Consent Decree with the U.S. Environmental Protection Agency (USEPA)(USCOE 1995). The PCB contaminated materials would be placed within a separate CDF subcell which would be designed to meet disposal requirements of the Toxic Substances Control Act (TSCA). Additional space may be available within the CDF for other sediments from the Grand Calumet River (GCR) system.

PROJECT DESCRIPTION

The IHC is located within the Calumet Lacustrine Plain, an area of generally low relief occupying the bed of glacial Lake Chicago (Blatchley 1898; Meyer 1946; Hartke *et al.* 1975). Most of the soils of the Plain are water-laid sand and clay. The East Chicago area was originally a mixture of sand dunes, prairie, savannas, wetlands, and meandering rivers between the Tolleston Beach Ridge, which was formed by the last stage of Lake Chicago, and the current level of Lake Michigan (Figure 1). The Grand Calumet River flowed across the southern edge of what eventually became the City. It was almost devoid of a current and was so clogged with tall grasses and reeds that it was almost

Figure No. 1.

B/81

1917 map of the Indiana Harbor/ East Chicago/Hammond/Gary area impassable. In 1872, army engineers surveyed the Grand Calumet and reported that the condition of the surrounding country was so wet and undevelopable, that no commercial advantage would be provided by dredging the river (Secretary of War 1873).

Despite these natural constraints to development, railroads crossed the area in the 1870s, and in 1887 the site of East Chicago was laid out. The expansion of the steel industry in the Chicago area was responsible for the origin and development of East Chicago. As land became too crowded and expensive in Illinois, the industrialists looked to adjacent, undeveloped Indiana as a place to expand. The first industry in the East Chicago area was established in 1888, and many others soon followed (Moore 1959).

As far back as the 1870s, local interests desired a safe, large vessel harbor on Lake Michigan in Lake County, Indiana, but no natural harbors existed. There were plans to make Wolf Lake and its outlet to Lake Michigan in Hammond into a harbor, but the City was unable to get Federal assistance for such an endeavor. Industrialists in East Chicago, however, decided to construct a canal to the Grand Calumet River, with or without Federal assistance. The canal was to be 3.5 miles long and would connect the river to Lake Michigan, with the intent of making the entire river and canal system navigable for commercial shipping. In addition, a pier was to be constructed into the lake at the mouth of the canal at a sand spit called Poplar Point (Moore 1959).

The East Chicago Company constructed both the outer harbor and the canal at its own expense. Work on the outer harbor began in 1901 and consisted of an 1,800 foot long breakwater on the north and a 1,200 foot long breakwater on the south. The area between the breakwaters was dredged to a depth of 21 feet. The Federal government was persuaded to assume maintenance of the outer harbor when it was completed, and also agreed to do the same for the ship canal. Construction of the canal began in 1903. It was to be 200 feet wide and 21 feet deep, with a bend 1.5 miles from the lake at "The Forks", where a branch was to extend 1.5 miles to connect with Lake George while the main canal continued 2 miles to the river. However, the entire Canal and Grand Calumet River navigation plan did not materialize, even though the canal was extended to the river, and navigation eventually ended at Chicago Avenue, about 2.5 miles from Lake Michigan. The Lake George Branch also was never completed, ending after about 1 mile (Moore 1959).

Federal involvement in the IHC was originally authorized in 1910 (House Doc. 1113, 60th Congress, 2nd Session) and was later modified by 10 other River and Harbor Acts (USCOE 1966). These Acts concerned the extent of Federal responsibility in maintaining navigation and changes in authorized depths as ships became larger. Several authorized project features, including deepening and widening the main canal between Columbus Drive and the GCR and deepening and widening the entire Lake George Branch, remained inactive for many years and were eventually deauthorized. The Federal government took over complete responsibility for the harbor and canal in 1925. The Federal navigation project now ends at Columbus Drive, about 2.0 miles from Lake Michigan, and includes approximately half of the Lake George Branch. It also includes the outer breakwaters and navigation lights, which have been modified extensively since 1910 as the configuration of the harbor changed due to expansion of the steel mills into the lake on fill.

As shown on Figure 2, the authorized depths and designated Reaches of the Federal navigation project are as follows:

- outer harbor approach channel - 29 feet - Reaches 1 and 2
- outer harbor anchorage and maneuver basin - 28 feet - Reaches 2, 3, and 4
- canal entrance channel - 27 feet - Reach 5
- main canal - 22 feet - Reaches 6 through 10
- 2 turning basins along the canal - 22 feet - Reach 9 and junction of Reaches 11 and 13
- Calumet River Branch of the canal - 22 feet- Reach 13
- Lake George Branch of the canal - 22 feet - Reaches 11 and 12

The Calumet River Branch is the outlet for the Grand Calumet River, and therefore is a flowing stream, while the Lake George Branch is a dead-end canal and does not flow.

All of the land surrounding Indiana Harbor and the entrance canal, Reaches 1 through 5, is man-made land (lakefill) created by Inland Steel and LTV Steel (IDNR 1979a) (see Figure 2). The mouth of the canal, which is at the landward end of Reach 5, is approximately at the original beach line of Lake Michigan. The lakeward extension of the steel mills began in 1908, when the industries petitioned the State to grant them rights to fill the lakebed because they considered themselves landlocked and unable to expand. Therefore, the outer harbor and entrance channel expanded into the lake along with the steel mills. The current configuration was established during the 1980s.

The entire East Chicago area has been extensively modified by urban and industrial developments. In addition to the steel mills, there are or were oil refineries, chemical companies, foundries, railroad car construction companies, a plaster and wall board construction plant, and various other industries. These industries were developed both on the natural land area and on the lakefill.

EXISTING CONDITIONS

Water Quality

The Grand Calumet River system drains about 25 square miles and consists of 3 sections: The East Branch (EBGCR), the West Branch (WBGCR), and the Indiana Harbor Ship Canal (IHC) and Indiana Harbor. The EBGCR is about 13 miles long and flows from its headwaters within the Indiana Dunes National Lakeshore/Marquette Park Lagoons and U.S. Steel property westward to the IHC. The WBGCR, however, flows both east and west. There is a natural hydraulic divide near Roxana Marsh on the Hammond/East Chicago boundary, with most of the discharges from Hammond flowing west to the Illinois River system (Mississippi River drainage) and most of the discharges from East Chicago flowing east to the IHC (USEPA 1985, Crawford and Wangsness 1987). However, the East Chicago portion can also flow west, depending on the water level of

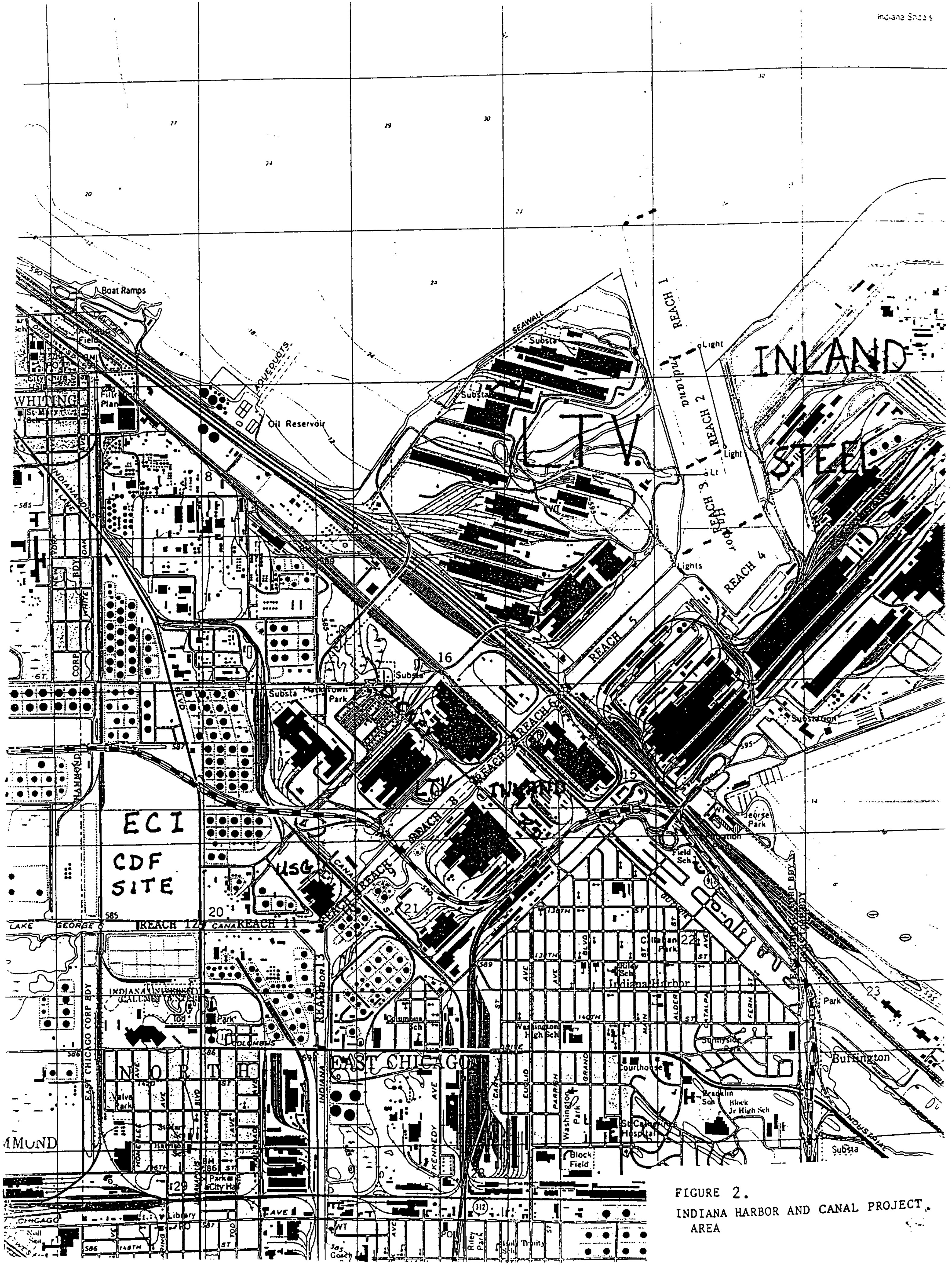


FIGURE 2.
INDIANA HARBOR AND CANAL PROJECT AREA

Lake Michigan, effluent flow in the 2 branches of the river and the IHC, and the influence of wind direction and velocity. Complete reversals in streamflow have been recorded within a 24-hour time period (Crawford and Wangsness 1987).

The IHC flows northward to Lake Michigan from the junction of the East and West Branches. However, the flow direction can be reversed in the canal at almost any time. The reasons for these fluctuations in streamflow are not known, but it has been suggested that they are due to significant constrictions in the width of the canal at several railroad crossings and changes in water volume in the canal between and downstream from these constrictions (Crawford and Wangsness 1987). The water volume changes could be due to varying flows from the 16 effluent outfalls that discharge into the IHC downstream from Reach 9, whose combined flow is about 3 times the average flow at the beginning of the IHC. "The flow reversals observed in the ship canal and the river may be due to backwater caused by the interaction of the volume and diel [24-hour] variation of the effluent discharges and the locations of their outfalls in the ship canal with respect to the channel constrictions".

Water and sediment quality have long been significant problems in the Indiana Harbor and Canal area. The majority of the industries and municipalities in the area discharge into the GCR or the IHC. It is estimated that municipal and industrial wastewater, industrial cooling and process water, and storm water runoff comprise more than 90 percent of the flow in the GCR/IHC (USEPA 1985, Crawford and Wangsness 1987).

For many years, such discharges were unregulated, and a wide variety of materials, from raw sewage to heavy metals and oils, were discharged into the system. In the mid-1930s, Indiana began to try to control the pollution by ordering East Chicago, Gary, Hammond, and Whiting to abate domestic pollution (Indiana Stream Pollution Control Board 1965). However, combined sewer overflows and industrial discharges from point and non-point sources remained a serious problem even after waste water treatment plants were constructed to handle domestic sewage. For example, refinery records from 1949 stated that "there is now as much oil on the surface of the canal that it is becoming a dangerous fire hazard." The ISPCB report in 1965 described the IHC as discolored and containing oil and other floatable material, so conditions had improved little from the 1930s and 1940s.

At a 1968 conference on Lake Michigan pollution, it was reported that the GCR's main use was as a receiver of municipal and industrial wastes (Miller 1968). The steel mills that discharged to the system were described as the most significant sources of wastes in the Lake Michigan Basin. The chief identifiable constituents in their discharges were oily wastes, waste pickle liquor, phenolic materials, ammonia, cyanide, and suspended solids. Oil refineries discharged oily wastes, phenols, and ammonia. It was indicated that: "Other wastes discharged intermittently may have serious local effects or may cause temporary excessive pollution. Among these wastes are accidental

8t

spills from storage tanks and barges; wastes from lake vessels, barge tows, and pleasure craft; and materials from dredging operations. ... Waters of the Indiana Harbor Canal and the Grand Calumet River are unsightly and characterized by floating debris, oil, discoloration, and high suspended solids loading." Channel banks, structures, and boats had a black coating of oil.

In the early 1960s, sampling in the harbor showed that the pollutants that posed the greatest threat to satisfactory water quality were ammonia nitrogen, total soluble phosphate, phenols, dissolved oxygen, and cyanide (Risley and Fuller 1966). Extremely elevated concentrations were documented for total phenols (354 ug/l in the canal, 548 ug/l at 151st St, 155 ug/l in the harbor), lead (35 ppb), zinc (87 ppb), and cyanide (19 ppb).

During this same mid- to late-1960s period, the Federal Water Pollution Control Administration (FWPCA) of the U.S. Department of the Interior was also conducting water quality studies on the GCR, IHC, the Calumet River and Harbor in Illinois, and adjacent Lake Michigan, as the Calumet Area Surveillance Project. Fifteen stream, harbor, and water intake/Lake Michigan stations were to be sampled on a weekly basis to determine chemical and microbiological conditions. Stations included a railroad bridge over the GCR in Gary, 151st Street and Dickey Road over the IHC in East Chicago, the outer end of the canal entrance channel (current Reach 5), and the inner end of the harbor approach channel (current Reach 2).

In their report on the period January through June 1967, the FWPCA stated that industrial pollution in the GCR/IHC had become more severe since the study started in 1965. The findings indicated that concentrations of iron, cyanide, ammonia, and phenolic compounds were all higher than in 1965 (Bowden 1967). Slugs of arsenic were occasionally encountered, and low pH values accompanied by high sulfates indicated pickling liquor wastes. The samplers reported floating oil during almost every sampling run on the GCR/IHC and in the harbor, and the waters were usually turbid, with an unpleasant odor. Oil was common on the water surface throughout the harbor and could be seen flowing from the harbor into Lake Michigan. Oil and grease were consistently found at samples from the water intakes in open Lake Michigan.

Similar results were reported for the period July 1967 through June 1968 (Bowden 1968). At Gary, the winter peaks in phenol concentrations were reported to be as high as ever, but sulfate concentrations were greatly reduced because U.S. Steel had completed its deep well disposal system for pickling liquor wastes during December 1967. The GCR was described as "still the same reddish-brown color it was in 1965 and oil has been reported on the surface on almost every occasion that the station has been visited. In addition, sludge beds are continuously being formed in the river. All of these conditions are violations of the [water quality] criteria."

At the 2 stations on the IHC, industrial waste levels also remained high, with total iron, phenol, and cyanide concentrations higher than 1965 levels (Bowden 1968). Phenol peaks were higher at 151st Street during the 1967-68 winter than in previous years, but they were lower at Dickey Road, apparently due to efforts by LTV Steel (then Youngstown Sheet and Tube Company) and Inland Steel to reduce phenolic discharges. Heavy metals levels remained similar to previous years.

The level of industrial pollution in the harbor remained high, and oil was reported on the surface on 11 of the 15 sampling periods between January and June 1968 (Bowden 1968).

During this period, there had been at least 2 major oil spill incidents within the IHC that had severely polluted these areas and continued out into Lake Michigan and contaminated about 45 miles of shoreline (Johnson *et al.* 1968).

> Oil pollution is a major problem in the Lake Michigan drainage basin. Discharges from industrial plants and commercial ships, and careless practices in loading and unloading cargos, pollute water in many areas. Oil discharges and spills produce unsightly and unhealthy conditions which affect beaches and recreational areas, contribute unpleasant taste and odor to water, coat the hulls of boats, and in many cases are toxic to fish and other aquatic life. Although oil contamination has been observed in many Lake Michigan areas, this type of pollution occurs principally in the Calumet Area of Illinois and Indiana, at the southern end of the lake (Johnson *et al.* 1968).

These authors concluded: "These findings strongly indicate the massive oil slick (Sept 17, and Oct 3, 1967) originated in Indiana Harbor and Canal."

The City of Chicago utilizes Lake Michigan water for its domestic water supply, so it has long been concerned about water quality in the southern portion of the lake. Therefore, its water department has regularly sampled raw water at the South Water Filtration Plant (SWFP), which gets its water from the Dunne (68th Street) Crib, located about 2 miles into the lake and about 9 miles from the mouth of Indiana Harbor and 3.75 miles north of Calumet Harbor, and from a shore intake at the plant itself. The plant is about 2.5 miles north of Calumet Harbor.

Beginning in 1948, the City has also regularly sampled sites on the IHC and Calumet River in order to determine the sources of pollution in Lake Michigan. The principal sources of pollution at the SWFP intakes have been identified as being from the IHC (Vaughn 1968 and 1970, Harrison *et al.* 1977 and 1979). The afore-mentioned 1967 oil slicks were recorded at the Dunne Crib, as are the effects of "normal" discharges from the IHC.

Of great significance to Chicago water quality are slugs of pollutants that drift around in the lake near the cribs. These are most noticeable as abnormal hydrocarbon odors, which have been described as being similar to those obtained by diluting oil refinery wastes with lake water (Vaughn 1968). "Usually, the water during these periods has an unusually high ammonia-nitrogen and phenol content and has abnormal chlorine absorption properties."

Twenty years of data, from 1950 through 1969, showed that the number of odor days peaked in 1951 with 127, followed by lower peaks of 94 in 1961 and 95 in 1966, after which they began to decline (Vaughn 1970).

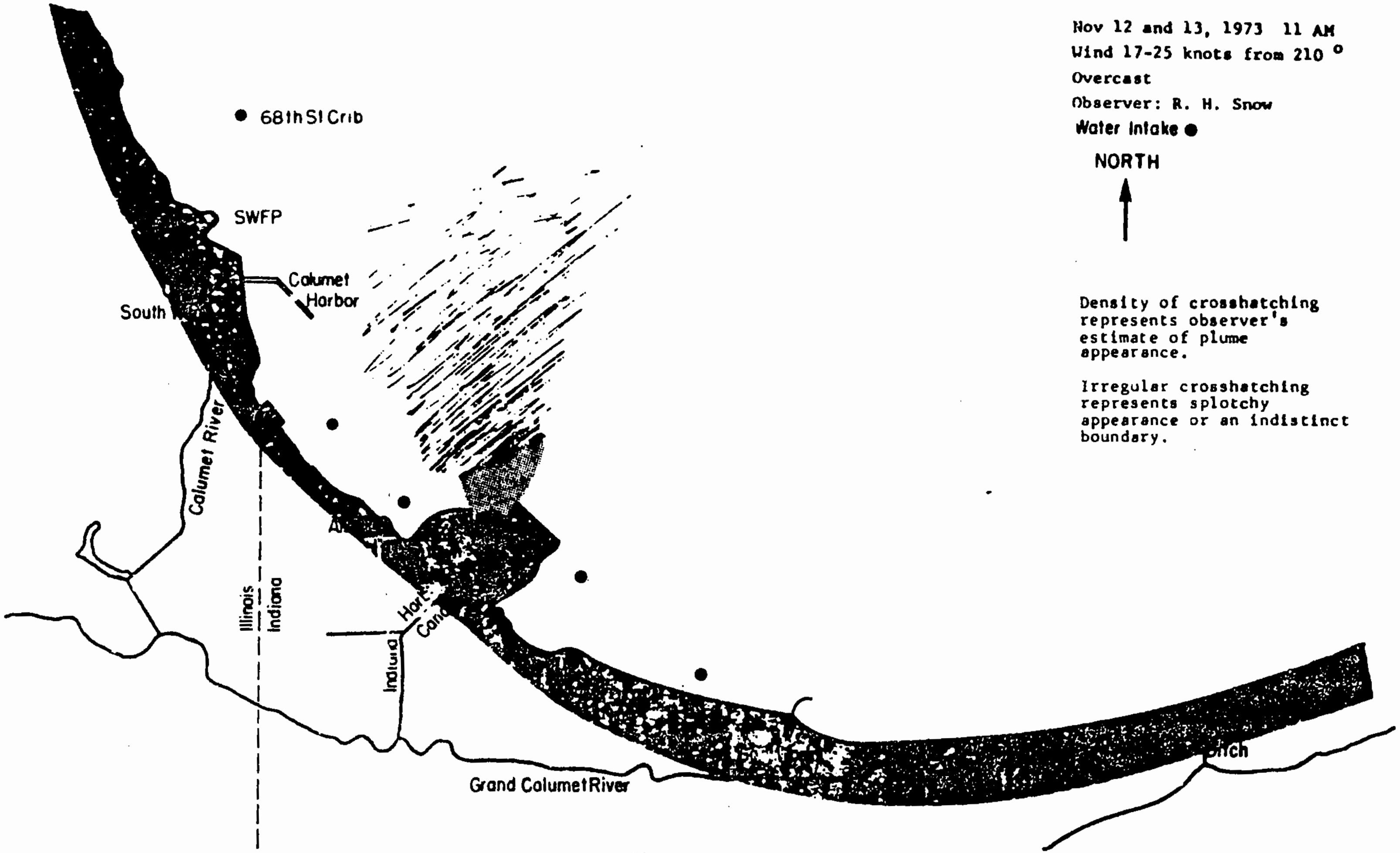
Studies in 1977 using dyes and chemicals to tag and trace the movements of IHC water within Lake Michigan confirmed that this is the source of pollution slugs that affect Chicago's water (Harrison *et al.* 1977). This pollution occurs both as wind-driven surface films and as sinking plumes that drop below the lake surface and follow the lake's bottom contour from the mouth of Indiana Harbor northwestward to Dunne Crib.

During summer months, the warmer, less dense water from the canal and harbor stays above the cooler lake water. The lake water does not mix with the harbor water but forms a wedge which extends in underneath the harbor water. The surface of the wedge has been found to vary from 8 to 12 feet in depth in Reach 2 to between 18 and 20 feet at Reach 5 (Bowden 1968). Distinct slugs of pollutants often remain on the lake surface and are moved around by winds and currents.

Snow (1974) studied the behavior of the plume and found evidence that several mechanisms act to disperse the effluents, depending on conditions at the mouth of the canal and harbor and in the lake. The most important are turbulent vertical mixing within the canal with intruding colder lake water, gravity spreading, vertical mixing of the plume due to turbulent eddies in the lake, and the direction of the natural lake currents and winds which carry along the floating plume.

Aerial observations of the pollution plume leaving Indiana Harbor were made in November and December 1973 (Snow 1974). The plume was a brownish or reddish purple color and was easy to observe in the otherwise clean lake water. Representative examples of the plume dispersion patterns are indicated in Figures 3 through 7. It was found that the plume could readily be followed by plotting a combination of the following pollutants which acted as tracers and provided a signature to positively identify the IHC effluents: total iron (Fe), conductivity, ammonia-nitrogen (N), coliform bacteria, chloride, pH, temperature, and fluoride. Concentrations exceeding water quality standards were measured as far as 5 miles from shore, particularly for ammonia-nitrogen and bacteria. High chlorophyll measurements showed that the IHC effluent had a nutrient effect on algal growth.

During winter, sinking plumes are more likely to occur. When the temperature of the water coming out of the harbor is near 4°C and the Lake Michigan temperature is close to 0°C, the denser canal water will sink below the colder, less dense lake water (Harrison *et al.* 1977 and 1979). Since the water intakes of the various municipal water plants are located essentially at the bottom of the lake, it is understandable that they can receive higher concentrations of pollutants under sinking plume conditions.



Nov 12 and 13, 1973 11 AM
Wind 17-25 knots from 210 °
Overcast
Observer: R. H. Snow
Water Intake ●

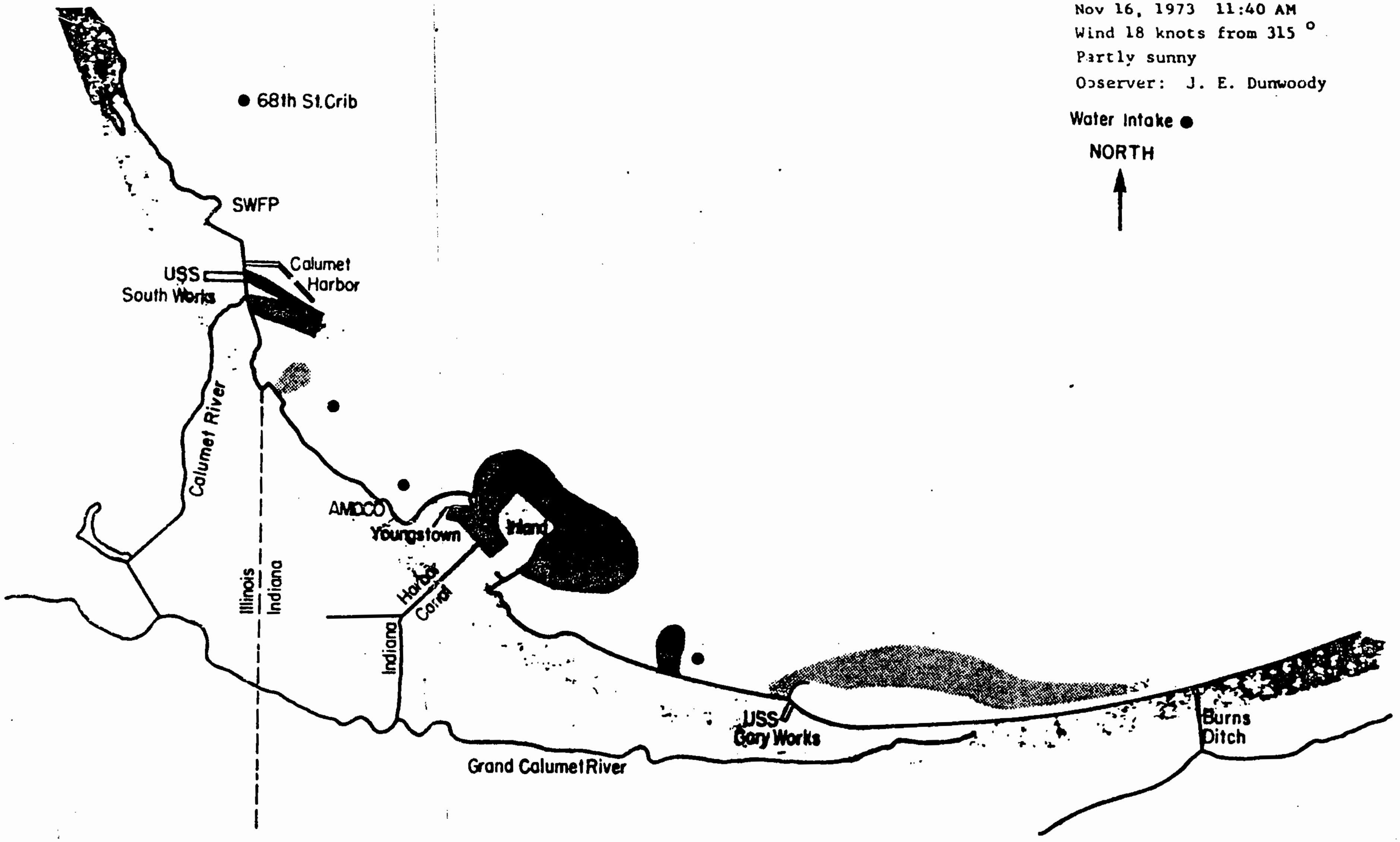
Density of crosshatching represents observer's estimate of plume appearance.

Irregular crosshatching represents splotchy appearance or an indistinct boundary.

Figure 3.

SKETCH SHOWING VISUAL APPEARANCE OF EFFLUENTS BY AERIAL OBSERVATIONS November 12 and 13, 1973

From Snow 1974



Nov 16, 1973 11:40 AM
Wind 18 knots from 315 °
Partly sunny
Observer: J. E. Dunwoody

Figure 4.

SKETCH SHOWING VISUAL APPEARANCE
OF EFFLUENTS BY AERIAL OBSERVATIONS
November 16, 1973

From Snow 1974

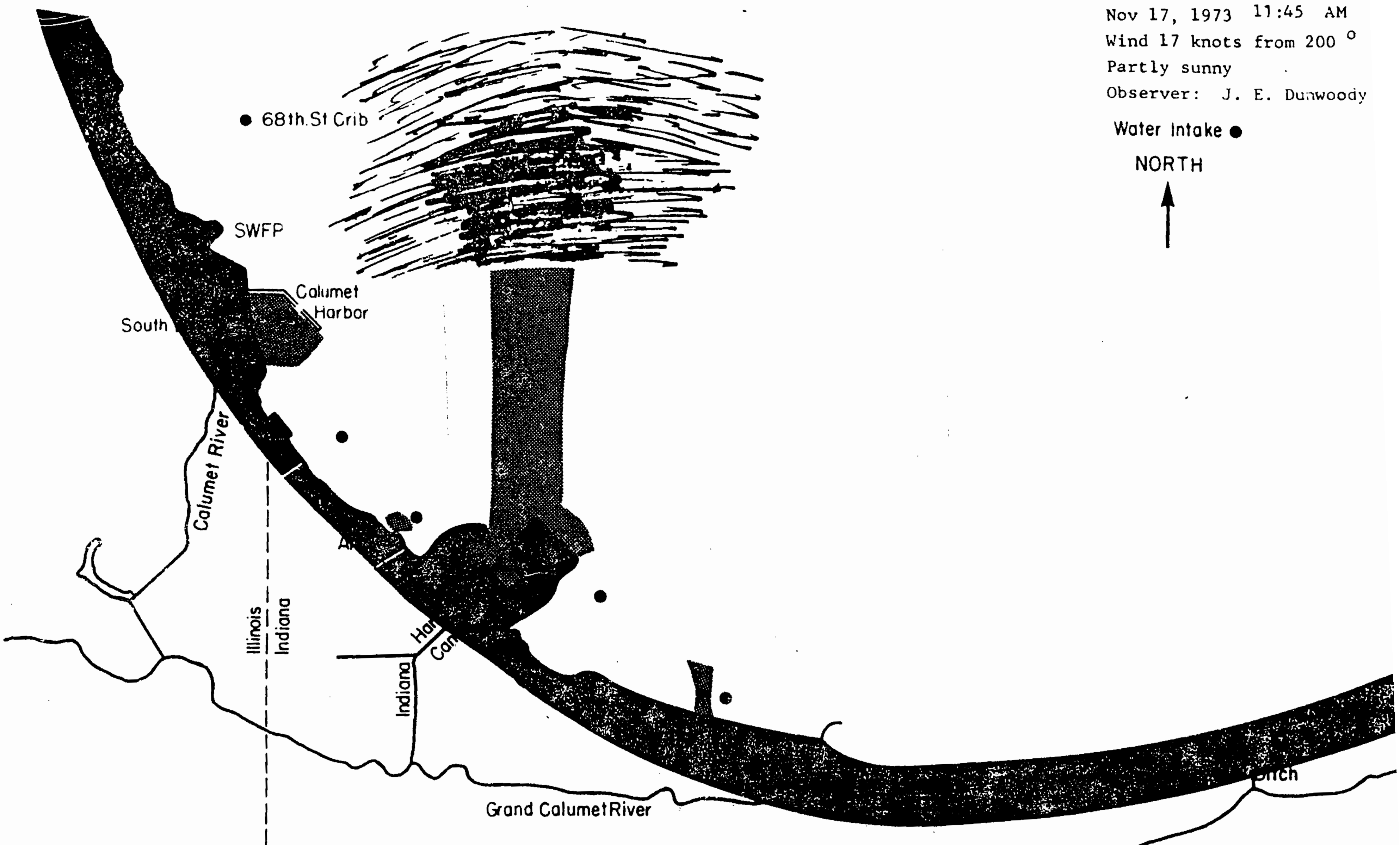
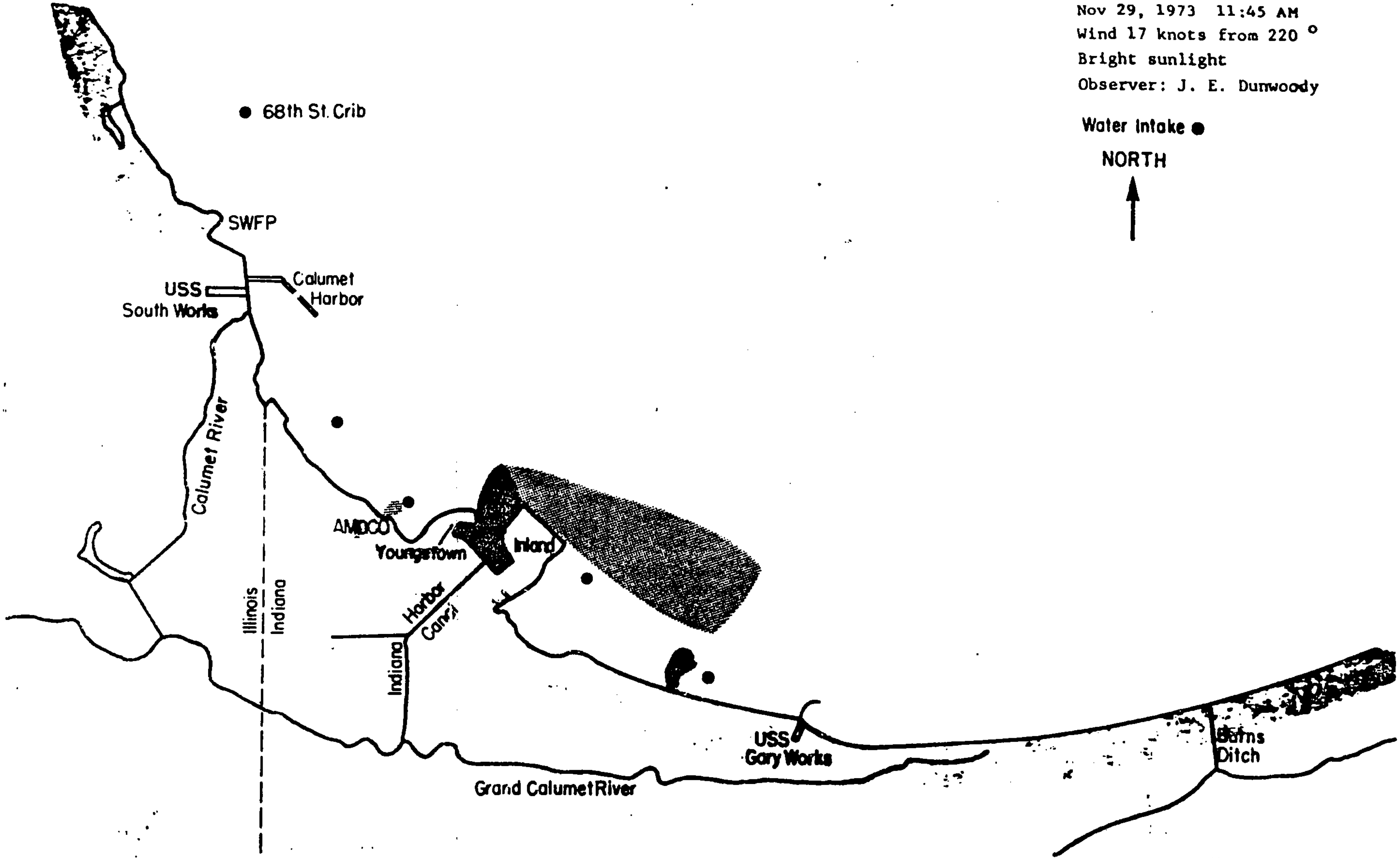


Figure 5.
SKETCH SHOWING VISUAL APPEARANCE
OF EFFLUENTS BY AERIAL OBSERVATIONS
November 17, 1973

From Sn 1974

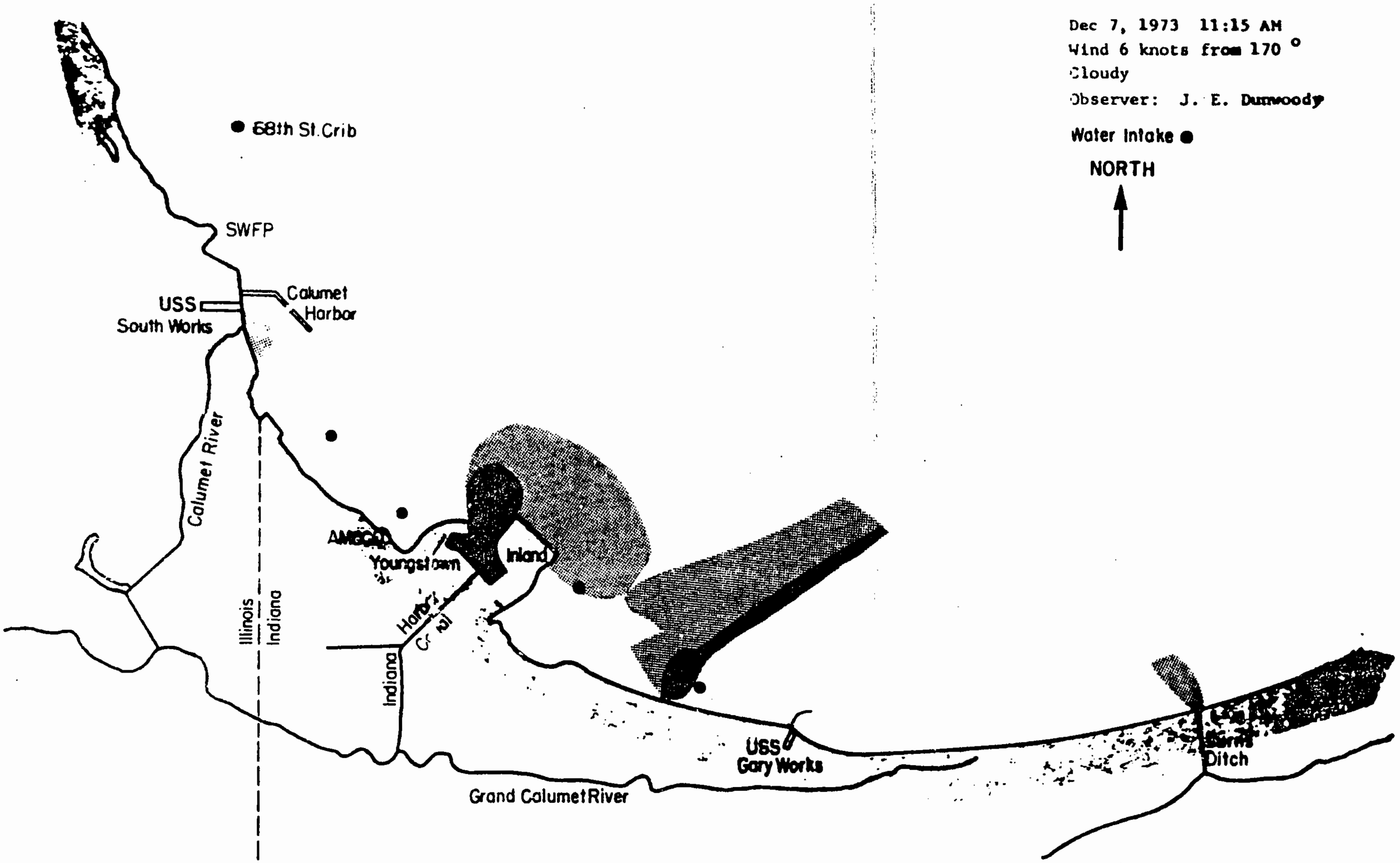


Nov 29, 1973 11:45 AM
Wind 17 knots from 220 °
Bright sunlight
Observer: J. E. Dunwoody

Figure 6.

SKETCH SHOWING VISUAL APPEARANCE
OF EFFLUENTS BY AERIAL OBSERVATIONS
November 29, 1973

From Snow 1974



Dec 7, 1973 11:15 AM
Wind 6 knots from 170 °
Cloudy
Observer: J. E. Dunwoody

Water Intake ●

Figure 7.

SKETCH SHOWING VISUAL APPEARANCE OF EFFLUENTS BY AERIAL OBSERVATIONS December 7, 1973

From Snow 1974

Through the 1970s, various studies on water quality within the GCR/IHC system indicated that it remained poor (USEPA 1972, Snow 1974, ISBH 1979, GLNPO 1982). However, data from the 1980s and 1990s indicate a general trend of improvements (ISBH 1984, Polls and Dennison 1984, Crawford and Wangsness 1987, Simon *et al.* 1989, Polls *et al.* 1993, IDEM 1992 and 1994).

The Indiana Department of Environmental Management (IDEM) conducts monthly water quality monitoring at 10 sites in the GCR/IHC, Indiana Harbor, and nearshore Lake Michigan. Within the GCR/IHC, regular monitoring is performed for 15 parameters: pH, dissolved oxygen (DO), fecal coliform, total dissolved solids (TDS), ammonia-N, cyanide, fluoride, dissolved Fe, phenol, total mercury (Hg), PCBs, chlorides, sulfates, total phosphorus (P), and oil and grease. During the 1970s, this monitoring indicated chronic water quality problems for many of these pollutants. In particular, there were frequent water quality standards violations for ammonia-N, cyanide, phenol, TDS, total P, chlorides, fluorides, Hg, sulfates, oil and grease, fecal coliforms, Fe, and DO (GLNPO 1982, ISBH 1984).

Significant improvements in water quality conditions have occurred since 1977. For example, in comparing data from 1977 and 1983, DO levels increased significantly while general decreases were evident for ammonia-N, cyanide, phenol, P, fecal coliforms, and oil and grease. Total Fe, Hg, chlorides, and sulfates remained fairly constant during this period (ISBH 1984).

During 1982 and 1986, the Metropolitan Water Reclamation District (MWRD) of Greater Chicago also conducted water quality sampling in the GCR/IHC, Lake Michigan, and the Calumet River. Twenty sampling stations were established, and 35 chemical and physical constituents were measured. The information was compared with data collected from similar locations during the 1960s and 1970s.

The results of the 1982 study showed that, compared to the 1970s, there was marked improvement in DO, ammonia-N, Fe, and total cyanides in the IHC and Indiana Harbor (Polls *et al.* 1993). The 1986 study showed that there were little or no changes from 1982 parameters for ammonia-N, P, alkalinity, fluoride, arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), Fe, Hg, lead (Pb), manganese (Mn), nickel (Ni), silver (Ag), zinc (Zn), hardness, chemical oxygen demand (COD), or 5-day biochemical oxygen demand (BOD_5) in waters of the IHC, Indiana Harbor, and southwestern Lake Michigan. Total solids and total volatile solids both decreased between 1982 and 1986, indicating an improvement in water quality. However, turbidity and fats, oils, and greases (FOG) increased between 1982 and 1986, indicating a deterioration in water quality. The conclusion was that although water quality in the 1980s was much improved over that of the 1960s and 1970s, the conditions essentially leveled off and did not continue to improve.

A study by the Indiana State Board of Health (ISBH) in 1980 and 1981 was designed to provide the data base necessary for the protections of water quality in the Indiana portion of Lake Michigan. The 240 square miles of the lake that are under Indiana's jurisdiction were sampled from April through November 1980, and May through October 1981 (ISBH 1982). Analysis for as many

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as 34 limnological parameters were made at each station, including heavy metals, PCBs, nutrients, DO, and temperature. It was found that the temperature regime played a major role in water quality by controlling dispersal of various constituents within the lake. For example, higher concentrations of chloride were found shoreward of the thermal bar, reflecting the impact of tributary and wastewater inputs to the system.

It was also determined that the large industrial and municipal complex of Hammond/East Chicago/Gary appeared to be adversely affecting the lake. "Water quality of the areas sampled in and around the Indiana Harbor Ship Canal was significantly "lower" than other areas, particularly those located offshore. Levels of dissolved solids, cyanides, phenolics, nutrients, and metals were consistently elevated in this area when compared to other lake samples" (ISBH 1982). The authors concluded: "These data suggest that the nearshore portion of Lake Michigan has a poorer water quality than that of open lake areas and degradation of water quality is greatest near heavily populated or industrialized areas, notably the Calumet and Michigan City Regions."

At the behest of the Corps, the Metropolitan Sanitary District (MSD) of Greater Chicago also sampled the IHC and Indiana Harbor in 1983 (Polls and Dennison 1984). A total of 14 samples were taken, with several being at the same locations as the 1982 and 1986 studies. A comparison of the 3 years of data at Columbus Drive shows that although most constituents were similar, total Kjeldahl nitrogen (TKN) in 1983 was more than twice 1982 and 1986 levels, and COD was much higher than the other years (23 mg/L in 1983, 13 in 1982, and 3 in 1986). At Dickey Road the results were similar, with TKN and COD being higher in 1983. At the Conrail bridge downstream from Dickey Road, TKN in 1983 was more than double that found in the other 2 years, but COD in 1982 and 1983 were comparable. The COD level in 1986 was considerably higher than in the 2 earlier years.

Water quality sampling in both the EBGCR and WBGCR in 1984 indicated that the waters in the East Branch generally met or were better than the criteria, but the West Branch usually did not meet the criteria (Crawford and Wangsness 1987). Phenol and total P were the only constituents which exceeded water quality criteria in the EBGCR. However, oil and grease, polycyclic aromatic hydrocarbons (PAHs), and PCBs were not measured.

Using fish community data, Simon *et al.* (1988) determined that water quality in the GCR/IHC system showed a steady improvement from 1985 to 1987. The EBGCR and the IHC showed the most improvement in the index of biotic integrity (IBI) rating, increasing from "very poor" in 1985 to "poor" in 1987. The WBGCR remained "very poor" throughout the study.

IDEM water quality sampling in 1992-93 indicated that: "While problems have existed in these waters for many years, some past pollutant problems have been resolved, and the concentrations of many substances have been reduced even though criteria violations still occasionally occur" (IDEM 1994). It was also indicated that "the banks of the harbor appear to be saturated with petroleum. The river and the harbor often have an oily sheen. The nearshore Lake Michigan waters often appear murky."

This oil sheen problem has continued to persist even as other water quality problems have lessened. It is especially persistent in the vicinity of now-closed refineries and their barge transfer facilities between Columbus Drive and Lake Michigan, including the Lake George Branch (IDEM 1991). Recently, IDEM and the owners of the former refinery properties have entered agreements to address this problem. However, significant reservoirs of FOG and petroleum-based materials persist in the sediments. It may not be possible to eliminate the oil problem until the historical deposits in the groundwater and sediments and current sources, such as stormwater runoff, are eliminated.

The International Joint Commission (IJC), a bi-national agency established by the United States and Canada, cooperatively addresses water quality and natural resources issues of the Great Lakes. In 1972, the first Great Lakes Water Quality Agreement was signed, which established objectives and criteria for the restoration and enhancement of water quality in the Great Lakes system. The 1978 Agreement shifted the emphasis from a primary concern with excess nutrient loadings toward control of toxic substances. A broadly drawn "ecosystem approach" to management and amelioration was also introduced (National Research Council and The Royal Society of Canada 1985).

Under this Agreement, problem areas that have failed to meet objectives have been identified as "Areas of Concern" (AOC). The AOCs were identified as locations where Agreement objectives were not being met and such failure had caused, or was likely to cause, impairment of beneficial use (GLNPO 1994).

> Impairment of beneficial use has been defined as a change in the chemical, physical or biological integrity of the Great Lakes System sufficient to cause any of the following: Restrictions of fish and wildlife consumption; tainting of fish and wildlife flavor; degradation of fish and wildlife populations; fish tumors or other deformities; bird or animal deformities or reproductive problems; degradation of benthos; restrictions of dredging activities; eutrophication or undesirable algae; restrictions on drinking water consumption, or taste and odor problems; beach closings; degradation of aesthetics; added costs to agriculture or industry; degradation of phytoplankton and zooplankton populations; loss of fish and wildlife habitat.

The area including the GCR/IHC, Indiana Harbor, and nearshore Lake Michigan has been determined by the IJC to be a Class A AOC. As a result of this designation, a Remedial Action Plan (RAP) is needed to address the water quality, aquatic habitat, and use impairment issues of the nearshore area of the lake (IDEM 1991, GLNPO 1994).

The goal of the RAP is to define the approach and activities needed to improve water quality in the GCR/IHC so that the designated uses for Lake Michigan are maintained or restored (IDEM 1994). Lake Michigan and its contiguous harbor areas have been designated for multiple uses including recreation, aquatic life, potable water supply, and industrial water supply. The lake has also been designated as a State resource water, which requires that existing water quality is to be maintained or improved with no degradation. The entire GCR/IHC system and Indiana Harbor are considered non-attainment areas for the

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designated uses. Lake Michigan is considered to only partially support the designated uses.

To address the problems, a "Master Plan for Improving Water Quality in the Grand Calumet River/Indiana Harbor Canal" was prepared by the U.S. EPA (1985), a draft "Northwest Indiana Environmental Action Plan" was prepared by IDEM (1987), and a Stage One RAP was prepared by IDEM (1991). The programs addressed in these documents concern National Pollution Discharge Elimination System (NPDES) permit enforcement, combined sewer discharges and need for controls/separation, pretreatment of industrial effluents prior to discharge to municipal sanitary sewers, and non-point source discharges. To date, no detailed studies of the Indiana portion of Lake Michigan have been undertaken to determine the results of these programs, as a follow-up to the 1980-81 ISBH studies.

The water quality of southern Lake Michigan has also been degraded by the releases of PCBs from various sources throughout the basin, including water and sediment from the IHC. Marti and Armstrong (1990) estimated that as much as 260 Kg/yr of PCBs enter Lake Michigan from 12 rivers, but no estimates were made for the GCR/IHC's contribution. The Calumet River was sampled, but because it flows away from Lake Michigan, it was not included in the Lake Michigan mass loading calculations. It is significant, however, that mean water concentrations in the Calumet River were 244 ng/l, or approximately 2.5 times more concentrated than the largest riverine source of PCBs to Lake Michigan (Fox River, Wisconsin 98 ng/l).

Pearson *et al.* (1996) presented an average PCB concentration of 1.56 ng/l in southern and southwestern Lake Michigan water samples, which was significantly higher in concentration than the rest of the lake (0.47 ng/l). Their data also suggest that the types of PCB sources in southern Lake Michigan are different due to different homolog profiles and partitioning behavior of the PCBs detected. The Corps DEIS states that as much as 191 Kg of PCBs enter Lake Michigan each year from contaminated sediments leaving IHC (USCOE 1995).

Sediment Quality

The many years of severe water pollution levels just described for the GCR/IHC system have resulted in equally severely polluted bottom sediments throughout the system (U.S. HEW 1965, Great Lakes Research Center 1968, Gannon and Beeton 1969, U.S. EPA 1971 and 1977, U.S. COE 1977, Romano *et al.* 1977, Bremer 1978, Hoke and Prater 1980, Environmental Laboratory 1980a and b, 1987, Zapotosky and White 1981, Polls and Dennison 1984, Polls 1988, Risatti and Ross 1989, Unger 1992, Hoke *et al.* 1993, Ingersoll *et al.* 1993, Polls *et al.* 1993, USCOE 1994).

For about 60 years, Indiana Harbor and the IHC were regularly dredged to maintain navigation depths. This dredging occurred both at private expense by the industries utilizing the facilities and under contract by the Corps. The material was excavated by bucket/dipper dredges, placed into dump scows, and deposited in Lake Michigan. Use of lake disposal areas was specified in almost all of the authorizing documents for Great Lakes harbors. The disposal area utilized by Indiana Harbor, Calumet Harbor, and several other southern lake ports occupied 90 square miles. It had been used for spoils disposal since 1924. The average depth at the site is 69 feet, with a maximum depth of 114 feet at the extreme northeast corner. The southwest corner of the area is 9 miles due east of the entrance gap in the breakwater at Calumet Harbor, putting it about 6.5 miles northeast of the entrance of Indiana Harbor (U.S. COE 1966). The location is shown on Figure 8.

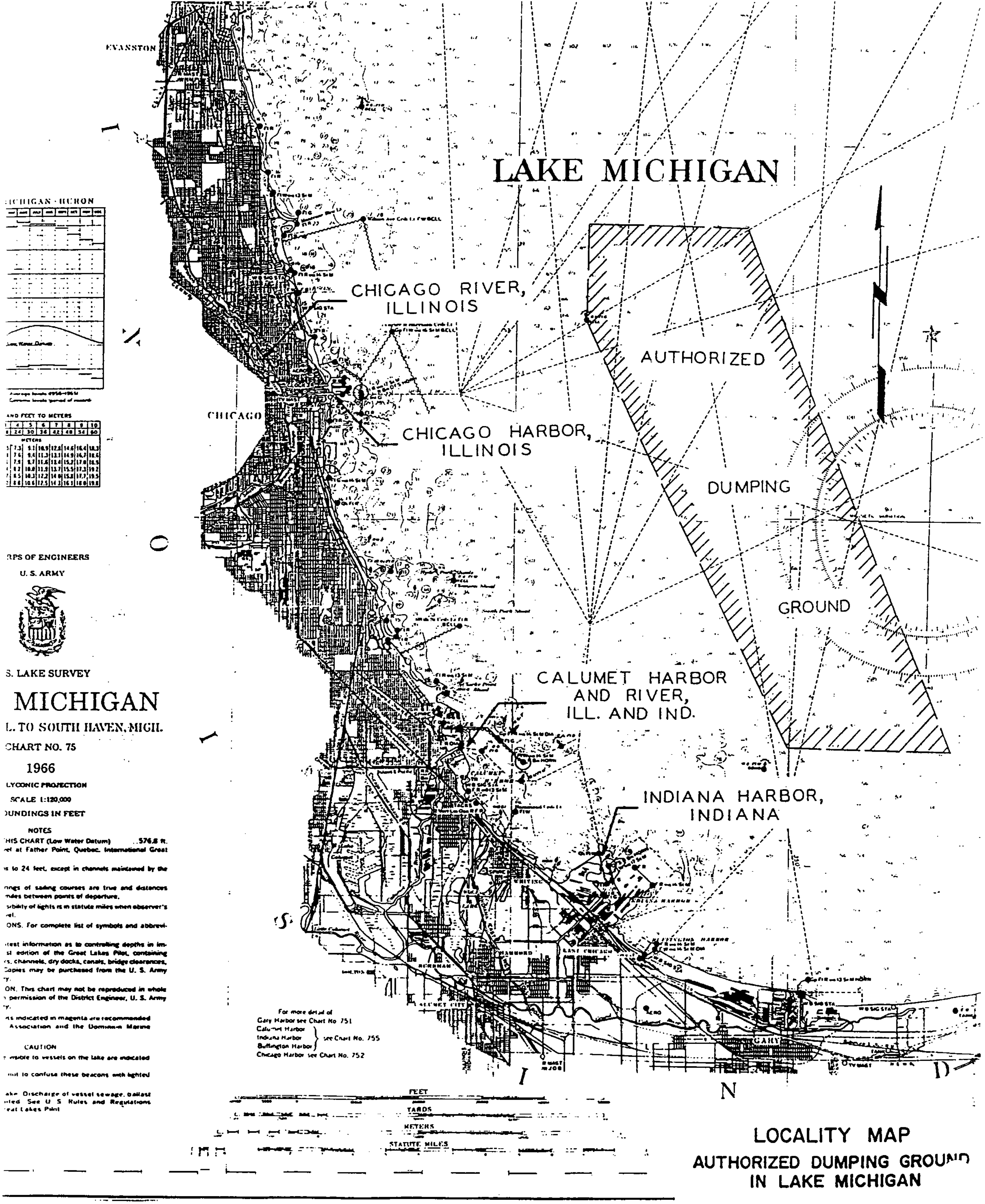
By the mid 1960s, it was realized that the IHC and Indiana Harbor sediments were highly polluted. Domestic and industrial wastes contaminated the GCR/IHC, the harbor, and adjacent Lake Michigan, and the pollution problem was indicated to be critical (Public Health Service 1965). The bottom of Lake Michigan was described as exhibiting biological degradation caused by organic enrichment. The reduced numbers of benthic organisms reflected inhibition by heavy settleable solids and toxic materials (USCOE 1966). Romano *et al.* (1977) estimated that 40 tons of Zn and 121 tons of Fe entered Lake Michigan each year, with the Grand Calumet River being:

> ... a major fluvial source of metals to Lake Michigan. Even if controls are placed on industrial and municipal sources of trace metals throughout the system, sediment metal loads now present in the Grand Calumet River may pose a threat to water quality in the southern basin of Lake Michigan for many years.

Because of this pollution at Indiana Harbor and at other Great Lakes ports, the States bordering the lakes became increasingly concerned about open-lake disposal of dredged sediments and essentially requested a ban on such disposal. These concerns led to a Corps feasibility study of alternate disposal methods for sediments throughout the Great Lakes. Fifteen of the worst harbors were studied, including Indiana Harbor (USCOE 1966). Several alternative disposal sites were considered for the IHC dredgings, including a lakefill in Chicago, the steel mill lakefills adjacent to Indiana Harbor, and abandoned stone quarries along the Chicago Sanitary and Ship Canal near Lemont, Illinois. No particular pollution control practices were considered to prevent migration of contaminants from these sites back to the lake or other waterways. The same basic dredging equipment was expected to be used, *i.e.* dipper dredges and bottom dump scows.

These initial feasibility studies led to the establishment of the "Pilot Program for Disposal of Dredgings from Great Lakes Harbors", a joint study by the Corps and FWPCA (Tarbox 1968). The objective of the 3 year program was to develop the most economical methods for management of whatever pollution problems might result from dredging operations on the Great lakes. The FWPCA was to sample, test, and analyze the materials to be dredged and the waters surrounding them, while the Corps was to test the effectiveness and compare costs of different types of disposal areas, methods of handling the dredged material, and methods of treating any effluent from the disposal areas.

Indiana Harbor was 1 of the 8 pilot study sites and was chosen because of its heavy pollution. For several years, beginning in 1967, the dredged material



LOCALITY MAP
AUTHORIZED DUMPING GROUND IN LAKE MICHIGAN
SEPTEMBER 1966
CORPS OF ENGINEERS CHICAGO, ILL.

Figure 8.

was deposited within the Inland Steel lakefill on the northeast side of the outer harbor. Dipper dredges and dump scows were utilized as before, with the scows entering the lakefill through a gap in the steel sheet pile bulkhead which encloses the lakefill (Tarbox 1968). The material was simply dumped from the scows into the water within the bulkheaded area.

At the time that the Pilot Program was underway, a "Conference on the Pollution of Lake Michigan and its Tributary Basin" was occurring. During its first session in 1968, this Conference developed a number of "Conclusions" and "Recommendations" concerning pollution problems in the lake and tributary streams.

Conclusion 11 stated:

> The maintenance of waterways for commercial and navigational use is a constantly necessary activity. The continued deposition of dredged material containing nutrients, oils, and solids of sewage and industrial wastes origin in Lake Michigan poses a distinct threat to the quality of the lake (FWPCA 1968).

Recommendation 11 of that report stated:

> The prohibition of the dumping of polluted material into Lake Michigan is to be accomplished as soon as possible. The Corps of Engineers and the States are requested to report to the Conferees within six months concerning their program, at which time the Conferees will consider adopting a coordinated approach toward the disposal of dredged material, together with a target date for putting the program into operation (FWPCA 1968).

In reports to later sessions of the Conference, the Corps indicated that they and the FWPCA were conducting studies on dredged materials and waters in the harbors where dredging occurred, in the open-lake areas where the materials had historically been deposited, and in various confined disposal areas (Tarbox 1969, Stewart 1970). It was further indicated that no dredged material from Indiana Harbor had been deposited into the lake during those years, but that it had been placed within the Inland Steel lakefill instead. Alternative spoil disposal sites for the Indiana Harbor dredgings were being pursued.

The Pilot Program report was completed in 1969, and the Secretary of the Army recommended that Congress pass legislation which would "provide for construction of contained dredge spoil disposal facilities for the Great Lakes and connecting channels..." (Stewart 1970). Such legislation was passed and required construction at the earliest practicable date of contained spoil disposal facilities with sufficient capacity to hold 10 years of dredgings at each site (P.L. 91-611; 33 U.S.C. 1293a).

The Corps has been unable to maintain the navigation channel at Indiana Harbor and the IHC since 1972 because no acceptable disposal site could be identified. Since that time, numerous studies have been conducted to determine the degree of pollution of the sediments and the need for special handling of toxic sediments regulated by TSCA.

The U.S. EPA collected grab samples from 13 sites in the IHC and harbor in 1977 (Figure 9). Sediment samples from the IHC and inner harbor were black or dark brown silt containing visible oil and petroleum odor. Sediments lakeward of the northern breakwater light were brown or gray sand and gravel. Sieve analysis data confirmed that, at most locations, sediment particles were predominantly silt and clay size (USEPA 1977).

Bulk sediment analysis showed that the IHC and inner harbor sites were grossly polluted with respect to virtually every parameter tested (Table 1). The 2 lakeward locations showed moderate levels of Zn, Mn, and As, with low levels of other constituents. The elutriate tests showed releases of Fe, Mn, and aluminum (Al) from virtually all samples. Samples from the IHC and inner harbor also showed release of TKN, ammonia, cyanide, and phenols. Several samples also released As and Hg. In general, samples from the 3 locations upstream from Canal Street exhibited the most release and samples in the outer harbor showed the least release. The bulk chemistry, PCB, and pesticides results showed all compounds except PCBs were below the laboratory's detection limits, but the detection limits for some compounds were higher than usual due to high interferences present in the samples (Table 2) (USEPA 1977).

In 1979, the Corps sampled IHC and harbor sediments from locations similar to those sampled by U.S. EPA in 1977. The core samples were composited for each 3 feet in depth, so there were several distinct samples at each site. A number of the parameters were much higher in the 1979 sampling, including COD, oil and grease, Zn, As, and Fe, but they varied considerably by depth. PCB levels were generally higher in 1979, with higher amounts at deeper depths being common, especially in the upstream reaches (current Reach 13 and the turning basin at The Forks), although the highest reading in 1979 was in current Reach 6 (Table 3) (Environmental Laboratory 1980a).

During the 1980s, both the MWRD and MSD of Greater Chicago conducted sediment sampling in the IHC, Indiana Harbor, and adjacent Lake Michigan. The 1982 and 1986 studies were conducted at the same sites and were compared with each other and with earlier studies in the 1960s and 1970s. The 1987 study, conducted at the request of the Corps, included some of the same sample sites as previous studies, but also included new sites within Lake Michigan.

The 1982 sampling showed that, in comparison with earlier studies, there was significant improvement in the quality of sediment for total volatile solids (TVS), Fe, and FOG in Indiana Harbor and southwestern Lake Michigan (Polls *et al.* 1993). An increase in the number of benthic invertebrate groups in the sediments of Indiana Harbor and the lake in 1982 also indicated an improvement in sediment quality.

A comparison of the 1982 and 1986 data for the IHC indicated that total solids (TS) increased 13 percent, while Fe and phenol increased 16.3 and 35.1

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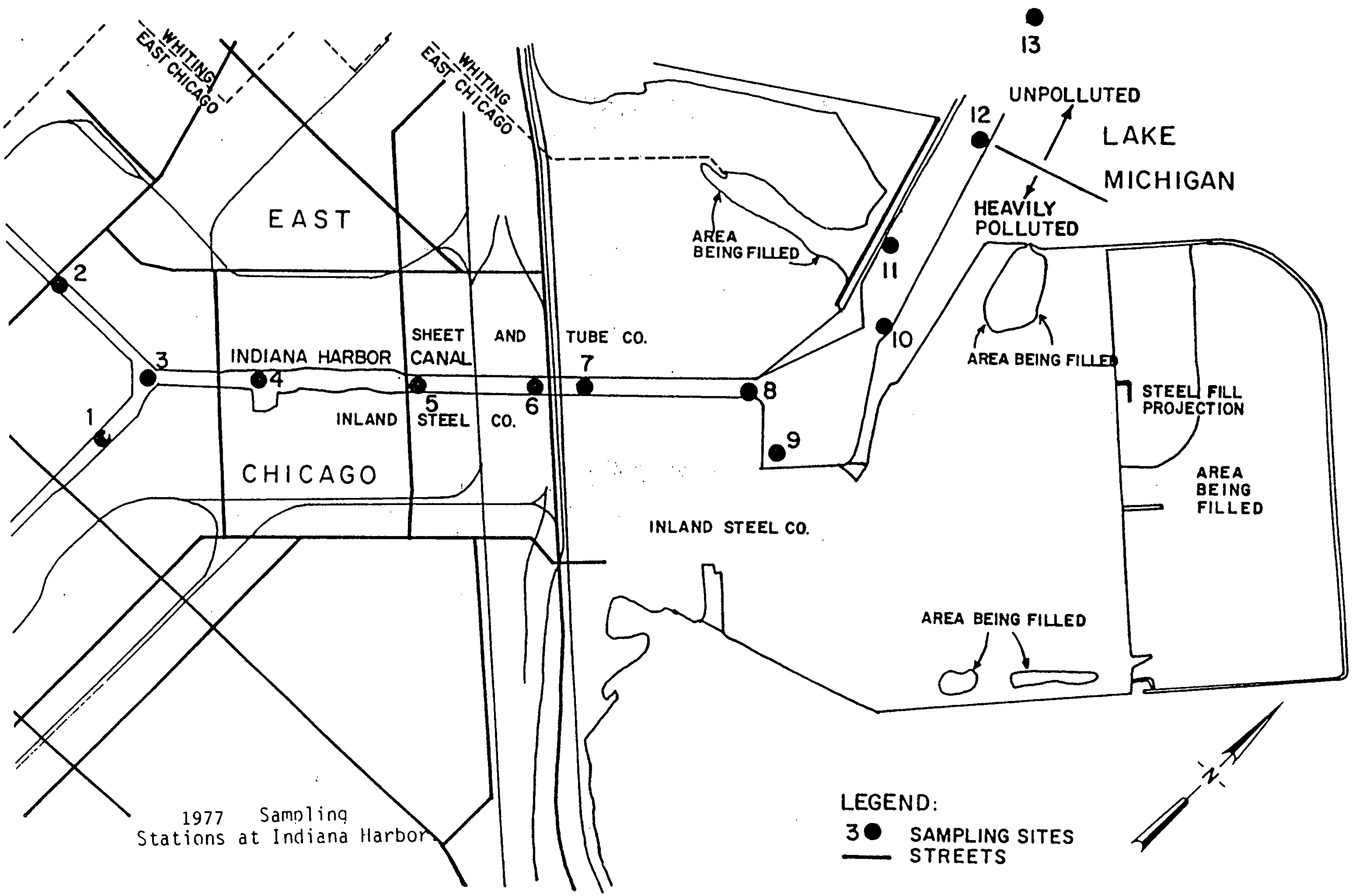
Figure

From USEPA 1977

Figure 9.



1977 Sampling Stations at Indiana Harbor

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Table 1.

BULK SEDIMENT ANALYSIS AT INDIANA HARBOR

HARBOR: Indiana Harbor, Indiana
SAMPLED: August 30, 1977

	Station													
Parameter	1	2	3	4	5	5 replicate	6	7	8	9	10	11	12	13
Total Solids %	22.8	33.6	41.1	41.5	71.1	63.4	56.5	46.5	61.1	35.1	44.4	47.1	72.0	70.7
Volatile Solids %	24.1	20.3	20.4	10.7	4.75	8.92	12.3	14.8	7.70	13.5	10.4	9.21	1.08	1.38
Chem. Oxy. Demand	520,000	390,000	340,000	190,000	40,000	190,000	170,000	180,000	96,000	220,000	130,000	120,000	8,200	8,200
T. Kjel. Nitrogen	9,500	4,000	3,900	3,100	520	980	1,600	3,100	1,300	2,300	1,700	2,200	140	330
Oil-Grease	80,000	140,000	89,000	28,000	15,000	44,000	35,000	36,000	23,000	76,000	38,000	19,000	<600	<600
Mercury	0.9	1.2	1.2	0.7	0.2	1.4	0.2	0.3	0.3	0.3	0.3	0.1	<0.1	<0.1
Lead	1,300	1,400	1,700	620	370	580	390	560	230	540	410	240	25	33
Zinc	4,200	4,600	10,000	3,000	1,800	4,000	1,500	2,700	860	2,400	2,000	880	150	160
T. Phosphorus	8,700	4,300	6,400	3,600	570	1,500	1,700	2,700	1,400	1,500	1,100	1,100	140	290
Ammonia Nitrogen	1,100	350	660	470	58	85	170	330	98	280	53	120	<10	<10
Manganese	2,100	1,500	3,900	1,400	2,000	1,800	1,800	1,900	6,600	2,000	1,300	1,800	320	320
Nickel	240	100	90	80	65	64	110	80	48	100	47	43	17	7
Arsenic	48	35	41	19	15	39	38	30	21	58	29	18	9	4
Cadmium	22	7	18	4	6	18	17	13	<1	30	6	1	1	1
Chromium	690	1,200	1,700	720	240	410	280	400	190	290	150	160	14	26
Magnesium	7,200	16,000	5,300	20,000	19,000	15,000	12,000	13,000	16,000	8,4000	20,000	24,000	8,700	31,000
Copper	380	290	290	240	150	230	300	270	110	260	120	99	<1	17
Iron	120,000	84,000	210,000	77,000	72,000	120,000	170,000	150,000	110,000	220,000	100,000	93,000	13,000	14,000

All values mg/kg dry weight unless otherwise noted.

From USEPA 1977

Table 2.

BULK SEDIMENT CHEMISTRY PCB AND PESTICIDES ANALYSIS (All values are mg/kg/dry weight).

HARBOR: Indiana Harbor, Indiana
SAMPLED: August 30, 1977

	Sample Site													
Compound	1	2	3	4	5	5 replicate	6	7	8	9	10	11	12	13
Hexachlorobenzene	*	*	*	*	*	*	*	*	*	*	*	*	*	*
beta Benzenehexachloride	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Lindane	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Treflan	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Aldrin	<0.3	<0.9	<0.7	<1.0	*	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*	*	*
Isodrin	<0.2	<1.3	<0.5	<1.2	*	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*	*	*
Heptachlor Epoxide	<0.15	<1.0	<0.35	<0.7	*	*	*	*	*	*	*	*	*	*
gamma Chlordane	<0.2	<0.2	<0.2	<0.2	*	*	*	*	*	*	*	*	*	*
o,p -DDE	*	*	*	*	*	*	*	*	*	*	*	*	*	*
p,p'-DDE	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	*	*	*	*	*	*	*	*
o,p -DDD	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
o,p -DDT	*	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	*	*	*	*	*
p,p'-DDD	*	<0.2	*	*	*	*	*	*	*	*	*	*	*	*
p,p'-DDT	*	<0.5	*	*	<0.65	*	<0.3	<0.3	<0.3	<0.3	*	*	*	*
Methoxychlor	<0.2	<2.0	<0.2	<0.2	<1.7	*	*	<1.4	*	*	*	*	*	*
Mirex	*	<0.2	*	*	*	*	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2,4-D. Isopropl Ester	<0.5	<0.5	<0.5	<0.5	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan I	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Dieldrin	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Endrin	*	*	*	*	*	*	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02
Endosulfan II	<0.02	<0.02	<0.02	<0.02	<0.02	*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
DCPA	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Tetradifon	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05
Aroclor 1016 (1242)	5.6	21.3	25.7	20.9	23.1	17.9	6.5	9.5	3.4	4.4	1.5	1.4	0.043	0.042
Aroclor 1248	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aroclor 1254	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.56
Aroclor 1260	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total PCB	5.6	21.3	25.7	20.9	23.1	17.9	6.5	9.5	3.4	4.4	1.5	1.4	0.043	0.098

*Concentration less than 0.1 mg/kg.

From USEPA 1977

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Table 3

Indiana Harbor Sediment Analysis Results

(All values mg/kg dry weight unless otherwise noted.)

Parameter	1-1-4	1-5-8	1-9-12	1-13-16	1-17-21	2-1-4	2-5-8	2-9-12	3-3-6	3-7-10
Total Solids, %	27.9	29.2	36.7	44.1	45.3	49.3	54.5	75.1	26.3	32.2
Volatile Solids, %	28.5	28.7	22.1	19.7	15.2	22.1	21.1	4.9	28.1	23.2
Chemical Oxygen Demand	265,700	269,200	189,100	208,300	160,700	257,000	234,500	57,300	311,700	224,200
Total Kjeldahl Nitrogen	10,500	10,800	8,200	6,200	4,100	2,500	2,500	880	9,100	7,500
Ammonia Nitrogen	3,000	3,900	2,900	2,300	1,800	370	390	250	1,900	1,700
Total Phosphorus	7,600	8,600	7,400	7,600	5,200	2,700	2,200	1,500	7,900	7,200
Oil and Grease	65,400	54,700	66,600	51,300	44,600	175,100	119,100	15,800	96,600	86,500
Mercury	2.1	2.1	2.2	1.3	1.0	1.4	0.8	<0.2	2.2	1.9
Lead	1,040	1,170	1,250	1,420	1,200	3,720	4,700	480	1,040	1,090
Zinc	4,100	4,700	7,200	8,600	8,400	9,100	9,900	530	4,900	5,800
Manganese	1,980	2,060	2,900	3,770	4,230	990	1,270	510	2,020	2,190
Nickel	210	350	150	100	80	170	140	34	220	210
Arsenic	42	64	50	78	40	54	62	13	39	41
Cadmium	13	15	13	16	17	37	30	3	12	11
Chromium	790	890	1,380	1,680	980	460	400	24	850	940
Magnesium	10,400	10,500	9,200	7,540	5,980	21,800	16,800	29,140	10,770	10,350
Copper	350	360	260	220	190	310	270	36	380	250
Iron	164,600	171,400	240,000	241,200	326,000	85,800	123,400	32,800	169,200	180,400
PCB's										
Aroclor 1242	13.15	2.19	56.40	64.40	51.66	5.86	0.86	<0.02	27.38	12.83
Aroclor 1248	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Aroclor 1254	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Aroclor 1260	2.04	8.56	2.34	3.56	2.25	2.07	0.16	0.02	2.02	1.52
Total PCB	15.19	10.75	58.74	67.96	53.91	7.93	1.02	0.02	29.40	14.35

(Continued)

From Environmental Laboratory 1980a

Table 3

(Continued)

Parameter	3-11-14	3-15-18	4-5-8	4-9-12	4-13-16	5-3-6	5-7-10	6-1-4	6-5-8	7-3-4	7-5-6	8-1-2	8-3-4
Total Solids, %	49.2	55.6	40.3	56.9	59.7	59.2	82.2	55.6	53.1	60.2	65.7	75.8	77.0
Volatile Solids, %	21.5	18.9	19.8	21.1	20.5	10.7	7.1	21.8	24.5	16.6	19.6	8.1	6.9
Chemical Oxygen Demand	194,800	207,000	224,700	198,400	200,000	122,100	43,900	314,400	315,700	277,500	267,100	92,000	57,300
Total Kjeldahl Nitrogen	4,300	3,300	4,300	3,500	3,200	1,600	740	3,200	3,400	2,400	2,000	1,100	900
Ammonia Nitrogen	1,000	980	700	900	960	130	70	510	750	620	570	110	100
Total Phosphorus	6,800	4,200	3,300	2,400	2,300	2,300	410	3,200	4,200	1,700	1,200	730	800
Oil and Grease	87,700	98,500	97,500	106,100	96,000	43,200	550	65,700	67,700	41,600	26,400	8,600	2,200
Mercury	1.3	0.7	2.4	1.0	2.5	0.6	<0.2	1.2	1.5	0.8	0.9	0.2	<0.2
Lead	980	1,360	1,600	1,550	1,410	530	22	630	770	450	360	140	40
Zinc	7,700	6,300	6,100	5,700	5,100	3,700	80	3,500	5,000	3,100	2,600	1,200	330
Manganese	2,820	2,460	1,590	1,460	1,460	1,290	470	2,360	2,650	2,760	3,450	880	490
Nickel	120	79	82	36	27	57	36	110	87	76	62	39	35
Arsenic	56	62	91	93	81		64	40	49	43	40	23	16
Cadmium	15	4	20	24	25	9	<1	8	9	6	9	5	1
Chromium	1,330	710	290	72	62	440	16	370	430	250	120	80	40
Magnesium	8,500	9,950	15,160	17,460	17,780	21,600	27,590	13,290	10,910	11,050	5,800	22,660	28,720
Copper	270	250	300	260	100	150	32	270	240	203	120	54	28
Iron	232,000	238,000	174,800	180,400	176,800	91,600	22,400	219,700	216,800	238,500	271,700	81,800	34,000
PCB's													
Aroclor 1242	39.65	20.45	11.34	<0.02	<0.02	31.74	<0.02	22.93	89.08	7.36	2.47	1.11	0.84
Aroclor 1248	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Aroclor 1254	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Aroclor 1260	2.50	1.26	0.37	0.08	0.12	1.82	<0.02	0.74	0.14	0.76	0.35	0.20	0.05
Total PCB	42.15	21.71	11.71	0.08	0.12	33.56	<0.02	23.67	89.22	8.12	2.82	1.31	0.89

(Continued)

Table 3

(Concluded)

Parameter	9-1-2	9-3-4	9-5	10-5-6	10-7-8	11-1-2	11-3-4	12-1-2	12-3-5	13-1-2	13-3-4
Total Solids, %	41.8	41.4	46.7	43.3	51.1	75.7	78.9	56.3	42.0	81.7	78.4
Volatile Solids, %	18.1	19.3	13.1	17.6	13.6	3.7	4.0	7.4	12.3	2.6	3.1
Chemical Oxygen Demand	382,600	415,700	290,700	304,500	232,400	37,900	62,000	163,300	186,500	29,100	41,700
Total Kjeldahl Nitrogen	2,400	2,500	1,800	2,600	2,000	680	750	2,100	1,900	480	700
Ammonia Nitrogen	450	670	560	570	450	50	30	340	300	10	<10
Total Phosphorus	1,300	2,700	780	1,500	1,400	740	680	1,800	1,700	600	600
Oil and Grease	100,500	76,000	69,100	49,600	40,200	510	680	26,900	27,200	310	520
Mercury	0.6	0.7	0.5	0.5	0.5	<0.2	<0.2	0.3	0.4	<0.2	<0.2
Lead	630	630	600	520	470	18	20	490	300	18	16
Zinc	2,300	4,700	3,100	4,400	3,900	80	80	4,300	1,700	110	50
Manganese	2,500	2,820	2,490	1,750	1,600	390	390	1,920	1,230	430	390
Nickel	110	120	110	74	70	32	34	54	36	22	24
Arsenic	65	101	80	63	68	12	12			18	14
Cadmium	5	6	5	9	9	<1	<1	8	7	<1	<1
Chromium	160	280	140	300	260	16	14	250	100	11	11
Magnesium	8,890	7,810	8,000	11,620	14,160	26,610	25,250	21,480	24,600	24,680	25,730
Copper	280	280	240	180	160	22	30	160	90	14	20
Iron	266,000	322,500	229,800	216,700	203,600	22,200	23,200	147,200	85,700	20,000	21,600
PCB's											
Aroclor 1242	3.13	5.41	11.47	1.89	7.67	<0.02	0.03	0.09	1.90	<0.02	<0.02
Aroclor 1248	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Aroclor 1254	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Aroclor 1260	0.45	1.06	0.49	1.06	1.12	<0.02	<0.02	0.57	0.45	<0.02	<0.02
Total PCB	3.58	6.47	11.96	2.95	8.79	<0.02	0.03	0.66	2.35	<0.02	<0.02

percent, respectively. At the same time, TVS dropped slightly. COD decreased 46.8 percent and FOG decreased 37.8 percent (Polls *et al.* 1993). The conclusion was that sediment quality in the IHC had improved slightly during that time period.

Except for TS, which increased 20.3 percent between 1982 and 1986, the constituents measured in Indiana Harbor sediments decreased in concentration between 1982 and 1986 (Polls *et al.* 1993). It was concluded that there had been a marked improvement in sediment quality in the harbor.

Between 1982 and 1986, there was little change in the mean TVS percentage and FOG concentration in sediments from southwestern Lake Michigan (Polls *et al.* 1993). Compared to 1982, the mean TS, COD, and Fe values decreased, but phenol concentration increased 200 percent from <0.1 to 0.3 mg/kg. In general, the sediment quality in this portion of the lake was considered to have improved.

Benthic community sampling in the IHC, Indiana Harbor, and southwestern Lake Michigan also indicated an improvement in sediment quality in these areas between 1982 and 1986 (Polls *et al.* 1993).

In 1987, 3 sites within the IHC, including the Lake George Branch, and 2 sites within the harbor were sampled, along with 25 sites aligned on 4 transects in Lake Michigan off the mouth of the harbor (Figure 10)(Polls 1988). The lake sediments were silts, sands, pebble, or gravels, while the harbor and IHC sediments were characterized as sludge. The bulk chemistry results are presented in Tables 4 through 8.

In 1989 and 1990, USEPA conducted a study of sediment quality and toxicity of the IHC through it's Assessment and Remediation of Contaminated Sediment (ARCS) program. Seven sites were sampled, 2 in the harbor, I each in the Lake George Branch, at Columbus Drive, and at The Forks, and 2 in the main IHC. This study revealed high levels of total polycyclic aromatic hydrocarbons (PAHs) (up to 731 mg/kg), arsenic (32-93 mg/kg), cadmium (5.2-24.2 mg/kg), chromium (407-2,610 mg/kg), copper (182-379 mg/kg), lead (396-1,354 mg/kg), mercury (0.7-2.1 mg/kg), nickel (<50-103 mg/kg), selenium (2.0-3.9 mg/kg), silver (0.2-7.1 mg/kg), zinc (2250-7960 mg/kg), 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (73-130 ng/g) and polychlorinated biphenyls (PCBs) (3-43 mg/kg) (Ingersoll *et al.* 1993). In addition, these sediments were found to contain high volatile solids, ammonia, cyanide, manganese, phosphorus, barium, iron, and aliphatic hydrocarbons. Portions of the sediments have been determined by EPA to be hazardous and subject to regulation under either TSCA (regarding PCB's) or Resource Conservation and Recovery Act (RCRA) (regarding benzene).

The Corps has conducted several sediment quality investigations in recent years to support its DEIS. Under contract to the Corps, USEPA conducted numerous sediment depth probings along 16 bank-to-bank transects throughout the entire IHC system (USCOE 1994). Chemical analyses were also conducted. The Corps' DEIS discusses 2 areas in the IHC dredging project area (transect 6 and transect 13) where sediments contain elevated levels of PCBs, which may be

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THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

MAP SHOWING LOCATION OF THIRTY SAMPLING STATIONS IN LAKE MICHIGAN, INDIANA HARBOR, AND THE INDIANA HARBOR CANAL

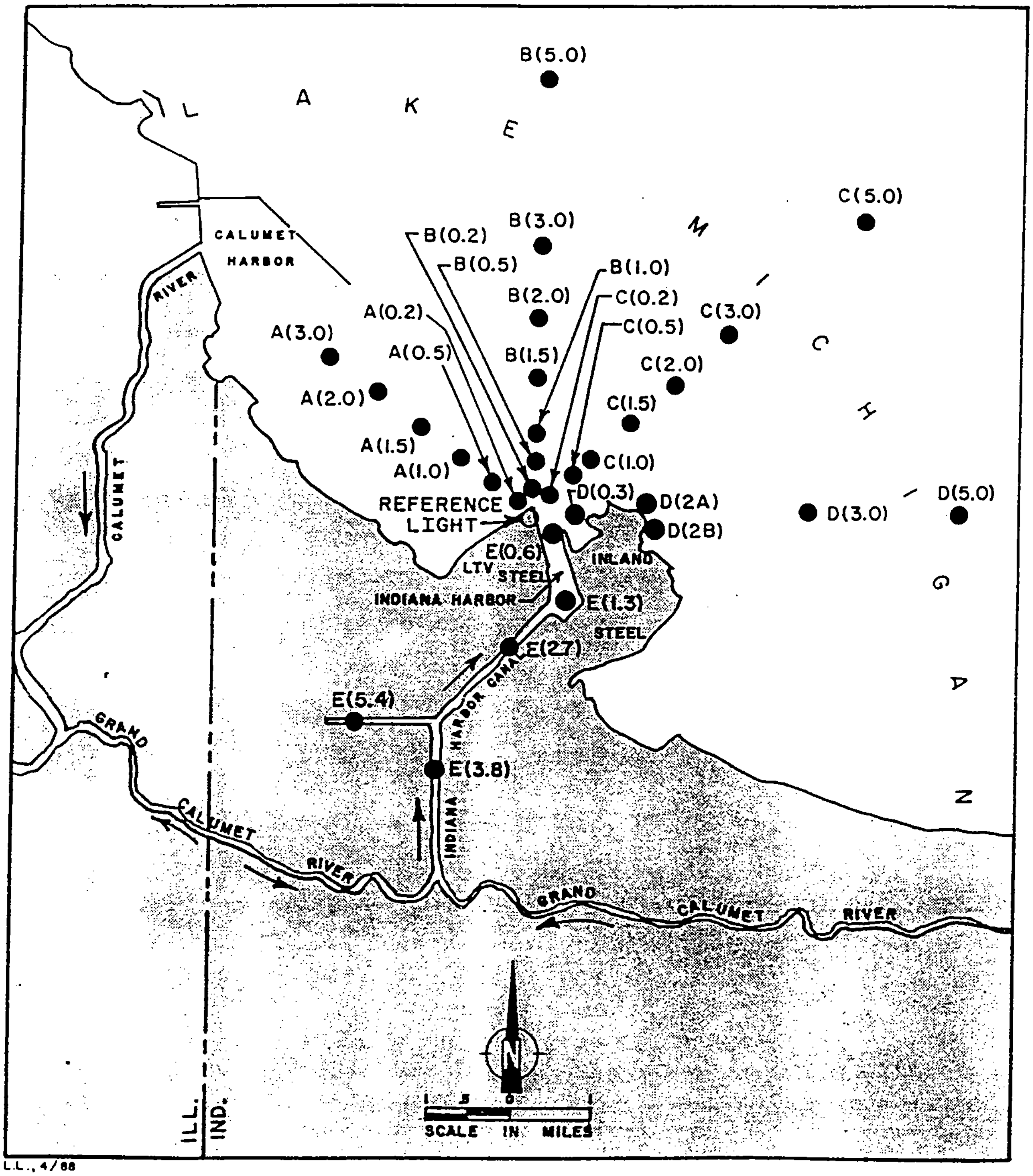

Figure 10.

From Polls 1988

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

TABLE 4

CHEMICAL CHARACTERISTICS OF SEDIMENT COLLECTED ALONG TRANSECT A IN LAKE MICHIGAN, SEPTEMBER 1987

	Station Designation					
Constituent*	0.2	0.5	1.0	1.5	2.0	3.0
Total Solids (%)	74.9	71.1	76.1	57.3	49.4	71.5
Total Volatile Solids (%)	1.1	2.6	0.8	1.7	5.4	0.9
Total Organic Carbon (mg/kg)	150	4,295	258	2,529	3,919	652
Fats, Oils and Greases (mg/kg)	<1	32	13	9	132	17
Arsenic (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium (mg/kg)	8.0	19.0	9.0	16.0	21.0	10.0
Iron (mg/kg)	8,200	16,220	8,660	7,760	12,220	6,500
Lead (mg/kg)	62.0	120.0	28.0	155.0	112.0	59.0
Manganese (mg/kg)	476.0	526.0	442.0	462.0	477.0	347.0
Nickel (mg/Kg)	40.0	70.0	20.0	40.0	40.0	20.0
Zinc (mg/kg)	110.0	90.0	50.0	100.0	120.0	70.0
Total PCBs (mg/kg)	0.04	0.05	0.03	0.03	0.09	0.01

*Expressed on a dry weight basis.

From Polls 1988

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

TABLE 5

CHEMICAL CHARACTERISTICS OF SEDIMENT COLLECTED ALONG TRANSECT B IN LAKE MICHIGAN, SEPTEMBER 1987

Constituent*	Station Designation						
	0.2	0.5	1.0	1.5	2.0	3.0	5.0
Total Solids (%)	69.8	65.0	51.1	64.1	64.3	67.4	73.2
Total Volatile Solids (%)	1.8	0.8	2.9	1.9	0.9	2.3	0.6
Total Organic Carbon (mg/kg)	83	1,674	1,380	2,534	2,546	240	216
Fats, Oils and Greases (mg/kg)	<1	85	112	27	28	<1	3
Arsenic (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium (mg/kg)	14.0	10.0	15.0	13.0	17.0	10.0	6.0
Iron (mg/kg)	13,160	5,630	9,160	6,950	7,980	14,090	3,420
Lead (mg/kg)	53.0	47.0	54.0	72.0	51.0	54.0	41.0
Manganese (mg/kg)	453.0	323.0	307.0	313.0	435.0	451.0	137.0
Nickel (mg/Kg)	20.0	20.0	20.0	40.0	20.0	20.0	10.0
Zinc (mg/kg)	80.0	60.0	60.0	60.0	70.0	60.0	20.0
Total PCBs (mg/kg)	0.02	0.06	0.09	<0.1	0.04	0.02	0.06

*Expressed on a dry weight basis.

From Polls 1988

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

TABLE ^{c}6

CHEMICAL CHARACTERISTICS OF SEDIMENT COLLECTED ALONG TRANSECT C IN LAKE MICHIGAN, SEPTEMBER 1987

Constituent*	Station Designation						
	0.2	0.5	1.0	1.5	2.0	3.0	5.0
Total Solids (%)	52.8	69.0	57.8	66.7	95.5	87.0	76.7
Total Volatile Solids (%)	3.0	0.7	2.7	0.6	1.0	1.0	0.7
Total Organic Carbon (mg/kg)	1,354	120	159	127	24	182	106
Fats, Oils and Greases (mg/kg)	746	9	<1	3	<1	<1	<1
Arsenic (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium (mg/kg)	44.0	7.0	19.0	3.0	11.0	8.0	1.0
Iron (mg/kg)	14,380	5,690	18,120	3,460	5,810	8,130	2,840
Lead (mg/kg)	93.0	49.0	49.0	32.0	22.0	26.0	22.0
Manganese (mg/kg)	1,141.0	186.0	425.0	113.0	510.0	276.0	138.0
Nickel (mg/Kg)	20.0	10.0	40.0	10.0	20.0	10.0	10.0
Zinc (mg/kg)	220.0	70.0	60.0	30.0	20.0	30.0	10.0
Total PCBs (mg/kg)	NA	0.06	0.02	0.05	<0.01	0.02	<0.01

*Expressed on a dry weight basis.
NA = No analysis (sample bottle broken in transit).

From Polls 1988

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

TABLE 7

CHEMICAL CHARACTERISTICS OF SEDIMENT COLLECTED ALONG TRANSECT D IN LAKE MICHIGAN, SEPTEMBER 1987

Constituent*	Station Designation				
	0.3	2A	2B	3.0	5.0
Total Solids (%)	63.5	85.8	59.4	49.5	38.0
Total Volatile Solids (%)	0.4	0.8	0.7	2.6	2.8
Total Organic Carbon (mg/kg)	298	126	522	1,667	1,069
Fats, Oils and Greases (mg/kg)	<1	<1	<1	<1	63
Arsenic (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium (mg/kg)	4.0	1.0	6.0	16.0	17.0
Iron (mg/kg)	7,210	3,820	4,620	10,140	9,730
Lead (mg/kg)	28.0	21.0	23.0	37.0	42.0
Manganese (mg/kg)	215.0	214.0	264.0	426.0	411.0
Nickel (mg/Kg)	<1.0	10.0	<1.0	20.0	10.0
Zinc (mg/kg)	50.0	10.0	30.0	70.0	70.0
Total PCBs (mg/kg)	0.02	0.01	0.02	0.01	0.08

*Expressed on a dry weight basis.

From Polls 1988

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

TABLE 8

CHEMICAL CHARACTERISTICS OF SEDIMENT COLLECTED ALONG TRANSECT E IN THE INDIANA HARBOR CANAL AND INDIANA HARBOR, SEPTEMBER 1987

Constituent*	Station Designation				
	0.6	1.3	2.7	3.8	5.4
Total Solids (%)	48.0	40.8	29.1	23.2	26.4
Total Volatile Solids (%)	6.5	9.7	20.6	19.7	20.1
Total Organic Carbon (mg/kg)	10,392	23,718	68,859	71,151	47,398
Fats, Oils and Greases (mg/kg)	12,433	32,968	74,293	59,970	104,224
Arsenic (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium (mg/kg)	108.0	150.0	576.0	478.0	602.0
Iron (mg/kg)	24,000	43,100	45,000	59,900	60,900
Lead (mg/kg)	255.0	439.0	963.0	940.0	153.0
Manganese (mg/kg)	978.0	1,118.0	996.0	1,207.0	1,207.0
Nickel (mg/Kg)	30.0	50.0	120.0	70.0	90.0
Zinc (mg/kg)	930.0	1,920.0	4,280.0	3,250.0	4,120.0
Total PCBs (mg/kg)	1.45	2.23	10.14	8.06	17.30

*Expressed on a dry weight basis.

From Polls 1988

exposed when the surficial sediments are removed by this dredging project (USCOE 1994, 1995). The deeper sediments at transect 13 contained 29.7 to 99.9 ppm PCBs at 24 to 36 feet below Low Water Datum (LWD). This transect extends from Columbus Drive to The Forks. Transect 6 is just upstream from Dickey Road in the main IHC.

The Lake George Branch at Indianapolis Boulevard had the highest concentrations of methyl mercury, selenium, 2-methyl naphthalene, chrysene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and benzo(ghi)perylene (Ingersoll *et al.* 1993). In addition, sediment at this location contained the second highest concentrations of fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, benzo(k)fluoranthene, lead, and benzo(a)pyrene (Ingersoll et al. 1993). While this pattern is not conclusive, it suggests that the unused portion of the west end of the Lake George Branch is serving as a source of contaminants to the rest of the IHC and Lake Michigan. This study did not analyze these sediments for PCBs, so no recent PCB data exists for this location.

Other sediment contaminant investigations in this area include Unger (1992) and Hoke *et al.* (1993) for the GCR, Risatti and Ross (1989) in the IHC, and Floyd Browne and Associates (1993) for the GCR to Columbus Drive on the southern project limits. Comparisons made between these and other previously-mentioned sediment studies, where there is overlap, do not all have the consistency that could be expected. For instance, sediment residues of PCBs and PAHs reported by Risatti and Ross (1989) (0.5 ppm and 0.9 ppm, respectively) are at least an order of magnitude lower than any of the other data sets for the area (ISBH 1978, Ingersoll *et al.* 1993, USCOE 1994, IDEM unpublished). Unger (1992) and Hoke *et al.* (1993) indicate a possibly significant source of PCBs and PAHs in the WBGCR, but report consistently lower sediment concentrations of PCBs from the EBGCR than reported by ISBH (1972), IDEM (unpublished, see Table 9), and Floyd Browne and Associates (1993). Pesticide residues in sediments as reported in Unger (1992) and Hoke *et al.* (1993) seem elevated relative to the low or "non-detect" for these same parameters in fish samples (IDEM unpublished), barn swallow hatchlings from the GCR (USFWS unpublished), and whole-body lesser scaup from IHC (USFWS unpublished). IDEM's PCB fish tissue data (Table 10, unpublished) also calls into question Risatti and Ross' (1989) sediment data.

Limited data exist for Lake Michigan sediment quality, however, Helfrich and Armstrong (1986) reported on the PAHs in the sediments of the southern basin of the lake. Five sediment core samples were taken in major sediment depositional zones. Two of the 5 surficial sediments of core samples contained significant levels of C1-C4 naphthalenes (0.2 to 6.2 ug/g total PAHs). Since naphthalenes are easily degraded or lost through weathering, their presence suggests a source either in close proximity or protected from these effects. Hoffman *et al.* (1984) found high levels of naphthalene and alkylated naphthalenes associated with sewage effluents containing petroleum hydrocarbons from industrial sources. Helfrich and Armstrong (1986) point out that Indiana Harbor is the largest center for petroleum products distribution of all of the Great Lakes ports (Scher 1979), and propose that PAHs in these Lake Michigan sediments originate from industrial sources.

Table 9. PCB sediment concentrations taken in the Grand Calumet River / Indiana Harbor Canal, 1986 to 1994 (ng/g, dry weight) (IDEM, unpublished).

DATE	LABNO	TotalPCB	LOCATION	SITE
08/13/86	DD3162	4100.	DICKEY RD.	INDIANA HARBOR CANAL
08/13/86	DD3150	1100.	KENNEDY AVE.	GRAND CALUMET RIVER
08/13/86	DD3151	2200.	KENNEDY AVE.	GRAND CALUMET RIVER
08/13/86	DD3149	1400.	KENNEDY AVE.	GRAND CALUMET RIVER
08/13/86	DD3152	350.	INDY BLVD	GRAND CALUMET RIVER
08/13/86	DD3153	2500.	INDY BLVD	GRAND CALUMET RIVER
08/13/86	DD3154	1500.	INDY BLVD	GRAND CALUMET RIVER
08/13/86	DD3157	6100.	CLINE AVE.	GRAND CALUMET RIVER
08/13/86	DD3158	1100.	CLINE AVE.	GRAND CALUMET RIVER
08/12/86	DD3159	1900.	BRIDGE ST.	GRAND CALUMET RIVER
08/12/86	DD3160	14000.	BRIDGE ST.	GRAND CALUMET RIVER
08/13/86	DD3161	3100.	DICKEY RD.	INDIANA HARBOR CANAL
08/13/86	DD3155	2000.	RAILROAD BRIDGE	LAKE GEORGE CANAL
12/09/87	80502092	< 2600.	BRIDGE ST.	GRAND CALUMET RIVER
12/09/87	80502093	570.	BRIDGE ST.	GRAND CALUMET RIVER
12/09/87	80502094	1600.	BRIDGE ST.	GRAND CALUMET RIVER
12/09/87	80502095	540.	BRIDGE ST.	GRAND CALUMET RIVER
12/09/87	80502096	13000.	VIRGINIA ST.	GRAND CALUMET RIVER
12/09/87	80502097	8900.	VIRGINIA ST.	GRAND CALUMET RIVER
12/09/87	80502098	230.	HOHMAN AVE.	GRAND CALUMET RIVER
12/09/87	80502099	230.	RAILROAD BRIDGE	LAKE GEORGE CANAL
12/09/87	80502100	1900.	RAILROAD BRIDGE	LAKE GEORGE CANAL
12/09/87	80502101	960.	DICKEY RD.	INDIANA HARBOR CANAL
12/09/87	80502102	10000.	DICKEY RD.	INDIANA HARBOR CANAL
12/09/87	80502103	2500.	INDY BLVD	GRAND CALUMET RIVER
12/09/87	80502104	6400.	INDY BLVD	GRAND CALUMET RIVER
12/09/87	80502105	1700.	KENNEDY AVE.	GRAND CALUMET RIVER
12/09/87	80502106	490.	KENNEDY AVE.	GRAND CALUMET RIVER
12/09/87	80502107	5000.	CLINE AVE.	GRAND CALUMET RIVER
06/14/88	80604958	1500.	DICKEY RD.	INDIANA HARBOR CANAL
06/14/88	80604959	2100.	RAILROAD BRIDGE	LAKE GEORGE CANAL
06/14/88	80604960	1300.	INDY BLVD	GRAND CALUMET RIVER
06/14/88	80604961	330.	KENNEDY AVE.	GRAND CALUMET RIVER
06/15/88	80604962	2200.	CLINE AVE.	GRAND CALUMET RIVER
06/15/88	80604963	2100.	CLINE AVE.	GRAND CALUMET RIVER
06/15/88	80604964	8000.	BRIDGE ST.	GRAND CALUMET RIVER
06/15/88	80604965	1700.	HOHMAN AVE.	GRAND CALUMET RIVER
06/14/88	80604968	1100.	CONFLUENCE EAST	GRAND CALUMET RIVER
06/21/88	80604966	50.	MERRILLVILLE,IN	RED ROOF INN POND
06/21/88	80604967	50.	WEST BASIN	MARQUETTE PARK LAGOON
11/01/88	DD2860	5600.	DICKEY RD.	INDIANA HARBOR CANAL
06/12/90	00604886	6400.	DICKEY RD.	INDIANA HARBOR CANAL
06/12/90	00604887	9300.	DICKEY RD.	INDIANA HARBOR CANAL
06/24/92	20700010	17000.	DICKEY RD.	INDIANA HARBOR CANAL
06/24/92	20700011	19000.	DICKEY RD.	INDIANA HARBOR CANAL

Table 9. PCB sediment concentrations taken in the Grand Calumet River / Indiana Harbor Canal, 1986 to 1994 (ng/g, dry weight) (IDEM, unpublished) (continued).

DATE	LABNO	TotalPCB	LOCATION	SITE
09/21/94	40902375	4000.	BRIDGE ST.	GRAND CALUMET RIVER
09/21/94	40902376	2400.	CLINE AVE.	GRAND CALUMET RIVER
09/28/94	41000225	7100.	KENNEDY AVE.	GRAND CALUMET RIVER
09/28/94	41000227	2000.	INDY BLVD	GRAND CALUMET RIVER
09/28/94	41000226	3800.	KENNEDY AVE.	GRAND CALUMET RIVER
09/28/94	MS41000264	0.	INDY BLVD	GRAND CALUMET RIVER
09/28/94	MSD41000265	0.	INDY BLVD	GRAND CALUMET RIVER
08/25/94	40801368	*2200.	DICKEY RD.	INDIANA HARBOR CANAL
08/25/94	40801369	*5700.	DICKEY RD.	INDIANA HARBOR CANAL
08/25/94	40801368	*2200.	DICKEY RD.	INDIANA HARBOR CANAL
08/25/94	40801369	*5700.	DICKEY RD.	INDIANA HARBOR CANAL
09/21/94	40902375	4000.	BRIDGE ST.	GRAND CALUMET RIVER
09/21/94	40902376	2400.	CLINE AVE.	GRAND CALUMET RIVER
09/28/94	41000225	7100.	KENNEDY AVE.	GRAND CALUMET RIVER
09/28/94	41000227	2000.	INDY BLVD	GRAND CALUMET RIVER
09/28/94	41000226	3800.	KENNEDY AVE.	GRAND CALUMET RIVER

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Table 10. PCB residues from fish in the Grand Calumet River / Indiana Harbor Canal, 1980 to 1994 (ng/g, wet weight)(IDEM unpublished data).

Date	Lab#	Species	Size	Mass	#	Whole?	Skin?	SITE	LOCATION	%Mois	%Lip	TotalPCB	
10/07/80	00658	CARP	16.5	101	5	W	T	IHC	DICKEY RD.	--	1.74	1421.	
09/15/82	00477	CARP	56.3	2088	3	W	T	GCR	CONFLUENCE	--	8.03	12504.	
09/15/82	00478	CARP	43.5	945	3	W	T	GCR	CONFLUENCE	--	8.82	4633.	
10/09/84	00199	CARP	51.3	2046	5	W	T	GCR	KENNEDY AVE.	--	7.35	5868.	
06/25/86	80502396	CARP	59.8	2979	3	W	T	GCR	INDY BLVD.	--	13.3	5100.	
06/02/86	80502398	CARP	68.5	4377	4	W	T	GCR	KENNEDY AVE.	--	14.5	5500.	
06/26/86	80502399	CARP	50.6	2093	4	W	T	GCR	CLINE AVE.	--	9.3	5100.	
06/25/86	80502403	CARP	66.2	3598	5	W	T	IHC	DICKEY RD.	--	16.6	7100.	
06/26/86	80502404	CARP	70.8	4918	3	W	T	GCR	BRIDGE ST.	--	13.5	9700.	
07/15/86	80502397	CARP	49.2	1447	5	W	T	MPL	EAST BASIN	--	7.6	320.	
07/15/86	80502400	LM BASS	32.	454	1	W	T	MPL	EAST BASIN	--	4.4	620.	
08/14/86	80502401	CARP	43.4	1088	3	W	T	MPL	MIDDLE BASIN	--	2.8	290.	
08/14/86	80502402	CARP	38.8	801	4	W	T	MPL	WEST BASIN	--	4.5	1100.	
10/08/86	00881	CARP	36.8	760	5	W	T	IHC	DICKEY RD.	--	5.48	3754.	
10/08/86	00882	CARP	39.2	963	5	W	T	IHC	DICKEY RD.	--	5.8	3138.	
07/07/87	80502405	CARP	58.7	2738	4	W	T	IHC	DICKEY RD.	--	14.	8000.	
07/08/87	80502406	CARP	29.3	490	2	W	T	GCR	CLINE AVE.	--	5.8	4300.	
07/08/87	80502407	G. SHINER	10.7	20	16	W	T	GCR	CLINE AVE.	--	3.7	2900.	
07/08/87	80502409	CARP	33.5	593	4	W	T	GCR	KENNEDY AVE.	--	8.3	4700.	
07/08/87	80502410	CARP	38.5	888	1	W	T	GCR	BRIDGE ST.	--	4.7	3300.	
11/01/88	90602983	CARP	61.5	3440	3	F	T	IHC	DICKEY RD.	--	6.08	1500.	
11/01/88	90602984	CARP	61.5	3440	3	F	T	IHC	DICKEY RD.	--	6.4	1700.	DUP of 90602983
11/01/88	90602985	CARP	74.	6691	1	F	T	IHC	DICKEY RD.	--	21.68	2200.	
08/15/90	11202139	CARP	58.8	2819	3	F	T	IHC	S. OF DICKEY	74.2	6.26	5500.	
08/15/90	11202140	CARP	58.8	2819	3	F	T	IHC	S. OF DICKEY	74.7	6.42	4500.	
08/15/90	11202141	CARP	43.8	1320	2	F	T	IHC	S. OF DICKEY	76.5	3.42	2500.	
08/15/90	11202142	GOLDFISH	19.	139	6	W	T	IHC	S. OF DICKEY	73.6	4.85	5700.	
09/30/92	30301041	CARP	80.	8427	1	F	T	IHC	DICKEY RD.	55.91	11.88	8600.	
09/30/92	30301042	CARP	80.	8427	1	F	T	IHC	DICKEY RD.	55.23	12.4	9200.	
09/30/92	30301043	CARP	37.7	874	5	F	T	IHC	DICKEY RD.	73.37	6.23	4500.	
09/30/92	30301044	CARP	54.2	2263	4	F	T	IHC	DICKEY RD.	72.4	8.34	4600.	
09/30/92	30301045	CARP	26.3	275	5	F	T	IHC	DICKEY RD.	72.6	4.52	2600.	

Table 10. PCB residues from fish in the Grand Calumet River / Indiana Harbor Canal, 1980 to 1994 (ng/g, wet weight)(IDEM unpublished data) (continued).

Date	Lab#	Species	Size	Mass	#	Whole?	Skin?	SITE	LOCATION	%Mois	%Lip	TotalPCB
09/21/94	41201208	(MS)	--	--	-	-	F	GCR	BRIDGE ST.	--	5.37	0.
09/21/94	41201209	(MSD)	--	--	-	-	F	GCR	BRIDGE ST.	--	5.37	0.
08/25/94	40900692	CARP	32.8	624	1	F	T	IHC	DICKEY RD.	78.2	2.7	3000.
08/25/94	40900693	CARP	53.7	2100	1	F	T	IHC	DICKEY RD.	77.9	3.46	4900.
08/25/94	40900694	CARP	49.5	2724	1	F	T	IHC	DICKEY RD.	62.4	20.8	23000.
09/21/94	41201188	CARP	50.7	1887	2	F	T	GCR	BRIDGE ST.	76.5	5.37	6800.
09/21/94	41201189	CARP	35.1	993	1	F	T	GCR	BRIDGE ST.	76.9	5.99	6600.
09/21/94	41201190	GOLDFISH	16.	78	8	W	T	GCR	BRIDGE ST.	76.3	3.92	4100.
09/21/94	41201191	CARP	37.2	762	2	F	T	GCR	CLINE AVE.	80.2	1.64	800.
09/21/94	41201192	CARP	46.1	1703	2	F	T	GCR	CLINE AVE.	76.3	5.09	8400.
09/21/94	41201193	CARP	46.1	1703	2	F	T	GCR	CLINE AVE.	76.3	5.18	7500.
09/21/94	41201194	CARP	78.5	7037	1	F	T	GCR	CLINE AVE.	69.3	11.98	27000.
09/21/94	41201195	GOLDFISH	15.2	70	8	W	T	GCR	CLINE AVE.	76.9	3.19	5300.
09/28/94	41201196	CARP	48.4	2072	3	F	T	GCR	INDY BLVD.	73.8	8.22	11000.
09/28/94	41201197	CARP	41.4	1052	3	F	T	GCR	INDY BLVD.	76.4	5.03	5700.
09/28/94	41201198	CARP	55.1	2696	1	F	T	GCR	INDY BLVD.	66.9	16.51	19000.
09/28/94	41201199	GOLDFISH	--	--	9	W	T	GCR	INDY BLVD.	75.3	4.55	3600.
09/28/94	41201200	CARP	41.3	1078	3	F	T	GCR	KENNEDY AVE.	77.	4.75	7900.
09/28/94	41201201	CARP	29.9	474	4	F	T	GCR	KENNEDY AVE.	77.	6.64	6500.
09/28/94	41201202	CARP	62.7	3632	2	F	T	GCR	KENNEDY AVE.	73.8	8.81	16000.
09/28/94	41201203	GOLDFISH	--	--	10	W	T	GCR	KENNEDY AVE.	76.3	3.44	5200.

KEY

Date - date collected
Lab# - IDEM sample number
Species - fish common name
Size - in centimeters
Mass - in grams
- number of fish in sample
Whole? - whole fish (W) or fillet (F)
Skin? - skin on (T or F)
SITE - nearest bridge crossing
LOCATION - Grand Calumet River (GCR); Indiana Harbor Canal (IHC); Marquette Park Lagoons (MPL)
%Mois - percent moisture
%Lip - percent lipid
TotalPCB - total PCB concentration in ng/g (ppb)

In an effort to assess the toxicological significance of the sediment chemistry data presented for the IHC, comparison to benchmarks that have been documented in the published literature is helpful. Long and Morgan (1990) summarized numerous sources of data and reported various effect levels for many contaminants, including both freshwater and marine environments. These authors suggested "effects range low" (ER-L) concentrations and "effects range midway" (ER-M) for the contaminants studied (Table 11). The ER-L is the value that Long and Morgan suggested as a low range concentration at which observed biological effects occurred, usually the lower 10 percentile of available data. The ER-M is the value that was approximately in the middle of the range of reported concentrations that were known to have caused observed biological impacts to organisms.

Clark and Jarvis (1990) reported PAH concentrations in sediments and tissues from "relatively clean areas around the Great Lakes", considering these to be "no effect levels" (Table 12). They also reported concentrations from "contaminated areas" and considered these to be "major biological effect levels" (Table 13).

As an example, Long and Morgan (1990) summarized data from various sources and recommended an ER-L of 4 parts per million (ppm) and an ER-M of 35 ppm for total PAHs in sediment. Total PAHs in IHC sediment exceed the ER-M by more than 20-fold. Sediment data reported by Helfrich and Armstrong (1986) for depositional sediments in Lake Michigan exceed the ER-L for total PAHs. It is likely that the sediments below the Corps proposed project depth are present at concentrations exceeding the proposed ER-Ms (see Table 3).

Sediment contamination upstream of the Corps project also exceed proposed ER-Ms (Hoke *et al.* 1993, Sobiech *et al.* 1994). Both of these studies included sediment toxicity tests in the GCR between 1988 and 1994, and they indicate that these sediments are highly toxic to aquatic invertebrates. This indicates a need for both source control and appropriate sediment remediation if the reestablishment of a healthy aquatic ecosystem is to occur.

Fish and Wildlife Resources

Benthic Invertebrates

The benthic invertebrate community has frequently been used to assess environmental quality of aquatic ecosystems. These organisms are sensitive to both physical and chemical changes in the environment. They also have sufficiently long life cycles and low motility, and, therefore, reflect past and present environmental conditions.

An unstressed community supports a large number of different groups with relatively few individuals within each group. However, when a community is stressed, the number of benthic groups decreases and the number of individuals in the remaining tolerant groups increases.

Table 11. Summary of ER-L (effects range-low), ER-M (effects range-midway), and overall apparent effects threshold concentrations for selected chemicals in sediment (dry weight) (Source: Long and Morgan 1990).

Chemical Analyte	ER-L Concentration	ER-M Concentration	Overall Apparent Effects Threshold
Trace Elements (ppm)			
Antimony	2	25	25
Arsenic	33	85	50
Cadmium	5	9	5
Chromium	80	145	--
Copper	70	390	300
Lead	35	110	300
Mercury	0.15	1.3	1
Nickel	30	50	--
Silver	1	2.2	1.7
Zinc	120	270	260
Polychlorinated Biphenyls (ppb)			
Total PCBs	50	400	370
Polycyclic Aromatic Hydrocarbons (ppb)			
Acenaphthene	150	650	150
Anthracene	85	960	300
Benzo(a)anthracene	230	1600	550
Benzo(a)pyrene	400	2500	700
Chrysene	400	2800	900
Dibenz(a,h)anthracene	60	260	100
Fluoranthene	600	3600	1000
Fluorene	35	640	350
2-methylnaphthalene	65	650	300
naphthalene	340	2100	500
Phenanthrene	225	1380	260
Pyrene	350	2200	1000
Total PAHs	4000	35000	22000

Table 12. Polycyclic aromatic hydrocarbon (PAH) concentrations considered to be "no effect levels" or concentrations in sediments from relatively clean areas around the Great Lakes (Source: Clark and Jarvis 1990).

Chemical Analyte	PAH concentration (ppm)
benzo(a)pyrene	0.03 - 0.05
chrysene	0.075
fluoranthene	0.08 - 0.10
phenanthrene	0.03 - 0.07
pyrene	0.05 - 0.10
total PAH	3.8

Table 13. Polycyclic aromatic hydrocarbon (PAH) concentrations considered to cause major biological effects or concentrations in sediments from contaminated areas around the Great Lakes (Source: Clark and Jarvis 1990).

Chemical Analyte	PAH concentration (ppm)
acenaphthene	2.5 - 7.5
acenaphthylene	8 - 20
anthracene	1 - 15
benzo(a)anthracene	2 - 25
benzo(a)pyrene	2.5 - 20
	10 - 15*
benzo(g,h,i)perylene	1 - 15
chrysene	3 - 30
fluoranthene	7 - 35
fluorene	2 - 15
indeno(1,2,3-cd)pyrene	1.5 - 15
phenanthrene	5 - 100
pyrene	5 - 50
total PAH	6.8

* - Concentration represents levels for river sediments passing through industrial or heavily-populated areas.

A number of the sediment, water quality, and fishery sampling studies conducted within the GCR/IHC, Indiana Harbor, and southwestern Lake Michigan included macrobenthic investigations. In March 1965, the Calumet Area Surveillance Project conducted biological sampling within the system (FWPCA 1966). The bottom type within both the IHC and harbor was ooze, with some silt at 151st Street, and the bottom odor was both sewage and petroleum. No benthic organisms were observed in the IHC. In the inner reaches of the harbor there were also no benthic organisms, but in the outer harbor there were oligochaetes (sludgeworms), hirudineans (leeches), and gastropods (snails).

In October 1967, 8 stations in Indiana Harbor and the IHC were sampled for benthic fauna (USCOE 1977). The 2 outermost stations were the only sites that yielded living fauna - tubificid worms. These station sites are influenced by the underlying wedge of incoming Lake Michigan water overlain by outgoing IHC water. The lack of fauna in the canal entrance channel and IHC proper was indicative of the polluted state of the canal environment.

General observations of samples collected in 1968 revealed signs of worms only within the outer reaches of the harbor in the entrance channel west of the eastern breakwater's north light (Gannon and Beeton 1969). Elsewhere, as far in as the division between the harbor and the canal, there was no sign of worm activity.

Benthic sampling again occurred in 1977 during U.S. EPA's sediment studies at 13 locations in the IHC and harbor (see Figure 9). Table 14 presents the results of that sampling. The studies revealed a virtual absence of benthic life at sites 2, 3, and 4 in the IHC. Populations at the remaining sites were heavily dominated by oligochaetes, except for site 13, where pelecypods (bivalve mollusks) were predominant. Site 8 at the mouth of the canal entrance channel had an extremely high density of oligochaetes. Other organisms collected were dipterans (true flies), hirudineans, amphipods (scuds), and gastropods.

During its studies of water and sediment quality in the GCR/IHC system and Lake Michigan in 1982 and 1986, the MWRD also investigated the benthic invertebrate community. In 1967-68, 3 major benthic invertebrate groups had been collected from southwestern Lake Michigan. During the 1982 survey, 8 benthic groups were collected in the same part of the lake (Polls *et al.* 1993). Similarly, in 1973, 3 benthic groups had been collected in Indiana harbor, while 7 groups were collected from the harbor in 1982.

Between 1982 and 1986, the number of benthic invertebrate groups increased from 4 to 5 in the GCR and IHC, and the percentage of tubificid worms decreased slightly (Polls *et al.* 1993). The number of benthic organisms also decreased substantially in both waterways. Overall, the slight increase in the number of benthic groups, the decrease in percent composition of worms, and the substantial decrease in the abundance of benthic invertebrates

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Table 14. MACROINVERTEBRATE DATA AT INDIANA HARBOR

HARBOR: Indiana Harbor, Indiana
SAMPLED: August 30, 1977

Taxa	Number of Organisms for Each Taxa by Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Diptera													
<u>Chironomus</u>	9												2
<u>Micropsectra</u>	1												
<u>Microtendipes</u>	1												
<u>Dicrotendipes</u>	2					1			1				
<u>Kiefferulus</u>	2												
<u>Procladius</u>	3											1	
<u>Brillia</u>	1												
<u>Chaoborus</u>		1											
<u>Chryptochironomus</u>												1	2
<u>Trichocladius</u>													3
Oligochaeta													
<u>Tubifex</u>	77				210	59	76	1,400	27	43	176	375	31
<u>Limnodrilus</u>	44				281	20	95	290	5	4	25		
<u>Peloscolex</u>	3				23		43	650	9	20	51		3
<u>Branchiura sowerbyi</u>								10					
<u>Unidentifiable immature</u>					45	8	24	150		30	35	25	8
Hirudinea													
<u>Glossiphonia</u>							1						3
<u>Macrobdella</u>													
<u>Haemopis</u>											1		1
<u>Helobdella</u>													4
Amphiopoda													
<u>Gammarus</u>													1
Pelecyopoda													
<u>Pisidium</u>				1									
<u>Sphaerium</u>				3		6	17	41	7	35	6		85
<u>Muscueium</u>								17			3		15
Gastropoda													
<u>Lymnaea</u>			1	2					2				2
<u>Physa</u>			1	4		21	4	16	48		8		4
<u>Goniobasis</u>				1	1			2					
<u>Helisoma</u>										3	1		
<u>Gyraulus</u>													7
Total # of organisms	143	1	2	11	560	114	260	2576	99	135	306	402	171
Total # of taxa	10	1	2	5	5	5	7	9	7	6	9	4	15

From USEPA 1977

indicated that there had been an improvement in the sediment quality of the GCR/IHC between those years.

During the same period, the number of benthic groups in Indiana Harbor remained at 6 (Polls *et al.* 1993). The percentage of worms decreased slightly, and the mean number of organisms decreased substantially, indicating an improvement in sediment quality. In Lake Michigan, the number of benthic groups decreased from 8 to 7 between 1982 and 1986. The percent composition of tubificid worms and the number of organisms also decreased. It was determined that these changes indicated an improvement in the lake sediment quality.

The 1983 water and sediment sampling studies by the MSD also included benthic invertebrate sampling (Polls and Dennison 1984). Table 15 is a composite list of species found at 18 locations in the IHC, Indiana Harbor, and Lake Michigan. The Lake Michigan sites off Jeorse Park in East Chicago and the Hammond Water Filtration Plant, were once considered possible locations for an in-lake CDF for the project dredgings. The 6 harbor study sites had from 3 to 8 taxa and 1,444 to 118,497 individuals. The largest number of individuals were tubificid worms at the mouth of the canal entrance channel. Within the IHC, the number of taxa per location varied from 1 to 6, and numbers of individuals ranged from 14,630 to 213,890, with tubificid worms again dominating. The 6 Lake Michigan sites had between 8 and 10 taxa and 7,765 to 26,434 individuals. Although tubificid worms were dominant at most locations, 1 site was dominated by nematodes.

During 1984, benthic and sediment samples were collected from within the harbor entrance channel and 2 locations in Lake Michigan. One site was offshore Whiting Park, west of Indiana Harbor, and the other was east of the entrance channel, just north of the Inland Steel lakefill. The Whiting site had mostly clean, fine, brown sand as the substrate, while the Inland Steel site generally had silt of sandy gravel over hard-packed clay (Limno-Tech., Inc. 1984). Table 16 lists the species found at the 3 sites.

A more recent benthic invertebrate study took place in 1988, when the Illinois Natural History Survey conducted a number of studies at the request of the Corps. One station was within the Lake George Branch, 3 were in the IHC, 2 were in the harbor, and 6 were in Lake Michigan off the LTV and Inland Steel lakefills. A total of 22 taxa of aquatic macroinvertebrates were collected, with tubificid worms being dominant at each locality (Risatti and Ross 1989).

The authors indicated that:

> Notably absent from the macroinvertebrate collections taken from the Indiana Harbor area during May, 1988, were Amphipoda, Isopoda, mysid shrimp, Decapoda, Ostracoda, Trichoptera, Ephemeroptera, and a diversity of chironomid and gastropod species. Species in these groups could be present within Indiana Harbor and its canals as well as outside of the Indiana Harbor/Inland Steel peninsula. Their absence from these collections could be a reflection of the sampling device used for

BENTHIC MACROINVERTEBRATES IN SEDIMENTS FROM INDIANA HARBOR, THE INDIANA HARBOR CANAL, AND SOUTHWESTERN LAKE MICHIGAN, NOVEMBER 1 - 2, 1983

- Coelenterata (Hydroids)
  - Hydridae
    - *Hydra* sp.
- Nematoda (Roundworms)
- Annelida
  - Oligochaeta (Aquatic Earthworms)
    - Tubificidae
  - Hirudinea (Leeches)
    - Glossiphoniidae
      - *Helobdella stagnalis*
    - Erpobdellidae
- Arthropoda
  - Arachnoidea
    - Hydracarina (Water Mites)
  - Crustacea
    - Isopoda (Aquatic Sow Bugs)
      - Asellidae
        - *Asellus* sp.
    - Amphipoda (Scuds)
      - Gammaridae
        - *Gammarus* sp.
    - Insecta
      - Diptera (Flies)
        - Chironomidae (Midges)
- Mollusca
  - Gastropoda (Snails)
    - Ancylidae (Limpets)
      - *Ferissia* sp.
    - Planorbidae (Orbit Snails)
      - *Helisoma* sp.
    - Physidae (Pouch Snails)
      - *Physella* sp.
    - Valvatidae (Round Mouthed Snails)
      - *Valvata* sp.
  - Pelecypoda (Clams)
    - Sphaeriidae (Fingernail Clams)
      - *Pisidium* sp.
      - *Sphaerium* sp.

Table 15.

From Polls and Dennison 1984

Table 16. Benthic Macroinvertebrates Found in Lake Michigan Off Whiting Park and Inland Steel and in the Indiana Harbor Entrance Channel (Limno-Tech, Inc. 1994)

	Whiting	Inland	Harbor
Onidaris			
Hydra sp.	+		
Nematoda	+	+	+
Mollusca			
Amnicola sp.	+		
Valvata sincera	+	+	
Sphaerium sp.	+	+	
Pisidium sp.	+	+	+
Oligochaeta			
Enchytraeidae		+	
Chaetogaster diaphanus	+	+	+
Piguetiella michiganensis	+	+	+
Styloria lacustris	+		
Nais sp.	+		
Uncinais uncinata	+	+	+
Aulodrilus americanus	+		
A. piqueti		+	
A. limnobius	+	+	
Potamothris moldaviensis	+	+	+
P. vejdovskyi		+	+
Limnodrilus hoffmeisteri		+	+
L. profundicola		+	
L. cervix		+	+
Stylodrilus heringanus		+	

Arcteonais lomondi		+	
Quistadrilus multisetosus		+	
Ilyodrilus templetoni		+	
Pristina foreli		+	
Immature Tubificidae w/o cap.	+	+	+
Immature Tubificidaw w/ cap.	+	+	+
Hirundinea		+	
Helobdella stagnalis	+	+	
Amphipoda			
Gammarus sp.	+	+	
Hyalella azteca	+		
Acari	+		
Diptera			
Chironomidae pupae	+	+	
Cryptochironomus sp.	+	+	+
Chironomus sp.	+	+	
Demicryptochironomus sp.	+		
Psectrocladius sp.	+		
Potthastia longimanus	+	+	
Pseudochironomus sp.	+	+	
Monodiamesa c.f. *tuberculata*	+	+	
Procladius sp.		+	
Totals	28	32	11

> collection, the low number of samples taken, small resident populations, or a combination of these factors. Certainly, the low density of oligochaetes in all of the samples collected during this project suggest either an extremely high level of toxicity, absence of suitable or preferred habitat, or both (Risatti and Ross 1989).

These studies were done before the arrival of zebra mussels (*Dreissena polymorpha*) in Lake Michigan. This nonindigenous bivalve mollusk species has since proliferated throughout the lake, with huge colonies attached to every available surface by means of their byssal threads. They are known to be covering breakwaters at Indiana Lake Michigan marinas and ports, and were found in the outer harbor (Station 3) during benthic sampling in 1991 (Ingersoll *et al.* 1993). These mussels were collected on artificial substrate samplers, but it is also possible that they have since become attached to the sediments as well, since they have been found to be able to attach to and form colonies on soft substrates such as sand and silt. Based upon observations of benthic organisms eaten by diving ducks in the IHC, however, there apparently are few zebra mussels within the upper canal (Custer, unpublished).

Ingersoll *et al.* (1993) confirmed the results of previous work - that the GCR/IHC system has a depauperate benthic invertebrate community. Except for 2 individual chironomids collected at Station 10 (Columbus Drive), no other insects were present in grab samples from the canal and harbor. Bivalve molluscs were rare, occurring only at 3 stations - The Forks and the inner and outer harbor. Tubificids were the most abundant organisms at all 7 stations, with *Limnodrilus hoffmeisteri*, a species considered tolerant of organic enrichment and metal contamination, dominating. The abundance of oligochaetes was extremely high at Station 10, approaching 1 million individuals per square meter.

There have also been several studies conducted on the benthic organisms within both branches of the GCR. IDEM has sampled macroinvertebrates at a number of locations for several years and has consistently found 5 main groups of organisms at nearly every site (Bright 1988, IDEM 1992 and 1994). "The most obvious characteristic of this assemblage of organisms is that each group is tolerant to moderate organic pollution and reduced dissolved oxygen concentrations. The presence of many "facultative" organisms (especially odonates, certain midges and snails) and a few intolerant species indicated that severe oxygen depletions do not occur frequently. Stresses associated with toxic chemicals were indicated by most samples" (IDEM 1994).

The USFWS collected benthic invertebrates from the WBGCR in 1992 and the EBGCR in 1994. Oligochaetes were dominant in the WBGCR, although dipterans, coleopterans, and gastropods were also found, for a total of 11 taxa (USFWS unpublished data). Eighteen taxa were collected from the EBGCR during the June 1994 survey (Sobiech *et al.* 1994). Dominant taxa consisted of annelids, arthropods, and mollusca. Table 17 presents the results of this sampling.

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Table 17

USFWS's invertebrate survey results from the June 1994 sampling of the East Branch Grand Calumet River. Number of invertebrates collected from artificial substrates are reported below followed by the percent total individuals collected in parentheses. A plus (+) indicates which taxa were collected during qualitative sampling.

Taxa	Transect 5*	Transect 16	Transect 24	Transect 32	Transect 36	Survey Totals
ANNELIDA (segmented worms)						
Oligochaeta (aquatic worms)	4 + (4.2)	+	5 (13.2)	14 + (23.3)	3 + (0.8)	26 (3.90)
Hirudinea (leeches)		+	8 + (21.0)	12 + (20.0)	2 + (0.5)	22 (3.30)
ARTHROPODA						
Amphipoda (scuds)					1 + (0.3)	1 + (0.15)
Decapoda (crayfish)			+			+
Insecta						
Odonata						
Zygoptera (damselflies)						
Lestidae					+	+
Coenagrionidae			+	+	+	+
Anisoptera (dragonflies)						
Aeshnidae	1 + (1.0)		+	+	+	1 + (0.15)
Hemiptera (true bugs)						
Corixidae (water boatmen)					+	+
Diptera (flies)						
Ceratopogonidae (biting midges)					1 (0.3)	1 (0.15)
Chironomidae (midges)	68 + (70.8)	31 (37.3)	23 + (60.5)	6 (10.0)	348 + (89.2)	476 + (71.36)
Empididae (danceflies)					1 (0.3)	1 (0.15)
Syrphidae (rattail maggots)				+		+
Stratiomyidae (soldier flies)				+		+
MOLLUSCA						
Gastropoda (snails)						
Planorbidae (orb snails)		+		1 + (1.7)	+	1 + (0.15)
Lymnaeidae (pond snails)	2 + (2.1)			+	+	2 + (0.30)
Physidae (pouch snails)	21 + (21.9)	51 + (61.5)	2 + (5.3)	27 + (45.0)	34 + (8.7)	135 + (20.24)
Bivalvia (clams)						
Corbiculidae (asian clams)		+		+	+	+
Dreissenidae (zebra mussels)		1 + (1.2)				1 + (0.15)
TOTAL # of INDIVIDUALS	96 (100)	83 (100)	38 (100)	60 (100)	390 (100)	667 (100)
TOTAL # of QUANITATIVE TAXA	5	3	4	5	7	14
TOTAL # of QUALITATIVE TAXA	5	6	6	9	12	11
TOTAL # of TAXA	5	7	7	11	14	18

+ Indicates that the taxa was present in the qualitative macroinvertebrate sample.
* Quantitative sampling was not possible, qualitative results are reported.

Fish

Lake Michigan

A high quality fishery exists in Lake Michigan in the vicinity of Indiana Harbor, and fish have gradually been returning to the harbor and the IHC as pollution has decreased (Table 18). The fishery composition in the lake has changed considerably through the years due to human influences. Once principally dominated by a few large, native predators, such as lake trout, lake whitefish, and lake sturgeon, the fishery now includes species from throughout the world. Some of these, such as the sea lamprey and alewife, were introduced unintentionally through man-made canals between the lakes or other means, such as ballast water from foreign freighters, while others, such as chinook and coho salmon, were intentionally introduced as new sport fish predators when the native fishery declined.

At the beginning of the European settlement era, 79 fish species inhabited Lake Michigan. Lake herring and deepwater coregonids (ciscos) were the most abundant fishes in the off-shore pelagic community (USFWS 1995). Lake herring declined markedly by the early 1900s due to heavy exploitation. It is likely that the explosive increase in the nonindigenous rainbow smelt and alewife in the 1950s and 1960s reduced lake herring to its present insignificance in the lake. Lake herring spawned anywhere along the Indiana shore in water 25 to 40 feet deep, with spawning occurring from November to mid-December (Goodyear *et al.* 1982).

Lake Michigan was the only lake to contain all 7 of the deepwater coregonids that were once recognized from the Great Lakes (Goodyear *et al.* 1982, USFWS 1995). Two of the species suffered severe declines from overfishing before the turn of the century. In the late 1960s, the remaining deepwater coregonids experienced year class failure that drove them to near extinction in the 1970s. The bloater, the smallest of the coregonids, is the only cisco that has persisted in significant quantities in the lake, and it is not listed as present near Indiana Harbor (see Table 18).

The lake trout was the most valuable commercial species in Lake Michigan from 1890 until the mid-1940s, and supported the largest lake trout fishery in the world before it was driven to extinction by attacks from the nonindigenous sea lamprey in the 1940s and 1950s (USFWS 1995). Lake trout spawned in both shallow waters and deeper offshore water, with spawning occurring from mid-October to early December (Goodyear *et al.* 1982). Control of sea lamprey was the first step necessary to restore lake trout in the Great Lakes, and eventually a chemical that kills the stream-dwelling larval phase of the sea lamprey was developed. Reintroduction of lake trout began in 1965, with the release of hatchery-reared fish, and continues today due to the species' failure to establish self-sustaining reproduction.

Beginning in 1974, lake trout and nonindigenous brown trout were stocked in Lake Michigan off Jeorse Park in East Chicago at the southeastern base of the Inland Steel lakefill. Brown trout are no longer stocked in Indiana waters,

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Table 18. Fish Species Collected from the Grand Calumet River, Indiana Harbor Canal, Indiana Harbor, and southwestern Lake Michigan During Various Sampling Activities.

		GCR/IHC	Harbor	Lake
Alewife	*Alosa pseudoharengus*	+	+	+
Gizzard shad	*Dorosoma cepedianum*	+	+	+
Steelhead trout	*Salmo gairdneri*	+	+	+
Brown trout	*S. trutta*		+	+
Lake trout	*Salvelinus namaycush*			+
Chinook salmon	*Oncorhynchus tshawytscha*	+	+	+
Coho salmon	*O. kisutch*	+		+
Lake whitefish	*Coregonus clupeaformis*			+
Rainbow smelt	*Osmerus mordax*	+		+
Central mudminnow	*Umbra limi*	+		
Goldfish	*Carassius auratus*	+	+	
Carp	*Cyprinus carpio*	+	+	+
Goldfish x Carp hybrid		+		
Rudd	*Scardinius erythrophthalmus*	+	+	
Golden shiner	*Notemigonus crysoleucas*	+		
Emerald shiner	*Notropis atherinoides*	+	+	
Spottail shiner	*N. hudsonius*	+	+	+
Blacknose shiner	*N. heterolepis*		+	
Spotfin shiner	*N. spilopterus*	+		
Sand shiner	*N. stramineus*		+	+
Bluntnose minnow	*Pimephales notatus*	+	+	
Fathead minnow	*P. promelas*	+	+	
Bullhead minnow	*P. vigilax*	+		
Longnose dace	*Rhinichthys cataractae*			+
White sucker	*Catostomus commersoni*			+
Longnose sucker	*C. catostomus*			+
Silver redhorse	*Moxostoma anisurum*		+	
Golden redhorse	*M. erythrurum*	+		
Channel catfish	*Ictalurus punctatus*			+
Black bullhead	*Ameiurus melas*	+		
Trout-perch	*Percopsis omiscomaycus*			+

Burbot	*Lota lota*			+
Rock bass	*Ambloplites rupestris*		+	+
Green sunfish	*Lepomis cyanellus*	+		
Pumpkinseed	*L. gibbosus*	+	+	+
Orangespotted sunfish	*L. humilis*		+	
Bluegill	*L. macrochirus*	+		
Smallmouth bass	*Micropterus dolomieui*		+	+
Largemouth bass	*M. salmoides*	+		
Black crappie	*Pomoxis nigromaculatus*		+	+
Yellow perch	*Perca flavescens*	+	+	+
Johnny darter	*Etheostoma nigrum*		+	+
Freshwater drum	*Aplodinotus grunniens*		+	+
Mottled sculpin	*Cottus bairdi*		+	+
Slimy sculpin	*C. cognatus*			+
Threespine stickelback	*Gasterosteus aculeatus*		+	

Sources: Indiana Department of Natural Resources studies; Polls and Dennison 1984; IDEM 1988; Risatti and Ross 1989; Simon *et al.* 1989; Simon 1992; Sobiech *et al.* 1994; Chicago District Corps sampling in 1994, 1995, and 1996 but lake trout are still stocked in waters of neighboring Illinois (Francis pers. comm.). This Illinois stocking site was identified as a "primary" lake trout rehabilitation zone in the 1985 Lake Michigan lakewide management plan for the species, which was developed to deal with the problem of lack of natural reproduction of lake trout in the lake (Great Lakes Fishery Commission 1985). Lake trout are also stocked in Michigan waters about 30 miles offshore on the south end of the lake (Holey pers. comm.). Lake trout reproduction has recently been confirmed at the underwater breakwater at Port of Indiana, about 15 miles east of Indiana Harbor (Marsden 1994).

The first alewife was recorded in Lake Michigan in 1949 (USFWS 1995). By 1957, alewife had dispersed throughout the lake, with an explosive population increase in the late 1950s and early 1960s. Alewife migrate in large schools from deeper water to inshore areas in March and April. They spawn along the entire Indiana shoreline, including harbor areas, to water depths of about 35 feet (Goodyear *et al.* 1982). During these high population years, major die-offs of alewife occurred in the spring after spawning and caused significant refuse problems along the shoreline.

The abundant and seemingly uncontrollable alewife was the impetus for introducing Pacific salmon into the lake to provide a put-grow-and-take fishery. Coho and chinook salmon stockings were initiated in the late 1960s in parts of the lake, although Indiana did not begin stocking until the mid-1970s (IDNR 1979b). Other nonindigenous salmon and trout were also stocked, particularly rainbow (steelhead) trout. Since that time, alewife populations generally declined. Although spring die-offs continued to occur, they were not the major problem they were in the late 1960s. In the late 1980s, alewife actually declined so significantly that there was a scarcity of food for the salmon, since alewife remained the major component of their diet, despite a concomitant increase in native species as the alewife declined (USFWS 1995). In 1995 and 1996, however, there were significant post-spawning die-offs along the Indiana shoreline, indicating that the population is currently increasing (Francis pers. comm.).

Steelhead were first introduced into the Lake Michigan drainage in 1880 when fry were planted in several Michigan rivers (Goodyear *et al.* 1982). By 1920, they were present throughout most of the lake. Their numbers became greatly diminished in the 1950s at the same time, and probably for the same reasons, as the native lake trout. Steelhead stocking has increased throughout the Lake Michigan basin since the 1960s and 1970s, and they are now locally abundant throughout the lake.

In Indiana waters near Indiana Harbor, chinook salmon were initially stocked at Jeorse Park. At the present time, no fish are stocked at Jeorse Park, but chinook are stocked at Whiting Park to the west of Indiana Harbor (Francis pers. comm.). Coho salmon and steelhead trout are stocked only in tributary streams, of which none are in the vicinity of Indiana Harbor.

Salmon and trout return to the nearshore area as adults during the fall breeding season. Steelhead spawning runs usually begin in August. Chinook generally come closer to shore beginning in September, while lake trout

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develop a spawning run along the shoreline between mid-October and mid-November (IDNR 1979b). There is no evidence of successful spawning in the area. Because these salmonids are present in Lake Michigan within the entire East Chicago/Whiting/Hammond/Gary area, there is significant boat fishing in the vicinity during the spring and fall periods of colder nearshore water temperatures.

Chinook populations were seriously affected in 1988 and 1989 due to bacterial kidney disease (BKD), but at the present time they are making a strong comeback (Francis pers. comm.). An abundant alewife population is providing ample food for the chinook, so surviving fish are healthy and not as susceptible to the BKD.

In pre-settlement Lake Michigan, nearshore fish communities were generally considered more diverse and productive than the offshore communities due to warmer temperatures and higher nutrient levels (USFWS 1995). Important nearshore fish species included lake sturgeon, lake whitefish, suckers, and yellow perch. Lake sturgeon are not present in the Indiana Harbor area, but the other species remain (Table 18). Lake whitefish and suckers are caught in Indiana waters, but they do not have the sport and commercial importance of yellow perch.

Historically, lake whitefish spawned in tributaries and near river mouths, with the adults beginning to concentrate in the shallow areas in October (Goodyear *et al.* 1982). Spawning occurred in late November and December, with the Wisconsin and Michigan shorelines being the major spawning sites. There was 1 spawning area in Indiana, however, at "South Chicago", which was approximately at the present location of Whiting. More recently, spawning has occurred offshore Michigan City, some 30 miles east.

Yellow perch are 1 of the most popular sport fish in Lake Michigan, possibly because they can easily be caught from shore. Their population has fluctuated through the years, with substantial declines in the 1960s (USFWS 1995). However, there were excellent populations in the 1980s.

The south shore of Lake Michigan is 1 of the major spawning areas for yellow perch. They probably spawn along the entire Indiana shoreline during late May and early June, but areas of concentration exist, particularly just west of Michigan City (Goodyear *et al.* 1982). In the 1970s, they were known to spawn off Indiana Harbor in the area now occupied by the Inland Steel lakefill.

The native yellow perch fishery is currently declining from unknown causes, with poor larval survival beginning in 1990 (USFWS 1995). It is possible that predation on the eggs and larvae by the increasing alewife population is at least part of the cause. Yellow perch are found throughout the East Chicago area during the summer, particularly along various breakwalls and breakwaters. They are therefore available to both boat and shoreline fishermen. They are also sought by Indiana's 13 commercial fishermen (Francis pers. comm.).

In early 1995, the 4 states that border Lake Michigan took joint action to reduce perch harvest by lowering commercial catch quotas, reducing sport catch limits, and closing all perch fishing in June. Although these efforts successfully reduced lakewide perch harvest by 50 percent, perch abundance continues to drop (Francis pers. comm.). Research in 1995 revealed that the perch population in Indiana declined 67 percent from 1994 to 1995. Therefore, the 25-fish daily catch limit remains in effect.

Rainbow smelt eggs planted in Crystal Lake, Michigan, in 1912 are believed to be the source of this species within all the Great Lakes except Lake Ontario (Goodyear *et al.* 1982). By 1936, smelt were dispersed throughout Lake Michigan. They generally migrate from deeper water to inshore areas and then into tributary streams about the time of ice breakup, and it is during these early spring runs that they are sought by fishermen. In Indiana, smelt spawn along the entire shoreline and in tributaries, with peak spawning activity in mid-April. Almost the entire Indiana beach zone is a nursery area. Most adults move offshore in June or July.

Other species known to spawn in Lake Michigan in the general vicinity of Indiana Harbor include gizzard shad, carp, emerald shiner, spottail shiner, trout-perch, johnny darter, and various sculpin (Goodyear *et al.* 1982). Other species listed as present in the GCR/IHC system are more likely to reproduce in the streams or are both in the lake and the streams.

The Indiana Department of Natural Resources regularly conducts creel surveys of Lake Michigan fishermen in order to determine how much fishing pressure is being exerted and what species are being caught. Information for the years 1993 through 1995 indicates that most fishing is done from boats, with boat fishermen expending about 64 percent of the total angler hours (total effort) and catching about 91 percent of the total harvest (Francis 1994, 1995, 1996). Yellow perch, coho, lake trout, steelhead, chinook, and brown trout are the major species caught. In 1993, an estimated 148,472 yellow perch were caught by sport fishermen, with 92 percent of that being by boat fishermen. This was down from a record 277,829 yellow perch caught in 1991, but it was considerably higher than the 67,831 caught in 1994 and 69,770 caught in 1995. These major drops of course reflect the declines in yellow perch reproduction. Throughout the 3 year period the largest yellow perch harvests were in the vicinity of the 2 western harbors, Hammond and East Chicago, which includes the Indiana Harbor area.

Fishing access is available at a number of locations near Indiana Harbor. To the west, both boat launch ramps and fishing piers are available at the Hammond Marina and Whiting Park, while to the east there are similar facilities at the Pastrick Marina in East Chicago. Three utilities in the vicinity of Indiana Harbor also allow public fishing access to lake Michigan at their facilities. To the west these are the Stateline Generating Station and Hammond Water Filtration Plant, while to the east there is the Dean Mitchell Generating Station.

While the number of yellow perch caught has been declining, the number of lake trout caught has been steadily increasing (Francis 1994, 1995, 1996). An estimated 11,970 lake trout were caught in 1993, 16,456 in 1994, and 25,350 in 1995. Coho have remained the dominant salmonid caught, and chinook and brown trout harvests have remained small. Chinook were up in 1994 and 1995, however, in comparison with the record low caught in 1993. All 3 years were very low in comparison with the record high year of 1982. These record lows, of course, were due to BKD decimating the chinook population in the late 1980s and early 1990s.

Because of the reduced numbers of yellow perch and chinook available to catch, total fishing effort (hours) by Indiana anglers in Lake Michigan declined almost 200,000 hours between 1987 and 1995 (594,317 hours in 1987 to 416,586 hours in 1995) (Francis 1996). Therefore, the value of the fishery to the State and local economy has also declined. For example, the number of trout and salmon stamps sold dropped from a high of 61,214 in 1984 to 37,693 in 1992, with 42,297 in 1995 (IDNR unpublished data). According to the most recent survey of fishing, hunting and wildlife-associated recreation in Indiana (1991 data), anglers spent 572,600 days fishing in Lake Michigan, at a value of $31 per day, for a total value of $17,750,600.00 (USFWS and Bureau of Census 1993).

The Great Lakes food web is contaminated by a variety of bioaccumulative toxic substances, causing unacceptable levels in some fish and wildlife. For example, PCB levels in Lake Michigan lake trout did not decline between 1986 and 1992, and PCBs in Lake Michigan coho salmon actually increased between 1984 and 1994 (USEPA 1996). The constant or increasing levels of PCBs have occurred despite declines in PCB levels in Lake Michigan water. Therefore, for a number of years Indiana has continued to issue public health advisories regarding the consumption of Lake Michigan fish. Advisories especially apply to vulnerable consumers, such as children, women of child-bearing age, and frequent consumers, such as sport and subsistence fishermen. Indiana currently is using the risk-based criteria recommended by the Great Lakes Sport Fish Advisory Task Force as the "Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory", which was proposed in 1993. This protocol is based upon health concerns, such as reproductive, neurological, immunological, and cancer effects, of various bioaccumulative chemicals.

Great Lakes fish of different species and sizes carry different burdens of potential carcinogens. Fish that bear the largest burdens tend to be large, bottom-dwelling, high in the food web, and high in fat content. Therefore, the consumption advisory varies by species and size of fish. The current advisory concerns PCBs and mercury, although mercury is considered a problem only for carp and longnose sucker, which are not popular sport or food fish (ISDH 1996). For PCBs, the advisory is based on a Health Protection Value of 0.05 ppm for unrestricted consumption, with no consumption advised for concentrations >1.9 ppm (National Wildlife Federation 1996). Indiana recommends that any size of carp and catfish and the largest (≥27 inches) brown trout and lake trout not be eaten at all. For smaller sized brown trout and lake trout, plus any sized steelhead, coho salmon, and chinook salmon, the consumption advisory varies by species and size and their body burdens of PCBs. The smaller fish generally have contamination levels of from 0.21 to

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1.0 ppm and a recommendation of 1 meal per month, while larger fish have PCB levels of 1.1 to 1.9 ppm and a recommendation of 1 meal every 2 months.

GCR/IHC

The fishery within the GCR/IHC has improved in recent years, although it continues to remain poor. In September 1980, the Indiana State Board of Health found 5 very small carp in Indiana harbor. The fish were in very poor condition and had no fins (Greenwood *et al.* 1984). In November 1980, USEPA collected 1 larger carp near the inner end of the canal entrance channel. Some alewife and a trout were observed in very poor condition in the same area, but no other individuals of any species were seen or were rolled by electrofishing equipment.

Between 1985 and 1988, 43 fish collections were made in the GCR/IHC system in order to determine the index of biotic integrity (IBI), a measure of fish community health (Simon *et al.* 1988). A total of 21 fish species were collected during these studies, with the largest number occurring within the IHC (14 species) (see Table 18). Based upon the IBI, the EBGCR and IHC showed the most dramatic improvements in water and habitat quality during those years. The WBGCR showed a significant reduction in water quality with the lowering of Lake Michigan water levels in 1987-88, and no fish were collected in that reach during those years.

A follow-up study to determine the IBI rating of the WBGCR was conducted in 1992 (Simon 1992). Seven stations were sampled between Indianapolis Boulevard in East Chicago and the junction of the river with the Calumet River in Illinois. The best habitat was at the east side of Indianapolis Boulevard because of instream vegetation, and 10 species of fish were collected here, with a "poor" IBI rating. Continuing west, septic conditions prevailed and fish species declined, with no fish found at Hohman Avenue near the State line. The last 6 stations had "very poor" IBI ratings.

USFWS fish sampling in the EBGCR in 1994 revealed 10 species of fish at 5 locations (Sobiech *et al.* 1994). Golden shiner were the most abundant, and bluntnose minnow was the only species taken at all 5 locations. The most upstream station had only 2 species and 3 individuals, and species diversity and fish numbers increased in a downstream direction. However, low numbers of individuals and low fish species diversity were observed throughout. The IBI ratings at all 5 locations was "very poor".

Wildlife

Wildlife resources in the vicinity of the IHC and Indiana Harbor are limited to the few remaining pockets of undeveloped or recently cleared lands within the vast urban-industrial complex of East Chicago, Hammond, Whiting, and Gary. The lands that are not heavily industrialized are largely characterized by commercial and residential developments. Although there are lawns, shade trees, and parks within the area, the value of these areas to wildlife is limited because of the lack of suitable cover and other habitat. The best remaining areas for wildlife are along undeveloped reaches of the GCR, including natural areas and nature preserves, abandoned industrial lands that are reverting to grassed or scrub-shrub habitats, isolated railroad rights-of-way, and the Migrant Trap along the Lake Michigan shoreline northwest of the Hammond Marina.

There is a large area of wildlife habitat along the Lake George Branch of the IHC in Hammond, west of the Federal project limits. Much of this land is natural wetlands, while other lands are abandoned industrial areas with wetlands intermixed with slag piles and other industrial waste. This area is shown on the National Wetlands Inventory (NWI) map as a complex of palustrine open water, forested, and emergent wetlands types, with water regimes varying from seasonal to permanent (Figure 11). These wetlands are remnants of the Lake George/Wolf Lake complex, which covered a large portion of the northern Hammond/Whiting/East Chicago area prior to settlement. Therefore, this area was historically deep wetlands or dune and swale habitat (see Figure 1).

The actual extent of wetlands at this time is different than that shown on the NWI, because changes have occurred since the map was drawn in 1984, based upon 1980 aerial photographs. For example, wetland vegetation and hydrology have developed on non-soils composed of cinders, slag, and similar materials. This is particularly true on the Mobil Oil property north of 141st Street and east of the Indiana Toll Road, a site once considered a possible location for the CDF for the Indiana Harbor dredgings (Site 14b) (USCOE 1986). This site is now protected under Indiana Department of Natural Resources' (IDNR) Classified Wildlife Habitat program.

Regardless of the origin of these wetlands at the western end of the Lake George Branch, the area provides habitat for a large variety of wildlife, particularly birds. Biologists from this office have observed mute swan, mallard, blue-winged teal, wood duck, red-tailed hawk, kestrel, great blue heron, green-backed heron, black-crowned night heron, sort rail, American coot, pied-billed grebe, woodcock, ring-billed gull, lesser yellowlegs, killdeer, other shorebirds, kingfisher, yellow warbler, yellowthroat, other warblers, tree swallow, Northern oriole, mourning dove, marsh wren, rufus-sided towhee, gray catbird, goldfinch, song sparrow, red-winged blackbird, grackle, cardinal, robin, and willow flycatcher on the Mobil Oil property (McCloskey pers. obs.).

Among these species, blue-winged teal, mallard, woodcock, killdeer, red-winged blackbird, tree swallow, yellowthroat, and marsh wren were specifically observed nesting, although the other songbirds were likely nesters as well. Numerous adult black-crowned night herons were observed in breeding plumage in a scrub-shrub wetland along the Mobil Oil/AMOCO property line south of the Lake George Branch, but nesting could not be confirmed (McCloskey pers. obs., Bower pers. obs.).

Brock (1986) calls this 141st Street site the "Hammond Cinder Flats": "If water is present during shorebird migration this site can be quite productive. ... During late summer and fall Black-bellied Plovers and peeps are regular;

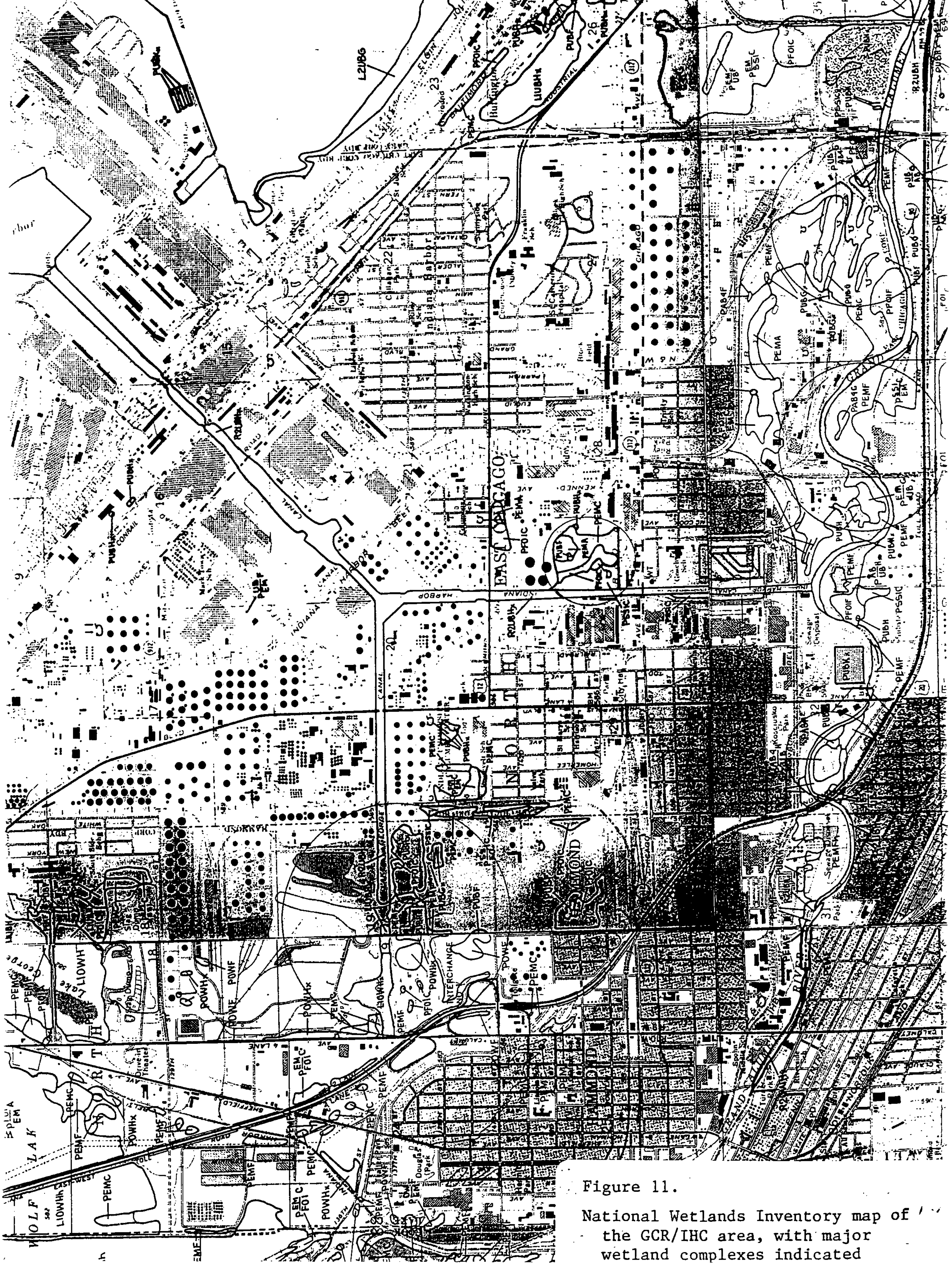

Figure 11.

National Wetlands Inventory map of the GCR/IHC area, with major wetland complexes indicated unusual shorebirds from this location include American Avocet, Hudsonian Godwit, and Western Sandpiper."

There also are wetlands along the GCR both east and west of the junction with the IHC. To the east are significant cattail marshes, which border the river in varying widths for about 6 miles. Landward of these marshes in several areas, the globally significant low dune and swale habitat still remains. It consists of an alternating series of low, linear beach ridges and inter-ridge swales/wetlands. This belt of low, linear ridges and intervening swales is unique to this area, being found no where else on earth except between the Tolleston Beach Ridge and modern Lake Michigan in northwest Lake County, Indiana (Bacone 1979). The dunes support either sand prairies or black oak savannas, and the swales are marshes or buttonbush swamps.

The largest tracts of this habitat type exist along both banks of the river between Kennedy and Cline Avenues. The north bank, consisting of about 300 acres of marshes, sand prairie, and black oak savanna, is owned by DuPont Chemical Company and is to be managed as a natural area under agreement with The Nature Conservancy (Labus pers. comm.). The south bank is partially owned by the Shirley Heinze Environmental Fund, Inc. as a nature preserve, while the remainder is in private ownership and remains unprotected. This site also consists of extensive cattail marshes along the river and inland dune and swale supporting numerous native species.

A second significant expanse of natural habitat exists along the EBGCR east of Industrial Highway at the west end of the US Steel complex in Gary. Here, 260 acres along both banks of the river are owned by the Indiana Department of Natural Resources and managed as Clarke and Pine East Nature Preserve. This area is dune and swale and cattail marsh habitat, with 2 abandoned sand mine pits/ponds. A colony of bank swallows has been known to nest in the high sandy bank of the pond adjacent to the river, and numerous other species have been reported as nesters and migrants (McCloskey pers. obs.).

A third marsh and dune and swale remnant exists along the north bank of the EBGCR between Kennedy Avenue and the IHC. This approximate 80 acre site contains an abandoned USS Lead Refining plant on about 20 acres, which is currently undergoing remediation under an agreement with USEPA. Part of the remediation area is cattail marsh adjacent to the river while the majority is upland. The western portion of the property, which extends to the upper end of the IHC, is dune and swale habitat containing numerous native plant and animal species (Sabuco 1994).

Roxana Pond/Marsh is a natural wetland along the WBGCR at the crossing of the Indiana Toll Road. Although it has been polluted by sewage sludge from the nearby Hammond and East Chicago sewage treatment plants, it is considered a significant habitat for waterbirds and shorebirds (Brock 1986). Water levels in the pond/marsh fluctuate considerably since it is at the divide where water can flow east or west. Also, like the WBGCR in general, its water level rises and falls with the level of Lake Michigan (Simon *et al.* 1989). Low water levels expose extensive mudflats, which provide feeding habitat for migrant shorebirds, while high water levels eliminate this habitat but provide feeding areas for numerous herons and egrets.

According to Brock (1986), most of the regular shorebirds have been seen at Roxana, often in great numbers. An impressive list of rare visitors has also been recorded, including marbled godwit, Hudsonian godwit, American avocet, stilt sandpiper, long-billed dowitcher, and red-necked phalarope. State-endangered yellow-headed blackbirds likely have nested there at times, and regular nesters include mallard, blue-winged teal, American coot, common moorhen, marsh wren, and red-winged blackbird. This site is thought to support the region's largest population of the common moorhen.

The Migrant Trap, about 3 miles northwest of the LTV Steel lakefill at Indiana Harbor, is another significant bird habitat in the area (Brock 1986). This name was given to this 16 acre site on the Lake Michigan shoreline by local birders after they discovered that large number of migrants that accumulate there during spring and fall migrations. It is a narrow strip of cottonwoods and shrubs among piles of old fill. The lake, surrounding industries, and the adjacent Hammond Marina completely isolate this scrubby grove, making it the only cover in the area. Its location at the south end of the lake makes it particularly valuable for neotropical migrants, which stage here either before or after long flights along or over the lake. The Migrant Trap is almost certainly the best single location along southern Lake Michigan for observing migrant passerines. It also attracts barn owls, short-eared owls, and other raptors. The main portion of this site is now protected through a conservation easement to the IDNR and is receiving enhancement plantings.

Whiting Park, also along the lakeshore, is about 1 mile east of the Migrant Trap. With its mowed lawns and large trees, it provides less cover for migrating birds, but still provides sufficient habitat to attract numerous species (Brock 1986). Whihala Beach County Park lies between the Hammond Water Filtration Plant and Whiting Park, but it is primarily dunes so there is sparce habitat for birds and other wildlife.

Despite the industrial lands along its banks, the IHC receives considerable use by wildlife, particularly waterfowl and waterbirds. Between the GCR and Columbus Drive, cattails, arrowhead, and other aquatic plants line the banks and provide habitat. Pockets of brushy habitat remain along the banks and provide habitat for songbirds as well. The largest block of habitat directly along the IHC is a palustrine emergent/scrub-shrub/forested wetland along the east bank between Chicago Avenue and Columbus Drive, as shown on the NWI map (see Figure 11).

The GCR/IHC is an important wintering area for lesser scaup in northwestern Indiana, especially after Lake Michigan freezes, because of the lack of other, more suitable habitat in the area. During winter several hundred lesser scaup, as well as smaller numbers of other species of diving ducks, are routinely seen on the canal (Simesko, Lake Dock Co., pers. comm.). Because the GCR/IHC does not freeze during winter, it offers valuable habitat for a species that otherwise would have to migrate much farther south (Root 1988).

The wintering lesser scaup population in the GCR/IHC is similar in size to other Great Lakes populations. The pre-1988 (prior to the zebra mussel invasion) maximum daily count for fall migrant lesser scaup off Point Pelee National Park, Ontario, Canada was 150 scaup (Wormington and Leach 1992). Wintering scaup on the Detroit River (January - March 1981) numbered <500 individuals on 12 of 16 census days (Noseworthy 1981). In 1980, a warmer winter with more open water, scaup numbers averaged 1345/day (Noseworthy 1981). Numbers of wintering lesser scaup in other parts of the Great Lakes are increasing due to the zebra mussel invasion (Wormington and Leach 1992).

In 1994, biologists from the USFWS and National Biological Service (NBS) investigated the feeding and movement patterns of wintering lesser scaup to better understand the ecological importance of the area, to help interpret contaminant levels in lesser scaup collected in the GCR/IHC during the winter of 1993-1994 (Custer, *et al.* in prep), and to aid in assessment and cleanup activities. The objectives were to determine if lesser scaup in the GCR/IHC were winter residents or a series of migrants, what proportion of their time was spent in the GCR/IHC if they were resident, and whether they fed in the GCR/IHC (Custer *et al.* 1996, Custer *et al.* in press).

The study area encompassed IHC and the GCR from Gary, Indiana to the Illinois border. A swim-in corral trap was erected in the IHC north of Columbus Drive and pre-baited with corn beginning on 17 December 1993. The first lesser scaup was caught on January 5, 1994.

Radio transmitters were implanted in 20 individuals in January 1994. Four lesser scaup disappeared and 4 died within the first 2 weeks after implantation; 12 lesser scaup remained in the GCR/IHC for the next 6-7 weeks and were tracked until early March 1994.

The biologists searched for radio-marked lesser scaup along the GCR/IHC 3 to 7 times per week during the next 6 weeks (10 January - 18 February) and twice during the seventh week. There were also 2 helicopter flights (26 January and 17 February 1994) along the Lake Michigan shoreline from Gary, Indiana, to Calumet Harbor, Illinois; along the GCR from its mouth to near its junction with the Calumet River in Illinois; around Indiana Harbor; and along the IHC.

Lesser scaup did not move into the canal until ice formed on the lake (Sparks pers. obs.). Ducks remained in the GCR/IHC until the end of February, when their numbers began to decline; few scaup were in the study area by mid-March. Lesser scaup numbers did not fluctuate greatly through the winter. Mean lesser scaup numbers for weeks 2, 3, and 6 of the study were 244 ± 42, 189 ± 17, and 184 ± 32 birds (Custer *et al.* 1996).

A total of 171 fixes on the remaining 12 male lesser scaup were obtained during the 7 week study period. All 12 birds stayed near the trap site during the first week after release. Six birds remained within 1500 m of the trap site throughout the study. Two birds remained near the trap site for the first 4 weeks and then moved 2600 m south to the confluence of IHC and GCR and remained there for 2 weeks. Three lesser scaup moved to the confluence of the

IHC and GCR during week 3 and remained there until the study ended. One lesser scaup moved out to Indiana Harbor, sometime during the first week, and probably remained there throughout the study. This bird was detected only on 45 percent of the searches because of the greater distance between the observation points and locations within Indiana Harbor. In addition, the estimates of lesser scaup numbers wintering in the IHC may also be underestimates because observations of Indiana Harbor proper were limited. No radio-marked lesser scaup were located outside the GCR/IHC (Custer *et al.* 1996).

The radio tracking indicated that most lesser scaup were resident on the GCR/IHC during winter and not a series of migrants. Four of 20 (20 percent) lesser scaup disappeared during the first week. These birds could have been migrants. Lesser scaup probably were present on the GCR/IHC more than indicated by the 62 percent of searches in which they were detected there; lesser scaup were likely present on the GCR/IHC at all times. This is supported by the failure to find radio-marked lesser scaup outside the GCR/IHC during the 2 helicopter flights and by the lack of any other available open water habitat in the immediate area (Custer *et al.* 1996).

Twenty-three percent (38 of 164 detections) of radio-marked lesser scaup were feeding when they were located for position fixes. Six radio marked lesser scaup remained at the trap site for the entire winter, while 5 other lesser scaup utilized the trap site for the first 2 to 4 weeks of the study. Oligochaete worms (*Limnodrilus spp.*) were the dominant food of lesser scaup in the IHC (Custer unpublished data). The degree of sediment ingestion also appeared to be significant. High densities of oligochaetes in the vicinity of the trap site (>400,000/m^2 compared to <6000/m^2 in other parts of the IHC) (Ingersoll *et al.* 1993) probably accounted for this choice of wintering sites within the canal. Few other invertebrate prey were available at the trap site or at other locations in the IHC during sampling in 1989 (Ingersoll *et al.* 1993).

The radio telemetry was used to collect 198 hours of 24-hour feeding behavior of 5 lesser scaup during January and February 1994. The birds fed for short periods of time intermittently during each 24-hour period. They fed a total of 1 hour 36 minutes during the day and 3 hours 46 minutes during the night. Mean dive duration (22.9 ± 0.64 sec) did not vary by time of day. Lesser scaup fed for short periods of time followed by longer non-feeding periods. The average length of a feeding bout was 11.1 min (Custer *et al.* in press).

Duration of feeding cycles may be a function of the type of prey consumed and the time needed to handle, process, and digest it. Oligochaetes are easy to capture, are very soft, and should be processed through the digestive system more quickly than other more traditional lesser scaup food such as molluscs and arthropods (Custer and Custer 1996).

General feeding patterns of lesser scaup were observed for several hours. It was found that lesser scaup fed while diving in 1 area or while slowly swimming, they dived and surfaced in a consistent pattern of underwater and surface times, and did not interrupt feeding with preening, bathing, resting, species are only occasional migrants through the area, including osprey, short-eared owl, and sedge wren.

Several State Species of Concern are present along the GCR as residents or migrants, including least bittern, marsh wren, sharp-shinned hawk, red-shouldered hawk, and brown creeper. The bittern and wren are known to nest in the cattail marshes along the river as well as at Roxana Pond and the various natural areas/nature preserves.

Table 19 lists the bird species that have been observed in and around the GCR/IHC, Indiana Harbor, and adjacent Lake Michigan. Many of these observations were made by Peregrine Watchers and were recorded in the Peregrine Falcon Journal (1990 through 1995). Observations at Roxana Pond, along the EBGCR, including Clarke and Pine East Nature Preserve, and at the Mobil Oil property along the Lake George Branch are included. Observations at the Migrant Trap, Whiting Park, Wolf Lake/Lake George, and Tolleston Ridges and Gibson Woods Nature Preserves (located south of the Toll Road in Hammond) are not included.

There have been only incidental observations of amphibians, reptiles, and mammals along or near the GCR/IHC system. Snapping turtles (*Chelydra serpentina*) and midland painted turtles (*Chrysemys picta marginata*) have been seen, both along the EBGCR and at the Mobil Oil property (Sobiech *et al.* 1994, McCloskey pers. obs.). Numerous amphibian and reptile species have been reported at the various remaining dune and swale habitats that are found along the EBGCR, including tiger salamander (*Ambystoma tigrinum tigrinum*), American toad (*Bufo americanus americanus*), Fowler's toad (*Bufo woodhousei fowleri*), Western chorus frog (*Pseudacris triseriata triseriata*), Blanding's turtle (*Emydoidea blandingii*), Eastern box turtle (*Terrapene carolina carolina*), six-lined racerunner (*Cnemidophorus sexlineatus sexlineatus)*, Chicago garter snake (*Thamnophis sirtalis semifasciata*), plains garter snake (*Thamnophis radix radix*), black rat snake (*Elaphe obsoleta obsoleta*), Eastern hognose snake (*Heterodon platirhinos*) (Bacone 1979, Sabuco 1994, McCloskey pers. obs.).

Among these amphibian and reptile species known from the general area, the Blanding's turtle is an Indiana Species of Special Concern. It is also a Federal Species of Concern (former Candidate Category 2) being investigated for possible listing as an endangered or threatened species under the Endangered Species Act.

Mammals known to occur within the Hammond/East Chicago/Gary urban area include white-tailed deer (*Odocoileus virginianus*), coyote (*Canis latrans*), Grey fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), mink (*Mustela vison*), raccoon (*Procyon lotor*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), opossum (*Didelphis virginiana*), gray squirrel (*Sciurus carolinensis*), Franklin's ground squirrel (*Spermophilus franklinii*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), Eastern cottontail (*Sylvilagus floridanus*), chipmunk (*Tamias striatus*), woodchuck (*Marmota monax*), big brown bat (*Eptesicus fuscus*), red bat (*Lasiurus borealis*), and a variety of mice and voles (McCloskey personal observations, Sparks personal

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Table 19. Bird Species Known From the Indiana Harbor, Indiana Harbor Ship Canal, Lake George Branch, and Grand Calumet River Area, including the ECI Site. This includes migrants, wintering species, and nesting species.

Double-crested cormorant	*Phalacrocorax auritus*
Horned grebe	*Podiceps auritus*
Pied-billed grebe	*Podilymbus podiceps*
White pelican	*Pelecanus erythrorhynchos*
Mute swan	*Cygnus olor*
Canada goose	*Branta canadensis*
*Mallard	*Anas platyrhynchos*
*Blue-winged teal	*A. discors*
Redhead	*Aythya americana*
Canvasback	*A. valisineria*
Greater scaup	*A. marila*
Lesser scaup	*A. affinis*
Ring-necked duck	*A. collaris*
Bufflehead	*Bucephala albeola*
Common goldeneye	*B. clangula*
White-winged scoter	*Melanitta deglandi*
Oldsquaw	*Clangula hyemalis*
Common merganser	*Mergus merganser*
Red-breasted merganser	*M. serrator*
Hooded merganser	*Lophodytes cucullatus*
Short-eared owl	*Asio flammeus*
Turkey vulture	*Cathartes aura*
Osprey	*Pandion haliaetus*
Sharp-shinned hawk	*Accipiter striatus*
*Red-tailed hawk	*Buteo jamaicensis*
Red-shouldered hawk	*B. lineatus*
Rough-legged hawk	*B. lagopus*
Broad-winged hawk	*B. platypterus*
*Peregrine falcon	*Falco peregrinus*
*Kestrel	*F. sparverius*
*Ring-necked pheasant	*Phasianus colchicus*

Common egret	*Casmerodius albus*
Great blue heron	*Ardea herodias*
*Green-backed heron	*Butorides virescens*
Little blue heron	*Florida caerulea*
*Black-crowned night heron	*Nycticorax nycticorax*
*Least bittern	*Ixobrychus exilis*
*American coot	*Fulica americana*
*Common moorhen	*Gallinula chloropus*
Sora	*Porzana carolina*
Black-bellied plover	*Pluvialis squatarola*
*Killdeer	*Charadrius vociferus*
Semipalmated plover	*C. semipalmatus*
Solitary sandpiper	*Tringa solitaria*
Greater yellowlegs	*T. melanoleuca*
Lesser yellowlegs	*T. flavipes*
American avocet	*Recurvirostra americana*
Spotted sandpiper	*Actitis macularia*
Hudsonian godwit	*Limosa haemastica*
Marbled godwit	*L. fedoa*
Western sandpiper	*Calidris mauri*
Least sandpiper	*C. minutilla*
White-rumped sandpiper	*C. fuscicollis*
Pectoral sandpiper	*C. melaanotos*
Dunlin	*C. alpina*
Stilt sandpiper	*C. himantopus*
Short-billed dowitcher	*Limnodromus griseus*
Long-billed dowitcher	*L. scolopaceus*
Common snipe	*Gallinago gallinago*
*American woodcock	*Scolopax minor*
Wilson's phalarope	*Phalaropus tricolor*
Red-necked phalarope	*P. lobatus*
*Ring-billed gull	*Larus delawarensis*
*Herring gull	*L. argentatus*

Caspian tern	*Hydroprogne caspia*
*Black tern	*Chlidonias niger*
*Rock dove	*Columba livia*
*Mourning dove	*Zenaidura macroura*
*Nighthawk	*Chordeiles minor*
Whip-poor-will	*Caprimulgus vociferus*
*Chimney swift	*Chaetura pelagica*
*Belted kingfisher	*Megaceryle alcyon*
*Flicker	*Colaptes auratus*
Red-headed woodpecker	*Malanerpes erythrocephalus*
*Eastern kingbird	*Tyrannus tyrannus*
*Willow flycatcher	*Empidonax traillii*
*Barn swallow	*Hirundo rustica*
*Tree swallow	*Iridoprocne bicolor*
*Bank swallow	*Riparia riparia*
Rough-winged swallow	*Stelgidopterix serripennis*
*Blue jay	*Cyanocitta cristata*
*Crow	*Corvus brachyrhynchos*
*Black-capped chickadee	*Parus atricapillus*
*Tufted titmouse	*P. bicolor*
Red-breasted nuthatch	*Sitta canadensis*
Brown creeper	*Certhia familiaris*
*Marsh wren	*Cistothorus palustris*
*House wren	*Trogolodytes aedon*
*Brown thrasher	*Toxostoma rufum*
*Catbird	*Dumetella carolinensis*
Mockingbird	*Mimus polyglottos*
*Robin	*Turdus migratorius*
Eastern bluebird	*Sialia sialis*
Hermit thrush	*Hylocichla guttata*
Swainson's thrush	*H. ustulata*
Golden-crowned kinglet	*Regulus satropa*
Ruby-crowned kinglet	*R. calendula*

*Yellow warbler	*Dendroica petechia*
Black-throated green warbler	*D. virens*
Yellow-rumped warbler	*D. coronata*
*Yellowthroat	*Geothlypis trichas*
*Warbling vireo	*Vireo gilvus*
White-eyed vireo	*V. griseus*
*Red-eyed vireo	*V. olivaceua*
*Starling	*Sturnus vulgaris*
*House sparrow	*Passer domesticus*
*Eastern meadowlark	*Sturnella magna*
*Red-winged blackbird	*Agelaius phoeniceus*
*Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
*Grackle	*Quiscalus quiscula*
*Brown-headed cowbird	*Molothrus ater*
*Northern oriole	*Icterus galbula*
*Indigo bunting	*Passerina cyanea*
*House finch	*Carpodacus mexicanus*
*Cardinal	*Richmondena cardinalis*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
*American goldfinch	*Spinus tristis*
*Rufous-sided towhee	*Pipilo erythrophthalmus*
Junco	*Junco hyemalis*
*Field sparrow	*Spizella pusilla*
Chipping sparrow	*S. passerina*
White-throated sparrow	*Zonotrichia albicollis*
*Song sparrow	*Melospiza melodia*
*Swamp sparrow	*M. georgiana*

*Known to nest

Based on sightings reported in the Peregrine Falcon Journal (1990-1995), personal observations by USFWS biologists, Brock (1986), and Sabuco (1994).

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observations, Bower personal observations). Beaver are even known from the lower IHC, where they cut down cottonwoods on LTV Steel property.

Of the species known in the GCR/IHC area, the Franklin's ground squirrel is State-threatened. This "prairie squirrel" inhabits prairies and savannas and similar areas, with railroad rights-of-way being common habitats (Mumford and Whitaker 1982, Johnson and Choromanski-Norris 1992). Junk piles and general debris among the tall grasses provide cover for their burrows. They are occasionally seen in the various nature preserves and along both active and abandoned railroads with this urban complex, and road-killed victims are sometimes found along city streets.

Endangered Species

The project area is within the range of the Federally endangered Peregrine falcon (*Falco peregrinus*), Karner blue butterfly (*Lycaedes melissa samuelis*), and Indiana bat (*Myotis sodalis*), and the threatened bald eagle (*Haliaeetus leucocephalus*). Peregrine falcons nest under the Cline Avenue bridge over the IHC. Possible impacts to these nesting birds has already been addressed through the Section 7 process of the Endangered Species Act, as amended, and a Biological Opinion was provided to the Corps on May 21, 1996. Since that time, a second falcon nest has been confirmed on the north end of the Inland Steel lakefill. Possible project impacts to these nesting birds has not yet been addressed.

Karner blue butterflies are known from several Nature Preserves near the EBGCR and may eventually be reintroduced to others, including several remaining dune and swale habitats directly along the river. However, this project will not affect these habitats or this endangered species.

There is no known suitable habitat for the Indiana bat along the IHC. Bald eagles are only incidental visitors to the south end of Lake Michigan, and are not likely to be found along the IHC.

It is also within the range of the following Species of Concern that are being considered for possible listing as threatened or endangered under the Endangered Species Act (Act): Black tern (*Chlidonias niger*), Blanding's turtle (*Emydoidea blandingii*), and Eastern massasauga rattlesnake (*Sistrutus catenatus catenatus*). Black terns nested along the GCR as recently as the late 1980s, utilizing relatively open cattail mudflats such as those found along the river, and Blanding's turtles are known from the various Nature Preserves near and along the GCR. Massasauga are historically known from area wetlands but there have been no recent confirmed sightings. The Act recognizes that candidate species should be conserved, even though formal consultation under Section 7 of the Act would not be required until the species are proposed for listing as threatened or endangered.

Toxicity Issues

Water

In 1986, the USEPA conducted a chronic toxicity investigation of several municipal and industrial effluent discharges into the GCR/IHC using standardized embryo-larval survival and teratogenicity screen tests (USEPA 1986, Simon 1988). At least some outfalls of LTV Steel, Inland Steel, and US Steel that were tested exhibited both acute and chronic toxicity, while DuPont and the 3 municipal treatment plants (Gary Sanitary District, Hammond Sanitary District, and East Chicago Sanitary District) exhibited only chronic teratogenic effects (Simon 1988). At the time of this toxicity study, Gary had 19 Industrial Users (IUs) making up 14 percent of its discharge, Hammond had 21 IUs making up 10 percent of its discharge, and East Chicago had 51 IUs making up 24 percent of its discharge (Brannon *et al.* 1986).

In addition to point source discharge concerns, storm water runoff and especially combined sewer overflow (CSO) discharges were thought to be significant. The USEPA (1983c) found 63 of 106 organic priority pollutants in urban stormwater runoff samples collected from around the country. However, PCBs were found in less than 1 percent of samples. Brannon *et al.* (1986) estimated that CSOs account for 11 billion gallons/year to the GCR/IHC system, which is a contribution of approximately 2.4 percent. CSOs are also estimated to contribute up to 56 x 10^6 lb/year of sediment loading to Lake Michigan.

IDEM (1994) reported on its 1993 whole effluent toxicity testing (WETT) of CSOs and storm water runoff in the GCR. Of the CSOs tested, 4 were toxic, 1 was slightly toxic, and 4 others were not toxic. Of the stormwater samples taken, 2 were toxic, 4 were slightly toxic, and 8 were non-toxic. Chemical analyses of the water samples taken revealed that, of the parameters measured, none were elevated. However, no organic pollutants (with the exception of oil and grease) were measured.

Sediments

In an effort to determine whether or not open water disposal of contaminated sediments pose a problem to aquatic life, Gannon and Beeton (1969) studied the effects of dredged materials from several Great Lakes Harbors on plankton and benthic invertebrates. Sediments from the IHC caused 50 to 100 percent toxicity in the amphipods *Pontoporeia affinis* and *Gammarus lacustris*. *Chironomus tentans* attempted to avoid contaminated sediments and exhibited 70 percent mortality in the first 24 hours, and 90 prcent mortality in the first 48 hours. These data are consistent with the complete lack of benthic organisms in 4 of 5 sediment samples collected in the IHC. Only in the sediment sample from the mouth of the harbor were any life forms noted, and this despite the sample having visible oil contamination.

In the mid-1960s, the Corps commissioned several investigations to determine toxicity and assess disposal alternatives for contaminated sediments from IHC (Environmental Laboratory 1987). These studies examined several things:

phyto-toxicity and plant contaminant uptake under flooded and non-flooded conditions, and toxicity to both terrestrial and aquatic species. These tests were deemed important because:

> dredged material placed in an upland or inlake CDF eventually may become a wildlife habitat and resting area for migratory birds. This situation has occurred in many CDFs around the Great Lakes, such as Times Beach, Buffalo New York where a prolific wildlife habitat has developed on contaminated dredged material (Environmental Laboratory 1987).

Yellow nutsedge took up significantly more metals in an upland condition, whereas simply drying the sediments accounted for a minor reduction in PAHs. To assess the potential terrestrial toxicity of IHC sediments, tests were designed utilizing earthworms. Several experimental (treatment) conditions were tried: ashing sediments in a muffle furnace for a day, drying in the sun for 7 days, drying in the sun for 21 days, drying in the sun for 21 days plus a manure amendment, and aging outdoors in shade for 6 months. For each condition, 28-day survival tests were then conducted. In all tests except the last treatment, earthworms exhibited avoidance followed by acute toxicity. The sediment that had aged for 6 months was the only treatment which had adequate 28-day survival (nearly 100 percent). There was no significant heavy metal residue change between beginning sediment concentrations and aged sediment, and only minor PCB losses during this 6-month time period. There was an order of magnitude reduction in PAHs during this 6 month aging period (3382 ppm to 388 ppm, respectively). The Corps (Environmental Laboratory 1987) concluded that naphthalene was implicated in the earlier earthworm toxicity tests. Earthworms contained 2.8 ppm PCBs and 131 ppm total PAHs (dry weight) after the 28-day test, bioaccumulating up to 50 percent of 7 individual PAHs. Additionally, they indicated that an upland CDF would need monitoring and management as it became biologically productive, due to this significant amount of bioaccumulation of contaminants.

Burton *et al.* (1989) conducted 48-hour sediment and elutriate toxicity tests on sediment from Waukegan and Indiana Harbors on *Hyallela azteca*, *Cerodubia daphnia*, and *Daphnia magna*. *Hyallela azteca* and *Cerodubia daphnia* exhibited significant mortality in the sediment toxicity tests, but only *Cerodubia daphnia* had any significant, albeit reduced, toxicity in the elutriate test. These findings are consistent with Hoke and Prater (1980) who found that bulk chemistries are better than elutriate tests for correlating with toxicity.

As part of EPA's ARCS program, Ingersoll *et al.* (1993) conducted 1 of the most comprehensive sediment toxicity assessments ever done in the Great Lakes and by far the best investigation ever done in the IHC. Elutriate samples were highly toxic to *Daphnia magna,* and most elutriates exceeded acute Ambient Water Quality Criteria (AWQC) for many parameters, including copper, cadmium, lead, mercury, and ammonia. Ten- and 14-day whole sediment toxicity tests for a host of test organisms had extremely poor survival: *Chironomus tentans* (0 to 46 percent survival), *Hyallela azteca* (0 to 1.3 percent survival), and *Chironomus riparius* (0 to 1.5 percent survival). Mouth part deformities were also documented in the Chronomid community in 2 out of 2 samples from Indiana Harbor.

Fish

The presence of contaminated sediment in the GCR/IHC has had 2 profound effects on the fishery inhabiting this area. Despite the potential for a high quality fishery due to the connection to Lake Michigan, it has been decimated in comparison to its historical diversity and abundance (Meek and Hildebrand 1908, Simon *et al.* 1988). For those pollution-tolerant cyprinids (e.g. minnows, carp and goldfish) that are found in the GCR/IHC system, many have shown various physiological and morphological ailments, including eroded fins, swollen eyes, deformed lower jaws, and evidence of internal hemorrhaging. It is likely that additional physiological ailments would be evident if it were not for the extripation of so many other fish species.

Brown bullheads from a variety of locations in North America have had elevated incidences of liver neoplasia associated with PAH-contaminated sediments from the Black, Buffalo, and Cuyahoga Rivers (Baumann *et al.* 1987, Baumann 1989, Baumann *et al.* 1991). Baumann and Harshbarger (1995) documented a significant reduction in the incidence of liver neoplasia in brown bullheads downstream of a coke-making facility that ceased operations. This further confirms the causal link between PAH-contamination and liver neoplasms in bullheads. Coke-making and petroleum refining and related industries are the major sources of PAHs in the GCR/IHC. Three species of bullhead catfish were historically present in the Calumet River system (Meek and Hildebrand 1910, Simon *et al.* 1988). It is very probable, given the high level of PAHs in the sediments of the GCR/IHC, that if bullhead catfish were reintroduced to the GCR/IHC, extremely high incidences of hepatic neoplasias would result.

Wildlife

PCBs

As previously discussed, the GCR/IHC has several areas of significant PCB sediment contamination (Table 9) (IDEM unpublished). As a result of this PCB sediment contamination, fish samples collected throughout the GCR/IHC also contained high levels of PCBs (Table 10, IDEM unpublished). Impacts to avian wildlife associated with PCBs, often discussed in terms of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxic equivalents (TEq) (see Safe 1987, Safe 1990, and USEPA 1994), has been well documented (Kubiak *et al.* 1989, Tillitt *et al.* 1992, Geisy *et al.* 1994, White and Seginak 1994, Hoffman *et al.* 1996, Henshel *et al.* submitted 1996). Research by Henshel *et al.* (submitted 1996) produced a No Observed Adverse Effect Level (NOAEL) for the chicken embryo of 100 pg/g, based on lethality. A value of 4 μg/g PCBs represents the NOAEL in bird eggs for lethality (Wiemeyer *et al.* 1984, Wiemeyer *et al.* 1988). In birds, additional impacts include aberrant behavior (Kubiak *et al.* 1989, Ulfstrand *et al.* 1971, Karlsson *et al.* 1974, Dahlgren and Linder 1971, Kreitzer and Heinz 1974), and acute toxicosis (Sileo *et al.* 1977, Stickel 1975).

Analysis of failed peregrine falcon eggs from Lake County, Indiana from 1990 through 1993 indicates they contained 4.3 to 11.17 ppm total PCBs (wet weight), with a mean concentration of 8.5 ppm (Table 20) (USFWS unpublished). Comparing other peregrine falcon egg data from Ohio, Minnesota, Michigan and Iowa from 1988 to 1995 (USFWS unpublished) to these results, only 3 were higher than the *average* concentrations for the Lake County falcon eggs. The PCB concentrations equated to an average TCDD TEqs of 43 ppt (Table 21). This calculated TCDD TEq does not quantify the dioxin or furan congeners present in these peregrine eggs. Based on these literature NOAELs, it is possible that peregrine falcon egg hatching success has been impaired due to PCBs in the IHC under existing conditions without the Corps dredging project.

Other PCB residue data (including TCDD TEQ data where available) for birds in the IHC area include herring gull eggs nesting on Indiana Harbor (Table 22, Canadian Wildlife Service, unpublished), great blue heron embryos from Indiana Dunes National Lakeshore (Table 22, USFWS unpublished), barn swallow embryos and barn swallow nestlings from selected bridges in the GCR/IHC watershed (Tables 23 and 24, USFWS unpublished), black-crowned night heron embryos and nestlings from Lake Calumet, Illinois (Table 25, USFWS unpublished), and lesser scaup carcasses from IHC (Tables 26 and 27, Custer, in prep). PCB uptake rates for the insectivorous barn swallows nesting in the GCR/IHC rival PCB uptake rates for the piscivorous black-crowned night herons from Lake Michigan's highly PCB-contaminated Green Bay (Custer, *et al.* in prep). All of these PCB residues were analyzed from what are thought to be viable wildlife samples, and do not necessarily reflect concentrations from co-located failed nests, when present.

Mink are 1 of the mammalian species most sensitive to PCBs (Platonow and Karsted 1973; Aulerich and Ringer 1977; Aulerich *et al.* 1985; Hornshaw *et al.* 1983; Ringer 1983; Foley 1991). Platonow and Karstad (1973) reported that the PCB Arochlor 1254 present at levels as low as 0.64 ppm caused almost 90 percent reproductive failure and 100 percent kit mortality; 1.0 ppm PCBs in the diet of adult mink can result in death. Congener specific PCB data have shown that hexachlorobiphenyls, when present at 0.1 ppm in the mink's diet, caused 50 percent mortality within 3 months and completely inhibited reproduction in any surviving mink (Aulerich *et al.* 1985). A more recent study established a PCB lowest observed adverse effect level (LOAEL) of 0.134 mg/kg mink body weight/day (Heaton *et al.* 1991). Placental transfer of PCBs increases embryotoxicity and increases deformities in kits (Ringer 1983, Heaton *et al.* 1991).

Biologically modified PCBs are more toxic to mink than corresponding technical mixtures, likely due to the more AHH-active congeners persistence being retained once they have been metabolized (Eisler 1986, Stickel 1975). Newell *et al.* (1987) gave a dietary protection level of less than 0.13 mg/kg total PCBs to protect mink from adverse impacts, or less than 0.0015 mg/kg body weight daily (Hornshaw *et al.* 1983). Kubiak and Best (1991) reported 0.069 ppm PCBs in the diet as a NOAEL for mink based upon reproductive success.

O'Shea et al. (1981) found that even in areas of Maryland with no recognized large-scale PCB pollution, exposure to these widespread contaminants may be sufficient to inhibit mink reproduction in wild populations. Kubiak and Best (1991) stated that in areas where fish and other prey contamination is high, mink populations have probably been significantly reduced, except where wandering immature individuals are trying to pioneer new territories (see also

Table 20. Total polychlorinated biphenyl (PCB) residues in failed peregrine falcon eggs from 2 Lake County, Indiana nests, 1990 to 1993 (parts per million, wet weight).

nest location	year	total PCBs
East Chicago, Indiana	1990	7.6
East Chicago, Indiana	1991	12.2
East Chicago, Indiana	1993	4.3
Gary, Indiana	1992	8.7
Gary, Indiana	1992	9.0
Gary, Indiana	1993	7.9
Gary, Indiana	1993	9.7
Gary, Indiana	1993	10.0

Table 21. Congener specific polychlorinated biphenyl (PCB) residues and calculated 2,3,7,8-TCDD TEqs in failed peregrine falcon eggs from a Des Moines, Iowa nest and 2 Lake County, Indiana nests, 1992, and 1993 (parts per million, wet weight).

	1993 Gary, IN	1993 Gary, IN	1993 Gary, IN	1993 E. Chi.	1992 Iowa	1992 Iowa	1992 Gary, IN	1992 Gary, IN
% Lipid	7.69	7.1	6.54	5.65	5.08	6.92	6.31	6.54
% Moisture	77	79	80	79.5	80	76.5	82	80
PCB# 77	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001
PCB# 114	0.0057	0.0061	0.0037	0.0054	0.0029	0.0036	0.007	0.0055
PCB# 105	0.041	0.048	0.024	0.039	0.028	0.035	0.039	0.029
PCB# 118/106	0.29	0.17	0.14	0.27	0.13	0.18	0.33	0.26
PCB# 126	0.0004	0.0004	0.0003	0.0005	0.0004	0.0004	0.0004	0.0004
PCB# 156	0.1	0.073	0.047	0.087	0.028	0.034	0.15	0.1
PCB# 169	0.0002	0.0002	0.0002	0.0002	<.0001	<.0001	0.0002	0.0002
PCB-TOTAL	9.7	10.0	7.9	4.3	1.5	2.7	8.7	9.0
2,3,7,8 TCDD TEqs (ppt)	37.0	69.57	26.09	39.06	23.2	21.8	46.99	39.89

Table 22. PCB concentrations in Herring Gull eggs from colonies on Indiana Harbor (East Chicago, IN), Lake Michigan (East Chicago, IN) and Green Bay, WI (Gull Island) and Great Blue Heron embryos from Indiana Dunes National Lakeshore (ug/g, wet weight).

HERRING GULL EGGS[1]	composite (n = 13)
1993 Indiana Harbor (East Chicago, IN)	15.87
1993 Lake Michigan (East Chicago, IN)	17.74
1994 Green Bay, WI (Gull Island)	16.24

GREAT BLUE HERON EMBRYOS[2]	mean (n = 10)	minimum	maximum
1993 Indiana Dunes National Lakeshore	10.37	0.80	56.0

[1] Canadian Wildlife Service, unpublished

[2] U.S. Fish and Wildlife Service, unpublished

Table 23. Organic pollutant concentrations in barn swallow embryos from a reference location and 4 sites on the Grand Calumet River/Indiana Harbor Canal.

	Geometric mean concentration (ug/g ww)/ (no of samples)				
	Lake Poygon, WI	Indianapolis Boulevard	Industrial Highway	151 st Street	Columbus Drive
DDE	0.14 A[1] (3)	0.30 A (3)	0.34 A (3)	0.36 A (2)	0.16 A (2)
Total PCBs	0.04 A (3)	2.37 B (3)	20.42 C (3)	1.55 (2)	1.90 B (2)
TCDD TEQs (ppt)[2]	0 (3)	216 (3)	639 (3)	251 (2)	139 (2)
Total aliphatic hydrocarbons	33.29 A (3)	24.69 A (3)	29.15 A (3)	47.24 A (2)	35.87 A (1)
Total aromatic hydrocarbons	0.044 A (3)	0.111 B (3)	0.082 B (3)	0.079 B (2)	0.085 B (1)

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[1] Means not sharing the same letter by location are significantly different (ANOVA, Bonferroni mean separation, alpha = 0.05)

[2] TEQs (ppt) after Kubiak 1991 as presented in Hoffman *et al.* 1996

Table 24. Organic pollutant concentrations in 13-day-old barn swallow chicks from a reference location and 4 sites on the Grand Calumet River/Indiana Harbor Canal.

	Geometric mean concentration ug/g wet weight/ (no of samples)									
	Lake Poygon, WI		Indianapolis Boulevard		Industrial Harbor		151 st Street		Columbus Drive	
DDE	0.027 (3)	A[1]	0.049 (3)	AB	0.083 (3)	B	0.071 (3)	AB	0.027 (3)	A[2]
Total PCBs	0.02 (3)	A	1.72 (3)	B	13.08 (3)	C	1.52 (3)	B	0.82 (3)	B
TCDD TEQs (ppt)[3]	0 (3)		139 (3)		500 (3)		124 (2)		80 (2)	
Total aliphatic hydrocarbons	13.69 (3)	A	16.51 (3)	AB	22.64 (3)	AB	23.48 (3)	AB	29.13 (3)	B[4]
Total aromatic hydrocarbons	0.048 (3)	A	0.152 (3)	B	0.079 (3)	AB	0.131 (3)	AB	0.144 (3)	AB[4]

[1] Means not sharing the same letter by location are significantly different (ANOVA, Bonferroni mean separation, alpha = 0.05)

[2] Mean separation shown for alpha = 0.15

[3] TEQs (ppt) after Kubiak 1991 as presented in Hoffman *et al.* 1996

[4] Mean separation shown for alpha = 0.10

Table 25. Predicted toxic equivalents in pipping black-crowned night-heron embryos and 10-d-old chicks collected from Lake Calumet, IL. Also included, for embryos only, are a reference (Chincoteague National Wildlife Refuge) and contaminanted site (Cat Island) (Custer et al. in prep.).

	Pipping embryos			10-d-old chicks
	Lake Calumet, IL	Chincoteague Nat. Wildl. Refuge, VA[a]	Cat Island, Green Bay, WI[a]	East Chicago, IL
Total PCBs (ug/g)[b]	4.67	1.12	9.32	1.74
n	9	6	18	9
PCB congener potencies based upon a broad range of toxic responses in mammals (Safe 1990)[c]	1,137 ± 199	212 ± 47	2,977 ± 517	300 ± 43

[a] Data from Rattner et al. 1993
[b] Values are geometric means
[c] Values are arithmatic means

Table 26. Geometric mean organochlorine concentrations (μg/g wet wt) of organochlorines, including individual PCB congeners in carcasses of male lesser scaup collected at Indiana Harbor, IN, winter 1993-94 and reference males (taken from Custer et al. in prep).

	Geometric mean concentration / (number detected above LOD)				Results of ANOVA	
Analyte	Reference immature males (n=5)	Jan 1994 immature males (n=6)	March 1994 immature males (n=5)	March 1994 adult males (n=6)	F	P
cis-nonachlor	---[a] (0)	0.013 (5)	--- (1)	--- (2)		
dieldrin	0.007 A[b] (1)	0.079 C (6)	0.019 AB (4)	0.034 BC (6)	11.1	0.0002
hexachlorobenzene	--- (0)	--- (2)	0.009 (3)	0.011 (4)		
heptachlor epoxide	0.005 A (0)	0.036 B (6)	0.018 B (4)	0.025 B (6)	9.9	0.0005
oxychlordane	0.005 A (0)	0.013 AB (5)	0.015 AB (4)	0.018 B (5)	4.4	0.0179
p,p'-DDD	--- (0)	0.011 (5)	--- (1)	--- (1)		
p,p'-DDE	0.007 A (1)	0.146 B (6)	0.195 B (5)	0.172 B (6)	14.3	0.0001
p,p'-DDT	--- (0)	0.018 (4)	--- (2)	0.010 (3)		
total PCBs	0.040 A (1)	1.275 B (6)	3.145 B (5)	4.887 B (6)	23.6	0.0001
trans-nonachlor	0.005 A (0)	0.020 B (5)	0.008 AB (2)	0.013 AB (4)	4.4	0.0167

[a] Dashed lines indicate that a mean was not calculated

[b] Means among collection groups within rows not sharing a common letter are significantly different (ANOVA)

Table 27. PCB 2,3,7,8-TCDD toxic equivalents (pg/g wet wt) in carcasses of male lesser scaup collected at Indiana Harbor, IN, winter 1993-94 and reference males (taken from Custer et al. in prep).

Toxic equivalents (Safe et al. 1990)	Geometric mean concentration / (number detected above LOD)				Results of ANOVA	
	Reference immature	Jan 1994 immature males	March 1994 immature males	March 1994 adult males	F	P
PCBs	6.5 A[a] (5)	133.9 B (6)	217.3 B (5)	327.5 B (6)	20.9	0.0001

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[a] Means among collection groups within rows not sharing a common letter are significantly different (ANOVA)

Government of Canada 1991, Gilman *et al.* 1991). Henny *et al.* (1981) attributed population declines of mink and river otter in the lower Columbia River, Oregon, to PCB contamination. Foley *et al.* (1988) correlated otter and mink PCB body burden with PCB concentrations in fish on a regional basis. It is likely that the GCR/IHC habitats are sufficiently contaminated with PCBs to preclude a reproducing mink population.

Petroleum Products and PAHs

Physical contact with petroleum can cause both acute mortality and chronic sublethal impacts to both birds and/or their eggs. Physical contact of birds to spilled oil has the primary effect of fouling the plumage (NOAA 1988). Oil causes disruption of the fine structure of the small strands that form the feathers, causing loss of their water-repellent characteristics. The plumage of oiled birds also becomes matted, allowing water to penetrate to the body surface, which results in chilling and hypothermia as well as a loss of buoyancy. The ultimate cause of death of heavily-oiled birds is believed to be hypothermia in most cases (Fry and Lowenstine 1985). Presumably those species that are able to leave the water and thereby reduce or avoid hypothermia (such as gulls, wading birds, and some waterfowl) are more tolerant to oil than more pelagic species (NOAA 1988). These changes in behavior can increase the birds' susceptibility to predation. Oiled birds that are able to maintain adequate body temperature may experience severe metabolic drain of fat and muscle tissues (Lambert and Peakall 1981, Dan Sparks pers. obs.). Increased metabolic activity, combined with decreased feeding, may result in death from starvation, and loss of buoyancy may result in drowning (Holmes and Cronshaw 1977). However, it can be difficult to quantify the importance of these effects in situations of heavy oiling because most birds die quickly as a result of hypothermia (NOAA 1988).

Oiled birds can readily ingest petroleum (oil or refined product) during preening. The effects of ingested oil include anemia, pneumonia, intestinal irritation, kidney damage, altered blood chemistry, decreased growth, and impaired osmoregulation (Crocker *et al.* 1974, Holmes and Cronshaw 1977, Miller *et al.* 1978, Ohlendorf *et al.* 1978, Stickel and Dieter 1979, Peakall and Gilman 1980, Peakall *et al.* 1981, Clark 1984, Fry and Lowenstine 1985). In general, however, the importance of these effects is at best unclear when dealing with heavy crude oil:

> It is not clear to what extent these physiological effects contribute to mortality following oiling, given the rapidity of death from hypothermia or drowning. It is evident, however, that ingestion of oil can contribute to the overall impacts of oil spills (NOAA 1988).

Another sublethal physiological impairment associated with the uptake of oil in birds is reduced reproductive fitness. Adults that are exposed to sublethal doses of oil and then ingest it may produce fewer eggs (Grau *et al.* 1977) or cease laying eggs (Hartung 1965). These effects have not been observed in all species tested, but the available data indicate that there is a potential for oiled birds to experience a decline in egg production (Coon and Dieter 1981). The viability of eggs produced following ingestion of oil also may be reduced

(Grau *et al.* 1977, Ainley *et al.* 1981). It has been suggested that the significance of these reproductive impairments are under-rated:

> Managers should be conscious of these [reproductive] effects, which though less apparent in nature, may in fact be more serious than the infrequent kill-offs occurring after catastrophic spills. For it may well turn out that a chronic reduction in reproductive success may be the most significant effect of oil pollution on populations of aquatic birds (Biederman and Drury 1980).

Studies done on the reproductive success on harlequin ducks and other sea birds in years following the *Exxon Valdez* incident has confirmed these suspicions (Patten 1993, Piatt 1993).

Avian reproduction can also be severely impacted by the adverse effects of oil on bird eggs. Breeding birds may pick up small quantities of oil on their plumage, feet, or nest materials (O'Connor 1967, Birkhead *et al.* 1973, Gochfeld 1979). Upon returning to their nests, adults can transfer the oil to the surface of their eggs during incubation. Contamination of eggs in this manner has been observed following actual pollution incidents (Gladstone 1929, Rittinghaus 1956, Birkhead *et al.* 1973) and confirmed by experimentation (Hartung 1965, King and Lefever 1979, Albers 1980, Lewis 1982). The probability of egg oiling is enhanced when birds may be exposed repeatedly at a chronic source, and there is a significant potential for reduced reproductive success in oiled birds (Lewis and Malecki 1984).

Laboratory studies have revealed as little as 1 μL of crude or refined oil applied to the surface of fertile eggs of various species caused embryonic death due to direct toxicity (Albers 1977, Szaro and Albers 1977, Dieter 1977, Hoffman 1978, Coon *et al.* 1979, Eastin and Hoffman 1978, Albers 1978, Hoffman 1979, Hoffman 1990). Additional field studies supported these findings (King and Lefever 1979, McGill and Richmond 1979, White *et al.* 1979, Lewis 1982). Egg oiling can stunt embryonic growth, induce teratogenic malformations, and decrease hatchability (reviewed in Easin and Hoffman 1978, Stickel and Dieter 1979, Ellenton 1982). The degree to which these effects are manifested depends on the amount of oil transferred to eggs (Albers 1977, Hoffman 1978, Szaro *et al.* 1980), the stage of incubation at which the contamination occurs (Szaro and Albers 1977, Albers 1978), and the composition of the oil (Szaro *et al.* 1978, Ellenton 1982). Exposure during the early stages of incubation are most toxic (NOAA 1988). Spilled oil may remain lethal for several weeks (Szaro *et al.* 1980) or may increase in toxicity over time (Macko and King 1980).

Couillard (1989) documented nearly 100 percent mortality at incubation day 8 in chicken eggs with a dose of 5 μL of Louisiana crude oil, and only 32 percent mortality with 12 μL on incubation day 9. This equates to a 16-fold decrease in sensitivity from day 8 to day 9. Number 2 diesel fuel caused significant mortality to mallard (*Anas platyrhynchos)* eggs at just 1 μL/egg (Albers 1977). Bunker C oil is quite toxic to mallards (Szaro 1979) at 3.3 μL/egg (Hoffman and Albers 1984). Industrial waste oil was found to be quite toxic to mallard embryos, with an LD_{50} of 3.2 μL/egg and with some teratogenic effects in survivors (Hoffman and Albers 1984). Ellenton (1982) fractionated Prudhoe Bay crude oil and Number 2 fuel oil and determined that the fraction with 2- and 3-ring aromatics was embryo toxic compared to the aliphatic fraction when injected over the air sac membrane of chicken eggs. Walters *et al.* (1987) reported that the aromatic fraction of Prudhoe Bay crude oil was responsible for most of the embryo toxicity when topically applied to chicken eggs, causing the induction of hepatic microsomal enzymes. The aliphatic fraction was found to be essentially inactive. Oil-induced mortality has been investigated in a wide range of species, including the following: Common eider (*Somateria mollissima*) (Szaro and Albers 1977), herring gull (*Larus argentatus*), greater black-backed gull (*Larus marinus*) (Coon *et al.* 1979, McGill and Richmond 1979, Lewis and Malecki 1984), laughing gull (*Larus atricilla*), and sandwich tern (*Sterna sandvicensis*) (White *et al.* 1979).

Despite the frequency of exposure of wildlife to petroleum pollutants, attempts are seldom made to detect these materials in tissues (Hall and Coon 1988). Once ingested by animals, petroleum hydrocarbons are metabolized and tend to mix with the many similar compounds normally present in tissues, making it difficult, but not impossible, to draw meaningful conclusions from the seemingly incomprehensible analytical reports (Hall *et al.* 1983, Hall and Coon 1988). Naf *et al.* (1992) injected chicken eggs with 0.2 ppm PAH mixture on day 4 of incubation, and on day 18 of incubation the eggs were chemically analyzed to find 94 percent of the injected PAHs had been metabolized. This is consistent with Hall and Coon's (1988) assertion that: "aromatic compounds are not commonly found in clean tissues and, when they are, tend to be present in very small amounts." This is important to keep in mind as the site-specific avian wildlife analytical data for IHC is discussed in the following text.

There are many surface seeps of petroleum products (crude or waste oil primarily) at the proposed confined disposal facility located on the Lake George Branch of IHC. Avian mortality associated with pooled oil areas has been documented in California (Thomas 1971), Colorado (Tully and Boulter 1970), New Mexico (Grover 1983), Wyoming (Esmoil 1991), Oklahoma, Texas (Flickinger 1981), and Indiana (Dan Sparks unpublished). Surface oil seeps, regardless of how small they are or where they occur, are extremely hazardous to wildlife. This site, and other facilities with similar land use histories, are underlain with petroleum-contaminated groundwater which are a source of petroleum contamination to the surface waters of IHC. The ever-present nature of the petroleum surface water contamination of the IHC is hazardous to waterfowl. In addition, field observations indicate that whenever sediments were disturbed in the IHC by wading, motor boat propeller, etc., sheens of petroleum products would appear (Sparks pers. obs.).

We have documented oil-related mortality to the following species in the IHC as a result of direct oiling: black-crowned night heron (*Nycticorax nycticorax*), mallard, great blue heron (*Ardea herodias*), blue-winged teal (*Anas discors*), herring gull and ring-billed gull (*Larus delawarensis*). Other IHC species likely affected include double-crested cormorants (*Phalacrocorax auritus*) and lesser scaup (*Aythya affinus*).

Avian wildlife, on being exposed to petroleum in the IHC, have been observed exhibiting the sublethal effects previously described. Incidental oiling has been documented in the following species in the IHC and GCR: ring-billed gull great egret (*Casmerodius albus*), mute swan (*Cygnus olor*), common merganser (*Mergus merganser*), Canada goose (*Branta canadensis*), belted kingfisher (*Megaceryle alcyon*), domesticated duck, mallard, and herring gull (Sparks pers. obs.). These slight oiling incidents are not likely to be lethal to the adult birds, but this type of incidental oiling could easily cause mortality to its eggs if oil was transferred to them. In more extreme cases, sublethal impacts can lead to acute mortality due to an increased suseptibility to predation, loss of buoyancy, flight impairment. This appears to be the most frequently documented sublethal oiling effect in the GCR/IHC.

Flight impairment has been observed in many avian wildlife species of the IHC, including double-crested cormorant (June 1994, June 1995), common merganser (April 1993, May 1995), Canada goose (May 10, 1995), barn swallow (May 10, 1995), blue-winged teal (April 6, 1993), wood duck (*Aix sponsa*) (June 1993), and white pelican (*Pelacanus erythrorhynchos*) (January 7, 1993) (Sparks pers. obs.). Although Canada geese do lose their ability to fly each year during their molting period, this occurs much later in the year after nesting is complete.

Flight-impaired birds are a potentially significant pathway of oil transfer to peregrine falcons and their eggs. NOAA (1988) stated that "consumption of oiled prey is a concern for peregrine falcons. Several peregrines were oiled in the ARCO *Anchorage* spill in Puget Sound in 1985." Based on the hundreds of days of field observations made by USFWS biologists in the GCR/IHC area since 1990, the effects of oil on avian wildlife we describe are common in this area. On April 20, 1993, a peregrine falcon was observed chasing an injured (oil-impaired) blue-winged teal near the junction of the IHC and the GCR (Sparks pers. obs.). Therefore, it is reasonable to conclude that peregrine falcons are taking oil-impaired prey, at least occasionally. In addition, it has been documented that peregrine falcons will bathe in the IHC (May 21, 1993 Peregrine Falcon Journal). We can reasonably conclude that peregrine falcons are being exposed to the potentially harmful effects of petroleum products and PAHs in the IHC.

Studies conducted by the USFWS and the National Biological Service (NBS) have documented the uptake of PAHs in nesting barn swallows (*Hirundo rustica*) and wintering lesser scaup (nesting and wintering, respectively) in the IHC (Tables 28 and 29, respectively) (USFWS unpublished). Both the barn swallows and the lesser scaup at the IHC bioaccumulated significant levels of PAHs relative to reference samples. This uptake of PAHs in lesser scaup is similar to the documented seasonal uptake of PAHs in double crested cormorants from the Houston Ship Channel (King *et al.* 1987). In addition, the induction of hepatic microsomal enzymes was elevated relative to controls for the IHC lesser scaup (Custer *et al.* in prep.) which is consistent with Walters *et al.* (1987) (previously discussed). Both these species are known prey species of the peregrine falcons nesting at the IHC. On March 4, 1993, as we were collecting lesser scaup from the IHC for food habits and contaminant analyses, we observed a peregrine falcon strike a lesser scaup in mid-air over the canal immediately north of Columbus Drive (Sparks pers. obs.). The peregrine was unable to retain its hold on the scaup, and the scaup fell to the canal and dove under the water. The scaup never resurfaced, but the peregrine falcon perched on a nearby petroleum storage tank adjacent to the canal for several minutes. We can

Table 28. Polycyclic aromatic hydocarbon (PAH) residues in barn swallow eggs (embryos) and 13-day old nestlings from Columbus Drive, Indiana Harbor Canal 1993 and from a reference site in Lake Poygon, Wisconsin, 1995 (parts per million, wet weight).

8500030	CD01a	CD01ec	CD04c	CD07c
	eggs	nestling	nestling	nestling
1,2,5,6-dibenzanthracene	<0.01	<0.01	<0.01	<0.01
1,2-benzanthracene	<0.01	<0.01	<0.01	<0.01
1-methylnaphthalene	0.01	0.02	0.02	0.02
1-methylphenanthrene	<0.01	<0.01	<0.01	<0.01
2,3,5-trimethylnaphthalene	<0.01	<0.01	<0.01	<0.01
2,6-dimethylnaphthalene	<0.01	<0.01	<0.01	<0.01
2-methylnaphthalene	0.02	0.03	0.02	0.03
acenaphthalene	<0.01	<0.01	<0.01	<0.01
acenaphthene	<0.01	<0.01	<0.01	<0.01
anthracene	<0.01	0.01	<0.01	0.01
benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01
benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01
benzo(e)pyrene	<0.01	<0.01	<0.01	<0.01
benzo(g,h,i)perylene	<0.01	<0.01	<0.01	<0.01
benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01
biphenyl	<0.01	<0.01	<0.01	<0.01
C1-chrysenes	<0.01	<0.01	<0.01	<0.01
C1-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01
C1-Fluoranthenes & Pyrenes	<0.01	<0.01	<0.01	<0.01
C1-fluorenes	<0.01	<0.01	<0.01	<0.01
C1-naphthalenes	0.03	0.05	0.04	0.05
C1-phenanthrenes	<0.01	<0.01	<0.01	<0.01
C2-chrysenes	<0.01	<0.01	<0.01	<0.01
C2-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01
C2-fluorenes	<0.01	<0.01	<0.01	<0.01
C2-naphthalenes	<0.01	<0.01	<0.01	<0.01
C2-phenanthrenes	<0.01	<0.01	<0.01	<0.01
C3-chrysenes	<0.01	<0.01	<0.01	<0.01
C3-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01
C3-fluorenes	<0.01	<0.01	<0.01	<0.01
C3-naphthalenes	<0.01	<0.01	<0.01	<0.01
C3-phenanthrenes	<0.01	<0.01	<0.01	<0.01
C4-chrysenes	<0.01	<0.01	<0.01	<0.01
C4-naphthalenes	<0.01	<0.01	<0.01	<0.01
C4-phenanthrenes	<0.01	<0.01	<0.01	<0.01
chrysene	<0.01	<0.01	<0.01	<0.01
dibenzothiophene	<0.01	<0.01	<0.01	<0.01
fluoranthene	<0.01	0.021	<0.01	<0.01
fluorene	<0.01	<0.01	<0.01	<0.01
indeno(1,2,3-cd)pyrene	<0.01	<0.01	<0.01	<0.01
naphthalene	0.02	0.03	0.04	0.03
perylene	<0.01	<0.01	<0.01	<0.01
phenanthrene	<0.01	0.01	<0.01	0.01
pyrene	<0.01	<0.01	<0.01	<0.01
total PAHs	0.08	0.15	0.12	0.15

Table 28. Polycyclic aromatic hydocarbon (PAH) residues in barn swallow eggs (embryos) and 13-day old nestlings from Columbus Drive, Indiana Harbor Canal 1993 and from a reference site in Lake Poygon, Wisconsin, 1995 (parts per million, wet weight) (continued).

8500030	PC313 nestling	PC315 nestling	PC326 nestling	PC313 pipper	PC315 pipper	PC326 pipper
1,2,5,6-dibenzanthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1,2-benzanthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1-methylnaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1-methylphenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,3,5-trimethylnaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,6-dimethylnaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2-methylnaphthalene	<0.01	0.011	0.011	<0.01	<0.01	<0.01
acenaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(e)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(g,h,i)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
biphenyl	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-Fluoranthenes & Pyrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-fluorenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-naphthalenes	<0.01	0.011	0.011	<0.01	<0.01	<0.01
C1-phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-fluorenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-naphthalenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-fluorenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-naphthalenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C4-chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C4-naphthalenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C4-phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	0.018
dibenzothiophene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
fluoranthene	<0.01	0.021	<0.01	<0.01	<0.01	0.014
fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
indeno(1,2,3-cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
naphthalene	0.015	0.035	0.014	<0.01	<0.01	<0.01
perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
phenanthrene	0.012	0.024	<0.01	<0.01	<0.01	0.012
pyrene	<0.01	0.011	<0.01	<0.01	<0.01	<0.01
total PAHs	0.025	0.113	0.036	--	--	0.044

Table 29. Polycyclic aromatic hydocarbon (PAH) concentrations in carcasses of male lesser scaup collected at Indiana Harbor Canal, winter 1993-1994 and a reference site (Custer *et al.* in prep.).

	Geometric mean concentration / (number detected above LOD)					
Analyte	Reference immature males (n = 5)	Jan 1994 immature males (n = 6)	March 1994 immature males (n = 5)	March 1994 adult males (n = 6)	Results of ANOVA	
					F	P
1,2,5,6-dibenzanthracene	---	---	---	---		
	(0)	(2)	(2)	(1)		
1,2-benzanthracene	---	---	---	---		
	(0)	(1)	(0)	(0)		
1-methylnaphthalene	0.015 A	0.025 B	0.020 AB	0.024 B	6.3	0.004
	(5)	(6)	(5)	(6)		
2-methylnaphthalene	0.026 A	0.042 B	0.036 AB	0.041 B	5.8	0.006
	(5)	(6)	(5)	(6)		
acenaphthene	---	---	---	---		
	(1)	(2)	(1)	(0)		
benzo(a)pyrene	0.008 A	0.007 A	0.011 A	0.011 A	0.5	0.680
	(2)	(2)	(3)	(4)		
benzo(g,h,i)perylene	---	---	---	---		
	(0)	(0)	(1)	(1)		
C1-naphthalenes	0.041 A	0.066 B	0.057 AB	0.065 B	6.1	0.005
	(5)	(6)	(5)	(6)		
chrysene	---	---	---	---		
	(0)	(1)	(1)	(0)		
fluoranthene	---	0.009	---	---		
	(0)	(4)	(1)	(0)		
indeno(1,2,3-cd)pyrene	---	---	---	---		
	(0)	(0)	(1)	(1)		

Table 29. Polycyclic aromatic hydocarbon (PAH) concentrations in carcasses of male lesser scaup collected at Indiana Harbor Canal, winter 1993-1994 and a reference site (Custer *et al.* in prep.) (continued).

Analyte	Geometric mean concentration / (number detected above LOD)				Results of ANOVA	
	Reference immature males (n = 5)	Jan 1994 immature males (n = 6)	March 1994 immature males (n = 5)	March 1994 adult males (n = 6)	F	P
naphthalene	0.030 A (5)	0.035 A (6)	0.031 A (5)	0.029 A (6)	1.3	0.315
perylene	--- (0)	--- (0)	--- (1)	--- (0)		
phenanthrene	0.005 A (0)	0.014 B (6)	0.009 AB (3)	0.006 A (2)	8.4	0.001
pyrene	--- (0)	0.010 (4)	--- (1)	--- (0)		
total PAHs	0.120 A (5)	0.224 B (6)	0.186 B (5)	0.182 B (6)	8.0	0.001

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[a] Dashed lines indicate that a mean was not calculated

[b] Means among collection groups within rows not sharing a common letter are significantly different (ANOVA)

reasonably conclude that peregrine falcons are being exposed through their food to the potentially harmful effects of PAHs in the IHC.

To further assess the potential for adverse reproductive impacts to avian wildlife utilizing the IHC, the USFWS investigated barn swallows nesting on Columbus Drive in 1993 and 1995. Our preliminary analysis of data collected indicate that in comparison to other sites studied (both contaminated and uncontaminated):

1) there is a much higher incidence of complete nest hatching failure;
2) fecundity (number of eggs laid per nest attempt) is reduced;
3) in general, eggs are smaller;
4) time to hatch is extended;
5) embryonic development is significantly delayed;
6) time to fledgling is extended; and,
7) gross observations have documented embryonic and nestling deformities.

Our efforts to quantify the extent and significance of these impacts are ongoing. It should be pointed out that each of these potential impacts can be related to impacts from petroleum products and PAHs documented in the literature and discussed in the previous section. Our findings support the contention made by Biederman and Drury (1980) that "a chronic reduction in reproductive success may be the most significant effect of oil pollution on populations of aquatic birds."

Furthermore, in the failed peregrine falcon eggs analyzed, PAHs were detected (Table 30, USFWS unpublished). Analytical chemistry results are also presented in Table 30 for failed peregrine falcon eggs from Des Moines, Iowa for comparison purposes. These data indicate that several individual PAHs are present in failed peregrine eggs, with the highest number of PAH compounds and the highest concentrations found in the egg from the IHC nest (0.53 ppm wet weight, total PAHs, Table 30). Brunstrom *et al.* (1990) found that 0.2 ppm PAHs (mixture) injected into the yolk of domestic duck eggs (on day 4 of incubation) had significantly increased mortality. Assuming 0.2 ppm to be a LOAEL for egg death, it is reasonable to conclude that peregrine falcons eggs have been adversely impacted by PAHs. Given these PAH concentrations, it is also likely that peregrine falcons in the IHC may also be exhibiting some of the adverse reproductive impacts that have been documented in the barn swallows of the IHC. Regardless, this much is clear:

1) contaminants of concern (PAHs) are bioavailable in the IHC;
2) peregrine falcon prey can be at least a sporadic source of oil in quantities that could be toxic to eggs;
3) uptake of PAHs has been documented by chemical analyses in peregrine falcon prey;
4) failed peregrine falcon eggs contain concentrations of PAHs above those known to cause significantly increased mortality in laboratory studies;

Table 30. Polycyclic aromatic hydocarbon (PAH) residues in failed peregrine falcon eggs from a Des Moines, Iowa nest and 2 Lake County, Indiana nests, 1992 and 1993 (parts per million, wet weight).

	Des Moines, Iowa	Des Moines Iowa	Gary, Indiana	East Chicago, Indiana
% Lipid	5.08	6.92	6.54	5.65
% Moisture	80	76.5	80	79.5
1,2,5,6-dibenzanthracene	<.01	<.01	<.01	<.01
1,2-benzanthracene	<.01	<.01	0.02	0.03
1-methylnaphthalene	0.02	0.03	0.02	0.02
1-methylphenanthrene	<.01	<.01	<.01	<.01
2,3,5-trimethylnaphthalene	<.01	<.01	<.01	<.01
2,6-dimethylnaphthalene	<.01	<.01	<.01	<.01
2-methylnaphthalene	0.02	0.02	0.03	0.03
acenaphthalene	<.01	<.01	<.01	<.01
acenaphthene	<.01	<.01	<.01	<.01
anthracene	<.01	<.01	<.01	<.01
benzo(a)pyrene	<.01	<.01	0.03	0.07
benzo(b)fluoranthene	<.01	<.01	0.02	0.13
benzo(e)pyrene	<.01	<.01	0.02	0.06
benzo(g,h,i)perylene	<.01	<.01	<.01	<.01
benzo(k)fluoranthene	<.01	<.01	0.02	<.01
biphenyl	<.01	<.01	<.01	<.01
C1-chrysenes	<.01	<.01	<.01	<.01
C1-dibenzothiophenes	<.01	<.01	<.01	<.01
C1-Fluoranthenes & Pyrenes	<.01	<.01	<.01	<.01
C1-fluorenes	<.01	<.01	<.01	<.01
C1-naphthalenes	0.04	0.05	0.05	0.05
C1-phenanthrenes	<.01	<.01	<.01	<.01
C2-chrysenes	<.01	<.01	<.01	<.01
C2-dibenzothiophenes	<.01	<.01	<.01	<.01
C2-fluorenes	<.01	<.01	<.01	<.01
C2-naphthalenes	<.01	<.01	<.01	<.01
C2-phenanthrenes	<.01	<.01	<.01	<.01
C3-chrysenes	<.01	<.01	<.01	<.01
C3-dibenzothiophenes	<.01	<.01	<.01	<.01
C3-fluorenes	<.01	<.01	<.01	<.01
C3-naphthalenes	<.01	<.01	<.01	<.01
C3-phenanthrenes	<.01	<.01	<.01	<.01
C4-chrysenes	<.01	<.01	<.01	<.01
C4-naphthalenes	<.01	<.01	<.01	<.01
C4-phenanthrenes	<.01	<.01	<.01	<.01
chrysene	<.01	<.01	<.01	<.01
dibenzothiophene	<.01	<.01	<.01	<.01
fluoranthene	<.01	<.01	<.01	<.01
fluorene	<.01	<.01	<.01	<.01
indeno(1,2,3-cd)pyrene	<.01	<.01	<.01	<.01
naphthalene	0.02	0.02	0.03	0.02
perylene	<.01	<.01	<.01	0.10
phenanthrene	0.01	0.01	<.01	0.02
pyrene	<.01	<.01	<.01	<.01
total PAHs	0.11	0.13	0.24	0.53

5) adverse effects have been documented in both peregrine falcons and their prey; and,
6) all of these concerns regarding PAHs have been previously reported in the literature.

Therefore, we conclude that PAHs are having an adverse effect on many species of avian wildlife present in the IHC due to the wide-spread petroleum contamination under existing conditions without the Corps dredging project.

WITH-PROJECT CONDITIONS

The USFWS believes that this project has the potential to provide tremendous long-term benefits to the fish and wildlife resources of the GCR/IHC system and nearshore Lake Michigan. However, there will be short-term impacts due to dredging and long-term impacts due to the exposure of the underlying contaminated sediments that will be not dredged. There will also be life-of the-project impacts associated with the construction and operation of the CDF.

Dredging of the GCR/IHC system will cause suspension of bottom sediments and a loss of substrate. The type of bottom sediment (sand, clay, silt, etc.), the type of dredging equipment used, and the degree of pollution of the sediments all play a part in the type and magnitude of the environmental impacts of dredging. Local winds and water currents also play a part because they can transport resuspended material. These are of significant concern at the IHC because of the volume of flow, the rapid flow reversals that occur, and the relationship of Lake Michigan currents and winds to the dispersion of the pollution plume.

During dredging operations, bottom sediments are mechanically disturbed and resuspended, creating the most visually obvious physical effects - discoloration of the water and reduction of light penetration. Sustar (1978) showed that sand produced very little turbidity when comparing the suspended particulate to a photo density scale (visual observation). Silty sand almost immediately produced turbidity, with very little increase in turbidity with additional disturbance. Clay produced successive increases in turbidity with each additional disturbance. The maximum turbidity with clay was greater than with silty sand.

The sediments of the IHC system are primarily silts and clays, with some occasional sand and gravel, primarily in the outer harbor (Ingersoll *et al.* 1993, USCOE 1994). Therefore, there will be turbidity associated with dredging activities. In addition to turbidity and reduction of light penetration, dredging can impact the water column and fish and wildlife through resuspension of contaminated materials, dissolved oxygen depletion, release of nutrients and other materials entrapped in the sediments, and creation of floating scum and debris (Allen and Hardy 1980). The IHC sediments are so saturated with petroleum products that merely wading in the canal causes oils to be released and surface sheens to appear (Sparks pers. obs.), so dredging will add to the already serious problems of oil pollution and PAH bioavailability.

A direct impact of dredging is the removal of benthic organisms from the dredging site. Recolonization of the dredged area can be rapid, however, and, considering that the exposed sediments will be equally contaminated as those removed, it is doubtful that the species composition would change markedly from that currently present. As previously indicated, the benthic community of the IHC system is dominated by pollution-tolerant species, primarily oligochaetes. The only change in composition that might occur is the addition of zebra mussels.

Other direct impacts to fish and wildlife are expected to be minor. However, secondary impacts are likely to occur in the form of increasing the existing adverse toxicity impacts that are already occurring. These impacts are discussed in the EXISTING CONDITIONS - **Toxicity Impacts** section of this Report and will not be repeated here. Secondary impacts can also include fish kills due to increases in ammonia and decreases in dissolved oxygen associated with the dredging operation.

The dredging project will cause increases in PAH bioavailability and food chain transport. The resuspension of contaminated sediments via dredging sediment disturbance will result in the creation of surface sheen of petroleum products. There will be increased oiling incidents of waterfowl, waterbirds, and various wildlife.

In addition, the dredging project will cause increases in PCB bioavailability and food chain transport as a result of resuspension of contaminated sediments and the exposure of more highly contaminated sediments. Sediments containing higher concentrations of PCBs will be exposed by this project (USCOE 1994 and 1995), which will lead to increased bioavailability to macroinvertebrates and fish. Diving ducks foraging in these areas will accumulate higher levels of PCBs, while PCB uptake in piscivorous birds (i.e. gulls) will also increase. Among other impacts, this increase of PCB concentrations in resident and migratory bird species which are preyed upon by the endangered peregrine falcon could significantly increase the risk of peregrine falcon egg hatching failure.

The choice of dredging equipment can have a significant effect on turbidity, sediment resuspension, and release of petroleum hydrocarbons. Selection depends on the sediment characteristics, volume of sediment to be removed, degree of contamination, location, distance to the disposal site, local environmental conditions (currents, waves, etc.), and equipment availability (Randall 1992). Mechanical dredging equipment, such as clamshells and dippers, have the advantage of removing the sediment at near its in situ density since little water is retained in the closed bucket (Herbich 1993a). However, the operating characteristics of mechanical dredges can produce high sediment resuspension, have high cost per unit of material moved due to low production volumes, and have low cleanup precision. Some of these adverse factors can be overcome through use of the water-tight or closed-bucket clamshell dredge (Randall 1992, Buchberger *et al.* 1993, Herbich 1993a).

The closed-bucket clamshell dredge has been field tested in a number of localities in the United States and Canada (Environmental Laboratory 1987, Buchberger *et al.* 1993, Herbich 1993a). Test results from the St. Johns River

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in Florida indicated that the enclosed clamshell had less turbidity in the upper water column than the open clamshell, but more turbidity near the sediment surface. According to Hayes *et al.* (1984), the use of a closed-bucket clamshell dredge can reduce upper water column turbidity by 39 to 56 percent, but it can also increase lower water column turbidity by 220 to 330 percent, compared to open-bucket dredges. The reason for this increased turbidity is that closed-bucket dredges tend to push water ahead of them as they descend, thereby stirring up sediments at the bottom. This problem can be avoided if the closed-bucket is modified so that top plates remain disengaged until the bucket is closed on the bottom.

At Hamilton Harbour, Ontario, a cable arm clamshell bucket was used to dredge contaminated sediments (Buchberger *et al.* 1993). The design of the cable arm clamshell bucket differs from conventional clamshell buckets because the sweep of the bucket is controlled by the use of cables. One main cable controls the descent of the bucket, 4 spreader cables control the opening of the shell, and another main cable closes and lifts the bucket. In addition, to reduce disturbance to the water column caused by lowering the bucket, a venting system was constructed to allow water and air to pass through the bucket during its descent. After observations showed sediment being forced upward into the bucket and laterally outward, away from the bucket, an inner deflecting plate was added to prevent this lateral movement to increase the amount of sediment that could be removed during each cycle. Water quality monitoring during the test showed little increase in turbidity and total suspended solids. The only problems encountered were in positioning the bucket relative to depth, which could be corrected by installation on a computerized on-site positioning system.

Hydraulic dredges include cutterhead, matchbox, Refresher, and Waterless dredges (Randall 1992). The cutterhead dredge is suitable for the removal of contaminated sediments because of its high production rates, flexibility, good operational characteristics, and low costs, but a large amount of water is added and sediment is resuspended by the rotating cutter or auger (Herbich 1993a). For these reasons, a number of specialty dredges have been developed for the removal of contaminated sediments. These include the Italian Pneuma pump, the Japanese Oozer, Cleanup, and Refresher dredges, and the Dutch matchbox. The matchbox is available in the United States, but unfortunately most of the other speciality dredges are not. These speciality dredges often include hoods or shields to minimize sediment resuspension and underwater television camera to closely monitor the operation.

Environment Canada has conducted field tests of the Pneuma pump on contaminated sediments at Collingwood Harbor, Ontario (Buchberger *et al.* 1993). The system consists of a pump body composed of 3 cylinders, a compressor, a shovel and distribution system that automatically controls the supply of compressed air to the cylinders, and a delivery pipeline (Herbich 1993a). When the pump is submerged, sediment and water are forced into 1 of the empty cylinders through an inlet valve. After the cylinder is filled, compressed air is forced into the cylinder, closing the valve and forcing the material through an outlet valve and into a discharge line. When the cylinder is empty, the air pressure is reduced to atmospheric pressure, the outlet valve closes, and the inlet valve reopens to repeat the cycle. Environment Canada found that the Pneuma pump had to be modified somewhat to work better in the type of sediments present, and debris within the dredging site caused clogging problems (Buchberger *et al.* 1993). Otherwise, it worked very well with minimum turbidity and sediment resuspension.

Matchbox suction head dredges have been experimentally tested at several locations, including Calumet Harbor, Illinois (Environmental Laboratory 1987), and New Bedford Harbor, Massachusetts (Herbich 1993b). The matchbox head replaces the traditional cutterhead and includes various plates and other design features to basically form a box to enclose the cutters and sediments. At Calumet Harbor, it was determined that the matchbox performed very well from the standpoint of production and very little sediment resuspension (Environmental Laboratory 1987). A difficulty was the inexperience of the dredge operator and his inability to place the matchbox at the proper level over the sediments. At New Bedford Harbor, there was no problem with the operator, but debris, which caused frequent plugging, was a problem (Herbich 1993b). To reduce plugging, the cut was reduced to only 6 inches per cut, which reduced the production rate. Resuspension of the sediment was minimized by slowing down operating parameters such as the swing speed, rate of advance, and cutterhead rotation. A standard cutterhead and a MudCat were also tested, and the cutterhead caused the least resuspension of sediment. It was pointed out however, that "[a]lthough the concentration of sediment resuspended by dredges may appear to be low, and continuous dredging operation would generate movement of substantial quantities of contaminated sediment."

The presently proposed dredging plan for the IHC system involves use of a closed-bucket clamshell dredge (USCOE 1995). Based upon available information about dredge performance (Randall 1992, Buchberger *et al.* 1993, Herbich 1993a and 1993b), and the fact that other types of dredges are apparently now available within the Great Lakes (*e.g.* matchbox and Pneuma pump), it would appear that other options are viable.

RECOMMENDATIONS

Surface Oil Sheen Prevention and Water Column Protection Plan

Surface water protective measures, including monitoring, need to be implemented to prevent occurrence of surface sheens of petroleum products resulting from the resuspension of petroleum-contaminated sediments. Additionally, similar protective measures to prevent in-situ water column exceedances of State water quality standards, including monitoring to detect such exceedances, needs to be developed.

To minimize the potential for water column impacts, primarily the resuspension of petroleum products, PAHs, and PCBs, the Corps should prepare, with the assistance of appropriate response agencies, a surface sheen prevention and water column protection program to minimize the possibility of sheen creation. The surface sheen prevention plan should include provisions for absorbent boom deployment, replacement, and frequent effectiveness assessment. The sudden flow reversals that can occur in the IHC must be taken into account in the design of the program and boom deployment. Continual monitoring for surface sheens should be established with particular attention given to monitoring potential wildlife contact with boomed or contaminated surface water areas. This plan should consider implementation of wildlife hazing techniques, if necessary. The water column protection aspects of this plan should make use of silt curtains, or other such protective devices as deemed feasible, to minimize water column turbidity. This plan shall provide signatory concurrence with appropriate response agencies.

The implementation of this plan should be continually evaluated for its effectiveness. Turbidity increases and sheen generation shall be primary performance measures; if these parameters can not be controlled within deployed containment measures, dredging operations should be temporarily suspended while containment measures are effectively redeployed.

Alternative Dredging Techniques

The Corps should reassess the use of hydraulic dredging, including the matchbox head and Pneuma pump, to minimize water column impacts to the IHC and Lake Michigan. By minimizing water column impacts, impacts to fish and wildlife would likely be significantly reduced. This change in technology would likely necessitate the construction of a larger water treatment facility than discussed in the DEIS. Consideration should be given to the construction of this plant on ECI site parcel on the south side of the Lake George Branch of IHC.

Construction of a Water Treatment Facility

The Corps should implement the construction of a water treatment facility at the CDF to ensure that effluent water quality meets appropriate water quality standards.

Sediment Toxicity Reduction Strategies

Given the contaminated nature of the GCR sediments upstream of the project area (Hoke *et al.* 1993, Sobiech *et al.* 1994), the Corps can not depend on "cleaner sediments" to come from upstream to function as a natural capping through the deposition of upstream sediments.

The Corps (Environmental Laboratory 1987) evaluated the effectiveness of capping contaminated Indiana Harbor dredged material from a toxicological and bioaccummulation potential perspective (In Appendix F). They indicated that:

> a 30-cm cap of Lake Michigan sediment (presumably sand) overlying Indiana Harbor sediment was highly effective in preventing the transfer of heavy metals, PAHs, phenol and PCBs from the contaminated sediment into the overlying water and aquatic biota.

These studies included 40-day bioaccumulation tests with fish, clams, and crayfish. It was also shown that a 30-cm cap produced in the laboratory an 80 percent reduction in phosphorus, an 83-100 percent reduction in ammonia, and a

40 percent reduction in sediment oxygen demand. As part of the evaluation of remedial technologies available for the Manistique River and Harbor Superfund Site, sediment capping was evaluated. While ultimately that technique was not chosen due to some site-specific impediments, sediment capping should be considered as a potential contaminated sediment management technique in the IHC.

The Corps (USCOE 1994) suggests that the total amount of non-native sediment in the IHC is approximately 6 million cubic yards (cy). Of this amount, it is likely that only 1 million cy will be dredged (USCOE 1995). Given that it is unlikely that all 6 million cy will ever be dredged, some steps should be taken to preclude these sediments or their contaminant constituents from discharging to Lake Michigan. Much of this additional sediment lies below the federal navigation channel (USCOE 1994). The navigation project should overdredge these areas to allow room for the placement of clean material to serve as a cap. This would prevent the deeper contaminated sediments from continuing to be a source of contaminants to the food chain and to Lake Michigan. The Corps (Environmental Laboratory 1987) and Superfund investigations of Manistique Harbor Superfund site have shown this technique to be suitable under certain conditions, conditions that seem to be present in the IHC.

These sediment capping efforts should also be explored in areas outside the federal navigation channel, especially with regard to the unused, highly contaminated (Ingersoll *et al.* 1993) Lake George Branch of IHC upstream of the federal navigation channel. The proposed CDF is located on this reach, but navigational access will not be needed beyond the project limits. Therefore, an effort should be made to either: 1) dredge and cap the upstream reaches, or 2) make provisions to fill and contain this contaminant source, including such measures as steel sheetpile bulkheads with an impermeable slurry-wall behind them. Long-term water quality benefits to Lake Michigan would exceed these one-time construction costs.

Finalization of a Wildlife Exclusion Plan

The Wildlife Exclusion Plan (WEP) for the Confined Disposal Facility (CDF) needs to be finalized (including USFWS concurrence on the plan) prior to the beginning of any dredging activity.

To minimize the potential for flight hazards to birds at the CDF, the Corps should prepare, with the assistance and concurrence of the USFWS, a Wildlife Exclusion Plan (WEP) to minimize the possibility for take of migratory birds. The WEP should attempt to minimize the potential for wildlife use, including shorebirds, so that contaminant uptake can be prevented. Specific measures, actions, and design plans should be identified and implemented prior to the CDF accepting dredged material. The implementation of this plan should be continually monitored during the initial year of the project to assess its success. During subsequent years, the plan should be evaluated quarterly or each time the CDF operations change operable disposal units.

CDF Spill Plan

A plan to effectively prevent and deal with potential spills associated with rehandling of dredged sediments needs to be established prior to the beginning of dredging. This plan should identify the precautions and spill-related water quality counter measures in place to be used if the situation arises.

We look forward to continuing to work with you on the Indiana Harbor and Ship Canal Maintenance Dredging and Disposal Project. If you have any questions regarding issues raised in this report, please contact Dan Sparks of my staff.

Sincerely yours,

David C. Hudak
Supervisor

cc: Senator Richard Lugar, Washington, DC
Congressman Peter Viscloskey, Washington, DC
Mr. Valdas V. Adamkus, Administrator, Region 5, U.S. Environmental Protection Agency, Chicago, IL
Colonel James R. Van Epps, Commander, North Central Division, Corps of Engineers, Chicago, IL
Mr. Patrick Ralston, Director, Indiana Department of Natural Resources, Indianapolis, IN
Mr. Tim O'Connor, Commissioner, Indiana Department of Environmental Management, Indianapolis, IN
Mr. David Herbst, Director, Indiana Division of Fish and Wildlife, Indianapolis, IN
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United States Department of the Interior

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IN REPLY REFER TO:
CENCC-PD-S

May 21, 1996

Lt. Colonel Robert E. Slockbower
District Engineer
U.S. Army Engineer District
Chicago
111 North Canal Street
Chicago, Illinois 60606-7206

Dear Lt. Colonel Slockbower:

Enclosed is the U.S. Fish and Wildlife Service's (USFWS) Biological Opinion regarding the effects of the Indiana Harbor and Canal (IHC) Maintenance Dredging and Disposal Project (Project) on the peregrine falcon (*Falco peregrinus*), a species federally listed as endangered. This Biological Opinion has been prepared pursuant to Section 7 of the Endangered Species Act of 1973, as amended (Act), and complies with appropriate regulations and guidance.

Based upon information provided in your Biological Assessment of August 16, 1995 and the Draft Environmental Impact Statement and Comprehensive Management Plan for the Project issued October 19, 1995, as well as information on the biology and ecology of the peregrine falcon and specific data on the various pairs of falcons that have nested along the Indiana Harbor Canal, plus research data compiled by the Bloomington, Indiana Field Office on the effects of IHC pollutants on barn swallows and other birds, we have made the determination that the Project is not likely to jeopardize the continued existence of this species. However, the nesting falcons along the IHC are likely to be adversely affected by the Project.

The USFWS is well aware that the nesting peregrines are being adversely impacted by the existing polluted conditions of the IHC. Our research on the barn swallows nesting along the IHC and our analysis of unhatched peregrine eggs, as described in the attached Biological Opinion, provide documentation of those adverse effects. We also recognize that dredging the IHC could provide significant environmental benefits to the harbor, canal, and adjacent areas of Lake Michigan. This includes benefits to the fish and wildlife species that utilize these habitats. However, our impact analysis indicates the likelihood of an increase in short term adverse impacts on the peregrines due to the project. The issues of concern include the release of additional oil to the water column due to dredging and the sublethal and acute toxicity impacts of this oil on the peregrines, the operation of the confined disposal facility (CDF), particularly the design and management of the Wildlife Exclusion Plan, and direct disturbance at the nest during dredging.

Because the Project is likely to have adverse effects on a listed species, we have included an incidental take statement pursuant to Section 7(b)(4) of the Act. This incidental take statement provides your agency with an exemption to the takings prohibitions of Section 9 of the Act as long as your agency complies with the mandatory terms and conditions contained in the incidental take statement. To the extent that this statement concludes that take of any threatened or endangered species of migratory bird will result from the agency action for which consultation is being made, the USFWS will not refer the incidental take of any such migratory bird for prosecution under the Migratory Bird Treaty Act (MBTA) of 1918, as amended (16 U.S.C. §§ 703-712), or the Bald Eagle Protection Act of 1940, as amended (16 U.S.C. §§ 668-668d), if such take is in compliance with the terms and conditions (including amount and/or number) specified herein. Please take note of the terms and conditions of this incidental take statement, and be aware that any failure to comply with these terms and conditions voids your exemption to the takings prohibitions of Section 9 of the Act and the MBTA. The incidental take statement begins on page 30 of the Biological Opinion.

Finally, we have included conservation measures in our Biological Opinion to help your agency comply with Section 7(a)(1) of the Act. These conservation measures are discretionary on the part of your agency, but would contribute greatly to the conservation of the peregrine falcon. We would also need to be informed of any of these conservation measures your agency chooses to implement.

This concludes formal consultation on the Indiana Harbor and Canal Maintenance Dredging and Disposal Project. Consultation should be reinitiated if: (1) new information reveals effects on listed species or critical habitats that were not considered in this Biological Opinion; (2) the action is modified in a manner that affects listed species or critical habitats that were not considered in the Biological Opinion; and (3) a new species is listed or critical habitat is designated that may be affected by the action.

We look forward to future cooperation with your agency to conserve our Nation's threatened and endangered species. Should there be questions, please contact me at 812/334-4261.

Sincerely,

David C. Hudak

David C. Hudak
Supervisor

Enclosure

cc: Senator Richard Lugar, Washington, DC
Congressman Peter Viscloskey, Washington, DC
Mr. Valdas V. Adamkus, Administrator, Region 5, U.S. Environmental Protection Agency, Chicago, IL
Colonel James R. Van Epps, Commander, North Central Division, Corps of Engineers, Chicago, IL
Mr. Patrick Ralston, Director, Indiana Department of Natural Resources, Indianapolis, IN
Ms Kathy Prosser, Commissioner, Indiana Department of Environmental Management, Indianapolis, IN
Mr. David Herbst, Director, Indiana Division of Fish and Wildlife, Indianapolis, IN
Dr. Redig and Dr. Tordoff, The Raptor Center, University of Minnesota, St. Paul, MN

Endangered Species Act

Section 7 Consultation - Biological Opinion

Action Agency: U.S. Army Corps of Engineers, Chicago District (Corps)

Action Considered During Consultation: Proposed maintenance dredging of Indiana Harbor and Canal (IHC) and construction and operation of a confined disposal facility (CDF) at East Chicago, Lake County, Indiana

Consultation by: Ecological Services Bloomington, Indiana Field Office, U.S. Fish and Wildlife Service (USFWS)

Date of Issuance: May 21, 1996

Description of the Action

The Corps proposes to maintenance dredge the entire IHC Federal navigation channel to authorized project depths, plus an average 0.5 foot overdredge. The dredged materials would be deposited in a CDF, constructed on the former Energy Cooperative, Inc. (ECI) site in East Chicago.

As shown on Figure 1, the authorized depths and designated Reaches of the Federal navigation project are as follows:

- outer harbor approach channel - 29 feet - Reaches 1 and 2
- outer harbor anchorage and maneuver basin - 28 feet - Reaches 2, 3, and 4
- canal entrance channel - 27 feet - Reach 5
- main canal - 22 feet - Reaches 6 through 10
- 2 turning basins along the canal - 22 feet - Reach 9 and junction of Reaches 11 and 13
- Calumet River Branch of the canal - 22 feet- Reach 13
- Lake George Branch of the canal - 22 feet - Reaches 11 and 12

The Calumet River Branch is the outlet for the Grand Calumet River (GCR), and therefore is a flowing stream, while the Lake George Branch is a dead-end canal and does not flow.

Prior to 1972, dredged material from the IHC was disposed of in a designated open water area of Lake Michigan or in the permitted lakefills of Inland Steel or LTV Steel, which are located along the outer harbor approach channel. In 1972, the U.S. Environmental Protection Agency (EPA) determined that disposal in Lake Michigan was no longer acceptable due to the polluted character of the dredged material. No maintenance dredging has occurred since that time because an acceptable disposal option could not be found.

There are an estimated 1 million cubic yards (CY) of sediments accumulated in the Federal navigation channel, which have reduced the water depths and impaired shipping. The primary shoaling problems are in the outer harbor anchorage and maneuver basin (Reaches 1 through 4), the canal entrance channel (Reach 5), and the canal in the vicinity of the 5 downstream railroad bridges (lower end of Reach 6) because these are the areas where the water velocity is reduced as the flow enters the lake. The solids therefore settle from the water column. For example, Reach 5, the canal entrance channel, is authorized at 27 feet but averages 24 feet. Upstream in the canal, Reach 8, between Cline Avenue and Dickey Road, is the shallowest.

The inadequate channel depths are causing deep-draft vessels to plow through sediments at various locations in the Federal channel, moving polluted sediments around and pushing them into berthing areas and along dockfaces outside the Federal channel. The stirred sediments are also carried by the river currents into Lake Michigan. It is estimated that between 100,000 and 200,000 CY of polluted sediments are being discharged from the harbor into the lake annually. The impact zone of this moving sediment and plume of polluted water is the nearshore area at least 5 miles into the lake from the harbor entrance.

Studies of IHC sediment quality have shown high levels of total polycyclic aromatic hydrocarbons (PAHs), dioxins, polychlorinated biphenyls (PCBs), and heavy metals such as arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. Additionally, these sediments contain high volatile solids, ammonia, cyanide, manganese, phosphorus, barium, iron, and aliphatic hydrocarbons. Portions of the sediments have been determined by EPA to be hazardous: The PCBs are subject to regulation under the Toxic Substances Control Act (TSCA), and benzene is subject to regulation under the Resource Conservation and Recovery Act (RCRA).

The ECI site, where the CDF is proposed to be constructed, contains about 168 acres, of which approximately 130 acres are expected to be utilized for the facility. The site was an oil refinery for many years and produced a variety of petroleum products. The company went bankrupt in 1981 and the site was eventually cleared of surface structures. However, RCRA closure and post-closure requirements were not met for contaminated areas, so a portion of the property has open RCRA status. The Indiana Department of Environmental Management (IDEM) and EPA have determined that soil and groundwater contamination is present and that corrective actions must be taken under RCRA.

A worst-case corrective action approach has been determined to be warranted for the ECI site. This would include construction of an in-place clay cap system and a slurry wall around the perimeter of the site, plus implementation of a groundwater gradient control system. These measures are required for the property regardless of whether or not a CDF is constructed there. However, it has been determined by IDEM, EPA, and the Corps that a plan to combine the required RCRA closure and corrective actions with the construction of a dredged material CDF is a viable option. Various elements required for RCRA closure/corrective action would be integral to the CDF construction, and the CDF would act as the final cap that is required for RCRA closure. Use of this site would also preclude converting a non-contaminated upland site to CDF use.

The CDF would have 3 separate cells surrounded by earthen dikes. One cell would be divided to create an isolated subcell for the disposal of PCB contaminated sediments. The maintenance and monitoring required by TSCA would be integrated into the maintenance and monitoring requirements for the CDF. The dikes would be constructed on top of a 3-foot layer of compacted clay tied into the slurry wall. The interior side slopes of the dikes would be lined with a 3-foot layer of compacted clay tied into the bottom clay layer.

Dredging is proposed for the entire Federal channel, including turning basins, using closed-bucket or environmental-bucket mechanical dredging equipment. Such buckets are designed to be totally closed when lifting dredged materials out of the water to minimize the loss of polluted sediments and reduce drippings as the dredged materials are transferred to barges. They also deliver sediments with a minimal amount of water, which is desirable for placement in an upland CDF.

The loaded barges would then be towed up the canal to the ECI property, which is along the Lake George Branch. At the ECI dock/CDF rehandling area, the dredged material would be unloaded from the barges and loaded into trucks. The trucks would then transport the material into the CDF along haul roads placed around the site and on top of the dikes. Alternate methods of transport, such as a conveyor system, may be considered during the detailed design phase of the project.

To allow for natural drying, the dredged material would be placed in the CDF in lifts of approximately 3 feet. Dump trucks would drive into the CDF and dump the material on the bottom in rows 3 to 4 feet high. Subsequent lifts would be windrowed if possible or dumped from the edge and mechanically distributed. Each cell would be graded towards a dewatering sump to avoid ponding of water. Construction and operation of the CDF may require an on-site treatment plant to provide initial treatment of the precipitation runoff within the CDF and groundwater collected from the gradient control system in order to meet pretreatment standards before discharging to the East Chicago wastewater treatment plant. Since birds and mammals might be attracted to the CDF, particularly if it has, or appears to have, standing water, a Wildlife Exclusion Plan (WEP) is to be designed and implemented for the facility.

The recommended CDF would have a capacity of approximately 4.67 million CY. This includes material from the Federal channel, both from the initial dredging and future maintenance dredging over a period of about 30 years, and material from berthing areas outside the authorized channel. This dredging of berthing areas would be accomplished by non-Federal parties. Only materials dredged from the IHC/GCR system would be disposed of in the CDF. Space within the CDF could also be provided for dredged materials from the Inland Steel Company Consent Decree sediment remediation activities and other similar activities which might be required by the EPA or IDEM along the IHC/GCR.

After the CDF is filled (35 years after initiation) it would be sealed with a clay cap, which would then be covered with sand and topsoil. These 3 layers would be a total of 5 feet deep. The clay would seal the CDF and provide the required RCRA capping. The sand would provide for drainage of precipitation off the CDF. The final layer of topsoil would be seeded and planted with as yet undetermined vegetation.

Consultation History

The Corps has not dredged the Federal channel at the IHC since 1972 because the sediments were determined to be too polluted for open lake disposal and no environmentally acceptable containment areas could be found. In 1986, a Draft Environmental Impact Statement (DEIS) on the dredging project and CDF was prepared, with an in-lake CDF off the East Chicago lakeshore as the preferred site. This site was abandoned due to environmental problems and local opposition, and the COE continued its investigation of sediment pollution while looking for a CDF site.

Meanwhile, in 1989, a pair of federally endangered peregrine falcons chose the SR 912 (Cline Avenue) bridge over the IHC as the site for their nest. Peregrine falcons have continued to nest under this bridge since that time.

By letter of July 14, 1994, the USFWS informed the Corps of the presence of nesting peregrine falcons within the Project area and requested that the Corps address this issue relative to the Endangered Species Act.

During teleconference calls on the Project between staff of the Service and Corps on August 19, November 16, and December 1, 1994, the presence of the nesting falcons was discussed. Concerns were expressed that the falcons and their prey could be adversely affected by contaminants re-suspended during the dredging process.

In a letter dated June 22, 1995, the Corps stated that the falcons nest under the Cline Avenue bridge over railroad tracks 2.5 miles southwest of Indiana Harbor and 3000 feet north of the IHC, at the northwest corner of the proposed CDF. Therefore, they expressed the opinion that the peregrines would not be impacted by the Project.

In a July 27, 1995, letter, the USFWS responded that it was our determination that the Project "may affect" the nesting peregrine falcons and that the Corps should initiate formal consultation under Section 7 of the Act.

The Corps' response, dated August 16, 1995, requested formal consultation regarding Project impacts on the falcons and provided a Biological Assessment (BA). However, this BA mistakenly identified the falcon nest as being under a Cline Avenue bridge over a railroad west of Indianapolis Boulevard, when in fact the nest is under the Cline Avenue bridge over the IHC, approximately 1 mile east of the site addressed by the Corps. The actual nest site is located approximately 300 feet from the IHC, and the falcons forage in the Harbor and Canal area, as well as adjacent sites.

On September 19, 1995, the USFWS responded to the Corps' letter and BA of August 16, 1995. This letter indicated that the BA addressed the wrong nest site and did not provide adequate information on the action being taken or the impacts of the action on the falcons. Specific Project information was requested, and the actual nesting site was indicated.

From September through November 1995, the Corps and USFWS conducted several teleconference calls on these matters.

On December 11, 1995, the Corps sent a letter to the USFWS requesting an update on their request for formal consultation. They indicated that they believed the information requested in the USFWS's letter of September 19, 1995, was provided in the October 19, 1995, DEIS, so they did not intend to revise the BA or otherwise provide additional information. This letter was received while the USFWS was on furlough due to the federal budget impasse, so the letter was not officially received until the USFWS returned to work on January 8, 1996.

By letter of January 22, 1996, the USFWS acknowledged receipt of the Corps' letter and indicated that although the DEIS did provide much of the information requested in the September 19,1995 letter, relevant information from experts on the falcons at East Chicago and information on potential toxicological impacts from pollutants was still missing. However, the USFWS acknowledged that the Corps apparently did not intend to provide the additional information, and indicated it would begin formal consultation with the information that had been provided.

Species Considered in this Biological Opinion

The only federally listed species that is likely to be affected by this proposed action is the peregrine falcon (*Falco peregrinus*), which is listed as an endangered species. No critical habitat has been designated for this species.

The peregrine is 1 of the most distinct birds of prey, known mostly for its "power dives" which have been timed at 220 mph. The name comes from the Latin word *peregrinus*, meaning "to wander" or "traveler". The peregrine has the long, pointed wings typical of a falcon. The head is black on top, coming down to form sideburns on the cheeks, sometimes referred to as a malar stripe. This stripe is accented by the white throat and sides of the neck, so that the bird appears to be wearing a helmet. The back is blue-gray, the underparts are barred dark blue or slate, and the tail is long and narrow, with black bands and a subterminal bar tipped white. Immatures are similar, but are generally brown dorsally, turning blue at the onset of sexual maturity.

Peregrines are sexually dimorphic in size and weight, with females (falcons) being larger than males (tiercels). Average measurements for falcons are wing span of 14 inches, tail length of 7 inches, and weight of 1.8 pounds. Average measurements for tiercels are wing span of 12.4 inches, tail length of 5.7 inches, and weight of 1.3 pounds (Southeastern Raptor Rehabilitation Center 1996).

Historically, the North American species of peregrine bred from northern Alaska, the subarctic boreal forests of Canada, east to Labrador, and south to Mexico. They inhabited mountain ranges and islands along the Pacific Coast to the Rocky Mountains, and were common in parts of the Adirondack, Allegheny, and Appalachian Mountains from New England and New York south to Georgia. They were also found in the Upper Mississippi Valley. The Plains area of the continent historically contained relatively few nesting peregrines. The plains, therefore, effectively separate the more suitable nesting habitat and historically dense nesting areas of temperate eastern and western North America.

Most peregrines from northern Alaska, Canada, and Greenland migrate in the fall to Central and South America (Cade 1960). Peregrines that nest south of Canada migrate lesser distances, and some may not migrate at all. The former eastern population was believed to be weakly to relatively nonmigratory, as are reintroduced birds (Enderson 1965, USFWS 1991).

Movements, whether they are local wanderings or seasonal migrations, are dictated by the prey base present at any given time. If the primary prey species is migratory, then peregrines will be also. The migratory instinct also is related to latitude, so that the instinct increases from north to south, and from west to east (USFWS 1991). Migratory peregrines tend to concentrate along ocean coastlines and shores of the Great Lakes (Hickey and Anderson 1968). Migration occurs in late September and early October, with many birds migrating from the tundra areas of Canada as far south as Costa Rica and Central America (Yates *et al.* 1988).

Life History of the Peregrine Falcon

Although some peregrines reach sexual maturity at 2 years of age, most do not breed until they are 3. Pair bonds are often retained through the non-breeding season, with indefinite monogamy being the rule. Peregrines nest preferentially on cliffs but will nest on bluffs or occasionally high in tall trees or even on the ground. They typically scrape shallow hollows in soil, decomposed rock, gravel, mats of vegetation, and the remains of prey in which to lay their eggs (Hickey and Anderson 1969).

Unlike many species of wildlife, some peregrines have readily accepted man-made structures as breeding habitat. For example, skyscraper ledges, tall towers, and bridges serve as the ecological equivalent of a cliff ledge. In 1988, 21 nesting pairs of peregrines present in various urban areas throughout North America successfully fledged more that 40 young (Pagel 1988). By contrast, in 1994, in the Midwest alone (United States and Canada) there were 31 successful nests on buildings, smokestacks, and bridges, with 83 successfully fledged young (Redig and Tordoff 1994).

The tiercel usually arrives first at the nest site, generally by March except in the Subarctic, and begins a series of aerial acrobatic displays to attract a mate. Some peregrines stay within the vicinity of their nesting sites throughout the winter (USFWS 1991). The mating aerial displays begin in late February or early March, depending on latitude. Eggs are laid in late March into April at intervals of 2 to 3 days. The clutch averages 4 eggs. Falcons will lay a second clutch if the first is lost early in the laying period. Incubation is shared by both parents, though it is mostly done by the female, and it lasts 30 to 34 days (Newton 1979). The young fledge in 35 to 42 days (Brown and Amadon 1968).

Historical data from the 1930s and 1940s both in North America and Europe showed that peregrine pairs averaged 4 eggs laid and 3 young raised per year, with the North American data being young seen (hatched) but not yet fledged (Hickey and Anderson 1969), and the European data being fledged young (Herren 1969, Terrasse and Terrasse 1969). How many young actually lived to adulthood is unknown. However, estimates have been made for fledgling (birds up to 1 year old) mortality ranging from 56 to 66.7 percent (Hickey 1969). Intentional shooting of birds was a major cause of death during this time period, so natural mortality likely would have been less.

The number of successful breeding pairs among all nesting pairs during that time period is not known, but several researchers set it at 60 percent (Hickey 1969). This included pairs that were on territory but did not lay eggs, pairs that laid eggs but did not successfully raise any young, and pairs that had eggs taken by collectors or abandoned their nests because of human disturbances. The young reared per successful pair averaged 2.5, and the young reared per occupied site averaged 1.5. Without human disturbances, productivity may have been greater.

Nesting data for peregrine falcons in the Midwest (United States and Canada) during 1994 was 2.8 young per successful pair, 2.3 per nesting pair, and 1.9 per territorial pair (Redig and Tordoff 1994). In 1995, there were 2.7 per successful pair, 2.2 per nesting pair, and 1.8 per territorial pair (Redig and Tordoff 1996).

Adult peregrines have no major predators other than man, and intentional shooting was once a major cause of death. Eggs and young are preyed on by various small carnivores and large owls such as the great horned. In fact, great horned owl predation is considered a factor in lack of successful nesting at a number of historic eyries in the Eastern mountains and along Midwestern river bluffs (Redig and Tordoff 1994, USFWS 1995a). Eggs were also once collected by humans, and young were collected by falconers to become trained hunters.

The aerie is the center of a home range that averages about 30 square miles. The minimum distance between adjacent eyries is 3 miles, and the resident pair vigorously defends the territory around the aerie within a 300 foot radius (Southeastern Raptor Rehabilitation Center 1996).

Birds, ranging in size from mallards and gulls to swallows and warblers, are the main food supply of peregrines. Peregrines depend upon direct pursuit in the open, hunting by utilizing high speed dives and hitting their prey in mid-air. Most hunting is done early in the day or in late afternoon. Medium-sized birds, such as pigeons, blue jays, and flickers, are most commonly taken. However, the diet depends upon what is readily available in the vicinity. Therefore, birds nesting near shorelines of the Great Lake or along the Atlantic or Pacific coasts would be more inclined to take gulls, shorebirds, or seabirds (Hickey and Anderson 1969). A recent survey of food habitats of Midwestern peregrines showed that the prey base of urban birds appears to change seasonally, with different diets during spring and fall migration than during summer or winter (Septon 1993). A wide variety of prey species are taken during the nesting season, even in urban areas.

Status and Distribution of the Peregrine Falcon

Peregrine falcons have never been very abundant, despite the almost world-wide distribution of their various races. Population trends of peregrines can be monitored with greater reliability than with many other birds because they exhibit a high degree of nest site fidelity. In the late 1930's and early 1940's, Hickey (1942) inventoried known peregrine eyries in the eastern United States, Canada, and Greenland. A total of 408 nesting sites were located, with 275 in the eastern United States. Hickey estimated 350 peregrine pairs in the east during that period, although that was a rough estimate since some regions were not surveyed. At the same time, about 1,000 pairs were estimated to be present in the western United States, Canada, and Mexico (Hickey 1969).

Then, beginning in the late 1940's, peregrines suffered a devastating and rapid decline. A growing concern over the dramatically declining peregrine population prompted a re-survey in 1964. Berger *et al.* (1969) compiled a list of 209 verified eyries in the region east of the Mississippi River. During the 1964 nesting season, 146 of these eyries were watched for breeding activity, but no such activity was observed. This survey confirmed what many biologists feared - the peregrine falcon was no longer a breeding species in the eastern United States. A third survey in 1975 was equally grim - no breeding pairs or occupied eyries were observed in the eastern United States, although most of the nesting habitat remained suitable (Fyfe *et al.* 1976).

Numerous observers reported precipitous declines in peregrine falcons beginning in the late 1940's (Hickey 1969). Both nesting adults and numbers of young produced were dramatically reduced. Research implicated organochlorine pesticides, particularly dichloro-diphenyl trichloroethane (DDT), as the cause. Organochlorines can affect peregrine falcons either by causing direct mortality or by adversely affecting reproduction by causing egg breakage, addling, hatching failure, and abnormal reproductive behavior by the parent birds (Hickey and Anderson 1968, Risebrough and Peakall 1988). DDE, a metabolite of DDT, prevents normal calcium deposition during eggshell formation, resulting in thin-shelled eggs that are susceptible to breakage during incubation.

DDE is the primary breakdown product of DDT and is equally persistent in the environment. DDT and DDE are not easily degraded to other, less toxic chemicals by microorganisms or by physical agents such as sunlight and heat. Therefore, once it is released into the environment, DDT and its breakdown products persist for many years (Freedman 1989).

DDT and its metabolites are not soluble in water but are highly soluble in fats or lipids. In the environment, most lipids are present in living organisms. Therefore, DDT and other organochlorine insecticides are easily accumulated in the fatty tissue of animals. Once in the food chain, DDT and DDE are transferred and biomagnified upward. Peregrine falcons are at the top of the food chain and accumulate these pesticides from their food sources (Freedman 1989).

Between the mid-1940's and 1972, when DDT was banned in the United States (it was banned in Canada in 1970), the peregrine falcon was essentially extirpated in eastern North America. Those birds that nested outside of areas where DDT was heavily used were affected less, although some individuals wintered in areas of pesticide use in Central or South America and likely encountered pesticides there (Freedman 1989).

Due to the severe population declines of American peregrine falcons, the USFWS, in 1970, listed this subspecies (*F. p. anatum*) as endangered under the Endangered Species Conservation Act of 1969, precursor legislation to the Endangered Species Act of 1973, as amended. It was subsequently listed under this later Act, as were additional subspecies due to similarity of appearance. This included the 1984 world-wide designation of the peregrine falcon (*Falco peregrinus*) as endangered (USFWS 1991).

Since the 1972 ban on the use of DDT, and 1974 restrictions on the use of the pesticides aldrin, endrin, and dieldrin, which are also organochlorines, residues of the pesticides have significantly decreased in many regions where they were formerly used (Freedman 1989).

Because nesting peregrines were no longer present in the eastern United States by the mid-1970's, the initial objective for peregrine recovery in this area was to re-establish the species through the introduction of captive-produced young (USFWS 1979). These young birds were produced from a variety of parental stocks, including American and European birds.

The first experimental release of young occurred in 1974. Birds have been hacked at historical eyries in the eastern mountains, along river bluffs, and on man-made structures within cities and at power plants. Within the Midwest, 729 captive-bred young were hacked between 1981 and 1994, with the largest number being 116 in 1989 (Redig and Tordoff 1994). Nationwide, more than 4,000 peregrines were released.

Sufficient numbers of these hacked young have survived to successfully breed on their own. In 1994 alone in the Midwest (United States and Canada), there were 62 pairs on territories, 51 pairs laid eggs, and 41 pairs successfully produced at least 116 young. Also in 1994, a total of 42 young birds were hacked in Indiana (Evansville), Minnesota, Arkansas, and Ontario (Redig and Tordoff 1994). In 1995, 67 pairs were known to be on territories, 53 pairs laid eggs, and 43 pairs successfully fledged 118 young (Redig and Tordoff 1996). Additionally, 29 young birds were hacked in Ontario, Kentucky, and Michigan. The nesting birds were on buildings in cities, on structures attached to smokestacks at power plants or factories, on bridges, and on natural cliffs or bluffs. Additional nesting pairs are expected in remote, uncensused areas.

In Indiana, the first confirmed peregrine falcon nesting since the extirpation of the original eastern population occurred in 1989 under the Cline Avenue bridge in East Chicago. This site has been in use since that time. In 1990, a pair also nested in Gary on US Steel property. At this time in 1996, there are 5 active nests in Indiana. Three of these are near or along the shore of Lake Michigan (East Chicago, US Steel, and Burns Harbor). There is also a pair in Evansville, but their nest box has been empty since the end of March (Castrale 1996).

Environmental Baseline

The environmental baseline is an analysis of the effects of past and ongoing human and natural factors leading to the current status of the species or its habitat and ecosystem. It includes past and present impacts of all Federal, state, or private actions and other human activities in the action area.

Numerous past and present activities along the IHC have affected the peregrine falcons which now utilize the Cline Avenue bridge. The initial activity, of course, was the construction of Indiana Harbor and the Ship Canal. Work on the outer harbor began in 1901, and construction of the canal began in 1903. The canal was to be 3.5 miles long and connect the Grand Calumet River to Lake Michigan, with the intent of making the entire river and canal system navigable for commercial shipping. However, that did not materialize, and navigation eventually ended at Chicago Avenue. The Lake George Branch also was never completed (Moore 1959).

The Federal navigation project for the IHC was originally authorized in 1910 and was later modified by 10 other River and Harbor Acts (U.S. COE 1966). The Federal project now ends at Columbus Drive, about 0.5 mile downstream of Chicago Avenue, and includes approximately half of the Lake George Branch.

All of the land surrounding Indiana Harbor and the entrance canal, Reaches 1 through 5, is man-made land (lakefill) created by the steel companies (IDNR 1979) (see Figure 1). The entire area along the harbor and canal has been extensively modified by urban and industrial developments. In addition to the steel mills, there are or were oil refineries, chemical companies, foundries, railroad car construction companies, a plaster and wall board construction plant, and various other industries.

Water and sediment quality has long been a significant problem in the Indiana Harbor and Canal area. The majority of the industries and municipalities in the area discharged into the GCR or the IHC. For many years, such discharges were unregulated, and a wide variety of materials, from raw sewage to heavy metals, were discharged into the system. In the mid-1930s, Indiana began to try to control the pollution by ordering East Chicago, Gary, Hammond, and Whiting to abate domestic pollution (U.S. Dept. of Health, Education and Welfare 1965). However, industrial discharges from point and non-point sources remained a serious problem for many years. For example, refinery records from 1949 stated that "there is now as much oil on the surface of the canal that it is becoming a dangerous fire hazard."

The Public Health Service (1965) reported that the GCR's main use was as a receiver of municipal and industrial wastes. The steel mills that discharged to the system were described as the most significant sources of wastes in the Lake Michigan Basin. The chief identifiable constituents in their discharges were oily wastes, waste pickle liquor, phenolic materials, ammonia, cyanide, and suspended solids. Oil refineries discharged oily wastes, phenols, and ammonia. The waterways were characterized by an unsightly appearance in the form of floating debris, oil, discoloration, and turbidity. Channel banks, structures, and boats had a black coating of oil.

Follow-up studies between July 1967 and June 1968 concluded that industrial pollution in the GCR/IHC system had not been greatly reduced since 1965 (F.W.P.C.A. 1968). Concentrations of iron, cyanide, and oil and grease had not declined. The level of industrial pollution in Indiana Harbor itself remained high. Phenol concentrations were still high but were lower than found in 1965 or earlier. Oil was common on the water surface throughout the Harbor. During this period, there had been at least 2 major oil spill incidents within the IHC that had severely polluted these areas and continued out into Lake Michigan and contaminated about 45 miles of shoreline (Johnson *et al*. 1968).

> "Oil pollution is a major problem in the Lake Michigan drainage basin. Discharges from industrial plants and commercial ships, and careless practices in loading and unloading cargos, pollute water in many areas. Oil discharges and spills produce unsightly and unhealthy conditions which affect beaches and recreational areas, contribute unpleasant taste and odor to water, coat the hulls of boats, and in many cases are toxic to fish and other aquatic life. Although oil contamination has been observed in many Lake Michigan areas, this type of pollution occurs principally in the Calumet Area of Illinois and Indiana, at the southern end of the lake" (Johnson *et al*. 1968).

These authors concluded: "These findings strongly indicate the massive oil slick (Sept 17, and Oct 3, 1967) originated in Indiana Harbor and Canal." More than 10 years later, Zapotosky and White (1981) documented that widespread petroleum surface water contamination was still present at almost every sampling point they visited on the GCR/IHC. In their August 17, 1994 report on the Grand Calumet Cooperative Project, EPA and IDEM acknowledged that "the presence of free phase hydrocarbons on the surface water [of the IHC] is a concern" (U.S. EPA and IDEM 1994).

The various petroleum products known to have been discharged into the IHC include: crude oil, diesel fuel, No. 6 fuel oil, heavy vacuum gas oil, unleaded gasoline, HX 40 motor oil, wash oil, lubricating oil, almag wash oil, bunker "C" oil, No. 2 fuel oil, and various waste oils and oil/water mixtures.

The many years of severe water pollution levels just described for the GCR/IHC system have resulted in equally severely polluted bottom sediments throughout the system (Great Lakes Research Center 1968, Gannon and Beeton 1969, U.S. COE 1977, 1980a and b, Romano *et al.* 1977, U.S. EPA 1977, Bremer 1978, Heimann 1980, Hoke and Prater 1980, Zapotosky and White 1981, Environmental Laboratory 1987, Polls 1988, Risatti and Ross 1989, Hoke *et al.* 1993, Ingersoll *et al.* 1993).

In 1989 and 1990, EPA conducted a study of sediment quality and toxicity of the IHC through it's Assessment and Remediation of Contaminated Sediment (ARCS) program. This study revealed high levels of total polycyclic aromatic hydrocarbons (PAHs) (up to 731 mg/kg), arsenic (32-93 mg/kg), cadmium (5.2-24.2 mg/kg), chromium (407-2,610 mg/kg), copper (182-379 mg/kg), lead (396-1,354 mg/kg), mercury (0.7-2.1 mg/kg), nickel (<50-103 mg/kg), selenium (2.0-3.9 mg/kg), silver (0.2-7.1 mg/kg), zinc (2250-7960 mg/kg), 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (73-130 ng/g) and polychlorinated biphenyls (PCBs) (3-43 mg/kg) (Ingersoll *et al.* 1993). In addition, these sediments contain high volatile solids, ammonia, cyanide, manganese, phosphorus, barium, iron, and aliphatic hydrocarbons. Portions of the sediments have been determined by EPA to be hazardous and subject to regulation under either TSCA (regarding PCB's) or RCRA (regarding benzene).

The Corps has conducted several sediment quality investigations in recent years to support its draft Environmental Impact Statement (DEIS). The Corps' DEIS discusses 2 areas in the IHC dredging project area (transect 6 and transect 13) where sediments contain elevated levels of PCBs (U.S. COE 1995). The deeper sediments at these locations contain higher concentrations of PCBs which will be exposed when the surficial sediments are removed by this dredging project.

Status of the Peregrine Falcon Within the Action Area

In 1989, peregrine falcons were discovered to be nesting under the Cline Avenue bridge over the IHC in East Chicago. Three young birds fledged in mid-June. Both adults were from Midwestern peregrine release programs, but their exact origins were undetermined until the following year, when the falcon was identified as Phoenix, a 1987 release from Fort Sheridan, Illinois, and the tiercel was identified as Floydy from Milwaukee, Wisconsin (Peregrine Falcon Journal 1990).

By late summer, the peregrines (adults and young) were no longer at the nest site. However, both adults were seen perched near the eyrie during the December 31, 1989 Christmas Bird Count. The tiercel was observed periodically in March 1990, and both birds were seen in the vicinity of the eyrie on March 30th.

Because the birds returned and appeared ready to nest, local individuals, under the guidance of Indiana Department of Natural Resources (IDNR) Non-game Wildlife Biologist John Castrale, set up a Peregrine Watch and began "The Peregrine Falcon Journal". This Journal has been kept ever since, and includes records of the observations of numerous Watchers of the birds' behaviors and other wildlife in the vicinity. The nest site is over land, approximately 300 feet west of the bank of the IHC, and not over the water of the canal, and observers can watch the peregrines without too much disruption of the birds' routines.

The peregrine pair had established a nest by April 1990. This nest was in an expansion joint under 1 of the highest parts of the bridge. However, heavy rains in early May washed out this nest because the expansion joint became a drainage pathway for the rain water.

It was feared that the peregrines would not renest at that late date, but they did. This time the nest was safely located on a large ledge under the bridge, not far from the expansion joint but much more protected from the weather. On July 17, 1990, both adults and their 2 young were captured at the nest and banded by Castrale and personnel of The Raptor Center of the University of Minnesota. An unhatched egg was collected from the nest and later analyzed by the USFWS, and blood samples were taken from all 4 birds for genetic tracing purposes (Peregrine Falcon Journal 1990).

On August 5, the first fledgling was seen flying. An observer noted that: "He was wet up to his breast; I believe he had landed in the canal." Later that same day, he was seen on the ground southwest of the nest site. When the observers tried to get it to fly, "It proceeded to hop and hop with short flights -- came down on bank of canal." The next day, this fledgling was found dead on the Cline Avenue Extension bridge (Peregrine Falcon Journal 1990). The remaining fledgling survived and eventually left the area.

In early 1991, both Phoenix and Floydy were back by January and established their nest by the end of March. They again chose the safe, covered ledge under the bridge. Floydy was found dead under the bridge on May 14, 1991 and his body was collected (Peregrine Falcon Journal 1991). His remains were sent to the USFWS's National Wildlife Health Center at Madison, Wisconsin.

On May 22, 1 female chick was banded at the nest. An unhatched egg was collected and sent to the USFWS for analysis (Peregrine Falcon Journal 1991). The chick subsequently fledged. An unknown, banded adult male was also observed in the eyrie area later in the summer of 1991.

The first peregrine sighting in the eyrie area in 1992 occurred on January 23. A female and an unbanded male were observed together and appeared to be well bonded (Peregrine Falcon Journal 1992). This was a new male, since the one seen in late summer 1991 was banded. It was later determined that the female was also new; what happened to Phoenix is unknown.

This pair nested in the same ledge area as the previous birds, and 4 young were produced, with no unhatched eggs. One fledgling male was killed on June 24 when it flew into a truck on the Cline Avenue Extension bridge while chasing a pigeon (Peregrine Falcon Journal 1992). The body was recovered and given to the USFWS for analysis.

For the 1993 nesting season, the 1992 female returned and has remained to the present, being known as Egore (hacked in Madison, Wisconsin in 1990). The tiercel was again a new bird, this one being banded. He was determined to be Kennicott, who was hacked in 1990 at Glen Ellyn, Illinois (Redig and Tordoff 1995). This pair produced 4 young and 1 unhatched egg. The egg was given to the USFWS for analysis. The hatchlings were banded on June 3, 1993, and blood samples were also taken (Peregrine Falcon Journal 1993).

The young fledged about June 23, and 1 young female was killed on the Riley Road exit ramp off the Cline Avenue Extension bridge on June 26. A second fledgling died while being held for observation after being retrieved from the ground near the nest site (Peregrine Falcon Journal 1993). The remains were sent to the National Wildlife Health Center.

Egore was observed at the eyrie site during the Christmas Bird Count on January 2, 1994. For the 1994 nesting season, a monitor camera was installed which looks into the nesting ledge. Although it does not continuously record activity, it can be turned on by the Peregrine Watchers to check on nesting activity and count the eggs and young. By March, both birds were observed in the area. Kennicott was found injured near the nest site on March 24, and he later died (Redig and Tordoff 1994). According to Castrale (1994), a new tiercel was believed to have fatally injured Kennicott. He was first seen at the eyrie on March 29, and was later identified as Marty, who was fledged wild at the King Power Plant, Bayport, Minnesota, in 1992. Egore was already incubating 3 eggs on March 29, and ultimately had a clutch of 5 eggs. Whether or not both tiercels were the fathers is unknown since the blood samples of the young have not yet been studied.

All 5 eggs hatched by May 20, and all 5 young fledged in mid-June. The 2 males and 3 females survived through the summer and moved on to other territories. The Raptor Center reports that "5 egg clutches have been reported before, but not all hatched, much less fledged." This was listed as "a record for the new Midwest population" (Redig and Tordoff 1994).

Both Marty and Egore were observed at the eyrie site during the Christmas Bird Count on December 31, 1994. Based on observations through the monitor camera, it appeared that 4 eggs were laid by March 29, 1995. Observers believed that 3 young were hatched by May 1, but only 2 young were banded in late May and later successfully fledged by early June (Peregrine Falcon Journal 1995). No body of a third hatchling was ever found, so there may have been only 3 eggs. The unhatched egg was sent to the USFWS for analysis.

The 2 peregrine adults were again observed in the eyrie area during the December 30, 1995 Christmas Bird Count. Based on the plumage and partial band numbers, it is believed that they were Egore and Marty. However, another bird was seen in the area on several occasions since nesting began in March. A dead tiercel, released in Iowa in 1992, was found on Inland Steel property recently, and may have been the third bird (Castrale 1996). Using the monitor camera, there appeared to be at least 3 eggs, and the first young hatched by the end of April. The hatchlings are tentatively going to be checked and banded on May 21, 1996.

The Peregrine Falcon Journal (1990 through 1995) provides a great deal of information on the behavior of the peregrines around the eyrie. It also lists identified food species and other species of birds observed in and along the IHC. Figure 1 shows the large-scale locations of the nest site in relation to the IHC, steel mills and proposed CDF. Figure 2 shows the location of the nest in relation to various bridge tiers and other local landmarks. The references in the Journal relate peregrine activities to these landmarks.

Throughout the 6 years of records in the Peregrine Falcon Journal, there are numerous references to the birds sitting on or feeding on structures associated with the bridge and/or its tiers in the IHC. Favorite spots appear to be the horizontal portions of the stormwater drain pipes, various brackets on the pipes, or ledges on the bridge. Peregrines prefer flat surfaces for perches, rather than fence posts and small tree branches like other raptors use (Castrale personal communication). A few typical references include:

- April 19, 1990: "Saw male on drain pipe on east column in canal."
- May 6, 1990: "Male back on light over canal."
- August 8, 1990: "Finally found young bird sitting on tier by canal eating a pigeon - I knew it was a pigeon because he dropped a wing off the tier."
- March 26, 1991: "Male perching on pipe over canal."
- May 1, 1991: "female on pipe parallel with the ground between first and second pilings over canal"
- April 7, 1992: "Found falcon on drain pipe at canal."
- June 23, 1992: "Adult male and one juvenile on drain over canal."
- April 4, 1993: "Female left nest site toward LTV, circled under bridge toward canal. Rose and landed on a clearance light over canal."
- May 21, 1993: "As I moved about some more, I noticed that one of the parents is perched on the canal drain pipe (north). I suspect it is the male. (Typist concurs as this seems to be one of his favorite perches)."
- June 9, 1993: "Female flew to cross pipe over canal"
- August 16, 1993: "Peregrine spotted perched on south blue warning light over canal and suspended from Cline Avenue."

- September 12, 1993: "I spotted the adult male perched on the top brace of the drain pipe of the north canal tier."
- May 11, 1994: "Male left site, flew to south canal column, top rung."
- June 7, 1994: "Female flew toward canal, male followed. Female landed on bracket of first column nearest canal."
- July 6, 1994: "All young are flying better today, diving low and playfully south of canal. At 5:15 pm adult male (?) flew like a bullet from north under Cline with kill in its talons and landed on horizontal pipe east side of Cline over canal."
- May 30, 1995: "One of the adults was next seen on the light that extends down from Cline Ave. (Over the shipping canal)."
- June 13, 1995: "Second adult spotted on the top rung of the east bound canal tier pipe."

There are also references to sitting on debris in the canal or bathing in the canal:

- July 8, 1992: "One juvenile (female? - large) found sitting on an empty wire spool on the canal mud flat under the bypass. It flushed off to the south, staying low along the canal until it was out of sight."
- July 22, 1992: "Falcon dove toward the canal's surface behind the channel bulkheads."
- May 21, 1993: "What I thought was the male parent was the female. She left the drain pipe and flew down to the shoreline not 20 yards from me. For next 5-10 minutes, she proceeded to take small drinks of water and then moved further into the water so her feet were submerged. Then she began to bathe. She stuck her head under water several times and shook it about. She squatted down to wet her under feathers. All the while looking about for danger. It was magnificent."

Food choices have also been described:

- April 8, 1990: "Pigeons were flying and male attacked one in mid-air and went to ground to devour it at 4:40."
- May 21, 1990: "Peregrine flying from canal toward Riley, may be female. Falcon circles the area, crosses the canal, makes a pass at blackbirds on canal edge, then flies to perch on Inland building catwalk."
- July 11, 1990: "Male flies in from east with bird (looked like grackle), lands on Riley Road off ramp column west of graffiti tier."
- April 17, 1991: "Falcon spotted on ledge north of graffiti column, eating a recent kill (pigeon)."
- May 12, 1991: "noted fairly fresh remains from kill (blue jay head on ground)."
- May 20, 1991: "She left her perch and attacked a gull - taking the gull all the way to the ground."

- March 7, 1992: "Male spotted atop first tier west bound lane of Cline, feeding. (Remains of mourning dove on ground.)"
- April 11, 1992: "Female takes off, flies over to yellow building, takes pigeon just above building, goes down briefly, then flies toward bridge with kill."
- May 7, 1992: "Male takes flicker in field between Dickey Road and Cline. Takes it to a cross-beam above canal and eats it all."
- May 25, 1992: "Male pursued small prey (perhaps starling), missed. Female joined pursuit, both circling high to southwest. Glare from sun on clouds caused me to lose sight - they must have been ranging out over the ECI property."
- June 30, 1992: "Female seen making kill over canal with two young following around her."
- July 15, 1992: "After flying up to repeatedly attack a ring-billed gull over the canal, it forced the gull to the canal surface, flew off to the top of a column on the east side of the canal."
- February 4, 1993: "[Male] flew out over canal, landed on high tension tower closest to canal (USG), launched unsuccessful attempt at prey (duck size)."
- March 28, 1993" "Just south of graffiti tier found fresh blue jay kill, also found pigeon feathers ... Found feathers that may have belonged to a duck."
- April 4, 1993: "Female turned toward south and immediately went east again after a gull and followed it over the canal, under the bridge - appeared to hit the gull, but came up empty, came back west over canal north toward LTV."
- July 4, 1993: "Immature bird flies from top of Riley Road column to northeast over the canal, dives on seagull, misses, and returns to top of same column."
- July 16, 1993: "Spotted a peregrine over George Lake as two blackbirds harassed the peregrine very high in flight. The peregrine swiftly clawed, grabbing a blackbird in his talons, flying east with it."
- May 4, 1994: "Parked by west recess - checked ground - found primary feathers from Yellow Shafted Flicker and Blue Jay at base of graffiti column."
- May 11, 1994: "Female leaves nest site after some vocalization, banks up over Cline Avenue, drifts down canal towards ECI property."
- June 9, 1994: "Within five minutes, the female returns with what appears to be a blackbird in her clutch."

Other birds observed in the area and along the IHC include the following:

- April 9, 1990: "Also seen: 2 red tailed hawks, 1 American egret, 2 red shouldered hawks, 2 accipiters, 7 crows, 2 buteos."
- April 19, 1990: "Saw red tailed hawk. Dozens of seagulls over canal. Left after noxious smell made us sick."
- April 22, 1990: "Robins, starlings and flickers in area. Black-crowned night heron flew over 9:00 am."
- April 27, 1990: "Many gulls and some mallards."

- May 5, 1990: "Other species seen: white winged scoter in canal, tree swallow, gulls."
- June 8, 1990: "Other birds about: Gulls, Rock Doves, Mourning Dove, a Black-crowned Night Heron fishing the east bank of canal, many nesting Starlings in overpass recesses, a Bluebird, a Kestrel hunting from tall pole west of yellow building, and 25 geese ? in vee southbound over East Chicago."
- June 9, 1990: "Other species seen: two Ring-necked Ducks in canal south of overpass."
- June 11, 1990: "Other birds: Gulls, Starlings, Red-winged Blackbird, Swallows, Pigeons, Kestrel, Crow, and Robin."
- May 1, 1991: "Also saw hawks, great blue heron."
- April 17, 1992: "Observed belted kingfisher over river and three (3) dark-eyed juncos feeding in weeds north of overpass."
- April 24, 1992: "Spotted kestrel, two (2) crows, two (2) hermit thrushes. No falcons."
- May 12, 1992: "Saw white-throated sparrow, swainson thrush and red-breasted grosbeak."
- May 30, 1992: "Saw pair of great blue herons following canal."
- March 7, 1993: "Saw cormorant fly over canal. Did not land. Two (2) male mergansers in canal."
- April 15, 1993: "Walked to canal - saw cormorant and buffleheads."
- June 9, 1993: "Other species sighted: numerous gulls, starlings, (1) rock dove, (1) mourning dove, (2) tree swallows, mallard ducks (male and female) in pond south of roadway."
- June 26, 1993: "Other birds spotted include indigo bunting, goldfinch, house sparrow, red-winged blackbird, starlings, gulls, and American crow and field sparrow."
- July 7, 1993: "Great blue heron flies in from northeast low, circles over canal twice and heads back in a northeasterly flight. Offspring leaves tier and chases heron and does aerial dance with heron in a mock hunting chase. Unbelievable!! Offspring attempting to hone his hunting skills; but should stick to smaller game for awhile."
- July 16, 1993: "Indigo bunting has nest in area as do goldfinch and song sparrow. Two (2) double crested cormorants landed in ship canal for one minute, flew up, circled, and headed south."
- May 10, 1994: "Drove to canal - gulls trailing tug on canal, that was leaving a very busy wake."
- June 13, 1994: "Male and female flew after green heron. Seemed like a protection of territory more than desire for a meal... Eight (8) cormorants flew through."
- October 26, 1994: "Flushed belted kingfisher down by canal."

These sightings serve to not only show what additional prey species are available to the peregrines in the area, but also what additional bird species are making use of habitats along the IHC.

Although the adult peregrines seem to generally accept the presence of humans near the nest site during the incubation period, during the hatching and fledging periods they appear to be much less tolerant. The Peregrine Watchers have described the following:

- June 6, 1992: "As Andrea walked past nest toward canal, female flew over to direction of nest, circled over where Andrea was walking, then flew back and landed on graffiti column. When we both headed toward canal, male flew in from the west of graffiti tier toward nest, both male and female flew into nest. Male immediately flew out and landed on graffiti tier. When we looked up at columns, both birds were at the top of separate columns watching us. As we walked around the site, they moved around tops of columns so they could keep us in view at all times. They seemed quite concerned with us being there. We heard the young in the nest, but were unable to see them."
- June 19, 1993: "Male on third graffiti column - spotted while exiting on Riley exit ramp. Set up scope - three (3) young spotted right edge of nest site. Female not in sight. Male moved to west side of column to watch us - I presume. Female (unnoticed upon arrival) on graffiti column, left column, flew in arc under Cline to Inland side of canal - lost sight of her - she reappeared, circled over parking area - lost sight of her again. Male still watching us. Female circled parking area, landed center graffiti column, vocalized."
- August 1, 1993: "Immediately, observer notices adult female peregrine falcon resting on northeast corner of column located directly north of graffiti column. Left wing is draped over side of tier. Peregrine seems to be torn between a strong desire to preen and trying to keep a cautious eye on observer. Several series of long screeches are heard. Every time observer moves, even slightly, falcon's head turns downward to watch me!"
- June 9, 1994: "Upon my arrival, the male falcon has taken flight. He appears to be giving me a good looking over as he circles overhead twice. My position is just west of the graffiti tier. ... A quick check outside the car reveals the male has left his perch again. Within minutes he returns flying out of the southwest and flies overhead within 20-25 feet. It's the male who is active today. On Monday it was the female. Three chicks are now visible from the nest."
- May 30, 1995: "Soon after the first adult left, the second adult left its perch too. Both were gone a short while only, but both were gone at the same time for sure.

  They couldn't have been far because they came back within 5-10 of leaving. Perhaps my presence brought them back as I was walking near the graffiti tier. ... As I saw the adult on the light by the canal, he/she must have seen me too. While only ~ ten feet east of the graffiti tier, on the south road, not near the nest at all, the adult immediately flew back to the graffiti tier, east bound, south column. The bird flew in low 10-15 feet, seemed to take a good look at me and perched about half way up the south column on a wooden slat. Once there he/she gave a few `cackling calls' as I proceeded to retreat to the car."

Peregrine falcons appear to have developed a high degree of nest site fidelity for this ledge under the Cline Avenue bridge. The nest site has been occupied for 8 consecutive years by 2 different falcons and 4 different tiercels, with rapid replacement of an individual when a resident disappears. They hunt throughout the area, including over the canal, the steel mills, Wolf and George Lakes, and the ECI property. They also have been documented to have occasional direct contact with the canal waters.

IHC Contaminants of Concern for the Peregrine Falcon

With regard to the peregrine falcon, the previously described contaminant problems can be categorized into 3 classes of "contaminants of concern" in the water column and sediments of the IHC: 1) heavy metals; 2) persistent, bioaccumulating polycyclic halogenated aromatic hydrocarbons (pHAHs), which includes PCBs, dioxins and furans; and 3) petroleum products, from crude oil to highly refined products, which contain polycyclic aromatic hydrocarbons (PAH) and aliphatic hydrocarbons.

There are 3 primary pathways in which the contaminants of concern are made available to biological resources utilizing the IHC: 1) bioaccumulation; 2) biomagnification; and 3) direct physical contact with petroleum products. **Bioaccumulation** is defined as the net uptake of a contaminant by an organism from food and water. This is the pathway by which peregrine falcon prey make contaminants that are present in the sediment of the IHC (such as heavy metals, pHAHs, and PAHs) available to peregrine falcons. **Biomagnification** is defined as the biological sequestering of chemicals from low concentrations in the environment to high concentrations in the target organism through the food chain. Peregrine falcons, being at the top of the food chain, can biomagnify contaminants (pHAHs and perhaps heavy metals) to potentially toxic levels in their organs, organ systems and/or eggs. **Direct physical contact** with petroleum products is extremely hazardous to all species of wildlife, including peregrine falcons and especially their prey.

There are many pathways of oil to the surface waters of the IHC which can then lead to environmental exposures and direct physical contact. The most prominent of these are: surface runoff from oil-contaminated areas; storm sewer discharges of infiltrating, contaminated groundwater; direct discharges of contaminated groundwater from properties adjacent to the IHC; unpermitted releases from point sources; and, resuspension of sediments which causes renewed releases of oil to the surface.

Impacts to Peregrine Falcons Associated with Contaminants of Concern

Heavy metals, pHAHs, and petroleum products including PAHs are present in the IHC sediments at levels that have been shown to adversely impact aquatic ecosystems (Long and Morgan 1990, Hoke *et al.* 1993, Ingersoll *et al.* 1993). Although adverse impacts to avian wildlife have been associated with each of these contaminant classes under various conditions, the potential for harm is related to the actual exposure scenario which we will discuss for the IHC.

Heavy Metals

In extreme situations, heavy metals can adversely impact avian wildlife. Irrigation drain water carrying high concentrations of selenium from the San Joaquin Valley caused serious embryonic deformities and mortality in a wide range of marsh nesting birds (Ohlendorf *et al.* 1986, Ohlendorf *et al.* 1988). These effects were documented throughout the aquatic food chain (Ohlendorf and Skorupa 1989). This type of heavy metal adverse impact has not been associated with Great Lakes sediment contamination, and is not a concern for peregrine falcons at the IHC.

Lead poisoning has been diagnosed in peregrine falcons on rare occasions (NWHRC 1995), and most likely was related to the ingestion of prey containing lead shot pellets. Concentrations of lead in the liver of a peregrine falcon fledgling from the project area in 1992 were non-detectable at 0.13 parts per million (ppm), more than an order of magnitude lower than the clinical LD_{50} of 6.0 ppm in birds. It is unlikely that existing environmental lead concentrations in the peregrine falcon prey base at the IHC pose any potential risks for adverse effects to peregrine falcons.

Mercury has also been studied with regard to its impacts to birds (Heinz 1979, Wiemeyer *et al.* 1984, Wiemeyer *et al.* 1988) because of its tendency to accumulate in tissues and eggs more readily than most other heavy metals. The USFWS's (USFWS 1995b) Biological Opinion regarding the promulgation of the Water Quality Guidance for the Great Lakes System pursuant to Section 118 of the Clean Water Act (which has been commonly referred to as the Great Lakes Water Quality Initiative [GLI]) agreed with EPA on a Lowest Observed Adverse Effect Level (LOAEL) for mercury for reduced hatching success of 0.80 $\mu g/g$ (Heinz 1979, U.S. EPA 1993). The USFWS calculated a protective No Observed Adverse Effect Level (NOAEL) of 0.0080 $\mu g/g$, wet weight, which would be applicable to peregrine falcon eggs from the IHC.

Effects of Heavy Metals on Peregrine Falcons at the IHC

Failed peregrine falcon eggs from the project area have been found to contain a mean concentration of mercury of 0.021 ppm, wet weight, with a maximum of 0.33 ppm (USFWS unpublished) (Appendix A). There may be potential risks for adverse effects to peregrine falcon eggs associated with mercury in the IHC under existing conditions without the Corps dredging project.

pHAHs

Impacts to avian wildlife associated with pHAHs has been well documented (Kubiak *et al.* 1989, Tillitt *et al.* 1992, Geisy *et al.* 1994, White and Seginak 1994, Hoffman *et al.* 1996, Henshel *et al.* submitted 1996). For purposes of this biological opinion, we discuss the toxicity of pHAHs in terms of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxic equivalents (TEq) (see Safe 1987, Safe 1990, and USEPA 1994 for a more in-depth review).

Recent studies have documented pHAH concentrations in peregrine falcon eggs. Henny *et al.* (1994) reported total PCBs in peregrine falcon eggs from Russia ranging from 3.0 to 21.0 ppm (mean = 12.13 ppm) with TCDD TEqs ranging from 410-2,600 ppt (mean = 1,501 ppt). Peregrine falcon eggs in California were reported to contain 1.4 to 13.0 ppm (mean = 4.8 ppm) with the mean TCDD TEqs 120 ppt. Unpublished data (USFWS and National Biological Service) for New Jersey peregrine falcon eggs contains TCDD TEqs at levels similar to those reported for both California and Russian peregrine falcons (Tom Augspurger, pers. com).

Previous Biological Opinions (Columbia River TMDL Implementation, USFWS 1994; GLI Implementation, USFWS 1995b), have identified a TCDD No Observed Adverse Effect Level (NOAEL) based on the most critical and sensitive life stage, the developing embryo. Research by Henshel *et al.* (submitted 1996) produced a NOAEL for the chicken embryo of 100 pg/g, based on lethality. To account for sublethal effects, the NOAEL is reduced by a magnitude of 10 to 10 pg/g (USFWS 1994). The NOAEL must also protect for sensitive individuals. Thus, the NOAEL must be further reduced by a factor of 10 to 1 pg/g TCDD, wet weight, in bird eggs. Similar NOAELs were determined by Verret (1976), Cheung *et al.* (1981), and White and Seginak (1994). Additionally, these Biological Opinions identified a NOAEL for total PCBs in bird eggs based on a variety of both field and laboratory studies. A value of 4 μg/g PCBs represents the NOAEL in bird eggs for lethality. An uncertainty factor of 10 for sublethal effects and an additional factor of 10 for protection of individuals results in a protective NOAEL of 0.04 μg/g, wet weight, in bird eggs (USFWS 1994, USFWS 1995b).

Effects of pHAHs on Peregrine Falcons at the IHC

Analysis of failed peregrine falcon eggs from Lake County, Indiana from 1990 through 1993 indicates they contained 4.3 to 11.17 ppm total PCBs (wet weight), with a mean concentration of 8.5 ppm (Appendix A) (USFWS unpublished). Comparing other peregrine falcon egg data from Ohio, Minnesota, Michigan and Iowa from 1988 to 1995 (USFWS unpublished) to these results, only 3 were higher than the *average* concentrations for the Lake County falcon eggs. These PCB concentrations were similar to the California peregrine residues; however, the TCDD TEqs averaged 43 ppt (Appendix A). This calculated TCDD TEq does not quantify the dioxin or furan congeners present in these peregrine eggs.

Based on these literature NOAELs, it is possible that peregrine falcon egg hatching success has been impaired due to PCBs in the IHC under existing conditions without the Corps dredging project. In addition, it is possible that the proposed dredging project could cause increases in PCB bioavailability and food chain transport as a result of resuspension of contaminated sediments and the exposure of more highly contaminated sediments. This could significantly increase the risk of peregrine falcon egg hatching failure.

Petroleum Products and PAHs

Physical contact with petroleum can cause both acute mortality and chronic sublethal impacts to both birds and/or their eggs. Physical contact of birds to spilled oil has the primary effect of fouling the plumage (NOAA 1988). Oil causes disruption of the fine structure of the small strands that form the feathers, causing loss of their water-repellent characteristics. The plumage of oiled birds also becomes matted, allowing water to penetrate to the body surface, which results in chilling and hypothermia as well as a loss of buoyancy. The ultimate cause of death of heavily oiled birds is believed to be hypothermia in most cases (Fry and Lowenstine 1985). Presumably those species that are able to leave the water and thereby reduce or avoid hypothermia (such as gulls, wading birds, and some waterfowl) are more tolerant to oil than more pelagic species (NOAA 1988). These changes in behavior can increase the birds' susceptibility to predation. Oiled birds that are able to maintain adequate body temperature may experience severe metabolic drain of fat and muscle tissues (Lambert and Peakall 1981, Dan Sparks pers. obs.). Increased metabolic activity, combined with decreased feeding, may result in death from starvation, and loss of buoyancy may result in drowning (Holmes and Cronshaw 1977). However, it can be difficult to quantify the importance of these effects in situations of heavy oiling because most birds die quickly as a result of hypothermia (NOAA 1988).

Oiled birds can readily ingest petroleum (oil or refined product) during preening. The effects of ingested oil include anemia, pneumonia, intestinal irritation, kidney damage, altered blood chemistry, decreased growth, and impaired osmoregulation (Crocker *et al.* 1974, Holmes and Chronshaw 1977, Miller *et al.* 1978, Ohlendorf *et al.* 1978, Stickel and Dieter 1979, Peakall and Gilman 1980, Peakall *et al.* 1981, Clark 1984, Fry and Lowenstine 1985). In general however, the importance of these effects is at best unclear when dealing with heavy crude oil:

> "It is not clear to what extent these physiological effects contribute to mortality following oiling, given the rapidity of death from hypothermia or drowning. It is evident, however, that ingestion of oil can contribute to the overall impacts of oil spills" (NOAA 1988).

Another sublethal physiological impairment associated with the uptake of oil in birds is reduced reproductive fitness. Adults that are exposed to sublethal doses of oil and then ingest it may produce fewer eggs (Grau *et al.* 1977) or cease laying eggs (Hartung 1965). These effects have not been observed in all species tested, but the available data indicate that there is a potential for oiled birds to experience a decline in egg production (Coon and Dieter 1981). The viability of eggs produced following ingestion of oil also may be reduced (Grau *et al.* 1977, Ainley *et al.* 1981). It has been suggested that the significance of these reproductive impairments are underrated:

> "Managers should be conscious of these [reproductive] effects, which though less apparent in nature, may in fact be more serious than the infrequent kill-offs occurring after catastrophic spills. For it may

> well turn out that a chronic reduction in reproductive success may be the most significant effect of oil pollution on populations of aquatic birds" (Biederman and Drury 1980).

Studies done on the reproductive success on harlequin ducks and other sea birds in years following the *Exxon Valdez* incident has confirmed these suspicions (Patten 1993, Piatt 1993).

Avian reproduction can also be severely impacted by the adverse effects of oil on bird eggs. Breeding birds may pick up small quantities of oil on their plumage, feet, or nest materials (O'Connor 1967, Birkhead *et al.* 1973, Gochfeld 1979). Upon returning to their nests, adults can transfer the oil to the surface of their eggs during incubation. Contamination of eggs in this manner has been observed following actual pollution incidents (Gladstone 1929, Rittinghaus 1956, Birkhead *et al.* 1973) and confirmed by experimentation (Hartung 1965, King and Lefever 1979, Albers 1980, Lewis 1982). The probability of egg oiling is enhanced when birds may be exposed repeatedly at a chronic source, and there is a significant potential for reduced reproductive success in oiled birds (Lewis and Malecki 1984).

Laboratory studies have revealed as little as 1 µL of crude or refined oil applied to the surface of fertile eggs of various species caused embryonic death due to direct toxicity (Albers 1977, Szaro and Albers 1977, Dieter 1977, Hoffman 1978, Coon *et al.* 1979, Eastin and Hoffman 1978, Albers 1978, Hoffman 1979, Hoffman 1990). Additional field studies supported these findings (King and Lefever 1979, McGill and Richmond 1979, White *et al.* 1979, Lewis 1982). Egg oiling can stunt embryonic growth, induce teratogenic malformations, and decrease hatchability (reviewed in Easin and Hoffman 1978, Stickel and Dieter 1979, Ellenton 1982). The degree to which these effects are manifested depends on the amount of oil transferred to eggs (Albers 1977, Hoffman 1978, Szaro *et al.* 1980), the stage of incubation at which the contamination occurs (Szaro and Albers 1977, Albers 1978), and the composition of the oil (Szaro *et al.* 1978, Ellenton 1982). Exposure during the early stages of incubation are most toxic (NOAA 1988). Spilled oil may remain lethal for several weeks (Szaro *et al.* 1980) or may increase in toxicity over time (Macko and King 1980).

Couillard (1989) documented nearly 100 percent mortality at incubation day 8 in chicken eggs with a dose of 5 µL of Louisiana crude oil, and only 32 percent mortality with 12 µL on incubation day 9. This equates to a 16-fold decrease in sensitivity from day 8 to day 9. Number 2 diesel fuel caused significant mortality to mallard (*Anas platyrhynchos)* eggs at just 1 µL/egg (Albers 1977). Bunker C oil is quite toxic to mallards (Szaro 1979) at 3.3 µL/egg (Hoffman and Albers 1984). Industrial waste oil was found to be quite toxic to mallard embryos, with an LD_{50} of 3.2 µL/egg and with some teratogenic effects in survivors (Hoffman and Albers 1984). Ellenton (1982) fractionated Prudhoe Bay crude oil and Number 2 fuel oil and determined that the fraction with 2- and 3-ring aromatics was quite embryo toxic compared to the aliphatic fraction when injected over the air sac membrane of chicken eggs. Walters *et al.* (1987) reported that the aromatic fraction of Prudhoe Bay crude oil was responsible for most of the embryo toxicity when topically applied to chicken eggs, causing the induction of hepatic microsomal enzymes. The aliphatic fraction was found to be essentially inactive. Oil-induced mortality has been investigated in a wide range of species, including the following: Common eider (*Somateria mollissima*) (Szaro and Albers 1977), herring gull (*Larus argentatus*), greater black-backed gull (*Larus marinus*) (Coon *et al*. 1979, McGill and Richmond 1979, Lewis and Malecki 1984), laughing gull (*Larus atricilla*) and sandwich tern (*Sterna sandvicensis*) (White *et al*. 1979).

Despite the frequency of exposure of wildlife to petroleum pollutants, attempts are seldom made to detect these materials in tissues (Hall and Coon 1988). Once ingested by animals, petroleum hydrocarbons are metabolized and tend to mix with the many similar compounds normally present in tissues, making it difficult, but not impossible, to draw meaningful conclusions from the seemingly incomprehensible analytical reports (Hall *et al*. 1983, Hall and Coon 1988). Naf *et al*. (1992) injected chicken eggs with 0.2 ppm PAH mixture on day 4 of incubation, and on day 18 of incubation the eggs were chemically analyzed to find 94 percent of the injected PAHs had been metabolized. This is consistent with Hall and Coon's (1988) assertion that: "aromatic compounds are not commonly found in clean tissues and, when they are, tend to be present in very small amounts." This is important to keep in mind as the site-specific avian wildlife analytical data for IHC is discussed in the following text.

Effects of Petroleum Products and PAHs on Peregrine Falcons at the IHC

There are many surface seeps of petroleum products (crude or waste oil primarily) at the proposed confined disposal facility located on the Lake George Branch of IHC (Photograph 1, Appendix B). During discussions that were part of the informal consultation, the Corps staff had mentioned that while visiting this site, they found evidence of adult avian mortality associated with these pooled oil areas. This is consistent with avian mortality evidence collected in California (Thomas 1971), Colorado (Tully and Boulter 1970), New Mexico (Grover 1983), Wyoming (Esmoil 1991), Oklahoma, Texas (Flickinger 1981), and Indiana (Dan Sparks unpublished). Surface oil seeps, regardless of how small they are or where they occur, are extremely hazardous to wildlife. This site, and other facilities with similar land use histories, are underlain with petroleum-contaminated groundwater which are a source of petroleum contamination to the surface waters of IHC.

The proposed confined disposal facility is located adjacent to the Lake George Branch of IHC, just west of Indianapolis Boulevard. Photographs 2-5, and 8-11 (Appendix B) document the ever-present nature of the petroleum surface water contamination indicative of the IHC. For reasons previously discussed, this area is hazardous to waterfowl.

Double-crested cormorants (*Phalacrocorax auritus*) are one of many species of piscivorous wildlife that can be found in the IHC year-round (Photograph 6, Appendix B). Hundreds of waterfowl, mostly lesser scaup (*Aythya affinus*) (Photograph 7, Appendix B), can also by found in the IHC from December to

March each year (Custer *et al.* 1996). Field observations indicate that whenever sediments were disturbed in the IHC by wading, motor boat propeller, etc., sheens of petroleum products would appear (Photograph 12, Appendix B).

Birds have died as a result of direct oiling in the IHC (Photograph 13, Appendix B). We have documented oil-related mortality in the following species: black-crowned night heron (*Nycticorax nycticorax*), mallard, great blue heron (*Ardea herodias*), blue-winged teal (*Anas discors*), herring gull and ring-billed gull (*Larus delawarensis*).

Avian wildlife, on being exposed to petroleum in the IHC, have been observed exhibiting the sublethal effects previously described. Incidental oiling has been documented in the following species in the IHC and GCR: ring-billed gull (Photograph 14, Appendix B), great egret (*Casmerodius albus*) (Photograph 15-16, Appendix B), mute swan (*Cygnus olor*), common merganser (*Mergus merganser*), Canada goose (*Branta canadensis*), belted kingfisher (*Megaceryle alcyon*), domesticated duck, mallard, and herring gull (Dan Sparks, pers. obs.). These slight oiling incidents are not likely to be lethal to the adult birds, but this type of incidental oiling could easily cause mortality to its eggs if oil was transferred to them.

In more extreme cases, sublethal impacts can lead to acute mortality. We documented a mute swan that had succumbed to oiling on the GCR in 1991 (Photograph 17, Appendix B). Being too weak to flee when approached (a prime target for predators), eventually this bird was retrieved and successfully rehabilitated by concerned citizens. In August 1992, a domesticated mallard was observed on the GCR exhibiting another life-threatening hazard associated with sublethal oiling - the loss of buoyancy (Photograph 18, Appendix B). This bird had entered the water just minutes before this photograph was taken. As it swam ahead of us, it began riding lower and lower in the water until it could no longer stay above the water's surface. At that point, the bird began a series of dives, swimming under water some distance, popping up for air, and diving again until it reached the shore.

The most frequently documented sublethal oiling effect in the IHC and GCR is associated with flight impairment, which is a very common problem for diving waterbirds. Photographs 19-26 (Appendix B) were taken in June 1995, documenting flight impairment associated with surface sheens of oil on the GCR. The photographs are of the GCR near the mid-point of the Gary Airport. Photograph 19 shows dozens of double-crested cormorants perching and loafing on a snag in the middle of the river. As we continued to approach this perch site, most birds abandoned the perch and began to fly away. We continued to pursue all non-flighted cormorants to determine if they could attain flight. Many could not, even after many attempts.

Flight impairment has been observed to be a major problem in many other avian wildlife species of the IHC, including: double-crested cormorant (June 1994, June 1995) (Photographs 19-26, Appendix B), common merganser (April 1993, May 1995) (Photograph 27-30, Appendix B), Canada goose (May 10, 1995) (Photograph 31, Appendix B), barn swallow (May 10, 1995) (Photograph 32-35, Appendix B), blue-winged teal (April 6, 1993), wood duck (*Aix sponsa*) (June 1993), and white pelican (*Pelacanus erythrorhynchos*) (January 7, 1993) (Dan Sparks, pers. obs.). Although Canada geese do lose their ability to fly each year during their molting period, this occurs much later in the year after nesting is complete.

Flight-impaired birds are a potentially significant pathway of oil transfer to peregrine falcons and their eggs. NOAA (1988) stated that "consumption of oiled prey is a concern for peregrine falcons. Several peregrines were oiled in the ARCO *Anchorage* spill in Puget Sound in 1985." Based on the hundreds of days of field observations made by USFWS biologists in the GCR/IHC area since 1990, the effects of oil on avian wildlife we describe are common in this area. On April 20, 1993 a peregrine falcon was observed chasing an injured (oil-impaired) blue-winged teal near the junction of the IHC and the GCR (Dan Sparks, pers. obs.). Therefore, it is reasonable to conclude that peregrine falcons are taking oil-impaired prey, at least occasionally. In addition, it has been documented that peregrine falcons will bathe in the IHC (May 21, 1993 Peregrine Falcon Journal). We can reasonably conclude that peregrine falcons are being exposed to the potentially harmful effects of petroleum products and PAHs in the IHC.

Studies conducted by the USFWS and the National Biological Service (NBS) have documented the uptake of PAHs in barn swallows (*Hirundo rustica*) and lesser scaup (nesting and wintering, respectively) in the IHC (USFWS unpublished) (Appendix C). Both the barn swallows and the lesser scaup at the IHC bioaccumulated statistically significant levels of PAHs relative to reference samples. The induction of hepatic microsomal enzymes was elevated relative to controls for the IHC lesser scaup (Custer *et al.* in prep.) which is consistent with Walters *et al.* (1987) (previously discussed). Both these species are known prey species of the peregrine falcons nesting at the IHC. On March 4, 1993 as we were collecting lesser scaup from the IHC for food habits and contaminant analyses, we observed a peregrine falcon strike a lesser scaup in mid-air over the canal immediately north of Columbus Drive (Dan Sparks, pers. obs.). The peregrine was unable to retain its hold on the scaup, and the scaup fell to the canal and dove under the water. The scaup never resurfaced, but the peregrine falcon perched on a nearby petroleum storage tank adjacent to the canal for several minutes. We can reasonably conclude that peregrine falcons are being exposed through their food to the potentially harmful effects of PAHs in the IHC.

To further assess the potential for adverse reproductive impacts to avian wildlife utilizing the IHC, the USFWS investigated barn swallows nesting on Columbus Drive in 1993 and 1995. Our preliminary analysis of data collected indicate that in comparison to other sites studied (both contaminated and uncontaminated):

1) there is a much higher incidence of complete nest hatching failure;
2) fecundity (number of eggs laid per nest attempt) is reduced;
3) in general, eggs are smaller;
4) time to hatch is extended;

5) embryonic development is significantly delayed;
6) time to fledging is extended; and,
7) gross observations have documented embryonic and nestling deformities.

Our efforts to quantify the extent and significance of these impacts are ongoing. It should be pointed out that each of these potential impacts can be related to impacts from petroleum products and PAHs documented in the literature and discussed in the previous section. Our findings support the contention made by Biederman and Drury (1980) that "a chronic reduction in reproductive success may be the most significant effect of oil pollution on populations of aquatic birds."

Fledging success of peregrine falcons in the post-DDT era is approximately 75 percent with an average clutch size of 4 eggs, as previously discussed. It can be assumed that average hatching success should be equal to or greater than 75 percent. Given that hatching and fledging success can, and has been, 100 percent at peregrine falcon nests in Indiana (including 1994 for the IHC nest, 1995 and 1996 for the Indianapolis pair), absent of pollution-related stresses, hatching success should be much higher than what routinely has occurred at the Lake County nests. The productivity (in terms of number of eggs laid and hatching success) of peregrine falcons in Lake County has been less than optimum (Figures 3 and 4). The original falcon at IHC (Phoenix) laid fewer eggs and overall had poor hatching success. The subsequent falcon at IHC (Egore) has fared better. Egore laid 4 or more eggs in her first 3 attempts, but has also had several eggs fail to hatch. At the Gary site in Lake County, that falcon (SuzyQ) has averaged only 50 percent hatching success over the years.

Furthermore, in the failed peregrine falcon eggs analyzed, PAHs were detected (Appendix A). Analytical chemistry results are also presented for failed peregrine falcon eggs from Des Moines, Iowa for comparison purposes (Appendix A). This data indicates that several individual PAHs are present in failed peregrine eggs, with the highest number of PAH compounds and the highest concentrations found in the egg from the IHC nest (0.53 ppm wet weight, total PAHs, Appendix A). Brunstrom *et al.* (1990) found that 0.2 ppm PAHs (mixture) injected into the yolk of domestic duck eggs had significantly increased mortality. Assuming 0.2 ppm to be a LOAEL for egg death, it is reasonable to conclude that peregrine falcons eggs have been adversely impacted by PAHs. Given these PAH concentrations, it is also likely that peregrine falcons in the IHC may also be exhibiting some of the adverse reproductive impacts that have been documented in the barn swallows of the IHC. Regardless, this much is clear:

1) contaminants of concern (PAHs) are bioavailable in the IHC;
2) peregrine falcon prey can be at least a sporadic source of oil in quantities that could be toxic to eggs;
3) uptake of PAHs has been documented by chemical analyses in peregrine falcon prey;

4) failed peregrine falcon eggs contain concentrations of PAHs above those known to cause significantly increased mortality in laboratory studies;
5) adverse effects have been documented in both peregrine falcons and their prey; and,
6) all of these concerns regarding PAHs have been previously reported in the literature.

Therefore, we conclude that take of peregrine falcon eggs is currently occurring in the IHC due to the wide-spread petroleum contamination under existing conditions without the Corps dredging project.

The proposed Corps dredging project will cause increases in PAH bioavailability and food chain transport. The resuspension of contaminated sediments via dredging sediment disturbance will result in the creation of surface sheens of petroleum products. There will be increased oiling incidents of peregrine falcon prey as a result of the Corps dredging activities, which increases the risk for peregrine falcon egg oiling and hatching failure.

In addition, the proposed dredging project will cause increases in PCB bioavailability and food chain transport through the resuspension of contaminated sediments. Sediments containing higher concentrations of PCBs will be exposed by this project (USACE 1995), which will lead to increased bioavailability to macroinvertebrates and fish. Diving ducks foraging in these areas will accumulate higher levels of PCBs, while PCB uptake in piscivorous birds (i.e. gulls) will also increase. This increase of PCB concentrations in peregrine falcon prey could significantly increase peregrine falcon egg concentrations leading to egg hatching failure due to pHAH embryo toxicity.

Biological Opinion

It is the USFWS's biological opinion that implementation of the Corps proposed maintenance dredging of IHC is not likely to jeopardize the continued existence of the peregrine falcon (*Falco peregrinus*) but will result in incidental take.

The Section 7 regulations (50 CFR 402) define "jeopardy" as an action that would be expected, directly or indirectly, to appreciably reduce the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction numbers or distribution of that species. While the existing conditions of the IHC have direct and indirect effects on peregrine falcons, and these effects will increase with the proposed project, this project will not significantly impair its ability to recover.

Although the USFWS has reached a not likely to jeopardize conclusion on the proposed dredging project, there remains a serious concern with the existing conditions and the incidental take as defined in the Act.

Incidental Take

Sections 4(d) and 9 of the Act, as amended, prohibit taking (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct) of listed species of fish or wildlife without a special exemption. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering. Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. Incidental take is any take of listed animal species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or the applicant. Under the terms of Section 7(b)(4) and Section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered a prohibited taking provided that such taking is in compliance with the terms and conditions of this incidental take statement.

Based on the analysis of all existing data available for the IHC project area (presented herein), the USFWS believes that the action is likely to result in incidental take of peregrine falcon eggs due to oil transfer to eggs from adults foraging on oil-contaminated prey. Incidental take may also be in the form of direct mortality to adults and fledglings due to contact with oil sheens generated on the IHC or resulting from flight hazards at the Confined Disposal Facility. Due to the sporadic nature of egg oiling risk, we estimate that the amount of incidental take would be measurable through overall nest hatching success rates and the contaminant monitoring of failed eggs as detailed below. The USFWS anticipates that the following take may occur:

1. One (1) adult peregrine falcon through inadvertent injury or death during implementation of the life of the Corps maintenance dredging of the IHC.

2. Two (2) eggs per year due to incidental oiling during incubation resulting from adult contact with petroleum-contaminated prey.

The following measures are non-discretionary, and must be implemented by the Corps so that they become binding conditions on the implementation of the Corps maintenance dredging of IHC, as appropriate, in order for the exemption in Section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity covered by this incidental take statement. If the Corps 1) fails to adhere to the terms and conditions of the incidental take statement, and/or 2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

This permit also constitutes a Special Purpose Permit under 50 C.F.R. §21.27 for the take of peregrine falcons (*Falco peregrinus*) in the amount and/or number and subject to the terms and conditions specified herein. Any such take will not be in violation of the Migratory Bird Treaty Act of 1918, as amended (16 U.S.C. §§ 703-12).

Reasonable and Prudent Measures

The USFWS believes that the following reasonable and prudent measures are necessary and appropriate to minimize take:

1. Finalization of a Wildlife Exclusion Plan. The Wildlife Exclusion Plan (WEP) for the Confined Disposal Facility (CDF) needs to be finalized (including USFWS concurrence on the plan) prior to the beginning of any dredging activity.

2. Surface Oil Sheen Prevention and Water Column Protection Plan. Implement surface water protective measures, including monitoring, to prevent occurrence of surface sheens of petroleum products resulting from the resuspension of petroleum-contaminated sediments. Additionally, develop similar protective measures to prevent in-situ water column exceedances of State water quality standards, including monitoring to detect such exceedances.

3. Peregrine Falcon Productivity Contaminant Monitoring Program. In order to quantify the amount of take occurring at the IHC peregrine falcon nest, and to gauge compliance with take provisions herein, failed eggs shall be analyzed for PAHs and PCBs. Significant decreases of hatching success or significant increases in concentrations of PCBs or PAHs shall trigger reinitiation of consultation.

4. Seasonal Restrictions for Dredging Activities Adjacent to Cline Ave Nest Site. During the period of fledging activity, seasonal dredging restrictions will apply within 500 feet either side of the centerline of the Cline Avenue Bridge over the IHC.

Terms and Conditions

To implement these reasonable and prudent measures, the USFWS offers the following mandatory terms and conditions. Compliance with these terms and conditions is necessary for exemption from the prohibitions of Section 9 of the Act.

1. To implement reasonable and prudent measure 1, the following terms and conditions are established:

    a. To minimize the potential for flight hazards for peregrine falcons at the CDF, the Corps shall prepare, with the assistance and concurrence of the USFWS, a Wildlife Exclusion Plan (WEP) to minimize the possibility for such take. This WEP shall also minimize the potential for wildlife use, including peregrine falcon prey species so that contaminant uptake can be prevented. Specific measures, actions, and design plans should be identified and implemented prior to the CDF accepting dredge material. The implementation of this plan should be continually monitored during the initial year of the project to assess its success. During subsequent years, the plan should be evaluated quarterly or each time the CDF operations change operable disposal units.

2. To implement reasonable and prudent measure 2, the following terms and conditions are established:

a. To minimize the potential for water column impacts, primarily the resuspension of petroleum products, PAHs, and PCBs, the Corps shall prepare, with the assistance of appropriate response agencies, a surface sheen prevention and water column protection program to minimize the possibility for take. The surface sheen prevention plan should include provisions for absorbent boom deployment, replacement and frequent effectiveness assessment. Continual monitoring for surface sheens should be established with particular attention given to monitoring potential wildlife contact with boomed or contaminated surface water areas. This plan should consider implementation of wildlife hazing techniques, if necessary. The water column protection aspects of this plan should make use of silt curtains, or other such protective devices as deemed feasible, to minimize water column turbidity. This plan shall provide signatory concurrence with appropriate response agencies and the USFWS.

b. The implementation of this plan should be continually evaluated for its effectiveness. Turbidity increases and sheen generation shall be primary performance measures; if these parameters can not be controlled within deployed containment measures, dredging operations should be temporarily suspended while containment measures are effectively redeployed.

c. A plan to effectively prevent and deal with potential spills associated with rehandling of dredged sediments shall be established prior to the beginning of dredging. This plan shall identify the precautions and spill-related water quality counter measures in place to be used if the situation arises.

3. To implement reasonable and prudent measure 3, the following terms and conditions are established:

a. In cooperation with the Indiana Department of Natural Resources and the USFWS, the Corps is required to provide adequate funding to analyze all failed eggs from the IHC peregrine falcon nest for contaminants of concern in IHC in order to assess compliance with the take provisions set forth herein. The USFWS will inform the Corps of significant changes in peregrine falcon productivity and cooperate with the Corps in assessing productivity and contaminant residue analyses relative to the Project's progress and implementation.

b. The USFWS will have the sole responsibility of ensuring that the appropriate analytical laboratory is conducting the analyses. For purposes of assessing compliance with the take provisions set forth herein, analysis PAHs and PCBs is required. PCB analysis shall consist of quantification of total PCBs and congener-specific analysis consistent with samples previously taken by the USFWS.

c. The potential for this project to enhance the bioavailability of PAHs and PCBs is significant. If it is determined through this monitoring effort that PCB bioavailability is significantly increased, reinitiation of consultation is warranted. For purposes of this consultation, significant declines in hatching success [50 percent or less in 2 consecutive years concurrent with either i) PCB concentrations above 8.5 ppm (previous mean conditions for Lake County peregrine falcon eggs), or ii) total PAHs above 0.1 ppm] shall reinitiate consultation.

4. To implement reasonable and prudent measure 4, the following terms and conditions are established:

a. Seasonal restrictions for dredging activities adjacent to the Cline Avenue peregrine falcon nest site shall be in place during the 3-week period prior to and post fledging. The actual dates for this seasonal restriction can be adjusted each year depending on the specific nest chronology. This would minimize the duration of the seasonal restriction, which could minimize the Corps down-time. Alternatively, a larger seasonal restriction of April 15 to July 15 could be utilized if actual nest chronology is not considered.

b. No dredging activities shall occur with 500 feet either side of the centerline (1000 feet total) of the Cline Avenue bridge over the IHC to protect the peregrine falcon nest site and behavioral activities which occur during the fledging of the chicks.

Reporting Requirements

Should the incidental take limit be exceeded, the Corps shall immediately cease the activity resulting in the take and reinitiate consultation with the USFWS to avoid violation of Section 9 of this Act. The proposed actions must be stopped in the interim period between the initiation and completion of the new consultation. The Corps should explain the cause of the taking.

The Corps shall provide an annual report of all incidents of wildlife injury or mortality associated with the CDF operation or dredging-related surface sheens. Upon locating a dead, injured, or sick individual of an endangered or threatened species, initial notification must be given to the USFWS's Division of Law Enforcement Office in Rosemont, Illinois at (708) 298-3250 and the

Bloomington, Indiana Field Office (812) 334-4261 immediately and in writing within 3 working days. Care should be taken in handling sick or injured specimens to ensure effective treatment and in handling dead specimens to preserve biological material in the best possible state for later analysis of cause of death. The finder has the responsibility to ensure that evidence intrinsic to the specimen is not unnecessarily disturbed. Any endangered or threatened species should be turned over to the Indiana Department of Natural Resources.

In the event migratory birds become oiled, the Corps shall also provide notification to the USFWS as previously described so that the birds can be salvaged to prevent potential peregrine falcon contacts, and so that arrangements can be made for rehabilitation.

Conservation Recommendations

Sections 2(c) and 7(a)(1) of the Act direct Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. The term "conservation recommendations" has been defined as USFWS suggestions regarding discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding development of information. The recommendations here relate only to the proposed action and does not necessarily represent complete fulfillment of the agency's Section 7(a)(1) responsibility for the species.

1. The Corps should implement the construction of a water treatment facility at the CDF to ensure that effluent water quality meets appropriate water quality standards.

2. The Corps should reassess the use of hydraulic dredging to minimize water column impacts to IHC, and Lake Michigan. By minimizing water column impacts, impacts to peregrine falcons and their prey would likely be significantly reduced. This change in technology would necessitate the construction of a larger water treatment facility than discussed in the DEIS. Consideration should be given to the construction of this plant on ECI site parcel on the south side of the Lake George Branch of IHC.

Reinitiation Requirements

This concludes formal consultation on the Corps proposed maintenance dredging of IHC as outlined in the August 16, 1995 request from the Corps. As required by 50 CFR 402.16, reinitiation of formal consultation is required if:

1. the amount or extent of incidental take is exceeded;

2. new information reveals effects of the agency action that may affect listed species or habitat in a manner or to an extent not considered in this opinion; or

3. the agency action is subsequently modified in a manner that causes an effect to the listed species or habitat not considered in this opinion; or

4. a new species is listed or critical habitat designated that may be affected by the action.

In instances where the amount or extent of incidental take is exceeded, any operations causing such take must be stopped in the interim period between the initiation and completion of the new consultation if any additional taking is likely to occur.

21 May 1996
Date

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APPENDIX A

Analytical Chemistry Data for Peregrine Falcons
Indiana Harbor and Ship Canal, 1990-1993

Table A-1. Mercury residues in failed peregrine falcon eggs from a Des Moines, Iowa nest and two Lake County, Indiana nests (parts per million, wet weight).

nest location	year	Hg
East Chicago, Indiana	1990	0.33
East Chicago, Indiana	1993	0.024
Gary, Indiana	1992	<.018
Gary, Indiana	1992	<.018
Gary, Indiana	1993	0.027
Gary, Indiana	1993	0.025
Gary, Indiana	1993	0.021
Des Moines, Iowa	1992	0.132
Des Moines, Iowa	1992	0.255

Table A-2. Total polychlorinated biphenyl (PCB) residues in failed peregrine falcon eggs from two Lake County, Indiana nests, 1990 to 1993 (parts per million, wet weight).

nest location	year	total PCBs
East Chicago, Indiana	1990	7.6
East Chicago, Indiana	1991	12.2
East Chicago, Indiana	1993	4.3
Gary, Indiana	1992	8.7
Gary, Indiana	1992	9.0
Gary, Indiana	1993	7.9
Gary, Indiana	1993	9.7
Gary, Indiana	1993	10.0

Table A-3. Congener specific polychlorinated biphenyl (PCB) residues and calculated 2,3,7,8-TCDD TEqs in failed peregrine falcon eggs from a Des Moines, Iowa nest and two Lake County, Indiana nests, 1992, and 1993 (parts per million, wet weight).

	1993 Gary, IN	1993 Gary, IN	1993 Gary, IN	1993 E. Chi.	1992 Iowa	1992 Iowa	1992 Gary, IN	1992 Gary, IN
% Lipid	7.69	7.1	6.54	5.65	5.08	6.92	6.31	6.54
% Moisture	77	79	80	79.5	80	76.5	82	80
PCB# 77	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001
PCB# 114	0.0057	0.0061	0.0037	0.0054	0.0029	0.0036	0.007	0.0055
PCB# 105	0.041	0.048	0.024	0.039	0.028	0.035	0.039	0.029
PCB# 118/106	0.29	0.17	0.14	0.27	0.13	0.18	0.33	0.26
PCB# 126	0.0004	0.0004	0.0003	0.0005	0.0004	0.0004	0.0004	0.0004
PCB# 156	0.1	0.073	0.047	0.087	0.028	0.034	0.15	0.1
PCB# 169	0.0002	0.0002	0.0002	0.0002	<.0001	<.0001	0.0002	0.0002
PCB-TOTAL	9.7	10.0	7.9	4.3	1.5	2.7	8.7	9.0
2,3,7,8 TCDD TEqs (ppt)	37.0	69.57	26.09	39.06	23.2	21.8	46.99	39.89

Table A-4. Polycyclic aromatic hydocarbon (PAH) residues in failed peregrine falcon eggs from a Des Moines, Iowa nest and two Lake County, Indiana nests, 1992 and 1993 (parts per million, wet weight).

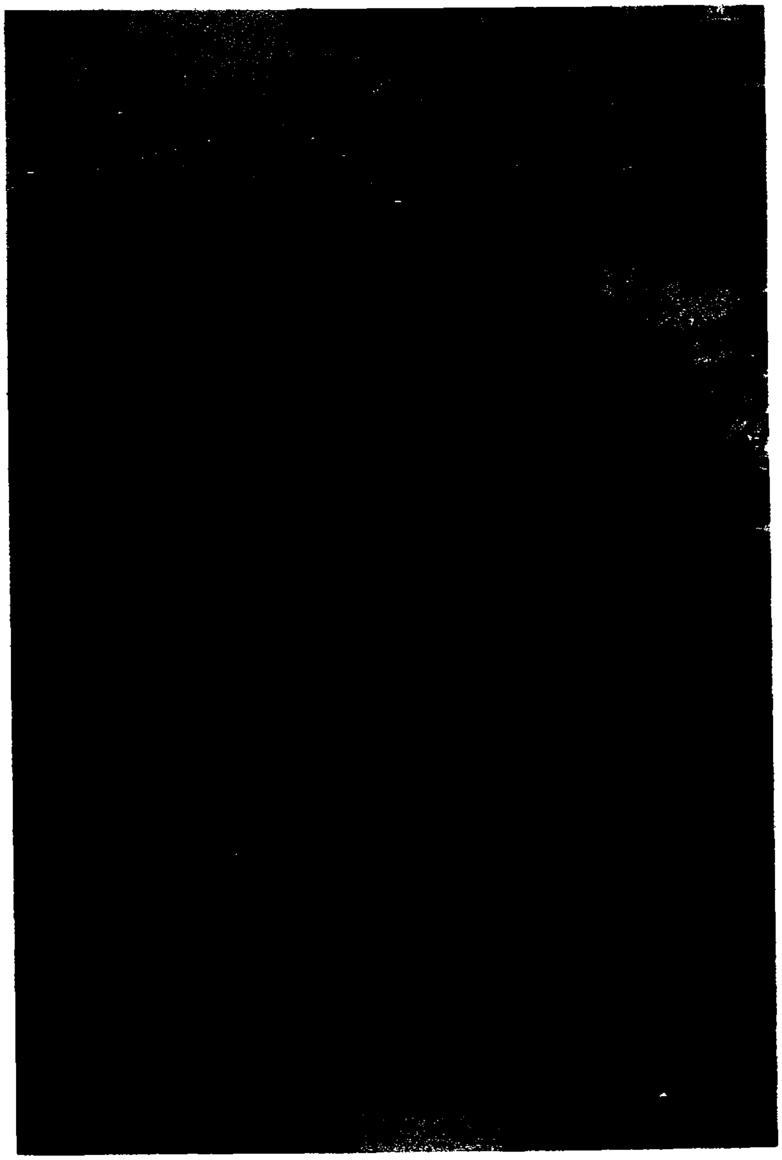
	Des Moines, Iowa	Des Moines Iowa	Gary, Indiana	East Chicago, Indiana
% Lipid	5.08	6.92	6.54	5.65
% Moisture	80	76.5	80	79.5
1,2,5,6-dibenzanthracene	<.01	<.01	<.01	<.01
1,2-benzanthracene	<.01	<.01	0.02	0.03
1-methylnaphthalene	0.02	0.03	0.02	0.02
1-methylphenanthrene	<.01	<.01	<.01	<.01
2,3,5-trimethylnaphthalene	<.01	<.01	<.01	<.01
2,6-dimethylnaphthalene	<.01	<.01	<.01	<.01
2-methylnaphthalene	0.02	0.02	0.03	0.03
acenaphthalene	<.01	<.01	<.01	<.01
acenaphthene	<.01	<.01	<.01	<.01
anthracene	<.01	<.01	<.01	<.01
benzo(a)pyrene	<.01	<.01	0.03	0.07
benzo(b)fluoranthene	<.01	<.01	0.02	0.13
benzo(e)pyrene	<.01	<.01	0.02	0.06
benzo(g,h,i)perylene	<.01	<.01	<.01	<.01
benzo(k)fluoranthene	<.01	<.01	0.02	<.01
biphenyl	<.01	<.01	<.01	<.01
C1-chrysenes	<.01	<.01	<.01	<.01
C1-dibenzothiophenes	<.01	<.01	<.01	<.01
C1-Fluoranthenes & Pyrenes	<.01	<.01	<.01	<.01
C1-fluorenes	<.01	<.01	<.01	<.01
C1-naphthalenes	0.04	0.05	0.05	0.05
C1-phenanthrenes	<.01	<.01	<.01	<.01
C2-chrysenes	<.01	<.01	<.01	<.01
C2-dibenzothiophenes	<.01	<.01	<.01	<.01
C2-fluorenes	<.01	<.01	<.01	<.01
C2-naphthalenes	<.01	<.01	<.01	<.01
C2-phenanthrenes	<.01	<.01	<.01	<.01
C3-chrysenes	<.01	<.01	<.01	<.01
C3-dibenzothiophenes	<.01	<.01	<.01	<.01
C3-fluorenes	<.01	<.01	<.01	<.01
C3-naphthalenes	<.01	<.01	<.01	<.01
C3-phenanthrenes	<.01	<.01	<.01	<.01
C4-chrysenes	<.01	<.01	<.01	<.01
C4-naphthalenes	<.01	<.01	<.01	<.01
C4-phenanthrenes	<.01	<.01	<.01	<.01
chrysene	<.01	<.01	<.01	<.01
dibenzothiophene	<.01	<.01	<.01	<.01
fluoranthene	<.01	<.01	<.01	<.01
fluorene	<.01	<.01	<.01	<.01
indeno(1,2,3-cd)pyrene	<.01	<.01	<.01	<.01
naphthalene	0.02	0.02	0.03	0.02
perylene	<.01	<.01	<.01	0.10
phenanthrene	0.01	0.01	<.01	0.02
pyrene	<.01	<.01	<.01	<.01
total PAHs	0.11	0.13	0.24	0.53

APPENDIX B

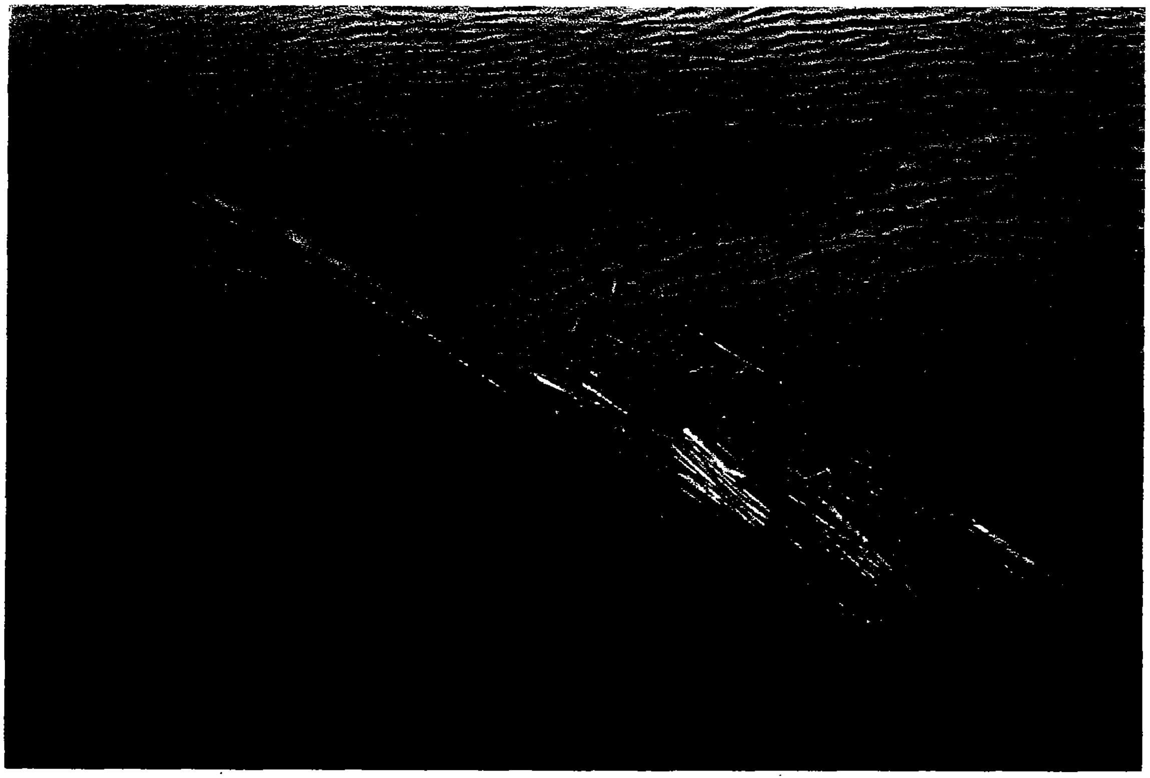
Photographs Documenting Existing Conditions of Indiana Harbor and Ship Canal and Grand Calumet River

Photographs 15, 16, 32 and 33 make reference to transect #035, #035, #026 and #025, repectively. These transect numbers coincide with the Floyd Browne Associates, Inc. 1993 Grand Calumet River Sediment Characterization Study for U.S. Steel, Gary, Indiana. These transects are located in the eastern 5 miles of the East Branch Grand Calumet River.

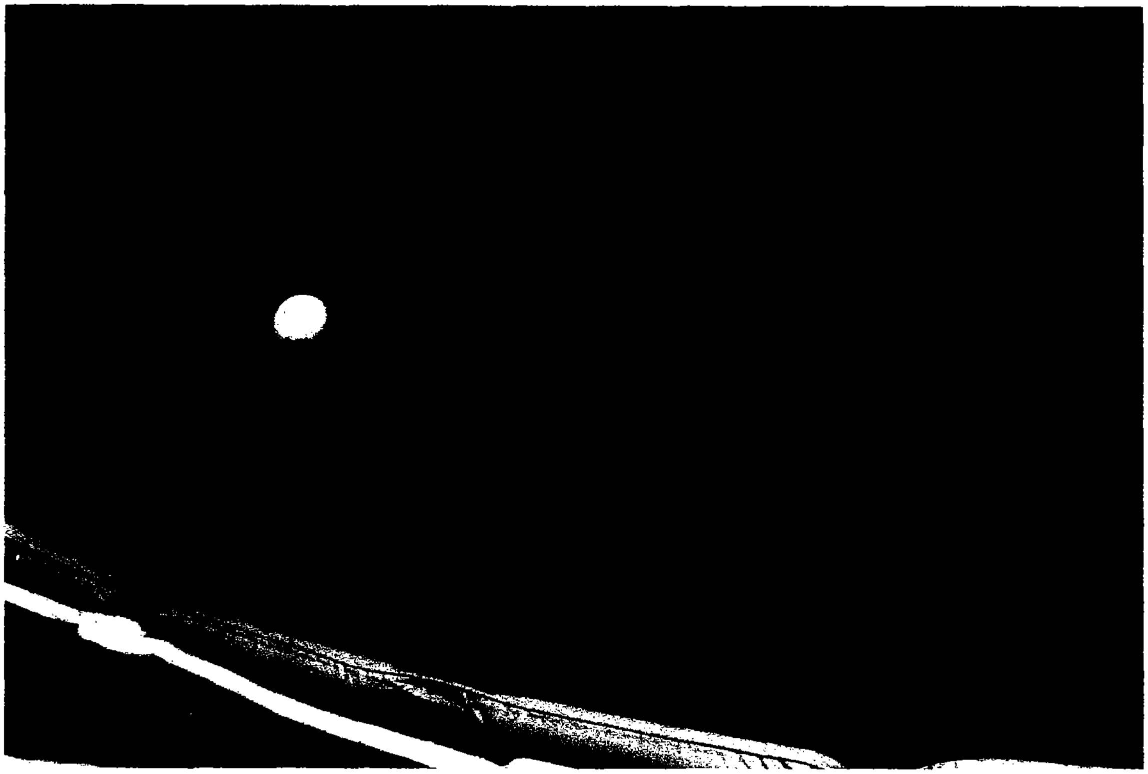
Photograph 1. This is one of the many surface seeps of petroleum products (crude or waste oil primarily) at the proposed confined disposal facility located on the Lake George Branch of Indiana Harbor Canal. These surface oil seeps, regardless of where they occur, are extremely hazardous to wildlife.



Photograph 2. This is the Lake George Branch of Indiana Harbor Canal, just west of Indianapolis Boulevard. This area is hazardous to waterfowl.



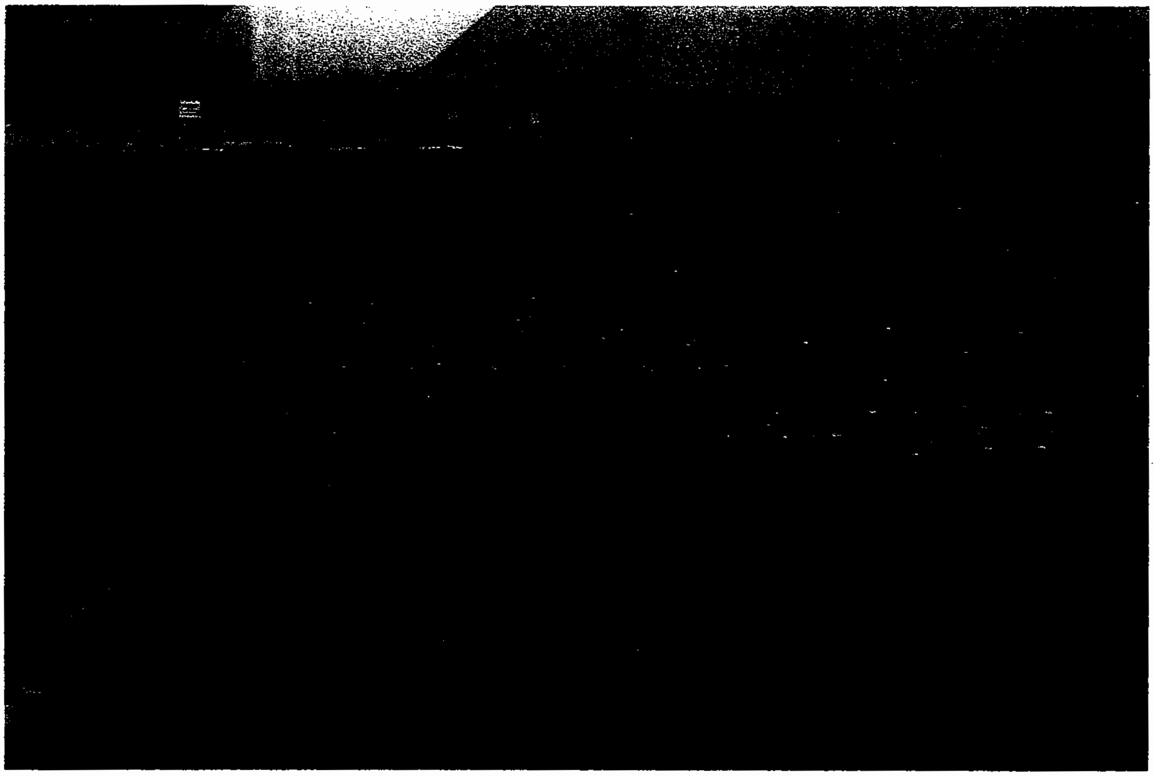
Photograph 3. This is the Lake George Branch of Indiana Harbor Canal, just west of Indianapolis Boulevard. This area is hazardous to waterfowl.



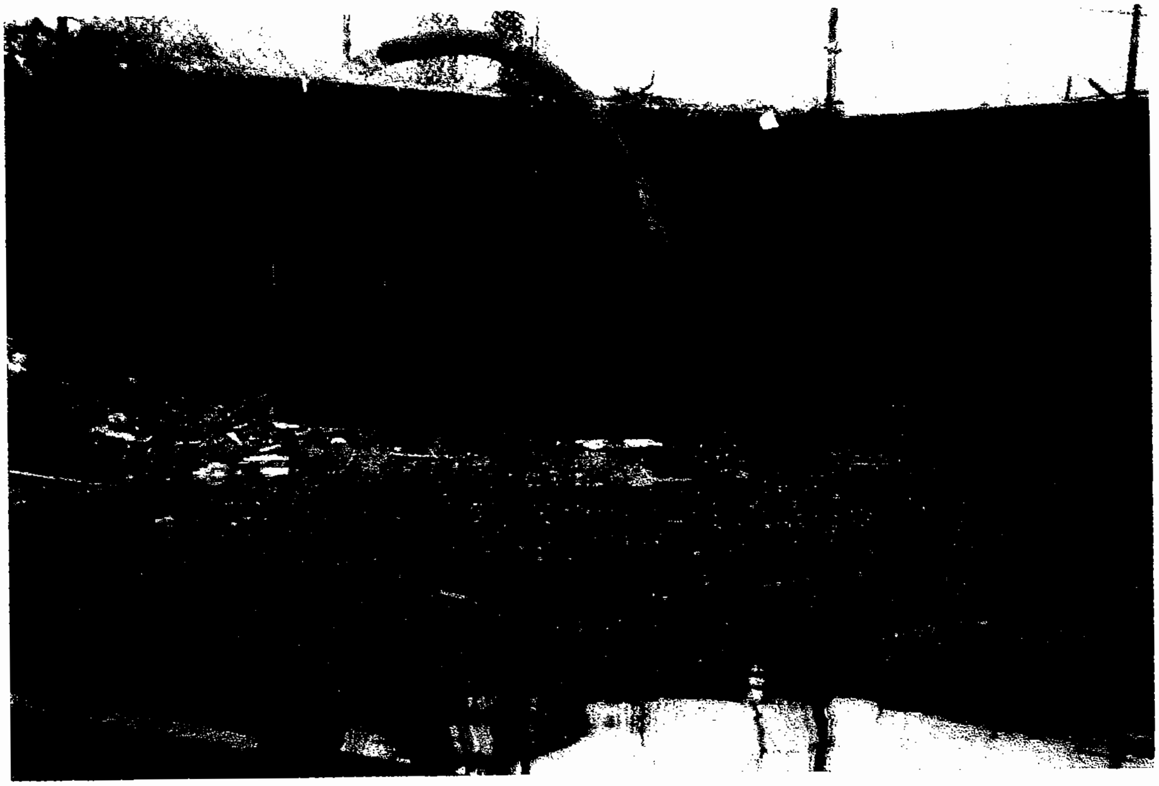
Photograph 4. This is the Lake George Branch of Indiana Harbor Canal, just west of Indianapolis Boulevard. This area is hazardous to waterfowl.

Photograph 5. This is the Lake George Branch of Indiana Harbor Canal, just west of Indianapolis Boulevard. This area is hazardous to waterfowl.

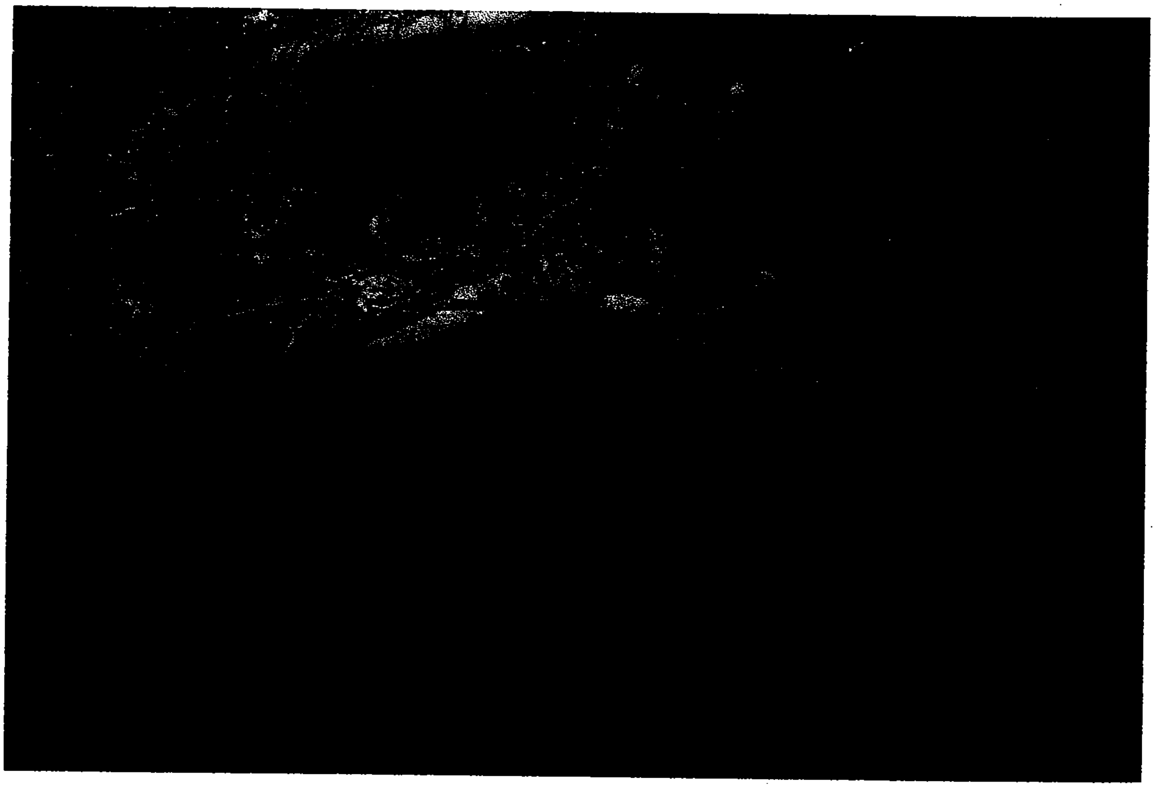
Photograph 6. Double-crested cormorants are one of many species of piscivorous wildlife that can be found in Indiana Harbor Canal year-round. This photograph of the Lake George Branch of Indiana Harbor Canal was taken in February 1994.



Photograph 7. Indiana Harbor Canal is home to hundreds of waterfowl each winter. By far the most numerous of the wintering diving ducks are lesser scaup, and can be found in these densities from December to March each year (Custer et al. 1996).

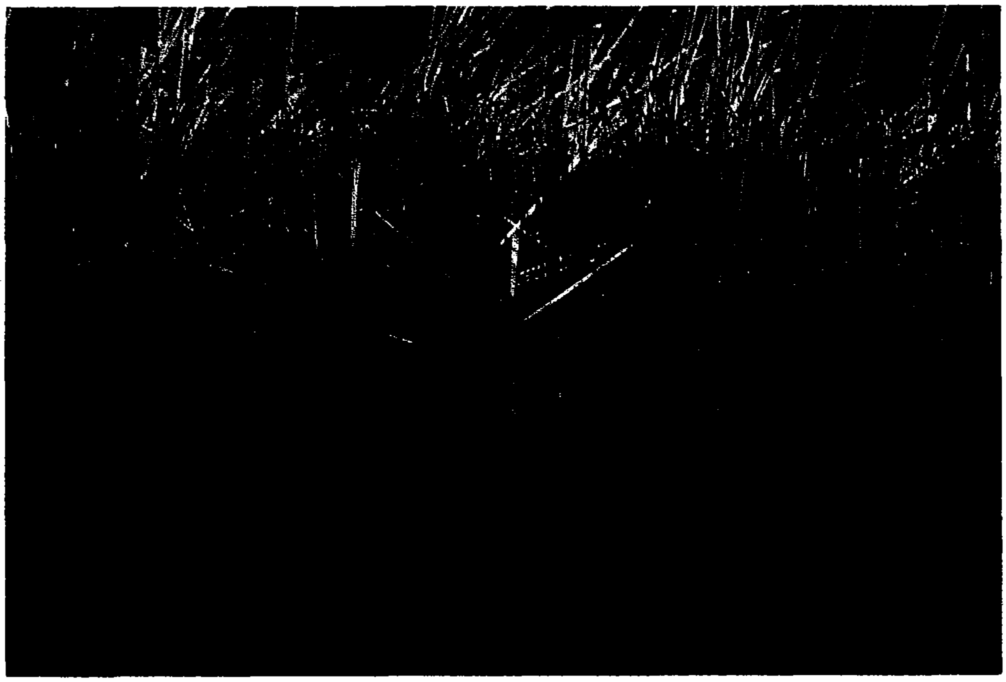


Photograph 8. This is one of the many boomed areas collecting petroleum products seeping through the bulkheads of Indiana Harbor Canal at Columbus Drive. These remain open hazards to wildlife. This photograph is of the area just out of view on the bottom left corner of the previous photograph (photograph 7).



Photograph 9. The shoreline of Indiana Harbor Canal at Columbus Drive is heavily oiled.

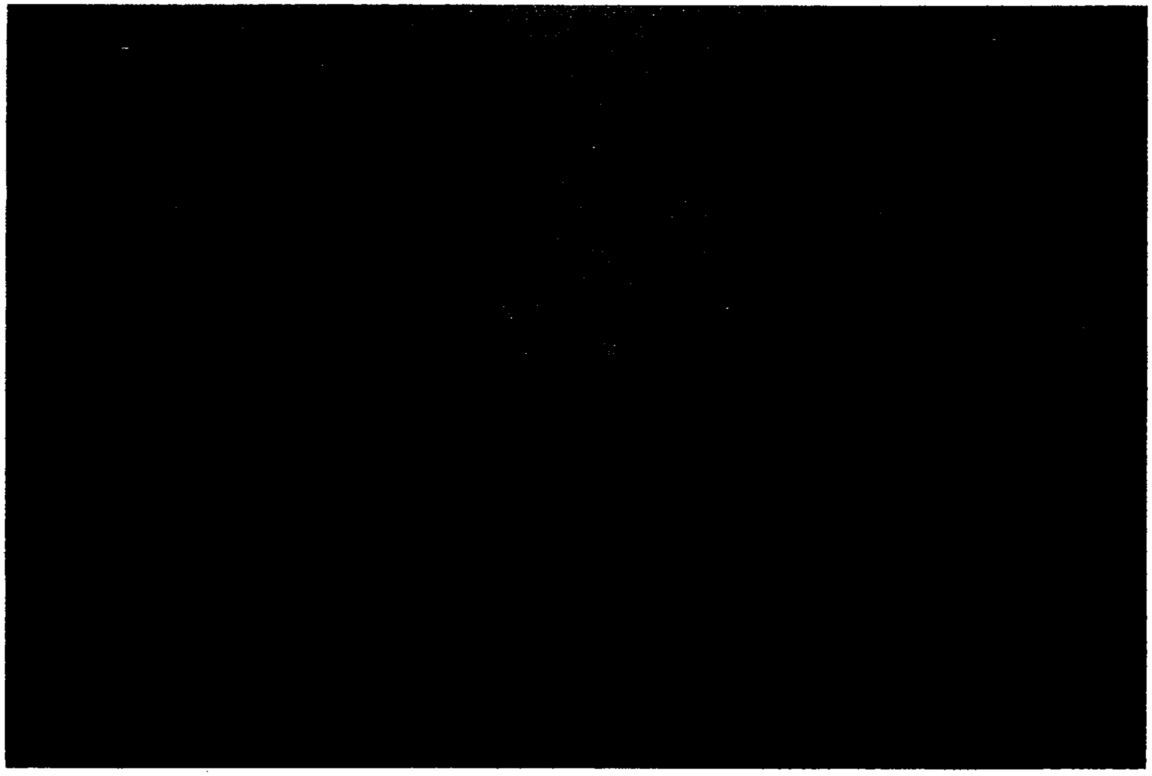
Photograph 10. Pipeline crossings are also a problem in the Indiana Harbor Canal area. This (abandoned?) pipeline lies along a heavily oiled shoreline.



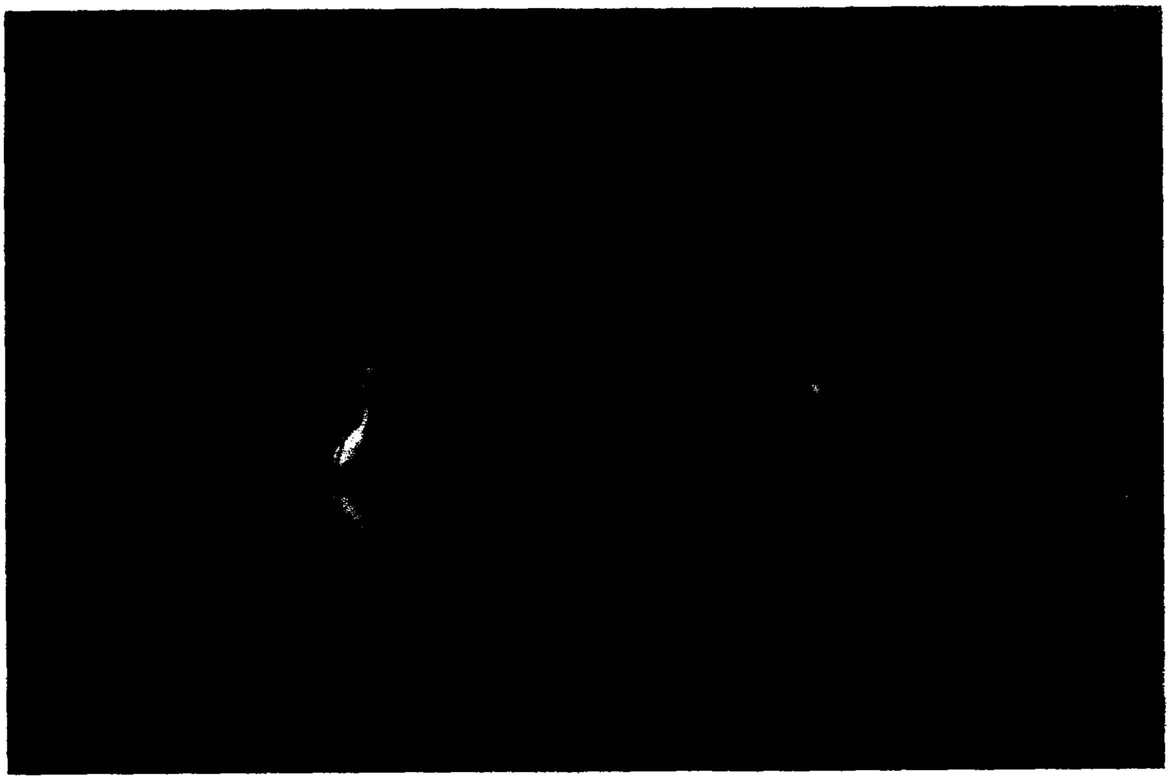
Photograph 11. This is the shoreline of the East Branch Grand Calumet River, several miles upstream of Indiana Harbor Canal. Wetland habitats along Indiana Harbor Canal upstream of the Federal Project Area are similarly oiled. Oiling is obvious by the "bath-tub ring" that is left behind on the cattails when water levels recede.

Photograph 12. Wildlife biologists wear respirators while tending to the swim-in diving duck trap set up in Indiana Harbor Canal in January 1994. This was due to the unpleasant nature of the air quality near the water's surface. Sheens would appear when sediments were disturbed while wading and working at the trap. This trap was located just off the bottom right corner of photograph 7.

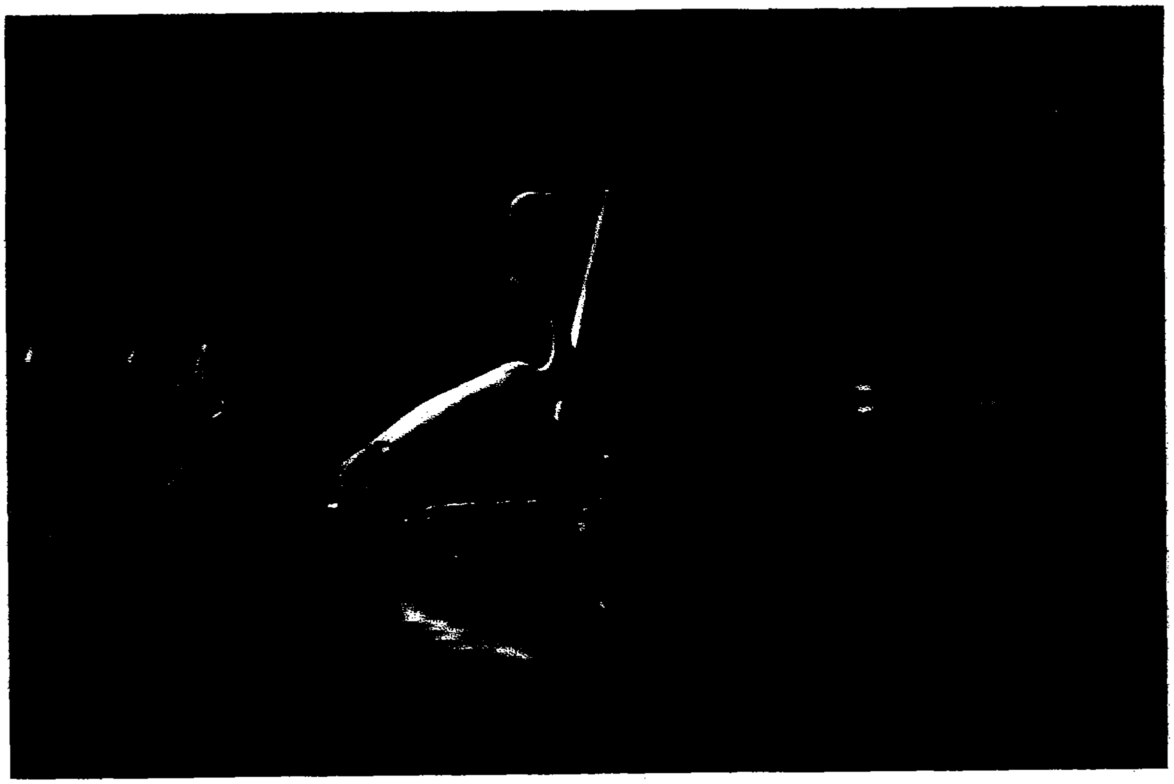
Photograph 13. These are just a few of Indiana Harbor Canal's many wildlife casualties. Left to right: the remains of a black-crowned night heron (scavenged), a mallard (drake), and a great blue heron were discovered in February 1994.



Photograph 14. This slightly oiled ring-billed gull (note brown patch behind head) was observed on June 28, 1994 after a minor "spill" incident in Indiana Harbor. While it is unlikely that this is a lethal situation for this bird, such incidental oiling could easily cause mortality to its eggs if transferred to them.

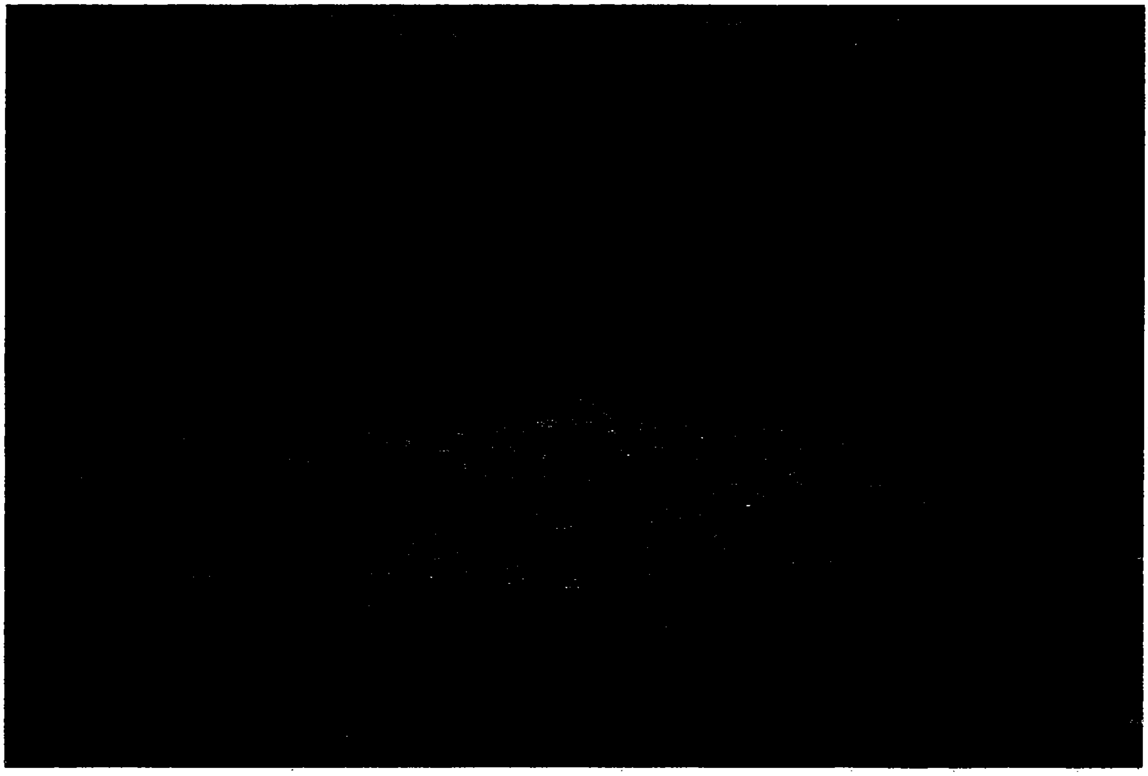


Photograph 15. Great egrets foraging in the Grand Calumet River immediately upstream of transect #035 on May 10, 1995. U.S. Steel's outfall #034 is at the far right.

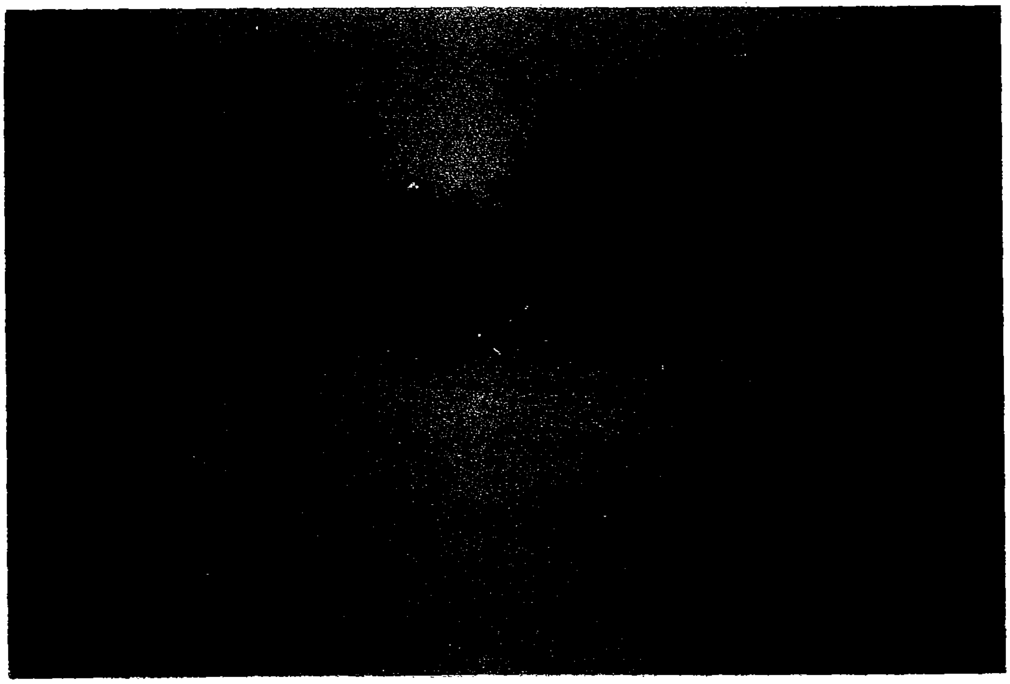


Photograph 16. A close-up of the great egret on the left side of the previous photograph. This egret is located on the south bank of the Grand Calumet River at transect #035. This photograph was taken May 10, 1995. Note the dark oil stains on the right wing and the discoloration of the head and neck. There is a distinct demarcation on the neck where the discoloration stops, indicative of how deeply this heron had foraged when this oiling occurred.

Photograph 17. This mute swan had also succumbed to oiling on the Grand Calumet River in 1991. Being too weak to flee when approached, eventually this bird was retrieved and successfully rehabilitated by concerned citizens.

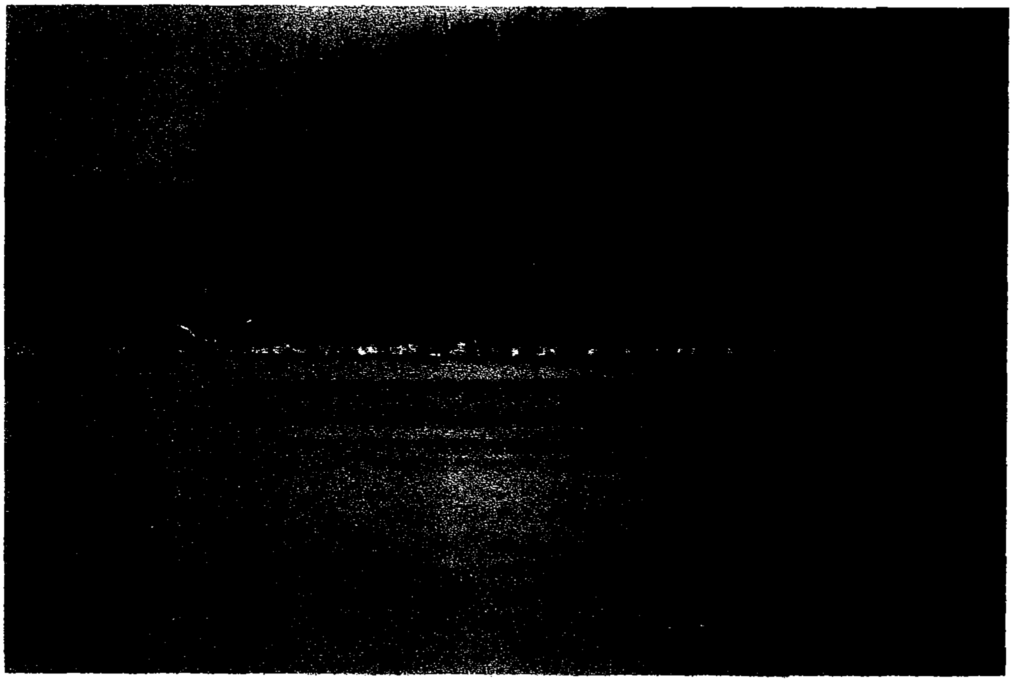


Photograph 18. In August 1992, this domesticated mallard (with a serious buoyancy problem) was observed on the Grand Calumet River. This bird had entered the water just minutes before this photograph was taken, but it began to ride lower and lower in the water until it made its way to shore.



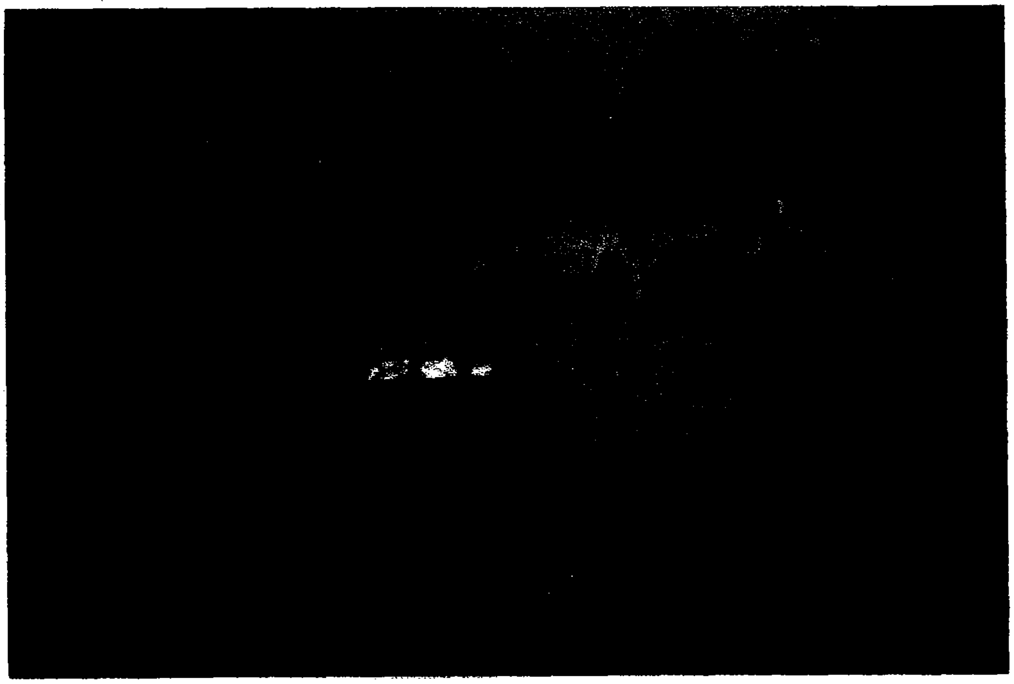
Photograph 19. This is the first of many photographs in series taken in June 1995, which documents flight impairment associated with the Grand Calumet River. These photographs are of the Grand Calumet River near the mid-point of the Gary Airport. This first photograph is of dozens of double-crested cormorants perching /loafing on a snag in the middle of the river.

Photograph 20. As we approached the snag, many of the double-crested cormorants begin to leave the snag. Although cormorants are not strong fliers, having been characterized as "fish with wings," they should have the ability to become air-borne if pursued. The first couple of birds are already air-borne.

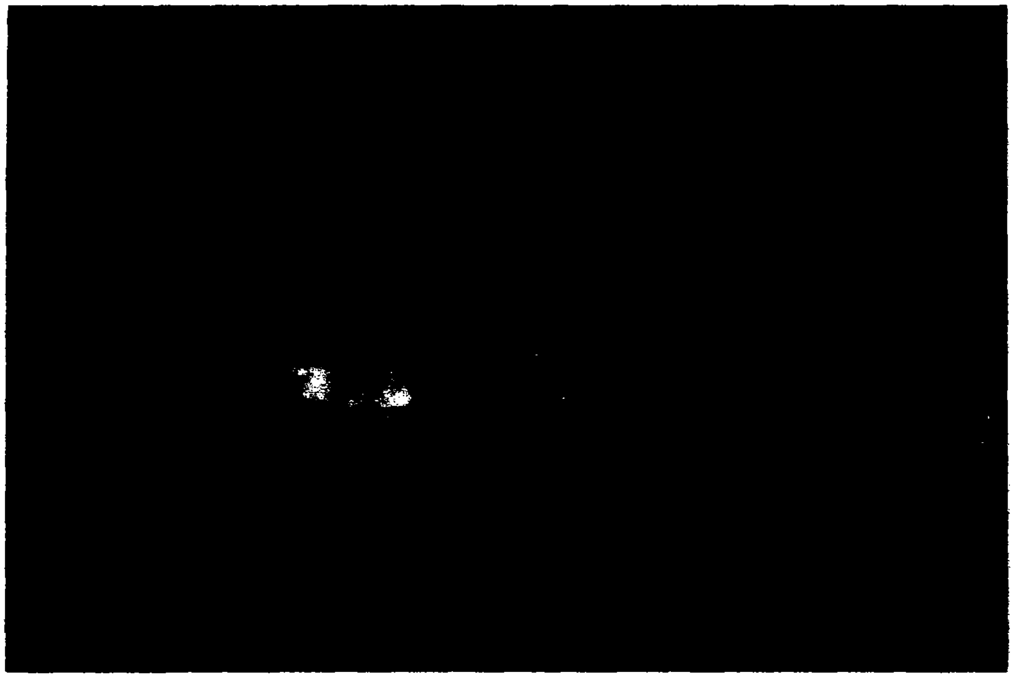


Photograph 21. This photograph (taken near the mid-point of the Gary Airport) is the third in a series demonstrating the difficulties which double-crested cormorants have attaining flight in the Grand Calumet River area. Several of the cormorants are now air-borne.

Photograph 22. This photograph (taken near the mid-point of the Gary Airport) is the fourth in a series demonstrating the difficulties which double-crested cormorants have attaining flight in the Grand Calumet River area. Seven of 10 cormorants appear to have attained flight.



Photograph 23. This photograph (taken near the mid-point of the Gary Airport) is the fifth in a series demonstrating the difficulties which double-crested cormorants have attaining flight in the Grand Calumet River area. We continued to pursue all non-flighted cormorants to determine if they could get air-borne. While 10 cormorants have attained flight (top left), this one did not.



Photograph 24. This photograph (taken near the mid-point of the Gary Airport) is the sixth in a series demonstrating the difficulties which double-crested cormorants have attaining flight in the Grand Calumet River area. We continued to pursue all non-flighted cormorants to determine if they could get air-borne. Two cormorants can be seen in flight (top right), but these three could not make it.

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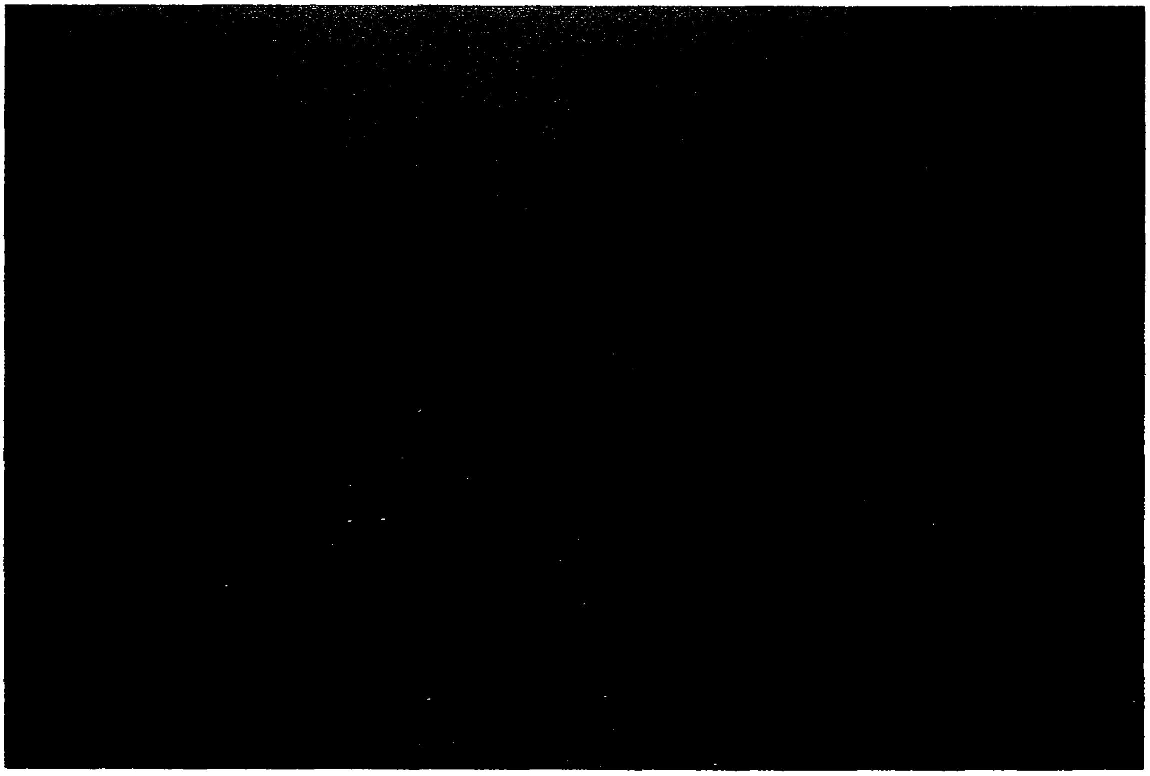
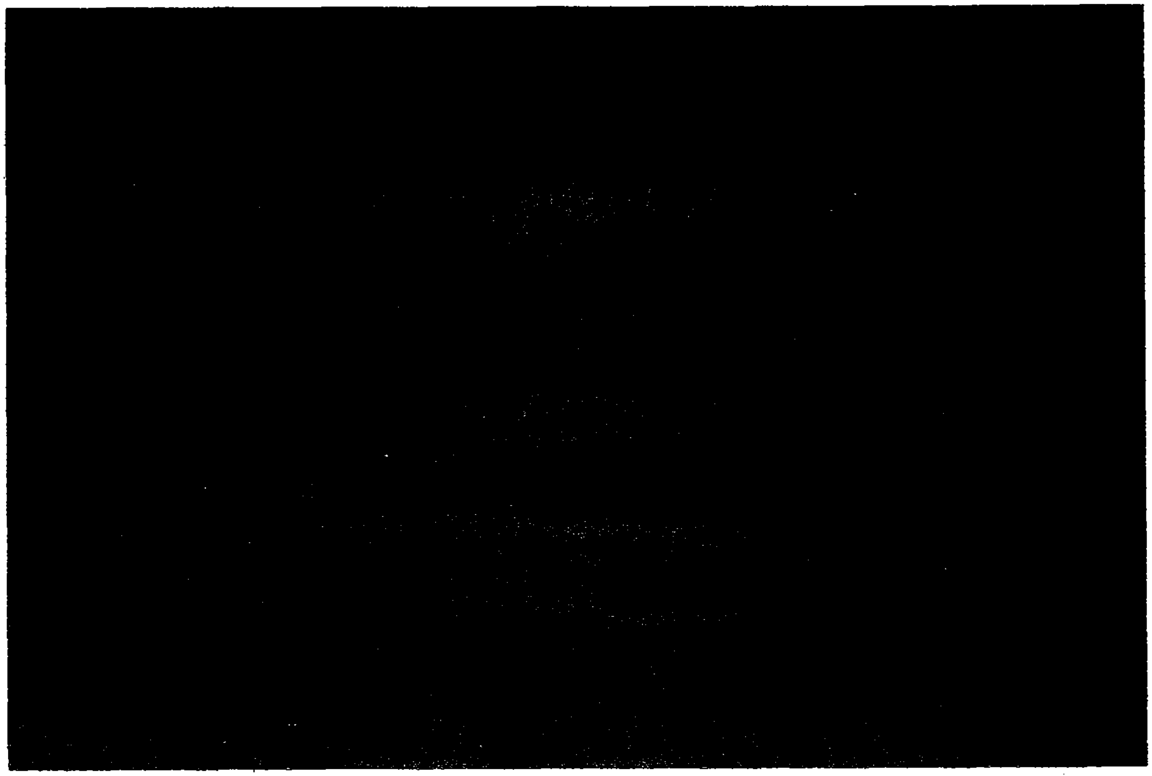
Photograph 25. This photograph (taken near the mid-point of the Gary Airport) is the seventh in a series demonstrating the difficulties which double-crested cormorants have attaining flight in the Grand Calumet River area. We continued to pursue all non-flighted cormorants to determine if they could get air-borne. A cormorant in the background has attained flight, while this one (foreground) can not.

Photograph 26. This photograph (taken near the mid-point of the Gary Airport) is the eighth in a series demonstrating the difficulties which double-crested cormorants have attaining flight in the Grand Calumet River area. We continued to pursue all non-flighted cormorants to determine if they could get air-borne. Many, like this one did not.

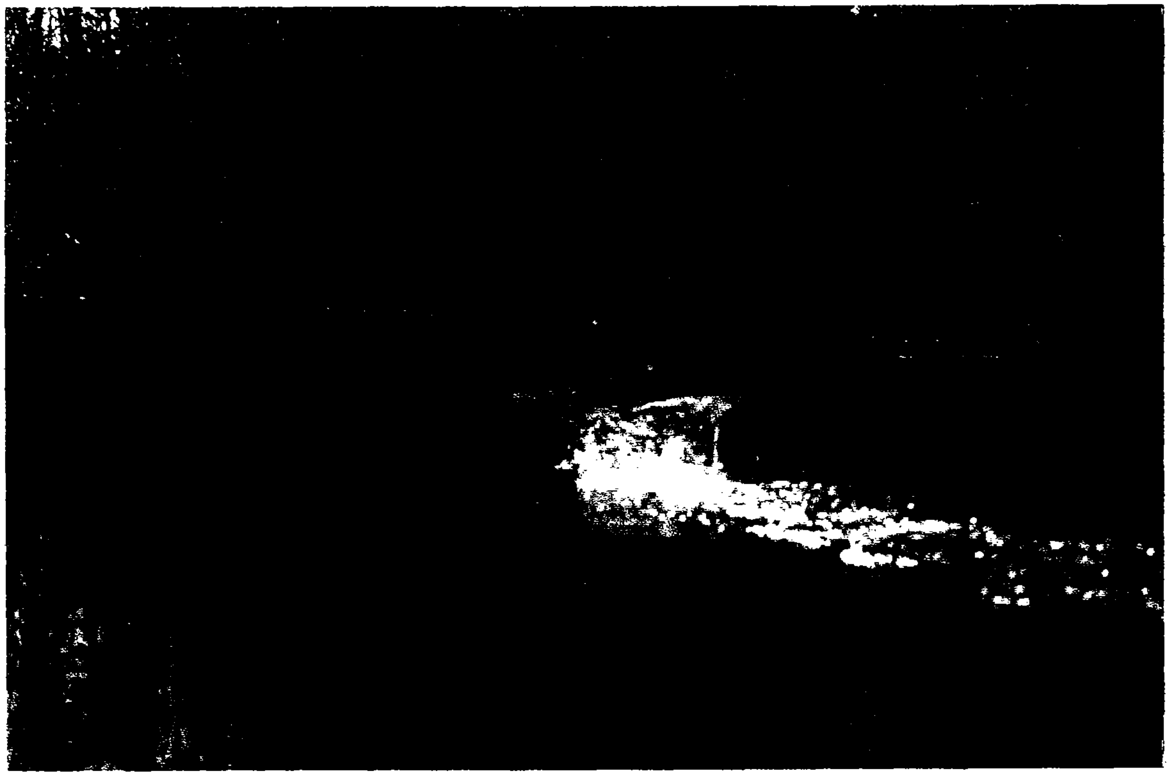


Photograph 27. Hundreds of common mergansers migrate through the Grand Calumet River region each spring. However, many are not able to continue their migration to their more northern nesting grounds due to incidental oiling and flight impairment. This photograph, taken in April 1993, is of a common merganser flying when approached.



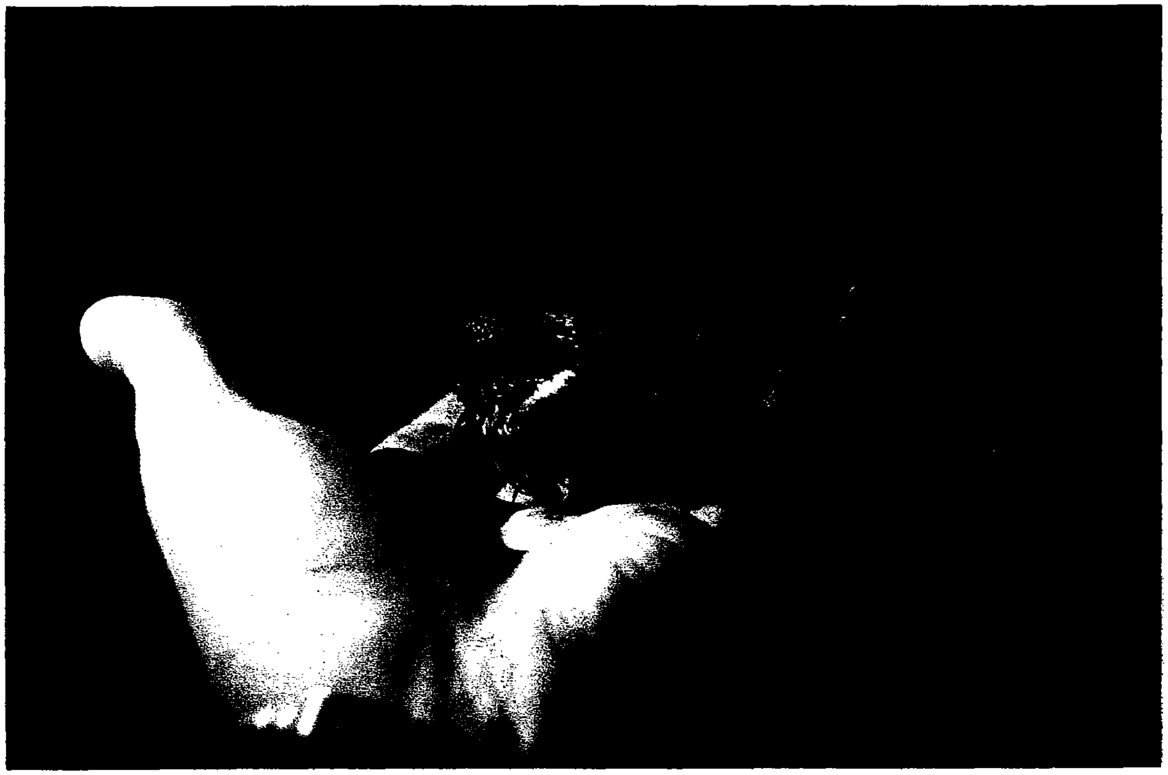
Photograph 28. This is a common merganser, but unlike the previous photograph, it can not attain flight. This photograph was taken in April 1993.

Photograph 31. This photograph depicts a similar flightless condition of a common merganser, however, this bird also appeared to be suffering from a buoyancy problem as well. This photograph was taken May 10, 1995. Common mergansers migrate through the Grand Calumet River / Indiana Harbor Canal area each spring by the hundreds during early spring. Some, such as this one, are not able to continue migrating on to their more northern breeding grounds.



Photograph 32. This Canada goose was photographed on May 10, 1995 near transect #026 of the Grand Calumet River. Although Canada geese do lose the ability to fly each year during their moulting period, this occurs much later in the year after nesting is complete. We followed this goose some distance; it was not able to get airborne.

Photograph 33. This blurred photograph is of a male barn swallow that landed in the Grand Calumet River (approximately at transect #025) as a result of territorial nest dispute with another male barn swallow. While both barn swallows landed in the river as a result of their aerial struggle, the other was able to regain flight with some difficulty. This barn swallow was able to wing-beat it (paddle?) to shore.



Photograph 34. We retrieved the barn swallow (shown in the photograph above) from the river bank in order to document its condition after having landed in the Grand Calumet River. In this condition, there is a serious risk of mortality from hypothermia and/or predation.

Photograph 35. Additional photograph of the barn swallow shown in the previous photographs after having been retrieved from the Grand Calumet River. In this condition, there is a serious risk of mortality from hypothermia and/or predation.

Photograph 36. Additional photograph of the barn swallow shown in the previous photographs after having been retrieved from the Grand Calumet River. In this condition, there is a serious risk of mortality from hypothermia and/or predation.

INDIANA HARBOR
Maintenance Dredging and Disposal Facilities

APPENDIX B

ECONOMIC ANALYSIS

March 1994
Revised August 1998
Economic Analysis Branch
Chicago District
U.S. Army Corps of Engineers
Chicago, Illinois 60606

PREFACE

The original economic analysis and Appendix B, Economic Analysis were completed in 1993 and published in March 1994 with some revisions in response to the 1993 Washington level review process. The analysis was completed by a former Chicago District economist who left the Corps in August 1995 to accept a position with the Federal Railroad Administration (FRA). The original analysis was based on 1993 prices, a project life of 34 years, an interest rate of 8 percent and a base year of 1998, as indicated on page of 14 of the original Appendix B. In 1996, the former Corps' economist updated the economic analysis while working that the FRA. The update was based on 1995 prices, an interest rate of 7-5/8 percent and a base year of 2000. In addition, this update reflected revised dredging plans which were based on new hydrographic soundings obtained in 1995. The new dredging plans are discussed in the supplement to Appendix Q, Sedimentation Investigation and Dredging Plans.

In 1997, the Chicago District proposed relocating the CSX Railroad spur at the ECI site outside of the footprint of the CDF to the north end of the ECI site. This relocation required a revision to the layout and cross-section of the CDF dikes which impacted the costs and therefore the economic analysis. The navigation benefits were subsequently updated to reflect this changed 1977 condition using the benefit models which had been developed for the original 1993 analysis. The revised analysis was based on the latest available (May 1996) vessel budget costs published by the Maritime Administration, an interest rate of 7-1/4 percent, a base year of 2001 and a project life of 31 years. The results of this update are shown in Table B-36A on page 46A under the column heading "Difference (1)".

In September 1998 the navigation benefits were again updated to reflect current conditions including the latest available (May 1996) vessel budget and operating costs, an interest rate of 7-1/8 percent, a base year of 2002, and a project life of 31 years. The results of this latest (1998) update are shown in Table B-36A under the column heading "Difference (2)".

The methodology used to update the benefits from 1997 (Difference(1)) to 1998 (Difference 2) included the following steps:

(1) The distribution of waterborne commerce by vessel class was computed, i.e., vessel class 10, 55%; vessel class 7, 31.3%; and vessel class 2, 13.7%.

(2) The operating costs by vessel class were determined based on the appropriate interest rates. The 1998 hourly operating costs used for vessel classes 10,7 and 2 were computed to be \$2,842, \$1,945 and \$1,322, respectively. The corresponding hourly operating costs used for the 1997 analysis were \$2,661, \$2,464 and \$1,384, respectively.

(3) Weighed average operating costs were determined using the information developed in steps (1) and (2), as follows: 1997, \$2,424 and 1998, \$2,353.

(4) The ratio between the 1997 and 1998 costs was computed as follows: \$2,353 ÷ \$2,424 = 0.9707.

(5) The transportation costs savings shown in Table B-36A under the column heading "Difference (1)" were multiplied by 0.9707 to obtain the current estimated transportation cost savings under the column heading "Difference (2)".

(6) The transportation cost savings were disconnected to determine the aggregate net present value. The appropriate interest and amortization factor was applied to the net present value to determine the annual equivalent transportation savings of \$14,333,000, as shown in Table B-36A.

The deviation of the average annual costs is shown in Table B-39A on page 50A. The average annual costs are estimated at \$6,848,000 based on October 1997 prices and an interest rate of 7-1/8 percent. The resulting benefit to cost ratio is 2.1 (\$14,333,000 ÷ \$6,848,000).

INDIANA HARBOR AND CANAL CONFINED DISPOSAL FACILITY

APPENDIX B

ECONOMIC ANALYSIS

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INDIANA HARBOR AND CANAL CONFINED DISPOSAL FACILITY

APPENDIX B

ECONOMIC ANALYSIS

INTRODUCTION

This appendix develops the commercial navigation and environmental benefits attributable to undertaking maintenance dredging of the Federal navigation channels at the Indiana Harbor and Canal (IHC) and providing for confined disposal of the dredged materials. The project area and navigation problems are briefly described. Existing and projected waterborne commerce and the vessel fleet at the IHC are discussed. The benefit analysis and results are discussed in detail.

EXISTING CONDITIONS

PROJECT AREA

The Indiana Harbor and Canal (IHC) are located in East Chicago, Indiana at the south end of Lake Michigan. East Chicago is in a highly industrialized steel-producing and petrochemical region. The existing Federal navigation project at the IHC is shown on Figure B-1. It includes north and east rubblemound breakwaters at the harbor entrance; an approach channel, 29 feet deep; an anchorage and maneuver basin, 28 feet deep; a canal entrance channel, 27 feet deep; a main canal channel and turning basin, 22 feet deep; and a channel in the Lake George and Calumet River Branches, 22 feet deep. The existing authorized Federal navigation project is complete. Two major steel companies, Inland Steel and LTV Steel, are located along both sides of the Federal navigation channel from the harbor entrance to the Cline Avenue bridge, a distance of about 3 miles. The U.S. Gypsum Company and the Amoco Oil Company (Amoco) are located further upstream along the north side of the canal and the Lake George Branch, respectively.

The Inland Steel Company is the fourth largest steel manufacturer in the U.S. and employs over 10,000 people at its Indiana Harbor plant. Inland Steel is a fully integrated steel manufacturing facility and recently started production of cold-rolled steel sheets and galvanized steel in a joint venture with Nippon Steel of Japan in New Carlisle, Indiana. Two subsidiaries, I/N Tek and I/N Kote, use steel that is manufactured at Inland's Indiana Harbor plant. Inland Steel's Indiana Harbor plant is in the process of mill upgrades and blast furnace relines scheduled for completion in 1994-95.

The LTV Steel Company is the second largest steel manufacturer in the U.S. and employs over 4,700 at its Indiana Harbor works. LTV's Indiana Harbor plant is a fully integrated plant with continuous casting and coating facilities. LTV has planned upgrades for its tin mill from 1993 to 1995, and blast furnace relines scheduled for 1993 and 1995-96. LTV operates two steel mills. The Indiana Harbor mill is the base mill which is usually run at full capacity, while the mill in Cleveland, OH is the swing capacity mill.

The Amoco Whiting Refinery is Amoco's oldest and second largest refinery. The refinery opened in 1891 and then processed 17,000 barrels of crude oil a day. Today, the Whiting refinery employs over 1,600 employees and processes 405,000 barrels of crude oil a day. They make 700 products, including 7 million gallons of gasoline per day. They also make diesel fuel, jet fuel, furnace oil, motor oils, wax, and asphalt.

WATERBORNE COMMERCE

Indiana Harbor received over 15 million tons of waterborne commerce in 1990, second only to the Port of Chicago in tonnage received on Lake Michigan. Of this total, over 12 million tons of material were received by the Inland Steel and LTV Steel Companies. The primary materials received by the steel mills are iron ore pellets and stone. Amoco, Safety-Kleen, and U.S. Gypsum accounted for the remaining receipts which included petroleum products and stone. Amoco shipped 1,098,000 tons of fuels and asphalt in 1991 and 2,014,500 tons in 1992 from the Amoco facility.

Table B-1 summarizes the existing LTV Steel Company and Inland Steel Company waterborne commerce receipts at Indiana Harbor. Iron ore pellets, or taconite, are shipped to Indiana Harbor and Canal from Duluth/Superior or Taconite Harbor, Minnesota or Escanaba, Michigan. A small percentage of the total ore shipments is Wabush, a type of iron ore, which is shipped from Point Noire, Canada. Stone, or calcite, is shipped from Calcite, Stoneport, or Doloport in Michigan. U.S. fleet vessels making deliveries to Indiana Harbor and Canal are dedicated to this trade and return empty to the point of origin. Ports of origin and destination are shown in Figure B-2. Indiana Harbor and Canal is primarily utilized by the industries along the harbor as a receiving port.

Amoco and Safety-Kleen use Indiana Harbor as a shipping port. Amoco ships asphalt and fuels from the Whiting Refinery to a variety of Great Lakes and Inland Ports. Safety-Kleen re-refines lubricating oils and ships to Inland Ports. The vessels used to transport fuel oils and asphalt are specialized and are dedicated to this trade, they return empty to Indiana Harbor.

FLEET COMPOSITION

The number of U.S. fleet vessels on the Great Lakes has declined over the past ten years, dropping to 185 vessels in 1990 from a high of 302 in 1980. However, the average carrying capacity for self-unloaders has increased by 81% over the same time period. This is due to the economies of scale inherent in shipping. There are only two U.S. fleet small (classes 1-4) bulk

The following tabulation shows the waterborne commerce statistics for years 1990-1996 for those commodities which would benefit from the proposed Indiana Harbor and Canal dredging.

Selected Waterborne Commerce at Indiana Harbor, 1990-1996

Year	Iron Ore Receipts	Stone Receipts	Asphalt Shipments	Fuel Shipments
1990	10,338,000	1,414,600	661,000	1,269,000
1991	9,637,000	1,423,400	602,000	840,000
1992	10,728,000	1,432,300	1,148,200	866,300
1993	11,002,000	1,148,000	1,054,000	887,000
1994	10,708,000	1,280,000	1,167,000	812,000
1995	11,326,000	1,149,000	856,000	791,000
1996	11,447,000	1,113,200	1,038,000	829,000

Source: Waterborne Commerce of the United States.

Table B–1 Waterborne Commerce Receipts at Indiana Harbor and Canal

LTV DELIVERIES – INDIANA HARBOR

LOCATION, MATERIAL	1988	1989	1990
TACONITE HARBOR (TACONITE) /1.	922,268	1,572,849	2,564,016
ESCANABA (EMPIRE)	1,776,880	969,133	375,784
TACONITE HARBOR (CLASSIFIER, CHIPS)	659,668	725,994	588,058
POINT NOIRE (WABUSH)	354,331	435,537	413,222
STONEPOINT (SINTER–HI–CAL)	163,609	160,410	164,696
DOLO PORTS (SINTER–DOLOMITE)	58,273	51,798	22,689
STONEPOINT (BLAST FURN HI–CAL)	74,696	107,763	40,262
CLEVELAND (MILL SCALE)	96,002	70,460	45,436
JONICK(FINES)	23,090	NA	NA
TOTAL METRIC TONS	4,130,817	4,113,964	4,214,163

1990 INDIANA HARBOR DELIVERIES TO INLAND STEEL

1990 INDIANA HARBOR DELIVERIES INLAND STEEL FLEET

1990 INDIANA HARBOR DELIVERIES – EDWARD L. RYERSON

Commodity	Origin	Tons
Royal	Escanaba	917,390 GT
Eveleth	Duluth	296,432 GT
Minntac	Duluth	50,609 GT
Ore Fines	Silver Bay	25,073 GT
Stone /2.	Calcite	140,369 GT
Total		1,429,873 GT

1990 INDIANA HARBOR DELIVERIES–M.V. JOSEPH L. BLOCK

Commodity	Origin	Tons
Viceroy	Escanaba	727,983 GT
Royal	Escanaba	32,691 GT
Minorca	Duluth	728,394 GT
LTV Fines		29,011 GT
Cyprus Fines	Silver Bay	28,426 GT
Total		1,546,505 GT

1990 INDIANA HARBOR DELIVERIES–STR. WILFRED SYKES

Commodity	Origin	Tons
Viceroy/Stone	Escanaba	42,576 GT
Viceroy/Siliceous /3.	Escanaba	162,402 GT
Viceroy	Escanaba	640,799 GT
Stone	Calcite/Stoneport	436,564 GT
Minorca	Duluth	57,933 GT
Royal/Siliceous	Escanaba	21,064 GT
Pellet Chips	Taconite Harbor	19,768 GT
Minntac	Escanaba	19,926 GT
Eveleth	Duluth	19,854 GT
Total		1,420,886 GT

1990 INDIANA HARBOR DELIVERIES OUTSIDE CARRIERS

1990 INDIANA HARBOR DELIVERIES TO INLAND STEEL BY OUTSIDE CARRIERS

Commodity	Origin	Tons	Gross Tons
Eveleth	Duluth	155,144 GT	
Minorca	Duluth	1,903,771 GT	
Wabush	Point Noire	453,802 GT	
Viceroy/Siliceous	Escanaba	453,802 GT	
Viceroy	Escanaba	222,294 GT	
QCM	Canada	151,745 MT	154,173 GT
Siliceous Ore	Canada	48,645 MT	49,423 GT
Mn Fines	Canada	15,003 MT	15,243 GT
Lime Creek Coal/4.	Thunder Bay	103,609 MT	105,470 GT
Total			3,513,122 GT

Notes

/1. The following commodity names refer to Iron Ore Pellets or Taconite: Eveleth, Minorca, Wabush, Viceroy, Empire, and Royal.
/2. Stone refers to Limestone or Dolomite, both are forms of calcite.
/3. Siliceous ore is raw iron ore.
/4. Lime Creek Coal is coking coal.

Sources: Inland Steel Co. and LTV Steel Co.

INLAND STEEL FLEET TOTAL	4,397,264 GT
OUTSIDE CARRIER TOTAL	3,513,122 GT
TOTAL (GROSS TON) INLAND STEEL DELIVIRIES 1990	7,910,386 GT
TOTAL (GROSS TON) INLAND STEEL DELIVIRIES 1993	8,100,691 GT
TOTAL (GROSS TON) LTV STEEL DELIVIRIES 1993	4,559,000 GT

TOTAL 1990 (GROSS TON) INLAND AND LTV STEEL DELIVERIES	**12,191,976**
TOTAL 1993 (GROSS TON) INLAND AND LTV STEEL DELIVERIES	**12,659,691**

carriers. Most of the U.S. fleet are medium (classes 5-8) vessels, 47 in total. All 14 of the large vessels (classes 9 and 10) are self-unloaders and all are part of the U.S. fleet. The large vessels are ore carriers, loading in Minnesota or Michigan.[1]

Shipments to LTV Steel are contracted to various shipping companies. Inland Steel Company both operates its own fleet and contracts to outside shipping companies. Iron ore pellets shipments to LTV are in general made by class 10 vessels. The Inland Steel Company fleet is comprised of two self-unloaders, the Wilfred Sykes (Class 6) and the Joseph L. Block (Class 7), and a straight deck bulk freighter, the Edward L. Ryerson (Class 7). These vessels account for 56% of total tonnage shipped to Inland Steel from U.S. ports. The remaining 44% is shipped via contract carriers, predominately in class 10 vessels or seaway size vessels. Based on conversations with representatives of Inland Steel's operations, the Inland fleet management plans to convert the Ryerson to a self-unloader and move to the more efficient larger vessels consistent with the availability of the required capital.

Shipments from Amoco are contracted to various shipping companies. Shipments of fuels are primarily made by the Coastwise Trading Company, a subsidiary of Amoco, via a self-powered tank barge the Great Lakes (Class 3). Asphalt shipments from Indiana Harbor to Chicago are made by shallow draft barge and to other U.S port destinations by deep draft tanker barge(Class 2).

PROBLEM AREAS

Commercial deep-draft vessel operations are adversely impacted by shoaling in the anchorage and maneuver basin, Reaches 3 and 4, and in the area under and on either side of the E. J. & E. Railroad bridge (see Figure B-3) near the five railroad bridges. Vessels have difficulty navigating and turning in Reaches 3 and 4 and sometimes run aground in Reach 4. The shoaling in the area near the railroad bridge causes time consuming delays in unloading cargo. Vessels delivering to the docks near the bridge must unload some cargo downstream and lessen their draft before moving into the bridge area to complete unloading. This is the shallowest area in Reach 5, where the depth in the Federal channel averages 24 feet. Continued shoaling in Indiana Harbor and Canal will exacerbate these problems and force the vessels to light load, increasing the transportation costs. Upstream of the five bridges, Reach 8 acts as the controlling reach for reaches 6-11.

FUTURE CONDITIONS

WATERBORNE COMMERCE PROJECTIONS

Tonnage to the Inland Steel and LTV Steel Companies is projected to increase from slightly over 12 million tons in 1990 to 12.7 million tons in 1998, the first year in which project

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[1] Greenwood's Guide to Great Lakes Shipping, 1991.

benefits are assumed to accrue. In 2030, the total shipments to Inland Steel and LTV Steel are projected to reach 14.9 million tons and by 2040 tonnage is expected to reach 15.5 million tons. These estimates include forecasts of deliveries from all ports and all commodities. Benefit estimation is based on domestic receipts of iron ore pellets and stone, which is expected to increase from a total of 10.1 million tons in 1990 to 12.4 million tons in 2030 and on shipments of asphalt and fuel from Amoco which are expected to increase from a total of 1.1 million tons (7 million barrels) in 1992 to 1.8 million tons in 2030.

The forecasts are based on the assumption that the future increase in tonnage delivered (ore and stone) is a result of increased demand for steel. Future tonnage increases are linked with growth in BEA projections for earnings in durable goods in the Great Lakes Region as shown in Table B-2. This method somewhat understates growth as productivity gains are not measured nor are the expected increases in the Inland Steel Company operations resulting from their subsidiary continuous cold-rolling mill and steel galvanizing lines. There are no long-term industry projections currently available for these items.

Iron Ore Pellets

The primary iron ore districts in the U.S. are grouped around the southern and northwestern shores of Lake Superior in Michigan, Minnesota and Wisconsin. The chief iron ranges are the Marquette and the Menominee in Michigan; the Penokee-Gogebic in Wisconsin; and the Mesabi, the Cuyuna, and the Vermilion in Minnesota. The Mesabi is the largest of the ranges. Most of the deposits of high grade ore have been depleted such that in the future most of the U.S. iron ore must come from low grade formations. The formation from which the deposits are derived is known as taconite, which contains about 25 to 30 percent iron.[2] Pieces of rock from the taconite formation are crushed and ground into fine particles. The iron bearing particles are separated from the rest with magnets. The concentrate is then rolled into pellets, heated, and hardened.

The reserves in taconite are much larger than the original reserves of high grade ore. There are 10 billion tons of material in the Mesabi Range alone. This amount of raw iron ore, by itself, would supply U.S. iron needs for 50 to 75 years at a growth rate of 2% annually.[3] The reserves in the Marquette Range are not well documented. However, they are substantially less than the reserves in the Mesabi Range. Estimated potential reserves are between 20 and 50 years, according to the Michigan Basin Geological Society.

Several factors influence the pellet origin mix, such as mine production, strikes, and the configuration of the blast furnace. Transportation cost savings can be realized by using pellets

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[2] Manual of Mineralogy 19th Ed.

[3] Report of Investigation 8552, U.S. Dept. of Interior, Bureau of Mines.

Table B-2 Durable Goods Earnings Growth Projections

DURABLE GOODS EARNINGS IN MILLIONS 1982 $	Actual 1988	Annual Growth	Projected 1995	Annual Growth	Projected 2000	Annual Growth	Projected 2005	Annual Growth	Projected 2010	Annual Growth	Projected 2020	Annual Growth	Projected 2040
GREAT LAKES	$83,592	1.00622	$87,302	1.00881	$91,218	1.00639	$94,169	1.00606	$97,058	1.00296	$99,970	1.00422	$108,757
ILLINOIS	$16,158	1.00741	$17,015	1.00710	$17,628	1.00629	$18,189	1.00596	$18,737	1.00277	$19,263	1.00420	$20,948
INDIANA	$12,244	1.01070	$13,191	1.01074	$13,914	1.00904	$14,555	1.00796	$15,143	1.00422	$15,795	1.00506	$17,473
MICHIGAN	$25,541	1.00399	$26,263	1.00452	$26,863	1.00400	$27,404	1.00436	$28,007	1.00182	$28,521	1.00345	$30,556
OHIO	$21,345	1.00734	$22,466	1.00764	$23,337	1.00659	$24,116	1.00611	$24,862	1.00299	$25,615	1.00424	$27,876
WISCONSIN	$8,305	1.01151	$8,997	1.01042	$9,476	1.00890	$9,905	1.00797	$10,306	1.00428	$10,756	1.00509	$11,905

Source: BEA Regional Projections

from Escanaba, however, the mines could not maintain the necessary high output. The pellet origin mix is assumed to remain constant for purposes of analysis. The projected tonnages by origin and vessel class are shown in Table B-3.

Stone

Calcite, in the form of limestone or dolomite is widely used in steel manufacture as a flux material. Calcite acts as an aid in the extraction of a blast furnace charge by fusing with unwanted material and forming a more liquid slag. It is one of the most common and widespread minerals and is found in the form of limestone or dolomite in masses of sedimentary rock in the Midwest. The stone delivered to Indiana Harbor generally originates from either Calcite or Stoneport, Michigan on Lake Michigan. The projected tonnages are shown in Table B-4.

Asphalt

Asphalt is a high boiling semisolid black or brown variety of bitumen either naturally occurring or derived via processing of petroleum. Asphalt consists of hydrocarbons that have combined with nitrogen, sulfur, and oxygen. While the constituents of asphalt are extremely variable, the physical properties are very stable except when heated. Heavy Venezuelan and Mexican crudes are napthenic in nature and have high asphalt content. Asphalt transportation requires special storage and handling equipment, with vessels dedicated to the trade. The most common uses of asphalt are road surfaces and building construction. The asphalt shipped from Indiana Harbor is produced at the Amoco Whiting Refinery. The projected tonnages are shown in Table-B-5.

Fuel Oils

Fuel oil consists largely of residues from crude oil distillation. These are generally blended with other fractions (products with lighter or heavier molecular weights) to obtain the required viscosity. Fuel oils are transported either by pipeline or in tanker vessels to distribution points. Fuel oils are used to primarily in steam generation for power stations, ships' boilers and industrial boilers. The fuel oils shipped from Indiana Harbor are produced at the Amoco Whiting Refinery. The projected tonnages are shown in Table B-6.

Table B–3 Projections of Iron Ore Receipts at Indiana Harbor

Origin	Duluth / Superior	Escanaba	Duluth / Superior	Escanaba
Vessel Class	10	10	7	7
Year	Tons Actual	Tons Actual	Tons Actual	Tons Actual
1990	2,995,939	1,832,800	1,172,990	2,678,014
Year	Tons Projected	Tons Projected	Tons Projected	Tons Projected
1991	3,014,574	1,844,200	1,180,286	2,694,671
1992	3,033,324	1,855,671	1,187,627	2,711,432
1993	3,052,192	1,867,213	1,195,014	2,728,297
1994	3,071,176	1,878,827	1,202,447	2,745,267
1995	3,090,279	1,890,514	1,209,927	2,762,343
1996	3,117,504	1,907,169	1,220,586	2,786,679
1997	3,144,970	1,923,971	1,231,339	2,811,230
1998	3,172,677	1,940,921	1,242,188	2,835,997
1999	3,200,628	1,958,021	1,253,131	2,860,982
2000	3,228,826	1,975,271	1,264,171	2,886,187
2001	3,249,458	1,987,893	1,272,249	2,904,630
2002	3,270,222	2,000,596	1,280,379	2,923,190
2003	3,291,119	2,013,379	1,288,561	2,941,869
2004	3,312,149	2,026,245	1,296,795	2,960,668
2005	3,333,313	2,039,193	1,305,081	2,979,587
2006	3,353,513	2,051,550	1,312,990	2,997,643
2007	3,373,836	2,063,983	1,320,947	3,015,809
2008	3,394,281	2,076,490	1,328,952	3,034,085
2009	3,414,850	2,089,074	1,337,005	3,052,471
2010	3,424,958	2,095,257	1,340,963	3,061,506
2011	3,435,096	2,101,459	1,344,932	3,070,568
2012	3,445,264	2,107,680	1,348,913	3,079,657
2013	3,455,462	2,113,919	1,352,906	3,088,773
2014	3,465,690	2,120,176	1,356,910	3,097,916
2015	3,475,949	2,126,451	1,360,927	3,107,086
2016	3,486,237	2,132,746	1,364,955	3,116,283
2017	3,496,557	2,139,059	1,368,995	3,125,507
2018	3,506,907	2,145,390	1,373,047	3,134,758
2019	3,517,287	2,151,741	1,377,112	3,144,037
2020	3,532,130	2,160,821	1,382,923	3,157,305
2021	3,547,036	2,169,940	1,388,759	3,170,629
2022	3,562,004	2,179,097	1,394,620	3,184,009
2023	3,577,036	2,188,293	1,400,505	3,197,445
2024	3,592,131	2,197,527	1,406,415	3,210,939
2025	3,607,290	2,206,801	1,412,350	3,224,489
2026	3,622,512	2,216,113	1,418,310	3,238,096
2027	3,637,799	2,225,465	1,424,295	3,251,761
2028	3,653,151	2,234,857	1,430,306	3,265,483
2029	3,668,567	2,244,288	1,436,342	3,279,264
2030	3,684,048	2,253,759	1,442,403	3,293,102
2031	3,699,595	2,263,270	1,448,490	3,306,999
2032	3,715,207	2,272,821	1,454,603	3,320,955
2033	3,730,886	2,282,412	1,460,741	3,334,969
2034	3,746,630	2,292,044	1,466,906	3,349,043
2035	3,762,441	2,301,716	1,473,096	3,363,176
2036	3,778,318	2,311,429	1,479,312	3,377,368
2037	3,794,263	2,321,184	1,485,555	3,391,621
2038	3,810,275	2,330,979	1,491,824	3,405,933
2039	3,826,354	2,340,816	1,498,120	3,420,306
2040	3,842,501	2,350,694	1,504,442	3,434,740

Source: Calculated from BEA Projections.

Table B–4 Projections of Stone Receipts at Indiana Harbor

Origin	Calcite
Vessel Class	7
Year	Tons Projected
1990	1,414,638
1991	1,423,443
1992	1,432,302
1993	1,441,217
1994	1,450,187
1995	1,459,213
1996	1,472,076
1997	1,485,052
1998	1,498,143
1999	1,511,349
2000	1,524,672
2001	1,534,410
2002	1,544,210
2003	1,554,073
2004	1,563,999
2005	1,573,988
2006	1,583,530
2007	1,593,129
2008	1,602,786
2009	1,612,503
2010	1,617,277
2011	1,622,066
2012	1,626,869
2013	1,631,686
2014	1,636,517
2015	1,641,363
2016	1,646,223
2017	1,651,098
2018	1,655,987
2019	1,660,890
2020	1,667,901
2021	1,674,941
2022	1,682,011
2023	1,689,110
2024	1,696,240
2025	1,703,400
2026	1,710,590
2027	1,717,811
2028	1,725,061
2029	1,732,343
2030	1,739,655
2031	1,746,998
2032	1,754,372
2033	1,761,777
2034	1,769,214
2035	1,776,682
2036	1,784,181
2037	1,791,712
2038	1,799,275
2039	1,806,870
2040	1,814,497

Source: Calculated from BEA Projections

Table B-5 Projections of Asphalt Shipments from Indiana Harbor

Vessel Class	2
Year	Tons
1992*	1,148,229
1993	1,159,711
1994	1,171,309
1995	1,183,022
1996	1,194,852
1997	1,206,800
1998	1,218,868
1999	1,231,057
2000	1,243,368
2001	1,255,801
2002	1,268,359
2003	1,281,043
2004	1,293,853
2005	1,306,792
2006	1,319,860
2007	1,333,058
2008	1,346,389
2009	1,359,853
2010	1,373,451
2011	1,387,186
2012	1,401,058
2013	1,415,068
2014	1,429,219
2015	1,443,511
2016	1,457,946
2017	1,472,526
2018	1,487,251
2019	1,502,124
2020	1,517,145
2021	1,532,316
2022	1,547,639
2023	1,563,116
2024	1,578,747
2025	1,594,534
2026	1,610,480
2027	1,626,585
2028	1,642,850
2029	1,659,279
2030	1,675,872
2031	1,692,630
2032	1,709,557
2033	1,726,652
2034	1,743,919
2035	1,761,358
2036	1,778,972
2037	1,796,761
2038	1,814,729
2039	1,832,876

*Projections are for all shipments, with actual shipments shown in 1992

Table B–6 Projections of Fuel Shipments from Indiana Harbor

Vessel Class	2
Year	Tons
1992*	866,328
1993	874,991
1994	883,741
1995	892,578
1996	901,504
1997	910,519
1998	919,624
1999	928,821
2000	938,109
2001	947,490
2002	956,965
2003	966,535
2004	976,200
2005	985,962
2006	995,822
2007	1,005,780
2008	1,015,838
2009	1,025,996
2010	1,036,256
2011	1,046,618
2012	1,057,085
2013	1,067,655
2014	1,078,332
2015	1,089,115
2016	1,100,006
2017	1,111,007
2018	1,122,117
2019	1,133,338
2020	1,144,671
2021	1,156,118
2022	1,167,679
2023	1,179,356
2024	1,191,149
2025	1,203,061
2026	1,215,091
2027	1,227,242
2028	1,239,515
2029	1,251,910
2030	1,264,429
2031	1,277,073
2032	1,289,844
2033	1,302,743
2034	1,315,770
2035	1,328,928
2036	1,342,217
2037	1,355,639
2038	1,369,196
2039	1,382,887

*Projections are for gas, distillate, intermediates, and fuel oils with actual shipments shown in 1992.

Scope of Analysis

The economic analysis concentrates on the deliveries of iron ore and stone to the steel mills from U.S. ports in Reaches 1 through 5. U.S. Gypsum has switched to a different source of material and does not expect to use the harbor and canal in the future for waterborne commerce. Amoco is experiencing navigation difficulties which are expected to become more severe in the future. The economic analysis for reaches 6-11 concentrates on shipments from Indiana Harbor to U.S. ports.

FLEET COMPOSITION

Fleet forecasts indicate that past trends towards larger vessels should continue; however, vessel size is limited by the Soo Locks (sill depth 32 feet) or the Straits of Mackinac (30 feet LWD). Currently the Poe lock is the largest lock and a constraint to vessel size. In the absence of another Poe size lock, no change in fleet mix is assumed in this analysis.

SEDIMENTATION/CHANNEL DEPTHS

An investigation of sedimentation rates and patterns within the Indiana Harbor and Canal (IHC) was completed to provide estimates of long-term navigation controlling depths for the economic analysis. The IHC was divided into 13 reaches as shown on Figure B-3 to facilitate this investigation which included the following activities:

- An analysis of historic sounding data, dredging records, Lake Michigan water levels and major storm events to develop a perspective on both long-term and short-term sedimentation rates.
- A preliminary sedimentation analysis to estimate the impact of channel depths within the IHC on sedimentation rates.
- Construction of a computer model to simulate the dredging process. The model incorporates the sedimentation rates developed in the previous two activities, the dredging volumes and bank sloughing.
- Development of the future "without project" channel conditions during the period of analysis and for three alternative maintenance dredging conditions utilizing the dredging simulation model.

The dredging simulation model was initially used to develop "without project" (without maintenance dredging) average annual sedimentation volumes and corresponding channel depths for each of the 13 reaches for the period 1998 to 2040. The constraining depth in 1998 as determined by this model is +4.25 in Reach 4 (23.75 LWD) and is expected to increase slowly to +5.37 by 2029 (22.63 LWD). The controlling depth for navigation in Reaches 6-11 in 1988 is +4.23 (17.77 LWD) in Reach 8 and is expected to increase to +6.33 (15.67 LWD) by 2029.. The results of the simulation are summarized in Tables Q-10 and Q-11 of Appendix Q - Sedimentation Investigation and Dredging Plans. The without project or baseline condition is shown in Table Q-13. These controlling channel depths were used to develop the "without project" waterborne commerce transportation costs used in the economic analysis.

The dredging simulation model was subsequently used to develop three alternative maintenance dredging plans. The first consists of dredging the harbor and berthing areas to authorized depths from the entrance to the E.J. & E. Railroad bridge (Reaches 1 through 5), with no dredging upstream of this bridge. This plan is identified as Alternative 1 - Partial Federal Channel Dredging Program. The second plan consists of dredging the entire Federal navigation project and berthing areas to authorized depths from the entrance to the upstream project limits on the Lake George and Calumet River Branches (Reaches 1 through 13). This plan is identified as Alternative 2 - Complete Federal Channel Dredging Program. The third plan consists of dredging the entire Federal navigation project and berthing areas of Alternative 2, as well as the remaining Inland Steel Company dockface areas. This plan is identified as Alternative 3 - Cooperative Dredging Program.

BENEFIT ANALYSIS

GENERAL

The economic benefits associated with maintenance dredging of the Indiana Harbor and Canal are the result of preventing lightloading of vessels and the associated transportation cost increases. The transportation costs for the projected waterborne commerce at Indiana Harbor and Canal were estimated for the future "without project" condition and the three alternative maintenance dredging conditions, i.e., Alternative 1, Alternative 2, and Alternative 3. The difference between the projected transportation costs "with" and "without project" represents the stream of project benefits.

The economic benefits of dredging the harbor and canal were based on the following assumptions:

- Commodity projections developed from 1998 to 2040.
- Future "without project" controlling depths in the harbor and canal channels developed by use of the dredging simulation model (Appendix Q).
- Depths in berthing areas to be commensurate with depths in the adjacent Federal channel.
- Transportation costs estimated by determining the voyage costs and the cargo tons carried per voyage at the future controlling depths for both "with" and "without project" conditions.

- Benefits discounted to an average annual equivalent basis at a Federal Discount rate of 8.0%. Benefits were estimated for a 34-year period for Alternative 1 - Partial Federal Channel Dredging Program, Alternative 2 - Complete Dredging Program, and Alternative 3 - Cooperation Dredging Program. The base year is 1998.
- Price levels based on 1993 dollars.

TRANSPORTATION COSTS

Transportation costs per ton were determined for various classes of vessels using the hourly vessel operating costs, the round trip voyage time, and the tons loaded. The greater the amount of tonnage carried, the lower the transportation cost per ton for a given voyage. The operating costs for a larger vessel are higher relative to a smaller class of vessel. However, the greater capacity of the larger class of vessel indicates lower transportation cost per ton may be realized relative to the cost per ton on a smaller class of vessel. For example, in 1990 the Inland Steel vessel Joseph Block (class 7) carried 760,600 tons of ore from Escanaba to Indiana Harbor. Assuming an average load of 31,056 tons, the Joseph Block would have made 24.4 trips at an annual cost of $4.14 million. If a class 10 vessel had been used and the average load had been 56,750 tons, the annual cost would be 3.39 million, a difference of $750,000.

Vessel operating costs, as determined by the Department of Transportation Maritime Administration, consist of the budget cost, fuel, wages, sustenance, supplies, insurance, maintenance and repair. The budget cost consists of construction contract prices, for three vessel contracts, with delivery in 1993. The vessels in all classes have self-unloading cargo handling systems. The operating costs are based on averages and do not reflect any particular operators actual experience. The 1993 vessel operating costs are shown in Table B-7.

Voyage costs were computed for each vessel class and trade route based on information from the Department of Transportation Maritime Administration and the LTV Steel Company. The voyage costs were used to determine transportation costs per ton for a given voyage. For example, the voyage cost on a class 10 vessel trip to Indiana Harbor from Escanaba may be determined by multiplying the number of trip hours for a round trip voyage (99 hours) by the vessel hourly operating cost. The applicable voyage costs are shown in Tables B-8 to B-12.

Cargo tons at a specific vessel draft can be determined by subtracting the tons lightloaded from the cargo tons capacity. The following formula was used to determine cargo tons.

Cargo Tons = (Max. Dwt-800)-(TPI((Max. Dft.-(Controlling Depth -Underkeel))*10))

Where:

Max. Dwt -800 = The number of long tons a vessel can transport, or carrying capacity net of stores, fuel and supplies (estimated at 800 tons). Source: Greenwood's Guide to Great Lakes Shipping. (1991)

TPI = Tons per tenth of a foot immersion factor. Source: LTV Steel Co.

Max. Dft = Maximum vessel draft.

Controlling Depth = The depth in the Federal channel which determines the maximum draft of a vessel or the shallowest area in the Federal channel.

Underkeel = The amount of clearance required between the bottom of the vessel and the channel bottom for safe operation. The safe drafts at authorized project depths used for the economic analysis were based on the following draft allowances shown in the Great Lakes Harbors Study Interim Report on Indiana Harbor, Indiana, published as House Document No. 195/89/1 and in the Great Lakes Harbors Study - Second Interim Report on Indiana Harbor, Indiana, published as House Document No. 227/89/1:

	Approach Channel	Anchorage/ Maneuver Basin	Canal Entrance Channel	Canal Channel
Authorized project depth, feet below L.W.D.	29.0	28.0	27.0	22.0
Draft allowances, feet:				
●Squat	-2.0	-1.0	-1.0	-0.5
●Clearance, exposed situation	-1.5	-1.5	-	-
●Clearance sheltered situation	-	-	-0.5	-0.5
Considered safe draft, feet below L.W.D.	25.5	25.5	25.5	21.0

The voyage cost was divided by the cargo tons carried at a given draft to determine the transportation cost per ton.

Table B-7 Great Lakes Vessel Operating

Vessel Class	2	3	4	5	7	10
Budget Cost*	$45,000,000	$50,000,000	$58,000,000	$62,000,000	$70,000,000	$110,000,000
Interest and Amortization for 50 Yrs. ** @0.08 = 0.0817	3,676,500	4,085,000	4,738,600	5,065,400	5,719,000	8,987,000
Divide by Shipping Season days = 270	13,617	15,130	17,550	18,761	21,181	33,285
Daily Operating Expense Overhead Percent = 12%	13,621 1,635	14,967 1,796	15,921 1,911	17,314 2,078	18,282 2,194	26,000 3,120
Total Daily Expenses	28,873	31,893	35,382	38,153	41,657	62,405
Hourly Operating Costs	1,203	1,329	1,474	1,590	1,736	2,600
Profit Factor Percent = 15%	180	199	221	238	260	390
Total Hourly Operating Costs	1,383	1,528	1,695	1,828	1,996	2,990

Source: D.O.T. Maritime Administration, May 1996
*Based on 1993 delivery date.
**Based on Vessel Life

Table B–8 Voyage Cost from Duluth/Superior (Vessel Class 10)

ORIGIN:	DULUTH\SUPERIOR
COMMODITY:	IRON ORE PELLETS
TONS RECEIVED 1990	2,995,939
DESTINATION:	INDIANA HARBOR

VESSEL CHARACTERISTICS CLASS 10	
DWT	78,850 GT
Max. Draft	34 FT
Underkeel Clearance	1.5 FT
TPI	284
Speed	14.2 MPH
Max. Discharge Rate	10000 Tons/Hour

TIME AT SEA	
Sea Miles	703 Mi.
Total Miles (River & Sea)	760 Mi.
Rd. Sea Miles/Speed	99.0 Hrs
Ldg. Harbor Moves	2.0 Hrs
Ldg. Dock & Undock	2.0 Hrs
Soo & St. Mary's	14.4 Hrs
Disch. Harbor Moves	3.0 Hrs
Dis. Pt. Dock & Undock	1.5 Hrs
Total Time at Sea	121.9 Hrs
Total Cost at Sea	**$364,649**

TIME IN PORT	
Load @75% Rated Cap.	7.9 Hrs
Disch. @80% Capacity	7.0 Hrs
Bunker Time	2.0 Hrs
Fog & Delay	1.1 Hrs
Total Time in Port	18.0 Hrs
Total Cost in Port	**$53,839**
Total Voyage Cost	**$418,487**

Source: LTV Steel Co. and Greenwood's Guide to Great Lakes Shipping 1991

Table B–9 Voyage Cost from Escanaba (Vessel Class 10)

ORIGIN:	ESCANABA, MI
COMMODITY:	IRON ORE PELLETS
TONS 1990	1,832,800
DESTINATION:	INDIANA HARBOR

VESSEL CHARACTERISTICS CLASS 10	
DWT	78,850 GT
Max. Draft	34 FT
Underkeel Clearance	1.5 FT
TPI	284
Speed	14.2 MPH
Max. Discharge Rate	10000 Tons/Hour

TIME AT SEA	
Sea Miles	286 Mi.
Total Miles (River & Sea)	286 Mi.
Rd. Sea Miles/Speed	40.3 Hrs
Ldg. Harbor Moves	2.0 Hrs
Ldg. Dock & Undock	2.0 Hrs
Soo & St. Mary's	0.0 Hrs
Disch. Harbor Moves	3.0 Hrs
Dis. Pt. Dock & Undock	1.5 Hrs
Total Time at Sea	48.8 Hrs
Total Cost at Sea	$145,907

TIME IN PORT	
Load @75% Rated Cap.	24 Hrs
Disch. @80% Capacity	7.0 Hrs
Bunker Time	2.0 Hrs
Fog & Delay	0.4 Hrs
Total Time in Port	33.4 Hrs
Total Cost in Port	$99,900
Total Voyage Cost	**$245,808**

Source: LTV Steel Co. and Greenwood's Guide to Great Lakes Shipping 1991

Table B–10 Voyage Cost from Duluth/Superior (Vessel Class 7)

ORIGIN:	DULUTH/SUPERIOR
COMMODITY:	IRON ORE PELLETS
TONS 1990	1,172,990
DESTINATION:	INDIANA HARBOR

VESSEL CHARACTERISTICS CLASS 7	
DWT	37,200 GT
Max. Draft	30.92 FT
Underkeel Clearance	1.5 FT
TPI	139
Speed	14.2 MPH
Max. Discharge Rate	6600 Tons/Hour

TIME AT SEA	
Sea Miles	703 Mi.
Total Miles (River & Sea)	760 Mi.
Rd. Sea Miles/Speed	99.0 Hrs
Ldg. Harbor Moves	2.0 Hrs
Ldg. Dock & Undock	2.0 Hrs
Soo & St. Mary's	14.4 Hrs
Disch. Harbor Moves	3.0 Hrs
Dis. Pt. Dock & Undock	1.5 Hrs
Total Time at Sea	121.9 Hrs
Total Cost at Sea	$243,411

TIME IN PORT	
Load @75% Rated Cap.	4.5 Hrs
Disch. @80% Capacity	5.6 Hrs
Bunker Time	2.0 Hrs
Fog & Delay	1.1 Hrs
Total Time in Port	13.2 Hrs
Total Cost in Port	$26,355
Total Voyage Cost	**$269,766**

Source: LTV Steel Co. and Greenwood's Guide to Great Lakes Shipping 1991

Table B-11 Voyage Cost from Escanaba (Vessel Class 7)

ORIGIN:	ESCANABA, MI
COMMODITY:	IRON ORE PELLETS
TONS 1990	2,678,014
DESTINATION:	INDIANA HARBOR

VESSEL CHARACTERISTICS CLASS 7	
DWT	37,200 GT
Max. Draft	30.92 FT
Underkeel Clearance	1.5 FT
TPI	139
Speed	14.2 MPH
Max. Discharge Rate	6600 Tons/Hour

TIME AT SEA	
Sea Miles	286 Mi.
Total Miles (River & Sea)	286 Mi.
Rd. Sea Miles/Speed	40.3 Hrs
Ldg. Harbor Moves	2.0 Hrs
Ldg. Dock & Undock	2.0 Hrs
Soo & St. Mary's	0.0 Hrs
Disch. Harbor Moves	3.0 Hrs
Dis. Pt. Dock & Undock	1.5 Hrs
Total Time at Sea	48.8 Hrs
Total Cost at Sea	$97,396

TIME IN PORT	
Load @75% Rated Cap.	24 Hrs
Disch. @80% Capacity	7.0 Hrs
Bunker Time	2.0 Hrs
Fog & Delay	0.4 Hrs
Total Time in Port	33.4 Hrs
Total Cost in Port	$66,686
Total Voyage Cost	**$164,082**

Source: LTV Steel Co. and Greenwood's Guide to Great Lakes Shipping 1991

Table B–12 Voyage Cost from Calcite (Vessel Class 7)

ORIGIN:	CALCITE, MI
COMMODITY:	STONE
TONS 1990	1,414,638
DESTINATION:	INDIANA HARBOR

VESSEL CHARACTERISTICS CLASS 7	
DWT	37,200 GT
Max. Draft	30.92 FT
Underkeel Clearance	1.5 FT
TPI	139
Speed	14.2 MPH
Max. Discharge Rate	6600 Tons/Hour

TIME AT SEA	
Sea Miles	410 Mi.
Total Miles (River & Sea)	410 Mi.
Rd. Sea Miles/Speed	57.7 Hrs
Ldg. Harbor Moves	2.0 Hrs
Ldg. Dock & Undock	2.0 Hrs
Soo & St. Mary's	0.0 Hrs
Disch. Harbor Moves	3.0 Hrs
Dis. Pt. Dock & Undock	1.5 Hrs
Total Time at Sea	66.2 Hrs
Total Cost at Sea	$132,266

TIME IN PORT	
Load @75% Rated Cap.	10 Hrs
Disch. @80% Capacity	7.0 Hrs
Bunker Time	2.0 Hrs
Fog & Delay	0.4 Hrs
Total Time in Port	19.4 Hrs
Total Cost in Port	$38,734
Total Voyage Cost	**$171,000**

Source: LTV Steel Co. and Greenwood's Guide to Great Lakes Shipping 1991

IMPACT OF LAKE LEVELS

Controlling depth is the constraint to safe vessel draft; a vessel cannot traverse an area safely if its draft is greater than the depth in the area. The authorized project depth in Reach 5 is 27 feet below low water datum and 28 feet below low water datum by the stone dock and the hopper dock in Reaches 3 and 4. Lake level changes offset controlling depths as they rise and fall. For example, if the lake level is LWD +1, the controlling depth is 28 feet in Reach 5. The vessel operators rationally use the higher lake levels to increase cargo tons carried on a given trip, thereby decreasing their transportation costs per ton. The benefit analysis incorporates lake level effects by basing benefits on the weighted average cost per ton. The weight assignments are lake level frequencies in one-foot increments from 1960 to 1990. Lake level frequencies are shown in Table B-13. Conditions in the harbor indicate that shoaling will force vessels to light load. However, comparisons of the weighted average costs indicate that at no time is an alternative means of transportation more cost-effective. Based on conversations with representatives of Inland Steel and LTV Steel, the additional cost incurred through the use of alternative means of transportation would be as follows: barge transfer would be approximately $4.50 ton and railroad transport in place of shipping activity would cost approximately $15/ton. A switch to smaller vessels, of which an adequate existing fleet does not exist, would incur additional costs of more than $2/ton, based on analysis of vessel operating costs. These cost estimates do not include capital expenditures to create appropriate handling facilities for rail and barge transport.

Table B-13 Lake Level Frequencies

Gage 7044 Calumet Harbor	
Lake Level	Frequency
576.80	5.85%
577.80	16.10%
578.80	24.39%
579.80	25.37%
580.80	23.17%
581.80	5.12%
Total	100.00%

Source: NOAA

NAVIGATION BENEFITS

Weighted average transportation costs are shown in Tables B-14 through B-33 for the projected controlling depths for "without project" conditions and for the three project conditions, i.e., Alternative 1 - Partial Federal Channel Dredging Program, Alternative 2 - Complete Federal Channel Dredging Program and Alternative 3 - Cooperative Dredging Program. The weighted average cost is then applied to the projected tonnages for "without project" conditions and "with project" conditions. The resulting transportation costs are shown in Tables B-34, B-35, and B-36. These benefits are based on domestic receipts of iron ore and stone by the two steel manufacturing firms at Indiana Harbor and for Alternatives 2 and 3, shipments from Reaches 6- 11 are included as well. Explicit transportation costs for Reaches 6-11 are not shown in order to preserve confidentiality of information. The transportation cost reduction represents the benefit stream. The benefit stream (1998 to 2031) represents the minimum level of benefits to be claimed for this project, because benefits still are estimated to accrue from some unknown period of time even after capping of the CDF is completed. The benefits are limited to the period 1998 to 2031 to provide a common basis of evaluation for all plans. Benefits for the Generic Clean Site are identical to those estimated for Alternative 2 - Complete Dredging.

ESTIMATED COSTS

Detailed estimates of cost for construction of the proposed confined disposal facility and the alternative dredging plans are contained in Appendix K - Cost Estimation. The average annual costs are shown in Tables B-37 through B-40.

COMPARISON OF BENEFITS AND COSTS

DEEP-DRAFT NAVIGATION BENEFITS

Table B-41 summarizes the comparison of benefits and costs of the three alternative dredging plans. All plans are economically justified by a wide margin based solely on deep-draft navigation benefits. Alternative 1 - Partial Federal Channel Dredging Program has average annual net benefits totalling $8.2 million. Alternative 2 - Complete Federal Channel Dredging Program has average annual net benefits of $12.7 million and Alternative 3 - Cooperative Dredging Program has average annual net benefits of $12.5 million. The Generic Clean Upland CDF Site has significantly lower average annual net benefits of $8.8 million. Therefore, Alternative 2 - Complete Federal Channel Dredging Program is the National Economic Development Plan because of its greater net benefits. In Alternative 2 - Complete Dredging, and in Alternative - 3 Cooperative Dredging, the maintained channels upstream of the E. J. & E. Railroad bridge (Reaches 6-13) will act as a sediment trap or settling area. This will reduce the quantity of sediment moving into and settling out in the downstream channel reaches (Reaches 1-5) where the intense navigation activity occurs. Adequate navigation depths in the downstream reaches will be more easily maintained for longer periods of time under Alternative 2 -Complete Dredging than under Alternative 1 -

Table B–14 Without Project Weighted Average Costs, Duluth/Superior to Indiana Harbor, (Vessel Class 10)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$8.05	3,172,787	$25,531,144
1999	$8.12	3,200,755	$25,984,427
2000	$8.19	3,228,970	$26,447,856
2001	$8.26	3,249,593	$26,826,674
2002	$8.31	3,270,348	$27,181,760
2003	$8.40	3,291,236	$27,637,542
2004	$8.43	3,312,257	$27,926,095
2005	$8.46	3,333,413	$28,201,830
2006	$8.48	3,353,620	$28,454,946
2007	$8.50	3,373,949	$28,693,912
2008	$8.52	3,394,402	$28,935,042
2009	$8.54	3,414,979	$29,161,351
2010	$8.55	3,425,091	$29,281,834
2011	$8.56	3,435,233	$29,402,856
2012	$8.57	3,445,404	$29,524,418
2013	$8.57	3,455,606	$29,629,172
2014	$8.58	3,465,838	$29,751,732
2015	$8.59	3,476,101	$29,857,324
2016	$8.59	3,486,393	$29,945,731
2017	$8.59	3,496,716	$30,052,022
2018	$8.60	3,507,070	$30,158,700
2019	$8.60	3,517,455	$30,248,000
2020	$8.60	3,532,302	$30,393,519
2021	$8.60	3,547,212	$30,521,810
2022	$8.61	3,562,184	$30,668,658
2023	$8.61	3,577,220	$30,798,110
2024	$8.61	3,592,320	$30,928,109
2025	$8.61	3,607,483	$31,058,656
2026	$8.61	3,622,710	$31,189,755
2027	$8.61	3,638,002	$31,321,407
2028	$8.61	3,653,358	$31,472,112
2029	$8.61	3,668,779	$31,604,956
2030	$8.61	3,684,264	$31,738,361
2031	$8.61	3,699,816	$31,872,328
2032	$8.61	3,715,433	$32,006,861
2033	$8.61	3,731,116	$32,141,962
2034	$8.61	3,746,865	$32,277,633
2035	$8.61	3,762,680	$32,413,877

Table B–15 Without Project Weighted Average Costs, Escanaba to Indiana Harbor, (Vessel Class 10)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$4.65	1,940,989	$9,034,469
1999	$4.70	1,958,099	$9,193,614
2000	$4.74	1,975,359	$9,356,283
2001	$4.77	1,987,976	$9,489,123
2002	$4.81	2,000,673	$9,613,691
2003	$4.85	2,013,451	$9,773,290
2004	$4.87	2,026,311	$9,874,690
2005	$4.89	2,039,253	$9,971,633
2006	$4.90	2,051,615	$10,060,658
2007	$4.91	2,064,052	$10,144,766
2008	$4.93	2,076,564	$10,229,630
2009	$4.93	2,089,153	$10,309,344
2010	$4.94	2,095,339	$10,351,741
2011	$4.95	2,101,543	$10,394,326
2012	$4.95	2,107,766	$10,437,100
2013	$4.95	2,114,007	$10,474,031
2014	$4.96	2,120,266	$10,517,154
2015	$4.96	2,126,544	$10,554,379
2016	$4.96	2,132,841	$10,585,631
2017	$4.97	2,139,156	$10,623,101
2018	$4.97	2,145,490	$10,660,708
2019	$4.97	2,151,843	$10,692,274
2020	$4.97	2,160,926	$10,743,610
2021	$4.97	2,170,047	$10,788,958
2022	$4.97	2,179,207	$10,840,762
2023	$4.97	2,188,406	$10,886,520
2024	$4.97	2,197,643	$10,932,472
2025	$4.97	2,206,919	$10,978,618
2026	$4.97	2,216,235	$11,024,959
2027	$4.97	2,225,589	$11,071,495
2028	$4.98	2,234,983	$11,124,659
2029	$4.98	2,244,417	$11,171,616
2030	$4.98	2,253,891	$11,218,772
2031	$4.98	2,263,405	$11,266,126
2032	$4.98	2,272,959	$11,313,680
2033	$4.98	2,282,553	$11,361,435
2034	$4.98	2,292,187	$11,409,392
2035	$4.98	2,301,863	$11,457,551

Table B–16 Without Project Weighted Average Costs, Duluth/Superior to Indiana Harbor, (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$9.65	1,242,231	$11,991,401
1999	$9.73	1,253,181	$12,194,571
2000	$9.81	1,264,228	$12,401,996
2001	$9.88	1,272,302	$12,570,561
2002	$9.94	1,280,429	$12,728,962
2003	$10.03	1,288,607	$12,930,026
2004	$10.07	1,296,837	$13,060,096
2005	$10.10	1,305,120	$13,184,754
2006	$10.13	1,313,032	$13,299,457
2007	$10.15	1,320,991	$13,408,202
2008	$10.17	1,328,999	$13,517,896
2009	$10.19	1,337,055	$13,621,360
2010	$10.20	1,341,014	$13,676,120
2011	$10.21	1,344,985	$13,731,115
2012	$10.22	1,348,968	$13,786,347
2013	$10.23	1,352,962	$13,834,488
2014	$10.24	1,356,968	$13,890,159
2015	$10.24	1,360,986	$13,938,675
2016	$10.24	1,365,016	$13,979,948
2017	$10.25	1,369,058	$14,028,781
2018	$10.25	1,373,112	$14,077,790
2019	$10.25	1,377,177	$14,119,474
2020	$10.26	1,382,990	$14,186,603
2021	$10.26	1,388,828	$14,246,485
2022	$10.26	1,394,690	$14,314,221
2023	$10.26	1,400,577	$14,374,642
2024	$10.26	1,406,489	$14,435,317
2025	$10.26	1,412,426	$14,496,249
2026	$10.26	1,418,388	$14,557,437
2027	$10.26	1,424,375	$14,618,884
2028	$10.27	1,430,387	$14,688,396
2029	$10.27	1,436,425	$14,750,396
2030	$10.27	1,442,488	$14,812,657
2031	$10.27	1,448,577	$14,875,181
2032	$10.27	1,454,691	$14,937,969
2033	$10.27	1,460,831	$15,001,023
2034	$10.27	1,466,997	$15,064,342
2035	$10.27	1,473,190	$15,127,929

Table B-17 Without Project Weighted Average Costs, Escanaba to Indiana Harbor, (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$5.87	2,836,095	$16,651,865
1999	$5.92	2,861,095	$16,933,998
2000	$5.97	2,886,316	$17,222,039
2001	$6.01	2,904,751	$17,456,116
2002	$6.05	2,923,303	$17,676,080
2003	$6.10	2,941,975	$17,955,288
2004	$6.13	2,960,765	$18,135,910
2005	$6.14	2,979,675	$18,309,016
2006	$6.16	2,997,738	$18,468,298
2007	$6.17	3,015,910	$18,619,307
2008	$6.19	3,034,193	$18,771,634
2009	$6.20	3,052,586	$18,915,310
2010	$6.20	3,061,625	$18,991,352
2011	$6.21	3,070,690	$19,067,721
2012	$6.22	3,079,783	$19,144,418
2013	$6.22	3,088,902	$19,211,270
2014	$6.23	3,098,048	$19,288,578
2015	$6.23	3,107,221	$19,355,950
2016	$6.23	3,116,422	$19,413,263
2017	$6.23	3,125,650	$19,481,075
2018	$6.24	3,134,905	$19,549,131
2019	$6.24	3,144,187	$19,607,016
2020	$6.24	3,157,459	$19,700,234
2021	$6.24	3,170,786	$19,783,389
2022	$6.24	3,184,170	$19,877,452
2023	$6.24	3,197,611	$19,961,355
2024	$6.24	3,211,108	$20,045,611
2025	$6.24	3,224,662	$20,130,224
2026	$6.24	3,238,273	$20,215,194
2027	$6.24	3,251,942	$20,300,522
2028	$6.25	3,265,668	$20,397,050
2029	$6.25	3,279,453	$20,483,145
2030	$6.25	3,293,295	$20,569,605
2031	$6.25	3,307,196	$20,656,429
2032	$6.25	3,321,156	$20,743,620
2033	$6.25	3,335,175	$20,831,179
2034	$6.25	3,349,252	$20,919,107
2035	$6.25	3,363,390	$21,007,407

Table B–18 Without Project Weighted Average Costs, Calcite Indiana Harbor, (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$6.12	1,498,143	$9,167,054
1999	$6.17	1,511,349	$9,322,372
2000	$6.22	1,524,672	$9,480,942
2001	$6.26	1,534,410	$9,609,804
2002	$6.30	1,544,210	$9,730,897
2003	$6.36	1,554,073	$9,884,605
2004	$6.38	1,563,999	$9,984,039
2005	$6.40	1,573,988	$10,079,336
2006	$6.42	1,583,530	$10,167,023
2007	$6.43	1,593,129	$10,250,155
2008	$6.45	1,602,786	$10,334,013
2009	$6.46	1,612,503	$10,413,108
2010	$6.46	1,617,277	$10,454,970
2011	$6.47	1,622,066	$10,497,012
2012	$6.48	1,626,869	$10,539,235
2013	$6.48	1,631,686	$10,576,038
2014	$6.49	1,636,517	$10,618,597
2015	$6.49	1,641,363	$10,655,686
2016	$6.49	1,646,223	$10,687,237
2017	$6.50	1,651,098	$10,724,569
2018	$6.50	1,655,987	$10,762,034
2019	$6.50	1,660,890	$10,793,901
2020	$6.50	1,667,901	$10,845,219
2021	$6.50	1,674,941	$10,890,996
2022	$6.51	1,682,011	$10,942,779
2023	$6.51	1,689,110	$10,988,969
2024	$6.51	1,696,240	$11,035,353
2025	$6.51	1,703,400	$11,081,933
2026	$6.51	1,710,590	$11,128,710
2027	$6.51	1,717,811	$11,175,684
2028	$6.51	1,725,061	$11,228,824
2029	$6.51	1,732,343	$11,276,221
2030	$6.51	1,739,655	$11,323,818
2031	$6.51	1,746,998	$11,371,616
2032	$6.51	1,754,372	$11,419,615
2033	$6.51	1,761,777	$11,467,817
2034	$6.51	1,769,214	$11,516,223
2035	$6.51	1,776,682	$11,564,833

Table B-19 Alternative 1 – Partial Dredging, Weighted Average Costs, Duluth/Superiorto Indiana Harbor (Vessel Class 10)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$7.96	3,172,787	$25,240,209
1999	$7.70	3,200,755	$24,634,116
2000	$7.46	3,228,970	$24,092,783
2001	$7.24	3,249,593	$23,540,358
2002	$7.35	3,270,348	$24,046,867
2003	$7.16	3,291,236	$23,574,365
2004	$7.01	3,312,257	$23,226,185
2005	$6.91	3,333,413	$23,033,430
2006	$7.17	3,353,620	$24,044,676
2007	$7.08	3,373,949	$23,898,553
2008	$7.03	3,394,402	$23,870,626
2009	$6.98	3,414,979	$23,832,636
2010	$6.93	3,425,091	$23,733,946
2011	$6.88	3,435,233	$23,625,786
2012	$6.83	3,445,404	$23,519,450
2013	$6.77	3,455,606	$23,404,096
2014	$6.84	3,465,838	$23,703,024
2015	$6.80	3,476,101	$23,641,053
2016	$6.76	3,486,393	$23,558,274
2017	$6.82	3,496,716	$23,858,630
2018	$6.79	3,507,070	$23,796,562
2019	$6.70	3,517,455	$23,583,650
2020	$6.77	3,532,302	$23,912,510
2021	$6.75	3,547,212	$23,936,188
2022	$6.70	3,562,184	$23,861,760
2023	$6.76	3,577,220	$24,194,282
2024	$6.73	3,592,320	$24,162,839
2025	$6.70	3,607,483	$24,165,199
2026	$6.76	3,622,710	$24,501,949
2027	$6.78	3,638,002	$24,673,570
2028	$6.77	3,653,358	$24,732,018
2029	$6.84	3,668,779	$25,079,259
2030	$6.89	3,684,264	$25,397,995
2031	$6.88	3,699,816	$25,445,455
2032	$6.95	3,715,433	$25,806,763
2033	$7.02	3,731,116	$26,175,806
2034	$7.09	3,746,865	$26,552,822
2035	$7.16	3,762,680	$26,938,061

Table B–20 Alternative 1 – Partial Dredging, Weighted Average Costs, Escanaba to Indiana Harbor (Vessel Class 10)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$4.60	1,940,989	$8,933,084
1999	$4.45	1,958,099	$8,722,888
2000	$4.32	1,975,359	$8,535,031
2001	$4.20	1,987,976	$8,342,792
2002	$4.26	2,000,673	$8,520,529
2003	$4.15	2,013,451	$8,356,141
2004	$4.06	2,026,311	$8,235,092
2005	$4.01	2,039,253	$8,168,344
2006	$4.15	2,051,615	$8,522,733
2007	$4.10	2,064,052	$8,472,338
2008	$4.08	2,076,564	$8,463,260
2009	$4.05	2,089,153	$8,450,653
2010	$4.02	2,095,339	$8,416,453
2011	$3.99	2,101,543	$8,378,928
2012	$3.96	2,107,766	$8,342,030
2013	$3.93	2,114,007	$8,301,964
2014	$3.97	2,120,266	$8,406,937
2015	$3.94	2,126,544	$8,385,566
2016	$3.92	2,132,841	$8,356,902
2017	$3.96	2,139,156	$8,462,384
2018	$3.93	2,145,490	$8,440,978
2019	$3.89	2,151,843	$8,366,741
2020	$3.93	2,160,926	$8,482,360
2021	$3.91	2,170,047	$8,491,112
2022	$3.88	2,179,207	$8,465,505
2023	$3.92	2,188,406	$8,582,414
2024	$3.90	2,197,643	$8,571,868
2025	$3.88	2,206,919	$8,573,157
2026	$3.92	2,216,235	$8,691,552
2027	$3.93	2,225,589	$8,752,118
2028	$3.93	2,234,983	$8,773,060
2029	$3.96	2,244,417	$8,895,111
2030	$4.00	2,253,891	$9,007,168
2031	$3.99	2,263,405	$9,024,277
2032	$4.03	2,272,959	$9,151,222
2033	$4.07	2,282,553	$9,280,852
2034	$4.11	2,292,187	$9,413,249
2035	$4.15	2,301,863	$9,548,497

Table B–21 Alternative 1 – Partial Dredging, Weighted Average Costs, Duluth/Superiorto Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$9.55	1,242,231	$11,866,923
1999	$9.27	1,253,181	$11,615,604
2000	$9.01	1,264,228	$11,390,349
2001	$8.77	1,272,302	$11,156,418
2002	$8.89	1,280,429	$11,382,509
2003	$8.68	1,288,607	$11,182,771
2004	$8.51	1,296,837	$11,036,323
2005	$8.40	1,305,120	$10,957,377
2006	$8.69	1,313,032	$11,404,969
2007	$8.59	1,320,991	$11,346,715
2008	$8.53	1,328,999	$11,339,962
2009	$8.47	1,337,055	$11,328,749
2010	$8.42	1,341,014	$11,288,130
2011	$8.36	1,344,985	$11,243,278
2012	$8.30	1,348,968	$11,199,144
2013	$8.24	1,352,962	$11,150,960
2014	$8.32	1,356,968	$11,284,934
2015	$8.27	1,360,986	$11,260,265
2016	$8.22	1,365,016	$11,226,396
2017	$8.30	1,369,058	$11,361,057
2018	$8.26	1,373,112	$11,336,347
2019	$8.17	1,377,177	$11,245,155
2020	$8.24	1,382,990	$11,393,597
2021	$8.21	1,388,828	$11,407,687
2022	$8.16	1,394,690	$11,378,551
2023	$8.23	1,400,577	$11,528,666
2024	$8.19	1,406,489	$11,518,523
2025	$8.16	1,412,426	$11,523,246
2026	$8.23	1,418,388	$11,675,271
2027	$8.25	1,424,375	$11,754,558
2028	$8.24	1,430,387	$11,784,068
2029	$8.31	1,436,425	$11,940,585
2030	$8.38	1,442,488	$12,084,452
2031	$8.36	1,448,577	$12,109,241
2032	$8.44	1,454,691	$12,271,714
2033	$8.51	1,460,831	$12,437,416
2034	$8.59	1,466,997	$12,606,441
2035	$8.67	1,473,190	$12,778,882

Table B–22 Alternative 1 – Partial Dredging, Weighted Average Costs, Escanaba to Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$5.81	2,836,095	$16,479,010
1999	$5.64	2,861,095	$16,130,015
2000	$5.48	2,886,316	$15,817,214
2001	$5.33	2,904,751	$15,492,366
2002	$5.41	2,923,303	$15,806,328
2003	$5.28	2,941,975	$15,528,961
2004	$5.18	2,960,765	$15,325,597
2005	$5.11	2,979,675	$15,215,968
2006	$5.28	2,997,738	$15,837,517
2007	$5.22	3,015,910	$15,756,622
2008	$5.19	3,034,193	$15,747,245
2009	$5.15	3,052,586	$15,731,674
2010	$5.12	3,061,625	$15,675,268
2011	$5.08	3,070,690	$15,612,985
2012	$5.05	3,079,783	$15,551,698
2013	$5.01	3,088,902	$15,484,787
2014	$5.06	3,098,048	$15,670,830
2015	$5.03	3,107,221	$15,636,574
2016	$5.00	3,116,422	$15,589,541
2017	$5.05	3,125,650	$15,776,538
2018	$5.02	3,134,905	$15,742,225
2019	$4.97	3,144,187	$15,615,591
2020	$5.01	3,157,459	$15,821,725
2021	$5.00	3,170,786	$15,841,291
2022	$4.96	3,184,170	$15,800,831
2023	$5.01	3,197,611	$16,009,289
2024	$4.98	3,211,108	$15,995,204
2025	$4.96	3,224,662	$16,001,763
2026	$5.01	3,238,273	$16,212,871
2027	$5.02	3,251,942	$16,322,973
2028	$5.01	3,265,668	$16,363,953
2029	$5.06	3,279,453	$16,581,300
2030	$5.10	3,293,295	$16,781,081
2031	$5.08	3,307,196	$16,815,504
2032	$5.13	3,321,156	$17,041,122
2033	$5.18	3,335,175	$17,271,225
2034	$5.23	3,349,252	$17,505,941
2035	$5.28	3,363,390	$17,745,402

Table B-23 Alternative 1 - Partial Dredging, Weighted Average Costs, Calcite to Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$6.06	1,498,143	$9,071,895
1999	$5.88	1,511,349	$8,879,769
2000	$5.71	1,524,672	$8,707,569
2001	$5.56	1,534,410	$8,528,736
2002	$5.63	1,544,210	$8,701,576
2003	$5.50	1,554,073	$8,548,882
2004	$5.39	1,563,999	$8,436,927
2005	$5.32	1,573,988	$8,376,575
2006	$5.51	1,583,530	$8,718,746
2007	$5.44	1,593,129	$8,674,212
2008	$5.41	1,602,786	$8,669,050
2009	$5.37	1,612,503	$8,660,478
2010	$5.34	1,617,277	$8,629,426
2011	$5.30	1,622,066	$8,595,138
2012	$5.26	1,626,869	$8,561,399
2013	$5.22	1,631,686	$8,524,564
2014	$5.27	1,636,517	$8,626,983
2015	$5.24	1,641,363	$8,608,124
2016	$5.21	1,646,223	$8,582,232
2017	$5.26	1,651,098	$8,685,176
2018	$5.23	1,655,987	$8,666,286
2019	$5.18	1,660,890	$8,596,573
2020	$5.22	1,667,901	$8,710,052
2021	$5.21	1,674,941	$8,720,824
2022	$5.17	1,682,011	$8,698,550
2023	$5.22	1,689,110	$8,813,308
2024	$5.19	1,696,240	$8,805,554
2025	$5.17	1,703,400	$8,809,165
2026	$5.22	1,710,590	$8,925,383
2027	$5.23	1,717,811	$8,985,995
2028	$5.22	1,725,061	$9,008,555
2029	$5.27	1,732,343	$9,128,207
2030	$5.31	1,739,655	$9,238,189
2031	$5.30	1,746,998	$9,257,140
2032	$5.35	1,754,372	$9,381,345
2033	$5.40	1,761,777	$9,508,020
2034	$5.45	1,769,214	$9,637,234
2035	$5.50	1,776,682	$9,769,060

Table B–24 Alternative 2– Complete Dredging, Weighted Average Costs, Duluth/Superior to Indiana Harbor (Vessel Class 10)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$7.83	3,172,787	$24,849,226
1999	$7.28	3,200,755	$23,301,605
2000	$7.07	3,228,970	$22,838,559
2001	$6.82	3,249,593	$22,172,470
2002	$6.91	3,270,348	$22,608,307
2003	$6.83	3,291,236	$22,477,499
2004	$6.88	3,312,257	$22,790,701
2005	$6.93	3,333,413	$23,109,577
2006	$6.99	3,353,620	$23,426,695
2007	$6.90	3,373,949	$23,291,607
2008	$6.81	3,394,402	$23,128,277
2009	$6.75	3,414,979	$23,043,898
2010	$6.80	3,425,091	$23,283,349
2011	$6.70	3,435,233	$23,011,356
2012	$6.70	3,445,404	$23,079,493
2013	$6.70	3,455,606	$23,147,831
2014	$6.75	3,465,838	$23,387,089
2015	$6.70	3,476,101	$23,285,115
2016	$6.70	3,486,393	$23,354,063
2017	$6.70	3,496,716	$23,423,214
2018	$6.75	3,507,070	$23,665,318
2019	$6.70	3,517,455	$23,583,650
2020	$6.70	3,532,302	$23,661,587
2021	$6.70	3,547,212	$23,761,463
2022	$6.75	3,562,184	$24,037,223
2023	$6.70	3,577,220	$23,962,481
2024	$6.70	3,592,320	$24,063,626
2025	$6.70	3,607,483	$24,165,199
2026	$6.75	3,622,710	$24,445,644
2027	$6.74	3,638,002	$24,503,782
2028	$6.70	3,653,358	$24,472,496
2029	$6.70	3,668,779	$24,575,795
2030	$6.75	3,684,264	$24,861,005
2031	$6.74	3,699,816	$24,920,131
2032	$6.70	3,715,433	$24,888,313
2033	$6.70	3,731,116	$24,993,367
2034	$6.75	3,746,865	$25,283,424
2035	$6.74	3,762,680	$25,343,554

Table B–25 Alternative 2– Complete Dredging, Weighted Average Costs, Escanaba to Indiana Harbor (Vessel Class 10)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$4.53	1,940,989	$8,796,778
1999	$4.22	1,958,099	$8,257,611
2000	$4.10	1,975,359	$8,096,715
2001	$3.96	1,987,976	$7,864,322
2002	$4.01	2,000,673	$8,017,532
2003	$3.96	2,013,451	$7,972,416
2004	$3.99	2,026,311	$8,082,714
2005	$4.02	2,039,253	$8,194,990
2006	$4.05	2,051,615	$8,306,608
2007	$4.00	2,064,052	$8,260,003
2008	$3.95	2,076,564	$8,203,485
2009	$3.91	2,089,153	$8,174,581
2010	$3.94	2,095,339	$8,258,737
2011	$3.88	2,101,543	$8,163,805
2012	$3.88	2,107,766	$8,187,978
2013	$3.88	2,114,007	$8,212,222
2014	$3.91	2,120,266	$8,296,325
2015	$3.88	2,126,544	$8,260,927
2016	$3.88	2,132,841	$8,285,388
2017	$3.88	2,139,156	$8,309,921
2018	$3.91	2,145,490	$8,395,024
2019	$3.89	2,151,843	$8,366,741
2020	$3.88	2,160,926	$8,394,489
2021	$3.88	2,170,047	$8,429,922
2022	$3.91	2,179,207	$8,526,953
2023	$3.88	2,188,406	$8,501,238
2024	$3.88	2,197,643	$8,537,121
2025	$3.88	2,206,919	$8,573,157
2026	$3.91	2,216,235	$8,671,836
2027	$3.91	2,225,589	$8,692,665
2028	$3.88	2,234,983	$8,682,177
2029	$3.88	2,244,417	$8,718,825
2030	$3.91	2,253,891	$8,819,181
2031	$3.91	2,263,405	$8,840,364
2032	$3.88	2,272,959	$8,829,698
2033	$3.88	2,282,553	$8,866,968
2034	$3.91	2,292,187	$8,969,030
2035	$3.91	2,301,863	$8,990,573

Table B–26 Alternative 2– Complete Dredging, Weighted Average Costs, Duluth/Superiorto Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$9.42	1,242,231	$11,699,232
1999	$8.81	1,253,181	$11,038,800
2000	$8.58	1,264,228	$10,844,695
2001	$8.30	1,272,302	$10,558,137
2002	$8.40	1,280,429	$10,754,744
2003	$8.31	1,288,607	$10,702,619
2004	$8.36	1,296,837	$10,845,475
2005	$8.42	1,305,120	$10,990,767
2006	$8.48	1,313,032	$11,134,952
2007	$8.39	1,320,991	$11,081,009
2008	$8.29	1,328,999	$11,014,458
2009	$8.21	1,337,055	$10,982,433
2010	$8.27	1,341,014	$11,090,285
2011	$8.16	1,344,985	$10,973,033
2012	$8.16	1,348,968	$11,005,524
2013	$8.16	1,352,962	$11,038,112
2014	$8.21	1,356,968	$11,145,993
2015	$8.16	1,360,986	$11,103,576
2016	$8.16	1,365,016	$11,136,454
2017	$8.16	1,369,058	$11,169,429
2018	$8.21	1,373,112	$11,278,594
2019	$8.17	1,377,177	$11,245,155
2020	$8.16	1,382,990	$11,283,098
2021	$8.16	1,388,828	$11,330,724
2022	$8.21	1,394,690	$11,455,839
2023	$8.16	1,400,577	$11,426,580
2024	$8.16	1,406,489	$11,474,811
2025	$8.16	1,412,426	$11,523,246
2026	$8.21	1,418,388	$11,650,488
2027	$8.20	1,424,375	$11,679,830
2028	$8.16	1,430,387	$11,669,782
2029	$8.16	1,436,425	$11,719,040
2030	$8.21	1,442,488	$11,848,443
2031	$8.20	1,448,577	$11,878,285
2032	$8.16	1,454,691	$11,868,066
2033	$8.16	1,460,831	$11,918,161
2034	$8.21	1,466,997	$12,049,763
2035	$8.20	1,473,190	$12,080,111

Table B–27 Alternative 2– Complete Dredging, Weighted Average Costs, Escanaba to Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$5.73	2,836,095	$16,246,145
1999	$5.36	2,861,095	$15,329,036
2000	$5.22	2,886,316	$15,059,493
2001	$5.05	2,904,751	$14,661,564
2002	$5.11	2,923,303	$14,934,581
2003	$5.05	2,941,975	$14,862,198
2004	$5.09	2,960,765	$15,060,575
2005	$5.12	2,979,675	$15,262,334
2006	$5.16	2,997,738	$15,462,557
2007	$5.10	3,015,910	$15,387,649
2008	$5.04	3,034,193	$15,295,233
2009	$5.00	3,052,586	$15,250,761
2010	$5.03	3,061,625	$15,400,531
2011	$4.96	3,070,690	$15,237,709
2012	$4.96	3,079,783	$15,282,828
2013	$4.96	3,088,902	$15,328,080
2014	$5.00	3,098,048	$15,477,890
2015	$4.96	3,107,221	$15,418,987
2016	$4.96	3,116,422	$15,464,643
2017	$4.96	3,125,650	$15,510,434
2018	$5.00	3,134,905	$15,662,026
2019	$4.97	3,144,187	$15,615,591
2020	$4.96	3,157,459	$15,668,280
2021	$4.96	3,170,786	$15,734,416
2022	$5.00	3,184,170	$15,908,158
2023	$4.96	3,197,611	$15,867,526
2024	$4.96	3,211,108	$15,934,503
2025	$4.96	3,224,662	$16,001,763
2026	$5.00	3,238,273	$16,178,456
2027	$4.99	3,251,942	$16,219,203
2028	$4.96	3,265,668	$16,205,250
2029	$4.96	3,279,453	$16,273,652
2030	$5.00	3,293,295	$16,453,348
2031	$4.99	3,307,196	$16,494,787
2032	$4.96	3,321,156	$16,480,596
2033	$4.96	3,335,175	$16,550,161
2034	$5.00	3,349,252	$16,732,910
2035	$4.99	3,363,390	$16,775,053

Table B–28 Alternative 2– Complete Dredging, Weighted Average Costs, Calcite to Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$5.97	1,498,143	$8,943,700
1999	$5.58	1,511,349	$8,438,821
2000	$5.44	1,524,672	$8,290,434
2001	$5.26	1,534,410	$8,071,369
2002	$5.32	1,544,210	$8,221,669
2003	$5.26	1,554,073	$8,181,821
2004	$5.30	1,563,999	$8,291,030
2005	$5.34	1,573,988	$8,402,101
2006	$5.38	1,583,530	$8,512,326
2007	$5.32	1,593,129	$8,471,088
2008	$5.25	1,602,786	$8,420,212
2009	$5.21	1,612,503	$8,395,730
2010	$5.24	1,617,277	$8,478,180
2011	$5.17	1,622,066	$8,388,544
2012	$5.17	1,626,869	$8,413,383
2013	$5.17	1,631,686	$8,438,295
2014	$5.21	1,636,517	$8,520,767
2015	$5.17	1,641,363	$8,488,340
2016	$5.17	1,646,223	$8,513,474
2017	$5.17	1,651,098	$8,538,682
2018	$5.21	1,655,987	$8,622,136
2019	$5.18	1,660,890	$8,596,573
2020	$5.17	1,667,901	$8,625,579
2021	$5.17	1,674,941	$8,661,988
2022	$5.21	1,682,011	$8,757,634
2023	$5.17	1,689,110	$8,735,266
2024	$5.17	1,696,240	$8,772,138
2025	$5.17	1,703,400	$8,809,165
2026	$5.21	1,710,590	$8,906,437
2027	$5.20	1,717,811	$8,928,869
2028	$5.17	1,725,061	$8,921,187
2029	$5.17	1,732,343	$8,958,843
2030	$5.21	1,739,655	$9,057,768
2031	$5.20	1,746,998	$9,080,581
2032	$5.17	1,754,372	$9,072,769
2033	$5.17	1,761,777	$9,111,065
2034	$5.21	1,769,214	$9,211,670
2035	$5.20	1,776,682	$9,234,871

Table B–29 Alternative 3– Cooperative Dredging, Weighted Average Costs, Duluth/Superiorto Indiana Harbor (Vessel Class 10)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$8.05	3,172,787	$25,531,144
1999	$7.82	3,200,755	$25,041,522
2000	$7.26	3,228,970	$23,448,840
2001	$7.03	3,249,593	$22,852,278
2002	$6.86	3,270,348	$22,439,234
2003	$6.91	3,291,236	$22,752,706
2004	$6.70	3,312,257	$22,187,589
2005	$6.75	3,333,413	$22,493,496
2006	$6.80	3,353,620	$22,797,497
2007	$6.85	3,373,949	$23,106,885
2008	$6.90	3,394,402	$23,410,782
2009	$6.70	3,414,979	$22,875,686
2010	$6.70	3,425,091	$22,943,421
2011	$6.75	3,435,233	$23,180,566
2012	$6.70	3,445,404	$23,079,493
2013	$6.70	3,455,606	$23,147,831
2014	$6.70	3,465,838	$23,216,372
2015	$6.75	3,476,101	$23,456,338
2016	$6.70	3,486,393	$23,354,063
2017	$6.70	3,496,716	$23,423,214
2018	$6.70	3,507,070	$23,492,570
2019	$6.75	3,517,455	$23,735,391
2020	$6.70	3,532,302	$23,661,587
2021	$6.70	3,547,212	$23,761,463
2022	$6.70	3,562,184	$23,861,760
2023	$6.75	3,577,220	$24,138,684
2024	$6.70	3,592,320	$24,063,626
2025	$6.70	3,607,483	$24,165,199
2026	$6.70	3,622,710	$24,267,200
2027	$6.75	3,638,002	$24,548,829
2028	$6.70	3,653,358	$24,472,496
2029	$6.70	3,668,779	$24,575,795
2030	$6.70	3,684,264	$24,679,529
2031	$6.75	3,699,816	$24,965,943
2032	$6.80	3,715,433	$25,257,058
2033	$6.85	3,731,116	$25,552,979
2034	$6.90	3,746,865	$25,853,819
2035	$6.95	3,762,680	$26,159,692

Table B–30 Alternative 3– Cooperative Dredging, Weighted Average Costs, Escanaba to Indiana Harbor (Vessel Class 10)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$4.65	1,940,989	$9,034,469
1999	$4.53	1,958,099	$8,864,993
2000	$4.21	1,975,359	$8,310,073
2001	$4.08	1,987,976	$8,102,208
2002	$3.98	2,000,673	$7,958,359
2003	$4.01	2,013,451	$8,068,740
2004	$3.88	2,026,311	$7,871,554
2005	$3.91	2,039,253	$7,979,332
2006	$3.94	2,051,615	$8,086,402
2007	$3.97	2,064,052	$8,195,350
2008	$4.00	2,076,564	$8,302,370
2009	$3.88	2,089,153	$8,115,672
2010	$3.88	2,095,339	$8,139,703
2011	$3.91	2,101,543	$8,223,063
2012	$3.88	2,107,766	$8,187,978
2013	$3.88	2,114,007	$8,212,222
2014	$3.88	2,120,266	$8,236,539
2015	$3.91	2,126,544	$8,320,890
2016	$3.88	2,132,841	$8,285,388
2017	$3.88	2,139,156	$8,309,921
2018	$3.88	2,145,490	$8,334,526
2019	$3.91	2,151,843	$8,419,881
2020	$3.88	2,160,926	$8,394,489
2021	$3.88	2,170,047	$8,429,922
2022	$3.88	2,179,207	$8,465,505
2023	$3.91	2,188,406	$8,562,945
2024	$3.88	2,197,643	$8,537,121
2025	$3.88	2,206,919	$8,573,157
2026	$3.88	2,216,235	$8,609,344
2027	$3.91	2,225,589	$8,708,440
2028	$3.88	2,234,983	$8,682,177
2029	$3.88	2,244,417	$8,718,825
2030	$3.88	2,253,891	$8,755,627
2031	$3.91	2,263,405	$8,856,407
2032	$3.94	2,272,959	$8,958,822
2033	$3.97	2,282,553	$9,062,910
2034	$4.00	2,292,187	$9,168,708
2035	$4.03	2,301,863	$9,276,256

Table B–31 Alternative 3– Cooperative Dredging, Weighted Average Costs, Duluth/Superior to Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$9.65	1,242,231	$11,991,401
1999	$9.41	1,253,181	$11,790,870
2000	$8.79	1,264,228	$11,110,803
2001	$8.53	1,272,302	$10,856,187
2002	$8.34	1,280,429	$10,680,548
2003	$8.40	1,288,607	$10,823,434
2004	$8.16	1,296,837	$10,580,218
2005	$8.21	1,305,120	$10,720,118
2006	$8.27	1,313,032	$10,858,865
2007	$8.33	1,320,991	$10,999,925
2008	$8.38	1,328,999	$11,138,522
2009	$8.16	1,337,055	$10,908,338
2010	$8.16	1,341,014	$10,940,638
2011	$8.21	1,344,985	$11,047,567
2012	$8.16	1,348,968	$11,005,524
2013	$8.16	1,352,962	$11,038,112
2014	$8.16	1,356,968	$11,070,795
2015	$8.21	1,360,986	$11,178,997
2016	$8.16	1,365,016	$11,136,454
2017	$8.16	1,369,058	$11,169,429
2018	$8.16	1,373,112	$11,202,502
2019	$8.21	1,377,177	$11,311,990
2020	$8.16	1,382,990	$11,283,098
2021	$8.16	1,388,828	$11,330,724
2022	$8.16	1,394,690	$11,378,551
2023	$8.21	1,400,577	$11,504,194
2024	$8.16	1,406,489	$11,474,811
2025	$8.16	1,412,426	$11,523,246
2026	$8.16	1,418,388	$11,571,886
2027	$8.21	1,424,375	$11,699,664
2028	$8.16	1,430,387	$11,669,782
2029	$8.16	1,436,425	$11,719,040
2030	$8.16	1,442,488	$11,768,506
2031	$8.21	1,448,577	$11,898,456
2032	$8.27	1,454,691	$12,030,398
2033	$8.33	1,460,831	$12,164,377
2034	$8.38	1,466,997	$12,300,434
2035	$8.44	1,473,190	$12,438,616

Table B–32 Alternative 3 – Cooperative Dredging, Weighted Average Costs, Escanaba to Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$5.87	2,836,095	$16,651,865
1999	$5.72	2,861,095	$16,373,399
2000	$5.35	2,886,316	$15,429,023
2001	$5.19	2,904,751	$15,075,450
2002	$5.07	2,923,303	$14,831,550
2003	$5.11	2,941,975	$15,029,968
2004	$4.96	2,960,765	$14,692,225
2005	$5.00	2,979,675	$14,886,498
2006	$5.03	2,997,738	$15,079,169
2007	$5.06	3,015,910	$15,275,052
2008	$5.10	3,034,193	$15,467,515
2009	$4.96	3,052,586	$15,147,870
2010	$4.96	3,061,625	$15,192,723
2011	$5.00	3,070,690	$15,341,210
2012	$4.96	3,079,783	$15,282,828
2013	$4.96	3,088,902	$15,328,080
2014	$4.96	3,098,048	$15,373,467
2015	$5.00	3,107,221	$15,523,720
2016	$4.96	3,116,422	$15,464,643
2017	$4.96	3,125,650	$15,510,434
2018	$4.96	3,134,905	$15,556,360
2019	$5.00	3,144,187	$15,708,401
2020	$4.96	3,157,459	$15,668,280
2021	$4.96	3,170,786	$15,734,416
2022	$4.96	3,184,170	$15,800,831
2023	$5.00	3,197,611	$15,975,306
2024	$4.96	3,211,108	$15,934,503
2025	$4.96	3,224,662	$16,001,763
2026	$4.96	3,238,273	$16,069,306
2027	$5.00	3,251,942	$16,246,746
2028	$4.96	3,265,668	$16,205,250
2029	$4.96	3,279,453	$16,273,652
2030	$4.96	3,293,295	$16,342,343
2031	$5.00	3,307,196	$16,522,797
2032	$5.03	3,321,156	$16,706,020
2033	$5.06	3,335,175	$16,892,069
2034	$5.10	3,349,252	$17,081,005
2035	$5.14	3,363,390	$17,272,891

INDIANA HARBOR
Maintenance Dredging and Disposal Facilities

APPENDIX B

ECONOMIC ANALYSIS

ATTACHMENT B-1

ENVIRONMENTAL BENEFITS

Table B–33 Alternative 3– Cooperative Dredging, Weighted Average Costs, Calcite to Indiana Harbor (Vessel Class 7)

Year	Weighted Ave. Cost	Projected Tonnage	Projected Delivery Costs @ Weighted Average Cost
1998	$6.12	1,498,143	$9,167,054
1999	$5.96	1,511,349	$9,013,755
2000	$5.57	1,524,672	$8,493,865
2001	$5.41	1,534,410	$8,299,219
2002	$5.29	1,544,210	$8,164,949
2003	$5.32	1,554,073	$8,274,180
2004	$5.17	1,563,999	$8,088,249
2005	$5.21	1,573,988	$8,195,198
2006	$5.24	1,583,530	$8,301,266
2007	$5.28	1,593,129	$8,409,102
2008	$5.31	1,602,786	$8,515,055
2009	$5.17	1,612,503	$8,339,087
2010	$5.17	1,617,277	$8,363,779
2011	$5.21	1,622,066	$8,445,523
2012	$5.17	1,626,869	$8,413,383
2013	$5.17	1,631,686	$8,438,295
2014	$5.17	1,636,517	$8,463,280
2015	$5.21	1,641,363	$8,545,997
2016	$5.17	1,646,223	$8,513,474
2017	$5.17	1,651,098	$8,538,682
2018	$5.17	1,655,987	$8,563,966
2019	$5.21	1,660,890	$8,647,666
2020	$5.17	1,667,901	$8,625,579
2021	$5.17	1,674,941	$8,661,988
2022	$5.17	1,682,011	$8,698,550
2023	$5.21	1,689,110	$8,794,600
2024	$5.17	1,696,240	$8,772,138
2025	$5.17	1,703,400	$8,809,165
2026	$5.17	1,710,590	$8,846,349
2027	$5.21	1,717,811	$8,944,031
2028	$5.17	1,725,061	$8,921,187
2029	$5.17	1,732,343	$8,958,843
2030	$5.17	1,739,655	$8,996,659
2031	$5.21	1,746,998	$9,096,001
2032	$5.24	1,754,372	$9,196,867
2033	$5.28	1,761,777	$9,299,289
2034	$5.31	1,769,214	$9,403,301
2035	$5.35	1,776,682	$9,508,937

Table B–34 Average Annual Navigation Benefits Alternative 1 – Partial Federal Channel Dredging

	Transportation Cost		
Year	Without Project	With Project	Difference
1998	$96,124,003	$95,339,191	$784,812
1999	$97,854,210	$94,207,619	$3,646,591
2000	$99,593,228	$93,227,058	$6,366,169
2001	$101,074,533	$92,182,926	$8,891,607
2002	$102,470,055	$93,996,474	$8,473,581
2003	$104,111,466	$93,121,835	$10,989,631
2004	$105,293,085	$92,572,379	$12,720,706
2005	$106,428,877	$92,434,004	$13,994,874
2006	$107,490,327	$95,568,586	$11,921,742
2007	$108,500,604	$95,532,704	$12,967,900
2008	$109,521,474	$95,823,403	$13,698,071
2009	$110,488,326	$96,072,043	$14,416,283
2010	$111,143,264	$96,130,471	$15,012,793
2011	$111,803,385	$96,166,471	$15,636,914
2012	$112,468,738	$96,210,939	$16,257,799
2013	$113,092,885	$96,234,255	$16,858,630
2014	$113,748,185	$97,374,672	$16,373,513
2015	$114,361,436	$97,531,005	$16,830,432
2016	$114,932,107	$97,633,643	$17,298,465
2017	$115,533,049	$98,767,285	$16,765,764
2018	$116,159,434	$98,933,472	$17,225,963
2019	$116,742,834	$98,689,881	$18,052,953
2020	$117,464,176	$99,915,235	$17,548,941
2021	$119,660,901	$101,826,365	$17,834,536
2022	$118,896,201	$100,457,526	$18,438,675
2023	$119,584,448	$101,702,812	$17,881,636
2024	$120,277,464	$101,954,590	$18,322,874
2025	$120,998,281	$102,325,130	$18,673,150
2026	$121,701,181	$103,592,153	$18,109,028
2027	$122,408,970	$104,410,192	$17,998,779
2028	$123,171,228	$104,921,842	$18,249,386
2029	$123,889,123	$106,227,252	$17,661,872
2030	$124,612,029	$107,457,701	$17,154,328
2031	$125,339,985	$107,949,922	$17,390,063
2032	$126,073,034	$109,303,454	$16,769,580
2033	$126,811,217	$110,681,120	$16,130,097
2034	$127,554,577	$112,083,566	$15,471,011
2035	$128,303,155	$113,511,460	$14,791,695
Sum			$563,610,842
Net Present Value			$135,472,762
Average Annual Benefit			$11,691,856

*Benefits are discounted through 2031. Discounted through 2035 average annual benefits = $11,776,982. Both conditions include without project conditions for reaches 6–11, as these reaches are not dredged.

Table B–35 Average Annual Navigation Benefits Alternative 2– Complete Federal Channel Dredging

Transportation Cost			
Year	Without Project	With Project	Difference
1998	$96,124,003	$94,283,151	$1,840,852
1999	$97,854,210	$90,351,422	$7,502,788
2000	$99,593,228	$89,597,376	$9,995,852
2001	$101,074,533	$88,290,455	$12,784,078
2002	$102,470,055	$90,008,482	$12,461,573
2003	$104,111,466	$90,196,257	$13,915,209
2004	$105,293,085	$91,613,459	$13,679,626
2005	$106,428,877	$93,061,897	$13,366,980
2006	$107,490,327	$86,635,522	$20,854,805
2007	$108,500,604	$87,719,465	$20,781,140
2008	$109,521,474	$87,611,235	$21,910,238
2009	$110,488,326	$87,851,491	$22,636,835
2010	$111,143,264	$88,870,048	$22,273,216
2011	$111,803,385	$88,496,264	$23,307,121
2012	$112,468,738	$89,061,639	$23,407,099
2013	$113,092,885	$89,635,127	$23,457,758
2014	$113,748,185	$90,686,649	$23,061,536
2015	$114,361,436	$90,816,954	$23,544,482
2016	$114,932,107	$90,607,170	$24,324,938
2017	$115,533,049	$89,033,417	$26,499,632
2018	$116,159,434	$90,700,714	$25,458,720
2019	$116,742,834	$90,812,831	$25,930,002
2020	$117,464,176	$91,375,995	$26,088,181
2021	$119,660,901	$93,812,334	$25,848,567
2022	$118,896,201	$93,146,183	$25,750,018
2023	$119,584,448	$92,312,126	$27,272,322
2024	$120,277,464	$93,297,885	$26,979,579
2025	$120,998,281	$92,983,888	$28,014,393
2026	$121,701,181	$94,383,275	$27,317,907
2027	$122,408,970	$94,889,135	$27,519,835
2028	$123,171,228	$95,160,163	$28,011,065
2029	$123,889,123	$95,805,610	$28,083,514
2030	$124,612,029	$96,955,204	$27,656,825
2031	$125,339,985	$97,491,569	$27,848,416
Sum			$739,385,101
Net Present Value			$197,436,211
Average Annual Benefit			$17,039,557

Table B-36 Average Annual Navigation Benefits Alternative 3- Cooperative Dredging

Transportation Cost			
Year	Without Project	With Project	Difference
1998	$96,124,003	$94,211,475	$1,912,528
1999	$97,854,210	$90,194,522	$7,659,688
2000	$99,593,228	$89,239,124	$10,354,103
2001	$101,074,533	$88,630,585	$12,443,948
2002	$102,470,055	$90,008,482	$12,461,573
2003	$104,111,466	$89,017,047	$15,094,419
2004	$105,293,085	$90,409,690	$14,883,395
2005	$106,428,877	$91,832,929	$14,595,948
2006	$107,490,327	$85,974,027	$21,516,300
2007	$108,500,604	$89,842,656	$18,657,949
2008	$109,521,474	$88,831,188	$20,690,286
2009	$110,488,326	$89,663,345	$20,824,981
2010	$111,143,264	$90,772,994	$20,370,271
2011	$111,803,385	$90,970,074	$20,833,310
2012	$112,468,738	$89,225,802	$23,242,936
2013	$113,092,885	$87,831,963	$25,260,922
2014	$113,748,185	$89,710,668	$24,037,517
2015	$114,361,436	$90,003,038	$24,358,399
2016	$114,932,107	$90,579,544	$24,352,563
2017	$115,533,049	$89,208,338	$26,324,711
2018	$116,159,434	$91,012,797	$25,146,637
2019	$116,742,834	$91,089,755	$25,653,079
2020	$117,464,176	$91,731,770	$25,732,406
2021	$119,660,901	$93,950,877	$25,710,024
2022	$118,896,201	$92,130,565	$26,765,636
2023	$119,584,448	$92,881,215	$26,703,233
2024	$120,277,464	$93,527,038	$26,750,426
2025	$120,998,281	$94,188,205	$26,810,076
2026	$121,701,181	$94,194,640	$27,506,541
2027	$122,408,970	$94,853,212	$27,555,759
2028	$123,171,228	$95,501,210	$27,670,018
2029	$123,889,123	$95,325,515	$28,563,609
2030	$124,612,029	$96,854,794	$27,757,235
2031	$125,339,985	$98,020,516	$27,319,469
2032	$126,073,034	$99,205,101	$26,867,933
2033	$126,811,217	$100,415,032	$26,396,185
2034	$127,554,577	$101,651,201	$25,903,376
2035	$128,303,155	$102,919,495	$25,383,660
Sum			$840,071,050
Net Present Value			$196,964,959
Average Annual Benefit			$16,998,885

Revised 2/21/94

*Benefits are discounted to 2031, if discounted through 2035 AAB equals $16,340,360

Table B-36A Average Annual Navigation Benefits Selected Plan: Dredging Alternative 3 Modified-- Cooperative Dredging Program

Year	Without Project	With Project	Difference (1)	Year	Difference (2)
2001	$ 89,574,055	$ 86,579,500	$ 2,994,556	2002	$ 2906816
2002	$ 90,232,600	$ 81,903,683	$ 8,328,917	2003	$ 8084880
2003	$ 90,755,099	$ 79,633,170	$ 11,121,929	2004	$ 10796056
2004	$ 91,282,701	$ 75,519,819	$ 15,762,882	2005	$ 15301030
2005	$ 91,717,515	$ 75,505,266	$ 16,212,249	2006	$ 15737230
2006	$ 92,106,495	$ 76,157,550	$ 15,948,945	2007	$ 15481641
2007	$ 92,498,233	$ 76,819,688	$ 15,678,545	2008	$ 15219164
2008	$ 92,792,952	$ 77,491,895	$ 15,301,057	2009	$ 14852736
2009	$ 93,089,307	$ 78,174,396	$ 14,914,911	2010	$ 14477904
2010	$ 93,387,311	$ 78,867,420	$ 14,519,891	2011	$ 14094458
2011	$ 93,636,432	$ 79,571,204	$ 14,065,229	2012	$ 13653118
2012	$ 93,886,795	$ 77,534,639	$ 16,352,155	2013	$ 15873037
2013	$ 94,138,408	$ 76,804,536	$ 17,333,871	2014	$ 16825989
2014	$ 94,340,222	$ 76,490,493	$ 17,849,728	2015	$ 17326731
2015	$ 94,542,976	$ 77,153,944	$ 17,389,032	2016	$ 16879533
2016	$ 94,746,679	$ 76,603,814	$ 18,142,865	2017	$ 17611279
2017	$ 94,951,337	$ 76,461,072	$ 18,490,265	2018	$ 17948500
2018	$ 95,105,404	$ 76,585,615	$ 18,519,789	2019	$ 17977159
2019	$ 95,311,854	$ 77,248,588	$ 18,063,266	2020	$ 17534012
2020	$ 95,467,506	$ 76,836,526	$ 18,630,980	2021	$ 18085092
2021	$ 95,675,775	$ 76,962,903	$ 18,712,871	2022	$ 18164584
2022	$ 95,833,035	$ 77,089,900	$ 18,743,135	2023	$ 18193961
2023	$ 95,991,067	$ 77,758,841	$ 18,232,226	2024	$ 17698022
2024	$ 96,149,877	$ 77,345,774	$ 18,804,103	2025	$ 18253143
2025	$ 96,361,720	$ 77,474,661	$ 18,887,059	2026	$ 18333668
2026	$ 96,522,187	$ 77,604,186	$ 18,918,001	2027	$ 18363704
2027	$ 96,683,450	$ 78,279,239	$ 18,404,211	2028	$ 17864968
2028	$ 96,845,513	$ 78,964,487	$ 17,881,027	2029	$ 17357113
2029	$ 97,008,385	$ 78,474,580	$ 18,533,804	2030	$ 17990764
2030	$ 97,172,069	$ 78,128,777	$ 19,043,293	2031	$ 18485325
2031	$ 97,336,574	$ 78,261,571	$ 19,075,003	2032	$ 18516105
Sum			$ 510,855,796		$ 495887720
Net Present Value			$ 177,344,967		$ 177091423
Average Annual Benefit			$ 14,698,269		$ 14333410

(1) 1997 analysis based on May 1996 vessel costs, 7-1/4 % interest rate, a 2001 base year, & 31-year project life.
(2) 1998 analysis based on May 1996 vessel costs, 7-1/8 % interest rate, a 2002 base year, & 31-year project life.

Table B–37 Average Annual Costs, Alternative 1– Partial Dredging

YEAR	DREDGING & TREATMENT	FIRST COSTS	IDC	TREATMENT MONITORING & O&M
1996	$0	$1,423,125	$172,568	$0
1997	$0	$4,325,351	$335,662	$341,338
1998	$2,399,100	$2,890,214	$104,502	$351,754
1999	$2,475,000	$0	$0	$351,754
2000	$2,459,600	$0	$0	$351,754
2001	$2,535,500	$0	$0	$351,754
2002	$2,535,500	$0	$0	$351,754
2003	$2,626,800	$0	$0	$351,754
2004	$2,626,800	$0	$0	$351,754
2005	$2,702,700	$1,033,462	$37,367	$351,754
2006	$2,687,300	$2,098,241	$75,867	$351,754
2007	$2,778,600	$0	$0	$351,754
2008	$2,354,000	$0	$0	$351,754
2009	$2,429,900	$0	$0	$351,754
2010	$2,429,900	$0	$0	$351,754
2011	$2,505,800	$0	$0	$351,754
2012	$2,505,800	$1,033,462	$37,367	$351,754
2013	$2,581,700	$2,098,241	$75,867	$351,754
2014	$0	$0	$0	$351,754
2015	$2,307,800	$0	$0	$351,754
2016	$2,368,300	$0	$0	$351,754
2017	$0	$0	$0	$351,754
2018	$2,231,900	$0	$0	$351,754
2019	$2,292,400	$0	$0	$351,754
2020	$0	$1,033,462	$37,367	$351,754
2021	$2,338,600	$2,098,241	$75,867	$351,754
2022	$2,399,100	$0	$0	$351,754
2023	$0	$0	$0	$351,754
2024	$2,262,700	$0	$0	$351,754
2025	$1,381,600	$0	$0	$351,754
2026	$0	$0	$0	$351,754
2027	$2,126,300	$0	$0	$351,754
2028	$2,202,200	$0	$0	$351,754
2029	$0	$0	$0	$351,754
2030	$713,900	$0	$0	$351,754
2031	$1,655,500	$0	$0	$351,754
2032	$0	$4,019,979	$145,351	$351,754
2033	$0	$4,019,979	$145,351	$351,754
TOTALS	**$64,914,300**	**$26,073,757**	**$1,243,136**	**$13,004,489**
NPV	$26,174,350	$10,386,859	$641,395	$4,132,324
AAC	$2,233,841	$878,094	$54,223	$350,935
Average Annual Cost				**$3,517,093**
Interest Rate=				0.08

Table B-38 Average Annual Costs, Alternative 2 - Complete Dredging

YEAR	DREDGING & TREATMENT	FIRST COSTS	IDC	TREATMENT MONITORING & O&M
1996	$0	$1,423,125	$172,568	$0
1997	$0	$4,598,771	$356,881	$334,521
1998	$2,399,047	$6,636,694	$239,964	$393,554
1999	$4,630,507	$0	$0	$393,554
2000	$2,459,767	$0	$0	$393,554
2001	$4,751,947	$0	$0	$393,554
2002	$2,535,667	$0	$0	$393,554
2003	$4,903,747	$0	$0	$393,554
2004	$2,626,747	$0	$0	$393,554
2005	$5,070,727	$0	$0	$393,554
2006	$0	$1,864,956	$67,432	$393,554
2007	$2,687,467	$3,786,426	$136,907	$393,554
2008	$2,778,547	$0	$0	$393,554
2009	$2,459,767	$0	$0	$393,554
2010	$0	$0	$0	$393,554
2011	$2,353,507	$0	$0	$393,554
2012	$2,429,407	$0	$0	$393,554
2013	$2,034,727	$0	$0	$393,554
2014	$0	$1,808,442	$65,388	$393,554
2015	$2,429,407	$3,671,686	$132,758	$393,554
2016	$2,505,307	$0	$0	$393,554
2017	$2,095,447	$0	$0	$393,554
2018	$0	$0	$0	$393,554
2019	$2,505,307	$0	$0	$393,554
2020	$2,581,207	$0	$0	$393,554
2021	$2,171,347	$0	$0	$393,554
2022	$0	$0	$0	$393,554
2023	$2,307,967	$0	$0	$393,554
2024	$2,368,687	$0	$0	$393,554
2025	$1,928,467	$0	$0	$393,554
2026	$0	$0	$0	$393,554
2027	$2,232,067	$0	$0	$393,554
2028	$2,292,787	$0	$0	$393,554
2029	$1,822,207	$0	$0	$393,554
2030	$0	$5,614,547	$203,006	$393,554
2031	$0	$5,614,547	$203,006	$393,554
TOTALS	$71,361,782	$35,019,194	$1,577,910	$13,715,357
NPV	$30,600,277	$14,770,461	$809,610	$4,532,042
AAC	$2,640,930	$1,260,580	$69,096	$388,864
Average Annual Cost				**$4,359,470**
Interest Rate=				0.08

Table B–39 Average Annual Costs, Alternative 3 – Cooperative Dredging

YEAR	DREDGING & TREATMENT	FIRST COSTS	IDC	TREATMENT MONITORING & O&M
1996	$0	$1,423,125	$172,568	$334,521
1997	$0	$4,598,771	$356,881	$393,554
1998	$2,399,047	$6,636,694	$239,964	$393,554
1999	$4,630,507	$0	$0	$393,554
2000	$2,459,767	$0	$0	$393,554
2001	$4,751,947	$0	$0	$393,554
2002	$2,535,667	$0	$0	$393,554
2003	$4,918,927	$0	$0	$393,554
2004	$2,626,747	$0	$0	$393,554
2005	$5,070,727	$0	$0	$393,554
2006	$2,687,467	$1,864,956	$67,432	$393,554
2007	$5,222,527	$3,786,426	$136,907	$393,554
2008	$0	$0	$0	$393,554
2009	$2,353,507	$0	$0	$393,554
2010	$2,429,407	$0	$0	$393,554
2011	$2,034,727	$0	$0	$393,554
2012	$0	$0	$0	$393,554
2013	$2,429,407	$0	$0	$393,554
2014	$2,505,307	$1,808,442	$65,388	$393,554
2015	$2,095,447	$3,671,686	$132,758	$393,554
2016	$0	$0	$0	$393,554
2017	$2,505,307	$0	$0	$393,554
2018	$2,581,207	$0	$0	$393,554
2019	$2,171,347	$0	$0	$393,554
2020	$0	$0	$0	$393,554
2021	$2,307,967	$0	$0	$393,554
2022	$2,368,687	$0	$0	$393,554
2023	$1,928,467	$0	$0	$393,554
2024	$0	$0	$0	$393,554
2025	$2,232,067	$0	$0	$393,554
2026	$2,292,787	$0	$0	$393,554
2027	$1,822,207	$0	$0	$393,554
2028	$0	$5,614,547	$203,006	$393,554
2029	$0	$5,614,547	$203,006	$393,554
2030	$0	$0		$0
2031	$0	$0		$0
TOTALS	**$71,361,175**	**$35,019,194**	**$1,577,910**	**$13,321,803**
NPV	$32,035,284	$14,892,157	$814,010	$4,531,337
AAC	$2,764,777	$1,270,966	$70,252	$388,803
Average Annual Cost				**$4,494,799**
Interest Rate=				0.08

Table B–40 Average Annual Costs, Generic Clean Upland CDF Site

YEAR	DREDGING & TREATMENT	FIRST COSTS	IDC	TREATMENT MONITORING & O&M
1996	$0	$8,388,000	$1,017,131	$345,789
1997	$0	$10,316,872	$800,625	$406,810
1998	$3,491,375	$20,587,679	$744,393	$406,810
1999	$6,745,587	$2,720,372	$98,361	$406,810
2000	$3,579,925	$5,523,179	$199,703	$406,810
2001	$6,922,687	$0	$0	$406,810
2002	$3,690,612	$0	$0	$406,810
2003	$7,144,062	$0	$0	$406,810
2004	$3,823,437	$0	$0	$406,810
2005	$7,387,575	$0	$0	$406,810
2006	$0	$2,564,922	$92,740	$406,810
2007	$3,911,987	$5,207,568	$188,291	$406,810
2008	$4,044,812	$0	$0	$406,810
2009	$3,579,925	$0	$0	$406,810
2010	$0	$0	$0	$406,810
2011	$3,424,962	$0	$0	$406,810
2012	$3,535,650	$0	$0	$406,810
2013	$2,960,075	$0	$0	$406,810
2014	$0	$0	$0	$406,810
2015	$3,535,650	$0	$0	$406,810
2016	$3,646,337	$2,487,197	$89,930	$406,810
2017	$3,048,625	$5,049,763	$182,585	$406,810
2018	$0	$0	$0	$406,810
2019	$3,646,337	$0	$0	$406,810
2020	$3,757,025	$0	$0	$406,810
2021	$3,159,312	$0	$0	$406,810
2022	$0	$0	$0	$406,810
2023	$3,358,550	$0	$0	$406,810
2024	$3,447,100	$0	$0	$406,810
2025	$2,805,112	$0	$0	$406,810
2026	$0	$0	$0	$406,810
2027	$3,247,862	$0	$0	$406,810
2028	$3,336,412	$0	$0	$406,810
2029	$2,650,150	$0	$0	$406,810
2030	$0	$5,595,000	$202,300	$406,810
2031	$0	$5,595,000	$202,300	$0
TOTALS	$103,881,143	$74,035,550	$3,818,359	$14,177,329
NPV	$44,554,172	$44,033,221	$2,619,680	$4,684,694
AAC	$3,845,208	$3,758,001	$223,576	$399,814
				$8,226,598
Interest Rate=				0.08

Table B-39A - Average Annual Costs, Selected Plan: Dredging Alternative 3 Modified--Cooperative Dredging Program [1/] [2/]

Year	Dredging & Treatment [3/]	CDF First Costs [3/]	**Total Cost**	IDC	Treatment Monitoring & O&M
1999	$0	$500,000	$500,000	$17,800	$0
2000	$0	$8,389,000	$8,389,000	$335,541	$0
2001	$0	$14,719,000	$14,719,000	$1,182,517	$0
2002	$2,641,000	$7,018,000	$9,659,000	$0	$2,353,200
2003	$4,965,000	$930,000	$5,895,000	$0	$2,353,200
2004	$2,693,000	$0	$2,693,000	$0	$2,353,200
2005	$5,100,000	$0	$5,100,000	$0	$2,353,200
2006	$2,785,000	$0	$2,785,000	$0	$2,353,200
2007	$5,264,000	$0	$5,264,000	$0	$2,353,200
2008	$2,852,000	$0	$2,852,000	$0	$2,353,200
2009	$5,418,000	$0	$5,418,000	$0	$2,353,200
2010	$2,943,000	$4,008,000	$6,951,000	$142,700	$2,353,200
2011	$0	$4,008,000	$4,008,000	$448,437	$2,353,200
2012	$5,588,000	$0	$5,588,000	$0	$2,353,200
2013	$2,596,000	$0	$2,596,000	$0	$2,353,200
2014	$4,787,000	$0	$4,787,000	$0	$2,353,200
2015	$0	$0	$0	$0	$2,353,200
2016	$2,676,000	$0	$2,676,000	$0	$2,353,200
2017	$2,747,000	$0	$2,747,000	$0	$2,353,200
2018	$2,330,000	$0	$2,330,000	$0	$2,353,200
2019	$0	$0	$0	$0	$2,353,200
2020	$2,652,000	$0	$2,652,000	$0	$2,353,200
2021	$2,835,000	$0	$2,835,000	$0	$2,353,200
2022	$2,418,000	$0	$2,418,000	$0	$2,353,200
2023	$0	$0	$0	$0	$2,353,200
2024	$2,527,000	$0	$2,527,000	$0	$2,353,200
2025	$2,612,000	$0	$2,612,000	$0	$2,353,200
2026	$2,130,000	$0	$2,130,000	$0	$2,353,200
2027	$0	$0	$0	$0	$2,353,200
2028	$2,507,000	$0	$2,507,000	$0	$2,353,200
2029	$2,557,000	$0	$2,557,000	$0	$2,353,200
2030	$2,063,000	$0	$2,063,000	$0	$2,353,200
2031	$0	$9,333,000	$9,333,000	$332,300	$2,353,200
2032	$0	$9,333,000	$9,333,000	$1,020,905	$2,353,200
TOTALS	$77,686,000	$58,238,000	$135,924,000	$3,480,200	$70,596,000
NPV	$30,531,000	$30,933,000		$1,649,300	$23,683,000
AAC	$2,407,000	$2,444,000		$130,037	$1,867,000
Average Annual Cost, Grand Total					$6,848,000
Interest Rate =					0.07125

1/ The Selected Plan is described on pages 112 to 119 of the Comprehensive Management Plan Report.

2/ Based on October 1997 prices.

3/ Based on construction sequence shown in Table K-15, Appendix K, Cost Estimates.

Table B-41 Comparison of Benefits to Costs (Navigation Only)

	Alternative 1 Partial Dredging	Alternative 2 Complete Dredging	Alternative 3 Cooperative Dredging	Alternative 4 Generic Clean Upland CDF*
Average Annual Navigation Benefit	$11,691.8	$17,039.5	$16,998.8	$17,039.5
Average Annual Costs	$3,517.1	$4,359.5	$4,494.8	$8,226.6
Benefit to Cost Ratio	3.3	3.9	3.8	2.1
Average Annual Net Benefit	$8,174.7	$12,680.0	$12,504.0	$8,812.9
Increment		Between Alt 2 & Alt 1	Between Alt 3 & Alt 1	Between Alt 4 & Alt 1
Incremental Benefit		$5,347.7	$5,307.0	$5,347.7
Incremental Cost		$842.4	$977.7	$4,709.5
Incremental Benefit to Cost Ratio		6.3	5.4	1.1

Partial Dredging producing greater navigation benefits. The dredging process under Alternative 2 will interfere less with downstream navigation because much more of the actual dredging will occur in the upstream reaches than under Alternative 1.

Sensitivity Analysis

Sensitivity analyses were performed based on alternate values for the commodity projections, demand for iron ore pellets and sedimentation rates. The project is relatively insensitive to sedimentation rate changes as shown in Table B-42. In the second case, commodity tonnages were held constant at 1990 recorded tonnage with no increases throughout the life of the project. The resulting commodity projection sensitivity is shown in Table B-43. The difference in navigation benefits is slight since the forecasted commodity growth was low. In the second case, shown in Table B-44, waterborne commerce was reduced to 44.3 percent of the 1990 tonnages and held constant throughout the project life. This reduced tonnage represents only the 1990 LTV Steel Company receipts which would yield average annual benefits of $5 million and a benefit-cost ratio of 1.25. A breakeven analysis indicates that the maintenance dredging would be justified based on only 35% of the 1990 waterborne commerce at the Indiana Harbor and Canal. The project is insensitive to vessel operating costs, which were investigated but not shown.

Table B-42 Sensitivity Analysis- Sedimentation Rate

Sedimentation Rate	Average Annual Benefits
0.16 ft/yr	$13,020,456
0.17 ft/yr	$12,922,561
0.18 ft/yr	$12,815,105
0.19 ft/yr	$12,691,488
0.20 ft/yr	$12,579,931
0.21 ft/yr	$12,458,589

ENVIRONMENTAL BENEFITS

An estimated 100,000 to 200,000 cubic yards of polluted sediments are discharged annually from the Indiana Harbor and Canal (IHC) into Lake Michigan. The sediments contain metals, Polynuclear Aromatic Hydrocarbons, (PAH's) and Toxic Substances Control Act of 1970 (TSCA) level Polychlorinated Biphenyls (PCB's). The adverse impacts of the discharge can be seen in the movement of the sediments in the nearshore zone for a distance of more than 5 miles from the harbor entrance with potential affect on water supply intakes, commercial fishing areas and recreation areas.

The proposed trapping of sediment and maintenance dredging at the IHC would reduce the volumes of polluted sediments discharged to Lake Michigan by an estimated 50 to 70 percent. This would result in improvements in water quality and in the quality and quantity of fish in the IHC area. A contingent value analysis was undertaken to estimate the NED environmental benefits attributable to the improvement in water quality and fisheries. The attachment to this appendix describes in detail the contingent value analysis that was completed. The analysis estimated the average annual environmental benefits at about $2.2 million. Table B-45 provides a comparison of the total project benefits and costs, including both navigation and environmental benefits.

PROJECT OPTIMIZATION

Optimum project depth was analyzed using modified dredging plans for all alternatives. Based on commercial navigation in Reaches 1-5, the benefits increase as project depth is increased as shown in Table B-46. An incremental analysis of the navigation benefits which accrue from dredging each additional reach upstream of Reach 5 was performed. This analysis is based on modified dredging plans, with no allowance for overdepth dredging for Alternatives 2 and 3. The results are shown in Table B-47. Until Reach 11 is dredged all navigation benefits accrue to reaches 1-5. The upstream reaches are an effective sediment trap and the project is incrementally justified on a reach by reach basis even if no navigation benefits in the upstream reaches are considered.

Table B-43 Sensitivity Analysis
No Commodity Growth* (Reaches 1-5)

Transportation Cost			
Year	Without Project	With Project	Difference
1998	$30,101,066	$29,305,551	$795,514
1999	$30,354,873	$27,332,414	$3,022,459
2000	$30,609,036	$26,589,003	$4,020,034
2001	$30,834,478	$25,689,253	$5,145,225
2002	$31,046,202	$26,013,529	$5,032,673
2003	$31,327,575	$25,712,146	$5,615,429
2004	$31,445,284	$25,896,776	$5,548,508
2005	$31,546,593	$26,084,090	$5,462,502
2006	$31,631,172	$26,274,148	$5,357,024
2007	$31,700,858	$25,978,392	$5,722,465
2008	$31,768,732	$25,654,990	$6,113,742
2009	$31,819,301	$25,417,699	$6,401,601
2010	$31,854,524	$25,598,089	$6,256,435
2011	$31,889,826	$25,239,846	$6,649,980
2012	$31,923,070	$25,239,846	$6,683,224
2013	$31,942,927	$25,239,846	$6,703,081
2014	$31,976,283	$25,417,699	$6,558,583
2015	$31,991,916	$25,239,846	$6,752,070
2016	$31,994,060	$25,239,846	$6,754,214
2017	$32,011,857	$25,239,846	$6,772,011
2018	$32,027,526	$25,417,699	$6,609,827
2019	$32,029,675	$25,261,941	$6,767,734
2020	$32,045,361	$25,239,846	$6,805,515
2021	$32,047,512	$25,239,846	$6,807,666
2022	$32,063,216	$25,417,699	$6,645,517
2023	$32,063,216	$25,239,846	$6,823,370
2024	$32,063,216	$25,239,846	$6,823,370
2025	$32,063,216	$25,239,846	$6,823,370
2026	$32,063,216	$25,417,699	$6,645,517
2027	$32,065,369	$25,373,000	$6,692,369
2028	$32,081,091	$25,239,846	$6,841,245
2029	$32,081,091	$25,239,846	$6,841,245
2030	$32,081,091	$25,417,699	$6,663,392
2031	$32,081,091	$25,373,000	$6,708,091
Sum			$205,865,002
Net Present Value			$60,991,359
Average Annual Benefit			$5,263,805

*Commodity tons for each year are 1990 tonnages.

Table B-44 Sensitivity Analysis
Reduced 1990 Tonnages* Reaches 1-5

Transportation Cost			
Year	Without Project	With Project	Difference
1998	$30,101,066	$29,305,551	$795,514
1999	$30,354,873	$27,332,414	$3,022,459
2000	$30,609,036	$26,589,003	$4,020,034
2001	$30,834,478	$25,689,253	$5,145,225
2002	$31,046,202	$26,013,529	$5,032,673
2003	$31,327,575	$25,712,146	$5,615,429
2004	$31,445,284	$25,896,776	$5,548,508
2005	$31,546,593	$26,084,090	$5,462,502
2006	$31,631,172	$26,274,148	$5,357,024
2007	$31,700,858	$25,978,392	$5,722,465
2008	$31,768,732	$25,654,990	$6,113,742
2009	$31,819,301	$25,417,699	$6,401,601
2010	$31,854,524	$25,598,089	$6,256,435
2011	$31,889,826	$25,239,846	$6,649,980
2012	$31,923,070	$25,239,846	$6,683,224
2013	$31,942,927	$25,239,846	$6,703,081
2014	$31,976,283	$25,417,699	$6,558,583
2015	$31,991,916	$25,239,846	$6,752,070
2016	$31,994,060	$25,239,846	$6,754,214
2017	$32,011,857	$25,239,846	$6,772,011
2018	$32,027,526	$25,417,699	$6,609,827
2019	$32,029,675	$25,261,941	$6,767,734
2020	$32,045,361	$25,239,846	$6,805,515
2021	$32,047,512	$25,239,846	$6,807,666
2022	$32,063,216	$25,417,699	$6,645,517
2023	$32,063,216	$25,239,846	$6,823,370
2024	$32,063,216	$25,239,846	$6,823,370
2025	$32,063,216	$25,239,846	$6,823,370
2026	$32,063,216	$25,417,699	$6,645,517
2027	$32,065,369	$25,373,000	$6,692,369
2028	$32,081,091	$25,239,846	$6,841,245
2029	$32,081,091	$25,239,846	$6,841,245
2030	$32,081,091	$25,417,699	$6,663,392
2031	$32,081,091	$25,373,000	$6,708,091
Sum			$205,865,002
Net Present Value			$60,991,359
Average Annual Benefit			$5,263,805

*Tonnages are held to 44.3% of 1990 tonnages.

Table B–45 Comparison of Total Benefits to Costs

	Alternative 1 Partial Dredging	Alternative 2 Complete Dredging*	Alternative 3 Cooperative Dredging*	Alternative 4 Generic Clean Upland CDF*
Average Annual Navigation Benefit	$11,691.8	$17,039.5	$16,998.8	$17,039.5
Average Annual Environmental Benefits*	$2,296.3	$2,296.3	$2,296.3	$2,296.3
Total Average Annual Benefits	$13,988.1	$19,335.8	$19,295.1	$19,335.8
Average Annual Costs	$3,517.1	$4,359.5	$4,494.8	$8,226.6
Benefit to Cost Ratio	4.0	4.4	4.3	2.4
Average Annual Net Benefit	$10,471.0	$14,976.3	$14,800.3	$11,109.2

*Environmental Benefits are considered to be Incidental Benefits and FDR =.08

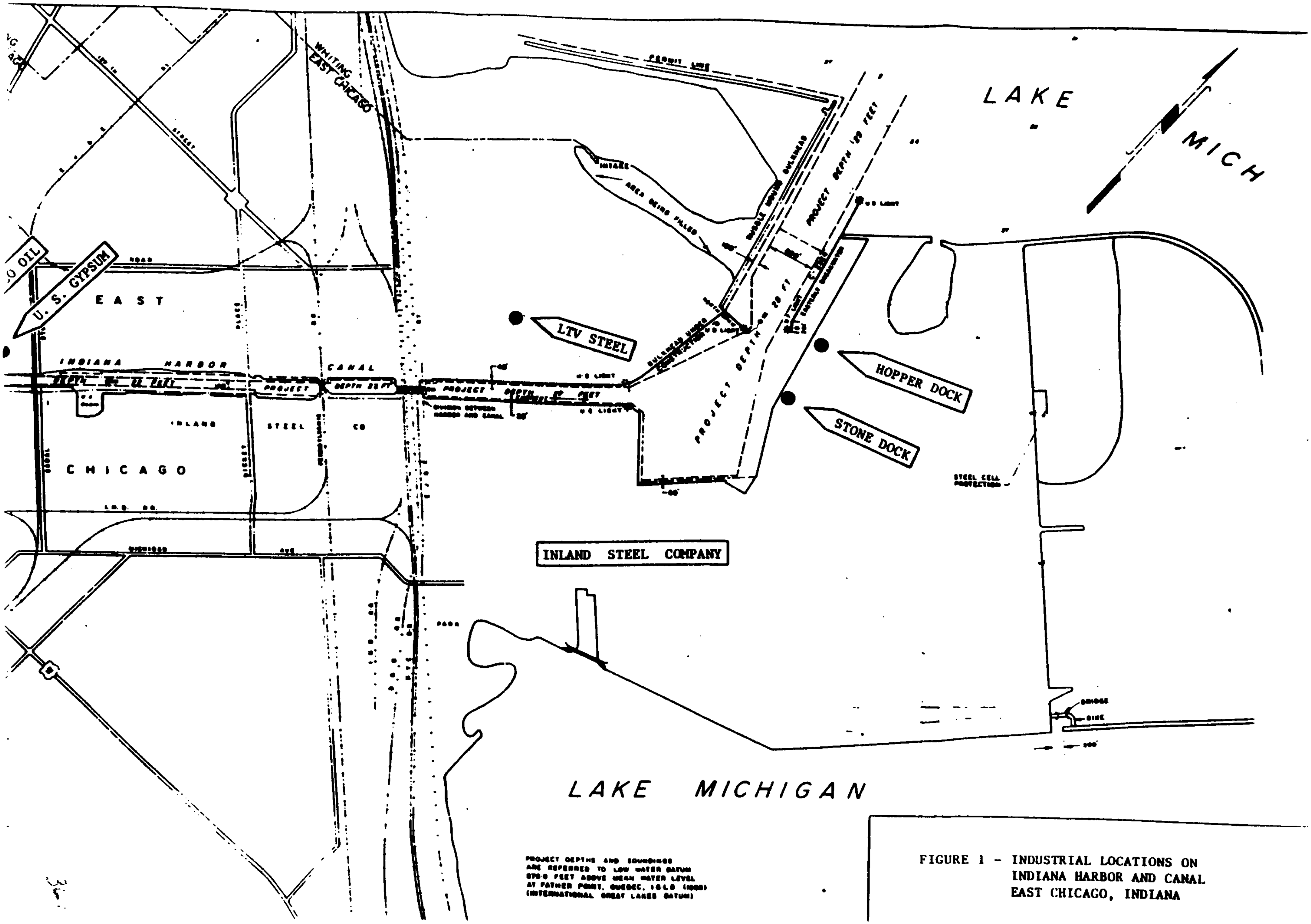

FIGURE 1 - INDUSTRIAL LOCATIONS ON INDIANA HARBOR AND CANAL EAST CHICAGO, INDIANA

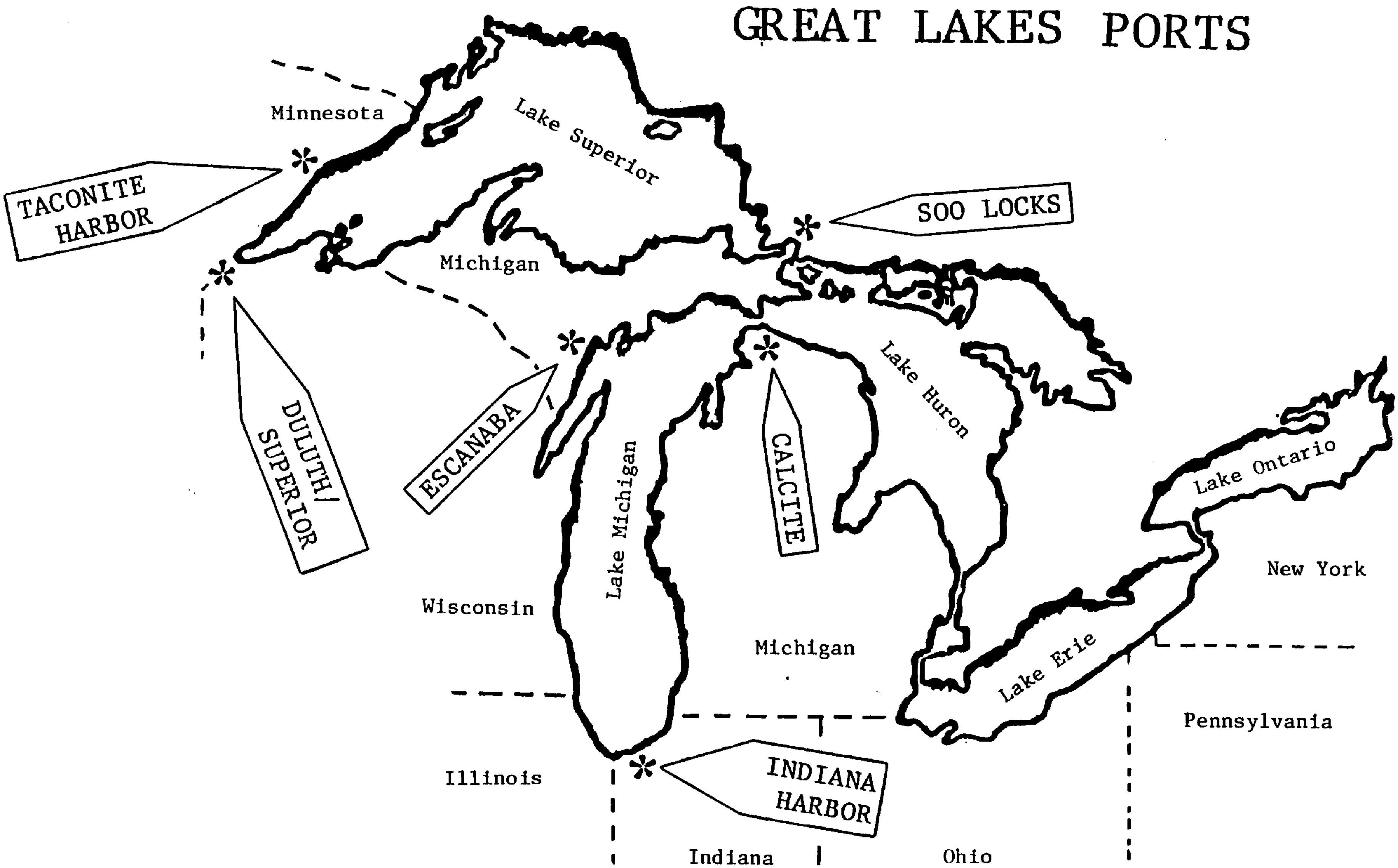

FIGURE 2 - ORIGINS AND DESTINATIONS
INDIANA HARBOR AND CANAL
EAST CHICAGO, INDIANA

INTRODUCTION

The assessment of environmental benefits from dredging Indiana Harbor and Canal is discussed in this section of the Economics Appendix. Ancillary to the navigation aspects of dredging Indiana Harbor and Canal, environmental benefits to society would be project externalities. The first section describes the study area and the nature of the problems addressed in the study of Indiana Harbor. The second section contains a discussion of contingent valuation methodology and a brief description of previous willingness to pay survey results. The third section details the willingness to pay survey methodology, followed by a discussion of the respondent profile and willingness to pay results. Finally, environmental benefit sensitivity is addressed.

STUDY AREA DESCRIPTION

This section describes the location and nature of the study area, including a summary of the factors which contribute to current conditions. This is followed by a brief description of the problem and two possible project impact topics.

The Indiana Harbor and Canal is located in the Northwest corner of Lake County, Indiana. It is between Calumet Harbor to the west and Burns Harbor to the east. The area is a section of the Gary-Hammond PMSA, the second largest urban area in Indiana. The land near Indiana Harbor and Canal has been an industrial zone since 1889. Correspondingly there is air, land, and water pollution. The primary industries have been steel manufacture and petroleum refining. Although steel manufacture has declined somewhat over the past fifteen years, several mills remain in operation today.

Many of the existing oil refineries are no longer operational or operate at diminished capacity. Several refineries use the area for storage facilities. Amoco is still operating the Whiting refinery, which is one of the largest in the country.

Indiana Harbor and Canal is a man-made waterway and is a tributary to Lake Michigan. It has been designated as an area of concern for environmental problems impacting the Great Lakes by the International Joint Commission. The harbor and canal have not been dredged since 1972. As a result of the lack of dredging the Federal Navigation channel has not been maintained and about 157 thousand cubic yards of sediment discharge annually, according to Chicago District estimates, into Lake Michigan. The sediment is polluted and contains both metals and PCB's. The impacts of the discharge can be seen for 5 to 10 miles from the harbor incorporating recreation areas, commercial fishing areas, and water supply intakes. (The impacts on navigation are discussed elsewhere in this appendix.)

The recreation opportunities in the vicinity of Indiana Harbor include several parks, golf courses, beaches, and marinas. Jeorse Park contains a beach and the recently renovated Robert A. Pastorick marina. Both facilities are operated by the East Chicago, Indiana Park

District. Whihala Beach County Park and Whiting Beach and Park are located 3 miles west of Indiana Harbor in Whiting and Hammond, Indiana. The City of Hammond recently opened a 1,000 slip marina, about 4 miles Northwest of Indiana Harbor. The activities frequently undertaken in the recreation areas around the discharge area are boating, fishing, swimming, hiking, and biking.

Both potable and industrial water supplies are taken from the area within two miles of the shore. The water intake for East Chicago is located just east of Jeorse Park.

CONTINGENT VALUATION METHOD (CVM)

This section describes the attributes of public (non-market) goods and various techniques used to evaluate non-market goods. A brief description of the travel cost method is given, followed by a discussion of the contingent valuation method.

Environmental assets, such as air and water quality are provided outside of the market system making estimation of the value of this type of good difficult. Ordinarily the market mechanism assumes that an individual's utility is dependent on the quantities of commodities purchased by the individual and that each producer's output is determined by the factors of production purchased by the producer. Information such as prices and quantities could be used to analyze such a market. However some commodities such as public goods, have different properties. A public good can simultaneously provide benefits to more than one consumer at a time, for example, more than one individual may use a public park at any given time. It is also difficult to exclude individuals from the use of public goods, anyone is permitted on a public beach. These properties imply that a different pricing mechanism is used than the pricing mechanism of the normal goods market where individuals are excluded from consumption of a good via price. Establishing market values for goods provided outside the market system requires a different methodology.

The inherent problems of public goods pricing mechanisms are a result of the unique properties associated with public goods. Several valuation techniques have been developed to evaluate non-market goods. The travel cost method (TCM) uses the variable travel cost incurred to visit a site as a proxy for price. It is based on observations of direct behavior, which limits its use to evaluate previously existing conditions. The contingent value method uses hypothetical markets to identify the value of a good, such as water quality improvements. The price and quantity are determined by asking individuals, usually via a survey, questions that indicate their willingness to pay for varying quality changes.

For purposes of this study the evaluation of environmental benefits accruing as a results of dredging the Indiana Harbor and Canal is accomplished via CVM.

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Previous Studies

This section provides a brief summary of results of previous contingent value method studies used to evaluate public goods in the Chicago area. Several public willingness-to-pay surveys have been undertaken to evaluate the maintenance of nature preserves, flood and erosion control, and water quality improvements in northeastern Illinois in recent years.

Richard Bishop and Kevin Boyle used a mail survey throughout the state of Illinois to determine public willingness-to-pay for the preservation of the State Nature Preserve at Illinois Beach State Park in a 1985 report to the Illinois Department of Conservation. Questionnaire response from a random sample of 600 Illinois head of households was analyzed using a Logit model. They determined that the average Illinois head of household placed an approximate value of $28 per year on the nature preserve. Interestingly, they also found that a lack of knowledge of the existence of the nature preserve does not preclude the valuation of the nature preserve. Of those surveyed from all counties, apart from Lake and McHenry counties, only seven percent knew that part of the park is a nature preserve, yet only eight percent indicated that the nature preserve was not at all important to them. Bishop and Boyle conclude that the underlying concern for the area is a result of "concerns or desires regarding the quality and quantity of environmental assets."[1]

The maintenance of nature preserves in Lake County, Illinois has also been the subject of study in a 1985 by Kevin Croke and Gary Brenniman for the Chicago District. Using a telephone survey of Lake County heads of households and a sample size of 350, they found that respondents were willing-to-pay on the average about $20 to avoid the conversion of fifty percent of the nature preserves to commercial use, and about $34 to avoid the conservation of 100% of nature preserves to commercial use. [2] Brenniman, Levy, and Logue determined public willingness to pay for the prevention of flood and erosion damage to selected Chicago lake front parks. Using a telephone survey of 1000 Chicago heads of households, they found that respondents were willing to pay $22.25 for flood and erosion control at Chicago's lake front parks including the Lincoln Park Zoo and the Museum of Science and Industry, and $22.75 without the zoo and museum.[3] The lower WTP value when

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[1] Bishop, Richard C. and Boyle, Kevin J. 1985, "The Economic Value of Illinois Beach State Nature Preserve". Final report to the Illinois Department of Conservation.

[2] Croke, Kevin and Brenniman, Gary R. 1985. "Public Willingness to Pay for the Maintenance of Nature Preserves" Prepared for : Economic Analysis Branch CENCC.

[3] Brenniman, Gary R., Levy, Paul S., & Logue, Rosemary R. 1991. "Two Flooding and Erosions Studies for areas in Northern Illinois" Prepared for : Economic Analysis Branch CENCC.

the zoo and museum are included reflects respondents' views that both the zoo and museum are already well funded.

Telephone survey data was analyzed by Croke and Brenniman in a 1984 study to determine the value of improved water quality in the rivers and creeks of the Chicago area. From a random sample of 350 Chicago area heads of households, they determined mean annual willingness to pay of $28.33, $35.04, and $43.20 for improved water quality to the levels that would support outing, boating, and fishing respectively. [4]

SURVEY METHODOLOGY

This section describes the methodology employed to collect survey data with respect to the willingness to pay of local residents to dredge Indiana Harbor of polluted sediment. The study area, the sample, the method of collecting data, and qualification requirements of the respondents is addressed. All surveys were completed by the Survey Center, a commercial market research firm based in Chicago. Further information on the survey methodology is provided in attachment A.

Survey Objective

The objective of this survey is to obtain monetary valuations of environmental benefits which are in any way perceived to be associated with dredging Indiana Harbor.

Study Area

The study area is defined as the region located within a ten mile radius of the anchorage and maneuver basin of Indiana Harbor. The sample consists of adults residing within the study area who have lived one year or longer at their current address. The vicinity includes both industrial and residential properties in Illinois and Indiana. There are 142,586 households in the ten mile radius area.

Questionnaire Design

The complete telephone questionnaire used for this survey can be found in appendix A. The survey was designed to assess residents' concerns about water quality in the area, to

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[4] Croke, Kevin and Brenniman, Gary. 1984. "Public Willingness to Pay for Improved Water Quality within Chicagoland Underflow Plan Area." School of Public Health, University of Illinois at Chicago.

determine whether they are willing to pay for improved water quality and if so, how much. The first section establishes the perceived water quality level of waterbodies in the area, recreational use of the waterbodies, and the reasons, if any, for improving water quality. The next section establishes through an iterative bidding process the amount the respondent is willing to pay to improve water quality by dredging the Indiana Harbor and Canal and explores the reasons the respondent is or is not willing to pay. The third section deals with the socio-economic status of the respondents. The information collected includes income, education, age, gender, and length of residency.

Sample Methodology

The Waksberg method of random digit dialing was used to generate the necessary telephone numbers. This method is designed to include both listed and unlisted numbers, and to decrease the chances of reaching non-residential or non-working numbers.

The Waksberg method was implemented in the following manner: First, the geographic study area was translated into zip code areas. The telephone exchanges which serve the zip code areas were then identified and those with a low probability of reaching a household in the designated zip code areas were excluded. Telephone numbers were created from the 62 exchanges selected, by generating the last four digits with a randomization algorithm.

Cluster analysis is a technique used to identify similar groups, in this case it is used to identify similar locations. A telephone number is actually a location indicator in itself. The prefix, the first three digits, indicates the switching district, the next four digits are further indicators of location (city block, building etc.). The cluster size selected by The Survey Center for the study was two. In order to obtain a sample size of 1000 interviews, 500 clusters of two interviews each would be necessary. Interviewing began with the first 500 randomly generated telephone numbers. Up to four attempts were made to complete an interview from the starting number, unless it became apparent that continued efforts would not result in a completed interview (refusal, disconnected, etc..). If the starting number was not usable, the last four digits of the starting number were randomized to produce another number for the cluster. This process was repeated until the interview quota for the cluster was completed.

Screening

In order to be qualified to respond to the survey, the potential respondent had to: 1) have at least heard of Indiana Harbor; 2) to have lived in the area for one year or more; and 3) be the head of household.

Interview Process

The original survey was pretested, reviewed, and edited through a series of pre-tests in which 50 households were interviewed. The survey questions were administered using CATI

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(Computer Assisted Telephone Interviewing). The average time required to complete an interview was 22 minutes. The interviews were conducted by trained interviewers during the day and evening hours on weekdays and week-ends from May 8 through June 16, 1991.

DISPOSITION OF TELEPHONE ATTEMPTS

The initial attempts to reach numbers generated by the Waksberg method resulted in dialing 10,620 telephone numbers. The 10,620 numbers dialed resulted in 5,849 (55.1%) actual household numbers. Of the original, 10,620 numbers dialed, 35.1% were disconnected numbers and 9.8% were business numbers. The potential respondent was either not available or the call was received by an answering device in 23.3% of the calls. All surveys were conducted in English. Language or communication difficulty occurred in 1.3% of the households contacted. Altogether 33.6% of the households contacted initially refused to respond to the survey, leaving 41.8% (2,448) households which could be screened.

In order to be considered qualified to respond to the survey, the potential respondent had to meet the screening requirements. The screening process itself proved to be a valuable source of information about the population; 45.3% (1108) of the potential respondents had never heard of Indiana Harbor. Approximately 9.0% of the potential respondents had moved within the past year. The remaining 1,120 respondents (45.7%) were qualified for the interview. During the interview process 10.7% (120) of the qualified households refused to complete the interview. The sample population (number of completed interviews) consists of the remaining 1,000 qualified households.

SOCIO-ECONOMIC PROFILE OF RESPONDENTS

Individuals responding to the questionnaire are generally at least high school graduates with moderately comfortable income levels. Most of the respondents have completed high school (87%) and 21% of the respondents have completed college. The average household income level is between $30,000 and $39,000. About 12% of the respondents have a household income level under $10,000 per year and 14% have a household income level of over $50,000.

The individuals responding have lived in the area for some time, and have kept the same address. On the average they have lived within 10 miles of Indiana Harbor for 25 years and at the same address for 15.65 years. Most live in single family homes, 76.9%, and most of them, 71.6%, own their homes.

The respondents average age is 44.84 years old with a range of 18 to 86 years old. A majority of the respondents do not have children at home, 62% do not have any children under 13 at home, 75% do not have any children between 13 and 19 years old at home and only 12.7 % have children from both ages groups at home. The average household has 3.15 members. A little over half, 52%, of the respondents are female heads of households.

All of the respondents said that they had heard of Indiana Harbor, but they were not asked if they knew where the harbor is located.

Detailed census data by census tract were not yet available. Preliminary county level data for some census categories have been released for Lake County, Indiana. A comparison of the two yields interesting information. However, Lake County is rather large and incorporates both rural, urban, and industrial areas indicating that the survey area population characteristics and the county population characteristics are not truly comparable. On the average the survey population is older than the population of Lake county, which has a median age of 33 years old. The population of Lake county has a smaller household size with 2.76 person per household. A greater percentage of the survey population owns their own home than the Lake County population, with 67.7% homeowners. Income information is not yet available.

Perception of Water Quality

The survey design (see appendix A) employs a "water quality ladder" which specifies water quality as it relates to recreational activities for a given waterbody. Four levels are used:

1. Is the waterbody clean enough so that people would be willing to have picnics or outings along the shores;
2. Is the waterbody clean enough so that people would be willing to boat on it;
3. Is the waterbody clean enough so that people would be willing to fish in it for game fish;
4. Is the waterbody clean enough so that people would be willing to swim in it.

The underlying assumption is that the more likely direct contact with the water is, the higher the water quality demanded. An individual may be willing to boat on a waterbody where they may not be willing to swim based on water quality. (Regarding the Indiana Harbor and Canal, it is recognized that water quality could probably not be improved to the levels that are conducive to swimming in the canal.)

The questionnaire was designed such that comparative perceptions of water quality levels and associated recreational use could be determined for Lake Michigan near Indiana Harbor (LM-IHBR), Indiana Harbor and Canal (IHBR), and the Grand Calumet(GCAL) river system. The respondents are asked whether the various waterbodies are clean enough to enjoy shore activities, boat, fish and swim. As shown in Table 1, the respondents placed IHBR between LM-IHBR and GCAL for water quality levels, with LM-IHBR having the highest, though still not very high, and GCAL the lowest level of water quality.

Table 1
Percent Responding that Waterbody is Clean Enough for Various Activities

Activity	Waterbody		
	IHBR	LM-IHBR	GCAL
Shore Activity	33.5%	44.6%	23.7%
Boat	62.2%	75.7%	44.3%
Fish	22.5%	32.0%	15.7%
Swim	14.5%	26.9%	9.0%

Source: compiled from survey responses.

It is not surprising given the low water quality levels shown above that the majority of the respondents have not used the waterbodies for recreational purposes during the last twelve months. Out the 1000 surveyed, only 13.7% had used Indiana Harbor, 4.3% the Indiana Canal, 28.1% Lake Michigan near Indiana Harbor, and 8.2% the Grand Calumet river system. It is also worthwhile to note that the aesthetic quality of the shore in the vicinity is not particularly appealing, and few of the individuals surveyed participated in shore activities. Nor is the water quality in the area appealing, fewer than one-third of those surveyed though that the water quality of Lake Michigan near Indiana Harbor was clean enough for swimming.

The respondents were asked the following question to determine whether dredging Indiana Harbor and Canal was important and why: "which one of the following reasons, if any, for dredging the Indiana Harbor is most important to you personally." The most common response to the question indicates that the survey population is concerned with the water quality of Indiana Harbor in its present condition. A total of 58.9 % of the respondents indicate that desire to have water quality improved and pollution reduced as a result of dredging was the most important reason for dredging. Another 33.9% answered that satisfaction from just assuming that the quality of these waters may be improved through dredging was most important.

Use of the waters for swimming, fishing, or boating was the most important reason for 9.9% of those surveyed, and recreational activities near shore for 4.7%. The satisfaction from knowing that others may be encouraged to use and enjoy these waters is the most important reason for dredging for 6.6%. Twenty-one respondents (2.1%) of the respondents do not associate any positive value with dredging Indiana Harbor and Canal.

Dredging Indiana Harbor and Canal is important to most of the respondents and some think that their health would be affected by dredging. When asked if they thought their health would be affected in any way, 36.2% thought that their health would be affected and 62% did not. Out of the respondents who thought that their health would be affected by dredging Indiana Harbor, 72.4 % thought that their health would be improved, and 23.5% thought their health would be harmed.

The respondents who thought their health would be improved or harmed were asked how would it be improved or harmed. Of those who said their health would be improved the following reasons (and percent response) were given:

Table 2
How would Health be Improved by Dredging Indiana Harbor

Reason	Percent Response
Cleaner water/better water quality	26.7%
Cleaner drinking water	13.7%
Get rid of chemicals/contaminants	12.2%
Improve air quality	6.5%
Could fish/eat the fish	6.5%
Lessen pollution/pollutants	5.7%
Get rid of debris/garbage	5.3%
Cleaner environment (not elaborated)	5.3%
Water would be purer	5.0%
Better for health (not elaborated)	4.2%
Smell better	3.8%
Air and water would be cleaner	3.4%
Could go swimming	3.1%
Would make Lake Michigan cleaner	1.5%
Total	100.0%

Source: compiled from survey responses.

Similarly, those who thought their health would be harmed were asked how they thought health would be harmed. Of those who said their health would be harmed the following reasons and percent response were given:

Table 3
How would Health be Harmed by Dredging Indiana Harbor

Reason	Percent Response
Would stir up pollution	22.4%
Sediments may pollute drinking water	16.5%
Deposited chemicals would be stirred up and contaminate the air	15.3%
What would be done with the sediments	10.6%
Do not know what's in the water	4.7%
Toxic waste	3.5%
Soil or ground water could be contaminated	1.2%
Other	20.0%
Not Answering	5.8%
Total	100.0%

Source: compiled from survey responses.

Whether the respondent thought health could be harmed or improved by dredging; water quality, pollution, and drinking water are substantial concerns.

Willingness to Pay Estimates

The mean willingness to pay of the respondents to improve water quality to levels such that Indiana Harbor and Canal could support shore activities, such as picnics or walks along the shore, and water contact activities, boating, fishing, swimming, and other reasons are shown in Table 4. The next table shows the mean willingness to pay for those who had used the Indiana Harbor or Canal in the last twelve months and for those who had not. As shown in Table 5 and Table 6, users of the Indiana Harbor and Canal are willing to pay more than non-users to improve water quality. Just as the respondents perceived the quality of Lake Michigan water to be higher, the users of Lake Michigan near Indiana Harbor are willing to pay more than other groups to improve water quality via dredging Indiana Harbor and Canal as shown in Table 7. Respondents indicated that the water quality of the Grand Calumet river system was very poor and are willing-to-pay less to improve water quality of Indiana Harbor. In fact those who used the Grand Calumet system were least willing-to-pay. This may reflect the poor water quality of the Grand Calumet system but more likely reflects the lower income of Grand Calumet users relative to the mean income of other waterbody users.

Table 4
Mean Willingness-to-Pay

Activity	Willingness-to-Pay
Outings	$23.19
Outings and Boating	$29.41
Outings, Boating and Fishing	$34.49
Outings, Boating, Fishing and Swimming	$39.48
Other	$98.14

Source: compiled from survey responses.

Table 5
Willingness-to-Pay of Users of Indiana Harbor and Non-Users of Indiana Harbor.

Activity	User	Non-User
Outings	$31.87	$21.81
Outings and Boating	$41.88	$27.42
Outings, Boating and Fishing	$48.40	$32.27
Outings, Boating, Fishing and Swimming	$55.65	$36.89
Number Responding	136	852

Source: compiled from survey responses.

Table 6
Willingness-to-Pay of Users of Indiana Canal and Non-Users of Indiana Canal.

Activity	User	Non-User
Outings	$28.14	$22.96
Outings and Boating	$38.19	$29.00
Outings, Boating and Fishing	$42.72	$34.10
Outings, Boating, Fishing and Swimming	$46.79	$39.12
Number Responding	43	944

Source: compiled from survey responses.

Table 7
Willingness-to-Pay for Dredging Indiana Harbor of Users of Lake Michigan Near Indiana Harbor Vs. Non-Users of Indiana Canal.

Activity	User	Non-User
Outings	$33.16	$19.28
Outings and Boating	$41.29	$24.75
Outings, Boating and Fishing	$48.29	$29.07
Outings, Boating, Fishing and Swimming	$54.55	$33.56
Number Responding	280	707

Source: compiled from survey responses.

It is assumed that non-users willingness-to-pay estimates are option and existence values only, while users willingness-to-pay estimates are use, option, and existence values for improving water quality. Use value is the difference between the user population and non-user population willingness to pay estimates. However, the separation of use value from option and existence values may not simply be the numerical difference between the willingness-to-pay of users from that of non-users. The user population conceptually has an additional component (use) of value not present in the non-user population, and a comparison of the two groups indicates a premium willingness-to-pay for users, however, the size of the premium is uncertain, as users may have an enhanced or diminished non use component (option, existence, bequest) of value. Since the distribution of the components of the composite value is unknown, the distinction between use, option, and existence values for users cannot be determined. The difference is reported but the interpretation of the difference may not be the true use value, although use is certainly a component, and adds a premium to the overall value.

Some respondents, 14.8%, are willing to pay still more than their previous high bid by category to increase environmental benefits through dredging Indiana Harbor and Canal. In other words they are willing-to-pay more for improved water quality for reasons other than for the four categories given: outing, boating, fishing, and swimming. The mean willingness to pay for other reasons is high, $98.14. The motivation to pay still more is largely due to environmental concern and recreation opportunity. Some cynicism towards government ability is also apparent. The reasons given and percent response of the more common responses are shown in Table 8.

Table 8
Why Would You be Willing-to-Pay More to Increase Environmental Benefits through Dredging Indiana Harbor

Reason	Percent Response
Improve water quality/make it cleaner	12.6%
Improve water for recreation-fishing, swimming and boating	12.6%
If politicians use the money correctly/assured the money would go towards cleaning the environment	10.5%
Improve area for environmental reasons/wildlife	8.4%
If I had greater income	7.7%
Guarantee that it won't be re-polluted	7.0%
Efforts were effective	6.3%
Improve drinking water	5.6%
Keep it safe for the future	5.6%
If government decides to fix problem instead of promises	4.2%
Other	19.5%
Total	100.0%

Source: compiled from survey responses.

Users Vs. Non-users

The values that individuals attach to water quality vary by the individuals perceptions of the importance of clean water for themselves or their families, either out of concern for the environment in general or for more specific reasons, such as recreation opportunity, health and safety, and the desire to leave something for future generations. The amount that they are willing-to-pay is certainly a function of these concerns, and the satisfaction they receive from higher water quality. However, all other goods and services consumed by the individual, (whether consumptive or non-consumptive by nature) must be paid for as well.

Household income determines the amount of money the household can spend on all goods and services, and is expected to be a significant factor in the willingness-to-pay for improved water quality in Indiana Harbor. Relative incomes of users of various waterbodies and non-users are shown in Figure 1. Regressions for the four willingness to pay categories (outing, boating, fishing, swimming) are run. The amount willing to pay is a function of income, education, number of children at home, distance from the harbor, and use of the harbor for recreational activities. The regressions are run both excluding and including use of the harbor for outings, boating, fishing, and swimming. The results are presented in Table 9. Obviously, the independent variables used here are not sufficient to explain willingness-to-pay, as evidenced by low adjusted R-squared. The use variable is not statistically significant at the 95% level of significance in any equation. However in the equation for boating, it is negative and statistically significant at the 90% level. This may reflect differences in waterbody use, individuals with lower income levels may use Indiana Harbor for boating while individuals with higher income levels may boat elsewhere. The general insignificance of the use variable implies that the water quality of waterbodies in the area may hold existence and option values unattached to a recreational use value.

Non-willingness-to-pay

A number of respondents are not willing to pay anything to improve water quality. In Figure 2 the distribution of the reported amounts respondents are willing to pay is shown. About 38% are not willing to pay anything to improve the water quality of Indiana Harbor to the level that would support shore activities and 31% are not willing to pay anything to improve the water quality to the level that would support swimming. As a higher level of water quality is assumed, the number of respondents who reported that they would not be willing to pay anything for improved water quality declines.

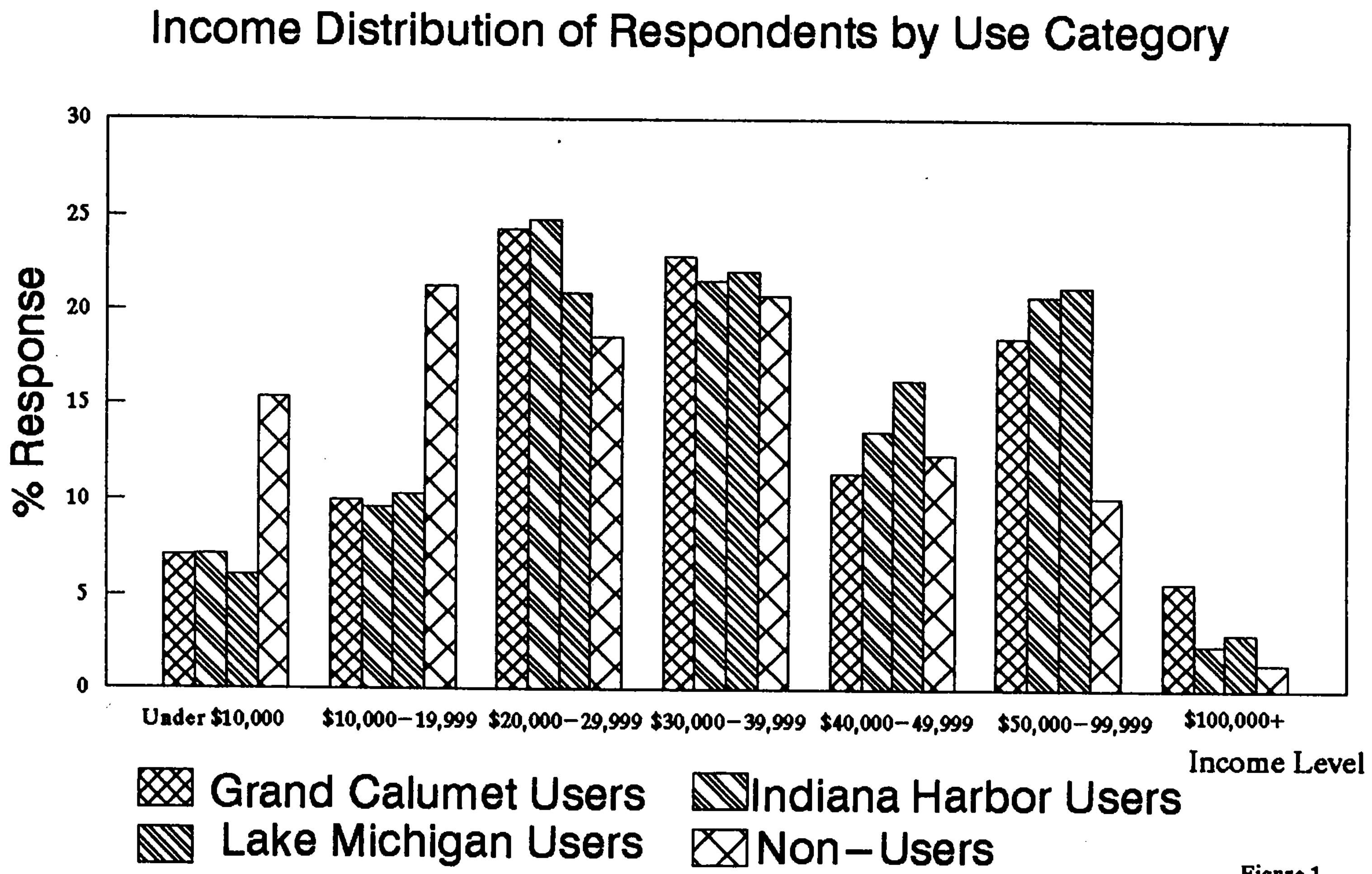
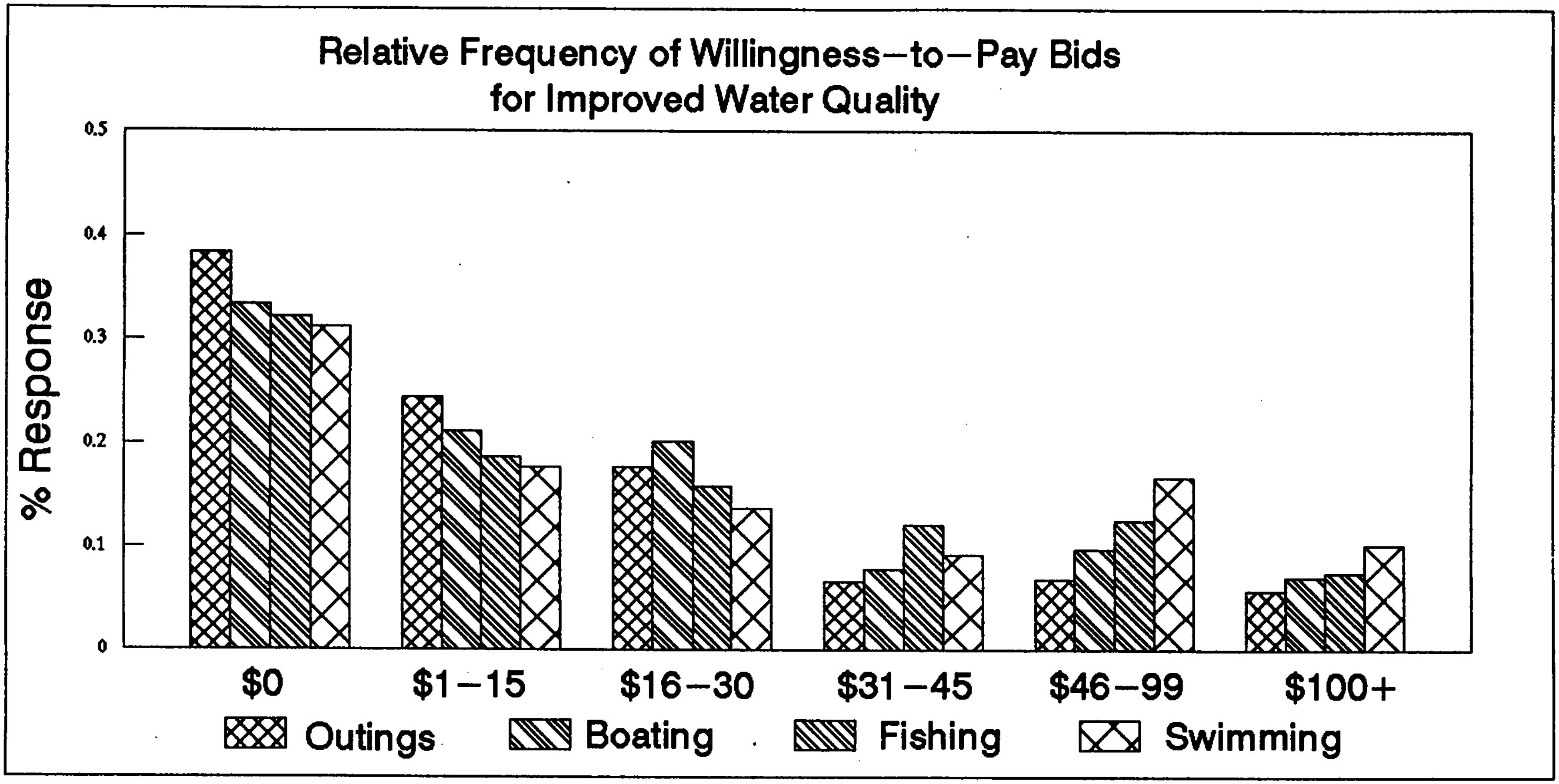

Income Distribution of Respondents by Use Category

Figure 1

Table 9 Regresion Results

	Estimated Coefficients of Independent Variables Absolute Value (T-Statistic)							
Dependent Var	Distance LM-IHBR	Income	Years of Education	NO. of Children (13-17yrs)	NO. of Children (under 12 yrs)	Uses for Activity in last yr.	Constant	Adjusted R-square
WTP-Outing ($)	-0.09329 (-0.920)	0.3990 (2.348)	-0.0237 (0.105)	-0.0193 (.101)	0.1761 (1.142)	NA NA	3.027 (9.23)	0.04
WTP-Outing ($)	0.2151 (0.767)	1.5689 (2.305)	-0.0814 (0.064)	-0.9408 (1.470)	0.02442 (0.043)	-0.4515 (0.485)	1.716 (1.157)	0.17
WTP-Boating ($)	-0.1279 (-1.209)	0.3858 (2.151)	0.0713 (0.299)	0.0496 (0.245)	0.2840 (1.757)	NA NA	3.141 (9.06)	0.07
WTP-Boating ($)	0.5359 (2.411)	0.1886 (0.295)	0.5991 (0.575)	-0.5355 (1.032)	0.0889 (0.193)	-1.638 (2.298)	3.037 (2.363)	0.45
WTP-Fishing ($)	-0.0858 (-0.812)	0.4186 (2.334)	0.1241 (0.0608)	-0.0135 (0.067)	0.3679 (2.276)	NA NA	3.0793 (8.87)	0.10
WTP-Fishing ($)	0.3842 (1.460)	0.8443 (1.328)	0.4599 (0.341)	-0.9396 (1.471)	0.5309 (0.884)	-1.0739 (1.525)	2.338 (1.550)	0.21
WTP-Swimming($)	-0.0383 (-0.346)	0.4374 (2.320)	0.1593 (0.634)	-0.0399 (0.188)	0.3551 (2.107)	NA NA	3.0412 (8.351)	0.09
WTP-Swimming($)	0.3692 (1.144)	0.7706 (0.992)	-0.4057 (0.259)	-0.7514 (0.645)	0.2748 (0.386)	0.0289 (0.019)	3.199 (1.692)	0.00



Relative Frequency of Willingness–to–Pay Bids for Improved Water Quality

Dollar Amount (1991$) Willing–to Pay to Improve Water Quality to a Level that would Support Activities such as Outings, Boating, Fishing, and Swimming

Figure 2

Those respondents who are not willing to pay anything to improve water quality in Indiana Harbor may bid $0 due to financial constraints or because an additional expenditure to improve water quality is not worth the improvement in water quality levels. They may also bid $0 because they feel the harbor is already clean enough or because they do not think it is possible to improve water quality in Indiana Harbor. In the latter case the $0 bid is known as a protest bid. The individual cannot participate in a market when there is no demand for the product: if the harbor is clean enough, they already have the product; and if it is not possible to improve the water quality, the product is not attainable.

The respondents were asked their reasons for their $0 response. The percentage of times that each of the reasons listed were chosen by the all respondents is shown in Table 10.

Table 10
Why Would You Not be Willing-to-Pay More to Improve Water Quality through Dredging Indiana Harbor

Reason	Percent Response
Enough money is already being spent to improve the environment/make area waterbodies attractive for outings.	25.4%
An improved environment around the area waterbodies is not worth anything.	9.0%
Too much is being spent to improve the environment in this area.	6.2%
The environment around the area's waterbodies cannot be improved enough to make them attractive for outings.	5.3%
The environment around the area's waterbodies is already suitable for outings.	4.3%
Other	13.3%
Not Responding	36.5%
Total	100.0%

Source: compiled from survey responses.

The respondents who indicated that they were not willing to pay anything are on the average a little older with a mean age of 49 years. They have fewer children (.77 on the average)and smaller households (2.91 per household) than those who are willing to pay to improve the water quality in Indiana Harbor. They are not as well educated, 42% percent of those who are not willing to pay have at least completed high school and 17% had at least completed college. More (18%) of the respondents who gave 0$ bids have household incomes under $10,000.

FUTURE WITH PROJECT

The effects on water quality of dredging Indiana Harbor and Canal are cumulative in nature. Initially the water quality in Indiana Harbor and Canal will improve after dredging takes place and the sediment trap is constructed. The water which flows into Lake Michigan will contain less polluted sediment, consequently the water quality in Lake Michigan near Indiana Harbor will improve. Out of the four categories on the water quality ladder (outing, boating, fishing, and swimming) for which willingness-to-pay for water quality improvement is evaluated the project impacts all categories to a degree. The projected impacts on both the quality and quantity of fish in the area are significant.

Environmental Benefits

The assessment of environmental benefits from dredging Indiana Harbor and Canal is based on several assumptions. The first is that environmental benefits are associated with the reduction in sediment discharge. The second assumption is that the sediment trap has efficiency between fifty percent and seventy percent. Efficiency of fifty percent is a conservative estimate based on historic dredging records and implies a fifty percent reduction in sediment discharge. The third assumption is that environmental benefits accrue from the first year of dredging and increase at a decreasing rate until initial dredging is complete.

The fourth assumption used to determine environmental benefits is that water quality improvements as a result of dredging Indiana Harbor and Canal could significantly impact water quality to the level that would support fishing in the area. As sediment discharge is reduced the amount of PCB's and other pollutants discharged with the sediment is reduced. As the fish population consumes lower levels of pollutants it is less likely that warnings against eating fish caught in the area would be required and more likely that the fish population will grow and diversify. The value associated with environmental benefits is a percentage (between 50% and 70%) of the mean annual value of improving the water quality to a level which would support fishing ($34.49) in the area corresponding to the percent sediment reduction. This value is applied to the appropriate household population.

The last assumption is that the project will be maintained by regular and routine operations and maintenance dredging.

Impact Population

The immediate project impact area is the area closest to Indiana Harbor and Canal, which includes the survey area. A little under half of the numbers originally dialed resulted in a potential respondent who had not heard of Indiana Harbor, it is reasonable to assert that many would be willing to pay to improve water quality through dredging Indiana Harbor and Canal, even if they had never heard of Indiana Harbor. However, considering the industrial nature of Indiana Harbor and Canal, the percent of the population in the survey area which has never heard of Indiana Harbor (48%) may be somewhat less likely to be willing to pay for water quality improvement through dredging the Indiana Harbor. Taking a very conservative approach, environmental benefits are claimed only on the percent of study area households which has heard of Indiana Harbor. The annual environmental benefits with a fifty percent sediment reduction (WTP $17.24) and a seventy percent reduction (WTP $24.14) are shown in Table 11. Benefit accrual over time with a 50% reduction in sediment discharged is shown in Figure 3. The secondary impact population, the population which will certainly benefit from water quality improvements through dredging Indiana Harbor and Canal, but for which no environmental benefits are claimed, would be the shore and near shore communities a greater distance than the survey area from Indiana Harbor and those communities with municipal water intakes nearby, the cities of Chicago, East Chicago, hammond, and Whiting.

Table 11
Annual Environmental Benefits from Dredging Indiana Harbor and Canal

Year	Cumulative % Sediment Reduction	Cumulative Benefits with 50% Total Sediment Reduction	Cumulative % Sediment Reduction	Cumulative Benefits with 70% Total Sediment Reduction
1998	35.0%	$1,204,359	49.0%	$1,686,103
1999	41.0%	$1,410,821	57.4%	$1,975,149
2000	45.0%	$1,548,462	63.0%	$2,167,846
2001	48.0%	$1,651,693	67.2%	$2,312,370
2002	50.0%	$1,720,513	70.0%	$2,408,718
Average Annual Benefit		**$1,640,199**		**$2,296,278**

Source: calculated from survey responses. FDR=0.08.

Sensitivity

The environmental benefit computation is based on a number of assumptions regarding the impact population and willingness to pay. The impacts of decreasing or increasing the percent willing to pay corresponding to percent sediment reduction to a water quality level equivalent to that which would support fishing are shown in Tables 12 and 13.

APPENDIX C

Analytical Chemistry Data for Two Peregrine Falcon Prey Species Indiana Harbor and Ship Canal

Table C-1. Polycyclic aromatic hydocarbon (PAH) residues in barn swallow eggs and 13-day old nestlings from Columbus Drive, Indiana Harbor Canal 1993 (parts per million, wet weight).

8500030	CD01a eggs	CD01ec nestling	CD04c nestling	CD07c nestling
1,2,5,6-dibenzanthracene	<0.01	<0.01	<0.01	<0.01
1,2-benzanthracene	<0.01	<0.01	<0.01	<0.01
1-methylnaphthalene	0.01	0.02	0.02	0.02
1-methylphenanthrene	<0.01	<0.01	<0.01	<0.01
2,3,5-trimethylnaphthalene	<0.01	<0.01	<0.01	<0.01
2,6-dimethylnaphthalene	<0.01	<0.01	<0.01	<0.01
2-methylnaphthalene	0.02	0.03	0.02	0.03
acenaphthalene	<0.01	<0.01	<0.01	<0.01
acenaphthene	<0.01	<0.01	<0.01	<0.01
anthracene	<0.01	0.01	<0.01	0.01
benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01
benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01
benzo(e)pyrene	<0.01	<0.01	<0.01	<0.01
benzo(g,h,i)perylene	<0.01	<0.01	<0.01	<0.01
benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01
biphenyl	<0.01	<0.01	<0.01	<0.01
C1-chrysenes	<0.01	<0.01	<0.01	<0.01
C1-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01
C1-Fluoranthenes & Pyrenes	<0.01	<0.01	<0.01	<0.01
C1-fluorenes	<0.01	<0.01	<0.01	<0.01
C1-naphthalenes	0.03	0.05	0.04	0.05
C1-phenanthrenes	<0.01	<0.01	<0.01	<0.01
C2-chrysenes	<0.01	<0.01	<0.01	<0.01
C2-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01
C2-fluorenes	<0.01	<0.01	<0.01	<0.01
C2-naphthalenes	<0.01	<0.01	<0.01	<0.01
C2-phenanthrenes	<0.01	<0.01	<0.01	<0.01
C3-chrysenes	<0.01	<0.01	<0.01	<0.01
C3-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01
C3-fluorenes	<0.01	<0.01	<0.01	<0.01
C3-naphthalenes	<0.01	<0.01	<0.01	<0.01
C3-phenanthrenes	<0.01	<0.01	<0.01	<0.01
C4-chrysenes	<0.01	<0.01	<0.01	<0.01
C4-naphthalenes	<0.01	<0.01	<0.01	<0.01
C4-phenanthrenes	<0.01	<0.01	<0.01	<0.01
chrysene	<0.01	<0.01	<0.01	<0.01
dibenzothiophene	<0.01	<0.01	<0.01	<0.01
fluoranthene	<0.01	0.021	<0.01	<0.01
fluorene	<0.01	<0.01	<0.01	<0.01
indeno(1,2,3-cd)pyrene	<0.01	<0.01	<0.01	<0.01
naphthalene	0.02	0.03	0.04	0.03
perylene	<0.01	<0.01	<0.01	<0.01
phenanthrene	<0.01	0.01	<0.01	0.01
pyrene	<0.01	<0.01	<0.01	<0.01
total PAHs	0.08	0.15	0.12	0.15

Table C-2. Polycyclic aromatic hydocarbon (PAH) residues in barn swallow pipping chicks and 13-day old nestlings from a reference site in Lake Poygon, Wisconsin, 1995 (parts per million, wet weight).

8500030	PC313 nestling	PC315 nestling	PC326 nestling	PC313 pipper	PC315 pipper	PC326 pipper
1,2,5,6-dibenzanthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1,2-benzanthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1-methylnaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1-methylphenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,3,5-trimethylnaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,6-dimethylnaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2-methylnaphthalene	<0.01	0.011	0.011	<0.01	<0.01	<0.01
acenaphthalene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
anthracene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(a)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(b)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(e)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(g,h,i)perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
biphenyl	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-Fluoranthenes & Pyrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-fluorenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C1-naphthalenes	<0.01	0.011	0.011	<0.01	<0.01	<0.01
C1-phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-fluorenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-naphthalenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C2-phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-dibenzothiophenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-fluorenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-naphthalenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C3-phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C4-chrysenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C4-naphthalenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
C4-phenanthrenes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
chrysene	<0.01	<0.01	<0.01	<0.01	<0.01	0.018
dibenzothiophene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
fluoranthene	<0.01	0.021	<0.01	<0.01	<0.01	0.014
fluorene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
indeno(1,2,3-cd)pyrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
naphthalene	0.015	0.035	0.014	<0.01	<0.01	<0.01
perylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
phenanthrene	0.012	0.024	<0.01	<0.01	<0.01	0.012
pyrene	<0.01	0.011	<0.01	<0.01	<0.01	<0.01
total PAHs	0.025	0.113	0.036	--	--	0.044

Table C-3. Polycyclic aromatic hydocarbon (PAH) concentrations in carcasses of male lesser scaup collected at Indiana Harbor Canal, winter 1993-1994 and a reference site (Custer *et al.* in prep.).

	Geometric mean concentration / (number detected above LOD)					
Analyte	Reference immature males (n = 5)	Jan 1994 immature males (n = 6)	March 1994 immature males (n = 5)	March 1994 adult males (n = 6)	Results of ANOVA	
					F	P
1,2,5,6-dibenzanthracene	--- (0)	--- (2)	--- (2)	--- (1)		
1,2-benzanthracene	--- (0)	--- (1)	--- (0)	--- (0)		
1-methylnaphthalene	0.015 A (5)	0.025 B (6)	0.020 AB (5)	0.024 B (6)	6.3	0.004
2-methylnaphthalene	0.026 A (5)	0.042 B (6)	0.036 AB (5)	0.041 B (6)	5.8	0.006
acenaphthene	--- (1)	--- (2)	--- (1)	--- (0)		
benzo(a)pyrene	0.008 A (2)	0.007 A (2)	0.011 A (3)	0.011 A (4)	0.5	0.680
benzo(g,h,i)perylene	--- (0)	--- (0)	--- (1)	--- (1)		
C1-naphthalenes	0.041 A (5)	0.066 B (6)	0.057 AB (5)	0.065 B (6)	6.1	0.005
chrysene	--- (0)	--- (1)	--- (1)	--- (0)		
fluoranthene	--- (0)	0.009 (4)	--- (1)	--- (0)		
indeno(1,2,3-cd)pyrene	--- (0)	--- (0)	--- (1)	--- (1)		

Table C-3. Polycyclic aromatic hydocarbon (PAH) concentrations in carcasses of male lesser scaup collected at Indiana Harbor Canal, winter 1993-1994 and a reference site (Custer *et al*. in prep.) (continued).

Analyte	Geometric mean concentration / (number detected above LOD)					
	Reference immature males (n = 5)	Jan 1994 immature males (n = 6)	March 1994 immature males (n = 5)	March 1994 adult males (n = 6)	Results of ANOVA	
					F	P
naphthalene	0.030 A (5)	0.035 A (6)	0.031 A (5)	0.029 A (6)	1.3	0.315
perylene	--- (0)	--- (0)	--- (1)	--- (0)		
phenanthrene	0.005 A (0)	0.014 B (6)	0.009 AB (3)	0.006 A (2)	8.4	0.001
pyrene	--- (0)	0.010 (4)	--- (1)	--- (0)		
total PAHs	0.120 A (5)	0.224 B (6)	0.186 B (5)	0.182 B (6)	8.0	0.001

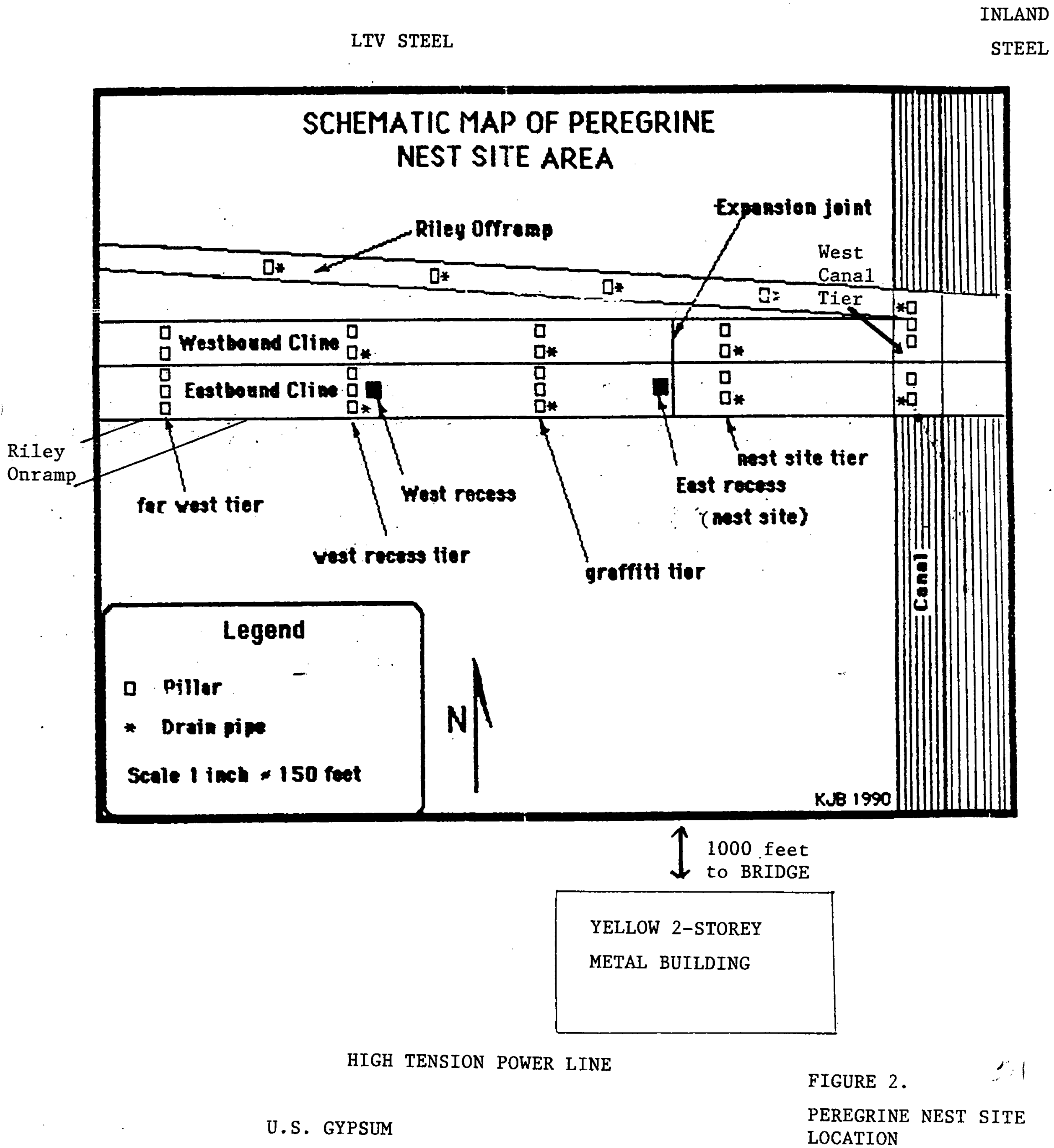


FIGURE 2.

PEREGRINE NEST SITE LOCATION

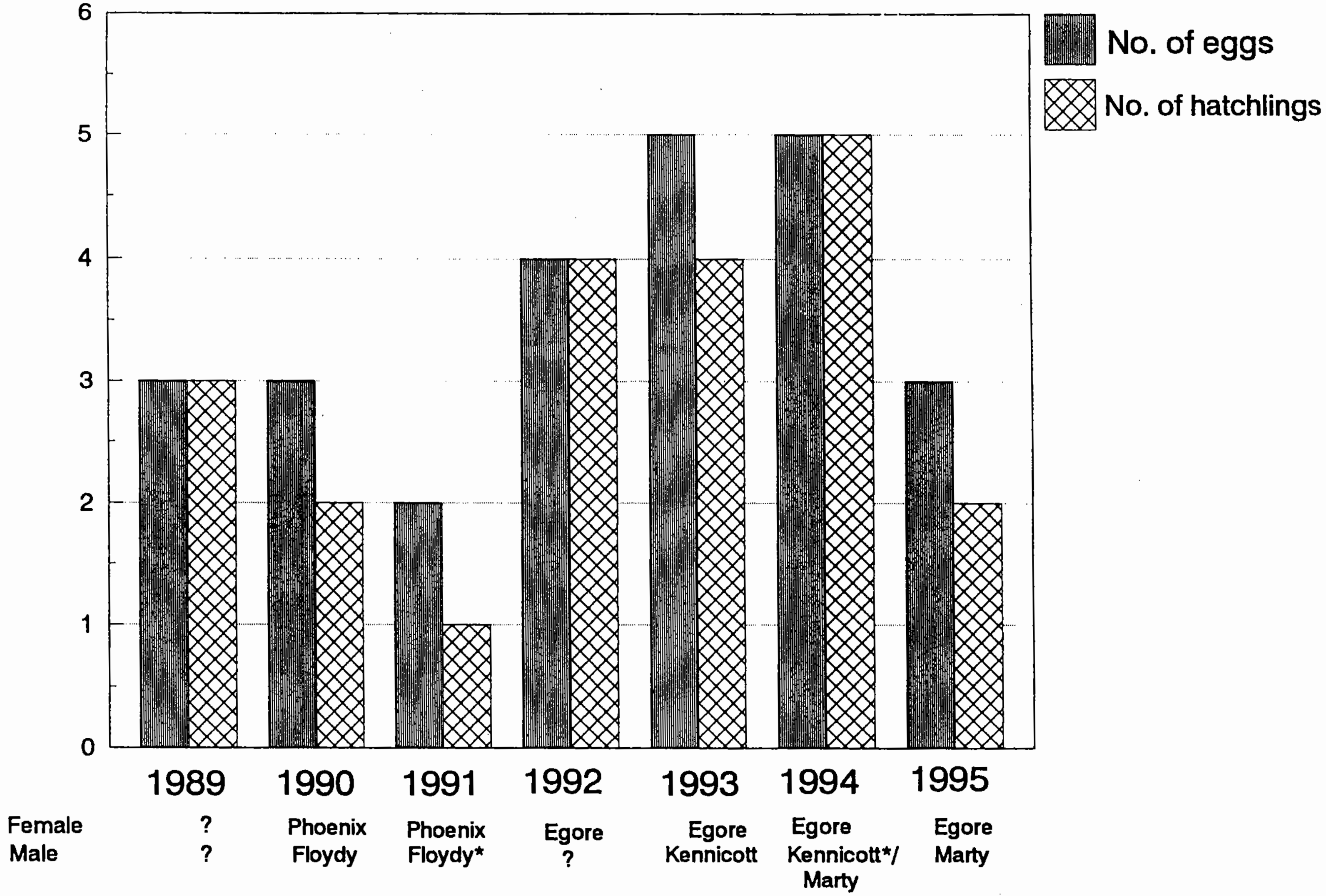


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Figure 3. Peregrine falcon productivity at the East Chicago, Indiana nest on Indiana Harbor Canal.

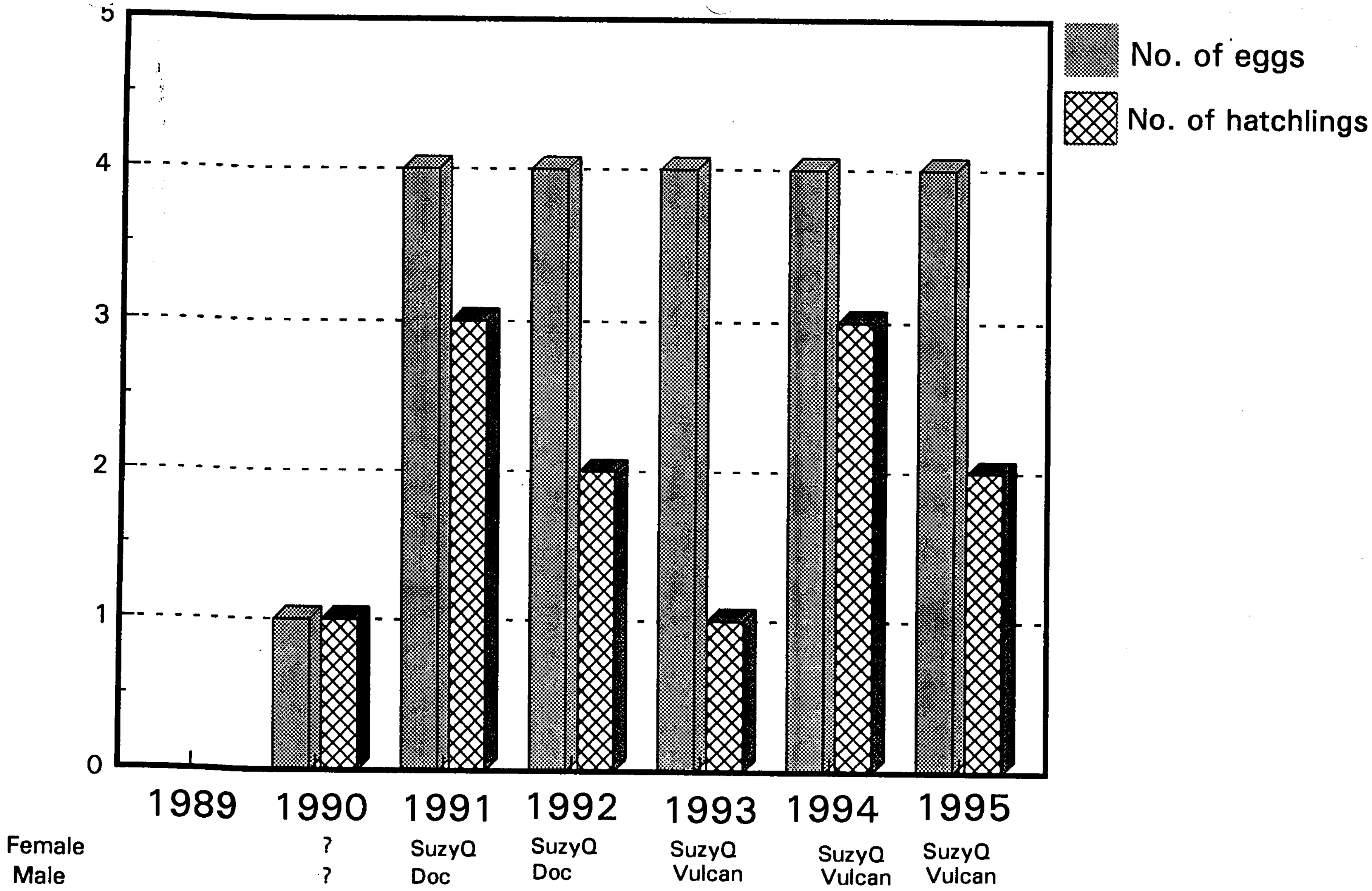

Figure 4. Peregrine falcon productivity at the Gary, Indiana nest at U.S. Steel.

United States Department of the Interior

TAKE PRIDE IN AMERICA

FISH AND WILDLIFE SERVICE
BLOOMINGTON FIELD OFFICE (ES)
620 South Walker Street
Bloomington, Indiana 47403-2121
(812) 334-4261 FAX 334-4273

IN REPLY REFER TO

September 19, 1995

Mr. Philip R. Bernstein
Chief, Planning Division
Environmental and Social Analysis Branch
Chicago District, Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

Attn: Dr. Ken Derickson, CENCC-PD-S

Dear Mr. Bernstein:

The U.S. Fish and Wildlife Service has received your August 16, 1995, letter transmitting a Biological Assessment and requesting formal consultation in accordance with 50 CFR Part 402, under Section 7 of the Endangered Species Act. This consultation was requested because of the potential impact of the Indiana Harbor and Canal dredging project on the Federally endangered Peregrine falcon (*Falco peregrinus*).

We have not received all of the information necessary to initiate formal consultation as outlined in the regulations governing interagency consultations (50 CFR §402.14). To complete the initiation package, we will require the following information:

1) description of the action being taken;

   o detailed description of how dredged sediments will be transported and transferred into the CDF, including precautions to prevent water column impacts;

   o detailed description of measures to be taken to prevent wildlife access to ponding within the CDF as dredging is occurring;

2) a description of the manner in which the action may affect the listed species; the following information is needed to determine the project's effect on the peregrine falcon prey base, and therefore, the potential for acute mortality of falcon eggs and perhaps adults;

   o site-specific detailed information on the level of contaminants in water and sediment;

   o specific details on dredging activity as it relates to resuspension of contaminants and potential water column impacts, including duration of these water column impacts;

   o discussion of wildlife use of the area, including seasonal variation of such use especially as this may relate to seasonality of dredging operations;

   o literature review of the potential acute and chronic toxicological impacts of the elevated pollutants found in Indiana Harbor Canal sediments.

The Biological Assessment contains inaccurate data and lacks other important information. The contents of the Biological Assessment are discretionary (50 CFR § 402.12(f)), however, if the following information were provided, it would make the review of the biological assessment and the preparation of the biological opinion less difficult.

The assessment does not discuss the correct location of the falcon nest under SR 912 (Cline Avenue). The actual nest site is about 1 mile east of the location shown on your map and addressed in the assessment. We have attached a copy of your map with the correct nest location highlighted. Peregrine falcons have nested in this location since 1989. Local individuals have maintained a "Peregrine Watch" during the nesting and fledgling seasons yearly since that first nest. Their observations have been provided to Indiana Department of Natural Resources Nongame Biologist, John Castrale. These reports indicate where in the vicinity of East Chicago and adjacent communities the falcons have been seen and what their activities were. That data along with information from other qualified peregrine falcon experts, including a discussion of the impacts to the correct location of the nest will greatly enhance the quality of the assessment.

Although the Corps has considered alternatives that will be addressed in the upcoming Draft Environmental Impact Statement, this information is not included in the material provided with the assessment. Information on alternatives analysis that the Corps considered with regard to the overall project, dredging equipment selection, and sediment management techniques would also enhance the quality of the assessment and aid in the preparation of the biological opinion.

Until we receive more information to address the identified deficiencies, or a statement explaining why that information cannot be made available, the formal consultation process for the project does not begin. We will notify your office when we receive this additional information. Our notification letter will also outline the dates within which formal consultation should be complete and the biological opinion delivered on the proposed action.

If you have any questions or concerns about this consultation or the consultation process in general, please feel free to call me at (812) 334-4261.

Sincerely,

Scott Pruitt, acting

for David C. Hudak
Supervisor

cc: R. Carlson, Chicago COE, CENCC-PP-PM, Chicago, IL
R. Tolpa, USEPA, WQC-15J, Chicago, IL
A. Fenedick, USEPA, SME-14, Chicago, IL
C. Alexander, USEPA, SME-14, Chicago, IL
W. Faatz, IDNR, Div. of Fish and Wildlife, Indianapolis, IN
J. Castrale, IDNR, Div. of Fish and Wildlife, Mitchell, IN
J. Smith, IDEM, OER, Indianapolis, IN

United States Department of the Interior

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IN REPLY REFER TO:

January 22, 1996

Mr. Philip R. Bernstein
Chief of Planning Division
U.S. Army Corps of Engineers
Chicago District
111 North Canal Street
Chicago, Illinois 60606-7206

Dear Mr. Bernstein:

This acknowledges the U.S. Fish and Wildlife Service's (Service) January 8, 1996, receipt of your letter dated December 11, 1995 requesting an update on your request for formal section 7 consultation under the Endangered Species Act. This consultation concerns the possible effects of your proposed Indiana Harbor Canal Maintenance Dredging and Disposal Activities on the peregrine falcon (*Falco peregrinus*).

As you know, we requested additional information from the Corps via our September 19, 1995 letter. The Draft Environmental Impact Statement (EIS) provided to our office in November 1995 did provide much of the information we had requested. Still missing from the information we requested is relevant information from experts on the species and potential toxicological impacts from pollutants. However, it is apparent from your December 11, 1995 letter that the Corps does not intend to supply that additional information, so we will begin formal consultation with the information that has been provided.

Section 7 allows the Service up to 90 days to conclude formal consultation with your agency and an additional 45 days to prepare our biological opinion (unless we mutually agree on an extension). Therefore, we expect to provide you with our biological opinion before May 22, 1996.

As a reminder, the Endangered Species Act requires that after initiation of formal consultation, the Federal action agency make no irreversible or irretrievable commitment of resources that limits future options. This practice insures agency actions do not preclude the formulation or implementation of reasonable and prudent alternatives that avoid jeopardizing the continued existence of endangered or threatened species.

If you have any questions or concerns about this consultation or the consultation process in general, please contact Elizabeth McCloskey at (219) 269-7640.

Sincerely Yours,

Scott Pruitt, acting

for David C. Hudak
Supervisor

THE RAPTOR CENTER
at the
UNIVERSITY OF MINNESOTA

August 14, 1996

Dr. Ken Derickson
U. S. Army Engineering District, Chicago CENCC-PD-S
111 No. Canal St.
Suite 600
Chicago, Il 60606-7206

Dr. Derickson:

This letter is written in response to your request for a review of Section 7 Consultation and Biological Opinion regarding the impact of dredging the Indiana Harbor and Canal on peregrine falcons nesting in the immediate vicinity.

The report accurately reflects the biology and history of extirpation and recent recovery of the peregrine falcon in the midwest. We concur with the conclusion that the dredging activity does not represent a threat to this recovered population. We also subscribe in general to the idea that these falcons are nesting in a heavily contaminated site and there is a possibility that some aspect of the proposed activity may lead to direct or indirect mortality.

There are several aspects of this report, however, wherein we question the conclusions drawn or disagree with them.

It is debatable, 1. whether peregrines at IHC are being affected adversely by local conditions as compared to the remainder of the population, 2. whether failure of eggs to hatch is related to contaminants at that site, and 3. whether an incremental decrease in productivity could be detected and linked to proposed dredging activity, especially over a short time frame.

It does not appear relevant to include data from the steel mill at Gary, Indiana to support the position that Lake County peregrines are faring more poorly than the rest of the population -- they are a substantial distance away from the IHC and their productivity is not affected by the same factors as the IHC falcons (e.g. SuzyQ and Doc were a brother and sister).

Unhatched eggs, even eggs bearing measurable levels of PCB's, do not prove the case that PCB's are responsible for hatching failure. This case for PCB's having an effect on reproduction of peregrines is tenuous at best in that where reproduction has been shown to be reduced as a result of contaminants, PCB's are found present with organochlorine pesticides which themselves have been shown unequivocally to interfere with productivity (Risebrough and Peakall, 1988). Further, the overall productivity of the Cline Avenue site is not different from the rest of the population; on the contrary it is one of the highest producing sites in the midwest population. The fledging success has an 8 year average (1989 - 1996) of 3 yg/y. The fledging success of the remainder of the population has ranged, in this same time period, from 2.1 - 3.0, with an average of 2.51 (see table from 1995 report.

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appended). Comparing their productivity to only one other site. Indianapolis. is not a fair comparison, hence the conclusion that the site is producing sub-optimally is not substantiated. Further, if persistent PCB's were a problem. one might expect occurrences of some of the other known defects associated with them, such as deformed beaks or other growth abnormalities, to be present. To date, all of the peregrine chicks banded at this site have been robust, healthy young.

The case that dredging will increase contaminants in the water column and cause a food-chain effect on the peregrines draws heavily on the premise that prey species in contact with the water. either at the dredging site or the CDF, comprise a significant portion of the peregrine's diet. Specifically, waterfowl. shorebirds. and gulls are the ones most likely to be in this pathway. However, an analysis of prey remains at urban peregrine eyries (Cade et al.. Peregrine Falcon in Urban North America, *in* Raptors in Human Landscapes, Academic Press 1966 -- appended)). clearly shows that such prey species are seldom taken by peregrines. Conversely, land birds, especially pigeons, flickers, blue jays, robins, blackbirds and cuckoos comprise the majority of prey taken. The observations by the Cline Avenue nest volunteers, (as stated in this the biological opinion under review) further support the idea that such land based birds are the majority of prey taken. In this report, sixteen of eighteen prey taken were in the category of land birds, the other two being one duck (species unspecified) and one gull actually taken. The probability of contamination in these land species with noxious substances released by dredging at the IHC is presumably orders of magnitude lower than what waterbirds would experience and the risk to peregrines is therefore much less.

We question the basis for provisions in the Incidental Take Permit regarding flight hazards and the baseline value of PCB's and PAH's.

Flight hazards at the CDF are not defined. Collisions with windows and sides of tall buildings followed by power lines and moving vehicles (high speed traffic) constitute the majority of flight hazards known to cause morbidity and mortality in peregrines. If none of these sources are associated with the CDF, then it is not likely incidental take from flight hazards would occur in conjunction with construction and operation of the CDF.

Oil contaminated pools of water either at the CDF or elsewhere would constitute an oiling hazard for peregrines that attempted to bath in them or from handling of prey similarly fouled. Mortality has been documented among peregrines by this mechanism, hence, provisions requiring containment and prevention of these pools are very important considerations.

Since it is stated in the biological opinion that take is already occurring, the pertinent question is whether additional incremental take will occur as a result of the dredging activities. The result of such finding would result in cessation of dredging activities and another round of Section 7 consultation. The bulk of these criteria are contained in item 3c. p. 33. We have these questions:

1. What is the baseline by which reduction in hatching success by 50% in two consecutive years would be measured against ? Is it the five that Egore produced in her first year, is it the current Indianapolis production of four, is it the average over the lifetime of this eyrie, is it the average over the lifetime of the current pair, or is it the average of the population in the midwest? One can see that quite different numbers could be used. We believe nest site productivity should be factored into this assessment also. We recommend that if 50% of the eggs laid fail to hatch or if nest site productivity falls below the site mean of 3yg/y in two consecutive years in conjunction with higher than acceptable contaminant levels (see below), the provisions of this section would prevail.

2. How valid is the application of the stated PCB level concurrent with decreased productivity? Since the 8.5 ppm for PCB's is a mean, the range is clearly greater. Any individual egg would have to fall outside the range at the 95% confidence interval in order to be declared different than the current situation -- remember, we are looking for incremental increase over the present circumstance. A crude approximation of the 95% level is two standard deviations from the mean, which in this case would be just under 13 ppm. hence that number would be more valid from a statistical point of view. In addition, the mean PCB concentration in peregrine falcon eggs from the East Coast in the period 1986 - 1987 was 13.8 ppm with a

maximum of 25 ppm, values considerably higher than the proposed value of 8.5 and coming from a population of peregrines that was regarded as stable at that point in time (Septon and Marks in Raptors in Human Landscapes, 1996 -- appended). Lastly, Peakall (1990) has stated : "....the best estimate for critical levels of ' PCBs' at which reproductive effects may occur was egg levels greater than 40 ppm" (quoted from Septon and Marks in Raptors in Human Landscapes -- in chapter appended).

With regard to PAH's it seems incongruous to set the trigger level at 0.1 ppm when that is the level found in the Des Moines eggs, a site that is presumed to represent ambient urban conditions with respect to PAH's. We believe a higher trigger level should be adopted.

In summary, we feel that a case has not been made to substantiate a current take of peregrine falcons at the IHC nor have criteria been established that would allow detection of an incremental increase in take from contaminants possibly released into the food chain by the dredging process. We believe there is a potential source of take from oiling of falcons that would attempt to bathe in pools of oil or oil contaminated water that may occur at the CDF or elsewhere in the area and therefore precautions should be taken to prevent such occurrence. In addition, the proposed seasonal restrictions are a reasonable and effective provision.

Please advise us if you have questions about our review.

Sincerely,

Patrick T. Redig DVM, PhD
Associate Professor
Director, The Raptor Center

Mark S. Martell BA, MS
Coordinator of Field Studies
The Raptor Center

enclosures

cc. John Castrale
H. B. Tordoff

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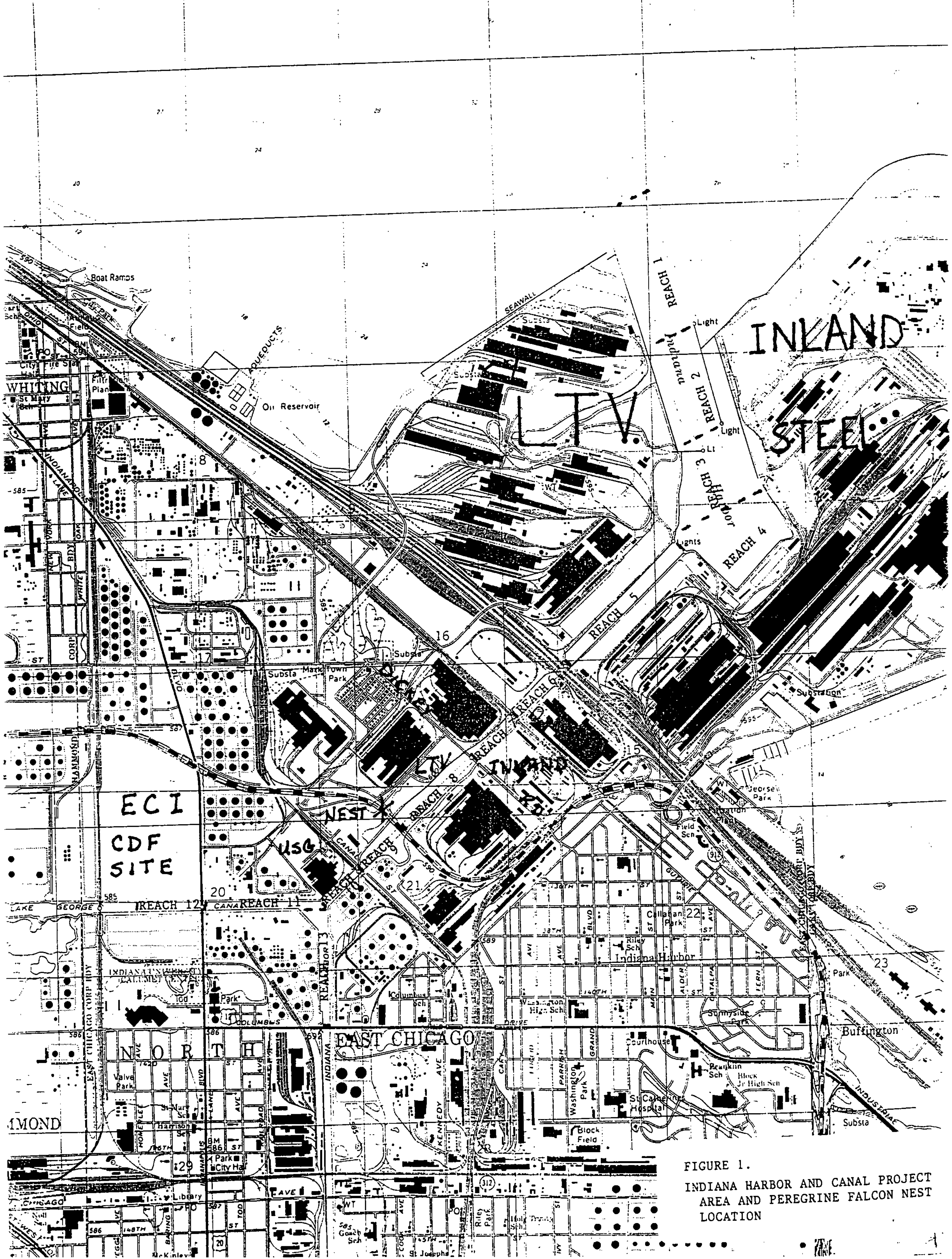

FIGURE 1.

INDIANA HARBOR AND CANAL PROJECT AREA AND PEREGRINE FALCON NEST LOCATION

INDIANA HARBOR AND CANAL MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES IN LAKE COUNTY, INDIANA

APPENDIX C

"NO ACTION" ALTERNATIVE

March 1994
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1. PURPOSE

1.1 This appendix will describe the environmental impacts of the "no action" alternative. No action is the alternative not to maintain the federal navigation project at Indiana Harbor and Canal. The commercial and economic importance of this navigation project and the consequences of no action are described in Appendix B, Waterborne Commerce. This appendix will first discuss the history of environmental contamination at Indiana Harbor and Canal, then discuss the mechanisms by which sediment contamination can impact water quality and aquatic life, evaluate the transport and fate of sediment contamination in the waterway and adjacent Lake Michigan, and finally consider the alternatives available to remediate the existing sediment contamination problems.

2. HISTORY OF REGIONAL ENVIRONMENTAL PROBLEMS

2.1 The Grand Calumet River (GCR) and Indiana Harbor Canal (IHC) have had a number of environmental problems since the industrialization and urbanization of northwest Indiana began earlier this century. The GCR/IHC is, for the most part, a man-made waterway carrying the discharges from industrial and municipal sources. The waterway is a major tributary to the southern basin of Lake Michigan.

2.2 A number of federal and state studies have examined the influence of the GCR/IHC on water quality in Lake Michigan. In the mid 1960's, the Federal Water Pollution Control Administration (FWPCA; the predecessor to USEPA) conducted a conference <u>In the matter of Pollution of the Interstate Waters of the Grand Calumet River, Little Calumet River, Wolf Lake, Lake Michigan and their Tributaries</u> (FWPCA, 1966). At this conference, representatives from Federal, state, and municipal agencies, universities, and citizens groups discussed the status of water pollution in the area, sources of contamination, and recommended specific water quality criteria for the specific waterways.

2.3 The water quality of the GCR/IHC was severely degraded with human and industrial pollution. Conditions were so polluted that most of the waterway was devoid of higher forms of aquatic life. Combined sewer overflows discharged raw sewage to the waterway and Lake Michigan, causing beach closings in adjacent communities.

2.4 In the mid 1970's, the State of Illinois and USEPA funded a series of investigations on the transport and dispersion of pollution plumes from the IHC in the Calumet region of Lake Michigan (Katz and Schwab, 1975; Katz and Schwab, 1976; Harrison et al, 1977; McCown et al, 1978). The transport and dispersion of pollution in southern Lake Michigan was simulated using computer models and found to be highly transient, depending on wind-generated currents. Dye and rare earth tracer studies tracked the polluted discharge from the IHC to the Southwest Filtration Plant intake of Chicago's potable water supply.

2.5 In 1973, the Grand Calumet River and the Indiana Harbor and Canal were designated a Problem Area by the International Joint Commission for the Great Lakes (IJC). In 1981, the IJC placed the GCR/IHC on its list of Areas of Concern (AOC). In 1985, the USEPA completed the Master Plan for Improving Water Quality in the Grand Calumet River and Indiana Harbor Canal (USEPA, 1985). This Master Plan examined the existing environmental conditions of the GCR/IHC, noting the dramatic improvements to water quality in the past 10-15 years. Recommendations were made to:

a) Continue the existing emphasis on pollutant controls.

b) Clarify the role of toxic pollutants in the river system.

c) Develop any additional toxic pollutant control programs that are necessary for restoration of the GCR/IHC.

2.6 The GCR/IHC is one of five AOCs specifically identified in Section 118 of the Clean Water Act of 1986 for priority consideration of environmental remediation demonstrations. This program is not a clean-up authority, but is intended to develop scientific and engineering guidance on ways to remediate in-place sediment contamination. A number of laboratory and field investigations are planned or underway for the GCR/IHC area of concern as part of this program.

2.7 As part of an IJC initiative, Remedial Action Plans (RAPs) have been prepared for areas of concern on the Great Lakes. The Indiana Department of Environmental Management (IDEM) **has submitted the Stage One Remedial Action Plan to the IJC (IDEM, 1991).** The draft RAP includes discussions of existing water, air, solid and hazardous waste problems in northwest Indiana and recommends actions for restoring or remediating environmental conditions. The Corps of Engineers has actively supported the development of the RAP and has provided technical assistance during its preparation.

2.8 Over the years, a large deposit of contaminated sediments has accumulated throughout the GCR/IHC. Both the USEPA Master Plan and the IDEM RAP have identified the bottom sediments as a significant non-point source of pollution to the waterway. This appendix will focus on the in-place sediment contamination in the GCR/IHC and its impacts on the environmental quality of the waterway and adjacent Lake Michigan.

3. SEDIMENT - WATER INTERACTIONS

3.1 Bottom sediments function as both a pollution sink and as a source in the environment. Pollutants that are insoluble or attached to particulate matter will settle to the bottom and become part of sediment deposits. In many urban areas, sediments are a reservoir of past contamination that has been discharged to the waterways and represent a significant non-point source of pollution to the overlying water. This section will discuss the characteristics of sediments, the mechanisms by which bottom sediments adversely impact water quality, describe the factors influencing these processes, and examine the specific impacts of the GCR/IHC sediments on water quality.

3.2 SEDIMENT CHARACTERISTICS

3.2.1 Sediments are wet soil. The physical characteristics of sediments are determined by the type of soil particles present (sand, gravel, silt, and clay). Sediment deposits are a natural occurrence in all waterways. Sediments accumulate in quieter reaches due to settling of soil particles which originate from many physical processes. Sediment sources include surface run-off, sheet and bank erosion, and atmospheric input. Other sources of sediments may include man-made discharges, chemical precipitation, and biological production/detritus.

3.2.2 Sediments are an integral part of the aquatic environment. Sediment particles can be suspended in the water column or settle to the bottom. Sediment deposits provide habitat for some aquatic organisms and are a food source for others. Sediments are a semi-fluid media. They can be moved by a number of forces. The transport of sediment particles will be discussed later in this appendix.

3.2.3 The chemical make-up of sediments is both natural and man-influenced. Naturally occurring chemicals include those elements that are part of the soil particles, eroded from rock (e.g., metals). Not all sediments with high metals concentrations are the result of pollution. Lake Superior, for example, has very high copper, chromium and nickel levels in its sediments, much of which is the result of natural erosion of mineral bedrock (Allan, 1986).

3.2.4 Biological production and detritus are naturally occurring sources of organic compounds in sediments. These compounds include a variety of lipids (fatty acids), alcohols, ketones, alkanes, aromatics, steroids, chlorophyll-related pigments, sugars and amino acids. All of these chemicals result from the breakdown of algae, aquatic plants, zooplankton, invertebrates, fish and terrestrial leaves and wood (Barnes and Barnes, 1978).

3.2.5 Human pollution can introduce chemicals not natural to bottom sediments or increase the levels of naturally occurring chemicals. The type of man-made contamination found in bottom sediments generally reflects the water-use practices of the tributary watershed. Elevated metal concentrations are commonly associated with heavy industry and street runoff. Increases in concentrations of some organics can be linked to obvious pollution from fossil fuel sources (e.g., napthalene and other aromatics) and domestic sewage (e.g., purines, pyrimidines, cholesterol and lactose). More obvious is contamination of sediment by strictly man-made compounds such as DDT, Mirex, Dieldrin and PCBs.

3.2.6 Comparisons of surface levels of trace elements in southern Lake Michigan sediments to deeper strata (geologically older deposits) suggest that bromine, chromium, copper, mercury, lead and zinc have been elevated by man's activities, while boron, beryllium, cobalt, nickel and vanadium have not (Frye and Shimp, 1973).

3.2.7 The physical and chemical character of the sediments in the IHC are described in Appendix E. The bottom sediments in the GCR/IHC are contaminated with a wide variety of pollutants. The sediments contain about 10 to 15 percent organic matter, nearly half of which is oil and grease. Specific organic pollutants present include polynuclear aromatic hydrocarbons (PAHs) and PCBs. The sediments also contain very high concentrations of metals. Most of the sediment contamination is of man-made origin. Sources include industrial and municipal discharges, combined sewer overflows, and runoff from urban and industrial areas.

3.3 MECHANISMS OF SEDIMENT IMPACTS ON WATER QUALITY

3.3.1 In-place contaminated sediments can exert a significant effect on water quality by acting as a sink for dissolved oxygen, a source for release of nutrients, and a source for release of contaminants. The mechanisms and rates of contaminant mobilization, the affects of sediment oxygen demand on dissolved oxygen (DO) levels, and the rates of nutrient release depend on a number of factors. A discussion of the mechanisms which enable in-place sediments to affect water quality and the factors which impact these mechanisms follows.

3.3.2 Sediment Oxygen Demand

3.3.2.1 Sediments can exert an oxygen demand on the overlying water column. This demand, called the sediment oxygen demand (SOD), is a critical factor in the relationship between sediment and the quality of the overlying water. SOD has two components: the oxygen demand exerted by biological activity in the sediment and the oxygen demand resulting from the chemical oxidation of reduced chemical species present in the sediment.

3.3.2.2 The SOD can be extremely high in highly organic sediments. Organic matter deposited in sediment causes an increase in the activity of microorganisms which metabolize the organic compounds by oxidation reactions which consume oxygen (DO) in the process. Since oxygen has a relatively low solubility in water, both sediment and the overlying water column can become anoxic resulting in the death of fish and other aquatic organisms.

3.3.2.3 The by-products of microbial metabolism can also be a source of reduced soluble nutrients and metals. The addition of large amounts of metals may increase existing sediment reserves of minerals which are then reduced, adding to the SOD. SOD generated reductions to the dissolved oxygen levels at the sediment-water interface can also effect the mobility of nutrients and other contaminants in sediments.

3.3.2.4 Sediment oxygen demand is measured in units of grams of dissolved oxygen consumed per square meter of sediment surface per day. Rates of SOD measured in bottom sediments of the Chicago canal system are as high as 10 g/m^2/day (Polls and Spielman, 1977; Butts and Evans,1978). The surface area of exposed sediments is the key factor. A given amount of sediments will exert a greater SOD if spread out over a larger area. The resuspension and transport of sediments will greatly increase the surface area exposed and the potential for oxygen depletion.

3.3.2.5 Continued oxidation can deplete the supply of organic matter at the sediment surface and result in decreased SOD. Secondary impacts may include the formation of an aerobic sediment layer which acts as a barrier to the migration of contamination from lower sediments. These conditions can occur where the sediment organic matter is not replenished or where the sediment surface layer is not disturbed. For most of the GCR/IHC, sediment sources continue to replenish the supply of organic matter to the bottom sediments and storm currents and boat traffic keep the sediment surface disturbed.

3.3.2.6 There has been only limited measurement of SOD at the GCR/IHC. Levels measured (HydroQual, 1984) were far less than expected, given the high organic composition of the sediments and the results of more extensive SOD measurements in the nearby and similarly polluted Chicago canal system (Polls and Spielman, 1977; Butts and Evans, 1978). Sediment oxygen demand is believed to be a significant impact on the water quality of the GCR/IHC, especially in reaches with lower flows. This was evidenced by the conditions on the West Branch of the GCR during the drought of 1988, when anoxic conditions caused odor problems in portions of Hammond.

3.3.3 Nutrient Releases

3.3.3.1 Sediments can exert a significant effect on water quality as a source of BOD and nutrients. The major nutrients of concern are carbon, nitrogen and phosphorous. These nutrients recycle continuously in the water column between particulate and sediment forms, dissolved organic forms, dissolved inorganic forms and biotic forms. Nutrient release from sediments results from decomposition of organic components in the sediment which causes the release of dissolved organic and dissolved inorganic nutrients (Bowie et al., 1985).

3.3.3.2 Nutrients are critical components of the eutrophication process since nutrient availability is a main factor controlling algal blooms. Nitrogen is also an important nutrient since the nitrification process consumes oxygen and may represent a significant portion of the total BOD (Bowie et al., 1985). The release of nutrients from sediments into overlying water which is already enriched with nutrients introduced through wasteloads adds to the oxygen demand of the aquatic system and can contribute to driving the system toward an anoxic condition.

3.3.3.3 Factors which affect the rate and volume of nutrients released from sediments include water velocity, dissolved oxygen levels, temperature and surface area of sediment exposed to the water column (HydroComp, 1977). Releases of BOD and nutrients from bottom sediments are quantified in units of grams/m^2/day. As with SOD, the surface area of exposure is key. In an aquatic system such as the GCR/IHC, in which a large surface area of enriched sediments are exposed to the water column and the sediments are frequently resuspended by boat traffic or storm events, the rate of nutrient release may be fairly high and the adverse impact on the DO in this aquatic system is substantial.

3.3.3.4 There have been no field measurements of BOD or nutrient release from sediments in the GCR/IHC. The elevated levels of nitrogen (as ammonia) in the sediments and the levels calculated for sediment interstitial water suggest that such releases may have significant effects on water quality.

3.3.4 Release of Contaminants

3.3.4.1 Sediments are a sink for many contaminants which have far lower solubilities in water than the nutrients described above. As a result, the releases of such contaminants as metals and trace organics from sediments is slower and more difficult to quantify. The solubility of many metals is dependent on the oxidative state of the sediment-water interface. Ferrous metals such as iron and manganese form insoluble precipitates under aerobic, oxidizing conditions. Releases of iron, manganese, nitrogen and phosphorous from undisturbed sediments are minimal where the overlying water is aerobic (Brannon et al, 1985). Where anaerobic conditions exist, however, these releases may be highly significant.

3.3.4.2 The release of organic contaminants from sediments to water and aquatic life has been evaluated using the theory of equilibrium partitioning. Equilibrium partitioning is the theoretical distribution of a contaminant between sediment and water or sediment and biota that reaches equilibrium over a certain period of time (Brannon et al., 1989). Equilibrium partitioning provides a useful tool for predicting the levels of hydrophobic organic contaminants (such as PCBs in water or fish) after prolonged exposure to sediment contamination.

3.3.4.3 A number of factors affect the equilibrium state of contaminants between sediments and water. Adsorption and desorption of contaminants from sediments is dependent on the chemical and physical nature of the adsorbing substrate, and the material being adsorbed. The mechanisms which bind organics to sediment particles include Van der Waal's forces, ion exchange, hydrophobic bonding and electrostatic bonding. Hydrophobic bonding is probably the major mechanism accounting for strong adsorption between sediments and hydrocarbons or other non-polar organic compounds.

3.3.4.4 Organic compounds which have hydrophobic characteristics, normally have low solubility in water, but have a high "attraction" to organic matter such as is found in sediments. The amount of carbon in sediment appears to be the major factor controlling the partitioning of hydrophobic compounds such as polynuclear aromatic hydrocarbons (PAHs) and PCBs (Karickhoff, 1980). PCBs (and other hydrophobic organics) are essentially "dissolved" in the organic matter which is part of, or attached to sediment particles.

3.3.4.5 The levels of a hydrophobic contaminant in water which is at equilibrium with a sediment can be predicted using the equation:

$$C_w = C_s K_d$$

where: C_w is the contaminant concentration in water at equilibrium (mg/l)
C_s is the contaminant concentration in sediment (mg/kg dry wt)
K_d is the partitioning coefficient for this specific contaminant and sediment (kg/l)

The partitioning coefficient (K_d) can be measured directly through laboratory studies or predicted using the equation:

$$K_d = K_{oc} \, TOC \, F_{oc}$$

where: K_{oc} is the octanol-water partitioning coefficient of the specific contaminant (kg/l)
TOC is the total organic carbon content of the sediment (%)
F_{oc} is a dimensionless factor relating the organic solvent properties of the sediment carbon and octanol

3.3.4.6 The release of organic contaminants in a sediment/ water system will depend on the sorptive properties of the sediment and contaminant. Sediments with higher amounts of organic matter can adsorb higher levels of organic contaminants than sediments with a low carbon content. Contaminants with a high partitioning coefficient are more tightly bound to the sediment carbon.

3.3.4.7 The flux of PCBs from in-place bottom sediments in the GCR/IHC has been estimated as about 6.8 x 10^{-5} ng/m^2/day (Brannon et al., 1989). This release rate is low because of the high organic composition of IHC sediments and the high partitioning coefficient for PCBs. Low release rates may be expected for other organic contaminants. As with SOD and nutrient release, the release of PCBs and other contaminants is related to surface area of sediments exposed to the water column which in turn is a function of the amount of sediment disturbance that is occurring.

3.4 SUMMARY OF WATER QUALITY IMPACTS

3.4.1 In order to analyze the impacts that sediment contamination has on the water quality of the GCR/IHC and Lake Michigan, the Chicago District contracted with the Waterways Experiment Station for an investigation of these impacts. This study examined existing information on sediment-water interactions, analytical and modeling tools available for predicting impacts, and site specific data for the GCR/IHC. This study represented the first detailed evaluation of the environmental impacts of the No Action alternative by the Corps of Engineers for a navigation project.

3.4.2 Among the conclusions of this study (Brannon et al., 1989) was that the overall transport and migration of sediment contamination was influenced by the following factors in descending order of importance:

Transport of contaminants associated with particulates
Transport of contaminants desorbed from resuspended particulates
Transport of soluble contaminants released from deposited sediment

The strong binding affinity of most contaminants to the sediment particles is the reason that sediment transport is the most important mechanism in the transport of sediment contamination. Movement of contaminants from in-place sediment deposits to the water column requires that the contaminants desorb into the interstitial water, then slowly diffuse into the overlying water (Lerman, 1979; Berner, 1971).

3.4.3 Exposure of sediment to the water column is the key to sediment-water impacts. SOD and losses of nutrients and contaminants are measured in units of surface area (m^2). In-place sediments have a finite surface area exposed to the water. The sediment surface in the GCR/IHC has an area of about 340 acres (14 miles of waterway with average width of about 200 feet). The actual surface area of in-place sediments will be greater than this due to bottom irregularities and sediment voids.

3.4.4 When sediments are in suspension, the sediment surface area exposed to the water column is greatly increased. As an example, the surface area of clay particles in suspension ranges between 12 and 778 m^2/gram (Lerman, 1978). The average surface area of suspended sediments within the GCR/IHC can be approximated using the following approach:

Volume of water in GCR/IHC
340 acres x 7 ft (ave. depth) = 2,380 acre-ft
= 104 million cu. ft.

Mass of suspended solids in GCR/IHC
104×10^6 cf x 10 mg/l TSS = 29 million grams
(10 mg/l is ave. TSS at Columbus Drive, IDEM, 1987)

Average surface area of suspended sediments in GCR/IHC
29×10^6 g TSS x 100 m^2/g = 290 million m^2
= 725,000 acres

The average surface area of suspended sediments is more than a thousand times that of the in-place sediments. Dispersal of sediments during transport will also increase the surface area exposed to the water column. This calculation is based on annual average levels of suspended solids: during storm events, when elevated flow rates in the GCR/IHC cause tremendous increases in the amount of resuspended sediments, the amount of surface area of the suspended sediments is much greater. Sediments discharged from the GCR/IHC are dispersed by littoral currents and wave action. These sediments will eventually settle over areas on many square miles.

3.4.5 Sediment transport, and the resulting transport of attached contaminants are especially important to the water quality of Lake Michigan, which receives the discharge from the GCR/IHC. Sediment resuspension and the ways in which sediments are resuspended and transported will be discussed in section 5.

4. SEDIMENT - AQUATIC BIOTA INTERACTIONS

4.1 Sediment contamination may have a number of adverse impacts on aquatic life, both directly and indirectly. These types of impacts will be described, the factors influencing the effects discussed, experimental methods to quantify these impacts described, and finally, the site specific impacts of GCR/IHC sediments on aquatic life will be examined.

4.2 SEDIMENT IMPACTS ON AQUATIC BIOTA

4.2.1 A toxic response is one that causes harm or the death of an organism. Despite the apparent simplicity of this concept, there is more than one way to consider toxicity. Acute toxicity is generally measured as death caused by a short-term direct exposure (typically to higher concentrations). Chronic toxicity is measured as a weakened health, cessation of growth, or impaired reproduction caused by a long-term direct or indirect exposure (typically to lower concentrations).

4.2.2 Bioaccumulation is the uptake and storage of persistent contaminants in the body of an exposed organism. Contaminants are taken in through various routes (food, water, skin contact) and accumulate because they are not readily excreted or degraded.

4.2.3 "Exposure" is the common variable in the above biological effects. In order for any contaminant to adversely impact a living organism, there must be some kind of contact or exposure. The greater the exposure, the greater the potential for adverse impacts. Exposure to sediment contamination is far more complex than exposure to water or airborne contamination. Sediment contamination can contact an organism directly (some animals forage or live in sediments) or indirectly (contaminants released to water or accumulated in prey organisms).

4.3 FACTORS AFFECTING SEDIMENT CONTAMINANT EXPOSURE

4.3.1 The presence of sediment contamination alone, does not insure that contaminant exposure will occur or that an organism will be impacted. Similarly, the assumption that larger concentrations of a contaminant (e.g., 10 ppm vs. 1 ppm PCBs) automatically implies a greater level of exposure is not always true. The real exposure potential to aquatic organisms of a chemical contaminating a sediment are dependent on a number of other factors, including:

- * physical factors (time, temperature and surface area)
- * chemical factors (water hardness/alkalinity, oxygen, sediment co-pollutants
- * biological factors (biological diversity, food web effects, and bioturbation)

4.3.2 Physical Factors

4.3.2.1 Time

4.3.2.1.1 Only a few of the more soluble sediment contaminants (e.g., ammonia) and reductions in dissolved oxygen are likely to cause immediate effects on exposed aquatic organisms. Many contaminants are very slow to desorb from the sediment particles and enter aquatic organisms. PCBs can accumulate in fish tissues on exposure to contaminated sediment, but increases in tissue level can generally be detected only after periods of days or weeks. The time that organisms spend in a contaminated area must be factored into any realistic assessment of the impact of this contaminated area on the Lake ecosystem.

4.3.2.2 Temperature

4.3.2.2.1 Temperature affects both the chemical behavior of contaminants and the metabolic and physical activity level of aquatic organisms. Most contaminants are more soluble, more mobile and more reactive when water or sediment temperatures are higher. Warmer water also generally increases the activity level, respiration rates, metabolic rates, feeding rates, and growth rates of aquatic organisms. The toxicity of sediment contaminants and rates of bioaccumulation are also temperature dependent.

4.3.2.3 Surface area

4.3.2.3.1 The "exposure" of any organism to sediment contamination is the key physical factor influencing bioeffects. Surface area, as used here, brings together a number of dimensions; distance from sediments, surface area of in-place bottom sediment deposits, and the surface area (3-dimensional) of resuspended sediment particles. The importance of surface area becomes evident when we consider the units applied to sediment-water impacts like SOD (grams of oxygen consumed per square meter per day).

4.3.2.3.2 Some organisms have direct contact with in-place bottom sediments. Bottom feeding fish such as carp, benthic invertebrates, and microorganisms either live in or forage in bottom sediments. Experiments (Halter and Johnson, 1977; Lynch and Johnson, 1982) have shown that allowing fish contact with the sediments on the bottom of an aquarium increases the bioaccumulation over an exposure of fish to the same sediment kept away from the bottom by screening.

4.3.2.3.3 The larger the surface area of bottom sediments exposed to the water column, the greater the opportunity for aquatic life to contact sediment contamination and show impacts. If a volume of contaminated sediments is spread out in a thin layer over a large area, the opportunity for adverse impacts are increased in proportion to the area. This is a common occurrence at the delta formation where a river discharges to a lake or ocean.

4.3.2.3.4 Resuspension of sediment particles in the water column by disturbances (storm flows, wave action and currents, boat traffic, dredging operations, biological organism activities, etc.) also increases the surface area of contaminated sediment exposure to organisms living in the water column. In this case, however the surface area of exposed sediment contamination is increased several hundred or thousand fold. The entire surface of suspended particles may become exposed, and organisms which do not normally feed on or in the bottom sediments can be contacted.

4.3.3 Chemical Factors

4.3.3.1 Water hardness and alkalinity

4.3.3.1.1 The alkalinity or acidity of water impacts the solubility of many chemicals. The solubility of many metals is very low in alkaline waters. Precipitation of many metals by alkalinity reduces the water column concentrations of this contamination. The Great Lakes contain hard water that is fairly alkaline (approximately 110 mg/l as $CaCO_3$).

4.3.3.1.2 Davies (1986) discusses, at length, the relationship between hardness, alkalinity and toxicity. The exposure of organisms to heavy metals appears to be reduced by competition at the gill membrane with calcium and magnesium ions in hard water. The reduction in toxicity by hard water is substantial (Lake Michigan water hardness typically ranges between 108 to 290 mg/l as $CaCO_3$).

4.3.3.2 Oxygen

4.3.3.2.1 One of the most obvious impacts a contaminated sediment deposit can have on aquatic biota that require oxygenated water to survive, is through the reduction of dissolved oxygen in the overlying water column (see discussion on SOD above). Low dissolved oxygen adds to the stress on organisms exposed to toxicants.

4.3.3.2.2 The solubility of many chemicals is influenced by the levels of dissolved oxygen. Many metals (e.g., Cd, Cu, Cr, Pb, and Zn) are stabilized in oxygen-free sediments as insoluble sulfides. Oxygenation of these metals can convert them to slightly more soluble oxides. However, the reduced forms of iron and manganese are more soluble than their oxides, which immediately coagulate and precipitate upon formation in an oxygenated water column. The iron hydroxide, as discussed below (4.3.3.3.3), has a strong affinity to bind other metals and sorption of the slightly soluble metal oxides in the water column occurs. Settling returns these oxide complexes back to the bottom (Burks and Engler, 1978).

4.3.3.2.3 Lake Michigan water is generally well oxygenated. Reaches of some harbors and canals having polluted sediments often have reduced oxygen levels. The interstitial (pore) water in polluted sediments is usually anoxic. Any disturbance of settled anoxic sediment can trigger a complex array of chemical interactions in the overlying water. The result may include short term increases in toxic metal concentrations, reductions in dissolved oxygen, and finally precipitation of dissolved metals as oxygen levels return and iron hydroxide scavenges the other metals. These episodes could cause stress to local organisms.

4.3.3.2.4 Additionally, an oxidized surface layer of sediment appears to be a barrier to release of many reduced chemical constituents to the water column from sediment deposits (Brannon et al., 1989). Continued disturbances of surface layer of highly polluted sediments can greatly degrade the nearby aquatic environment and expose fish and other organisms to recurring and varying stresses.

4.3.3.3 Co-pollutants

4.3.3.3.1 Bioaccumulation experiments (McFarland et al., 1984; Mac et al., 1985; Lynch and Johnson, 1982; Meier and Rediske, 1984; Dillon, 1984) suggest that more highly polluted sediments do not necessarily cause the greatest contaminant exposure risk to aquatic organisms. These experiments indicate that the bioaccumulation of organic contamination by aquatic organisms is reduced by elevated concentrations of organic carbon in the test sediments. These results are consistent with the principles of equilibrium partitioning described above.

4.3.3.3.2 Sediments with only moderate concentrations of organic pollutants (such as PCBs) and low levels of organic carbon may represent a greater exposure risk to the aquatic community than the sediments with the higher concentrations of PCBs and other contaminants.

4.3.3.3.3 Some metals, most notably iron, can also function as co-pollutants. Lee and Jones (1987) have recognized the role that iron hydroxide has in scavenging and binding large amounts of specific contaminants to sediments. Significant amounts of copper and other trace metals may be bound tightly by a ferric hydroxide film on sediment particles. Many areas of the Great Lakes have sediments with highly elevated iron content from steel industry discharges and air fallout of fine iron dust. The binding of metals to iron contaminated sediments may be another mechanism where some of the more contaminated sediments could have less impact on the aquatic system than apparently cleaner bottom materials.

4.3.3.3.4 These iron hydroxide and other co-pollutant binding effects may also explain the difficulty some researchers (Tatum, 1986; Neff et al., 1978; Mac and Willford, 1986; Mac et al., 1985) had in showing substantial bioaccumulation of heavy metals from highly contaminated sediments despite numerous studies (Dillon, 1984; Dillon and Gibson, 1985) showing that exposures to dissolved metal salts cause significant accumulations in aquatic organisms.

4.3.3.3.5 In a major study of metal bioaccumulation (Neff et al., 1978), 136 species-sediment-metal combination experiments were performed. Only 36 experiments showed a statistically significant accumulation response. In many of these cases, the uptake was quantitatively marginal and of doubtful ecological significance. In 13 of the experiments, metal concentrations were significantly lower than in control animals.

4.3.4 Biological Factors

4.3.4.1 Biological diversity

4.3.4.1.1 The most obvious factor influencing sediment-biota interactions is the presence or absence of aquatic organisms. Polluted bottom sediments provide habitat capable of sustaining a number of pollution-tolerant animals, such as carp, goldfish, aquatic worms, midges, and a variety of microorganisms. Other, less pollution-tolerant organisms either avoid areas with polluted sediments or may succumb to bioeffects.

4.3.4.1.2 Most areas with high levels of sediment contamination exhibit a low diversity of biota, but support high abundance of the pollution-tolerant species. Many polluted sediment deposits contain dense (over 100,000 worms/square meter) worm populations. Recent sampling in the Chicago River (Dorkin et al., 1986) indicated that some areas of the most contaminated sediments had worms in population densities greater than 1 million/square meter. Sampling of the IHC (Polls and Dennison, 1984; Risatti and Ross, 1989) showed worm densities as high as 340,000 per square meter in some areas of the canal.

4.3.4.1.3 Even though pollution-tolerant species may dominate areas having sediment contamination, game fish or other, less tolerant species have been found feeding in or near such sites. Improvements to water quality (DO increases or ammonia reductions) caused by source controls may make areas with even severe sediment contamination accessible.

4.3.4.2 Food web effects

4.3.4.2.1 Aquatic organisms do not need to have direct contact with sediment contamination to show bioeffects. Direct contact with sediment contaminants or contact with contaminants released to the water column allow bioaccumulation by aquatic organisms. Contaminated organisms become food for other larger organisms. This "food web" transfer of contaminants may be very important for some contaminants (e.g., PCBs and DDT) while less important for other contaminants (e.g., azaarene, dibenz (a,h) acridine, brominated biphenyls).

4.3.4.2.2 Persistent hydrophobic contaminants like PCBs which are excreted and degraded very slowly tend to be most concentrated by aquatic organisms. These are most readily transferred to top predators through the food web. The more hydrophobic contaminants are generally taken up by organisms more slowly. Less hydrophobic contaminants are generally degraded and excreted more rapidly. Contaminants that are eliminated rapidly relative to uptake rates are less likely to concentrate in the tissues of aquatic organisms (Spacie and Hamelink, 1982).

4.3.4.2.3 It should be noted that the bottom of the Lakes is an important feeding habitat for most of the sport and commercial fishery. Even fish that feed mostly on other fish either supplement their diet with bottom organisms or the fish they eat feed off the bottom. Fish stomach contents generally contain some detritus and/or sediment when analyzed (Webb, 1973; Webb and McComish, 1974; McComish, 1975; Miller, 1973) suggesting a close relationship of these fish with the bottom of the Lake.

4.3.4.3 Bioturbation

4.3.4.3.1 Bioturbation refers to disturbances of bottom sediment by the activities of aquatic organisms. Karickhoff and Morris (1985) have shown that oligochaete worms inhabiting test tanks in population densities near 100,000 worms/square meter were capable of transporting 90% of the contaminants from the top 6-10 centimeters to the sediment surface. These contaminants had been ingested by the worms and egested to the sediment surface bound in sand-size fecal pellets. Pollutant release from the sediment to the water column was enhanced 4-6 fold over 90 days by the presence of the worms. The activities of larger organisms (e.g., fish preying upon bottom invertebrates) and even much smaller organisms (microbes creating gases that can disturb sediment upon release) also play a role in contaminant transfer from sediments to the water column.

4.4 METHODS TO EVALUATE SEDIMENT - BIOLOGICAL INTERACTIONS

4.4.1 There are a number of laboratory and field methods for measuring and evaluating the biological impacts of sediment contamination. Many of these methods have been applied to the sediments of the GCR/IHC. Approaches to measuring toxicity and bioaccumulation potential will be described and then the results of site-specific tests will be summarized below.

4.4.2 Surveys of Existing Biota

4.4.2.1 The simplest indication of toxicity or bioaccumulation caused by sediment contamination is to survey the aquatic life in and around the site and to measure the levels of contamination in the bodies of collected organisms. In most cases, this information cannot provide conclusive proof that the sediment contamination was the cause of toxicity or bioaccumulation. Such a relationship can only be inferred, since there may be other sources of contamination present.

4.4.2.2 The aquatic biota of the GCR/IHC have been surveyed on a number of occasions (Gannon and Beeton, 1969; CDM/Limnetics, 1976; Indiana State Board of Health, 1979-82; Potos, 1981). Some upstream areas of the canal were found to be virtually devoid of non-microbial aquatic life in these earlier investigations. More recent sampling by the Indiana Department of Environmental Management and the Corps of Engineers (1983-1988) have shown progressively greater density and diversity of aquatic life inhabiting these waters.

4.4.2.3 The Corps of Engineers (and its contractors) have surveyed the existing aquatic biota in Indiana Harbor and Canal and adjacent Lake Michigan on two occasions (Polls and Dennison, 1984; Risatti and Ross, 1989). Benthic macroinvertebrate sampling by Polls and Dennison (1984) yielded fourteen major taxonomic groups with three stations containing oligochaete worms at densities exceeding 100,000 per square meter. Benthos sampling by Risatti and Ross (1989) yielded 22 taxa but no stations had worm densities exceeding 100,000 per square meter.

4.4.2.4 Fish sampling by Polls and Dennison (1984) in November of 1983 yielded large numbers of Carp, Goldfish, Gizzard shad and Yellow perch. Densities of these fish were highest near the Lake but fish were captured at all areas of the harbor and canal including those known to have the highest levels of sediment contamination.

4.4.2.5 Electrofishing during 1983 yielded 1,089 lbs (273 lbs/hour; 1,422 total fish) of fish from the harbor of which 1,071 lbs were large Carp. The smaller forage species, the Gizzard shad, accounted for 55 percent of the total number of fish collected. Electrofishing of the canal yielded 19 lbs of fish per hour (80 percent Carp by weight; 22 percent Gizzard shad and 19 percent Yellow perch by number). Electrofishing of two nearshore Lake Michigan areas in the IHC vicinity yielded 73 lbs of fish per hour (54 percent Carp by weight; 38 percent Gizzard shad by number; and salmon/trout 43 percent by weight and 13 percent by number).

4.4.2.6 Resampling in the spring of 1988 (Risatti and Ross, 1989) also collected many Carp, Goldfish, Gizzard shad, Alewife and Golden shiners in the canal and harbor, with electrofishing yields of 18 lbs of fish per hour in the canal and 13 lbs/hour in the harbor. Carp dominated these collections by weight with Alewife and Gizzard shad dominant by number.

4.4.2.7 The reappearance of more diverse aquatic life in the GCR/IHC is concurrent with water quality improvements over the last two decades (USEPA, 1985; IDEM, 1988). These improvements in water quality (increased DO and reduced ammonia) are probably brought about by a combination of more stringent source controls and the decline of many industries. These water quality improvements have allowed organisms that are less pollution-tolerant to move further up the GCR/IHC. This, in turn, has increased the amount of direct exposure to sediment contamination by the aquatic organism community of Lake Michigan and the IHC.

4.4.2.8 A limited amount of aquatic biota, mostly fish, have been collected and their tissues analyzed for contaminants. Forty-three composite samples of a variety (plankton, periphyton, crayfish and fish) of biological tissue materials were collected in 1988 (Risatti and Ross, 1989) and analyzed for PCBs, metals, water, lipid and ash content for the Chicago District.

4.4.2.9 The average PCB concentration for fish collected during this study was 1.4 ppm for canal samples and 0.8 ppm for harbor samples. The highest fish PCB concentration found was a Carp caught in the canal analyzed to contain 7.9 ppm. Yellow perch collected from east of the Inland Steel lakefill had PCBs of 0.4 ppm and Alewife from the nearshore Lake in front of the harbor entrance had PCBs of 0.1 ppm. All other fish samples were collected from the canal or the harbor.

4.4.2.10 Carp captured in the canal had levels of PCBs ranging from 0.2 to 7.9 ppm, while harbor Carp ranged from 0.6 to 4.4 ppm. Gizzard shad ranged from 0.2 to 0.4 ppm in the canal and 0.1 to 1.6 in the harbor. Alewife from the canal ranged from 0.1 to 0.5 ppm PCBs and 0.02 to 0.4 ppm in the harbor. Sunfish from the canal had PCBs of 0.5 ppm and harbor sunfish had PCBs of 0.8 ppm. Goldfish were only taken from the canal and the PCBs in these fish samples ranged from 0.7 to 1.1 ppm.

4.4.2.11 A plankton tow sample from the canal was analyzed to contain 0.2 ppm PCBs and one from the harbor contained 0.5 ppm. Four periphyton samples scraped from the harbor walls ranged from 0.03 to 0.28 ppm PCBs. Two crayfish samples collected from the canal had PCB concentrations of 0.1 and 0.5 ppm. Two crayfish samples from the harbor had PCBs of 0.1 and 0.2 ppm. One crayfish sample from the nearshore Lake directly in front of the harbor entrance had PCBs of 0.1 ppm.

4.4.2.12 The average value of 32 fish samples analyzed for the metals; arsenic, cadmium, chromium, copper, lead and zinc were 143 ppb, 13 ppb, 1.7 ppm, 2.2 ppm, 1.8 ppm, and 45.3 ppm, respectively. Compared to metals determined in fish collected from Lake Superior waters, IHC samples were 45 times higher in lead, 28 times higher in chromium, four times higher in zinc, and two times higher in copper. However, mercury levels in IHC fish were lower by an order of magnitude and contained only half as much cadmium than these Lake Superior samples (Risatti and Ross, 1989).

4.4.2.13 Periphyton and plankton samples had concentrations of a number of metals (arsenic, cadmium, chromium, copper, nickel, lead and zinc) that were much higher than the fish and crayfish tissue samples. Risatti and Ross (1989) suggest that while the literature supports the metal concentrating ability of algae, the particulates (sediment particles) trapped in these algal samples may account for much of the apparent metals uptake.

4.4.2.14 Additional surveys of aquatic biota and body-burden analysis are being conducted by the IDEM as part of investigations for the Remedial Action Plan (RAP) for the GCR/IHC.

4.4.3 Laboratory Toxicity Assays

4.4.3.1 Laboratory experiments are intended to reflect phenomena which occur in the field. There are, however, important differences between laboratory and field conditions which must be considered. In the field, organisms are capable of responding defensively to many of the everyday encounters with toxic materials. If the toxic material can be sensed, as with physical contact with an irritating substance, an organism can attempt to retreat from the affected area. There is no avenue of escape in a laboratory test tank. In the field, many mobile organisms wander extensively. For example, the actual time that a school of Yellow perch spend in a contaminated harbor may not be comparable to the time spent during a forced exposure in an aquarium experiment. Extrapolating from laboratory exposures to field situations is difficult.

4.4.3.2 A variety of sediment toxicity measuring techniques have been developed. These techniques range from simple acute (short life/death) tests to very sophisticated and longer sublethal exposures where researchers attempt to measure more subtle effects like growth, behavioral changes and reproductive success.

4.4.3.3 Prater & Hoke Study

4.4.3.3.1 During 1977, Prater and Hoke (1980) performed multi-species toxicity tests on sediment grab samples from five Lake Michigan navigation projects, including the IHC. These studies were funded by the USEPA. The tests were 96 hour, aerated, static phase, whole sediment assays with recirculation of test water and with organism-sediment contact allowed. The test species were: Hexagenia limbata, a mayfly; Daphnia magna, a water flea; Asellus communis, an aquatic sowbug; and Pimephales promelas, the Fathead minnow.

4.4.3.3.2 A two-inch layer of sediment was placed in a multi-species exposure tank and eight liters of water was aerated and recirculated through the tank for 96 hours. Test water was analyzed for a number of parameters at the end of the exposure period. Fathead minnows were not strongly affected by the IHC sediments, showing only 10 % mortality in two (canal sediment samples) of the twelve tests. The mayfly and the water flea responded with mortality in the IHC tests that was substantially higher than in the other four harbors tests, ranging from 100 % mortality in many of the canal sample tests, decreasing lakeward to from 30 % down to 10 % in the harbor and approach channel sample tests.

4.4.3.4 WES Studies

4.4.3.4.1 The Waterways Experiment Station (WES) conducted bioaccumulation tests with IHC sediments during 1986, designed to evaluate the effectiveness of capping the sediments with lake sand in a contained aquatic disposal (CAD) scenario (i.e., subaqueous placement and capping technique). The WES experiments were very similar to the static-phase bioassays described above. The clam (Anondonta grandis), the red swamp crayfish (Procambarus clarkii) and fingerling Yellow perch (Perca flavescens) were the test species used in these experiments.

4.4.3.4.2 While 95 % of the animals exposed to either lake sand only or IHC sediment capped by 30 cm of lake sand survived, all crayfish and most of the Yellow perch exposed directly to IHC sediment (uncapped) died within three days of the test initiation and less than 20 % of the clams survived the 40-day test period. Part of the mortality in the uncapped tests was caused by resuspension (bioturbation) of the sediment material by extremely active crayfish. The physical stresses of this resuspension may have clogged gills in addition to the higher rate of release of sediment contaminants to the water column.

4.4.3.5 Illinois Natural History Survey Study

4.4.3.5.1 Toxicity studies on sediments commonly employ a technique which utilizes an elutriate of a sediment (normally the solution from a 1:4, sediment:water mixture that has been shaken vigorously for some time period and filtered or settled). These elutriate procedures are useful in demonstrating the "potential" toxicity that could be leached from a sediment into an overlying water column under severe disturbance conditions such as a dredging operation.

4.4.3.5.2 During 1988, the Chicago District contracted with the Illinois Natural History Survey (INHS) to conduct sediment toxicity assays with IHC sediments. Risatti and Ross (1989) subjected IHC and nearshore Lake Michigan sediment samples to three different elutriate toxicity assays: the Microtox bioluminescent bacterial test using Photobacterium phosphoreum; a freshwater algae test using Selenastrum capricornutum; and a nematode test using Panagrellus redivivus. Since these tests assay a bacteria, a plant and an animal species, they can be used to estimate a fairly generalized potential toxicity due to chemicals releasable to the water column from sediments under severe resuspension conditions (e.g., storms). As more understanding of these tests is developed, this potential toxicity may allow assessment of the detrimental impacts that in-place contaminated sediments have on the Lake ecosystem.

4.4.3.5.3 The results of these tests indicated a high level of sediment elutriate toxicity at all IHC and vicinity stations sampled (including nearshore Lake stations) for this battery of test organism species. These high toxicity results occurred despite very low PCB levels found in these sediment samples, suggesting that from an acute toxicity perspective, ammonia, metals and other factors may be a more important concern than PCBs.

4.4.4 Theoretical Equilibrium Fish Tissue Burdens

4.4.4.1 The equilibrium partitioning principles described in section 3.3.4 have also been used to predict the concentrations of hydrophobic organic contaminants in fish and other aquatic life in equilibrium with sediment contamination. McFarland and Clarke (1986) theorized, based on empirical results from bioaccumulation assays, that the sediment contribution to the body burden of a fish at equilibrium with the sediment PCBs could be calculated as a function of sediment PCB and TOC concentrations and fish lipid levels. An important assumption is that all PCB exposure is from the sediment (ie, none is from food or other sources). The theoretical mathematical function is:

$$C_f = (C_s\ L_f\ F_1)\ /\ TOC$$

where; C_f = PCB concentration in fish (ppm-wet weight)
C_s = PCB concentration in sediment (ppm - dry)
L_f = Lipid content of fish tissue (%)
TOC = Total organic carbon of sediment (%)
F_1 = Dimensionless factor relating solubility of contaminant in lipid and sediment carbon

4.4.4.2 Using these methods, the levels of PCBs in fish which reach equilibrium with IHC sediments were calculated. The results are summarized on table C-1. These tissue concentrations represent what would be expected if a caged fish bioaccumulation experiment were performed (i.e., holding fish in cages above the sediments sampled until steady state concentrations were achieved). The levels of PCBs projected for fish at equilibrium with IHC sediments would exceed FDA action limits (2 ppm).

4.4.4.3 The actual levels of PCBs in fish collected from the IHC were below the projected levels. Biological material (forty-three composite plankton, periphyton, crayfish and fish tissue samples) collected from the project area and analyzed by Risatti and Ross (1989) ranged from 0.01 ppm to 7.9 ppm PCBs, averaging 0.8 ppm PCBs and 9 percent lipid. This is not unexpected, since most fish may remain in the IHC for only short periods, and would not reach equilibrium with the sediment contamination. The highest PCB body burden (7.9 ppm) was found in the fish species (Carp) most likely to remain within the IHC for extended periods.

Table C-1: Calculated PCB Body Burdens for Selected Fish at Equilibrium with IHC Sediments[1] [2]

Fish Species	Lipid (%)[3]	PCB (ppm)[4]
Carp	11.4	9.8
Gizzard shad	14.0	12.0
Alewive	9.4	8.1
Yellow perch	2.4	2.1
Rainbow trout	7.2	6.2

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1 Average PCB and TOC concentrations of surface sediments of IHC are 4 ppm and 8% respectively (from MSDGC, 1988; Risatti & Ross, 1989).
2 Preference factor of PCBs of 1.72 (after McFarland and Clarke, 1986).
3 After Clarke et al, 1988. Lakewide averages (1970-1986)
4 PCBs expressed as whole body concentration.

4.5 SUMMARY OF BIOLOGICAL IMPACTS

4.5.1 Both direct and indirect exposure to sediment contamination and the potential impacts of this exposure on aquatic organisms have been described. These impacts include toxicity, bioaccumulation, and reductions to species diversity. Water quality improvements in the GCR/IHC in the past 10-15 years have been dramatic. Areas of this waterway that had been completely devoid of higher forms of aquatic life in the past have more recently been recolonized by pollution tolerant and even some more diverse forms of aquatic life.

4.5.2 Sediment contamination impacts such as bioaccumulation and chronic toxicity, which had not been significant before the water quality improvements may become more important in the future. The adverse aquatic impacts of the GCR/IHC sediment contamination are more easily detected within the waterway, and become more subtle and transient proceeding toward the harbor and into the Lake. The mechanisms of sediment - biota interactions are the same in the Lake as the GCR/IHC. The levels of sediment contamination are reduced as the sediments are dispersed throughout southern Lake Michigan, but the exposure to more sensitive aquatic life may be increased. The transport of sediments and attached contamination is controlling this exposure and the resulting impacts on the ecology of Lake Michigan.

5. SEDIMENT TRANSPORT

5.1 Sedimentation and sediment transport are natural processes which occur in all waterways. Sedimentation in the Federal navigation channel at Indiana Harbor is the reason behind the proposed dredging. Sediment transport is <u>the most important mechanism</u> by which sediment contamination in the GCR/IHC impacts the water quality and aquatic life of Lake Michigan.

5.2 This section will examine the sources of sediment which enter the GCR/IHC, the ways in which these sediments are resuspended and transported, and the consequences of this sediment transport on the environmental quality of the waterway and Lake Michigan.

5.3 SEDIMENT SOURCES

5.3.1 The sources of sediments to a waterway are determined by the hydrologic and land-use conditions of the watershed. The most prominent source of sediments in natural rivers is soil erosion. Soil erosion is the result of surface runoff and bank erosion. Erosion of soil is especially severe from agricultural lands and from lands that have been disturbed and lack vegetative cover. The GCR/IHC is not an agricultural watershed, but is almost entirely urban/industrial. The sediment sources reflect these land uses.

5.3.2 There are three major sources of sediments to the GCR/IHC. These are:

Municipal and industrial point discharges
Combined sewer overflows
Urban runoff (sewered and unsewered)

The significance of these sources and the types of contaminants associated with them will be examined, and the total loading of sediments to the GCR/IHC estimated using existing information. Other sources of sediments, such as atmospheric deposition, are routed to the waterway by one or more of the above sources or represent a relatively small portion of the total sediment contribution.

5.3.3 Point Sources

5.3.3.1 The GCR/IHC is essentially a man-made waterway. There is very little natural, base flow. Over 90% of the system's dry weather flow originates as treated municipal and industrial wastewater (McCown et al., 1976). The specific dischargers are more fully described in the draft Remedial Action Plan (IDEM, 1988), USEPA Master Plan (USEPA, 1985), and wasteload allocation study (HydroQual, 1984).

5.3.3.2 Three municipal wastewater treatment plants, serving the East Chicago, Gary and Hammond Sanitary Districts, discharge to the Grand Calumet River. These three plants discharge a total of about 128 million gallons per day (MGD). These discharges are permitted under the NPDES program (Section 402 of the Clean Water Act). Suspended solids are a component of these flows. The levels of suspended solids in the treated effluent is dependent on the type of treatment process used and its efficiency level.

5.3.3.3 There are over 40 outfalls along the GCR/IHC for discharges from industries and manufacturers. The three major steel mills (Inland Steel, LTV, and USX), discharge a total of about 1,056 MGD (IDEM, 1988). Other industries and manufacturers discharge a total of about 15 MGD. Most of the water discharged from the steel mills is cooling and process water, some of which has been recycled through the plant. The levels of suspended solids in these discharges is influenced by the levels in incoming water from Lake Michigan as well as the level and type of treatment applied.

5.3.3.2 Using the results of wasteload allocations studies for the GCR/IHC completed in 1974 (Combinatorics, 1974) and 1984

(HydroQual, 1984), the levels of suspended solids discharged to the GCR/IHC from permitted municipal and industrial sources were estimated. Only those dischargers to the portions of the waterway tributary to Lake Michigan were included. The total loadings of suspended solids for these years were:

1974	129 million pounds
1984	57 million pounds

The decrease in the loadings of suspended solids from point sources between 1974 and 1984 is dramatic (56%). This decrease is the result of more stringent effluent requirements and reductions to industrial production in the area. The loadings in 1974 are likely small in comparison to the loadings during the 1950's and 1960's, when steel mills discharged large quantities of fines and ash from the steel making process to the GCR/IHC.

5.3.3.3 The types of contaminants associated with particulates discharged from point sources are specific to the type of industry, processes, and treatment used. Up until the late 1960's, steel mill discharges contained large amounts of fine particulates from the steel-making process, high in ferrous metals. The USEPA Master Plan and IDEM RAP provide detailed descriptions of the monitored contaminants in permitted discharges to the GCR/IHC. Very limited monitoring results exist for toxic and bioaccumulative compounds.

5.3.4 Combined Sewer Overflows

5.3.4.1 A combined sewer system is one in which storm water is routed through the same pipe or sewer as sanitary flows. Normally during dry weather, sanitary flows from residential homes and discharges from some industries and businesses are the only flows in the combined sewer. During a rain storm, the sewers must carry much greater flows of water that runoff from streets, yards, and lots. When these flows exceed the capacity of the sewer or the capacity of the wastewater treatment plant, a mixture of stormwater and raw sewage is discharged directly to the river. This discharge is called a combined sewer overflow (CSO).

5.3.4.2 The sanitary districts of East Chicago, Gary, and Hammond are all totally or partially serviced by combined sewers. This represents a combined sewer drainage area of 15.7 square miles (Combinatorics, 1974), or about 23 percent of the GCR/IHC watershed. There are 15 CSO outfalls along the GCR/IHC. It is estimated that about 11 billion gallons of CSOs are discharged to the GCR/IHC each year. Of this total, about 9.7 billion gallons are discharged to portions of the waterway tributary to Lake Michigan.

5.3.4.3 The levels of suspended solids in combined sewer overflows are influenced by a number of factors. During a storm, there is commonly a "first flush" phenomena which causes very high levels of solids to be discharged in the first minutes or hours of a heavy rainfall. This is believed to be caused by the accumulation of solids within the combined sewer during dry weather conditions, when flows in the sewer may be slow. These deposits are flushed out rapidly by the high flows accompanying a storm.

5.3.4.4 The time between heavy rainfall events also effects the levels of suspended solids in CSOs. The amount of deposits which accumulate in the sewer and the amount of grit, dirt, and soot which accumulate on streets or in gutters increase with the duration between storms. Other factors which have an effect are the amount of paved areas, quantity of atmospheric deposits from automotive and industrial sources, and the frequency of street sweeping done by local municipalities.

5.3.4.5 In a study conducted by USEPA (1984) the combined sewer overflows from five cities were sampled. The average concentration of suspended solids found was 273 mg/l. Using this as representative of CSOs in northwest Indiana, the annual loading from combined sewer overflows to the GCR/IHC would be about 22 million pounds. Given the factors described above which influence the levels of suspended solids in CSOs, together with the conditions in northwest Indiana (intense urban/industrial area with elevated atmospheric deposition), this loading estimate is probably low.

5.3.4.6 Combined sewer overflows are a mixture of raw sewage and stormwater. As a result, CSOs contain high levels of BOD and ammonia. CSOs also contain contaminants from industries and businesses which discharge to the combined sewers and those found in runoff from urban areas serviced by combined sewers. Elevated levels of metals and other priority pollutants have been found in CSOs from other cities (USEPA, 1984)

5.3.5 Urban Runoff

5.3.5.1 About 77 percent of the GCR/IHC watershed is not serviced by combined sewers. Some of this area has a separate sewer system. Most are lands where water drains to the GCR/IHC through roadside ditches or overland. The amount of water draining to the GCR/IHC from unsewered or separately sewered areas can be estimated using hydrologic methods. A study done in 1982 (TenEch) compared the flows from combined sewer overflows and urban runoff. The simulated flows for a one-year storm were 314,474 and 1,010,985 cubic feet respectively. Using the proportions from this comparison, urban runoff would discharge about 31 billion gallons to the GCR/IHC each year.

5.3.5.2 As with CSOs, there are a number of factors which influence the levels of suspended solids in urban runoff. The levels of atmospheric deposition and time between storm events would have similar effects as for CSOs. In addition, the soil conditions, vegetation cover, local topography, and drainage patterns would effect the erodability of soil. Examples of suspended solids levels in urban runoff from different land types in the Chicago area are shown in table C-2 (after Polls and Lanyon, 1980).

Table C-2: Suspended Solids in Nonpoint Runoff from Homogeneous Land Uses in Northeastern Illinois (after Poll and Lanyon, 1980)

	Total Suspended Solids (mg/l)	
Land-Use Type	Mean	Range
Forest	34	20 - 51
Agricultural	762	5 - 6,100
Light Industry	302	8 - 3,222
Commercial	386	26 - 2,938
Highway	266	10 - 1,432
Single family	513	23 - 6,470
Multi-family	797	25 - 3,484

Runoff sampling done at a steel mill property in East Chicago (TenEch, 1982) found levels of suspended solids ranging from 15 to 1596 mg/l.

5.3.5.3 With the conditions in northwest Indiana, one might expect higher than normal levels of suspended solids in urban runoff. Atmospheric deposits from automotive and industrial sources are high. A large portion of the unsewered lands are industrial properties having byproducts of the steel making process in holding areas or permanently disposed, and maintain sparse vegetation. Given these conditions, the average levels of suspended solids expected in urban runoff to the GCR/IHC should be in the range of 300 to 500 mg/l.

5.3.5.4 With a projected level of 400 mg/l suspended solids, together with the flow described above, the annual loading from urban runoff would be about 103 million pounds.

5.3.5.5 The factors affecting the amount of sediments in urban runoff also effect the chemical composition of these solids. High levels of metals are commonly found in urban runoff resulting from auto emissions, and atmospheric deposition. Other priority pollutants have been found in urban runoff from cities monitored as part of the National Urban Runoff Program (USEPA, 1983).

5.3.6 Total Sediment Loading

5.3.6.1 The total sediment loading to the GCR/IHC from all three sources is shown on table C-3. The sediment loading estimates are only a rough approximation. More detailed information, especially on the contribution from urban runoff, is necessary for more precise estimates.

Table C-3: Annual Sediment Loading to GCR/IHC

Source	Annual Loading Pounds (millions)	Cubic Yards
Point Discharges (1984)	57	48,000
Combined Sewer Overflows	22	18,000
Urban Runoff	103	86,000
Total Loading	182	152,000

5.3.6.2 Also shown on table C-3 is the volume (in cubic yards) these sediments would represent as bottom deposits. The mass-volume relationship was determined using the average total solids levels of sediment samples (50% by weight) and the specific gravity of dry sediment solids (2.5-2.7 g/cm^3). With these values, one cubic yard of in-place sediments contains about 1200 pounds of dry solids.

5.4 SEDIMENT TRANSPORT MECHANISMS

5.4.1 The majority of the GCR/IHC watershed is tributary to Lake Michigan. Water flows into the Lake and carries sediment particles with it. This section will examine the movements of sediments entering the GCR/IHC, and the fate of sediment discharged from this waterway to Lake Michigan.

5.4.2 Sediment transport is the movement of sediment particulates after entering a waterway. Sediment transport is a hydraulic phenomena, controlled largely by the water movements; dry weather and storm flows in rivers, and littoral currents and waves in lakes and oceans. Other factors that can impact sediment transport are physical disturbances such as boat and ship traffic, dredging, and even the movements of aquatic organisms (bioturbations).

5.4.3 Hydraulic Factors

5.4.3.1 The ability of a sediment particle to be moved is determined by the size of the particle, its mass, and the velocity of water. Fine-grained particles, such as silt and clay are usually more easily mobilized than coarse sediments. High velocities which accompany heavy rainfall are able to keep sediment in suspension and scour sediments that have deposited on the bottom.

5.4.3.2 Sediment transport is a balance between competing forces. Gravity tends to draw sediment particles to the bottom (sedimentation). Water movements/currents scour sediments from the bottom, keep them in suspension, and move them downstream. Which of these opposing forces predominates is determined by the hydraulic characteristics of the waterway.

5.4.3.3 As an example, consider the Calumet Branch of the IHC (figure C-1). The portion of the channel south of 141st Street is between 5 and 8 feet deep. The navigation channel (north of 141st Street) is over 20 feet deep when properly maintained. If the same flow of water passes through these adjoining reaches, the velocity in the upstream (south) reach is over 3-times that in the navigation channel (north). The higher velocities in the shallow reach promote resuspension and transport. The lower velocities in the deeper reach promote settling.

5.4.3.4 After a period of time, a waterway will reach a point where settling and scour/resuspension are in balance. The amount ~~of sediments~~ entering a waterway equals the amount leaving. Both processes still occur, but are equal. Under these "steady-state" conditions, the morphology of the streambed is steady. Any change to the hydrology of the watershed or hydraulics of the river can throw this balance off. For example, a new discharger or a change in land use practices can increase flows sufficiently to scour selected reaches. The construction of an artificially deepened navigation channel creates an unnatural feature which enhances settling.

5.4.3.5 The majority of the GCR/IHC waterway is in a steady-state condition. The water depths in the GCR have changed little in the last 20 years (typically 3-8 feet). The portion of the IHC between the GCR and 141st Street, originally constructed to a 15 foot depth, has silted in to similar depths. The rest of the IHC is kept out of equilibrium only by two activities; dredging and ship traffic.

5.4.4 Influence of Navigation Channel

5.4.4.1 Sedimentation in the navigation channel has required the dredging of over 3.4 million cubic yards of sediments between 1955 and 1972. The navigation channel acted as a sediment trap,

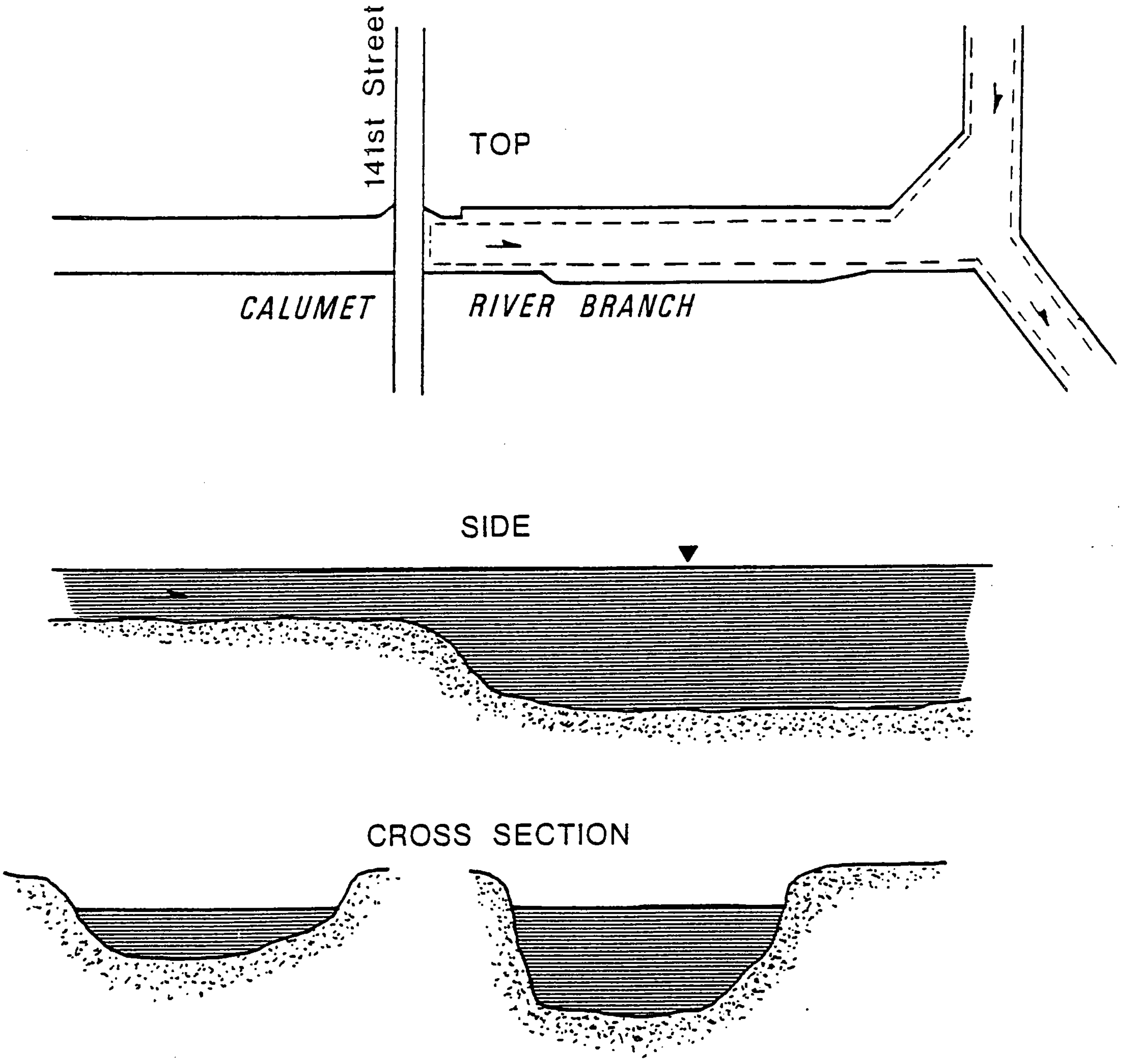

Figure C-1: Hydraulic Conditions - Calumet River Branch

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capturing a portion of the sediments transported by the GCR/IHC before they are discharged to Lake Michigan. The efficiency of this sediment trap can be estimated from the annual sediment loadings (above) and the history of dredging (Appendix H).

5.4.4.2 Using the 1974 point discharge loadings, the total sediment loading to the GCR/IHC was about 254 million pounds, or 212,000 cubic yards per year. Between 1965 and 1972, the Corps of Engineers and private industry dredged an average of 150,000 cubic yards each year. This suggests that the navigation channel had a sediment trap efficiency of about 70 percent. Allowing for higher point discharges prior to 1974, the actual sediment trap efficiency of the navigation channel was more likely in the range of 50 to 70 percent.

5.4.4.3 The navigation channel has not been maintained at authorized depths since 1972. Bathymetric surveys conducted by the Corps of Engineers since 1972 show the progressive siltation of the channel. The deposition of sediments in the Calumet River Branch of the navigation channel is shown in figure C-2 as an example. There is presently about 1,000,000 cubic yards of sediments that have deposited since 1972. Most of these sediments appear to have deposited between 1972 and 1976, with a lesser amount between 1976 and 1980. Since 1980, there has been relatively little additional deposition, although there has been redistribution of deposits.

5.4.4.4 The navigation channel has not effectively functioned as a sediment trap since 1980. As shown in figure C-2, portions of the channel have approached "steady state" water depths (8-10 feet). Other portions of the channel still have navigable depths, at least in the middle of the channel. It is believed that these depths are maintained by a combination of physical disturbances; ship traffic and storm currents.

5.4.4.5 Ship movements can resuspend sediments by the "prop wash" currents created by turning propellers, by wake formation, and by deep vessels literally plowing into sediment deposits during turning and docking maneuvers. Sediments are scoured from the most heavily traveled path (middle of the channel) and accumulate along the sides. Currents in the IHC , which are normally not fast enough to scour sediments increase dramatically during storm events. These storm flows can scour sediment deposits, especially in areas where the channel is constricted by bridges or docked vessels.

5.4.5 Sediment Loadings to Lake Michigan

5.4.5.1 The sediment loadings to the GCR/IHC have been estimated above (table C-3). Evidence suggests that most of the waterway has reached a steady-state condition. The deep-draft navigation

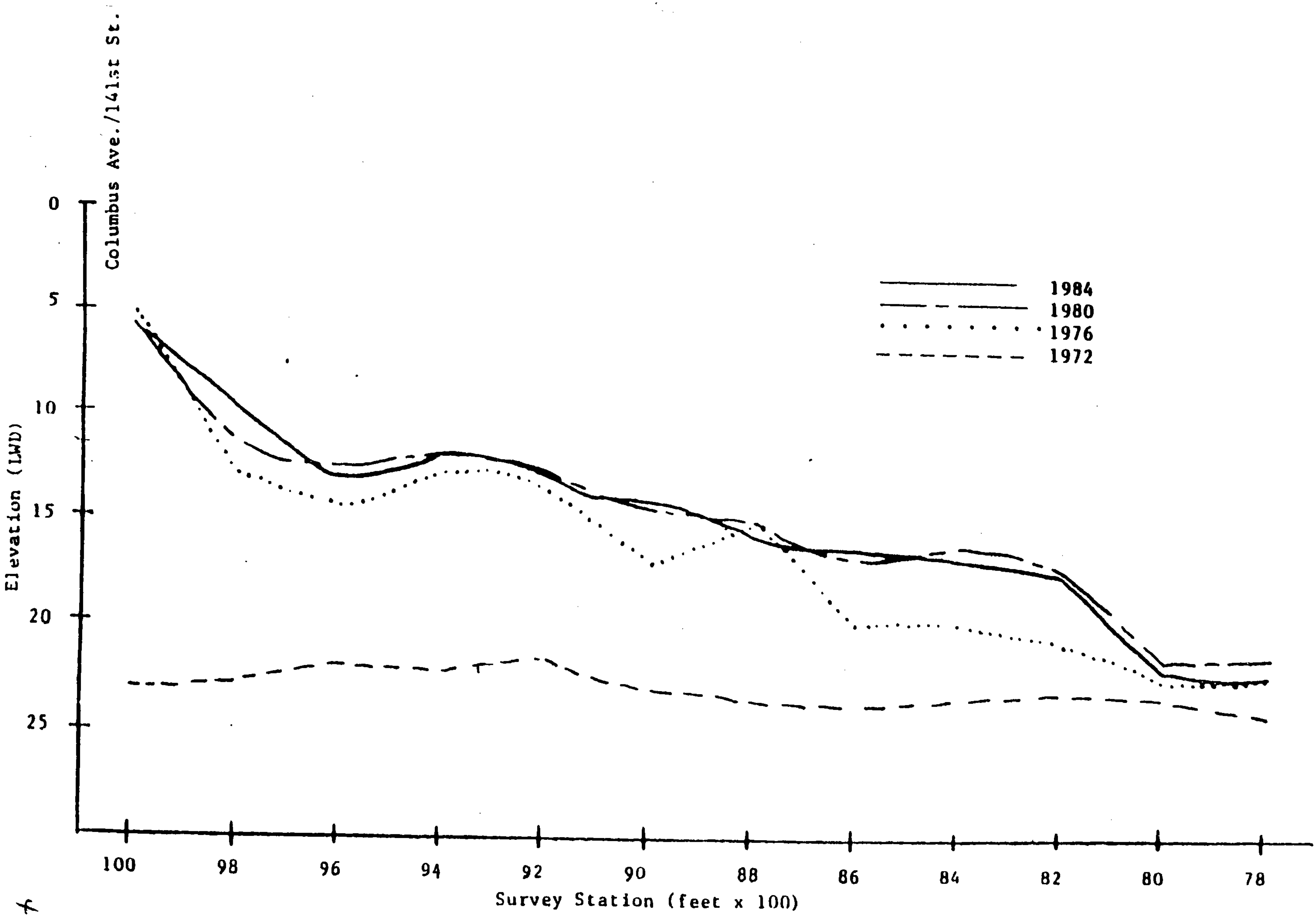

Figure C-2: Sediment Deposition in Calumet River Branch channel at Indiana Harbor and Canal can act as an efficient sediment trap, if properly maintained. Bathymetry surveys indicate that the navigation channel is no longer functioning as a sediment trap because it has not been maintained since 1972.

5.4.5.2 The annual loading of sediments from the GCR/IHC to Lake Michigan is estimated on table C-4 for two conditions. The first condition is the no action alternative. The second condition is with a fully maintained navigation channel. A sediment trap efficiency of 50 percent has been used, and is considered a conservative (low) estimate based on historic dredging records.

5.4.5.3 Also shown on table C-4 are the annual loadings of sediment contaminants discharged from the GCR/IHC to Lake Michigan. These quantities were calculated using the sediment yield mass and the average concentrations of contaminants found in recent surficial samples collected from the IHC (MSDGC, 1988; Risatti and Ross, 1989; Unger, 1989). Surface sediment samples represent the most recently deposited materials, and the materials which are most likely to be "in motion".

Table C-4: Annual Sediment and Sediment Contaminant Loadings from GCR/IHC to Lake Michigan (pounds)[1]

	Project Condition		
	No	Maintained Channel	
Constituent	Action	50%[2]	70%
Total suspended solids	182,000,000	91,000,000	54,600,000
Arsenic	6,500	3,300	2,000
Cadmium	2,000	1,000	600
Chromium	67,000	34,000	20,000
Copper	25,000	13,000	7,400
Iron	17,500,000	8,700,000	5,200,000
Lead	100,000	50,000	30,000
Manganese	200,000	100,000	60,000
Mercury	130	60	40
Nickel	13,000	6,500	4,000
Zinc	530,000	260,000	160,000
Ammonia	150,000	77,000	46,000
Phosphorous	470,000	230,000	140,000
Oil & Grease	10,300,000	5,200,000	3,100,000
PCBs	360	180	110

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1 Contaminant loadings represent particulate loadings only, and are based on recent surface sediment data.
2 Indicates percent of suspended solids trapped by maintained navigation channel.

5.4.5.4 It is estimated that the GCR/IHC is presently discharging over 150 million pounds of sediments to Lake Michigan each year. Associated with these sediment particles are hundreds to millions of pounds of specific contaminants. Most of the sediment loadings to the GCR/IHC and sediment transport within the waterway occurs during rainfall events. The result is that a large "slug" of sediment and its contaminants are washed into Lake Michigan during relatively few periods of moderate and heavy rainfall.

5.4.5.5 The above estimates indicate that the presence of a deep-draft navigation channel at the mouth of this waterway can reduce the sediment and sediment contaminant loadings to Lake Michigan by 50 percent. The distribution and fate of sediments discharged to Lake Michigan will be considered next.

5.4.6 Sediment Movements in Southern Lake Michigan

5.4.6.1 Substantial amounts of contaminated fine-grained sediments exist in harbors and canals around southern Lake Michigan and every year, large amounts of contaminated sediments are discharged by tributaries to the Lake. Major tributaries of southern Lake Michigan include the Milwaukee/Menominee/Kinnicic Rivers, Grand Calumet River/Indiana Harbor Canal, Burns Waterway, Trail Creek, and St. Joseph River. Additional sediments are released from protected harbors and canals in urban areas.

5.4.6.2 Sediments that reach the nearshore Lake will be subjected to forces that will scatter and cycle the particles (and contaminants they hold) into the water column, to biota, detritus and the bottom. Sediment particles are continually resuspended, transported and redeposited into deeper areas through a process called focusing (Thomas and Frank, 1983). This process will continue until these particles and their contaminants reach the ultimate deposition zones in the deeper parts of the Lake. For a given particle of sediment it may take many years to finally come to rest on the lake bottom.

5.4.6.3 Near Shore Transport

5.4.6.3.1 The fate of sediments discharged from a tributary in the near-shore waters of Lake Michigan is difficult to predict. Near-shore currents in southern Lake Michigan run parallel to the shoreline in either a clockwise or counterclockwise direction, depending on the prevailing wind conditions (Mortimer, 1975). Sediments discharged from the GCR/IHC will be transported by these currents either north toward Chicago or east towards Gary and the Indiana Dunes. Shoreline features, such as protected harbors and lake fills can create pockets where sediments moved by littoral currents deposit.

5.4.6.3.2 In an effort to trace the movements and deposition of sediment contamination released from the IHC to Lake Michigan, the Chicago District contracted with the Metropolitan Sanitary District of Greater Chicago (MSDGC) for sediment sampling in the IHC and adjacent Lake Michigan (MSDGC, 1988). A similar study had been performed over 20 years earlier (Snow, 1968). Samples of surface sediments were collected from transects extending five miles from the harbor.

5.4.6.3.3 Several trends were found with the MSDGC study. The most obvious trend was that sediment contamination levels decreased in the IHC from upstream to downstream, and that contaminant levels in Lake sediments generally decreased with distance from the harbor mouth. Sediments between Indiana Harbor and Calumet Harbor showed higher levels of metals and organic matter than other transects. This is attributed to the sheltered "pocket" created in the shadow of these two protected harbors, allowing for at least temporary sediment deposition.

5.4.6.3.4 Sediment samples from transects going north and northeast of the harbor showed that there were localized areas of deposition and scour. Much of the area within a mile of the harbor mouth is subject to high wave energy, and fine grained sediments are rapidly dispersed. The Indiana Shoals, a natural sand bar formation located northeast of the Inland Steel fill, was another area where fine-grained sediments were rapidly dispersed. Samples from two to five miles from the harbor showed evidence of contamination from metals and organic matter from the GCR/IHC.

5.4.6.3.5 The transect running east of the harbor indicated that this was the prevailing direction of sediment transport in nearshore Lake Michigan. Samples collected three and five miles from the harbor contained levels of metals and organic matter comparable with samples within a half mile of the harbor. It is presumed that the area between the Inland Steel fill and Burnham Harbor may be a "pocket" where GCR/IHC sediments deposit. More extensive sampling would be necessary to confirm this and track the transport of sediment contamination further east.

5.4.6.4 Basin Transport and Deposition

5.4.6.4.1 Because of the circular flow pattern in southern Lake Michigan (Mortimer, 1975), this is a partially closed system. This means that there is limited turnover of water between the southern basin and the rest of the Lake.

5.4.6.4.2 There are two major depositional basins in Lake Michigan south of Milwaukee: the Waukegan and the Southern basins (figure C-3). The central portion of southern Lake Michigan (approximately 40 miles offshore and northeast of Chicago) is in

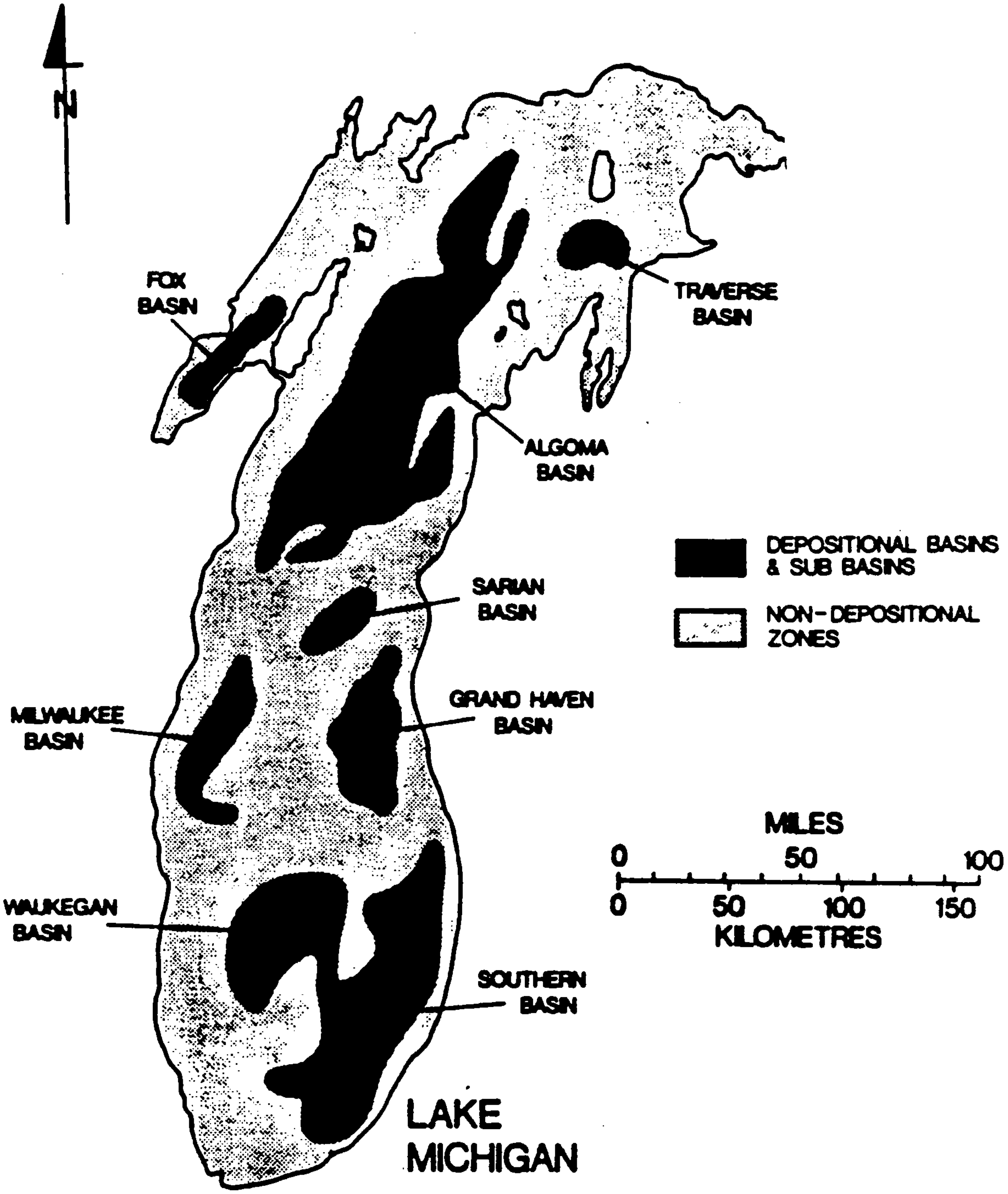

Figure C-3: Depositional Basins in South Lake Michigan excess of 300 feet deep for an almost circular area of an approximate 40 mile diameter. Depths as great as 530 feet exist in three depressions inside of this area of the Lake.

5.4.6.4.3 Both of these described sedimentation basins are the result of slow focusing of fine-grained materials by currents and wave action into the central deep zone. The southern basin includes many shallower areas on the eastern side of the Lake indicating that other factors in addition to depth (including sources of pollution and heavy sediment loads) may also shape the distribution of these two sedimentation basins.

5.4.6.4.4 Two major zones (figure C-4) of higher than average sediment concentrations of PCBs, DDT, and heptachlor epoxide (Frank et al., 1981) coincide roughly with the higher concentrations of silty-clays and clays (Thomas and Frank, 1983) of the Waukegan and Southern sedimentation basins. The distribution contours for PCB concentrations in sediments of the southern Lake Michigan (Thomas and Frank, 1983) can be interpreted as indicating Waukegan Harbor, Indiana Harbor and Canal, St. Joseph River and a few other areas as probable major contributors to the PCB loading of this portion of the Lake.

5.4.6.4.5 The ultimate fate of fluvial sediments from tributaries to southern Lake Michigan, including sediments from the GCR/IHC, is deposition to the bottom of these two basins. Sediments are slowly buried by successive deposition of new materials. More stringent controls of sources of sediment contamination will result in more contaminated sediments being covered by less contaminated materials in the future.

5.5 IMPACTS OF SEDIMENT TRANSPORT

5.5.1 The above discussions have shown that in-place sediment contamination have adverse impacts on water quality and aquatic life in the GCR/IHC. It has also been shown that the resuspension and transport of sediments greatly increases the potential exposure of sediment contamination to the water column and aquatic organisms.

5.5.2 The same mechanisms by which sediment contamination can impact water quality and aquatic biota in the riverine environment of the GCR/IHC apply to sediment contamination impacts after it enters Lake Michigan. What is different, is the level of exposure to sediment contamination and the type of organisms that are exposed.

5.5.3 Wave action and currents in the nearshore, littoral zones of the Lake will resuspend fine-grained sediment transported into this area. The particles will be repeatedly lifted into the water column until they reach the very deep sedimentation basins

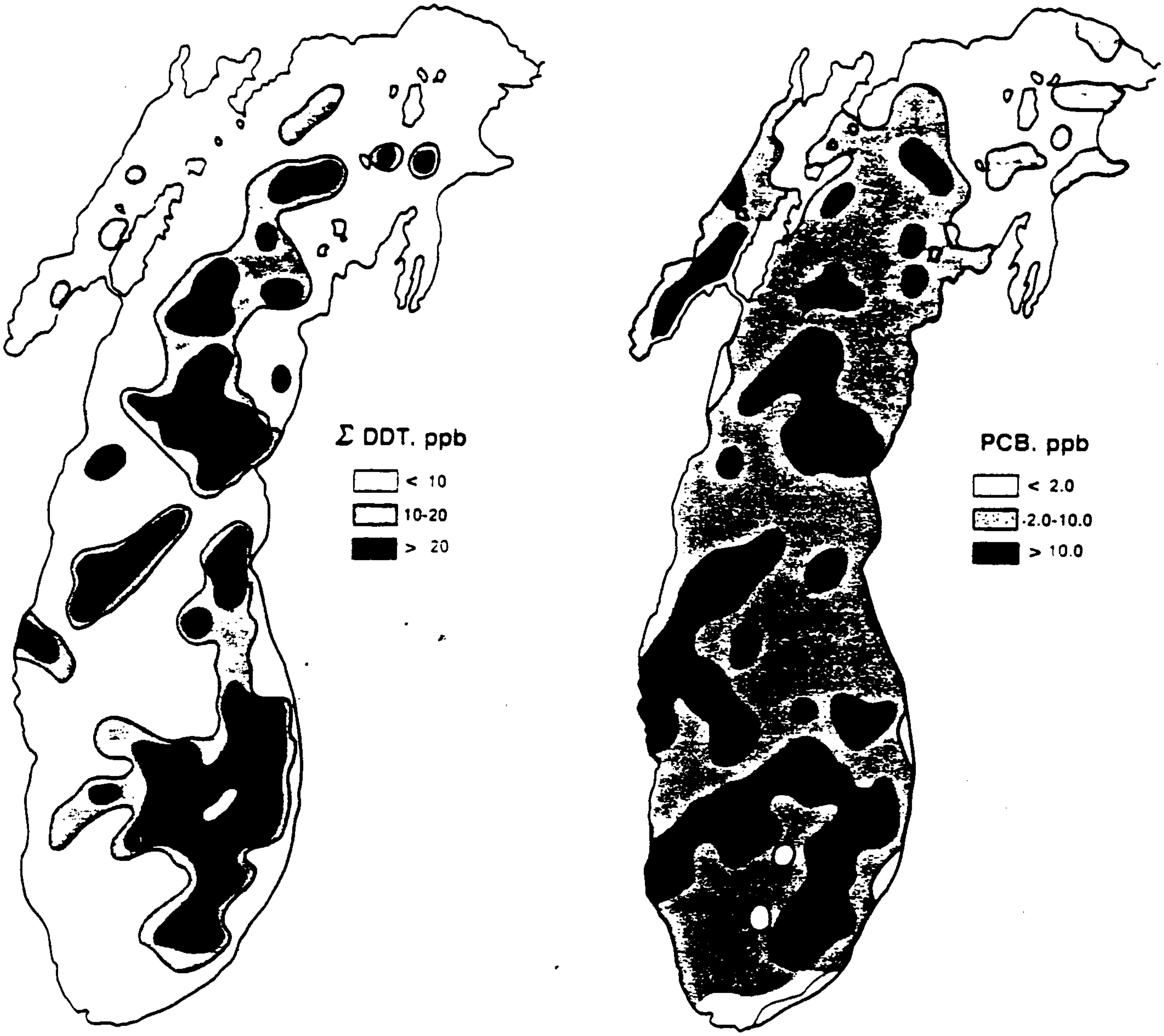

Figure C-4: Distribution of DDT and PCBs in Surficial Bottom Sediments of Lake Michigan miles offshore. Throughout this continual resuspension, these particles are able to lose contaminants to the water column or contact organisms. Any given particle may be subjected to a cycling from the bottom to the water column repeatedly for a period of many years before settling onto the deep sedimentation zones of the Lake.

5.5.4 The level of exposure to sediment contamination within this nearshore, littoral zone is especially important. Within the GCR/IHC sediment deposits are up to 15 feet deep, and the surface exposed to the water column relatively small (340 acres). The number and diversity of aquatic organisms exposed to the sediments is also limited. In the littoral zone of Lake Michigan, sediment contamination is spread out over many square miles. The number and diversity of aquatic life able to contact this sediment contamination is increased dramatically.

5.5.5 The littoral zone of Lake Michigan (generally within 5-10 miles of shore) occupies an important role in the ecology of the Lake and its use by man. Almost all potable and industrial water supplies are taken from within two miles of shore. Recreational activities such as boating and swimming, and both recreational and commercial fishing are concentrated in this littoral zone. Fish populations are dominated by Yellow perch, but this zone is also frequented by game fish for feeding and spawning. Diverse benthic communities and the presence of aquatic plants and forage species of fish attract shorebirds, gulls, terns, and diving ducks.

5.5.6 The loading and cycling of sediment contamination into the littoral zone promotes the exposure of these contaminants to diverse organisms which are less pollution tolerant than those encountered in the GCR/IHC. In areas where sediments discharged from the GCR/IHC deposit (such as pockets created by man-made structures), the levels of sediment contamination may cause acute reactions in aquatic life (toxicity). For most of the littoral zone, the dispersal of sediment contamination will cause more subtle impacts on aquatic life (bioaccumulation/sub-lethal).

5.5.7 The impacts of sediment contaminant loadings from the GCR/IHC on Lake Michigan are difficult to quantify. The mass loadings of metals, nutrients, and organic contaminants associated with sediment particles (shown in table C-4) does not tell the whole story, but does indicate the magnitude of the problem from a cumulative standpoint. Atmospheric deposition is believed the largest source of pollution to the Great Lakes for many contaminants. Sediment transport may be just as important because these loadings are directed to the littoral zone of the Lake around centers of human population.

5.5.8 The transport of sediment contamination from the GCR/IHC to Lake Michigan represents a significant, long-term environmental problem for this valuable resource. The significance of sediment contamination impacts on water quality and aquatic life have been appreciated only in recent years. Recent initiatives have resulted in a Master Plan (USEPA, 1985) and Remedial Action Plan (IDEM, 1988) for the GCR/IHC. Remediation of sediment contamination is considered in the RAP and being evaluated under the Section 118 program administered by USEPA. Alternatives for remediating the sediment contamination problems of the GCR/IHC are discussed in the next section.

6. SEDIMENT CONTAMINATION REMEDIATION ALTERNATIVES

6.1 The draft RAP for northwest Indiana (IDEM, 1988) includes a number of options for the management of sediment contamination. The completion of this Draft EIS and the investigations completed by the Chicago District on the no action alternative and advanced treatment technologies (Appendix G) will supplement the RAP and plans for sediment contamination management.

6.2 The Chicago District has actively supported the IDEM and USEPA in the development of the RAP and Master Plan documents. The District will continue to support these and other agencies in the implementation of the RAP by providing the technical knowledge and expertise it has accumulated through the navigation dredging programs. This section will review alternatives for the abating sediment contamination, remediation of in-place sediment contamination, controls to limit sediment transport, and funding authorities for sediment contamination remediation.

6.3 SOURCE CONTROLS

6.3.1 Source controls are the only vehicle for a permanent solution to sediment contamination. Remediation without source controls will only produce a temporary solution. Programs which reduce the quantity of sediments entering the GCR/IHC and the levels of sediment contamination will have two benefits. First, they will reduce the adverse impacts of sediment contamination on water quality and aquatic life in the GCR/IHC and Lake Michigan. Secondly, they will reduce the costs of maintenance of the navigation channel.

6.3.2 Some sediment and sediment contaminant sources are easier to control than others. Point discharges are currently regulated under the Clean Water Act (NPDES permit program). The effects of such regulation can be easily seen in the reductions to suspended solids loadings from point sources between 1974 and 1984 (a 56% reduction). The RAP calls for full compliance of all NPDES discharges and the resolution of enforcement actions against violators.

6.3.3 Combined sewer overflows are not as easily controlled as point discharges. The cost of separating sewers (into sanitary and storm sewers) in many urban areas is prohibitive. Alternatives that have been applied in Chicago and Milwaukee is to construct a detention basin or tunnel to temporarily store combined sewer flows during storms for later treatment and discharge. The capital costs and lands required for these options may also be limiting. The NPDES permits with the sanitary districts of East Chicago, Hammond and Gary will be modified by the IDEM to require satisfactory maintenance and operation of the combined sewer systems.

6.3.4 Urban runoff is the most difficult source to control. However, there are a number of measures which, individually promote small reductions, but together can prove quite effective. An effective air quality control plan can reduce atmospheric deposition. Street sweeping can remove street grit, soot, and dirt before it is washed into the sewers. Erosion controls at construction sites, and promotion of vegetation on vacant or industrial lands can all reduce sediment loadings. Small catchment basins, settling ponds, and sediment traps can capture sediment in runoff from unsewered areas.

6.4 REMEDIATION OF IN-PLACE SEDIMENT CONTAMINATION

6.4.1 Environmental remediation of in-place contaminated sediments until recently has only been addressed at sites of chemical spills or areas with extremely high levels of contamination. Remediation options for in-place sediments include removal (dredging), capping with clean materials, and in-place treatment.

6.4.2 Sediment Removal

6.4.2.1 The alternative methods for dredging (Appendix H), confinement, and treatment (Appendix G) of contaminated sediments are fully described in other parts of this DEIS. The evaluation of the feasibility and costs of alternatives considered for sediments dredged from the Federal navigation channel are directly applicable to sediments from other areas of the GCR/IHC. Some differences exist and might result in different recommendations. For example, the water depths in the GCR might limit the use of mechanical dredges.

6.4.2.2 Among the most important technical factors in evaluating dredging and disposal alternatives is the volume of sediments to be removed. The methods of dredging; number, size and location of disposal sites; and feasibility of advanced treatment are all dependent on this factor. In most cases, the volume of sediment contamination which can be removed is determined by funding constraints.

6.4.3 Capping

6.4.3.1 Capping is the process by which in-place sediment contamination is covered by clean materials. The intent of capping is to limit the exposure of sediment contamination to the water column and aquatic life. The sediment contamination remains in the waterway, but its availability is reduced. Capping has been used in Japan to remediate sediment contamination in some harbors used for recreational and commercial fisheries.

6.4.3.2 The feasibility of capping is dependent on the hydraulics of the waterway. Capping material must seal the sediment contamination from the overlying water, prevent penetration by benthic or burrowing organisms, and be resistant to scour. Waterways having high flows (even if infrequently) may require gravel or small stone as part of the cap. If capping material is more dense than the sediments they cap, the capping material may settle to the bottom of sediments. Capping is only effective where all sources of sediment contamination have been controlled. Otherwise, the cap surface will become covered or contaminated by future deposition.

6.4.4 In-Place Treatment

6.4.4.1 In-place (or in-situ) treatment consists of the destruction, modification, or immobilization of one or more sediment contaminants in-place. There is very little known about the feasibility of in-place treatment of sediment contamination. No pilot or full-scale applications have been demonstrated. Theoretically feasible alternatives include fixation/solidification and biodegradation.

6.4.4.2 Fixation/solidification in-place would require the injection of stabilizers or additives into the sediment deposits and mixing of the sediment and additives. The process would create a solidified sediment mass, resistant to erosion. The feasibility of this process, its costs and impacts on water quality are unknown.

6.4.4.3 A number of sediment contaminants are degraded by microorganisms indigenous to bottom sediments. Organic matter (hydrocarbons) and synthetic organics (such as PCBs) can be metabolized or transformed to other chemical forms. A discussion of the biodegradation of PCBs in natural sediments is provided in Appendix G. Biodegradative processes which occur under aerobic conditions are different from, and generally more rapid than those occurring under anaerobic conditions. Since all bottom sediments except for a thin surface layer are under anaerobic conditions, biodegradation of organics is a slow process. Aeration of sediment deposits would require resuspension, and thus would be counterproductive from a water quality perspective.

6.5 SEDIMENT TRANSPORT CONTROLS

6.5.1 The resuspension and transport of sediments has been shown to be the most important mechanism by which sediment contaminants are transported. Controls which reduce the resuspension and transport of in-place sediment contamination will reduce the exposure of these contaminants to the water column and aquatic biota.

6.5.2 The resuspension of sediment deposits could be reduced by changing the hydrology and hydraulics of the GCR/IHC or by reducing or eliminating physical disturbances which cause resuspension. In order to reduce flows in the GCR/IHC it would be necessary to cut-back or eliminate flows from major industrial dischargers or make massive changes to the existing land-use practices of the watershed. Without the discharge of cooling and process waters from the steel mills, the GCR/IHC would have virtually no dry weather flow, and major portions of the waterway might become anaerobic. The implementation of controls which limit sediment loadings in CSOs and urban runoff (described above) would also reduce peak storm flows and the resulting scour and resuspension.

6.5.3 Sediment resuspension in the navigation channel could be reduced if shipping and dredging were banned. In the long run, this would aggravate the sediment transport to Lake Michigan. Other proposals have suggested that the direction of flow in the GCR be changed by the construction of a wall at the junction of the GCR and IHC, so that all GCR flow would go to Illinois Waterway through the Cal Sag channel. This would reduce the sediment loading to Lake Michigan, but would require major modifications to the west branch of the GCR. Implementing this proposal would require the resolution of complex political and legal questions.

6.5.4 One method of trying to control sediment transport that has been used in some waterways is the construction and operation of a sediment trap or settling basin. A deepened channel, pool or basin can be excavated within a waterway to catch sediments before they can migrate downstream. Sediments which deposit are dredged and disposed nearby. This practice is used to prevent deposition in waterway reaches of high quality or valued use, or is simply more cost-effective than removing sediments from a long stretch of river.

6.6 AUTHORITIES FOR SEDIMENT REMEDIATION

6.6.1 Plans without funding or a means of implementation are not a solution. Sediment contamination is a large problem, involving many sources and routes of transport and exposure. No single solution, acting alone will suffice. A well coordinated series of actions will be required just to begin to remediate the problem and its impacts. The RAP, prepared by the IDEM is the logical vehicle for coordinating and directing these actions.

6.6.2 A regulatory framework already exists for source controls on point discharges and CSOs. Urban runoff controls will require a more wide-based plan involving participation of the Federal, state, local, and industrial interests. The implementation of source controls is not immediate, and the benefits would be gradual and progressive.

6.6.3 There are a number of programs and authorities through which the remediation of in-place sediment contamination may be pursued. These include:

Superfund
Section 115 (CWA)
Enforcement actions
Navigation maintenance

6.6.4 There are three waterways on the Great Lakes which have been placed on the National Priorities List (NPL) for Superfund action. These are: Waukegan Harbor, Illinois; Fields Brook/Ashtabula Harbor, Ohio; Sheboygan River/Harbor, Wisconsin. All three have been placed on the NPL because of PCB contamination in bottom sediments. In order for a site to be recommended for inclusion on the NPL, the site must be rated by the USEPA using the Hazard Ranking System (HRS) and be recommended by the state for inclusion.

6.6.5 A consent decree has been signed by the USEPA and Outboard Marine Corporation for the remediation of about 50,000 cubic yards of PCB contaminated sediments from Waukegan Harbor and a larger volume of contaminated soil on OMC property. The majority of contaminated sediments will be confined on-site in a facility built from a small slip. A portion of contaminated sediments and soil (less than 15,000 cubic yards) will be treated by a thermal extraction process and the PCBs destroyed by incineration.

6.6.6 Section 115 of the Clean Water Act directs the USEPA to identify waterways with in-place toxic pollutants and, working through the Corps of Engineers, to remove and dispose these materials from critical port and harbor areas. A total of $15 million was authorized for this program, but the funding has never been appropriated by Congress nor any clean-up conducted under this authority.

6.6.7 The USEPA, as part of its enforcement responsibilities under the Clean Water Act has initiated legal actions against the sanitary districts of Hammond, East Chicago, and Gary, and the USX and Inland Steel companies for violations of discharge permits. The USEPA Enforcement Branch has begun discussions with Hammond about the possibilities of performing remedial dredging of contaminated sediments from the GCR. These discussions are preliminary and no agreements have yet been signed. However, this may provide a viable means for at least a partial remediation of in-place sediment contamination.

6.6.8 The Chicago District, U.S. Army Corps of Engineers has authority to maintain the Federal navigation channel at IHC. The nature and limits of this authority are described in the EIS and Letter Report. The plan proposed by the Corps of Engineers would remove approximately 1 million cubic yards of in-place contaminated sediments and provide for the future dredging of an additional 3 to 4 million cubic yards. Contaminated sediments dredged from the Federal channel would be disposed to a confined disposal facility (CDF) constructed on the site of a former refinery in East Chicago.

6.6.9 The Corps of Engineers' dredging program is authorized to maintain navigation projects and not as environmental remediation. Nevertheless, over the last 20 years the CDF program has removed and confined more than 50,000,000 cubic yards of polluted sediments from the Great Lakes. The disposal of polluted sediments into confined facilities (CDFs) has considerably reduced the loading of pollutants transported into the open Lakes.

6.6.10 Aside from the above authorities and programs, specific authorization by Congress, state legislature, or local municipalities are the only other sources of funding for remediation of sediment contamination. The only known specific authorization for sediment remediation at a single site was Section 116 of the Clean Water Act, in which the New York Department of Environmental Conservation was authorized to remove and dispose of PCB contaminated sediments from the Hudson River. Although several dredging and disposal plans have been developed and proposed, only a small portion of the sediment contamination has been removed under this authority.

7. SUMMARY

7.1 This appendix has described the environmental impacts of the "no action" alternative. Under the no action alternative the federal navigation project at Indiana Harbor and Canal would not be maintained. This appendix has also evaluated alternatives for remediating the environmental depredation caused by sediment contamination in the Grand Calumet River (GCR) and Indiana Harbor Canal (IHC), including maintenance dredging of the navigation channel.

7.2 The Grand Calumet River and Indiana Harbor Canal is for the most part, a man-made waterway carrying the discharges from industrial and municipal sources. The waterway is a major tributary to the southern basin of Lake Michigan and has a long history of severe water quality depredation. The GCR/IHC is one of 42 areas of concern designated by the IJC for environmental problems impacting the Great Lakes, and is one of five areas on the Great Lakes identified by Congress for priority consideration of demonstrations of sediment contamination remediation.

7.3 The GCR/IHC has extensive sediment contamination over the entire length of the waterway. Sediment contaminants include metals, nutrients, organic matter, PCBs, and PAHs. There are several mechanisms by which sediment contamination can adversely impact water quality, including oxygen depletion (SOD), nutrient release, and release of toxic and persistent chemicals. The are also a number of mechanisms by which sediment contaminants can impact aquatic biota, including toxicity (acute and chronic) and bioaccumulation. The type and levels of exposure to sediment contamination determines the environmental impacts.

7.4 Sediment contaminant impacts, such as SOD, nutrient and contaminant release are measured in units per surface area exposed (square meters). In-place, the exposure of sediment contamination and its impact are finite and limited. The in-place sediment contamination in the GCR/IHC has a surface area of around 340 acres. Suspended sediments have over a thousand times greater surface area (750,000 acres) exposed to the water column. The exposure and adverse impacts of sediment contamination are greatly magnified by sediment resuspension and transport.

7.5 There are three major sources of sediments and sediments contamination to the GCR/IHC; municipal and industrial discharges, combined sewer overflows, and urban runoff. These sources contribute an estimated 182 million pounds (or 152,000 cubic yards) of sediments to the waterway each year. Most of the GCR/IHC has reached a steady-state condition, meaning there is a balance of sediment deposition and scour/transport. The result is that the annual loading of sediment to the GCR/IHC equals its annual sediment discharge to Lake Michigan. It is estimated that approximately 67,000 pounds of chromium, 100,000 pounds of lead, and 360 pounds of PCBs are discharged each year with the sediment yield of the GCR/IHC to Lake Michigan.

7.6 This annual sediment loading is essentially dumping 152,000 cubic yards of contaminated sediments into Lake Michigan at the mouth of Indiana Harbor each year. The adverse impacts of this loading can be seen in the surface sediments of the nearshore Lake, for a distance of more than five miles from the harbor. The transport and resuspension of this material in the littoral zone of the lakeshore greatly increases the exposure of sediment contaminants to the more diverse and sensitive aquatic life which inhabits the area. It is in this littoral zone that this sediment contamination from the GCR/IHC has the greatest potential to impact man, through recreational activities and potable water supplies.

7.7 Once sediment contamination has left the GCR/IHC into Lake Michigan, it is essentially beyond remediation. Among the remedial alternatives and abatement options examined, controls on point and non-point sources of sediments and sediment contaminants are the most effective and permanent solutions. The implementation of the Remedial Action Plan by the IDEM provides a framework for coordinating many of these actions.

7.8 Among the options for remediating in-place sediment contamination, removal (dredging) appears the only practical solution. Existing authorities for conducting cleanup dredging are limited. The Corps navigation dredging program, although not authorized as a cleanup action, can provide two significant benefits to the environment. Maintenance dredging can remove up to four to five million cubic yards of existing and future contaminated sediments from portions of the waterway. The maintenance of the navigation channel at authorized depths can also create a sediment trap effect, reducing the annual sediment loadings from the GCR/IHC to Lake Michigan by 50 to 70 percent.

7.9 The navigation dredging of the Federal channel at Indiana Harbor will not remediate all of the sediment contamination in the GCR/IHC. The Corps actions will, however, be a significant step in the environmental remediation of the GCR/IHC and may serve as both an incentive and example for sediment cleanup activities.

7.10 The maintenance of the channel at authorized depths will not completely eliminate the discharge of contaminated sediments from this waterway to Lake Michigan. The reductions to sediment contamination loadings and the long-term environmental benefits resulting from the maintenance of the navigation channel at Indiana Harbor may not be fully appreciated for some time. With even a limited knowledge of sediment-water and sediment-biota interactions, the consequences of the no action alternative are unacceptable to the environmental quality of Lake Michigan.

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INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES

APPENDIX D

BIOLOGICAL ASSESSMENT

June 1993
Supplemented September 1995
Environmental and Social Analysis Branch
Chicago District
U.S. Army Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

APPENDIX D

BIOLOGICAL ASSESSMENT

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APPENDIX D

BIOLOGICAL ASSESSMENT

INDIANA HARBOR AND CANAL
OPERATION AND MAINTENANCE ACTIVITIES
LAKE COUNTY, INDIANA

1. PURPOSE AND NEED

1.1 The following biological assessment has been prepared under the authority of Section 7 of the Endangered Species Act and in response to informal comments with the Bloomington Field Office, U.S. Fish and Wildlife Service (USFWS) in their Draft Coordination Act Report on Indiana Harbor and Canal, operation and maintenance activities in Lake County, Indiana (dated January 30, 1989).

2. DESCRIPTION OF THE PROJECT AREA

2.1 The Indiana Harbor and Canal federal navigation project is located in a highly urban\industrial area of northwestern Lake County, Indiana, immediately southeast of Chicago, Illinois (plate 1). The project area is within the Grand Calumet River basin and drains into the southern portion of Lake Michigan at East Chicago, Indiana. Steel mills, oil refineries, power plants, and other industries are found in the area. These industries are point sources for a variety of pollutants and, in conjunction with other point sources (i.e. sewage treatment plants) and non-point sources (i.e. surface runoff, air pollution deposition, etc...), have greatly degraded the terrestrial and aquatic environments in and immediately adjacent to the harbor and canal.

3. DESCRIPTION OF THE PROJECT

3.1 The existing features of this federal navigation project are described in detail in U.S. Army Corps of Engineers (1986). The proposed project involves performing operation and maintenance activities, including dredging and disposal operations to maintain a viable, navigable channel in the harbor and canal. About one million cubic yards of contaminated sediments must be dredged initially to restore authorized project depths. Confined disposal of this material is required by law. Future dredging and disposal operations would be performed as needed. Three potential disposal sites are being evaluated in detail at the present time. The site locations and preliminary confined disposal facility (CDF) designs were presented in the Final Plan of Study (dated November 14, 1988). In addition, a fourth and fifth alternative were informally discussed over the phone on January 9, 1989. These included a potential upland disposal site located on property formerly occupied by Energy Cooperative, Inc., in East Chicago, Indiana, north of the Lake George branch of the canal and closing off of the Lake George branch itself. All five sites are examined in this biological assessment (plates 2-5).

4. THREATENED OR ENDANGERED SPECIES POSSIBLY OCCURRING IN THE PROJECT AREA

4.1 The USFWS provided a list of the following federally listed or candidate species whose range extends into the general vicinity of the project area in their draft Coordination Act Report (dated January 30, 1989):

Common Name	Scientific Name	Status
Indiana bat	*Myotis sodalis*	Endangered
Pitcher's thistle	*Cirsium pitcheri*	Threatened
Peregrine Falcon	*Falco peregrinus*	Endangered
Forked aster	*Aster furcatus*	Candidate
Heart-leaved plantain	*Plantago cordata*	Candidate
Fragrant (Beach) sumac	*Rhus trilobata arenaria*	Candidate
Prairie fame flower	*Talinum rugosperum*	Candidate
Karner blue butterfly	*Lycaeides melissa samuelis*	Candidate

5. SPECIES BIOLOGY AND DISTRIBUTION

5.1 Important biological factors and present known distribution are discussed by species in the following paragraphs. Although candidate species are not required by law to be evaluated in the biological assessment process, they are included here in the event that they should be proposed for listing or are actually listed between now and the project construction start-up date.

5.2 Indiana Bat

5.2.1 The project area is within the general range of the Indiana bat. This bat hibernates in caves during the winter and forages and breeds along wooded riparian habitats during non-winter months. Maternal colonies use mature trees (generally with a diameter at breast height of 16 inches or greater) with loose bark for roosting. No critical habitat has been designated for this species in the vicinity of the project area (USFWS, Undated; draft Coordination Act Report dated January 30, 1989). This bat has been reported in the past at Baileytown (now within the boundary of the Indiana Dunes National Lakeshore) many miles east of the project area (Russell Mumford, retired, Purdue University, Pers. Comm.).

5.2.2 The nearby Little Calumet River basin has only marginal summer habitat, at best (letter from R. Kirkpatrick, Ball State

University, dated August 13, 1980). The only known reports of Indiana bats or suitable summer habitat anywhere near the project area are from the Kankakee River basin in Indiana and in bordering Cook County, Illinois (Brack and Holmes, 1982; Natural Land Institute, 1981). Bats were collected from several sites along the Kankakee River during July 1982. The closest collection site was about 35 miles southeast of the harbor and canal area (Brack and Holmes, 1982). Incidental sitings of these bats have been reported during the summer in Cook County prior to 1979, but exact dates and locations are not given (Natural Land Institute, 1981).

5.3 Peregrine Falcon

5.3.1 The project area is within the general range of the Peregrine Falcon (USFWS, Undated). This bird reportedly uses Miller Beach along Lake Michigan approximately seven miles east of Indiana Harbor during migration (USFWS, Draft Coordination Act Report dated January 30, 1989). In addition, young falcons have been successfully hacked at several locations in north eastern Illinois (Illinois Beach State Park and Fort Sheridan, Lake County, and University of Illinois, Circle Campus, Cook County) from 1986 to 1988 as part of a reintroduction effort sponsored by the Illinois Department of Conservation, Chicago Academy of Science, and Lincoln Park Zoo. A nesting attempt was made on a building ledge in the Chicago area during 1987, but only one, non-viable egg was laid. These release locations are approximately 40, 26, and 18 miles northwest of the project area, respectively.

5.3.2 Peregrine Falcons forage primarily on birds in open areas, often near water. Recent reintroduction/hacking efforts have shown that these birds will roost and forage in urban environments with tall buildings (which provide safe ledges similar to their natural canyon/bluff environment). Some of the released birds have returned to the general area where they were hacked in later years and nested, as was demonstrated in Chicago. Approximately 30 to 50 of these birds migrate and forage along the Indiana shoreline in September and October. In addition, individuals that were released in the Chicago area have been observed foraging as far east as the Hammond Filtration Plant (Ken Brock, Pers. Comm). No critical habitat has been designated for this species (USFWS, 1988).

5.4 Pitcher's Thistle

5.4.1 This plant was officially listed as threatened recently on July 18, 1988 (Recce, 1988). It occurs primarily on dry sand of stabilized, well-developed shoreline dunes along the Great Lakes. It is also found in dry "blowouts" behind main dunes in open areas of older dunes formed during higher Pleistocene lake levels. It is infrequently found on the lower, wetter areas of the beach which are more frequently inundated and disturbed by storm wave forces (Alverson, 1981).

5.4.2 This plant is presently known from seven sites along the Lake Michigan shoreline in Indiana (John Bacone, Indiana Department of Natural Resources, Pers. Comm., as cited in Recce, 1988). There is one past location in the Indiana Harbor area, but it was lost several years ago. These seven existing areas are located about nine miles or more east of the project area (letter from John Bacone, Indiana Department of Natural Resources, February 21, 1989). No critical habitat has been designated for this species (Recce, 1988).

5.5 Forked Aster

5.5.1 This plant is found in woods, shaded cliffs, and on wooded slopes. It has been reported in bordering Porter County, Indiana, and Kankakee County, Illinois, but not in Lake County, Indiana (Britton and Brown, 1970; Swink and Wilhelm, 1979).

5.6 Heart-leaved Plantain

5.6.1 This plant is found in or along swamps and cool, clear, shaded, streams, and usually prefers calcareous habitats. It has been reported in bordering Cook and Will Counties in Illinois and Porter County, Indiana, but not in Lake County, Indiana (Britton and Brown, 1970; Swink and Wilhelm, 1979).

5.7 Fragrant or Beach Sumac

5.7.1 This plant occurs on low dunes near Lake Michigan. It is presently only found in Lake County, Indiana, in association with _Quercus velutina_ on swell and swale topography. It has been reported in bordering Cook County, Illinois, and Porter County, Indiana, in the past (Swink and Wilhelm, 1979). The closest swell and swale topography is located in Indiana Dunes National Lakeshore approximately 13 miles east of the project area.

5.8 Prairie Fame Flower

5.8.1 This plant is found in prairie habitats associated with other prairie species on sandy soils. The only "recent" report of this species in the vicinity of the project area was from bordering Cook County, Illinois, in 1962. It has been reported in Lake, Porter, and Newton Counties in Indiana prior to 1962 (Britton and Brown, 1970; Swink and Wilhelm, 1979).

5.9 Karner Blue Butterfly

5.9.1 This species is found locally in pine barren habitats associated with wild blue lupine (_Lupinus perennis_), its larval food source. A small, isolated colony was reported near Hessville, Indiana, and several individuals were also reported at Indiana Dunes State Park (about 20 miles east of the project area) sometime prior to 1978 (Greenwalt, 1978).

5.9.2 This species was proposed for listing as federally threatened in the Federal Register on July 3, 1978. One area of critical habitat was also proposed in Albany County, New York (Greenwalt, 1978). This proposal was officially withdrawn from further consideration on September 2, 1980 (USFWS, 1980).

6. PROJECT AREA INSPECTIONS

6.1 The project area, including all potential disposal sites, have been visited by biologists of the Chicago District, U.S. Army Corps of Engineers, between 1981 and 1989. No listed or candidate species or suitable habitats have ever been observed during this time in or along the Indiana Harbor and Canal or at any of the proposed disposal sites.

7. EXPECTED IMPACTS

7.1 Since no listed or candidate species, designated critical habitats, or suitable habitats are known from the project area, no direct impacts to such species are expected as a result of the proposed dredging and disposal activities. Dredging would temporarily resuspend contaminants into the water column and make them more bioavailable to area biota for a short period of time. However, this impact is not expected to be greater than existing resuspension impacts that normally occur during high volume/ velocity storm flows and when ships "plow" through the bottom sediments (due to insufficient channel depths) while navigating the channel. Any potential short-term, minor impacts due to dredging and contaminant resuspension would be offset by the long-term benefits to area biotic resources by the removal and isolation of contaminated sediments from the aquatic and terrestrial communities.

6.2 It is possible that shorebirds feeding on the CDF, during filling operations, could pick up contaminants and pass them on to Peregrine Falcons in the southern end of Lake Michigan which may prey upon them. However, it would be highly unlikely that this would have a significant impact upon Peregrine Falcons (Ken Brock, Indiana University-Northwest, Pers. Comm.). Further, the potential for such contaminant uptake is an existing condition due to the contaminated state of the canal and harbor.

6.3 Based on modelling studies conducted by the Chicago District the confined disposal facility, once filled and capped, would permanently isolate approximately 99.999% of all contaminants from the aquatic and terrestrial environments. Therefore, any potential contaminant/food chain impact to listed or candidate species (which are located many miles from the project area), would be insignificant, especially when compared to the no action alternative (where large quantities of contaminated sediments would continue to be available to the food chain of Indiana Harbor and Canal and nearshore, southern Lake Michigan well into the foreseeable future). No secondary, indirect, or cumulative impacts would occur to those listed or candidate species discussed in this biological assessment. Therefore, no alternative actions or special conservation measures are deemed necessary. In summary, no significant adverse impacts would occur to any federally listed or candidate species due to the proposed project.

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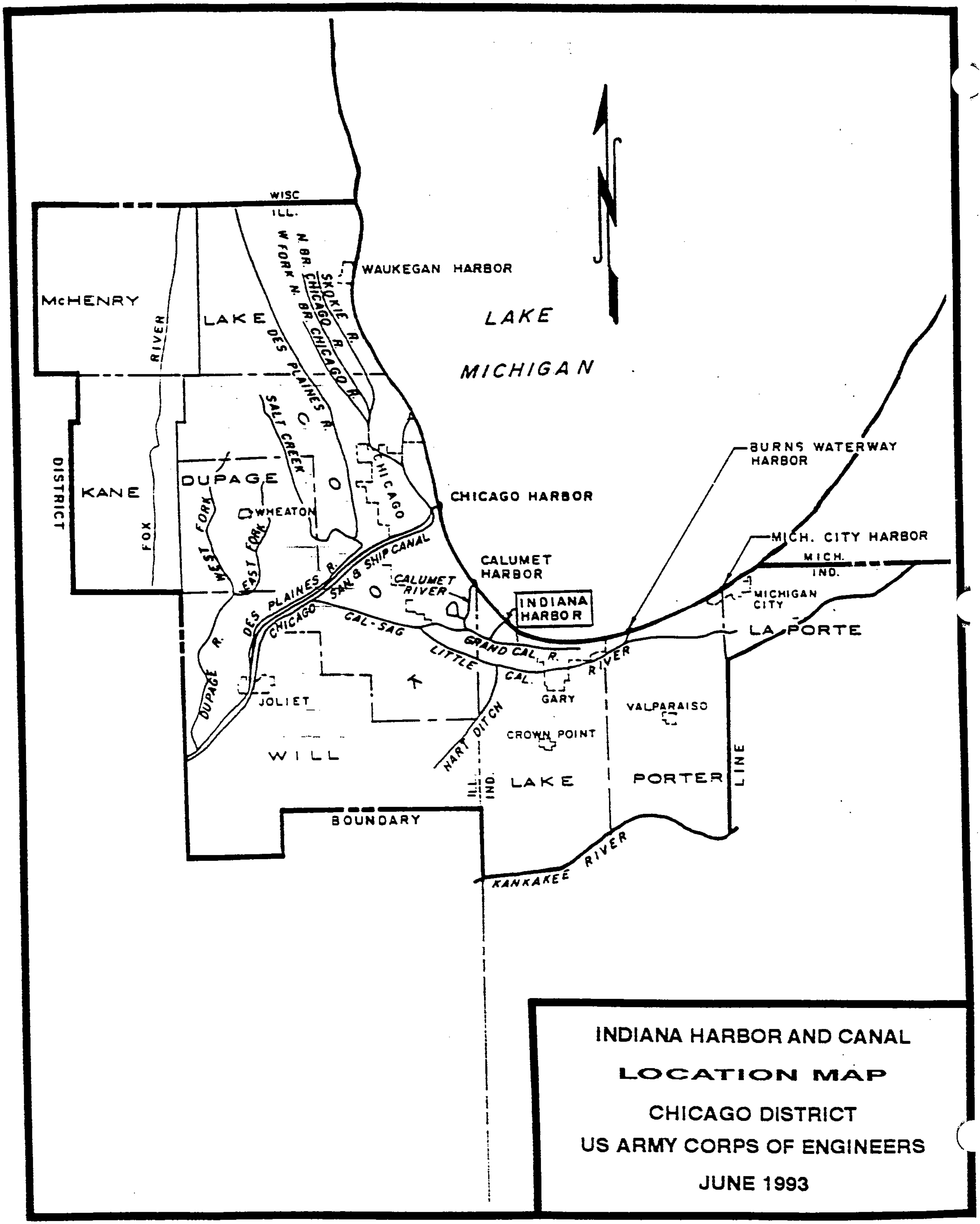


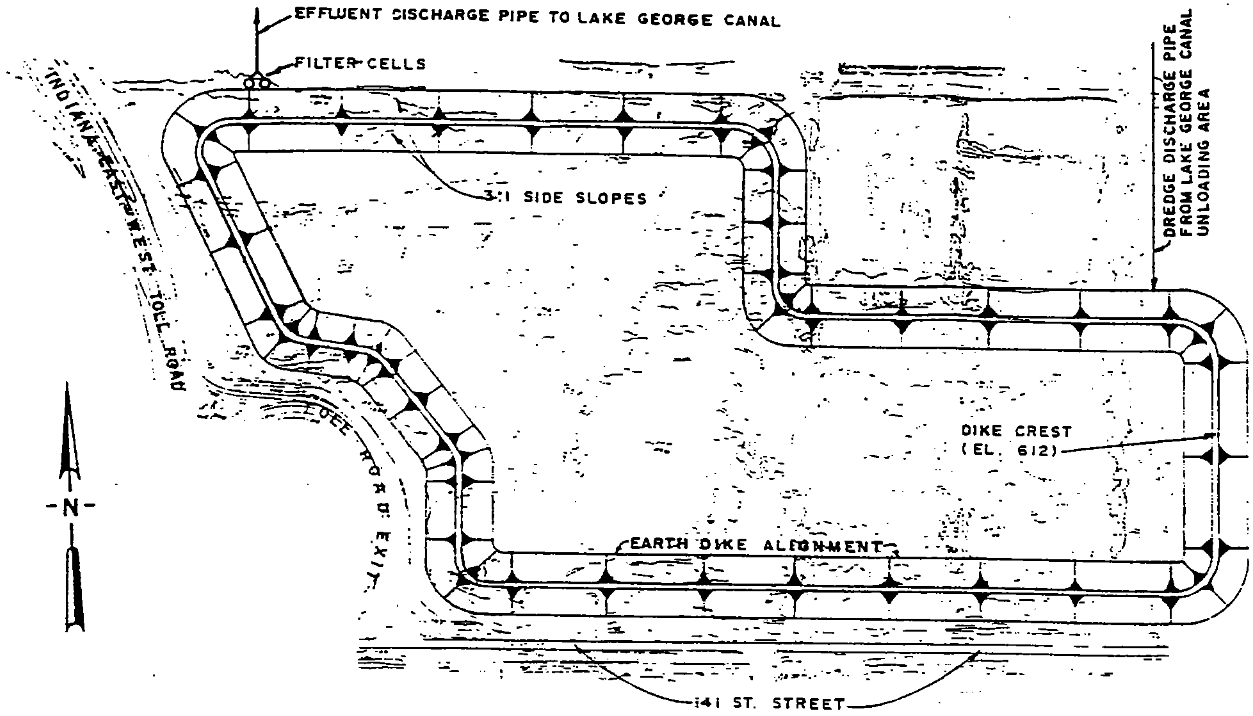
INDIANA HARBOR AND CANAL

LOCATION MAP

CHICAGO DISTRICT

US ARMY CORPS OF ENGINEERS

JUNE 1993



SITE 148

CREST OF DIKE ELEV. 612

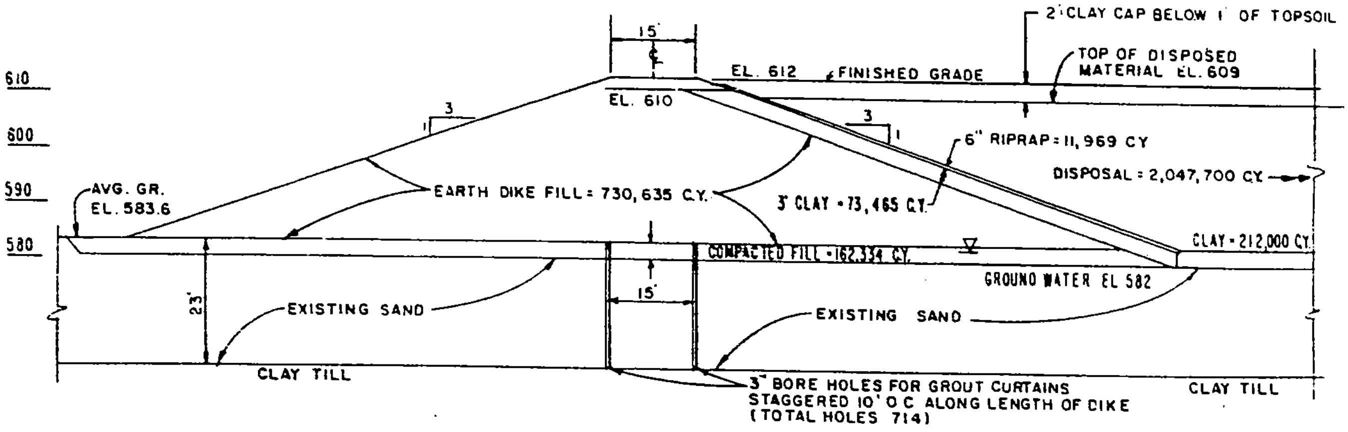
TOP OF DISPOSAL MATERIAL AT EL. 609

DISPOSAL CAPACITY = 2,047,700 C.Y.

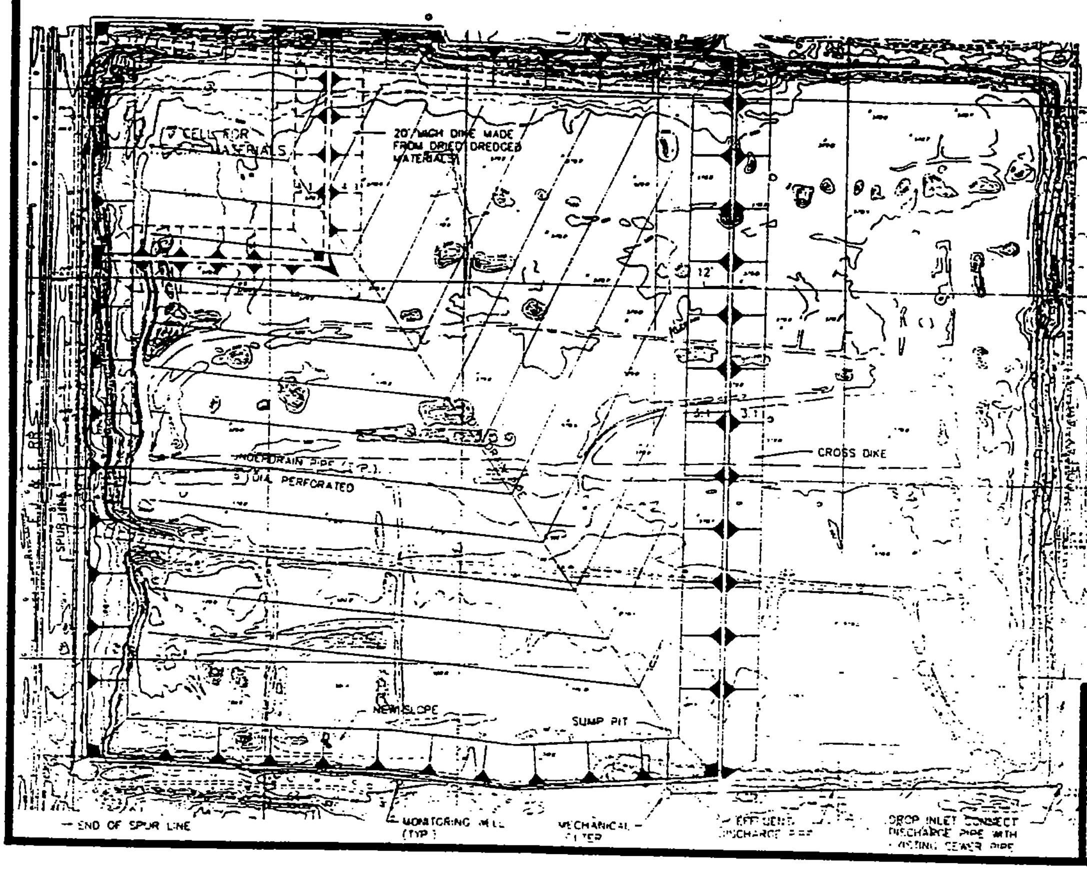
VOLUME OF EARTH DIKE FILL = 893,000 C.Y.

NATIONAL GEODETIC VERTICAL DATUM OF 1929

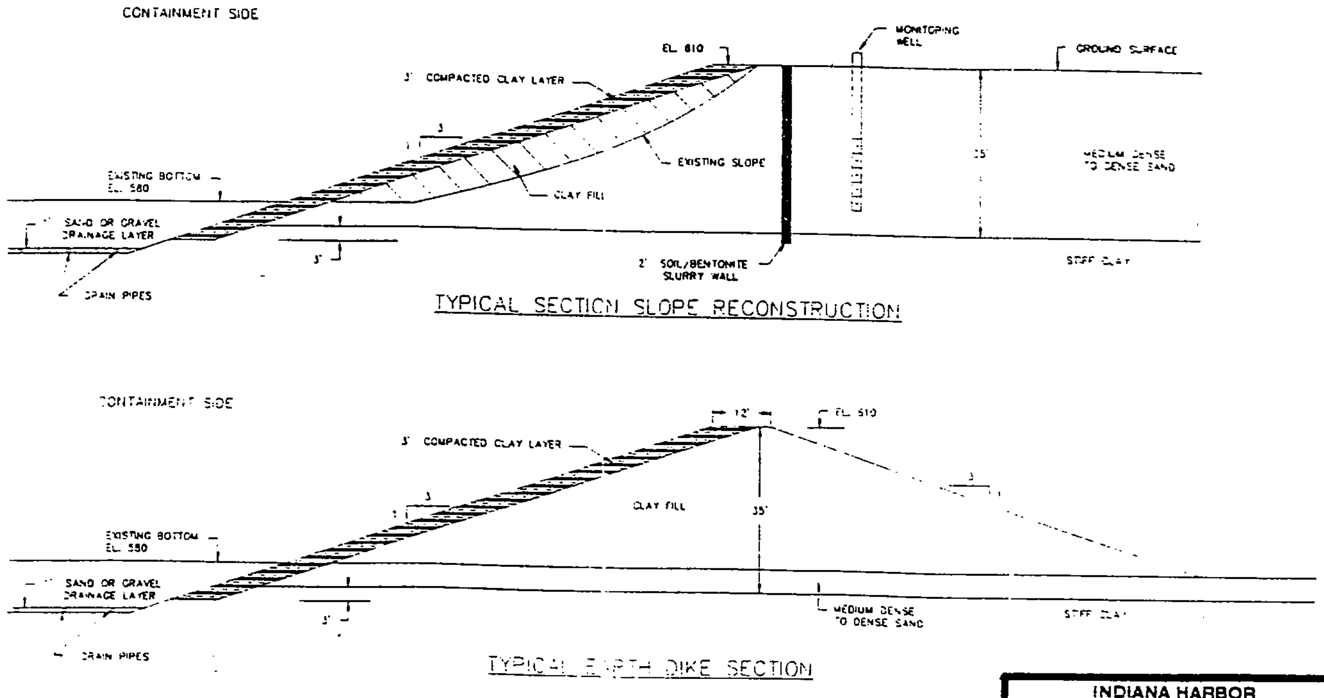
INDIANA HARBOR
CONFINED DISPOSAL FACILITY
SITE 14b CDF
HAMMOND, INDIANA
PLAN VIEW
CHICAGO DISTRICT
US ARMY CORPS OF ENGINEERS
MARCH 1983



INDIANA HARBOR
CONFINED DISPOSAL FACILITY
SITE 14b CDF
HAMMOND, INDIANA
TYPICAL EARTH DIKE SECTION
CHICAGO DISTRICT
US ARMY CORPS OF ENGINEERS
MARCH 1983



INDIANA HARBOR
CONFINED DISPOSAL FACILITY
J-PIT CDF
GARY, INDIANA
PLAN VIEW
CHICAGO DISTRICT
US ARMY CORPS OF ENGINEERS
APRIL 1989

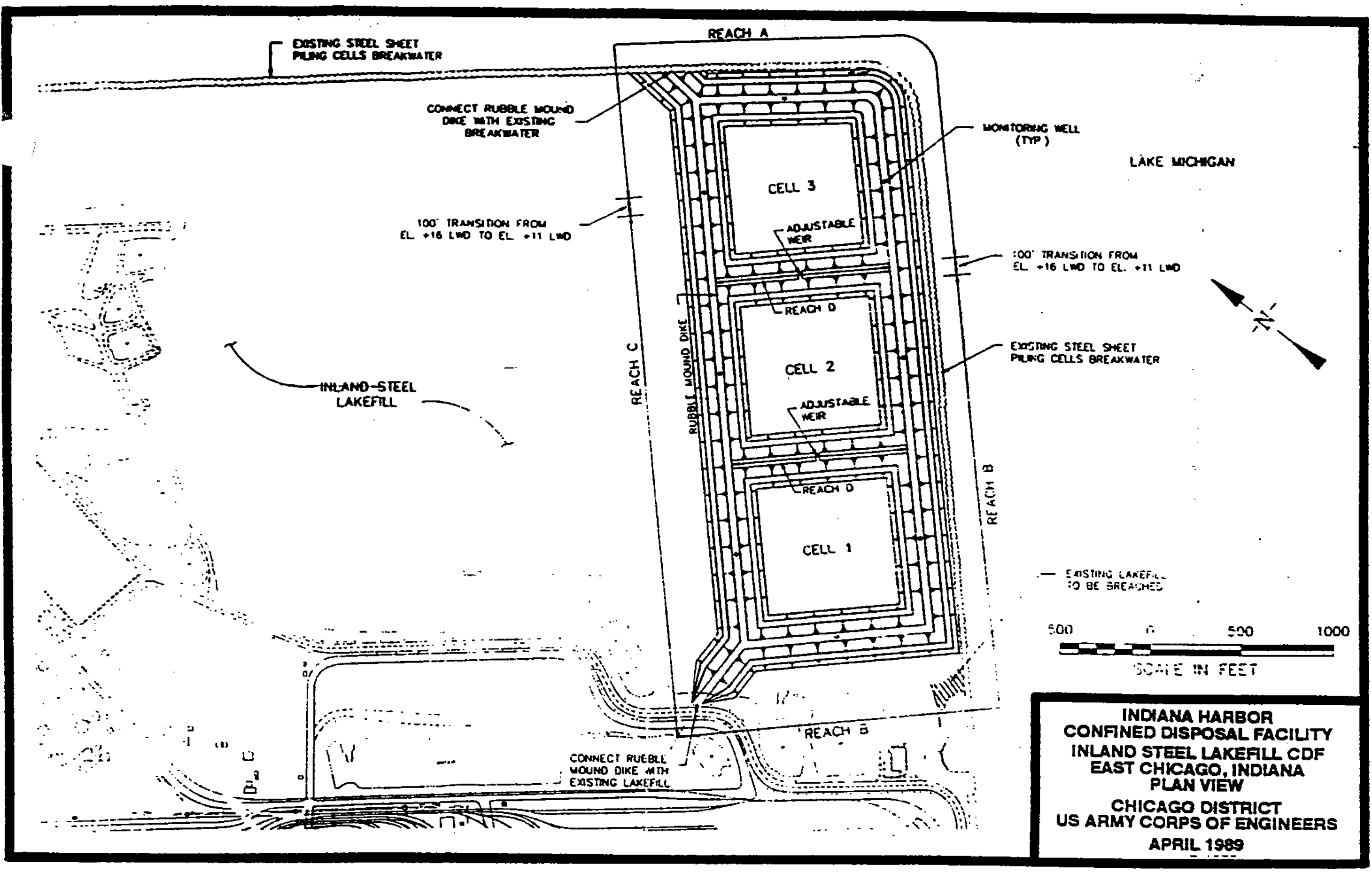


NOTES.

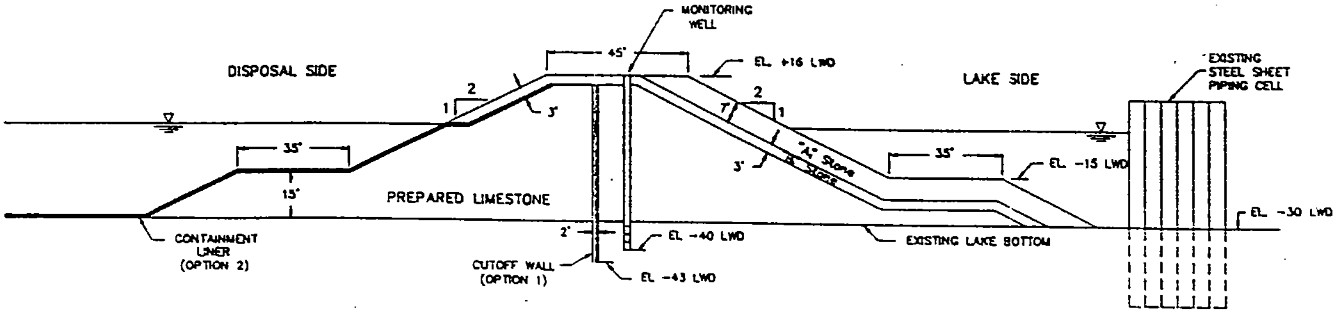
1. DRAINAGE LAYER AND DRAIN PIPES WILL BE SLOPED TOWARD A DEWATERING SUMP
2. GROUNDWATER IS APPROXIMATELY 10' BELOW GROUND SURFACE
3. CLAY FILL AND COMPACTED CLAY MATERIAL TO COME FROM EXCAVATION OF THE BOTTOM OF THE CONTAINMENT AREA

20 10 0 20 40
SCALE IN FEET

INDIANA HARBOR
CONFINED DISPOSAL FACILITY
J-PIT CDF
GARY, INDIANA
TYPICAL EARTH DIKE SECTION
CHICAGO DISTRICT
US ARMY CORPS OF ENGINEERS
APRIL 1989



INDIANA HARBOR
CONFINED DISPOSAL FACILITY
INLAND STEEL LAKEFILL CDF
EAST CHICAGO, INDIANA
PLAN VIEW
CHICAGO DISTRICT
US ARMY CORPS OF ENGINEERS
APRIL 1989



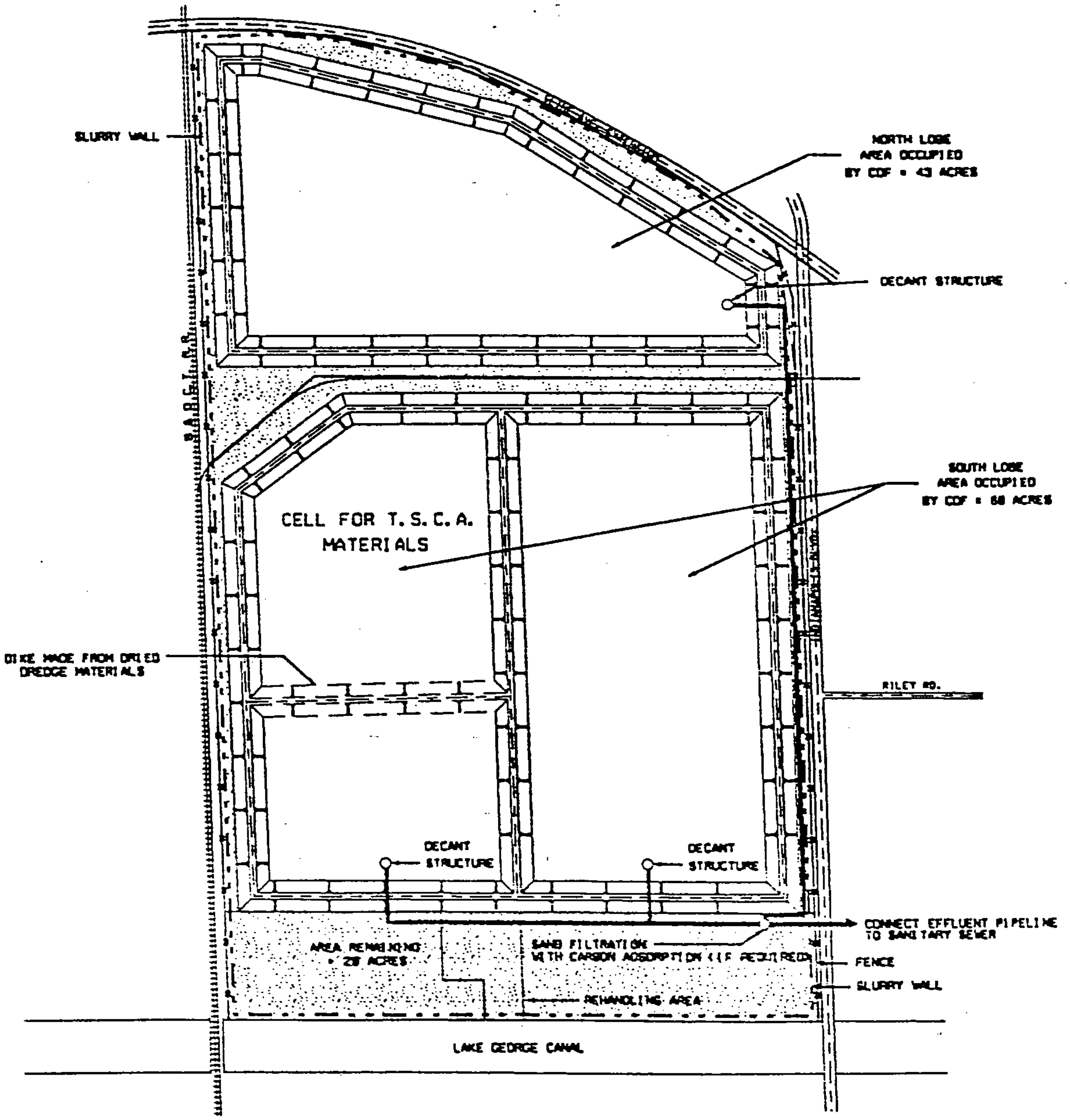
TYPICAL SECTION – REACH A

STONE SIZES

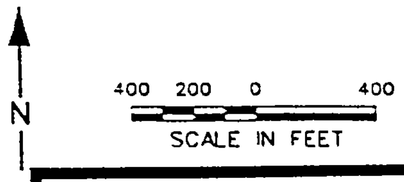
"A" STONE	1.3T	–	3T
"B" STONE	175LBS	–	600LBS

30 15 0 30 60
SCALE IN FEET

INDIANA HARBOR
CONFINED DISPOSAL FACILITY
INLAND STEEL LAKEFILL CDF
EAST CHICAGO, INDIANA
TYPICAL DIKE SECTION
CHICAGO DISTRICT
US ARMY CORPS OF ENGINEERS
APRIL 1989



NOTE: ONLY THE TWO SOUTH LOBES WOULD BE USED IN
ALTERNATIVE 1 - PARTIAL FEDERAL CHANNEL
DREDGING; THE NORTH LOBE WOULD NOT BE
CONSTRUCTED. THE NORTH LOBE PROPERTY WOULD
BE CAPPED WITH CLAY TO COMPLETE RCRA CLOSURE.
ALL THREE LOBES WOULD BE USED IN
ALTERNATIVE 2 - COMPLETE FEDERAL CHANNEL
DREDGING AND ALTERNATIVE 3 - COOPERATIVE
DREDGING PROGRAM.



INDIANA HARBOR
CONFINED DISPOSAL FACILITY
ECI SITE
RCRA CLOSURE/CORRECTIVE ACTION
WITH CDF PROJECT
PLAN VIEW
CHICAGO DISTRICT
US ARMY CORPS OF ENGINEERS
JUNE 1993

Plate D-5

INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES

APPENDIX D

SUPPLEMENTAL BIOLOGICAL ASSESSMENT
(Peregrine Falcon)

September 1995
Environmental and Social Analysis Branch
Chicago District
U.S. Army Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

SUPPLEMENTAL BIOLOGICAL ASSESSMENT
(Peregrine Falcon)

INDIANA HARBOR AND CANAL
OPERATION AND MAINTENANCE ACTIVITIES
LAKE COUNTY, INDIANA

Purpose and Need

The following Biological Assessment has been prepared under the authority of Section 7 of the Endangered Species Act, and in response to informal consultations with the Bloomington Field Office, U.S. Fish and Wildlife Service (USFWS) in their Fish and Wildlife Coordination Act letter of July 27, 1995. This letter was in response to the Chicago District, Army Corps of Engineers (USACE) letter of notification (dated June 22, 1995) of potential impacts to the endangered Peregrine Falcon (***Peregrinus falco***) from proposed Indiana Harbor and Canal operation and maintenance activities, in Lake County, Indiana.

Description of the Project Area

The Indiana Harbor and Canal federal navigation project is located in a highly urban/industrial area of northwestern Lake County, Indiana (Plate 1). The project area is within the Grand Calumet River basin, and drains into the southern portion of Lake Michigan at East Chicago, Indiana. Steel mills, oil refineries, power plants, and other industries are found in this area. These industries are point sources for a variety of pollutants and, in conjunction with other point sources (i.e., sewage treatment plants) and non-point sources (surface runoff, air pollution deposition, etc.), have greatly degraded the terrestrial and aquatic environments in and immediately adjacent to the Indiana Harbor and Canal.

Description of the Project

The proposed project (see attached summary for details) involves operation and maintenance activities, including dredging and disposal operations, to maintain a viable, navigable channel in the federally controlled portions of the Indiana Harbor and Canal (IHC). This project provides a sheltered harbor and a deep-draft channel for commercial navigation traffic. The IHC is a major facility supporting the commerce and industry of northwest Indiana. Sediments which enter the Grand Calumet River/Indiana Harbor and Canal (GCR/IHC) waterway deposit in the federal channel, reducing depths, and restricting the movements of navigation traffic. In order to maintain authorized channel depths, these sediments must be dredged periodically.

The navigation channel at Indiana Harbor and Canal has not been maintained since 1972 because an economically feasible and environmentally acceptable method of dredged material disposal has not been approved. There are an estimated one million cubic yards of backlog dredging at this harbor. This is causing deep-draft navigation difficulties and associated increases in the transportation costs of waterborne commerce. In addition, between 100,000 and 200,000 cubic yards of polluted sediments are being discharged annually to Lake Michigan.

Because of the highly urbanized and industrial nature of the GCR/IHC watershed, the bottom sediments are contaminated with a variety of pollutants. The GCR/IHC has been designated as a Great Lakes "area of concern" by the International Joint Commission (IJC). In January 1988, the Indiana Department of Environmental Management (IDEM) released a draft Remedial Action Plan (RAP) to address water quality, aquatic habitat, and use impairment issues related to this area of concern. In-place sediment contamination was identified as a significant environmental problem that is adversely impacting water quality and aquatic life in the waterway and Lake Michigan.

The draft RAP outlined options for remediating the sediment contamination problem. The completion of the USACE EIS on Indiana Harbor and Canal project maintenance dredging was identified as "an essential step toward implementation of the GCR/IHC Remedial Action Plan".

Because these sediments are contaminated, they will have to be disposed of in a confined disposal facility (CDF). Five potential CDF sites are being evaluated in detail at the present time. One of the proposed CDF sites (Recommended Plan, Plate 2), ECI (Energy Cooperative, Inc.), is located about 1/2 mile from a federal endangered species, Peregrine Falcon, nesting site. The Peregrine Falcon is the subject of this biological assessment.

Species Distribution and Biology

The project area is within the general range of the Peregine Falcon. The Peregrines reportedly use Miller Beach along Lake Michigan, approximately seven miles east of Indiana Harbor, during migration. In addition, young falcons raised in captivity have been successfully reestablished at several locations in northeastern Illinois from 1986 to 1988 as part of USFWS's reintroduction efforts. As a result of these efforts, a pair of Peregrines are nesting on the underside of the Riley road up-ramp to Cline Avenue (Route 912) high-rise bridge. This bridge is located just north of the Indiana Harbor and Canal, and about 1/2 mile east of the ECI disposal site (Plates 2 & 3).

Peregrine Falcons forage primarily on birds in open areas, often near water. In the project area, it has been observed by U.S. Fish and Wildlife (USFWS-Bloomington, IN office) personnel feeding on grebes and other waterfowl which swim and feed on these canals. Its breeding is currently limited to buildings, bridges and other man-made structures in the Chicago Area. No critical habitat has been designated for this species.

As a result of reintroduction efforts by the USFWS, and a ban on organochlorine pesticides (e.g., aldrin and dieldrin), regional populations of Peregrine Falcons have stopped declining. In fact, the recovery program has been so successful, that the USFWS has proposed removing the Peregrine Falcon from the its list of endangered and threatened wildlife (Federal Register, Volume 60(126): pp. 34406-34409).

Project Area Inspections

The project area, including all potential disposal sites, have been visited by biologists of the USACE. During these visits, a Peregrine Falcon was observed feeding on a pigeon on one of Cline Avenue's concrete support structures, about 100 yards north of the Indiana Harbor Canal and 1/2 mile east of the ECI site. Based on discussions with Mr. Dan Sparks of USFWS-Bloomington, IN, USFWS personnel have observed the subject Peregrines at their nesting site, and at the canals during their pollution studies in the project area.

Expected Impacts

The proposed project will involve several episodes of dredging in Indiana Harbor and Canal, and construction and filling of a confined disposal facility adjacent to the canal, over a period of several years. The confined disposal area will be fenced and screened (according to plans developed in consultation with USDA animal control staff in Indianapolis) before capping, to prevent uptake of contaminants by wildlife. Additionally, any standing water in the CDF will be removed by associated drainage systems to prevent attraction of wildlife to these sites.

Because the nesting site is about 1/4 mile from the closest proposed dredging area, and the dredging area is already highly industrialized, it is unlikely that there will be any adverse affects to the Peregrine Falcon from the noise associated with the dredging activities. Increases in noise during construction of the ECI CDF, or disposal activites, should not adversely impact the nesting activities of these Peregrines, since the nest is about 1/2 mile away from the eastern boundary of this disposal site. Furthermore, this nesting site is already subject to considerable noise from road and rail traffic passing over and under the nest, respectively.

Another concern would be the potential for increased uptake of PCB's and other pollutants by the Peregrines, from resuspended contaminated sediments, particularly in the canal portions of the project. Grebes and other diving ducks apparently feed and swim in these canals, and Peregrines feed on these waterfowl. USFWS studies, currently underway, indicate that these waterfowl are already contaminated with toxic pollutants. However, the resultant resuspension of contaminated sediments is not likely to have any adverse affect on the Peregrines for two reasons. First, because of the short duration of the resuspension of these sediments, it is not likely that there will be any significant increase in toxic pollutants in the waterfowl that feed in these canals. Second, it is likely that the dredging activities will keep potential prey for the Peregrine Falcon out of the immediate area of these activities, further reducing the likelihood of significant increases of contaminants in these prey.

Sediment analyses in these canals indicate that discarded petroleum products, from adjacent refineries, have accumulated in these sediments. Upon dredging these petroleum products will be released and will float to the surface. According to USFWS-Bloomigton, these "oils" are very toxic to Peregrine eggs. Therefore, if a Peregrine becomes contaminated with these "oils" while preying on waterfowl in these canals, its eggs could be exposed to these toxic pollutants during nesting activities. Contamination of the eggs by these "oils" could inhibit egg development and hatching, thereby affecting reproductive success of this pair of Peregrines. For the two reasons discussed in the previous paragraph, it is unlikely that there will be sustained exposure to these "oils" by the Peregrine Falcons' prey. Furthermore, it is more likely that the viability of these eggs, and the Peregrines themselves, will be affected by their feeding habits. Peregrine Falcon waterfowl prey feed on benthic organisms (mostly oligochaetes) in the canals which contain elevated levels of toxic pollutants. Ingestion of these elevated pollutants on a daily basis is a more serious threat than periodic potential exposure to prey contaminated with toxic "oils".

Therefore, the USACE expects no adverse impacts or "no incidental taking" of the Peregrine Falcon. Given the current highly polluted state of the sediments in the project area, the project will markedly improve the local environmental conditions. This would have a beneficial impact on these nesting Peregrine's by reducing its prey's exposure to toxic pollutants, thereby enhancing the reproductive success of this pair of Peregrine Falcons.

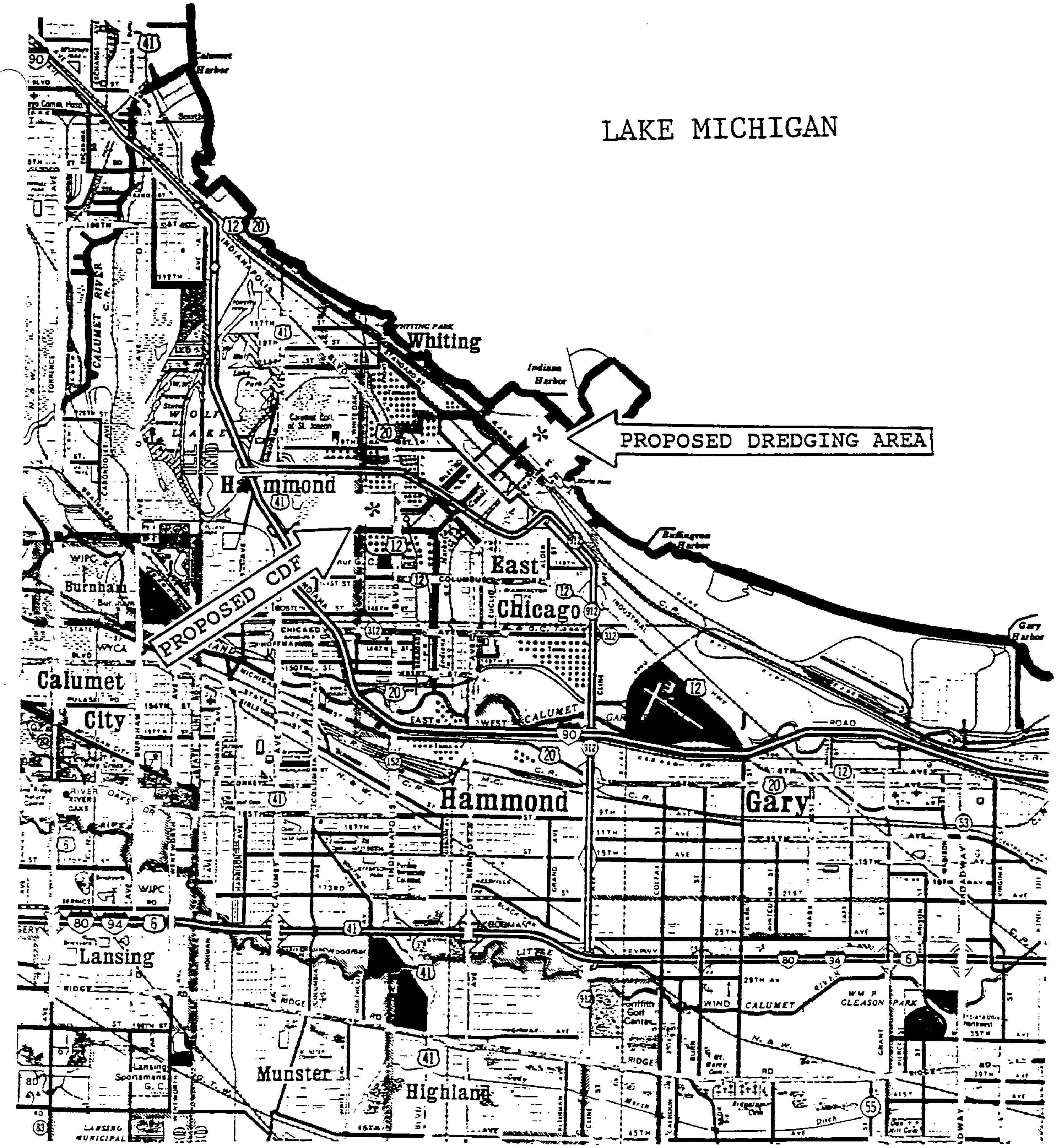


PLATE 1 - VICINITY MAP
INDIANA HARBOR AND CANAL
LAKE COUNTY, INDIANA

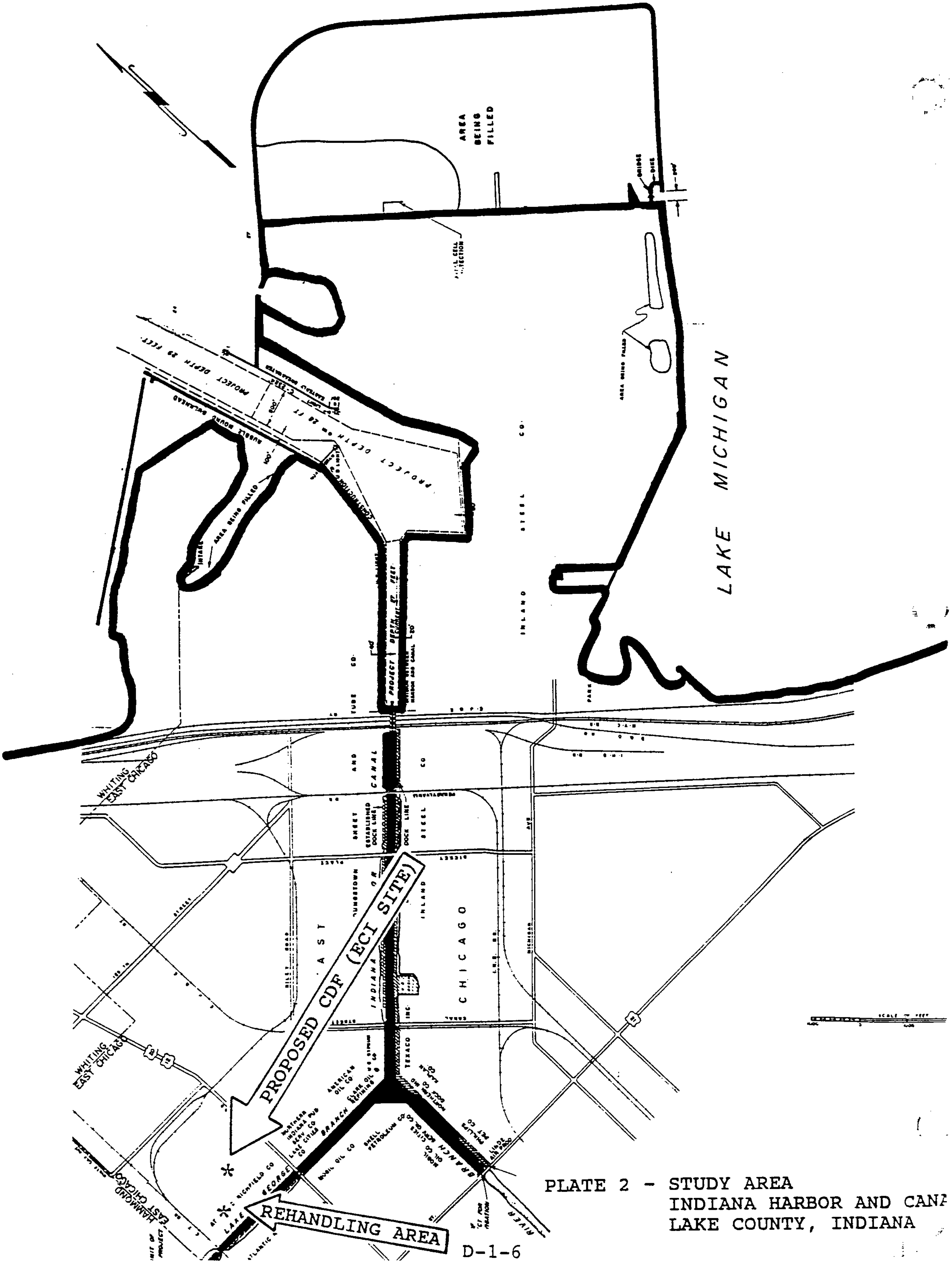


PLATE 2 - STUDY AREA
INDIANA HARBOR AND CAN
LAKE COUNTY, INDIANA

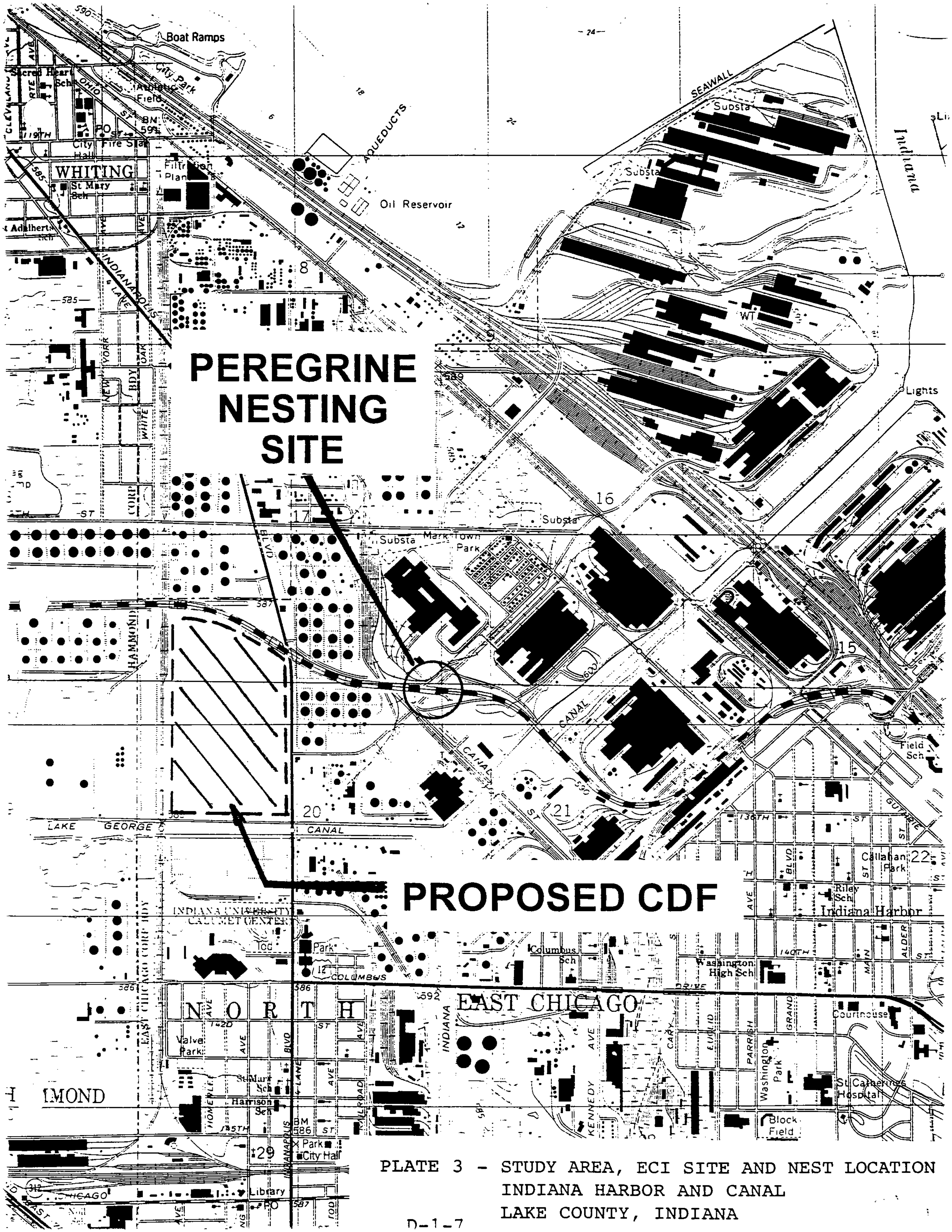


PLATE 3 - STUDY AREA, ECI SITE AND NEST LOCATION
INDIANA HARBOR AND CANAL
LAKE COUNTY, INDIANA

INDIANA HARBOR & CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES IN LAKE COUNTY, INDIANA

APPENDIX E

SEDIMENT QUALITY

April 1995
Environmental Engineering Section
Chicago District
111 North Canal Street
Chicago, Illinois 60606

TABLE OF CONTENTS

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1. PURPOSE AND OBJECTIVE

1.1 This appendix will provide information about the bottom sediments within Indiana Harbor and Canal that must be dredged in order to restore and maintain the navigation channel at authorized depths. This appendix will first describe the laws and regulations which govern the disposal of dredged sediments. Next, the types of laboratory testing methods, criteria, and decision making procedures will be discussed. Finally, the test data compiled for the Indiana harbor and Canal sediments will be examined and the disposal alternatives and controls summarized.

2. HISTORICAL BACKGROUND

2.1 The Indiana Harbor and Canal (IHC) are part of a small highly industrialized watershed in northwestern Indiana. The Grand Calumet River discharges into Lake Michigan via the Indiana Harbor and Canal. The harbor and canal serve deep draft commercial navigation from the Great Lakes. The project area is shown on plate 1 in the main body of the EIS.

2.2 The U.S. Army Corps of Engineers (USACE) is authorized to maintain federal navigation channels in the harbors and canals by periodic dredging. Dredging was first performed to remove materials deposited by littoral drift and the process of delta formation that periodically blocked usage of natural harbors. The need for the construction of larger, deeper harbors and connecting channels resulted from the advent of larger vessels. Natural shoaling processes tended to fill these larger harbors and channels so that periodic dredging is now required in many areas to maintain safe, navigable harbors and channels.

2.3 Rapid industrialization and urbanization of the project area was accompanied by untreated discharges from industries and municipalities into the IHC. The sediments of the harbor and canal are predominantly fine-grained materials that have a high affinity to adsorb many pollutants. Consequently, deposited sediments contain many of the pollutants discharged to the waterway.

2.4 The bottom sediments in the Indiana Harbor and Canal have been sampled by the U.S. Environmental Protection Agency (USEPA) and the USACE. The USEPA collected grab samples from the federal channel in 1977, and collected core samples in 1990, 1991, and 1992. The USACE collected grab samples most recently in 1987, 1988, and 1993 (under contract for USEPA). Sediment samples have been collected by other federal and state agencies, and by university researchers. Analyses performed on the collected samples included bulk chemical, standard elutriate, EP-toxicity, TCLP and PCB analyses and determinations of physical and engineering properties. The sampling and testing revealed that the bottom sediments range from oily silt to grey sand and gravel. In addition, the sediments were found to contain high levels of heavy metals, organics, PCBs and nutrients. A portion of the project sediments have been found to contain sufficiently elevated concentrations of PCBs for their disposal to be regulated under the Toxic Substances Control Act (TSCA). In addition, a portion of the project sediments were determined by USEPA and the Indiana Department of Environmental Management (IDEM) to be "presumptively hazardous." These materials will not be dredged by the USACE. These materials will be addressed as part of the site specific remedial activities in the vicinity of the Federal Project. If dredged without further testing, the presumptively hazardous sediments would be treated in accordance with the standards of RCRA Subtitle C prior to land disposal.

2.5 The USEPA Region V developed guidelines in 1977 for the classification of sediments according to the level of certain pollutants in the sediments. Based on these guidelines, other available biological guidelines, and USEPA policy, testing of the sediments determined that the dredged material is not suitable for open-lake disposal. Consequently, other disposal alternatives for the sediments must be evaluated to determine the most appropriate method. Disposal options include: a confined disposal facility (CDF), contained aquatic disposal (CAD), and a number of different treatment options that may be used to reduce volume and/or contamination of sediments prior to disposal.

3. DREDGED MATERIAL DISPOSAL REGULATIONS

3.1 REGULATORY REQUIREMENTS

3.1.1 The National Environmental Policy Act (NEPA) of 1969 required all Federal agencies to prepare an environmental assessment (EA) or an expanded environmental impact statement (EIS), depending upon impact significance, for all proposed major Federal actions. Section 309 of the Clean Air Act directs the USEPA to review and comment in writing on all impact statements.

3.1.2 The USACE prepares an EA/EIS for its proposed dredging and disposal operations. The impact statement is reviewed by the USEPA, U.S. Fish and Wildlife Service, state environmental and regulatory agencies, as well as local municipalities and private citizens.

3.1.3 The required permits for this project are discussed in the main body of the EIS.

3.2 USEPA POLLUTIONAL CLASSIFICATION

3.2.1 The regulation of dredge and fill activities made necessary the development of methods for assessing the environmental effects of dredging and disposal of contaminated bottom sediments. A number of analytical methods have been used for this assessment, including physical analysis, bulk chemical analysis, elutriate analysis, filtering and leaching analysis, static and suspended-phase bioassays, and bioaccumulation analysis.

3.2.2 Ideally, the methods used to evaluate the effect of a proposed dredging or disposal operation should simulate the physico-chemical conditions of the operation. Toward this end, standard elutriate tests and static phase bioassays were developed to simulate the effects of open-water disposal of dredged materials. Suspended-phase bioassays can be used to simulate the effects of increased turbidity from dredging on indigenous organisms. Modified elutriate, filtering and leachate tests can simulate the desorption of contaminants from sediments within a confined disposal facility.

3.2.3 Section 404 of the Clean Water Act directs the USACE to regulate the disposal of dredged materials using criteria promulgated by USEPA. From historical Great Lakes harbor sediment data, the USEPA Region V developed guidelines for determining disposal methods for dredged materials from Great Lakes harbors and waterways. These interim guidelines established a classification scheme for sediments based on bulk chemical concentrations of nineteen parameters. The 1977 USEPA Region V "Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments" are contained in table E-1. Note that there are additional biologically-based guidelines for sediment including those developed by NOAA and the Province of Ontario; in general, these guidelines provide more stringent levels as protective of various biological endpoints.

3.2.4 Although these guidelines recognized the "variability of sampling and analytical techniques" and recommended consideration of "additional factors" in sediment classification, they did set rigid numerical guidelines for mercury and PCBs. These were established because both are directly available for bioaccumulation by aquatic organisms and transfer up into the food chain.

3.3 MANAGEMENT STRATEGY FOR THE DISPOSAL OF DREDGED MATERIAL

3.3.1 The 404 guidelines provide general regulatory guidance and objectives but not a specific technical framework for evaluating or managing contaminated sediment that must be dredged. The guidelines cannot adequately address the many technical factors that must be considered when removing and disposing of contaminated sediments. Since the nature and level of contamination vary greatly on a project-to-project basis, the appropriate method of disposal may involve any of several available disposal alternatives. In addition, control measures to manage specific problems associated with the presence or mobility of contaminants may be required as part of any given disposal alternative.

Table E-1: USEPA 1977 Guidelines for Pollutional Classification of Great Lakes Harbor Sediments

PARAMETER	NONPOLLUTED	MODERATELY POLLUTED	HEAVILY POLLUTED
Volatile Solids (%)	< 5	5-8	> 8
Chemical Oxygen Demand	< 40,000	40,000-80,000	> 80,000
Oil and Grease	< 1,000	1,000-2,000	> 2,000
Total Kjeldahl Nitrogen	< 1,000	1,000-2,000	> 2,000
Ammonia	< 75	75-200	> 200
Cyanide	< 0.10	0.10-0.25	> 0.25
Manganese	< 300	300-500	> 500
Phosphorous	< 420	420-650	> 650
Arsenic	< 3	3-8	> 8
Barium	< 20	20-60	> 60
Cadmium	*	*	> 6
Chromium	< 25	25-75	> 75
Copper	< 25	25-50	> 50
Iron	< 17,000	17,000-25,000	> 25,000
Nickel	< 20	20-50	> 50
Lead	< 40	40-60	> 60
Zinc	< 90	90-200	> 200
Mercury	*	*	> 1
PCBs	*	*	> 10

All concentrations are mg/kg, unless otherwise noted.

3.3.2 An overall management strategy for disposal of dredged material was developed by the USACE Waterways Experiment Station (WES) to supplement the 404 regulatory guidance (Francingues, et. al. 1985). This management strategy provides a framework for decision making to select the best possible disposal alternatives and to identify appropriate control measures to offset problems associated with the presence of contaminants.

3.3.3 The dredged material disposal management strategy developed for the USACE dredging program addresses a wide range of dredged material characteristics, dredging techniques, and disposal alternatives. The management strategy considers the nature of the sediment to be dredged, potential environmental impacts of dredged material disposal, nature and degree of contamination, dredging equipment, project size, site-specific conditions, technical feasibility, economics, and other socioeconomic factors.

3.3.4 A flow chart of the technical management strategy is shown on figure E-1. The two major features of the technical management strategy are consideration of disposal alternatives and steps required for selection and implementation of appropriate disposal management strategies. The steps identified are as follows:

a. Conduct an initial evaluation to assess contamination potential

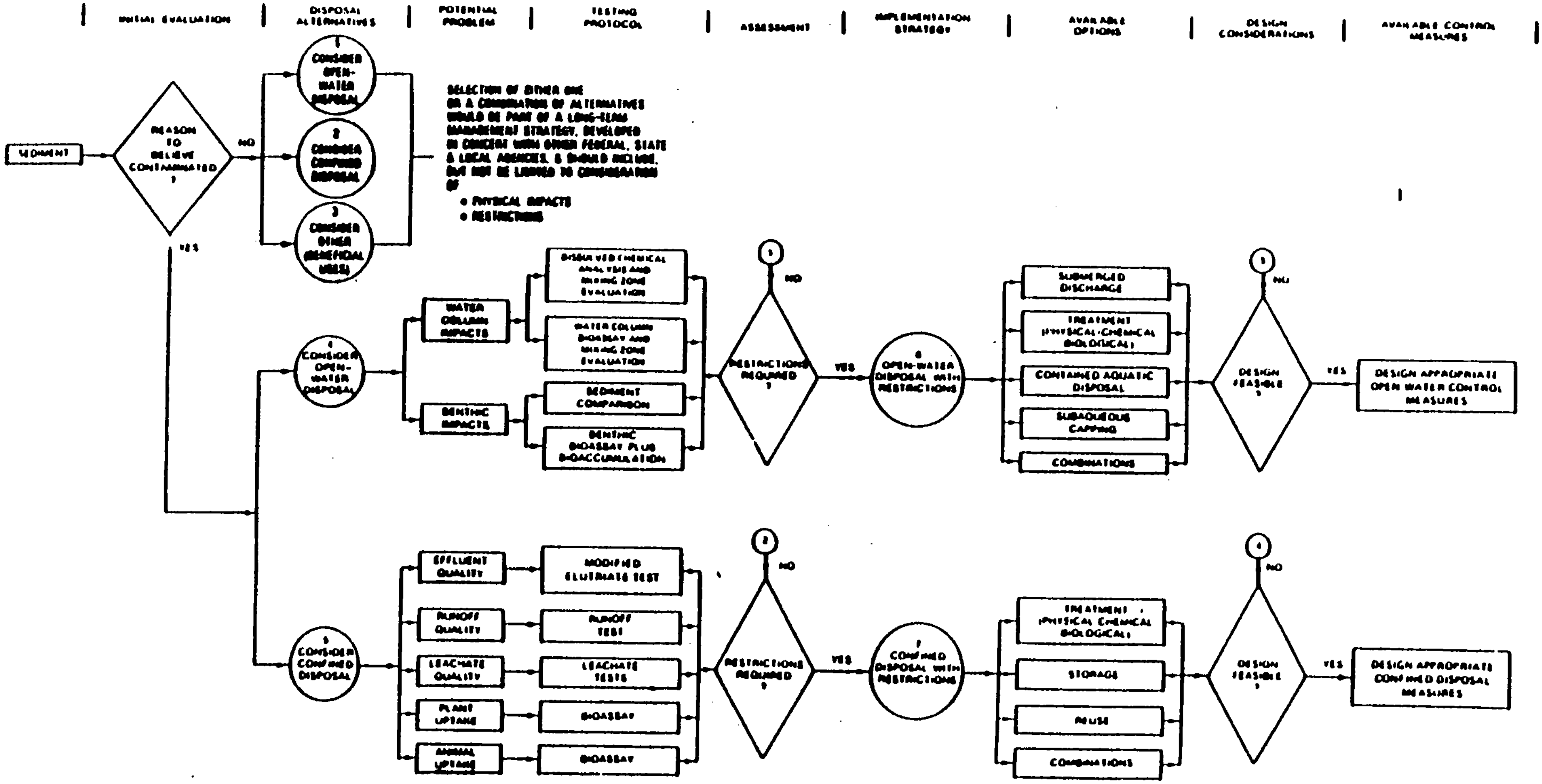


Figure E-1: Management Strategy Flowchart

b. Select a potential disposal alternative.
c. Identify potential problems associated with that alternative.
d. Apply appropriate testing protocols.
e. Assess the need for disposal restrictions.
f. Select an implementation plan.
g. Identify available control options.
h. Evaluate design considerations for technical and economic feasibility.
i. Select appropriate control measures.

This management strategy was applied to the evaluation of the Indiana Harbor and Canal sediments to aid in the selection of an appropriate disposal method, and to determine the control measures necessary during dredging and disposal operations, as well as for maintenance after the project has been completed. This appendix will follow the Management Strategy to the completion of the testing protocols. The Environmental Engineering Appendix (Appendix F) will complete the Management Strategy from this point.

4. INITIAL EVALUATION

4.1 The initial evaluation is intended to establish a "reason to believe" that the sediment in a waterway may be contaminated, based on watershed characteristics, water-use practices, or historic sediment quality data. Although the existence of tamination in sediments within Indiana Harbor and Canal is well established, and for purposes of decision-making an initial evaluation is unnecessary, the following evaluation was completed to present relevant information about the waterway and the existing and historic conditions of sediment quality.

4.2 WATERSHED CHARACTERISTICS

4.2.1 The Grand Calumet River and Indiana Harbor Canal (GCR/IHC) drain approximately 67 square miles of highly urbanized and industrialized areas in northwestern Indiana and discharges to Lake Michigan at Indiana Harbor. The cities of Gary, Hammond, Whiting, and East Chicago are within this watershed. Major industries in the watershed include three large steel mills (USX, Inland, and LTV), several petrochemical storage and refinery installations (including Standard Oil, Atlantic Richfield, Phillips Pipeline, and Texaco). Other industries include U.S. Gypsum and Dow Chemical.

4.2.2 The topography of the area is flat, except for remnant beach ridges, man-made landfills and borrow pits. The Grand Calumet River basin lies within the Calumet Lake Plain. Industrial development of this glacial lakebed has resulted in the leveling of high dunes and ridges and the filling of the lowlands and ponds with sand and steel mill slag.

4.2.3 For the most part, the GCR/IHC is a man-made waterway. The GCR was deepened and widened during the late 1800's to facilitate drainage of wetland areas for industrial and residential development. The Indiana Harbor Canal was constructed by local industries for navigation and to allow for the drainage of the GCR to Lake Michigan. The Indiana Harbor deep-draft navigation project was authorized by the River and Harbor Act of 1919. Authorized depths in the federal navigation channels are from -22 to -29 feet Low Water Datum. Channel widths range from 160 to 800 feet. A more detailed discussion on the history of the GCR/IHC is provided in the main body of the EIS.

4.2.4 As a watercourse, the Grand Calumet River originates with the discharge from the USX steel mill in eastern Gary. The east arm of the river flows approximately 8 miles in a westerly direction, where it joins the west arm and turns north into the Indiana Harbor Canal. On the west arm of the Grand Calumet River, there is a natural divide between the portion draining east to the IHC and the portion draining west to the Calumet Sag Channel (which flows to the Illinois River). About 2 miles of the west arm drains to the IHC.

4.2.5 The Grand Calumet has a very limited natural flow. More than 90% of the dry weather flow in the Grand Calumet River/ Indiana Harbor Canal originates as treated municipal and industrial wastewater, industrial cooling and process water. River currents are generally sluggish, often stagnant in the west arm of the Grand Calumet River. Water depths in the GCR are generally less than 8 feet. Currents in the IHC are influenced by the fluctuations of lake levels at the harbor mouth.

4.3 SOURCES OF SEDIMENTS AND POLLUTANTS

4.3.1 The Grand Calumet River/Indiana Harbor and Canal, like all waterways, carries suspended solids with its flow. Sedimentation is a natural process resulting from the settling of suspended solid particles onto the channel bottom. These suspended solids are discharged to the river from municipal and industrial point sources, urban runoff, combined sewer overflows, and from scour of upstream banks and bottom materials. Sediments transported by the river settle out in the channel as stream velocity diminishes, with a portion of the sediments discharged to the lake.

4.3.2 There are 39 permitted outfalls on the Grand Calumet River and Indiana Harbor and Canal. These outfalls are point sources of sediments and pollutants. In addition to these controlled point sources, the sanitary districts of Gary, Hammond and East Chicago have combined sewer systems which overflow to the Grand Calumet River/Indiana Harbor Canal even during relatively light rainfall. Surface runoff from unsewered areas also contributes to the pollution and sediment loading of the waterway.

4.3.3 The USACE has estimated that roughly 130 million pounds of sediments enter the GCR/IHC each year (see Appendix C). Bathymetric surveys of the federal navigation channel indicate that there has been very little new accretion of sediment in recent years. This suggests that there is a near balance (or equilibrium) of sediments coming in and going out of the GCR/IHC.

4.3.4 The Indiana Department of Environmental Management (IDEM) has initiated two interconnected programs to remediate the exiting environmental problems of the GCR/IHC watershed. The Environmental Action Plan (EAP) and Remedial Action Plan (RAP) are designed the identify existing environmental problems in the watershed and provide a vehicle for affecting remedial actions. Both plans address the sources of pollution and sediments to the GCR/IHC described above and target remedial options for dealing with the in-place sediment contamination.

4.4 HISTORIC SEDIMENT DATA

4.4.1 The bottom sediments within the Indiana Harbor and Canal are among the most intensively sampled and tested sediments in the country. Over 300 sediment samples have been collected since 1977. Sediment samples have been collected from the stations shown on plate 1. Virtually every existing sediment testing protocol has been applied to Indiana Harbor sediments. In fact, a number of new testing procedures were developed as part of research conducted by the USACE on IHC sediments (Environmental Laboratory, 1987).

4.4.2 Because of the preponderance of sampling and testing data available on IHC sediments, a portion of this data will be discussed here and the remainder discussed in a later section of this Appendix. Here, as part of the Initial Evaluation step of the Management Strategy, we summarize all of the sediment sampling investigations that have been conducted, but describe only those laboratory results which are part of environmental regulatory criteria.

4.4.3 Regulatory Testing Protocols

4.4.3.1 The USEPA 1977 Region V "Guidelines for Pollutional Classification of Great Lakes Harbor Sediments" are based on bulk chemical analysis. In addition, physical and standard elutriate analyses are used in the Great Lakes for evaluations under Sections 404 and 401 of the Clean Water Act. Other environmental laws have testing criteria which may or not be applicable to dredged materials.

4.4.3.2 Bulk Chemical Analysis.

4.4.3.2.1 Bulk analysis employs a complete digestion of the sediment sample by a strong acid/base or organic solvents. The digest is then analyzed, and the total content of chemical species is determined. Results are compared against the range of values developed by USEPA Region V to determine the level of contamination and determine if the materials are suitable for open-lake disposal.

4.4.3.3 Physical Analysis.

4.4.3.3.1 Physical analysis of sediment samples consists of a number of different tests to determine the following properties: grain size distribution, liquid limit, plastic limit, plasticity index, specific gravity, organic content, water content and salinity. Sieve analysis is used to determine the particle sizing of the sediment and to classify it according to soil type (i.e. sand, silt, clay, etc.).

4.4.3.4 Standard Elutriate Analysis.

4.4.3.4.1 The standard elutriate test is a short term sediment-leaching procedure. The test method is to combine one part by volume of sediment with four parts of site water. The suspension is agitated at maximum speed on a mechanical shaker for thirty minutes. The suspension is allowed to settle for one hour, then centrifuged, and filtered and the filtrate is analyzed. The standard elutriate test was specifically developed to simulate the release/desorption of chemical con.pl 66 stituents during hydraulic dredging and open water disposal. The test provides information on the potential effects of dredging and disposal operations on water quality.

4.4.3.5 EP-Toxicity and TCLP Analysis.

4.4.3.5.1 The EP-toxicity test is similar to the TCLP test procedure except that the sample is leached under controlled acid conditions. In 1983, at the request of the Indiana Board of Health, five composite samples of the project sediments were analyzed using the RCRA EP-toxicity test. The EP-toxicity test was used under RCRA to define hazardous waste characteristic of toxicity until September 1990, when it was superseded by the Toxicity Characteristic Leaching Procedure (TCLP). All of the 1983 EP-toxicity test results for all parameters were found to be below the applicable regulatory thresholds. Consequently, the Project sediments were determined at that time to be unregulated under the RCRA Subtitle C hazardous waste regulations. Although the USACE does not recognize the applicability of RCRA to dredged material, USEPA determined that the replacement of the EP-toxicity test created a need to re-characterize the project sediment by TCLP. The TCLP characterization effort and results are described in the next section.

4.4.3.6 PCB Analysis.

4.4.3.6.1 The analysis of polychlorinated biphenyls (PCBs) is routinely conducted as part of bulk chemical testing. The absolute concentration of total PCBs in sediment samples is of special significance because of the criteria of the Toxic Substances Control Act (TSCA). Any material (including dredged materials) may be classified as "toxic" if it contains greater than 50 parts per million (ppm) of PCBs.

4.4.4 Sediment Sampling Investigations

4.4.4.1 The sediments from the Grand Calumet River and Indiana Harbor and Canal (GCR/IHC) have been sampled by a number of agencies and institutions for varying purposes. The USEPA and USACE have sampled sediments from the federal navigation channel in order to determine the appropriate disposal methods for dredged materials. The USACE, USEPA, Indiana Department of Environmental Management, and a number of researchers from leading universities have also sampled the sediments from the GCR/IHC in order to assess the presence and distribution of contaminants, survey benthic biota, and examine the impacts of sediment contamination on water quality and aquatic life.

4.4.4.2 This appendix will focus on the sampling of sediment within the federal navigation channel. Appendix C will discuss in detail the sampling and testing of sediments from areas outside the navigation channel in nearshore Lake Michigan.

4.4.4.3 Sampling and analysis of bottom sediments was performed by the USACE and USEPA during 1968-1971 in relation to the cooperative pilot study on alternate dredged disposal methods (USACE, 1969). This sediment data is so limited in comparison to later sampling events that it will not be discussed in detail. In 1977 the USEPA collected 13 grab samples from the Indiana Harbor and Canal. Samples were evaluated using physical, bulk chemical and standard elutriate analyses (USEPA, 1977). The USEPA has collected core samples from the IHC in 1990, 1991, and 1992. Sampling was conducted to determine the presence and distribution of contamination. Regulatory testing protocols (described above) were applied to these samples.

4.4.4.4 The sediments collected from the canal and inner harbor during the 1977 sampling event were dark brown or black, oily silt. Sediments in the approach channel were brown or grey, sand and gravel. Most of the sediments in the harbor and canal were predominantly silt and clay. The sediments from the center of the canal, the eastward end of the approach channel and in the vicinity of the harbor were more sandy in composition.

4.4.4.5 In 1977, the sediments were found to contain high levels of metals (arsenic, cadmium, copper, iron, lead, magnesium, manganese, nickel and zinc), organics, nitrogen, phosphorous, volatile solids and PCBs. Comparison of these results with the USEPA 1977 interim guidelines results in the classification of the Indiana Harbor and Canal as heavily polluted. In general, sediments collected from the upstream portions of the canal were more highly contaminated than those from the outer harbor and approach channel.

4.4.4.6 The USACE has sampled the sediments from the IHC in 1979, 1980, 1983, 1984, 1985, 1987, 1988(2), and 1993 (contracted by USEPA). Sampling in 1979, 1983, 1984, 1987, 1988, and 1993 was conducted to determine the presence and distribution of contamination. Regulatory testing protocols (described above) were applied to these samples. Sampling done in 1980, 1985, and 1988 was conducted for additional testing protocols designed to simulate confined disposal operations, and for research investigations on biological impacts.

4.4.4.7 The USACE collected core samples at thirteen locations in the Indiana Harbor and Canal in 1979 (USACE, 1979). The sampling locations were the same used by USEPA in 1977. The purpose of this sampling program was to determine the distribution, both laterally and vertically, of sediment contamination. Three foot sections of each core comprised subsamples used for physical, bulk chemical, and standard elutriate analyses of the sediments. The results of the sediment analyses concurred with the USEPA's 1977 sampling and testing. However, two sites were found to contain PCB concentrations in excess of 50 ppm (dry weight). The PCB contamination appears to be very localized with the high levels only found in deeper samples.

4.4.4.8 In 1980, the WES collected a large composite of sediments from three locations in the IHC for additional analyses (USACE, 1980). Tests included settling, filtration, leaching, coagulation, bioassay and bioaccumulation analyses. The results of these analyses are discussed later in this appendix, and in Appendix C.

4.4.4.9 In 1983, two sediment sampling investigations were completed. A total of 27 core samples were taken for PCB and EP-Toxicity analyses by an engineering consultant contracted by the USACE (USACE, 1983). Subsamples from each core were analyzed to develop the vertical distribution of PCB contamination, in terms of above and below project depth. The results of the PCB testing corroborated the 1979 PCB analysis. Elevated levels of PCBs were limited to two specific areas of the IHC and levels exceeding 50 ppm were only found in the deeper subsamples. Generally, the PCB concentration increased with increasing depth. The other sampling event of 1983 was performed at the request of the Indiana State Board of Health. Five composite samples from sediment cores were collected and analyzed for EP-Toxicity. All constituents analyzed were below the "maximum concentration of contaminants for characteristic of EP-Toxicity." Therefore, based upon the EP-toxicity results, none of the project sediments would require handling in accordance with RCRA if dredged. However, the EP-toxicity test was replaced by the TCLP test in

1990. As discussed below, USEPA tested the project sediment using TCLP in 1990, 1991, and 1992.

4.4.4.10 In 1984, the Detroit District of the USACE collected 18 core samples for an investigation on the feasibility of deepening selected Great Lakes harbors (USACE, 1984). Sampling was limited to the harbor and approach channel. Physical and bulk chemical analysis were performed, including a full priority pollutant analysis of a portion of the samples. This analysis showed the presence of a number of polynuclear aromatic hydrocarbon (PAH) compounds in the sediments.

4.4.4.11 In 1985, the USACE collected sediments from two locations (reaches with PCB levels greater than 50 ppm) in the IHC and one in Lake Michigan. The sediment was composited for a major research investigation performed by WES (Environmental Laboratory, 1987). As part of this effort a number of laboratory testing procedures were first developed. Testing included bulk chemical and physical analysis, settling, modified elutriate, leachate, surface runoff, capping, solidification, bioassay, and bioaccumulation tests. The results of most of these analyses will be discussed later in this appendix and in Appendices C and F. The bulk chemical analysis confirmed the presence of high levels of PAH compounds in sediments from the IHC.

4.4.4.12 In 1987, the USACE contracted the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) to conduct a sediment sampling program designed to investigate the dispersal and deposition of sediments discharged from the GCR/IHC to Lake Michigan (Polls, 1988). Grab samples were collected from the canal, harbor, and Lake Michigan up to 5 miles lakeward from the harbor mouth. Sediments were analyzed for bulk chemical composition of selected parameters. The results of this study are described in Appendix C.

4.4.4.13 In 1988, the USACE conducted two separate sediment sampling investigations. The Illinois Natural History Survey and Illinois State Geological Survey were contracted to collect grab samples from the IHC and adjacent Lake Michigan for bulk analysis, survey of benthos, and for a series of toxicity screening tests along with a biological survey and tissue-burden testing of aquatic organisms (Risatti and Ross, 1989). The results of this investigation are discussed in Appendix C.

4.4.4.14 Also in 1988, the USACE contracted the Indiana University - Northwest to collect core samples and one large composite sample from the IHC (Unger, in preparation). A total of 31 core samples were collected from areas of the IHC which had limited bulk chemical data. The results showed levels of metals, nutrients, and oil & grease contamination generally comparable with other areas of the IHC. However, the levels of PCBs and PAHs found were considerably lower than in previous sampling events. The large composite sample was used for bench-scale testing of advanced treatment technologies discussed in Appendix G.

4.4.4.15 In 1990, the USEPA collected core samples from six locations in the Indiana Harbor and Canal area. Only five of the samples were collected from within the boundaries of the federal navigation channel. All of the samples were analyzed using the TCLP test protocol to determine the status of the project sediments under Subtitle C of RCRA. The 1990 TCLP results initially passed their laboratory review and were approved for regulatory use. However, further review of the 1990 TCLP results determined that the TCLP methodology for the organic constituents was not conducted properly and, therefore, the initial data approval for these compounds was rescinded. During the interim, the 1991 TCLP sampling event as based upon the 1990 TCLP results was completed. Samples from 10 locations in the project were collected and analyzed according to the TCLP methods. Only one regulatory exceedance was found to be associated with the 1990 or the 1991 TCLP data sets. This was a benzene value included with the 1990 data set, which was later found to have been obtained from a location outside of the limits of the Federal project. In addition and as noted above, this benzene value along with all of the organic data from the 1990 TCLP data was later found to be unusable for regulatory determinations.

4.4.4.16 When the data quality problems associated with the 1990 results were discovered, USEPA decided to resample the entire Federal project. In June 1992, the USEPA collected 16 sediment core samples from 14 locations covering all sections of the Federal project. Two of the 16 core samples were field duplicates. The samples were collected to characterize the project sediments under Subtitle C of RCRA. The TCLP analysis of the samples included metals, volatiles, semi-volatiles, pesticides, and herbicides. With the exception of one of the samples, all of the TCLP results were found to be acceptable for regulatory determinations and to be below the TCLP regulatory thresholds. The exception was associated with a benzene exceedance which also had a calibration error, rendering the results unusable for regulatory determinations. However, the USEPA/IDEM laboratory review did emphasize the potential that properly tested sediments from this location could exhibit a regulatory exceedance for benzene. Consequently, USEPA/IDEM determined that all of the project sediment with the exception of the sediment associated with the benzene exceedance/calibration error would not be regulated as RCRA hazardous waste if dredged. The sediment represented by the exceedance/calibration error was determined to be "presumptively hazardous" and will not be dredged by the USACE as part of the navigation project. The volume of the presumptively hazardous sediment, as shown in figure E-2, is approximately 60,000 cubic yards.

4.4.4.17 In November 1993, the USEPA contracted the USACE (Chicago District) to collect core samples from the Calumet River Branch of IHC. Samples were collected from four locations below project depths. Each core sample was subdivided to develop a vertical concentration profile. Bulk chemistry and the TCLP test were performed for metals, nutrients, and organics (USACE, 1994). The chemical characteristics of sediment below project depth in the Calumet River Branch is similar to the

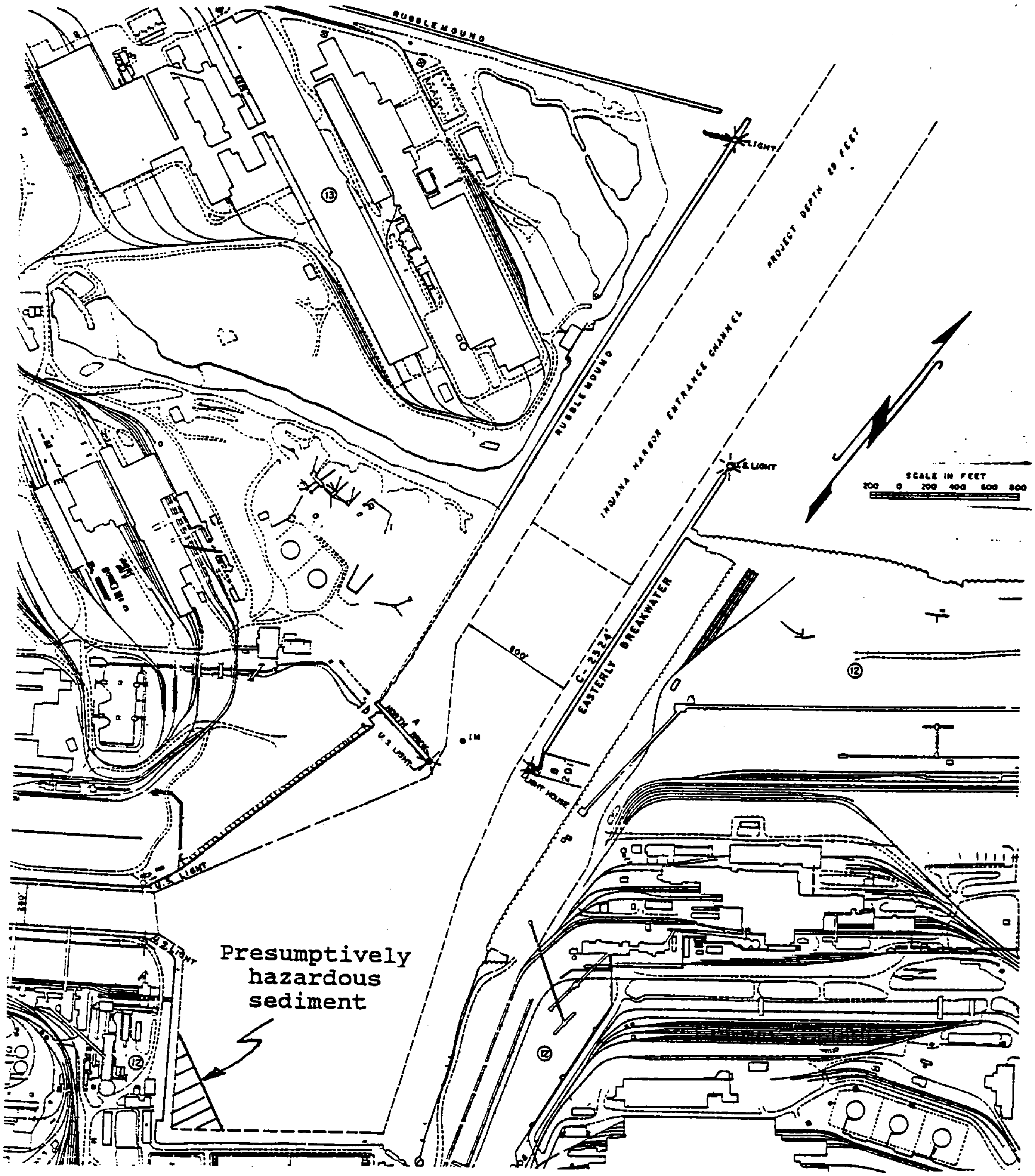


Figure E-2: Location of Presumptively Hazardous Sediment

sediment above project depth with the exception of chromium. The levels of chromium appear to increase somewhat with increasing depth. Sediment depth probings were performed to determine the depth to till. The soft unconsolidated sediment extended down to -30 to -40 Low Water Datum.

4.4.5 Summary of Sediment Quality Data

4.4.5.1 There are approximately 1 million cubic yards of sediments within the authorized navigation channel at Indiana Harbor and Canal. The sediment deposits are up to 18 feet above project limits. For the most part, the sediment deposits are deepest along the sides of the channel. Existing depths mid channel are at or near project depth in much of the IHC, except for the turning basin and Calumet branch where the depths are appreciably above project depth.

4.4.5.2 The bulk chemistry from the discrete sampling events consistently shows high levels of metals, nutrients, oil & grease, and volatile solids. The sediments are classified as "heavily polluted" according to the 1977 USEPA guidelines. There is a lateral trend of decreasing levels as one moves downstream and into the lake. This trend is more distinct for some parameters than it is for others. This variability in trends is apparent in figures E-3 and E-4. The levels of total volatile solids show a clear trend of decreasing as one moves out of the harbor and canal (figure E-3), while the levels of iron vary widely throughout the harbor and canal and show no clear trend (figure E-4). There are no consistent vertical trends for most parameters. However, the database for PCBs displays both lateral and vertical trends.

4.4.5.3 The highest levels of PCBs are present in the deeper layers of sediment in two areas; one is the most upstream portion of the Calumet River branch, and the other is the north bank of the main canal between the first (most downstream) two bridges. The levels of PCBs range from less than 1 ppm to 115 ppm. The absolute levels of PCBs has a high degree of variability between sampling investigations. Approximately 70,000 cubic yards of sediments have levels of PCBs equal to or exceeding 50 ppm and are subject to regulation under TSCA.

4.4.5.4 Bulk chemical analysis has shown the presence of PAH compounds in sediment samples. No discernible distribution trends are evident, but the samples collected in 1985 (Environmental Laboratory, 1987) showed elevated levels of several PAH compounds. Additional sediment sampling and analysis of PAHs were conducted in 1992 and 1993. The analytical results were similar to the concentrations from the 1985 sampling event. The levels of PAH compounds present in some samples are considered very high in comparison to values found in other Great Lakes harbor sediments.

4.4.5.5 The USEPA/IDEM determined that a portion of the sediment in the navigation channel was "presumptively hazardous"

Figure E-3: Total Volatile Solids

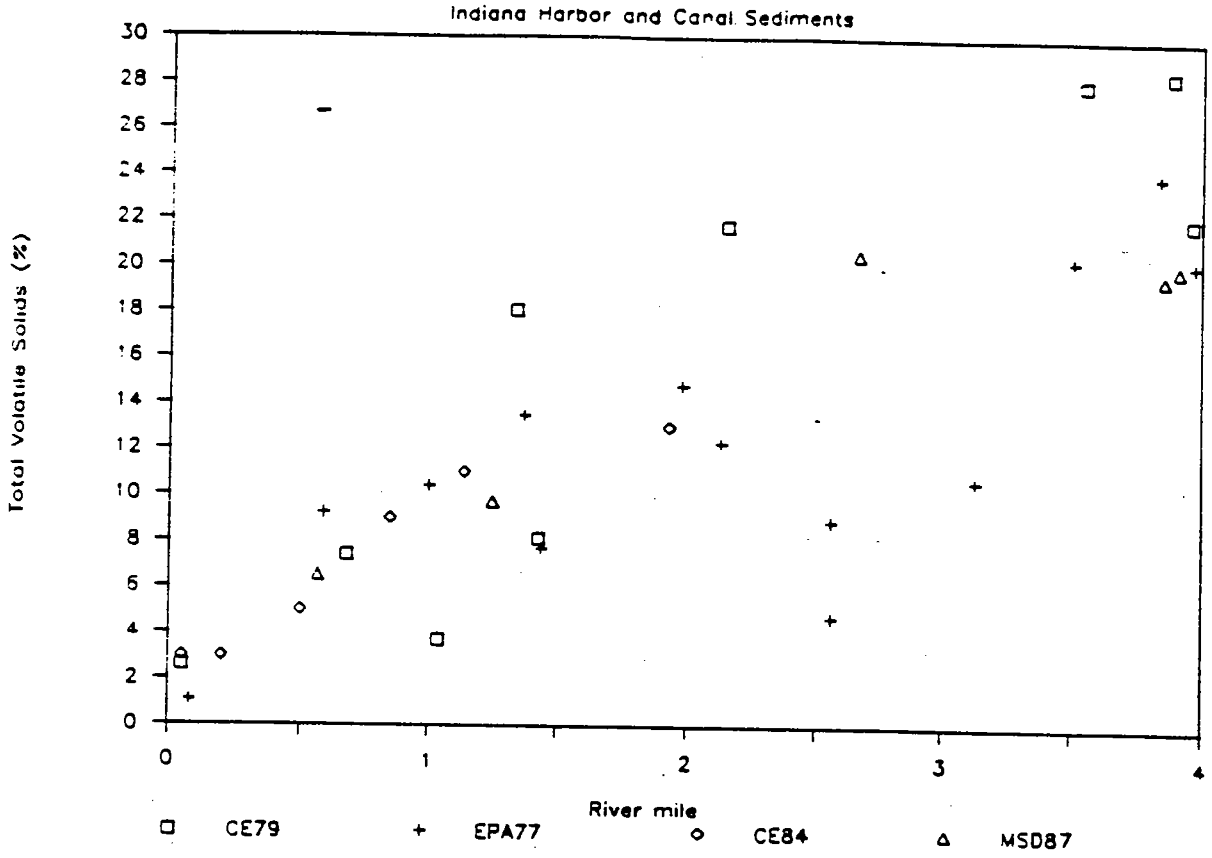
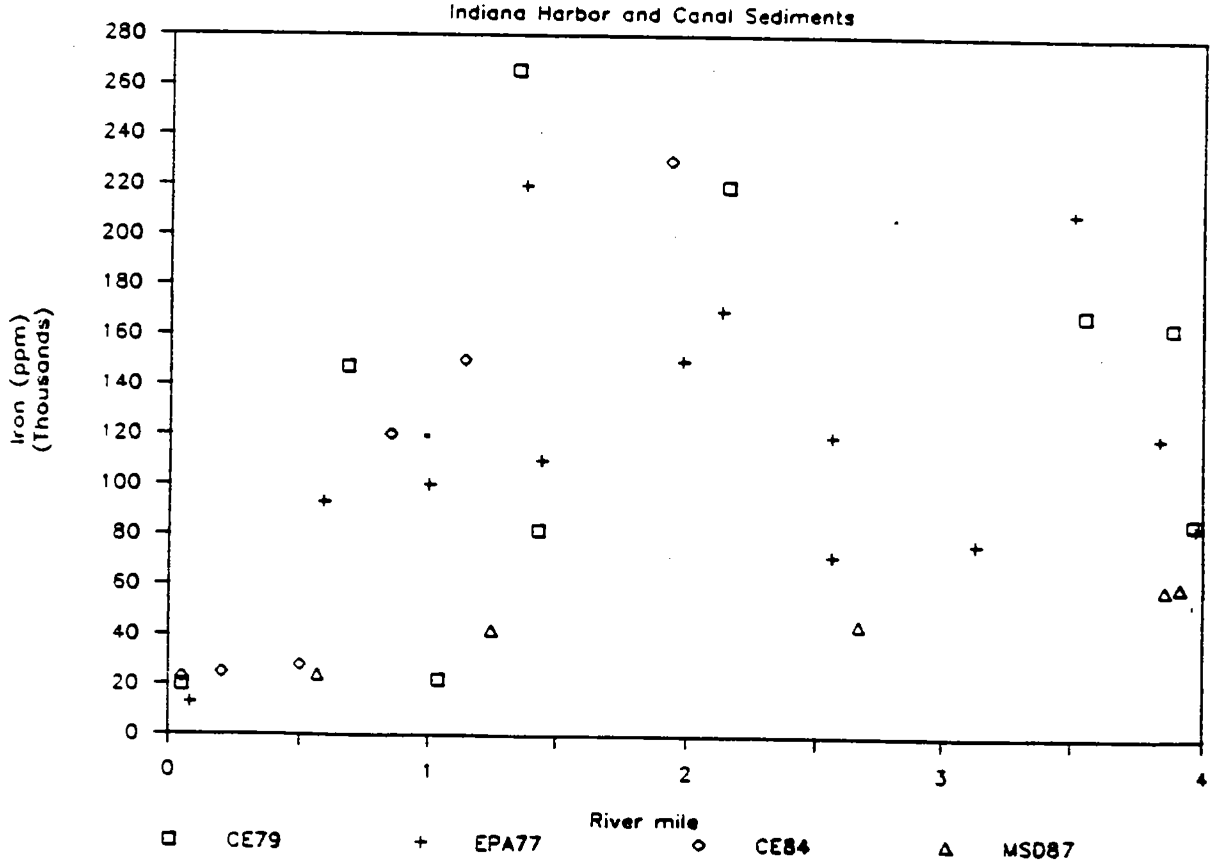


Figure E-4: Iron Concentrations



and will not be dredged by the USACE as part of the navigation project. The designation presumptively hazardous means that upon dredging, these sediments would require handling in accordance with RCRA Subtitle C, unless further retesting clarified that the sediments did not exhibit the hazardous waste characteristic of toxicity for benzene. These materials will be addressed as part of the site specific remedial activities in the vicinity of the Federal project.

4.5 INITIAL EVALUATION SUMMARY AND CONCLUSIONS

4.5.1 The initial evaluation set forth in the management strategy is designed to determine if there is reason to believe that the sediments to be dredged are contaminated at levels which would preclude unconfined, open water disposal. The evaluation procedure has considered the nature of the watershed, potential sources of sediments and contamination, and historic sediment quality data.

4.5.2 There are a number of known sources of sediments and contamination into the waterway, including municipal and industrial dischargers, combined sewer overflows, and urban runoff. These types of sources are known to contribute organic matter, nutrients and metals to other waterways.

4.5.3 From the historic sediment data described above, the volume-weighted concentrations of measured contaminant parameters has been calculated. The concentrations determined from each sampling event were weighted against a representative volume of sediment in order to determine the average concentration. The results are contained in table E-2. The pollutional classification for each parameter, based on the 1977 guidelines is also contained in table E-2. The Indiana Harbor sediments are heavily polluted for almost all of the parameters contained in the guidelines. Therefore, all the sediments in the waterway are considered to be heavily polluted.

5. IDENTIFY DISPOSAL ALTERNATIVES

5.1 The next step in the dredged material management strategy is to identify the available disposal alternatives and determine potential problems with each alternative.

5.2 OPEN-WATER DISPOSAL

5.2.1 Up until the mid-1960's dredged materials from navigation projects around the Great Lakes were disposed with economics as the key criteria. This meant that dredgings were deposited into the open waters of the lakes, usually 2-5 miles offshore. During the 1960's environmental concerns were raised about the water quality impacts caused by the open-lake disposal of sediments from industrialized harbors and waterways. In response to these concerns, the USACE and Federal Water Pollution Control Administration (predecessor of USEPA) agreed to seek alternatives to open lake disposal for dredgings determined to be polluted. The USEPA 1977 guidelines, and later the 404 guidelines (discussed earlier) were developed to delineate which sediments were suitable for open-lake disposal.

Table E-2: Volume-Weighted Mean Concentrations and Pollutional Classification of Indiana Harbor and Canal Sediments

Parameter	Volume-Weighted Mean Concentration	Pollutional Classification
Volatile Solids	14.1 %	Heavily
COD	207,575	Heavily
Oil & Grease	63,627	Heavily
TKN	2,929	Heavily
Ammonia	845	Heavily
Cyanide	1.4	Heavily
Manganese	1,914	Heavily
Phosphorus	2,555	Heavily
Arsenic	53	Heavily
Barium	45	Moderately
Cadmium	11	Heavily
Chromium	370	Heavily
Copper	156	Heavily
Iron	144,623	Heavily
Nickel	99	Heavily
Lead	837	Heavily
Zinc	3,669	Heavily
Mercury	0.7	Non-polluted
PCBs	8.9	Heavily

All concentrations are mg/kg dry weight, unless otherwise noted.

5.2.2 Sediments that do not contain contaminants above background levels may be disposed of in open-waters. "Clean" sediments can also be considered for beneficial uses (beach nourishment, or marsh and wetland development.) Polluted sediments cannot be disposed of in open-waters without any restrictions because of the possible impacts on the water quality and aquatic life. The initial evaluation has shown the sediments in Indiana Harbor and Canal to be "heavily polluted" according to USEPA criteria and therefore unsuitable for unconfined, open-lake disposal.

5.3 CONFINED DISPOSAL

5.3.1 Historical Perspective

5.3.1.1 The confinement of dredged materials began in the late 1960's as part of a pilot program conducted jointly by the USACE and Federal Water Pollution Control Administration (FWPCA). A three-year study on dredging and water quality problems on the Great Lakes was conducted (USACE, 1969). Although no conclusive evidence of water quality impairment could be shown from the practice of open-lake disposal, the study concluded that the unconfined disposal of polluted sediments was to be avoided.

5.3.1.2 As an alternative to open-lake disposal of dredged materials from polluted harbors and waterways, the USACE constructed the first confined disposal facilities (CDFs) as part of this pilot program. The FWPCA monitored the impacts of these early CDFs. As a result of the recommendations of the pilot program, Congress passed in 1970 a law (PL91-611, Section 123) which directed the USACE to construct and operate CDFs for the disposal of maintenance dredgings from Great Lakes harbors determined to be polluted and unsuitable for open-lake disposal.

5.3.1.3 The USACE has a total of 48 navigation projects on the Great Lakes requiring confined disposal for maintenance dredgings. Thirty confined disposal facilities, serving 38 projects have been constructed by the Buffalo, Chicago and Detroit Districts.

5.3.1.4 The usual method of confinement is to provide dikes on public lands high enough and encompassing areas large enough to contain 10 (or more) years of maintenance dredgings together with any backlog of material which may have accumulated. The CDFs are designed to confine the dredged sediments and thereby limit contaminant pathways to groundwater or to reenter the waters of the Great Lakes.

5.3.2 Potential Impacts of Confined Disposal

5.3.2.1 In order to assess the potential impacts of confined disposal of dredged materials we must examine the physicochemical properties of the sediments and the routes of contaminant loss or migration. The sediments in the IHC are composed of predominantly fine-grained materials, silts and clays. Silts and clays have a high affinity for many of the pollutants in the sediments. Hydrophobic contaminants like PCBs and PAHs have a special attraction for fine sediments containing organic material. The Indiana Harbor sediments also contain a significant amount of oil and grease which has a strong affinity to hydrophobic contaminants.

5.3.2.2 Once deposited within a CDF, sediments become consolidated and compacted. Consolidated silts and clays have low permeabilities and are fairly resistant to water transport via percolation or seepage. Sediments placed in an upland CDF are dewatered through surface drainage, surface drying and cracking. In an in-water CDF only those sediments placed above the water table will become dried, the rest will remain saturated.

5.3.2.3 Confined disposal areas are used to retain dredged material solids while allowing carrier water to be released as effluent from the confinement area. The two objectives inherent in the design and operation of a CDF are to: (a) provide adequate storage capacity to meet dredging requirements, and (b) attain the highest possible efficiency in retaining solids during the dredging operation in order to maintain effluent quality. These considerations are basically interrelated and depend upon effective design, operation, and management of the CDF.

5.3.2.4 Confined disposal of contaminated sediments must be planned to hold dredged material solids within the site and restrict contaminant mobility out of the site in order to control or minimize potential environmental impacts. There are six possible mechanisms for transport of contaminants from confined disposal sites that should be considered:

a. Release of contaminants in the effluent during disposal operations.
b. Surface runoff of contaminants in either dissolved or suspended particulate form following disposal.
c. Leaching of contaminants into ground water.
d. Plant and animal uptake of contamination from deposited sediments.
e. Contaminant uptake by animals foraging on vegetation growing on deposited sediments.
f. Wind-blown particle or volatile loss of contaminants during and after placement of dredged material.

5.4 SEDIMENT TREATMENT TECHNOLOGIES

5.4.1 There are a number of technologies for the treatment of wastes that may be applicable to dredged materials. A detailed examination of sediment technologies was made by the USACE for the Indiana Harbor sediments. The results of this investigation are described in Appendix G. One of the conclusions of this investigation is that none of the sediment treatment technologies can function without the use of a confined disposal facility, either for temporary storage, dewatering, handling, or permanent storage of residues. This Appendix will discuss only the control measures needed to restrict contaminant loss from a CDF. The additional controls which would be necessary for the implementation of an sediment treatment technology in combination with a CDF are described in Appendix G.

6. SEDIMENT TESTING

6.1 Of the disposal alternatives considered above, only confined disposal and sediment treatment in combination with confined disposal were found to be feasible. The potential impacts of confined disposal have been identified. The next step in the dredged material management strategy is to perform testing to determine if the disposal impacts would be significant. The sediment testing described above simply confirmed the presence of contamination. Presence of contaminants alone does not determine the significance of environmental impact.

6.2 In 1980 and 1985 the Waterways Experiment Station (WES) designed and conducted a number of tests with IHC sediments to simulate the conditions during confined disposal operations. The tests were designed to measure the amount of contaminant loss and impacts on water quality, animal and plant uptake. These tests and the results will be discussed next.

6.3 PHYSICAL TESTS

6.3.1 Physical analysis of the Indiana Harbor sediments was performed by WES with samples collected in 1980 (USACE, 1980) and 1985 (Environmental Laboratory, 1987). Additionally physical characterization of Indiana Harbor sediments has been conducted by the U.S. Bureau of Mines, as part of the Assessment and Remediation of Contaminated Sediments (ARCS) Program. The ARCS Program is discussed in more detail in Appendix G. The physical and engineering properties of the sediments are summarized in table E-3.

6.3.2 Grain-size analysis was also performed on the samples collected in 1980 and 1985. The results of the grain-size analysis are shown on figure E-5. The sediment was found to be mostly silt and clay, with some sand.

6.3.3 The permeability of the IHC sediment collected in 1985 was measured as part of the permeameter testing for leachates. The results indicated that following consolidation and compaction, the sediments would have a permeability less than that provided by clay liners used for toxic and hazardous waste landfills (0.0000001 cm/sec). This testing is further discussed below.

6.4 EFFLUENT QUALITY TESTING

6.4.1 When dredged materials are disposed to a CDF, water associated with the sediments or used to convey the sediments must be drained to maintain capacity for more dredgings. This return water or effluent is generally routed to the nearest waterway. The method of dredging and mode of operation of the CDF control the quantity and quality of this effluent. Mechanically dredged materials are placed into a CDF with roughly the

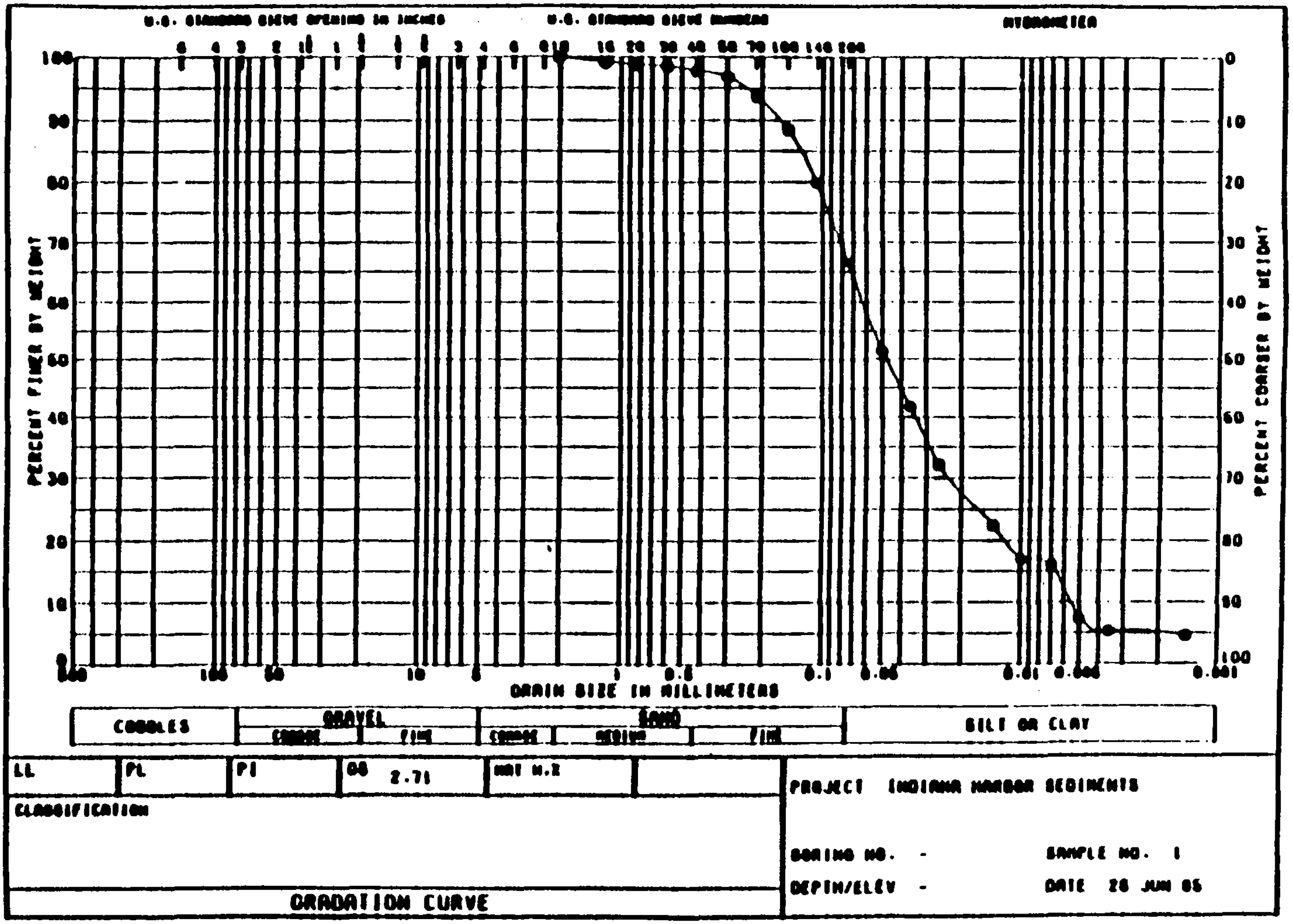


Figure E-5: Grain Size Distribution Curve same amount of water they had in-situ. Only a portion of this water is free draining. Hydraulic dredging adds at least four volumes of water to every volume of sediments dredged and disposed. The result is that the sediments enter the CDF in a slurry with all solids in suspension and there is approximately 5 times as much water that needs to be drained and discharged.

Table E-3: Physical Properties of Indiana Harbor and CanalSediments

Plasticity	
Liquid Limit, LL	60
Plastic Limit, PL	27
Plasticity Index, PI	33
Soil Classification	CH (Highly Plastic Clay)
Other Properties	
Specific Gravity, Gs	2.71
Organic Content, %	14
In Situ Water Content, %	51
Salinity, ppt	< 1
Permeability, cm/sec	8.66×10^{-8}

6.4.3 When dredgings are disposed to a CDF hydraulically, the CDF functions as a primary settling basin. Dredged material undergoes sedimentation, while clarified supernatant waters are discharged from the site. The effluent may contain levels of both dissolved contaminants and particulate-associated contaminants. Secondary treatment, such as filtration or coagulation may be used to reduce the levels of suspended contaminants.

6.4.4 Different laboratory tests have been developed to simulate the physical processes that occur within the CDF. These tests include settling, filtering, pore water extraction, and modified elutriate tests. In addition, computer models have been developed to simulate these physical and chemical processes and project effluent quality.

6.4.5 <u>Settling Tests</u>.

6.4.5.1 Zone settling tests were performed to determine the minimum surface area required for effective zone settling following hydraulic disposal (USACE, 1980). This test is not required for mechanical disposal. Flocculent settling tests were performed to estimate the settling properties of the sediment (USACE, 1980, Environmental Laboratory, 1987). The flocculent settling tests indicated that a retention time of five hours would result in a removal of 99.5 percent of the suspended solids. This retention time would result in the removal of suspended solids down to a level of 0.32 g/l in the upper 2 feet of the water column. The settling properties of the Indiana Harbor and Canal sediments are reasonably good and high suspended solids removal can be expected from a properly designed and operated containment area.

6.4.6 Filtration Tests.

6.4.6.1 Filtration is one of the most commonly used controls for wastewater treatment. Filtration has been by the USACE to clarify discharges from dredged disposal operations. The WES performed filtration analysis with a suspension of IHC sediments to determine the efficiency of different filter media, including sand and activated carbon (USACE, 1980). The results are summarized on tables E-4 and E-5. The tests showed that filter media of sand or carbon alone removed in excess of 97 percent of the suspended solids, and that a combination media of sand and carbon removed 99 percent of the influent suspended solids on average. Problems, however, were encountered when the filter became clogged as a layer of oily sludge formed on top of the filter media.

Table E-4: Summary of Laboratory Filter Tests

Test Run	Filter Media	Filter Depth (cm)	Concentration (mg/l)	Head (cm)	Initial Discharge (lpm)	Total Volume of Throughput (l)	Length of Test Before Plugging (min)
Sand I	Fine Sand	120	1490	157	0.49	45.4	75*
Sand II	Fine Sand	120	1490	220	0.68	37.9	115
Carbon	Calgon Filtrasorb 400	120	1490	157	0.49	60.6	105
Sand-Carbon	Fine Sand Filtrasorb 400	240	1490	179	0.42	53.0	---

* Test was terminated at an effluent flow rate of 0.15 lpm.

Table E-5: Suspended Solids Analysis of Filter Tests

Sample Identification	Sample No. 1 (g/l)	2 (g/l)	3 (g/l)	Avg (g/l)	Removal Efficiency (%)
Supernatant	1.510	1.473	1.490	1.491	--
Sand I	0.028	0.040	0.028	0.032	97.9
Sand II	0.047	0.038	--	0.043	97.1
Carbon	0.022	0.035	--	0.029	98.1
Sand-Carbon	0.008	0.017	0.019	0.015	99.0

6.4.7 Modified Elutriate Tests

6.4.7.1 The standard elutriate test is sometimes used to evaluate water quality impacts during the open-water disposal of hydraulicly dredged sediments. This test does not reflect the conditions existing in confined disposal sites which influence contaminant release. Therefore, a modified elutriate test procedure was developed to predict both the dissolved and particulate associated concentrations of contaminants under confined disposal conditions (Palermo et al, 1986). The test reflects the settling behavior of dredged material, the retention time of the CDF, and the chemical environment in ponded water during active disposal of hydraulically dredged materials.

6.4.7.2 Modified elutriate tests were performed with Indiana Harbor sediments (Environmental Laboratory, 1987). The results of the modified elutriate test are summarized in table E-6. Results of analysis of the site water used to prepare the elutriate slurry are included in table E-7. These tests show elevated levels of most metals over the levels found in the site water, with the exception of mercury and manganese. The only organic contaminants that showed elevated levels in the modified elutriate test were ammonia nitrogen and Aroclor 1248 (one form of PCBs).

Table E-6: Results of Modified Elutriate Test

	Constituent Concentration of Modified Elutriate Test Samples	
Constituent	Unfiltered Water	Filtered Water
Arsenic	0.148 ± 0.050	0.004 ± 0.003
Cadmium	0.0026 ± 0.0008	0.0023 ± 0.0005
Chromium	0.182 ± 0.088	0.035 ± 0.005
Copper	0.077 ± 0.024	0.035 ± 0.008
Lead	0.211 ± 0.066	0.064 ± 0.064

(continued)

Table E-6 (continued): Results of Modified Elutriate Test

	Constituent Concentration of Modified Elutriate Test Samples	
Constituent	Unfiltered Water	Filtered Water
Mercury	0.0176 ± 0.0005	<0.0008
Nickel	0.058 ± 0.010	0.032 ± 0.000
Zinc	1.151 ± 0.175	0.430 ± 0.046
Iron	7.94 ± 3.16	0.686 ± 0.104
Manganese	0.246 ± 0.154	0.039 ± 0.007
Total phosphorus	42.6 ± 17.0	0.38 ± 0.10
Ammonia nitrogen	40.4 ± 18.0	44.2 ± 0.5
Aldrin	<0.00001	0.00011 ± 0.00003
A-BHC	<0.00001	<0.00001
B-BHC	<0.00001	<0.00001
G-BHC	0.00012 ± 0.00021	<0.00001
D-BHC	<0.00001	<0.00001
Chlordane	<0.0002	<0.0002
PPDDD	<0.00001	<0.00001
PPDDE	<0.00001	<0.00001
PPDDT	<0.00001	<0.00001
Dieldrin	<0.00001	<0.00001
A-Endosulfan	<0.00001	<0.00001
B-Endosulfan	<0.00001	<0.00001
Endosulfan sulfate	<0.00001	<0.00001
Endrin	<0.00001	<0.00001
Endrin aldehyde	<0.00001	<0.00001
Heptachlor	<0.00001	<0.00001
Heptachlor epoxide	0.00026 ± 0.00004	0.00004 ± 0.00006
PCB-1016	<0.0002	<0.0002
PCB-1221	<0.0002	<0.0002
PCB-1232	<0.0002	<0.0002
PCB-1242	<0.0002	<0.0002
PCB-1248	31.5 ± 16.4	0.0034 ± 0.0017
PCB-1254	<0.0002	<0.0002
PCB-1260	<0.0002	<0.0002
Toxaphene	<0.0002	<0.0002
Acenaphthene	0.39 ± 0.22	<0.01
Flourene	0.30 ± 0.17	<0.01
Phenanthrene	0.77 ± 0.46	<0.01
Fluoranthene	0.59 ± 0.35	<0.01
Pyrene	0.54 ± 0.30	<0.01

(continued)

Table E-6 (continued): Results of Modified Elutriate Test

	Constituent Concentration of Modified Elutriate Test Samples	
Constituent	Unfiltered Water	Filtered Water
Anthracene	0.20 ± 0.12	<0.01
Chrysene	0.34 ± 0.20	<0.01
Benzo(a)anthracene	0.24 ± 0.17	<0.01
Benzo(b)fluoranthene	0.43 ± 0.28	<0.01
Benzo(k)fluoranthene	0.43 ± 0.28	<0.01
Benzo(a)pyrene	0.26 ± 0.19	<0.01
Indeno(1 2 3-c d)pyrene	0.09 ± 0.16	<0.01
Dibenzo(a h)anthracene	<0.10	<0.025
Benzo(g h i)perylene	0.08 ± 0.14	<0.025
Total organic carbon	1073 ± 607	44.5 ± 3.7
Phenol	0.070 ± 0.015	0.037 ± 0.004
Dissolved solids	154 ± 6	
Suspended solids	5392 ± 299	
Conductivity	<5 mmhos	
Dissolved oxygen	1.3 ± 0.1	
pH	7.59	

All concentrations in ppm unless otherwise noted.

Table E-7: Chemical Characterization of Indiana Harbor Site Water

Constituent	Concentration in Site Water
Arsenic	<0.005
Cadmium	0.0007
Chromium	0.004
Copper	0.005
Lead	<0.001
Mercury	0.0020
Nickel	0.008
Zinc	<0.03
Iron	<0.03
Manganese	0.042
Total phosphorus	0.01
Ammonia nitrogen	0.607
Aldrin	0.00002
A-BHC	<0.00001
B-BHC	<0.00001
G-BHC	<0.00001
D-BHC	<0.00001
Chlordane	<0.0002
PPDDD	<0.00001
PPDDE	<0.00001
PPDDT	<0.00001
Dieldrin	<0.00001

(Continued)

Table E-7 (continued): Chemical Characterization of Indiana Harbor Site Water

Constituent	Concentration in Site Water
A-Endosulfan	<0.00001
B-Endosulfan	<0.00001
Endosulfan Sulfate	<0.00001
Endrin	<0.00001
Endrin aldehyde	<0.00001
Heptachlor	<0.00001
Heptachlor epoxide	<0.00001
PCB-1016	<0.0002
PCB-1221	<0.0002
PCB-1232	<0.0002
PCB-1242	<0.0002
PCB-1248	0.0003
PCB-1254	<0.0002
PCB-1260	<0.0002
Toxaphene	<0.0002
Naphthalene	<0.01
Acenaphthylene	<0.01
Acenaphthene	<0.01
Flourene	<0.01
Phenanthrene	<0.01
Anthracene	<0.01
Fluoranthene	<0.01
Pyrene	<0.01
Chrysene	<0.01
Benzo(a)anthracene	<0.01
Benzo(b)fluoranthene	<0.01
Benzo(k)fluoranthene	<0.01
Benzo(a)pyrene	<0.01
Indeno(1 2 3-c d)pyrene	<0.025
Dibenzo(a h)anthracenen	<0.025
Benzo(g h i)perylene	<0.025
Total organic carbon	4.6
Phenol	<0.01
Dissolved solids	342
Suspended solids	<4

All concentrations in ppm unless otherwise noted.

6.4.8 Coagulation Testing

6.4.8.1 Coagulation using polymer addition is a commonly used control in wastewater treatment. Previous experimentation has shown that various polyelectrolytes and polymers could be effective aids in the removal of suspended solids from dredged materials (Wand and Chen, 1977, Jones et al, 1978). Conventional coagulants such as alum and ferric sulfate were found less applicable due to the need for large dosages and pH control.

6.4.8.2 Coagulation was investigated as a technique for removal of solids and associated contaminants from supernatant water with Indiana Harbor sediments (USACE, 1980). Suspensions of Indiana Harbor sediments and site water were used for standard jar tests conducted with the Phipps and Bird (model 300) six-paddle stirrer. Stock solutions of four commercially available polymers were used. Polymers were found to affect greater than 95 percent removal of solids at optimum dosages. On the basis of these results, two polymers were selected for use in large batch coagulation testing to determine contaminant removal efficiencies. The results of these tests indicated that the polymer treatment was very effective in removing the various contaminants. Summaries of the solids and chemical contaminant removal by coagulation are show in table E-8.

Table E-8: Results of Coagulation Tests

Parameter	Supernatant Concentration	End Concentration (Removal Eff.)			
		Magnifloc 577C		Nalco 603	
Susp. Solids	1771	6.3	(99.6)	2.6	(99.8)
PCBs	11 (ug/l)	0.18	(98.4)	0.16	(98.5)
Turbidity	790 (NTU)	3.5	(99.6)	4.3	(99.5)
TKN	46.3	0.67	(99)	0.63	(99)
Phosphorus	5.57	<0.10	(--)	<0.10	(--)
Phenol	0.033	<0.01	(--)	<0.01	(--)
Oil & Grease	600	71	(88)	80	(87)
Arsenic	0.019	<0.010	(--)	<0.010	(--)
Cadmium	0.0412	0.0004	(99.0)	0.0004	(99)
Chromium	0.989	0.009	(99.1)	0.006	(99.4)
Copper	0.350	0.006	(98.3)	0.003	(99.1)
Lead	1.110	0.001	(99.9)	0.002	(99.8)
Nickel	0.113	0.008	(93)	0.007	(94)
Zinc	7.77	0.073	(99.1)	0.062	(99.2)
Mercury	0.0022	<0.0002	(--)	<0.0002	(--)

All concentrations are mg/l unless otherwise noted.

6.5 RUNOFF AND LEACHATE TESTING

6.5.1 After dredged materials have been taken out of the water there are a number of potential routes for contaminant loss. These include surface runoff and leaching. Like the routes of contaminant loss discussed above, surface runoff and leaching can impact water quality, but at different times and in different ways. The effluent quality testing addressed physical processes that occur during the act of dredged material disposal. Runoff and leaching are routes of contaminant loss which may occur after (or in between) disposal operations.

6.5.2 Surface runoff is the transport of sediment contaminants caused by rainfall, runoff, and erosion. Surface runoff occurs when the amount of rainfall exceeds the absorption capacity of the dredged material. Leaching is the transport of sediment contaminants with water that percolates through the dredged material layers. The potential for contaminated dredged material to cause adverse impacts through surface runoff or leaching depends on several factors including the chemical form of the contaminants and the physical properties of the dredged material.

6.5.3 Dredged material from Indiana Harbor in its in-situ condition is anaerobic with a pH between 7 and 8. Most contaminants are relatively insoluble, bonded to the sediment soils and are not mobile. When wet dredged material is confined and dewatered, physical and chemical changes occur as the anaerobic sediments dry and oxidize. The extent to which the material dries and oxidizes affects both the surface runoff water quality and leachate quality. Dry sediments are more resistant to erosion. However, if the sediment contains high levels of sulfide, oxidation may cause the formation of sulfuric acid and reduce the pH. This can cause contaminants such as heavy metals to become very soluble in surface runoff and leachate. Laboratory tests were performed with Indiana Harbor sediment to determine if controls were required for surface runoff or leaching.

6.5.4 <u>Surface Runoff Testing</u>

6.5.4.1 Laboratory tests, including soil lysimeter, air drying, oven drying, DTPA extract and peroxide extract tests, were performed with Indiana Harbor sediments to help predict surface runoff water quality from drying dredged material (Environmental Laboratory, 1987). Results indicate that contaminants in surface runoff from wet, anaerobic Indiana Harbor sediments were in poorly soluble forms and generally dependent on runoff suspended solids concentrations.

6.5.4.2 Lysimeter test results for wet, unoxidized sediments are shown in table E-9. The mean filtered runoff concentrations are within the USEPA maximum criteria for the tested parameters, except that several heavy metals (zinc, chromium and cadmium) exceeded the USEPA criteria for the protection of aquatic life. Any dilution of discharged runoff will reduce soluble concentrations of contaminants to meet USEPA criteria. Filtered concentrations of PCBs met the USEPA criteria for this standard.

Table E-9: Lysimeter Test Results for Wet, Unoxidized Sediments

Parameter	Mean Unfiltered Runoff Concentration	Mean Filtered Runoff Concentration
pH	7.64	7.66
Conductivity (S/m)	0.0052	0.0052
Suspended Solids	6600	---
DDE	< 0.00001	0.00004
PCB-1248	0.051	0.0015
PAHs	18.03	0.148
Naphthalene	6.91	0.115
Acenaphthylene	0.212	< 0.005
Acenapthene	0.780	0.010
Phenanthrene	1.67	0.0097
Anthracene	0.494	< 0.005
Fluoranthene	1.57	< 0.005
Pyrene	1.35	< 0.005
Chrysene	0.843	< 0.005
Benzo[a]anthracene	0.787	< 0.005
Benzo[b]fluoranthene	1.12	< 0.005
Indeno[1,2,3-C.D]pyrene	0.195	< 0.005
Benzo[g h i]perylene	0.124	< 0.005
Heavy metals		
Cadmium	0.154	0.0021
Copper	1.79	0.0237
Nickel	0.707	0.0297
Zinc	30.9	0.360
Manganese	9.04	0.0170
Chromium	4.06	0.056
Lead	6.80	0.0670
Iron	627	1.39
Mercury	0.0037	< 0.0002
Arsenic	0.232	< 0.005

All values are mg/l unless otherwise noted.

6.5.5 Leachate Quality Testing

6.5.5.1 Two types of leaching tests were applied to Indiana Harbor sediment (Environmental Laboratory, 1987). Batch leaching tests identified the critical factors influencing contaminant mobility and quantified release rates, under varying environmental conditions that may be encountered in confined disposal.

Batch leaching tests also provided the desorption coefficients needed to model mass transfer of contaminants from the solid phase to the aqueous phase. Divided-flow permeameter leaching tests simulated the field leaching processes and verified the mass transfer equation and the generality of the desorption coefficients determined in the batch leaching tests.

6.5.5.2 Sequential batch leach tests indicate the release characteristics of Indiana Harbor sediment for arsenic, cadmium, chromium, lead, zinc, PAHs, and PCBs. Tests to determine the shaking time required to reach steady state values, the proper liquid-solids ratio at which to conduct batch tests, and the potential for alteration of sediment release characteristics caused by changes in oxidation of the sediment, were also performed.

6.5.5.3 Sequential batch leaching tests involve exposing the sediment to successive inputs of fresh distilled deionized water and analyzing the leachate. These tests were conducted using sediment maintained under anaerobic conditions and sediment that had been exposed to air for 6 months to simulate conditions during confined disposal.

6.5.5.4 A series of batch leaching tests was also run to determine if exposure of leachate from a batch test to unleached sediment would change the leaching characteristics of the sediment. Results indicated that the distribution coefficient for metals in anaerobic leachate did 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 of arsenic, chromium, lead and zinc. The data indicates that the release of organics in leachate is very low. The PAHs and PCBs are strongly partitioned toward the sediment phases. A summary of probable maximum leachate contaminant concentrations is presented in table E-10.

Table E-10: Summary of Probable Maximum Leachate Contaminant Concentrations for Indiana Harbor Sediment

Contaminant	Anaerobic	Aerobic
Arsenic	0.034	0.016
Cadmium	0.009	0.0995
Chromium	0.195	0.013
Lead	0.370	0.055
Zinc	1.27	0.454
Total PCB	0.00054	0.0032
Total PAH	1.82	0.0674

All concentrations in mg/l.

6.5.5.5 Continuous flow column leaching tests were performed on both anaerobic and aerobic Indiana Harbor sediment. A permeant-porous media equation was used to predict permeameter leachate quality as a function of volume throughput. Most contaminants in the permeameter leachate were below or slightly above the detection limit.

6.6 BIOLOGICAL TESTING

6.6.1 After dredged material has been placed in either an upland or in-lake CDF environment, plants can invade and colonize the site. In most cases, fine-grained dredged material contains large amounts of nitrogen and phosphorous, which tend to promote vigorous growth of plants on dredged material placed in confined disposal sites at elevations that range from wetland to upland terrestrial environments. Because of the contaminants present in the dredged material there is potential for movement of contaminants from the dredged material into plants.

6.6.2 Animals have also been known to invade and colonize confined dredged material disposal sites. In some cases, prolific wildlife habitats have become established on these sites. Concern has developed recently on the potential for animals inhabiting either in-water or upland terrestrial confined disposal sites to become contaminated and contribute to the contamination of food chains associated with the site.

6.6.3 Biological testing was conducted with Indiana Harbor sediments (USACE 1979b; Environmental Laboratory, 1987) to determine if plants and animals which colonize the confined disposal site would be subject to either toxicity or uptake of contaminants.

6.6.4 Plant Bioassays

6.6.4.1 Testing performed by WES utilized sediment samples from the Indiana Harbor and Canal to grow an index plant, Cyperus esculentus under both wetland and upland environments. Plant growth, phytotoxicity, and the bioaccumulation of contaminants were monitored during the growth period. Plants were harvested and analyzed for contaminants. The test results indicated the potential for plants to become contaminated in either environment. However, the index plant performed much better in the wetland environment than the upland environment.

6.6.5 Animal Bioassays

6.6.5.1 Bioassay tests were conducted by WES in 1986 using earthworms (Eisenia foetida). The earthworms could not tolerate untreated sediment or most of the treated sediments. Treatment included ashing in a muffled furnace, drying in sunlight for 7 and 21 days, drying in the sunlight for 21 days plus added manure, and aging outdoors in the shade for six months. Adequate 28 day survival was demonstrated only for the aged sediment. The earthworms were placed into a Plexiglas cylinder, which contained the aged sediments. The sediments were wetted by capillary action from a basin surrounding the cylinder. The cylinder was covered with mesh to retain the earthworms and the sediments.

6.6.5.2 After 28 days, 95 percent of the specimens were retrieved and the tissues were analyzed for toxic metals, PCBs and PAHs. The concentrations of arsenic, cadmium, copper, lead, and nickel increased significantly in earthworm tissues during the exposure period, while chromium, mercury and zinc did not. The uptake of PCBs by the earthworms was significant. The earthworms accumulated PCB concentrations that were about 25 percent the concentration of the aged sediments. Bioaccumulation of PAHs was significant for five of the 16 compounds tested for. Those that accumulated (pyrene, benzo[b]fluoranthene, benzo[k]flouranthene, benzo[a]pyrene, and indeno[1,2,3-c.d]pyrene) were found in concentrations equal to 50 percent of the concentration of the aged sediments.

7. SUMMARY

7.1 An initial evaluation of the environmental history of the Indiana Harbor and Canal established a reason to believe that the sediments in the harbor and canal were contaminated with industrial and other pollutants. A review of sediment test data, both current and historic, revealed that there were significant concentrations of contaminants in the sediment. A comparison of the bulk chemical analyses performed with the USEPA pollutional guidelines established that the harbor and canal are heavily polluted. Contaminated sediments are not suitable for open-water disposal, and must be confined.

7.2 A confined disposal facility for contaminated dredged material must be designed to contain the dredged material and any contaminants associated with the dredged material. To support this design, potential routes of contaminant loss were identified using the Management Strategy procedures. These routes of contaminant loss include; effluent, surface runoff, leachate, and plant/animal uptake. Testing was conducted to simulate the transport of contaminants through these different pathways, and the results summarized herein.

7.3 The data and analysis within this appendix was used in the Environmental Engineering Appendix (Appendix F) to develop the designs for confined disposal, establish required control measures for path of contaminant loss, and evaluate the available options based on existing environmental regulations.

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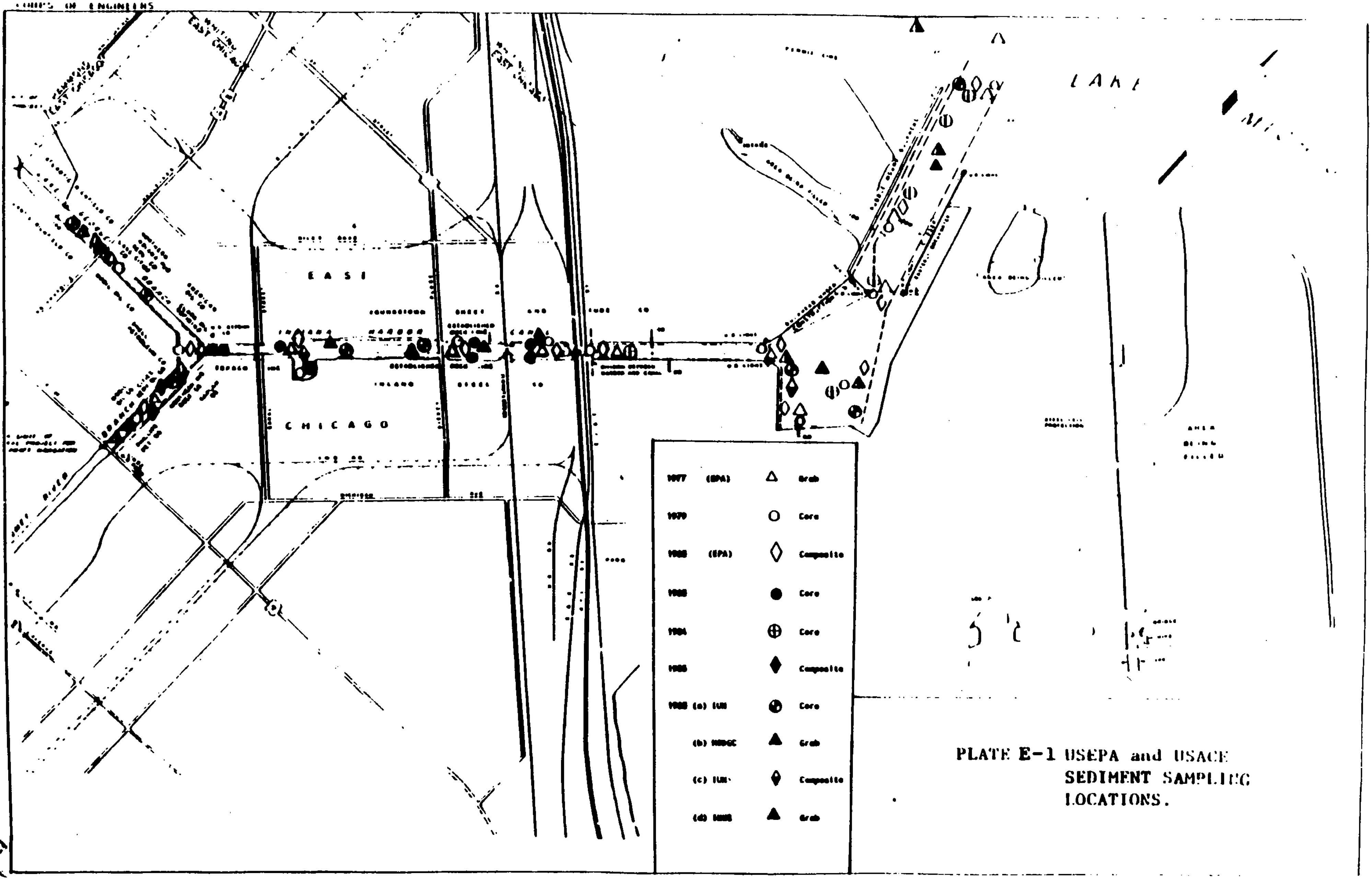

PLATE E-1 USEPA and USACE SEDIMENT SAMPLING LOCATIONS.

INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES IN LAKE COUNTY, INDIANA

APPENDIX F

ENVIRONMENTAL ENGINEERING

April 1995
Environmental Engineering Section
of Hydrology and Hydraulics Branch
U.S. Army Engineer District, Chicago
111 North Canal Street
Chicago, Illinois 60606-7206

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- Sensitivity Checks to Delta Volume Model
- Comparison of Simulation and Sensitivity Values for the Delta Formation Model
- In-lake CDF Operation Parameters - Results

F-2 Volatilization Parameters and Results

- Indiana Harbor PCB Volatilization Model Definitions
- Sensitivity Analysis for Flux Equations
- Volatile Mass Loss of PCBs From Exposed Sediment
  - Inland Steel Site
  - J-Pit Site
  - 141st Site
  - ECI Site
  - Proposed Plan (ECI Site Modified)
- Summary of PCB Mass Loss for Each Site

F-3 Hydraulic Disposal Mass Flux Calculations

F-4 Input and Output Summaries for Cap and Cover Designs

1. PURPOSE AND OBJECTIVE

1.1 This appendix will provide the technical documentation of water and air quality analyses conducted on four alternative confined diposal facility (CDF) sites considered for the dredged materials from Indiana Harbor and Canal. Sections 1 through 7 were written during the third phase of the project (mid 1980's to late 1990), comparing the four alternative locations. The ECI site was selected during the fourth phase of the plan formulation (1991-1995). The CMP itemizes the changes incorporated into the fourth phase design. Part B of this appendix (sections 8 through 12) has been added to present the current design. One of the changes between the third and fourth phases has been the CDF size. In the initial proposal (third phase), the CDF had been 90 to 95 acres. During the fourth phase, the size of the CDF has increased to 130 acres. The appendix will include information on the existing surface water, groundwater, and air quality of the impacted areas, computer simulation of the four CDF alternatives considered, projected losses of organic chemicals (PCBs) from these facilities due to volatilization, projected quality of effluent and return water treatment, and a comparison of the water and air quality impacts of the CDF alternatives considered. The computer simulations are based on a presumed dredging/disposal operational scheme which is very simplified . The intent of this analysis is to provide a comparison of relative impacts from the differing CDF alternatives rather than an intensive estimation of impacts from a specific design. A more detailed review of impacts will be developed in the design phase when the actual dredging/disposal scheme will be finalized.

1.2 The <u>Management Strategy for Disposal of Dredged Materials</u> (Francingues et al, 1985) as applied in Appendix E, Sediment Quality has shown that the dredged materials from Indiana Harbor and Canal are not suitable for open-water disposal. A number of tests were preformed to: quantify the type and amount of contaminants within the sediments; describe the transport of these contaminants through different pathways; and determine where environmental controls are required. This data and analysis will be used here to develop the designs for confined disposal, establish required control measures for path or contaminant loss, and evaluate the available options based on existing environmental regulations.

1.3 This appendix will first provide a discussion of the existing conditions with respect to surface waters, groundwater, and air quality in the impacted areas. Next the analytical methods used to simulate the water quality and air quality impacts of CDF operations are described. The assumptions used and results of analyses are discussed. Possible environmental controls which mitigate water and air impacts are reviewed in the following section. Next, the environmental impacts of the CDF alternatives are compared and summarized. The last and most up-to-date section, Part B, presents the same analysis included in the sections above but as applicable for the current proposal of the ECI site.

2. EXISTING CONDITIONS

2.1 EXISTING WATER QUALITY CONDITIONS

2.1.1 Water quality standards for all streams, rivers, and lakes have been established by the State of Indiana. These standards are specific for individual waterways and their associated water use designation. The existing water quality in Lake Michigan and Indiana Harbor and Canal, and the groundwater conditions in the project area are described below. The water quality standards discussed in this appendix were taken from 1989. Current water quality standards will be considered and incorporated in future documents.

2.1.2 Lake Michigan

2.1.2.1 Lake Michigan is used for potable water supply, industrial water supply, commercial and sport fisheries, and recreation. Potable water intakes for the cities of Hammond, Whiting, and East Chicago are situated in relatively close proximity to Indiana Harbor. Factors affecting water quality in the nearshore Lake include the discharges from the Grand Calumet River and Indiana Harbor Canal, discharges from other tributaries, atmospheric sources, and releases from recreational marinas.

2.1.2.2 The quality of Lake Michigan water near Indiana Harbor is generally very good, meeting most State standards for water quality. Pollutants which enter Lake Michigan are quickly dispersed by nearshore littoral currents and diluted in the large volume of water in the lake. The State water quality standards for Lake Michigan are very restrictive so as to preserve the lake's water quality and to minimize the impacts of contaminant discharges.

2.1.2.3 The water quality of Lake Michigan in the vicinity of Indiana Harbor is regularly monitored by the Indiana Department of Environmental Management (IDEM). Monitoring stations are shown on plate F-1. Water quality data from the three stations closest to the harbor and the State water quality standards for Lake Michigan, for 1989, are shown on table F-1.

2.1.2.4 The state standard for phosphorus is exceeded mainly during the spring and summer months. Fecal coliform levels also exceed the state standard, nearly exclusively during the summer months. The ammonia nitrogen, phenols, and mercury levels reported by IDEM have detection limits higher than the water quality standards for these parameters; therefore, no conclusions can be made concerning these contaminants. Likewise, no conclusion can be made with regard to the level of polychlorinated biphenyls (PCBs) in Lake Michigan as analysis of this chemical parameter was not included in the sampling and testing program by IDEM.

2.1.3 Grand Calumet River/Indiana Harbor and Canal

2.1.3.1 The Grand Calumet River/Indiana Harbor and Canal (GCR/IHC) are part of a small, but highly industrialized watershed located in East Chicago, Indiana. The Grand Calumet River drains approximately 77 square miles of Lake and Porter counties and discharges to southwestern Lake Michigan via Indiana Harbor and Canal. Over 90 percent of dry-weather flows are from municipal and industrial discharges.

2.1.3.2 The GCR/IHC are designated by the State of Indiana as industrial water supply, partial body contact, limited aquatic life waters. These waterways have a history of water quality problems and have been identified by the International Joint Commission on the Great Lakes as an Area of Concern (AOC).

Table F-1: Water Quality and State Water Quality Standards for Lake Michigan Near Indiana Harbor and Canal (1989)

Parameter	Units	Monitoring Station LM EC	LM H	LM W	State Standard
Ammonia	mg/l	0.11	0.10	0.10	0.02
Arsenic	ug/l	1.0	1.4	0.9	50
Barium	ug/l	21.0	21.0	20.0	1000
Cadmium	ug/l	2.0	2.0	2.0	10
Chloride	mg/l	---	---	---	15
Chromium	ug/l	10.0	10.0	10.0	50
COD	mg/l	10.0	15.0	7.0	---
Copper	ug/l	31.0	5.0	5.0	---
Cyanide	mg/l	0.005	0.005	0.005	0.01
DO	mg/l	---	---	---	7
Fecal coliform	#/100 ml	15	29	101	20
Fluoride	mg/l	---	---	---	1.0
Hardness	mg/l	149	147	145	---
Iron (dissolved)	ug/l	51.0	57.0	58.0	150
Iron (total)	ug/l	---	---	246	---
Lead	ug/l	10.0	10.0	10.0	50
Manganese	ug/l	---	---	196	---
Mercury	ug/l	0.100	0.167	0.100	0.05
Nickel	ug/l	10.0	10.0	10.0	---
Nitrate+Nitrite	mg/l	0.3	0.3	0.3	---
Oil & grease	mg/l	2.6	---	---	---
PCB	ug/l	---	---	---	0.001
pH		7.8	7.9	7.8	7.5 - 8.5
Phenols	ug/l	5.6	5.0	5.0	0.001
Phosphorus	mg/l	0.04	0.05	0.03	0.03
Selenium	ug/l	---	---	---	10
Sulfate	mg/l	---	---	---	26
TDS	mg/l	195	82	44	172
TKN	mg/l	---	---	0.3	---
Zinc	ug/l	15.0	63.0	19.0	---

--- indicates no data or standard available Source: IDEM, 1986

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2.1.3.3 The water quality of GCR/IHC is recognized as being very poor in comparison to Lake Michigan and to other nearby waterways that do not have large industries associated with them. The water quality standards for Indiana Harbor and Canal are less restrictive than those for Lake Michigan with a few exceptions; standards are stricter for chromium and lead in the harbor and canal and are the same for ammonia nitrogen and PCBs.

2.1.3.4 The water quality of the GCR/IHC is routinely monitored by IDEM. Monitoring results from four stations in the project area and the State water quality standards (1989) for the GCR/IHC are summarized on table F-2. The level of ammonia nitrogen exceeded the state standard for the GCR/IHC throughout the entire year. Fecal coliform levels exceeded the state standard mainly during the winter months. The metals concentrations were well within the State standards for those metals that have a discharge standard for the GCR/IHC (chromium, dissolved iron, lead, mercury). No conclusion can be reached about PCB levels in the GCR/IHC as this chemical parameter was not included in the sampling and analysis program by IDEM.

2.1.3.5 The IDEM has prepared a draft Environmental Action Plan (IDEM, 1990) for northwest Indiana. This plan (also referred to as the Remedial Action Plan - RAP) examines the existing environmental problems of the Grand Calumet River and Indiana Harbor and Canal and evaluates remedial alternatives, including pollutant source controls and contaminated sediment management. The implementation of the EAP/RAP should improve the water quality of the Indiana Harbor and Canal and adjacent Lake Michigan.

2.1.3.6 In March of 1990, the State of Indiana adopted new water quality standards. The new water quality standards for Lake Michigan and Indiana Harbor and Canal are listed on tables F-3 and F-4. The Final Acute Value (FAV) is two times the Acute Aquatic Criterion (AAC) and is the standard that undiluted discharge must meet. The AAC is the water quality standard applicable outside the zone of initial dilution or the zone of discharge-induced mixing.

2.1.3.7 The new standards also define the following classifications: Chronic Aquatic Criterion (CAC), Terrestrial Life Cycle Safe Concentration (TLSC), and Human Life Cycle Safe Concentration (HLSC), a criterion to protect human health from unacceptable cancer risk of greater than one additional occurrence of cancer per 100,000 population. The most stringent of the classifications is the standard that is applicable for a specific chemical parameter.

Table F-2: Water Quality and State Water Quality Standards for the Grand Calumet River/Indiana Harbor Canal (1989)

Parameter	Units	Monitoring Station IHC 0	 IHC 1,2	 IHC 3S	 IHC 3W	State Standard
Ammonia	mg/l	0.60	1.14	1.96	1.63	0.02
Arsenic	ug/l	1.2	1.7	2.3	2.0	---
Barium	ug/l	23	23	25	27	---
Cadmium	ug/l	2.0	2.0	---	---	---
Chloride	mg/l	---	---	---	---	125
Chromium	ug/l	10	10	---	---	25.0
COD	mg/l	16	19	18	18	---
Copper	ug/l	7	5	---	---	---
Cyanide	mg/l	0.011	0.007	0.013	0.010	0.05
DO	mg/l	7.9	5.8	5.5	5.8	4.0
Fecal coliform	#/100 ml	39	1519	3055	1458	1000
Fluoride	mg/l	---	---	---	---	1.3
Hardness	mg/l	164	177	195	195	---
Iron (dissolved)	ug/l	68	105	127	212	300
Iron (total)	ug/l	415	635	1087	809	---
Lead	ug/l	10	10	---	---	25.0
Manganese	ug/l	111	94	---	---	---
Mercury	ug/l	0.1	0.1	0.1	---	0.5
Nickel	ug/l	10	10	---	---	---
Nitrate+Nitrite	mg/l	0.7	0.9	1.7	1.4	---
Oil & grease	mg/l	3.5	5.2	2.9	5.6	10
PCB	ug/l	---	---	---	---	0.001
pH		7.8	7.4	7.2	7.1	6.0 - 9.0
Phenols	ug/l	---	8	7	5	10
Phosphorus	mg/l	0.03	0.05	0.09	0.06	0.10
Sulfate	mg/l	---	---	---	---	100
TDS	mg/l	248	279	339	342	---
TKN	mg/l	---	1.7	---	---	---
Zinc	ug/l	37	50	---	---	---

--- indicates no data or standard available Source: IDEM, 1986

2.2 GROUNDWATER QUALITY

2.2.1 Local Geology and Groundwater Use

2.2.1.1 The Grand Calumet River/Indiana Harbor Canal area is located in Lake County in northwestern Indiana. The GCR/IHC watershed borders Lake Michigan on the north, Burns Ditch and the Little Calumet River on the east and south, and the Calumet River/Cal-Sag Channel on the west.

2.2.1.2 The GCR/IHC area lies entirely within the Calumet Lacustrine Plain physiographic province. Several distinct dune/beach complexes were formed in this province during the Pleistocene and

Table F-3: Indiana Water Quality Standards for Lake Michigan

Parameter	Standard		
	(ug/L)	(mg/l)	
Dissolved oxygen	7,000	7.00	
pH	7.5-8.5		
Fecal Coliform	125/100mL		
TDS	200,000	200	daily max
Unionized ammonia	50	0.05	daily max
Total Phosphorus	40	0.04	daily max
Flouride	1000	1.00	daily max
Chloride	20000	20.00	daily max
Sulfate	50000	50.00	daily max
Phenols	3	0.003	daily max
Total Cyanide	5.2	0.0052	
Arsenic	0.022	0.000022	
Barium	1000	1.00	
Cadmium	1.6	0.0016	
Cr (+3)	289	0.289	
Cr (+6)	11	0.011	
Copper	17	0.017	
Iron	300	0.30	daily max
Lead	5	0.005	
Mercury	0.05	0.00005	
Nickel	13.4	0.0134	
Selenium	10	0.01	
Zinc	149	0.149	
Silver	4	0.004	
Total PCB's	0.00079	7.90E-07	

1. assumes water hardness of 150 mg/L as $CaCO_3$
2. standards are most stringent of Acute Aquatic Criteria (AAC), Chronic Aquatic Criteria (CAC) human health, and point of water intake
3. stds. taken from Indiana Administrative Code, Title 327 - Water Pollution Control Board, 3/3/90

Table F-4: Indiana Water Quality Stds. for Indiana Harbor and Ship Canal

Parameter	Standard		
	(ug/L)	(mg/l)	
Fecal Coliform	1000/100mL		
TDS	350,000	350	
Unionized ammonia	20	0.02	
Total Phosphorus	100	0.10	
Flouride	1300	1.30	
Chloride	125000	125.00	max
Sulfate	100000	100.00	max
Phenols	10	0.010	
Total Cyanide	50	0.05	
Cr (total)	25	0.025	
Iron	300	0.30	
Lead	25	0.025	
Mercury	0.5	0.0005	
Total PCB's	0.001	1.00E-06	

1. assumes water hardness of 150 mg/L as $CaCO_3$

2. standards are most stringent of Acute Aquatic Criteria (AAC), Chronic Aquatic Criteria (CAC) human health, and point of water intake

3. stds. taken from Indiana Administrative Code, Title 327 - Water Pollution Control Board, 3/3/90

4. east branch of Grand Clumet River are all points east of the Indianapolis Blvd. bridge

Holocene Epochs when Lake Michigan was at a higher level. The extensive, surficial, thin Calumet aquifer was formed from these deposited dune, beach, and lacustrine, silts, sands, and gravels. The shallow Calumet aquifer underlies about 10 feet of overburden. Glacial till and lacustrine clay underlie the Calumet aquifer. Carbonate bedrock of silurian age underlies the glacial till and lacustrine clay.

2.2.1.3 The Calumet aquifer is composed of fine to medium sand with a saturated thickness of 0 to 45 feet. The aquifer is generally thickest in the eastern part of the GCR/IHC area. The aquifer thins to the west and pinches out to lacustrine clay near the Indiana/Illinois state line. The aquifer pinches out to glacial till in the southwestern part of the GCR/IHC area in the valley of the Little Calumet River. Slag fill along Lake Michigan is considered to be part of the aquifer in this report.

2.2.1.4 The Calumet aquifer has an average hydraulic conductivity of 60 feet per day. Preliminary analysis of this shallow groundwater flow system in the drainage basin of the GCR/IHC has been performed by Watson and Fenelon (1988). The analysis indicates that the groundwater flow patterns appear to be dominated by two broad, low divides located between Lake Michigan and the Grand Calumet River, and between the Grand Calumet River and the Little Calumet River. Aquifer/stream interactions were found to be quite complex.

2.2.1.5 Analysis indicates that changes in the level of Lake Michigan combine with seasonal variations in groundwater recharge and wetland processes to produce short term and long term fluctuations in the level of the water table. Preliminary digital model simulations conducted by USGS suggest that the water table has been lowered by several feet from pre-urban, preindustrial development conditions. Lowering of the water table appears to have been actuated by drainage of former marsh lands to sewers, ditches, and possible downward leakage to the bedrock (Watson and Fenelon, 1988).

2.2.1.6 The Calumet aquifer is not a major water supply because all the municipalities in the GCR/IHC area obtain water from Lake Michigan. However, a few thousand domestic wells in the aquifer probably are still in use outside municipal corporation limits. This estimate would also include wells in the Calumet aquifer outside the GCR/IHC area.

2.2.1.7 Residential land occupies about 50 percent of the Grand Calumet River/Indiana Harbor Canal area. Commercial areas, light industry, steel and petrochemical industries occupy the remaining 50 percent of the area. These sources of pollution directly overlie the thin, low hydraulic gradient Calumet aquifer water table.

2.2.2 Groundwater Quality Data

2.2.2.1 To make a preliminary assessment of the Calumet aquifer water quality without duplication of work being done at many sites in the area, Banaszak and Fenelon sampled 35 stainless steel wells, including six pairs of nested wells, in a 50 square mile area. A broad survey of a number of parameters was conducted to determine those present in the groundwater. Due to the costs associated with laboratory analyses, one sample per well was taken from a total of 35 wells in the Calumet aquifer study area. Field characteristics measured were temperature, pH, specific conductance, dissolved oxygen, and alkalinity. Additional analyses were three nutrients; three common anions; bromide; boron; silica; four common cations; 11 heavy metals; and 88 organic chemicals, including some organic chemical groups, such as phenol.

2.2.2.2 The median groundwater pH measured was 7.3, but samples from three wells screened in slag had pH values above 11. Median alkalinity was 290 mg/l (milligrams per liter) as $CaCO_3$, but concentrations in three samples exceeded 900 mg/l. Median specific conductance was 1,200 us/cm (microseimens per centimeter at 25 degrees Celsius), but six values exceeded 2,380 us/cm. Of these six samples, three were from fresh slag and the other three were contaminated by petroleum products.

2.2.2.3 Sixty seven of the 88 organic chemicals analyzed for, including trichloroethylene, were not detected. Phenol, however, was found in samples from all 35 wells and benzene was found in 17 of 31 samples. Medians of both chemicals in samples from wells in or near steel or petrochemical plants were significantly different (at the 95-percent confidence level) from medians in samples from all other wells (Banaszak and Fenelon, 1988).

2.2.2.4 A statistical summary of the water quality characteristics measured in the GCR/IHC area is provided in tables F-5 through F-7. For the general area, the median concentrations of iron, nitrogen ammonia, and sulfate exceeded Indiana water quality standards for the East Branch of the Grand Calumet River and Indiana Harbor Ship Canal. The median concentration of manganese exceeded USEPA Quality Criteria for Water (1986) for water and fish ingestion. An evaluation of the inorganic and organic constituents considering USEPA 1986 secondary drinking water recommended limits and primary recommended maximum contaminant levels (RMCLs) is summarized in Banaszak and Fenelon (1988).

2.2.2.5 <u>141st Street Site.</u>

2.2.2.5.1 The 141st Street CDF site is in the Grand Calumet River/Lake Michigan groundwater drainage system. Groundwater flow at this site may be influenced by infiltration to sewers to the southwest draining the Hammond sewer system, and by wetlands and the Lake George Branch of the Indiana Harbor Canal to the north.

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Table F-5: Statistical Summary of Field Groundwater Quality Characteristics Measured in the Grand Calumet River/ Indiana Harbor and Canal Shallow Groundwater Table

Parameter	Number of Samples	Median	Minimum	Maximum
Alkalinity (mg/l)	34	290	28	434
Oxygen (mg/l)	34	0.7	0.0	8.0
pH	35	7.26	6.70	11.83
Temperature (°C)[1]	19	18.9	12.5	20.0
Temperature (°C)[2]	15	14.7	12.1	19.0

---

1 Samples from shallower wells.
2 Samples from deeper wells.
After Banaszak and Fenelon, 1988.

Table F-6: Statistical Summary of Inorganic Constituents Found in the Grand Calumet River/Indiana Harbor and Canal Area Shallow Groundwater Table

Parameter	Number of Samples	Number above Detection	Detection Limit	Median	Minimum	Maximum
Aluminum	35	15	10	---	---	1100
Ammonia[1]	26	26	---	0.80	0.01	640
Arsenic	35	26	1	3	---	76
Barium[2]	17	16	1	46	---	180
Barium[3]	13	11	1	109	---	1000
Boron	31	31	---	300	20	1900
Bromide[1]	31	20	0.010	0.03	---	4.4
Cadmium	35	2	1	---	---	2
Calcium[1]	35	35	---	130	36	610
Chloride[1]	35	35	---	109	1.8	1200
Chromium	35	12	10	---	---	100
Copper	35	13	1	---	---	70
Fluoride[1]	35	35	---	0.9	0.1	10
Iron	29	25	1	420	---	66000
Lead	35	4	5	---	---	200
Magnesium[1]	35	32	0.10	21	---	94
Manganese	30	25	1	160	---	2100
Mercury	35	29	0.10	0.20	---	3.90
$NO_2 + NO_3$[1]	27	12	0.010	---	---	5.50
Phosphorus[1]	25	11	0.010	---	---	0.260
Potassium[1]	35	35	---	5.9	1.0	219
Silica[1]	35	35	---	20	7.4	55
Sodium[1]	35	35	---	62	1.9	860
Sulfate[1]	35	35	---	93	7.2	1200
Zinc	35	29	3	9	---	130

--- Indicates no data available or relevant.
1 All units are ug/l, except those marked 1, which are mg/l.
2 Samples from shallower wells.
3 Samples from deeper wells.
After Banaszak and Fenelon, 1988.

2.2.2.5.2 The groundwater quality of three wells in the area was studied by Banaszak and Fenelon (1988, unpublished data). Well D-40 is located about one mile east of the site near Indianapolis Blvd. Well pair E-6/E-7 is located about 1.5 miles northwest of the site near the intersection of Sheffield Avenue and 129th Street. These wells provide general vicinity groundwater quality data rather than site specific data due to the possible flow complexities in the area.

Table F-7: Statistical Summary for Four Organic Chemicals Found in the Grand Calumet River/Indiana Harbor and Canal Area Shallow Groundwater Table

Parameter	Number of Samples	Number above Detection	Detection Limit	Median	Minimum	Maximum
Benzene[1]	30	16	0.20	0.20	---	1900
Bis(2-ethyl hexyl) phthalate	35	20	5.0	8.0	---	100
Phenols	35	35	---	3	1	310
Toluene	30	11	0.20	---	---	1.50

--- Indicates no data available or relevant.

[1] All units are ug/l.

2.2.2.5.3 Results of the laboratory analyses for the three wells in the vicinity of the 141st Street site (D-40, E-6, E-7) are presented in table F-8. Results of samples taken from these three wells indicated benzene, iron, phosphorus, ammonia nitrogen, sulfate, and phenol were higher than the average values measured in the entire study area.

2.2.2.6 J-Pit Site

2.2.2.6.1 The J-Pit CDF site may be on the water table altitude divide between the Grand Calumet River and the Little Calumet River preliminarily plotted by Watson and Fenelon (1988). The groundwater flow direction at the site is not known. Factors which may influence the probable complex flow pattern include any pumping which may be taking place at the sand pit, flow due to sewer line infiltration, and old wetland flow patterns.

2.2.2.6.2 Three wells in the area were sampled during the preliminary study of Banaszak and Fenelon. Well B-10 is located about 1.3 miles northeast of the site. Well C-18 is located about 1.1 miles north of the site. Well C-20 is located 1 mile northwest of the site. These wells provide general vicinity groundwater quality data rather than site specific data due to the possible flow complexities in the area.

2.2.2.6.3 Results of the laboratory analyses for wells in the vicinity of the J-Pit site (B-10, C-18, C-20) are also presented in table F-8. The level of chloride found in the sample from well C-18 (240 mg/l) was higher than the average value measured in the other wells in the study area.

Table F-8: Groundwater Quality Analytical Data From Wells in the Grand Calumet River/Indiana Harbor and Canal Area Shallow Groundwater Table Near the Alternative CDF Sites

	Well Identification					
Parameter	B-10	C-18	C-20	D-40	E-6	E-7
Aluminum	< 10	20	20	10	< 10	1100
Ammonia[1]	---	0.8	0.2	0.87	6.8	2.6
Arsenic	< 1	< 1	1	3	2	9
Barium	8	99	38	34	200	44
Boron	90	320	190	190	470	300
Bromide[1]	0.022	0.13	0.078	< 0.01	< 0.01	< 0.01
Cadmium	< 1	< 1	2	< 1	< 1	< 1
Calcium[1]	57	120	59	77	200	140
Chloride[1]	40	240	11	11	95	53
Chromium	10	< 10	< 10	< 10	< 10	< 10
Copper	< 1	< 1	< 1	< 1	2	< 1
Fluoride[1]	0.7	0.3	0.4	< 1	0.5	0.9
Iron	< 3	---	8	2800	4600	6
Lead	< 5	< 5	< 5	< 5	< 5	5
Magnesium[1]	19	22	8	12	51	94
Manganese	< 1	430	430	690	160	< 1
Mercury	0.3	0.2	0.2	0.1	0.2	0.2
$NO_2 + NO_3$[1]	---	< 0.01	0.016	< 0.01	< 0.01	1.4
Phosphorus[1]	---	< 0.01	0.01	0.26	< 0.01	< 0.10
Potassium[1]	1.5	5.9	1.6	1.5	6.3	12
Silica[1]	8.3	19	17	24	47	23
Sodium[1]	9.3	190	21	25	63	58
Sulfate[1]	31	93	71	49	420	250
Zinc	15	16	9	< 3	9	4
Diss. Solids[1]	260	990	280	350	1100	750
Tot. Hardness[1]	219	390	180	240	710	740
Chloroform	---	0.8	< 0.2	< 0.2	0.2	---
Cyanide[1]	< 0.01	< 0.01	< 0.01	< 0.01	8.2	0.19
Tot. Phenols	1	2	2	4	2	14
Benzene	0.4	0.3	< 0.2	120	1.2	2.3
Ethylbenzene	< 0.2	< 0.2	< 0.2	< 0.2	0.3	< 0.2
Bis(2-ethyl hexyl) phthalate	12	11	< 5	7	32	< 5
Xylene	< 0.2	< 0.2	< 0.2	< 0.2	1.9	< 0.2

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[1] All units are ug/l, excepted those marked with a 1, which are mg/l.

--- Indicates no data available.

Source: Preliminary unpublished data collected by Banaszak and Fenelon.

2.2.2.7 ECI Site

2.2.2.7.1 The ECI CDF site is located between the Lake George Branch of the Indiana Harbor Canal and Lake Michigan. Groundwater flow at this site may be influenced by pumping from nearby petrochemical tank farms surrounding the site, and the Lake George Branch of the canal immediately south of the site.

2.2.2.7.2 Two wells in the area were sampled during the preliminary study of Banaszak and Fenelon. Well D-40 is located across the Lake George Branch 1/3 mile south of the site. Well pair E-6/E-7 is located 1.6 miles northwest of the site. These wells provide general vicinity groundwater quality data rather than site specific data due to the possible flow complexities in the area.

2.2.2.7.3 The wells in the vicinity of the 141st Street site (D-40, E-6, E-7) are also the wells indicative of the groundwater quality in the area of the ECI site due to the close proximity of these two sites. The results from these three wells were previously discussed in section 2.2.2.5.3 and are presented in table F-8.

2.2.2.8 The implementation of the EAP/RAP would gradually improve the groundwater quality in northwest Indiana. The identification and remediation of leaking landfills and enforcement against unpermitted dumping and discharges should reduce pollutant loading to the groundwater. LTV Steel Company and Amoco Oil Company currently have groundwater pumping operations which reclaim fuel oil and petrochemical contamination from a contaminant layer that floats on top of the water table. The captured materials are used as a fuel supplement for plant operations.

2.3 AIR QUALITY

2.3.1 Sources of air pollution are both mobile and stationary. Mobile sources, i.e., automobiles and trucks, are the major sources of carbon monoxide (CO) and important sources of volatile organic compounds (VOCs). Sources of ozone depend on stationary sources of VOC as well as mobile sources. The stationary sources include gasoline marketing, refining, and storage. Additional industrial operations include the surface coating of metal, cans, coils, and paper.

2.3.2 The IDEM maintains an inventory of emissions from all significant traditional industrial sources in northwest Indiana. The largest contributors are U.S. Steel, Inland Steel, Commonwealth Edison, American Oil, LTV Steel, and Northwest Indiana Public Service Company. Together these six sources account for 85% of the particulate matter, 95% of the sulfur dioxide, 99% of the volatile organic compounds, 91% of the nitrogen oxides, and 99% of the carbon monoxide contained in the IDEM's industrial emissions inventory. In addition, motor vehicles contribute significant amounts of pollutants (IDEM, 1988).

2.3.3 The air quality in northwest Indiana is lower than that specified under the Clean Air Act. All of the portions of Lake County are currently classified as non-attainment for sulfur dioxide, carbon monoxide, and ozone. Violations of the lead and particulate standard have also been measured. The particulate situation has been a long standing problem, however progress has been made. In 1980 the highest measured annual average concentrations of total suspended particulates were in the range of 100-120 ug/m^3. In 1985, the highest measured annual average concentration was near 90 ug/m^3.

2.3.4 The impacts from the air emission of toxic substances are now being studied by the IDEM. An inventory of toxic emission is being developed and high risk sources will be identified. Risk assessments will be performed to evaluate the need for additional control measures. The urbanized area of northwest Indiana will be included in a study to assess the potential risk from a number of combined toxic sources. The IDEM and USEPA Region 5 plan to establish a toxic monitoring site in the study area. This site will represent the first long term ambient toxic monitoring in Northwest Indiana.

2.3.5 The implementation of the EAP/RAP would reduce future air pollution loadings and may improve the overall air quality of northwest Indiana.

3. METHODS OF ANALYSIS

3.1 This section will discuss the scientific and engineering basis used to determine the water and air quality impacts of the confined disposal of dredged materials from Indiana Harbor and Canal and used to design controls necessary to minimize these impacts.

3.2 GUIDANCE AND RESEARCH

3.2.1 The Corps' design of a confined disposal facility is geared toward compliance with Section 404 of the Clean Water Act of 1977. This act was specifically created for the regulation of dredge and fill activities. Section 404(b)(1) guidelines provide general regulatory guidance for decision making on the disposal of dredged materials. USEPA Region 5 guidelines provide guidance for determining if dredged materials from Great Lakes harbors are suitable for open-water disposal. Sections 404 and 401 of the Clean Water Act of 1977 requires that the Corps obtain certification from the appropriate State agency that the dredged material disposal will not violate applicable water quality standards.

3.2.2 A specific technical framework for determining the appropriate dredged material disposal alternative and appropriate controls is provided in the Management Strategy for Disposal of Dredged Material developed by the Corps' Waterways Experiment Station (WES) to supplement the 404 regulatory guidance (Francingues et al, 1985). This strategy contains a logical sequence for sediment testing to determine if contaminant loss or migration is significant and requires a control.

3.2.3 Guidance for the design of specific features and controls for a confined disposal facility is available in a number of sources. Since the mid-1970s, the Corps has conducted or contracted over 400 research studies and demonstrations related to dredging and dredged material disposal. Over 270 technical reports were developed as part of the Dredged Material Research Program (USACE, 1978). Other research programs which are still ongoing include:

Long-term Effects of Dredging Operations Program
Field Verification Program
Environmental Effects of Dredging Programs
Dredging Operations Technical Support Program

In addition, the Corps actively transfers dredging and disposal technology information with foreign countries, including England, Japan, France, and the Netherlands.

3.3 CDF DESIGN OVERVIEW

3.3.1 Most people are familiar with what a municipal wastewater treatment plant does and have some appreciation of how it operates. Most people also understand how a landfill for solid waste is built. The designs used for a CDF are unfamiliar to most people, including engineers, scientists, and regulators. This is because a CDF is not a wastewater treatment facility and is not a solid waste landfill, but performs some of the functions of both.

3.3.2 The unique properties of a CDF are required because of the specific physical properties of dredged materials. A wastewater treatment facility is designed to receive water with relatively few solids. A solid waste facility is designed to receive solids with little water. Sediments are half water, half solids by weight. As a result, neither a conventional wastewater facility or landfill can adequately cope with dredged materials. However, certain design features of each are used in a CDF.

3.3.3 Water treatment controls that may be a part of a CDF design and operation include settling basin(s), sand filtration, and polymer flocculation/coagulation. These features are designed to allow the drainage of water associated with dredged materials with as few suspended solids as practicable. Features of landfills that may be a part of a CDF design and operation include barrier systems (clay or synthetic liners), caps, leachate collection, and groundwater monitoring systems. These features reduce the infiltration and migration of dissolved contaminants.

3.3.4 As with wastewater treatment facilities and solid waste landfills, no practicable system of controls is absolutely perfect. Municipal wastewater treatment facilities (with secondary treatment capability) typically achieve a 95 percent removal of suspended solids and a 90 percent reduction in BOD. The containment efficiency of a landfill is more difficult to quantify as a percentage. Some use the number and permeability of barrier systems as an indication of performance.

3.3.5 A CDF has two significant advantages over wastewater treatment and conventional landfills which greatly enhance both the treatment efficiency and pollution containment efficiency. These are the chemical and physical characteristics of the dredged materials. These material properties, particularly with the more contaminated sediments, are the keys to an efficient CDF.

3.3.6 Research has shown that most contaminants associated with dredged materials are strongly bound to the sediment particles. This is especially true for hydrophobic organics (such as PCBs), and heavy metals (such as lead, cadmium and zinc). Because relatively few sediment contaminants become dissolved during disposal operations, most pollutants can be controlled using conventional treatment methods (settling, filtration, coagulation). As an example, the Chicago Area CDF, which uses settling and filtration, has a suspended solids retention efficiency of over 99.999 percent.

3.3.7 Physically, most contaminated sediments contain high levels of fine-grained particles; silt and clay. After dredged and disposed, these sediments will consolidate and compact into a soil mass of very low permeability. This will inhibit the movement of water and any dissolved contaminants. Testing with Indiana Harbor Canal sediments (USACE, 1987) indicates that the permeability of dredged materials following consolidation will be less than 10^{-7} cm/sec, which is comparable with the permeability of a clay liner or cap.

3.3.8 The chemical and physical properties of dredged materials promote a highly efficient treatment and containment in a CDF. The levels of dissolved contaminants which are able to migrate are very low, often below standard detection limits. The quantities of water able to seep or leach from a CDF are similarly small. The quality and quantities of water and contaminants must be estimated using computer simulation techniques. The application of these analytical approaches to CDFs will be described next.

3.4 CDF SIMULATION METHODS

3.4.1 Quantification of environmental impacts from a CDF project are drawn from a variety of sources. The predictive methodologies used to delineate these impacts are constantly being refined and improved. Experience with other CDFs, stochastic, physical, and empirical modeling are currently being used to predict impacts from the construction, operation, and maintenance of a CDF.

3.4.2 Water quality models and computer simulation of environmental phenomena have only been widely used since the early 1970s. The basis of these models are the principles of conservation of mass and energy. The models apply mathematical representations of physical, chemical, and biological processes to a finite "piece" of the environment.

3.4.3 Water quality models were first applied to CDFs in 1985 by the Chicago District, Corps of Engineers. A simple, mass-balance model was applied to a CDF proposed for Indiana Harbor (USACE, 1986). Since then, the modeling of CDFs has been extended to other facilities on the Great Lakes. An interagency CDF workgroup (USEPA, USACE, and USFWS) has supported the use of mathematical models for predicting water quality impacts of CDFs. The USEPA Environmental Research Laboratory in Athens Georgia and Corps' Waterways Experiment Station in Vicksburg, Mississippi have developed contaminant-fate models for PCBs at confined disposal facilities.

3.4.4 The Chicago District of the Corps has developed a series of mathematical models of water quality for the existing CDF at Calumet Harbor, Chicago Illinois. Preliminary calibration has been conducted using nitrogen data obtained during disposal monitoring. In addition, the Chicago District developed a model of a proposed CDF at Waukegan Harbor. The PCBs in the CDF discharge projected using the Corps and USEPA models were very similar. The experience from these efforts as well as those developed from USEPA and Corps research were applied to the Indiana Harbor Project.

3.4.5 A mathematical model has been developed, by the Chicago District, to simulate the mass flux of PCBs entering the air through volatilization. This model is theoretical in nature and developed to estimate the PCB mass loss from a operating CDF at Indiana Harbor. Parameters used by the model need to be field verified and lab tested in order to calibrate the model to actual conditions occurring at a CDF. For this reason the model simulated results are expected to be within one or two orders of magnitude of actual PCB volatile losses. However, at this time the models can be used in a relative manner to rank different CDF options and the no action alternative.

3.4.6 Modeling, as described above is currently the state of art process to define and predict environmental impacts from a CDF project. However, there are inherent variabilities associated with each CDF design as well as location. The physical conditions at a site, general layout, types of controls applied, and character of sediments of a particular harbor or canal are site specific, excluding the use of a general model capable of being used for all CDFs. For example, an in-lake CDF model must account for both the effects of, and to Lake Michigan, while an upland CDF model simulates the impacts to the groundwater beneath the site.

3.4.7 Operational methods include a number of variables which can only be approximated. A contractor performing the dredging and disposal is restricted on how to handle and rehandle dredged materials, however there is a range of acceptable methods that would meet the Corps' plans and specifications. Each method may cause different short term environmental impacts, although the total impacts should be comparable.

3.4.8 The models developed and discussed below, to simulate environmental effects from the operation and use of a CDF for dredged materials from Indiana Harbor and Canal, are preliminary in nature. The purpose of these models is to provide an indication of potential impacts and not definite consequences. Parameters used represent the most likely mode of operation. In some cases a worst-case has been assumed. The consequence of overuse of individual worst-case assumptions is often multiplicative. In light of this, the results of the model simulations should not be construed to represent the absolute effects of an actual operation, but rather, a conservative demonstration of probable effects.

3.4.9 As design and operational parameters are finalized, the models will be updated and calibrated to simulate a better approximation of CDF conditions and impacts. The model will continue to serve as a valuable tool for the environmental management of the recommended CDF. Modifications to operating procedures can be tested to optimize treatment and containment efficiency. The next sections will describe the specific models used to simulate the water quality and air quality impacts of the CDF alternatives considered.

4. WATER QUALITY ANALYSIS

4.1 MODEL APPROACH

4.1.1 The approach taken to simulate environmental impacts from a CDF at Indiana Harbor was to separate the water quality and air quality impacts. To affect water or air quality, a contaminant must have the ability to become mobile and exit the facility. The pathways that a contaminant may travel to leave the CDF are different for air and water.

4.1.2 A CDF water quality simulation must account for a number of physical and chemical processes which may occur inside the CDF, including:

Settling of solids
Delta formation
Changes to CDF pond volume
Release of soluble contaminants during disposal
Dilution of dissolved contaminants in pond water
Oxidation/reduction of contaminants
Dewatering/consolidations of sediments

The first part of a water quality model is a mathematical representation of the physical environment of the empty CDF (surface areas, depths, and volumes). The above processes occur within this physical environment and respond to changes in one another.

4.1.3 The simulation of water quality in an in-lake CDF is more complicated than for an upland CDF. This is because of the presence of a large pond which is a permanent feature for nearly the entire life of the facility. An upland facility may have large or small ponded areas during individual disposal operations. The assumptions applied for all models will be described first, then the water quality model used for the one in-lake CDF will be described, and finally the model used for the three upland CDFs described.

4.2 ASSUMPTIONS

4.2.1 The physical and chemical properties of dredged materials are described in Appendix E. These properties are representative of the existing sediments in the IHC which represent the dredging backlog. The levels of contamination in future maintenance dredgings should be substantially lower than the in-place sediments. The implementation of the Environmental Action Plan and Remedial Action Plan initiated by the IDEM should reduce the sources and levels of settlable contaminants to the Grand Calumet River and Indiana Harbor Canal.

4.2.2 All of the analyses conducted for both the in-lake and upland CDF models utilized volume-weighted bulk chemical concentrations and averaged sediment pore water concentrations based on test results from the in-place sediments. These pore water and bulk chemical concentrations were assumed constant for all parameters except PCB, which varied depending upon whether the sediments being dredged were classified as backlog TSCA or non-TSCA materials, or maintenance materials. For all parameters, except PCBs, the use of existing sediment contamination levels for predicting CDF water quality represents a worst-case analysis. As the levels of sediment contamination are reduced, the water quality impacts associated with dredging and disposal of future sediments will be decreased.

4.2.3 The concentration of PCB associated with each type of sediment was determined by calculating a weighted average from the results of several previous sampling and analysis events. For the TSCA sediment, the weighted average PCB concentration was calculated to be 38 mg/kg (ppm). For the non-TSCA backlog sediment, the PCB concentration was calculated at 6 mg/kg. The weighted average PCB concentration for the future maintenance sediment was calculated as 2 mg/kg. This value was determined from analysis results of surficial grab samples taken in 1987, 1988, and 1989. The surficial sediments are the most recently deposited bottom materials and are indicative of the trend toward less polluted sediments that will continue in the future.

4.3 IN-LAKE CDF WATER QUALITY MODEL

4.3.1 The in-lake CDF model will simulate the concentrations of dissolved and particulate contaminants in the CDF pond in a time series analysis. The underlying assumption is that the CDF pond functions as a fully mixed reactor. The calculated concentrations of dissolved and particulate contaminants in the CDF pond are used to design water treatment systems and project the quality of effluent.

4.3.2 The in-lake CDF water quality model is composed of two parts. The first is the model of the dredged material delta formed as the facility is filled. This is purely a representation of a physical phenomena. The second part is the mass balance analysis which includes the release of soluble contaminants to the CDF pond, dilution in ambient pond water, and chemical transformations of selected contaminants. The delta formation model and the mass balance model will be described first, the construction and operation features of the upland CDF then described, and finally the results of the simulation presented.

4.3.3 Delta Formation Model

4.3.3.1 The most complicated part of developing a model to simulate the filling of a CDF is how to mathematically represent the physical processes which take place inside the CDF --an accounting of the dredgings and water. It is from these accountings that the loadings to the pond and volumes for dilution are based. In order to develop these accountings, it is necessary to know how the CDF will be operated. This includes the methods of dredging and disposal, rate of disposal, location of placement, and operational controls. The model must be able to represent not only how fast the dredgings enter the CDF, but also where the dredgings lie relative to the water surface. This is complicated when the pond water surface is not fixed, but is controlled by a number of factors.

4.3.3.2 The delta volume algorithms are shown in attachment F-1. The dredged material delta was physically represented as a trapezoid. The interior of the CDF can be represented as a trapezoidal prism as shown in attachment F-1. The delta model for the Inland Steel site CDF was developed to represent the filling of this facility in four operations for each cell, or a total of twelve operations.

4.3.3.3 In the initial operations, when the CDF is near empty, the dredged material would be unobstructed and flow outward. As filling continued the previously placed material would hinder movement. Since these sediments maintain a very flat slope the result is to raise the base elevation for the incoming material. This situation can be approximated by reducing the initial delta cross section in height, as shown in attachment F-1.

4.3.3.4 From experience with deltas at the Chicago CDF, a dredged material delta angle of repose (or slope) of 30-50:1 (h:v) is assumed. The height of the delta above the waterline is determined either by physical constraints of the dike crest elevation and size of crane/chute or by a limit imposed by the Corps on its contractor.

4.3.3.5 Key parameters used for simulation of the delta include the type of filling (mechanical or hydraulic), duration, and amount of material. These parameters can only be approximated, however, from experience with past CDFs and a knowledge of the backlog and maintenance dredging required an estimate can be assumed. It should be noted that some features of these operations are at the contractor's discretion, based on field conditions at the time of operation, equipment used and other factors. Therefore, the parameters used for simulation may differ from the actual filling parameters.

4.3.3.6 A layout of the filling sequence for all cells is shown in attachment F-1. In order to simulate the physical filling process, a series of sensitivity checks were incorporated into the model based on experience and best available information as shown in attachment F-1. In this manner, the base elevation of dredged material is raised over time to match the sensitivity checks.

4.3.4 Mass Balance Model

4.3.4.1 The mass balance portion of the in-lake CDF water quality model simulates the water quality within the CDF pond. This model has been tailored for the CDF considered at the Inland Steel site and is a modification of the model applied to the Chicago Area CDF. The model was developed on a Lotus 1-2-3 spreadsheet.

4.3.4.2 The primary assumption of the water quality model is that an in-water CDF acts like a large, fully-mixed reactor vessel. The model must account for loadings of dissolved contaminants into the CDF pond and releases of contaminants from the pond, and must calculate the diluted concentration of dissolved pollutants after mixing of sediment and pond water. The quality of effluent or seepage from the CDF before the application of any post-treatment is the mixed concentration of the pond water. In order for any dissolved contaminant to be discharged from the CDF, it must be released in a soluble form from the sediment to the pond water.

4.3.4.3 Pore Water Concentrations

4.3.4.3.1 Pore water is the water in the interstices of the sediment matrix. Pore water and its dissolved contaminants are released into the CDF pond during disposal operations. Information concerning the quality of pore water was obtained from the results of laboratory analyses performed by WES on Indiana Harbor sediment samples (USACE, 1987). Direct analysis of pore water leached from sediments was conducted for some chemical parameters (USACE, 1987). For other parameters, the pore water concentrations were back calculated using the results of a modified elutriate on sediment samples (USACE, 1987).

4.3.4.3.2 The calculation used to determine the pore water concentration from elutriate results is as follows:

$$C_p = ((C_e*V_e)-(C_w*V_w))/(V_p)$$

where:

C_p = concentration of chemical parameter in the pore water
V_p = volume of pore water
C_w = concentration of chemical parameter in the dilution water
V_w = volume of dilution water
C_e = concentration of chemical parameter in elutriate
V_e = volume of elutriate

The modified elutriate test (Palermo et al, 1986) combines one volume of sediment with four volumes of site water to form the slurry. Sediment (in-situ) is approximately 2/3 pore water by volume. Using these ratios, the above equation is reduced to:

$$C_p = 7C_e - 6C_w$$

The measured and calculated pore water concentrations are shown on table F-9. This method of pore water estimation is extremely conservative. It can greatly overestimate the pore water concentrations for those parameters which are desorbed from sediment particles during the elutriate mixing procedure.

Table F-9: Measured and Calculated Pore Water Concentrations

Parameter	Measured Pore Water Concentration	Calculated Pore Water Concentration
Ammonia	NM[1]	305
Arsenic	0.014	NC[2]
Cadmium	0.0047	NC
Chromium	0.060	NC
Copper	NM	0.210
Cyanide	NM	0.190
Iron	NM	4.6
Lead	0.089	NC
Manganese	NM	0.021
Mercury	0.0002	NC
Nickel	NM	0.180
Nitrate + Nitrite	NM	16
TKN	NM	310
Phenols	NM	0.200
Phosphorus	NM	2.0
Zinc	0.330	NC

All units mg/l.

[1] Not measured.

[2] Not calculated.

4.3.4.3.3 The concentration of PCB in the sediment pore water was determined by using equilibrium partitioning concepts. The distribution coefficient (K_d) for PCB was measured through laboratory analyses performed on Indiana Harbor sediment collected in 1985 (USACE, 1987). This distribution coefficient was applied to the weighted average PCB concentration of the sediment to determine representative dissolved PCB concentrations in the pore water for TSCA, non-TSCA, and future sediments. The calculation of the dissolved PCB concentrations in the pore water is as follows:

$$C_p = C_s/K_d$$

where:

K_d = distribution coefficient (l/kg)
C_s = avg. PCB in TSCA sediment (mg/kg)
C_s* = avg. PCB in non-TSCA backlog sediment (mg/kg)
C_s** = avg. PCB in future maintenance sediment (mg/kg)
C_p = TSCA sediment pore water dissolved PCB conc.
C_p* = non-TSCA backlog sediment pore water diss. PCB conc.
C_p** = future maintenance sediment pore water diss. PCB conc.

Using the distribution coefficient (K_d) of 256,000 l/kg, the following PCB levels in sediment pore water were calculated:

C_s = 38 mg/kg $\quad$ C_p = 0.148 ug/l
C_s * = 6 mg/kg $\quad$ C_p* = 0.023 ug/l
C_s ** = 2 mg/kg $\quad$ C_p** = 0.008 ug/l

4.3.4.3.4 For some chemical parameters no elutriate test results or pore water analyses were available. The concentrations used for these parameters were estimated using data from other contaminated sediments or previous modeling efforts.

4.3.4.4 Ambient Pond Water Quality

4.3.4.4.1 An in-lake CDF is a piece of lake that has been surrounded by a stone filled dike. Monitoring data from the Chicago CDF indicates that the water quality of the CDF pond before disposal operations have begun, and for the majority of time between disposal operations, is essentially the same as the adjacent Lake (USACE, 1985; USACE, 1987; USACE, 1988). The initial water quality of the Inland Steel CDF pond was assumed comparable to nearshore Lake Michigan, and recent monitoring data was used (IDEM, 1986).

4.3.4.4.2 Ambient levels of PCBs were assumed to be 5 parts per trillion (ppt). This concentration is considered representative of ambient conditions in nearshore Lake Michigan. Most sampling and analysis programs have detection limits that exceed this level for PCBs or do not test for this parameter at all.

4.3.4.4.3 The above ambient concentrations were assumed representative of the initial CDF pond water quality for all operations in Cells #1 and #2, and for operations 1,2, and 3 in Cell #3. For operation 4 in Cell #3, the initial pond water concentration was assumed to be the model simulation output from operation 3 since the pond volume was relatively small.

4.3.4.5 Pore Water Release Algorithms

4.3.4.5.1 The prime function of the in-lake model is to account for all inputs and withdrawals of water and pollutants from the CDF pond. Loadings of water and soluble contaminants to the pond come from the sediment disposal process. All other potential contaminant loadings are considered insignificant relative to the loadings from the disposal process.

4.3.4.5.2 The model calculates the release of dissolved contaminants during mechanical disposal of dredged sediments. There are no existing laboratory testing protocols to simulate this release. Dr. Ed Thaxton of Vanderbilt University prepared a preliminary examination of this process for WES with recommendations for possible laboratory and theoretical approaches (Thaxton, 1986). Dr. Thaxton visited the Chicago Area CDF as part of his research on this subject. The development of a predictive method for mechanical disposal is a scheduled research program at WES.

4.3.4.5.3 The Chicago District conducted special studies at the Chicago Area CDF in order to assess the release of contaminants during the disposal of mechanically dredged materials (Miller, 1986). These investigations showed that one literally had to move within 50 feet of the disposal point to see any increase in suspended solids. The release of dissolved pollutants from the disposal operation was not discernible for lead, zinc, or PCBs but was distinguishable for ammonia nitrogen. Weekly monitoring of the Chicago Area CDF pond during all three operations (USACE, 1985; USACE, 1986a; USACE, 1987a) similarly showed detectable increases only for nitrogen (as NH_3 and TKN).

4.3.4.5.4 It is reasoned that during the disposal of mechanically dredged sediments to an in-lake CDF soluble contaminants will be released to the pond in two methods. The first method is the release of sediment interstitial water to the pond as sediments are placed into the water and settle rapidly to the bottom. The second method is the drainage of interstitial water from sediments that are placed on the delta above the waterline.

4.3.4.5.5 To model the water quality of the CDF pond, one must determine how much of the sediment interstitial water is released and drains from the sediments during disposal. Once the sediments are placed and have settled to the bottom or have drained available excess water, they no longer release significant loadings to the pond (relative to the loadings from actively disposed sediment).

4.3.4.5.6 From the physical information on the sediments the amount of solids and pore water in the dredged materials (on a percent basis) can be calculated as follows:

$$\mathrm{PSVOL1} = (\mathrm{PSOL}/\mathrm{SG})/((\mathrm{PSOL}/\mathrm{SG})+(1-\mathrm{PSOL}))$$
$$\mathrm{PPORE} = 1 - \mathrm{PSVOL1}$$

where:

PSVOL1 = percent solids (by volume) of sediments
PPORE = percent water (by volume) of sediments
PSOL = percent solids (by weight) of sediments
SG = specific gravity of sediment solids (specific gravity of water = 1.0)

4.3.4.5.7 Not all of this pore water is available for release to the CDF pond. The two methods of pore water release described above are different and should have different release rates or percentages associated with them. In order to separate these two release methods and calculate the volumes of pore water released from each, how much of the sediments are placed above and below the pond water surface must be determined.

4.3.4.5.8 These volumes were determined using the delta model described above. For operations 1, 2, and 3, it was assumed that approximately 97% of dredgings would be submerged. For operation 4, about one-half of the dredgings were assumed to be submerged.

4.3.4.5.9 The release of pore water from sediments which are placed above the waterline (QUNSAT) is estimated from the physical and engineering properties of the sediments. Mechanically dredged sediments typically have the same solids and water content as in-situ sediments. This has been verified from samples of sediments collected at the Chicago Area CDF during disposal (USACE, 1984, 1985a, 1986a). Dredged material placed on an upland surface will lose water by drainage and drying. Fine-grained dredged materials will, after a long period, typically have a water content approaching its liquid limit (USACE, 1978). As a conservative assumption, the percent of pore water available for release by drainage from unsaturated sediments (USATREL) was determined as the difference between the sediment water content as disposed and the liquid limit. These relationships are illustrated as follows:

PSVOL2 = 1/(1+(LL*SG))
USATREL = (1-PSVOL1) - (1-PSVOL2)
QUNSAT = TVOL*USAT*USATREL

where:

PSVOL2 = percent solids (by volume) of sediments at LL
USATREL = percent of pore water in unsaturated sediments released to pond by drainage
QUNSAT = volume (cy) of pore water drained from unsaturated sediments
TVOL = total volume (cy) of dredged sediments
USAT = percent of dredgings above waterline

Values for the above parameters, measured from sediments collected from Indiana Harbor and Canal are summarized on table F-10.

Table F-10: Sediment Physical Parameters (Data from investigation by WES for Chicago District)

Variable	Definition	Value
PSOL	Total solids of sediments (as dredged)	49%
LLMUD	Liquid limit of sediments	60%
SG	Specific gravity of solids	2.71 g/cm^3
PSVOL1	Percent solids by volume (as dredged)	26%
PSVOL2	Percent solids by volume (as liquid limit)	38%

4.3.4.5.10 The volume of pore water released from sediments which are placed below the waterline (QSAT) is calculated as follows:

$$\mathrm{QSAT} = \mathrm{TVOL} * \mathrm{SAT} * \mathrm{SATREL}$$

where:

QSAT = volume of pore water released to pond from saturated sediment
SAT = percent of dredgings below waterline
SATREL = percent of pore water in saturated sediments released to pond during disposal

The release of pore water from sediments disposed directly to the CDF pond will be determined by physical factors. Sediments that are disposed into a CDF with significant force or which settle through significant depths should have greater opportunity for pore water release than those which slide into a delta which has mounded to a height near the waterline.

4.3.4.5.11 This phenomenon was witnessed at the Chicago CDF during the second (1985) disposal operation. After the first four weeks of disposal, the delta approached the water surface and sediments placed into the CDF caused a lateral displacement of delta sediments with very little turbulence. No laboratory tests have yet been developed to quantify the percent release factor (SATREL). For the application of this model, values of SATREL were determined from engineering judgment using the experience from the Chicago CDF water quality model and monitoring data. Dredgings which travel more than 10 feet from the pond water surface before reaching the base of the CDF were considered to experience 100% release of the sediment pore water. Disposed sediments which traveled 10 feet or less before contacting the CDF bottom were considered to undergo a 90%-10% release of sediment pore water, depending upon the underwater travel distance.

4.3.4.6 Pond Volume and Dilution Algorithms

4.3.4.6.1 The loadings to the CDF have been defined above. The releases or withdrawals from the CDF (QOUT) were determined based on the volume of CDF pond water displaced during each week of the various operations. The pumpage from the CDF is equal to this CDF pond water displacement volume. Thus, the pond volume is constantly changing on a weekly time step according to the above loading and withdrawal information. The calculation of the pond volume is as follows:

$$\mathrm{PVOL}(t) = \mathrm{PVOL}(t-1) + \mathrm{SVOL}(t) + \mathrm{QUNSAT}(t) - \mathrm{QOUT}(t)$$

where:

PVOL(t) = volume of water in CDF pond (cy) @ week t
PVOL(t-1) = volume of water in CDF pond (cy) @ week t-1

QOUT(t) = volume of water pumped from CDF (cy) during week t
SVOL(t) = volume of sediments (cy) placed below waterline during week t
= TVOL(t)*SAT

4.3.4.6.2 The dissolved concentration of a chemical contaminant in the CDF pond at time (t) is calculated using a mass balance equation as shown below:

$$C_d(t) = \frac{C_d(t-1)*[PVOL(t-1)-QOUT(t)-QSAT(t)]+C_p*[QSAT(t)+QUNSAT(t)]}{PVOL(t)}$$

where:

$C_d(t)$ = dissolved chemical concentration (mg/l) in CDF pond @ time t
C_p = sediment pore water chemical concentration (mg/l)

This mass balance equation is based on the assumption that the volume of pore water released from saturated sediments is replaced with pond water (having a quality equal to $C_d(t-1)$).

4.3.4.7 Chemical Transformations

4.3.4.7.1 Most chemical parameters are assumed to be conservative by the in-lake water quality model, meaning there is no degradation, transformation, readsorption, or uptake. As a result, the output from this model will overestimate the concentrations of dissolved chemical substances which will occur under field conditions. The only parameters for which chemical or biological reactions are simulated are ammonia nitrogen and PCB. Other parameters for which transformations are anticipated to significantly effect actual concentrations, such as iron, manganese, phosphorous, cyanide, and phenol, are also discussed.

4.3.4.7.2 This model simulates nitrification, which is the oxidation of ammonia (NH_3) to nitrite (NO_2) and nitrate (NO_3). This process occurs naturally in waters where a sufficient dissolved oxygen (DO) level and nitrifying bacteria are available. Nitrification follows first-order reaction kinetics and is simulated using the following equation:

$$NH_3(t) = NH_3(t-1)*e^{-Kt}$$

$$K = K_{20}*A^{(T-20)}$$

where:

$NH_3(t)$ = dissolved ammonia concentration (mg/l)
K = nitrification rate (/day)
t = time (days)
A = nitrification constant
K_{20} = nitrification rate @ 20 ^{o}C (/day)
T = water temperature (^{o}C)

4.3.4.7.3 For this application of the model, nitrification rates were obtained from literature values (USEPA, 1985). A nitrification rate (K_{20}) of 0.1 /day and a nitrification constant (A) of 1.08 were considered representative of the freshwater system being modeled. These nitrification values were used with the water quality model of the Chicago Area CDF and were found to produce results consistent with CDF pond monitoring data.

4.3.4.7.4 The in-lake model calculates the concentrations of PCBs in the CDF pond using two approaches. The first approach applies the mass balance algorithm to the pore water and pond water concentrations as described earlier. The second approach uses algorithms developed by the USEPA Environmental Research Laboratory in Athens, Georgia. The USEPA laboratory developed a spreadsheet model for application to the CDFs at the request of USEPA Region V. This model determines the dissolved levels of PCBs in the CDF pond through equilibrium partitioning concepts.

4.3.4.7.5 Equilibrium partitioning uses the relative chemical solubilities of hydrophobic organic compounds (like PCBs) in sediment and water to estimate the concentrations of the compound in these two media at equilibrium. PCBs are poorly soluble in water and have a high affinity for sediments, particularly those with a significant organic content. The ratio of PCB concentrations in sediment and water at equilibrium is referred to as K_d. This partitioning coefficient (K_d) can be calculated from chemical properties of the contaminant (PCB) and information about the organic content (TOC) of the sediment or through a number of laboratory procedures. The value of K_d for Indiana Harbor sediment was determined by WES as 256,000 l/kg (WES, 1987).

4.3.4.7.6 The USEPA spreadsheet model determines the dissolved concentrations of PCBs in the CDF pond by assuming equilibrium with the PCBs associated with suspended solids. The algorithm used for this model is as follows:

$$PCB_d(t) = \frac{C_s}{K_d + (1/SS(t))}$$

√68-69

where:

$PCB_d(t)$ = concentration of dissolved PCBs in pond (mg/l)
C_s = concentration of PCBs in suspended sediment (mg/kg)
$SS(t)$ = concentration of suspended solids in pond ($mg/l*10^6$)

4.3.4.7.7 Dissolved iron and manganese are metals that readily oxidize with dissolved oxygen to form hydrous oxides which precipitate and settle to the bottom sediments. When the sediment pore water is released to the CDF pond water, the dissolved iron and manganese will be exposed to a relatively high concentration of dissolved oxygen. Rapid oxidation will occur and these metals will settle as inactive precipitates to the CDF bottom. As a result, the levels of dissolved iron and manganese in the CDF pond will be far less than predicted by the model.

4.3.4.7.8 Phosphorus rarely occurs in its elemental form in natural waters but does exist in waterways as the compound phosphate. Phosphorus as phosphate is one of the major nutrients required for plant growth and is essential for life. Phosphates are used by algae and higher aquatic plants and may be stored in excess of use within the plant cells (USEPA, 1976). The release of phosphorus from the sediment pore water to the CDF pond will result in the uptake of this pollutant (in the form of phosphate) by algae and other aquatic plants. This catabolism of phosphate will reduce the actual levels of dissolved phosphorous in the CDF pond below those predicted by the model.

4.3.4.7.9 Phenols are a class of organic compounds that are considered to be highly reactive with respect to oxidation. Under the anoxic conditions encountered in the sediment pore water, phenols do not have the ability to be oxidized due to the absence of dissolved oxygen. The ambient pond water does have a relatively high dissolved oxygen concentration, especially when compared to the sediment pore water. Upon release of the pore water to the pond, the phenols should be rapidly oxidized, and the dissolved levels in the pond would be less than those predicted by the model.

4.3.4.7.10 Undissociated hydrogen cyanide is the predominant form of cyanide in all but highly alkaline waters. For waters with a pH of 8.0 or less and at a temperature of 20^o C, the fraction of free cyanide existing as hydrogen cyanide exceeds 95 percent (USEPA, 1980). Hydrogen cyanide is a very volatile compound and as such does not occur in high concentrations in natural waters. The portion of free cyanide that is not volatilized has a distinct tendency to be fixed in the form of insoluble or undissociable complexes by trace metals or may complex irreversibly with heavy metals in water (USEPA, 1980). The volatilization and complexation of cyanide should reduce the dissolved levels in the CDF pond below those predicted by the model.

4.3.4.8 Suspended Solids

4.3.4.8.1 The above algorithms are used to predict the concentrations of the dissolved chemical parameters in the CDF pond. The total concentrations of these parameters are the sum of the dissolved and suspended contaminant levels. Suspended chemical constituents are enmeshed in the suspended solids matrix. No predictive methods are available to mathematically represent the resuspension during mechanical disposal or settling of fine-grained sediments at low concentrations. The suspended solids concentration levels used for the in-lake CDF model were derived entirely from the operating and monitoring experience at other CDFs where mechanical dredged disposal was used.

4.3.4.8.2 The suspended concentrations of a chemical constituent can be estimated using the suspended solids concentration and sediment bulk chemical concentration. The algorithm used to determine these suspended concentrations is as follows:

$$C_{ss}(t) = TSS(t)*C_b/10^6$$

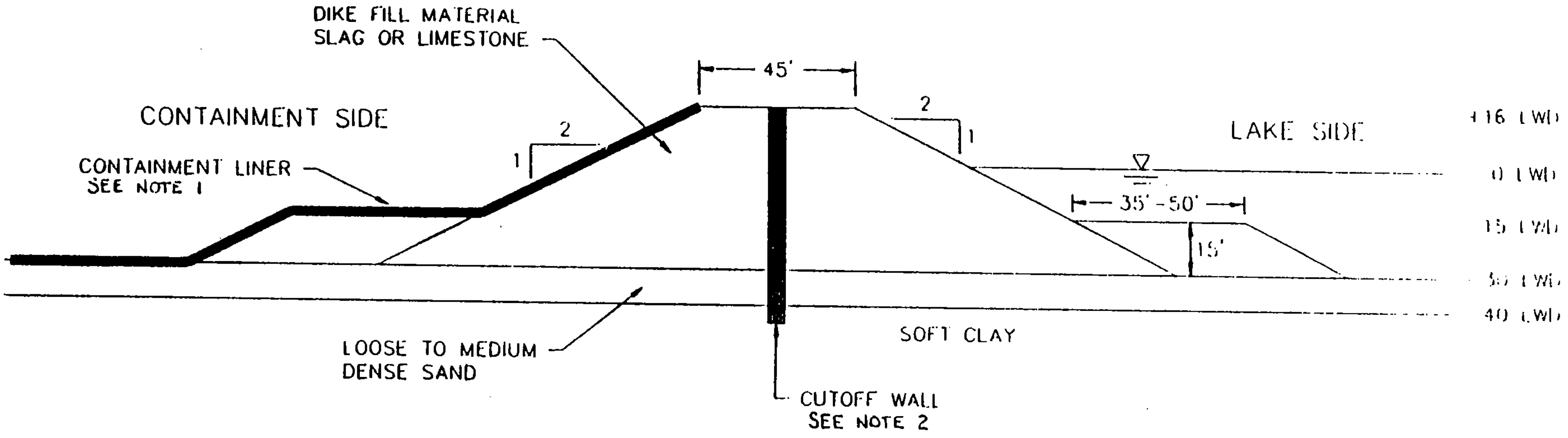
where:

$C_{ss}(t)$ = concentration of suspended chemical (mg/l)
$TSS(t)$ = concentration of total suspended solids (mg/l)
C_b = bulk concentration of chemical in sediment (mg/kg dry weight)

4.3.5 Inland Steel CDF Alternative

4.3.5.1 Design and Operation

4.3.5.1.1 The proposed CDF at the Inland Steel site is an in-lake facility located along the south eastern side of the Inland Steel lakefill (plate F-2), covering an area of approximately 120 acres. The CDF would be divided into three separate cells, interconnected by adjustable overflow weirs. The facility is formed by dikes of graded stone constructed on existing lake bottom and extending to an elevation of +16 ft LWD along the northwest side of cell #3 and +11 ft LWD along the rest of the CDF. The CDF dikes are trapezoidal in cross section (figure F-1), with a total height of 41 to 46 feet, a base width of about 300 to 350 feet and a crest width of 45 feet. The bulk of the dikes are formed of gravel-sized crushed limestone. Larger stone (up to several tons each) is placed on the outside face for erosion protection from waves.



NOTES:

1. CONTAINMENT LINER OPTIONS INCLUDE: GROUT MATTRESS, ASPHALTIC GABION MATTRESS, AND SYNTHETIC MEMBRANE.

2. CUTOFF WALL OPTIONS INCLUDE: BENTONITE/CEMENT SLURRY OR CEMENT GROUT SLURRY.

3. UNDERLYING SOFT CLAY WAS NOTED TO BE OCCASSIONALLY ORGANIC FOR THAT CONDITION, THIS CROSS-SECTION MAY NEED TO BE ALTERED.

50 0 50
SCALE IN FEET

Figure F-1

FEBRUARY 1989

INDIANA HARBOR CDF
INLAND STEEL SITE
CONCEPTUAL CROSS-SECTION
(TYP)

4.3.5.1.2 The current plan for the design of the CDF is to construct a diked disposal area with a barrier system that will prevent the migration of the dredged material through the dike. The types of barrier systems being investigated include:

- A cement/bentonite slurry wall through the dike
- A grouted mattress liner within the cells
- a synthetic liner within the cells

Further information on these barrier systems can be found in Appendix L. The design intent is to restrict any flow through the dike to the lake from the beginning of operations. An additional barrier system of non-TSCA dredged material will be used in Cell #1 to encapsulate the TSCA material and further prevent PCB migration through the CDF dike.

4.3.5.1.3 The three CDF cells each have a capacity of about 1 million cubic yards. The mode of operation described below is considered representative but not the only way it may occur. It is assumed that each CDF cell would be filled in four operations of 200,000 to 300,000 cubic yards each. Cell #1, the most westerly cell, is to be filled first, and contain all TSCA material to be dredged. This cell would be completely filled before placement of any dredgings in either Cell #2 or Cell #3, and Cell #2 would be filled completely before placement of material in Cell #3. All of the cells would be capped and covered after filling.

4.3.5.1.4 Dredged materials will be brought to the CDF in barges or scows, each containing about 1000 to 1500 cubic yards of material. The sediments will be disposed using mechanical methods. This practice greatly reduces the resuspension of sediments within the CDF pond which in turn improves the overall quality of the effluent from the CDF. The precise method of sediment rehandling is left to the contractor's discretion. However, the Corps will require that the contractor prevent spillage or drippings from entering the lake. Examples of mechanical rehandling systems used by dredging contractors at the Chicago Area CDF are shown on figure F-2.

4.3.5.1.5 Dredged sediments will form a delta inside the CDF during placement. This delta will be highest at the CDF dike and slope toward the CDF interior. It is estimated that between 500,000 and 750,000 cubic yards of dredged material could be placed in Cell #1 before the material would need to be reworked. At this time most of the diked surface, along two sides of the cell will be lined with dredged materials extending to within 5 feet of the dike crest.

✓13-14

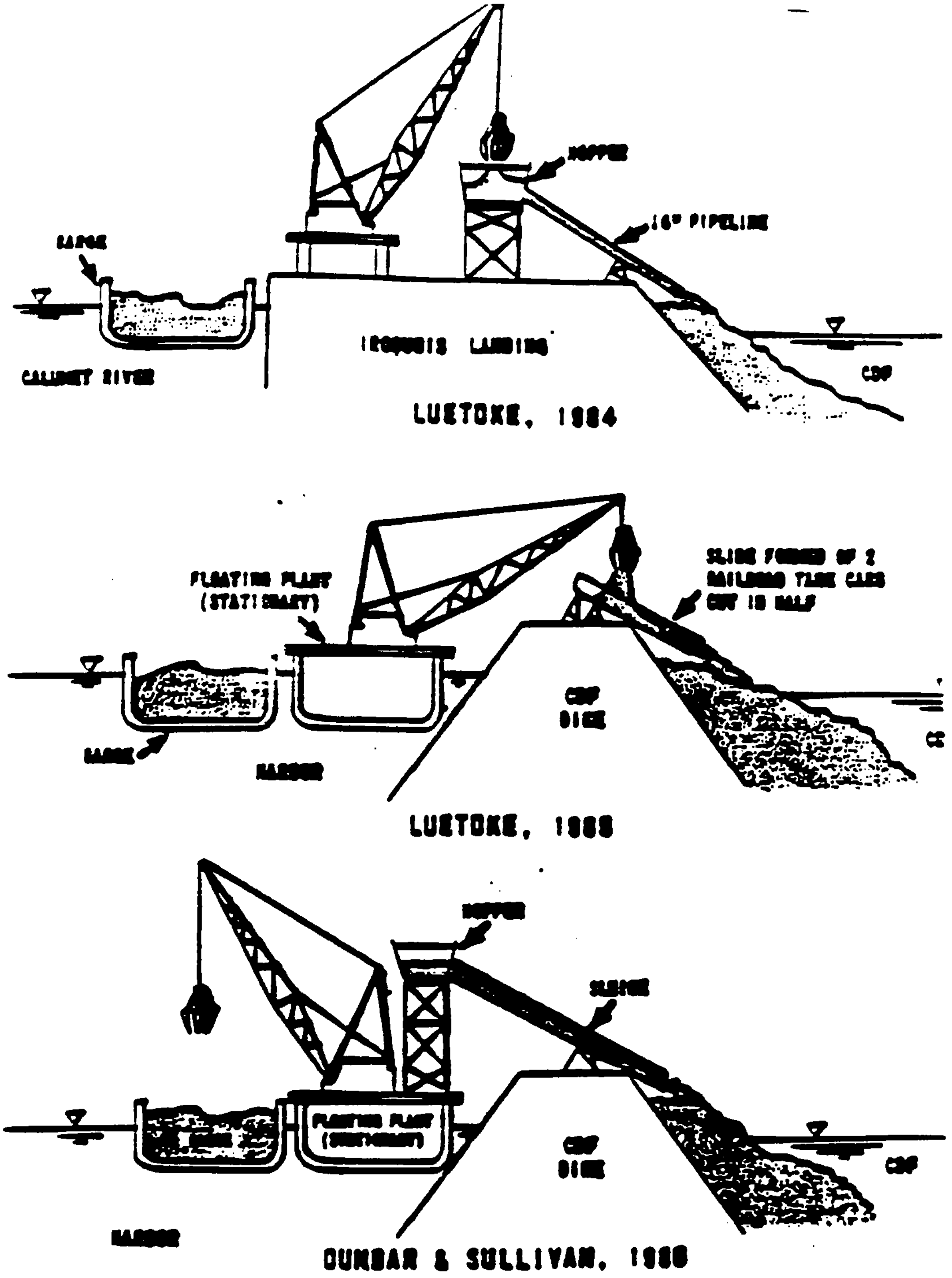


Figure F-2

Mechanical Rehandling Operations used at
Chicago Area CDF

4.3.5.1.6 The sediments would be reworked in order to construct a containment liner for the TSCA material. Once constructed, the TSCA material would be placed within the CDF. During this operation an additional amount of dredgings (non-TSCA) would be placed over the TSCA material to cover and encapsulate the TSCA material.

4.3.5.1.7 Although the placement is more difficult, the sediments comprising the TSCA operation can be disposed in the CDF using mechanical means. The difficulty arises from the fact that these materials are to be placed in the middle of the CDF. However, due to the relatively small cell size, and the fact that the dike crest can be accessed by construction equipment, this problem can be overcome. Cells #2 and #3 would be filled in a similar manner, except that no TSCA materials would be handled.

4.3.5.1.8 As dredged material is deposited into the CDF an equal volume of pond water will be pumped out in order to maintain a static pressure head with Lake Michigan. The water would be pumped from the cell furthest from the one being filled to maximize detention times for settling. Internally, water would pass over adjustable weirs connecting the cells. Pumped water would be treated and discharged to Lake Inland.

4.3.5.1.9 The above method of pumping will also have the effect of diluting the discharged water from Cell #1 through two cell volumes of water similar in quality to Lake Michigan. The effluent from Cell #2 will be discharged through Cell #3 prior to any post-treatment, resulting in the dilution of this effluent by one cell volume of water similar in quality to Lake Michigan. The effluent from Cell #3 will not have the benefit of any dilution effects associated with it.

4.3.5.2 Results of Analysis

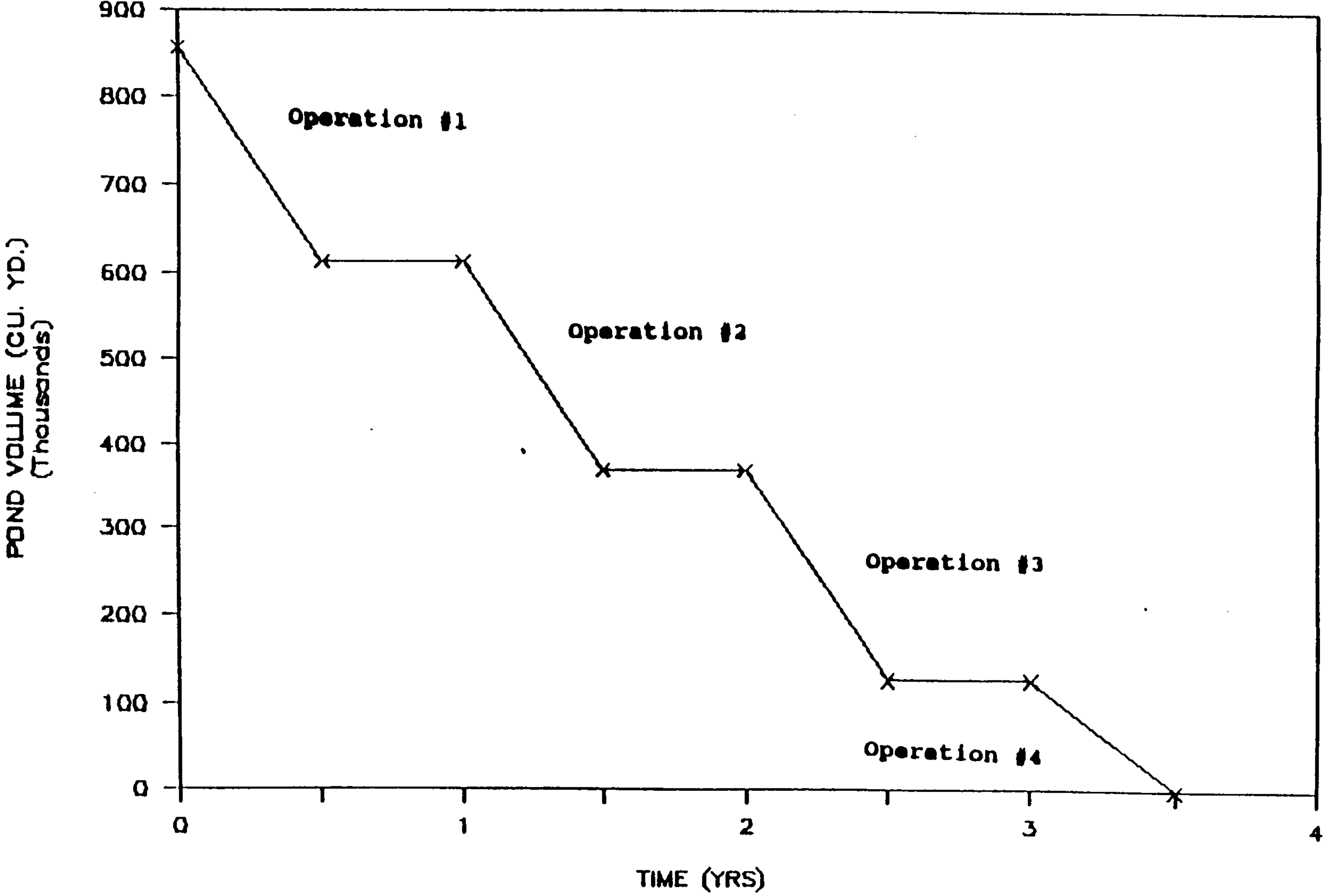
4.3.5.2.1 The delta formation model was applied to the Inland Steel CDF design described above. The delta formation for a single cell was simulated. The detailed results of the simulation are provided in attachment F-1. These results would be the same for filling Cell #2 and Cell #3.

4.3.5.2.2 The mass balance model was used to predict the quantity and quality of water within the CDF pond with the above CDF operation procedures. The volume of the CDF pond diminishes with successive disposal operations, as shown on figure F-3. The volume of water pumped from the CDF also changes with time. During operation #1,#2, and #3 the pumpage would be maintained at about 15,000 cubic yards per week. Pumpage would decreases during the last disposal operation to each of the three cells to about 2,000 cubic yards per week. This is caused by the elimination of the CDF pond within each cell, which causes less water to be displaced, and less pumpage to maintain hydrostatic equilibrium with the Lake.

Figure F-3

INLAND STEEL SITE

POND VOLUME CELL #1



4.3.5.2.3 The quality of water within the CDF pond can not be demonstrated with a single table or figure. Pond water quality will vary with time within a single disposal operation. It will also vary from one operation to another. In addition, the water in each cell of the CDF might be considered as a separate pond. Because the water quality impacts of the CDF are principally related to the water pumped out of the facility, the simulation results of the water quality for the cell being filled will be presented. The water quality results take into consideration the dilution effects for cell #1 and Cell #2.

4.3.5.2.4 During each disposal operation, the quality of water in the CDF pond (and the pumpage) will change. In general, concentrations will increase as the operation progresses. After the operation is completed (and pumpage has ceased) the pond quality will gradually revert to conditions comparable with ambient Lake Michigan water quality. Figure F-4 shows the time-series trend of dissolved nickel for the first operation in Cell #1 as an example. Most other parameters will follow a similar trend. Ammonia-nitrogen will have a more complicated time-series trend because the simulation considers the oxidation of ammonia to nitrite/nitrate.

4.3.5.2.5 The reduction to the CDF pond volume as the CDF becomes filled will cause less dilution of released sediment pore water. As a result, the average and maximum concentrations of most constituents in the pumpage water will increase with successive disposal operations. The total quality (dissolved and suspended) of pumpage water for each disposal operation is summarized on table F-11. Shown are the average and maximum concentrations of modeled parameters.

4.3.5.2.6 These results represent the character of the pumpage from the CDF without any post-treatment. Water treatment alternatives and compliance with applicable standards are discussed in section 6. The water quality model does take into account the different sediment types based on PCB levels, discussed in section 4.2.3. The actual concentration of some parameters will be different from the simulated results because of chemical or biological processes not simulated by the model.

4.3.5.2.7 Algae and zooplankton populations will be resident in the CDF ponds throughout its operation. Dissolved phosphorous and nitrogen released during disposal operations should promote algae growth. An algae bloom is unlikely to occur until the last two operations in the last cell. However, the growth of algae populations and predation by zooplankton in the CDF ponds should significantly reduce levels of dissolved phosphorous and nitrogen compounds. In addition, the settling of biological detritus in the CDF pond should reduce the levels of dissolved organic and metals which are consumed by or adsorbed to algae or zooplankton.

Figure F-4

Time-Series Trend of Dissolved Nickel

Cell #1 Operation #1

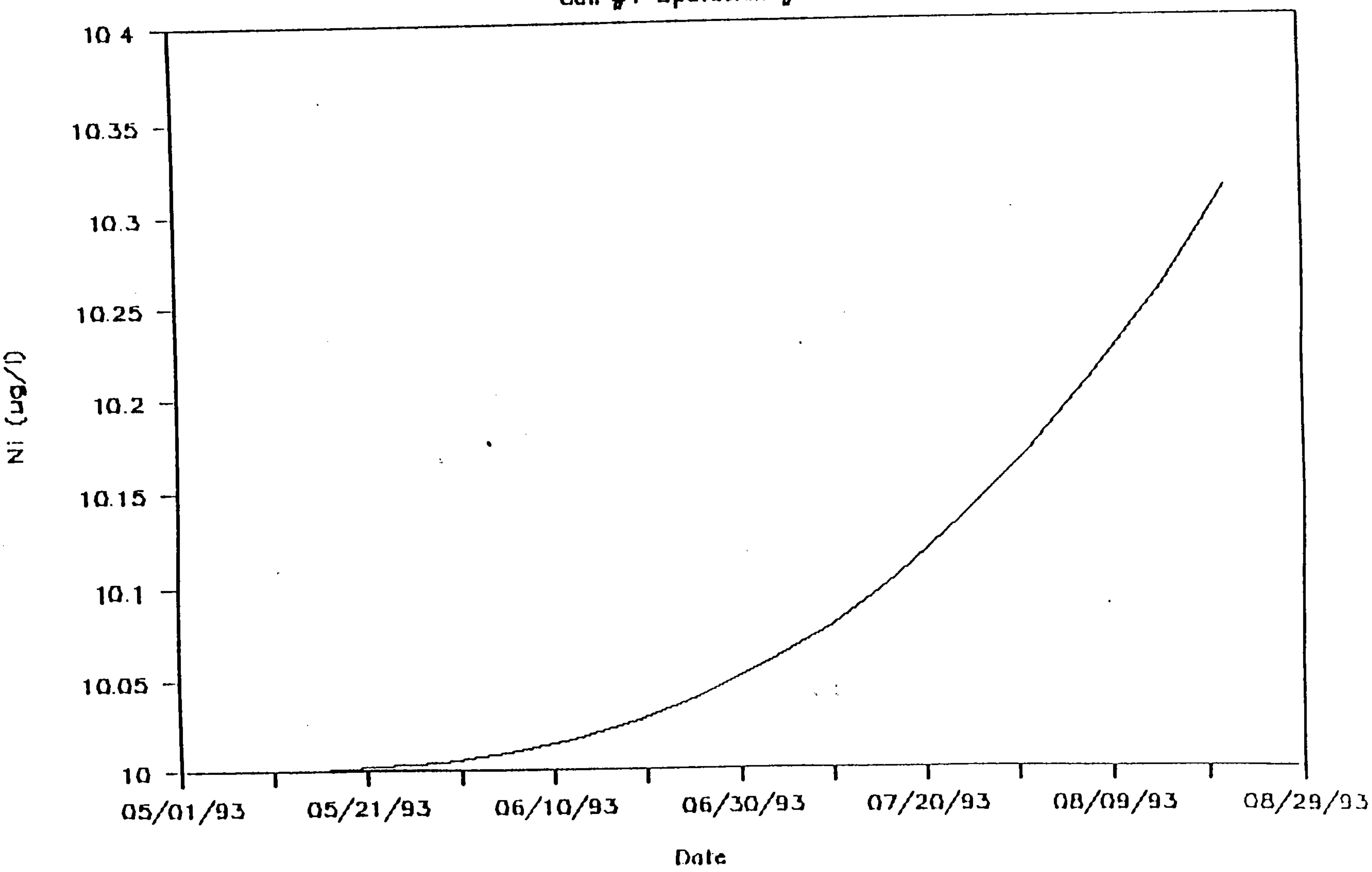


Table F-11: Predicted Untreated Effluent Characteristics
Mechanical Disposal - Inlake CDF

Parameter		Cell #1 50 % Filled					
		Dissolved Conc.		Suspended Conc.		Total Conc.	
		AVG.	MAX.	AVG.	MAX.	AVG.	MAX.
TDS	mg/l	---	---	182	184	182	184
Total Solids	mg/l	182	184	10	10	192	194
Temperature	°C	---	---	---	---	19	23
pH		---	---	---	---	8	8
Phosphorus	mg/l	0.04	0.05	0.03	0.03	0.1	0.08
TKN	mg/l	0.63	1.41	0.03	0.03	0.7	1.4
NH_3 Nitrif. rate	/day	0.09	0.13	0.00	0.00	0.1	0.13
NH_3 (no nitrif.)	mg/l	0.43	1.19	0.01	0.01	0.4	1.2
NH_3 (w/ nitrif.)	mg/l	0.18	0.31	0.01	0.01	0.2	0.32
Arsenic	ug/l	1.11	1.14	0.53	0.53	1.6	1.7
Barium	ug/l	20.80	21.03	0.00	0.00	21	21
Cadmium	ug/l	2.00	2.01	0.11	0.11	2.1	2.1
Chromium	ug/l	7.56	7.69	3.70	3.70	11	11
Copper	ug/l	8.07	8.59	1.56	1.56	10	10
Iron	ug/l	251	262	1446	1446	1697	1708
Lead	ug/l	10.08	10.28	8.37	8.37	18	19
Manganese	ug/l	196	196	19	19	215	215
Mercury	ug/l	0.12	0.12	0.01	0.01	0.1	0.13
Nickel	ug/l	10.18	10.59	0.99	0.99	11	12
Zinc	ug/l	32.62	33.35	36.69	36.7	69	70
Cyanide	ug/l	5.35	6.16	0.01	0.01	5	6
Total PCB	ng/l	5.10	5.33	60.00	60.0	65	65
Total Phenol	ug/l	5.32	5.61	0.03	0.03	5	6

(continued)

Table F-11: Predicted Untreated Effluent Characteristics
Mechanical Disposal - Inlake CDF (continued)

Parameter		Cell #2 50 % Filled					
		Dissolved Conc.		Suspended Conc.		Total Conc.	
		AVG.	MAX.	AVG.	MAX.	AVG.	MAX.
TDS	mg/l	---	---	195	216	195	216
Total Solids	mg/l	195	216	10	10	205	226
Temperature	°C	---	---	---	---	19	23
pH		---	---	---	---	8	8
Phosphorus	mg/l	0.07	0.12	0.03	0.03	0.1	0.15
TKN	mg/l	5.23	13.44	0.03	0.03	5.3	13.5
NH_3 Nitrif. rate	/day	0.09	0.13	0.00	0.00	0.1	0.13
NH_3 (no nitrif.)	mg/l	4.90	12.87	0.01	0.01	4.9	12.9
NH_3 (w/ nitrif.)	mg/l	1.04	1.84	0.01	0.01	1.0	1.8
Arsenic	ug/l	1.30	1.63	0.53	0.53	1.8	2.2
Barium	ug/l	22.16	24.60	0.00	0.00	22	25
Cadmium	ug/l	2.04	2.11	0.11	0.11	2.2	2.2
Chromium	ug/l	8.32	9.68	3.70	3.70	12	13
Copper	ug/l	11.09	16.48	1.56	1.56	13	18
Iron	ug/l	315	429	1446	1446	1761	1875
Lead	ug/l	11.24	13.30	8.37	8.37	20	22
Manganese	ug/l	193	196	19	19	212	215
Mercury	ug/l	0.12	0.13	0.01	0.01	0.1	0.14
Nickel	ug/l	12.60	16.94	0.99	0.99	14	18
Zinc	ug/l	36.92	44.62	36.69	36.7	74	81
Cyanide	ug/l	7.92	12.77	0.01	0.01	8	13
Total PCB	ng/l	5.05	5.13	20.00	20.0	25	25
Total Phenol	ug/l	8.24	13.30	0.03	0.03	8	13

(continued)

Table F-11: Predicted Untreated Effluent Characteristics
Mechanical Disposal - Inlake CDF (continued)

Parameter		Cell #3 50 % Filled					
		Dissolved Conc.		Suspended Conc.		Total Conc.	
		AVG.	MAX.	AVG.	MAX.	AVG.	MAX.
TDS	mg/l	---	---	335	482	335	482
Total Solids	mg/l	335	482	75	75	410	557
Temperature	^{o}C	---	---	---	---	19	23
pH		---	---	---	---	8	8
Phosphorus	mg/l	0.42	0.78	0.20	0.20	0.6	0.98
TKN	mg/l	59.13	115.6	0.22	0.22	59.3	116
NH_3 Nitrif. rate	/day	0.09	0.13	0.00	0.00	0.1	0.13
NH_3 (no nitrif.)	mg/l	57.28	112.1	0.06	0.06	57.3	112
NH_3 (w/ nitrif.)	mg/l	8.15	9.73	0.06	0.06	8.2	10
Arsenic	ug/l	3.46	5.72	3.98	3.98	7.4	10
Barium	ug/l	38.15	54.90	0.00	0.00	38	55
Cadmium	ug/l	2.51	2.99	0.83	0.83	3.3	4
Chromium	ug/l	17.27	26.62	27.75	27.8	45	54
Copper	ug/l	46.48	83.50	11.70	11.7	58	95
Iron	ug/l	1065	1850	10847	10847	11911	12697
Lead	ug/l	24.78	38.95	62.78	62.78	88	102
Manganese	ug/l	163	192	144	144	307	336
Mercury	ug/l	0.14	0.15	0.05	0.05	0.2	0.20
Nickel	ug/l	41.05	70.84	7.43	7.43	48	78
Zinc	ug/l	87.43	140.3	275.2	275.2	363	415
Cyanide	ug/l	39.79	73.17	0.07	0.07	40	73
Total PCB	ng/l	5.56	6.10	150.0	150.0	156	156
Total Phenol	ug/l	41.45	76.23	0.22	0.23	42	76

4.3.5.2.8 The dissolved concentrations of iron, manganese and other parameters will also be reduced through chemical reactions and adsorption. Anoxic pore water contains high levels of dissolved iron and manganese. When exposed to the oxygenated water in the CDF pond, iron and manganese will rapidly form insoluble precipitates. Virtually all of the iron and manganese will drop out of solution. In addition, a number of other dissolved parameters will co-precipitate or become adsorbed onto the precipitates formed by this process. These other parameters which should experience reduced dissolved concentrations include phosphorous, cadmium, chromium, lead, and zinc.

4.3.5.2.9 The concentrations of organic contaminants, such as phenol and cyanide should be significantly less than reflected by the model simulation. Phenol should be rapidly oxidized under aerobic conditions. Cyanide will experience volatilization, and will also form complexes with metals that will settle out.

4.4 UPLAND CDF WATER QUALITY MODEL

4.4.1 The water quality impacts of the upland CDFs (141st Street, J-Pit, ECI sites) have been predicted using two different models. This is necessary because two methods of disposal operation were considered (mechanical and hydraulic), and the conditions within the upland CDF affecting water quality are very different with these two methods.

4.4.2 For the mechanical disposal operation a mathematical model, the Hydrologic Evaluation of Landfill Performance (HELP) model, developed by the WES for the USEPA, was applied. The model was designed to evaluate barrier systems and other environmental controls used at landfills (Schroeder, 1986). The HELP model has been applied to the upland CDFs by the Chicago District to provide information about the quantity and quality of water discharged during disposal operations. This information will be used, in turn, to assess the impacts on receiving waters and to determine post-treatment requirements for the CDF discharge for each site. This model is also used to evaluate the performance of cap and cover designs for all the CDFs.

4.4.3 For the hydraulic disposal operation, a variation of the inlake CDF model was applied. This model was much simpler than the inlake CDF model. There are no delta formation algorithms with this model, and the CDF pond is a transient feature.

4.4.4 Mechanical Disposal

4.4.4.1 Mechanical disposal may be used with any of the upland CDFs. With mechanical disposal, dredged materials are transported into the CDF by truck (or by rail). The dredgings are placed and moved around with earth moving equipment. As with the Inland Steel CDF, the upland CDFs would be filled in sections. Dredgings would be placed into an area to a certain elevation, and then that portion of the facility would be graded and capped. At any time, one portion of the CDF might be capped, while another is being disposed to, and another is empty. To predict the water quality impacts of the upland CDF, the model must account for the differences between these portions of the site.

4.4.4.2 Dredged material placed on an upland surface will lose water by drainage and drying. Although localized ponding may occur for limited times during disposal or after storms, there is no permanent pond. The drying of dredged materials and formation of a crust is a two-stage process. First stage drying typically ends with the dredged materials having a water content equal to 1.8 times their liquid limit (USACE, 1987). Second stage drying continues until a water content of 1.2 times the plastic limit.

4.4.4.3 The HELP model was applied to develop a water budget for the upland CDF with mechanical disposal. This was done because mechanically dredged materials have so little free-draining water that other factors, such as precipitation and evaporation/ transpiration become more important. The HELP model is a hydrologic model which can predict the amount of water which falls onto a surface, the amount that runs off, the amount that percolates into the ground, the amount lost through evapo-transpiration, and the amount collected by leachate collection systems.

4.4.4.4 The upland CDFs will all have an underdrain, comparable in some ways to a leachate collection system. Any water which drains from the dredgings as well as precipitation will be collected by this system and pumped from the CDF. The quantity and quality of this pumpage was predicted by utilizing the HELP model for a number of CDF surface conditions, as follows:

Empty - post construction CDF floor with no dredgings placed
New - dredged material surface during or shortly after disposal (no vegetation)
Aged - dredged material surface some time after disposal, with moderate to dense vegetation
Capped - surface of CDF post cap/cover placement

As stated above, one or more of these conditions may occur within the upland CDF at one time. The total surface area of the CDF at a given stage of filling is represented by some combination of these conditions. For example, at the half-filled point, one third of the CDF area would be capped, one third would be empty, and the remaining third would be divided between new and aged.

4.4.4.5 The suspended solids levels in the water pumped from the underdrain system was assumed to be around 50 ppm. The underdrain will either be trenched into existing surface soils, composed of fine grained sand (141st Street and ECI) or be constructed with a layer of sand/gravel from offsite. The presence of the sand layer should restrict the movement of solids into the underdrain, much like a filter.

4.4.5 Hydraulic Disposal

4.4.5.1 Hydraulic disposal of mechanically dredged sediments is an option being considered for two of the upland sites (141st

Street, ECI sites). With this method, barges of dredged materials would be brought to the unloading area and the sediments slurried by the addition of canal water and piped to the CDF. The amount of additional water required to slurry and transport the dredged materials is dependent on a number of factors; sediment physical characteristics, pump type, pipeline distance, etc.

4.4.5.2 The amount of additional water required to transport the dredged material is very important to the water quality model, since it represents an additional volume to be drained, treated and discharged. A pond will develop during the disposal operation and be drained shortly after completion of each operation. With hydraulic disposal, the CDF functions as a large settling basin. The upland CDF would only be divided into two or three cells. Primary settling would occur in the cell being discharged to. Most of the solids would settle out in this cell. Water would be drained from this cell to the adjoining cell which functions as a secondary settling basin. Polymer flocculants may be added to the water to enhance settling performance.

4.4.5.3 Water would be pumped directly out of the secondary settling basin during disposal. The underdrain system could not keep pace with the necessary pumpage rate during disposal. At other times, the underdrain could function to drain precipitation, as with mechanical disposal. The model must determine the volume of the CDF pond and the quality of water drained.

4.4.5.4 Pond Volume

4.4.5.4.1 The volume of the pond is a function of the rates of pumpage both into and out of the upland CDF. The rates of pumpage are determined by the dredging rate, slurry composition, and detention time required for settling. For the purposes of this model, the quantity of additional water necessary to hydraulically dispose of the dredgings is assumed to be four times the volume of sediments dredged. This 4:1 ratio is representative of a standard cutterhead hydraulic dredge, and is the ratio used with the elutriate test procedure.

4.4.5.4.2 It must be recognized that when pumping out from a barge, less additional water may be required to form a suitable slurry. In addition, innovative pumps are available which can handle slurries with greater solids levels, and may require little additional water. The 4:1 (additional water:sediment) ratio used here represents a worst case. As the amount of water that is needed to hydraulically transport the dredged materials is decreased, less water will have to be drained and discharged, and the water quality will approach that with mechanical disposal.

4.4.5.4.3 The pond volume can be expressed on a weekly basis for the hydraulic disposal method as follows:

$$\mathrm{PVOL}(t) = \mathrm{PVOL}(t-1) + [\mathrm{HVOL}(t) + \mathrm{QSAT}(t)] - \mathrm{QOUT}(t)$$

where:
PVOL(t) = pond volume
HVOL(t) = volume of sluice water
QSAT(t) = pore water released to pond
QOUT(t) = volume of water pumped from CDF

4.4.5.5 Pond Water Quality

4.4.5.5.1 The quality of water drained from the upland CDF during hydraulic disposal is determined for both dissolved and particulate contaminants. Laboratory procedures have been developed to project these components, and have been applied to Indiana Harbor sediments (see Appendix E).

4.4.5.5.2 The level of particulate contaminants in the CDF pond is determined by the amount of suspended solids. This, in turn, is determined from settling tests performed with the sediments to be dredged. Two sets of settling tests have been performed with Indiana Harbor sediments (USACE, 1980; USACE, 1987). These tests were performed using a 4:1 sediment slurry. Initially, this slurry has a solids content of about 15% to 20%. With a detention time of nine days, the levels of suspended solids are reduced to about 1300 mg/l in the pond water (USACE, 1987).

4.4.5.5.3 The detention time within the upland CDF is calculated from the capacity in the settling basin(s) and the throughput rate. With a typical dredging operation, 250,000 cubic yards of sediments (mechanically dredged) will be disposed in 1,250,000 cubic yards of slurry in 3-4 months. Because the CDF cells have considerable capacity, water would not have to be pumped out of the CDF immediately. This delay in pumpage will enhance detention time. A minimum detention time of two weeks can be provided by the upland CDFs, although for much of their operation longer detention times will be available. During the last two dredging operations, the CDF may not have capacity remaining for adequate settling times. As a result, these disposal operations may have to be handled mechanically.

4.4.5.5.4 With hydraulic disposal (assuming a 4:1 ratio), polymer flocculation followed by secondary settling will be required to reduce the suspended solids to manageable levels. Laboratory tests with a variety of flocculants have been performed with Indiana Harbor sediments (USACE, 1980). Several flocculants were capable of reducing suspended solids by 99.5 percent. With extended settling times, followed by polymer flocculation and secondary settling, the water drained from the upland CDF should contain suspended solids levels of 50 ppm or less.

4.4.5.5.5 The dissolved contaminants in the water drained from the upland CDF can be projected using the modified elutriate test. This test (Palermo, 1986) was specifically developed for application to hydraulic disposal to upland CDFs. The levels of dissolved constituents in the modified elutriate from Indiana Harbor sediments (USACE, 1987) is shown on table E-6 of the Appendix E.

4.4.5.5.6 Because there is no permanent pond in the upland CDF, there is no dilution effect (as in the in-lake CDF pond). As was done for the in-lake water quality model, most chemical parameters are assumed to be conservative in the upland CDF model. The only parameters for which chemical or biological reactions are simulated are ammonia nitrogen and PCBs. These reactions were simulated in the same manner used for the in-lake CDF pond. Chemical transformations described for the in-lake CDF model, such as oxidation, formation of insoluble precipitates, and uptake by algae will reduce the levels of dissolved constituents but are not simulated by the model.

4.4.6 141st Street Site CDF Alternative

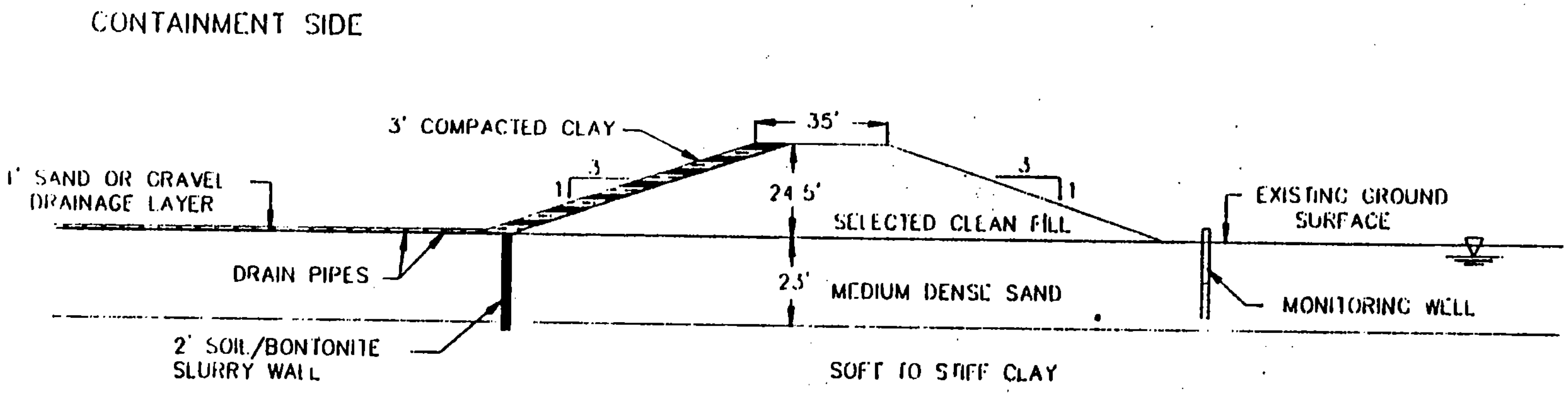
4.4.6.1 Design and Operation

4.4.6.1.1 This site is located east of the Indiana toll road, north of 141st Street in Hammond (plate F-3). The CDF would be approximately 83 acres in area, constructed with a design capacity of about 2 million cubic yards and an estimated design life of about 20 years. This design capacity is smaller than the other CDF plans because of limitations on available real estate and dike height. The CDF would be roughly rectangular in shape and divided into 2 cells of different sizes.

4.4.6.1.2 The CDF would be constructed of earthen dikes using offsite materials. Dikes would be constructed to an elevation of 25 feet above existing ground surface. The CDF dikes are trapezoidal in cross section (figure F-5) with a base width of about 180 feet and a crest width of 35 feet. The proposed barrier system provides a 3 foot layer of compacted clay placed along the dike face. A soil/bentonite slurry cutoff wall extending from the toe of the dike down approximately 23 feet to an existing clay formation will complete the barrier system.

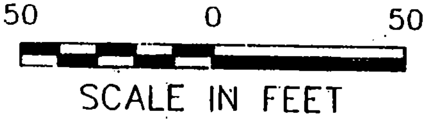
4.4.6.1.3 An underdrainage system trenched into the existing sand on the floor of the CDF would be used to collect drainage and promote dewatering during mechanical disposal. The underdrainage system has many similarities with the "leachate collection system" used in hazardous waste landfills. While both

Figure F-5



NOTES.

1. Drainage layer and drain pipe will be sloped to drain towards the dewatering cell.
2. Groundwater at approximately 3' Below Ground Surface



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systems can collect water seeping through disposed material to protect groundwater from contamination, there are differences in their operation.

4.4.6.1.4 Leachate systems remain operational for an extended period (many years). The underdrainage system in the upland CDF is intended to collect water draining from wet dredged materials in order to promote drying and consolidation (Hammer, 1981). As the dredged material fines clog the sand layer it will reduce the permeability of the underdrain. The consolidation of dredged material above the underdrainage system will also limit permeability.

4.4.6.1.5 Dredged material may be transported to the site either mechanically or hydraulically. A haul distance of approximately 3 miles by truck or about 1 mile by pipeline would be required. An unloading facility would be located near the upstream end of the Lake George Branch of the Federal channel. The material inside the CDF may need to be reworked by use of earth moving equipment.

4.4.6.1.6 The first two operations will dispose non-TSCA sediments to the CDF. Using these materials, a containment "bowl" would be constructed within one cell in the CDF. The TSCA material would be placed into this "bowl" and covered with more non-TSCA materials. Once a cell was filled and the dredged materials had consolidated the cap and cover would be constructed.

4.4.6.1.7 There are two options for the discharge of water from this CDF. One is to the Lake George Branch of the canal. The other is to the sanitary sewer system of Hammond. Because of the larger pumpage rates associated with hydraulic disposal, discharge to the Lake George Branch is the only option with this disposal method. With mechanical disposal, both discharge options will be considered. Treatment alternatives for the CDF effluent are discussed in section 6.

4.4.6.2 <u>Results of Analysis</u>

4.4.6.2.1 The water quality impacts associated with the upland CDF at the 141st Street site with mechanical disposal was simulated using the HELP model described above. The input parameters to the HELP model for this application are shown on table F-12. The quantity and quality of water pumped from the underdrain are shown on table F-13. These results reflect the pumpage from the CDF at two stages of filling; the mid point of filling in cells 1 and 2, respectively. The water quality results shown reflect the character of the pumpage without any post-treatment.

Table F-12: Input Parameters - HELP Model Water Quality Analysis

CDF Surface Conditions	Layers	Parameters
Empty	Drainage	K= 10^{-2} cm/sec
		S= 1.5%
	Clay	K= 10^{-7} cm/sec
New	Dredged Material	K= 10^{-7} cm/sec
	Drainage	K= 10^{-2} cm/sec
		S= 1.5%
	Clay	K= 10^{-7} cm/sec
Aged	Dredged Material	K= 10^{-7} cm/sec
	Drainage	K= 10^{-2} cm/sec
		S= 1.5%
Capped	Topsoil	K= 10^{-3} cm/sec
	Drainage	K= 10^{-2} cm/sec
		S= 1.5%
	Clay	K= 10^{-7} cm/sec
	Dredged Material	K= 10^{-8} cm/sec

Table F-13: Predicted Untreated Effluent Characteristics, 141st Street Site - Mechanical Disposal

	Concentration in:			
Parameter	Porewater	Precipitation	Cell #1 Outflow	Cell #2 Outflow
TDS[1,2]	302	107	117.0	116.8
Total Solids[1]	352	283	286.5	286.5
Phosphorus	2.0	0.023	0.1	0.1
TKN	310	0.3	16.1	15.9
NH_3	305	0.435	16.0	15.7
Arsenic[2]	0.014	0.0011	0.0018	0.0017
Barium[1,2]	0.025	0.021	0.021	0.021
Cadmium	0.0047	0.0003	0.0005	0.001
Chromium[2]	0.060	0.01	0.013	0.013
Copper	0.210	0.002	0.013	0.012
Iron	4.60	0.0528	0.29	0.28
Lead	0.089	0.0066	0.011	0.011
Manganese[2]	0.021	0.20	0.19	0.19
Mercury[2]	0.0002	0.000122	0.0001	0.0001
Nickel	0.018	0.0004	0.010	0.009
Zinc	0.330	0.0195	0.035	0.035
Cyanide[2]	0.190	0.005	0.014	0.014
PCB[2] Cell #1	0.0016	0.00001	0.000091	---
Cell #2	0.0002	0.00001	---	0.000020
Total Phenol[2]	0.200	0.0052	0.015	0.015

All concentrations in mg/l (ppm).
Outflow concentrations assume cells #1 and #2 are 50% filled.
Outflow rates from cell #1 are 18.95 gallons per minute (gpm) from surface drainage and 1.02 gpm from porewater for a total of 19.97 gpm.
Outflow rates from cell #2 are 3.76 gpm from surface drainage and 1.22 gpm from porewater for a total of 4.98 gpm.
Notes:
1 Porewater data not available for parameter. Indiana Harbor and Canal water quality concentration used (source IDEM 1986).
2 Precipitation data not available for parameter. Lake Michigan water concentration used (source IDEM 1986).

4.4.6.2.2 There is a noticeable trend in water quality similar to that seen with the in-lake CDF. The quantity of water pumped from the CDF diminishes as filling progresses, while the concentrations of most constituents increase. This is the result of changing surface conditions inside the CDF. In the first stage, water draining from the dredgings in cell 1 is mixed with larger volumes of rainwater which has drained from empty cell 2. In stage two, the majority of drainage comes from the dredgings in cell 2. The contribution of cell 1 (now capped) to the water balance of the CDF is minor.

4.4.6.2.3 For hydraulic disposal, the volume of water pumped from an upland CDF is simulated to be 1,200,000 cubic yards at a rate of 74,000 cubic yards per week. The CDF pond will reach a volume of about 148,100 cubic yards. At this point, the model assumes that pump out and disposal are equal. Were the pond volume allowed to increase, and pump out slowed, there would be additional settling time and less polymer flocculants would be necessary to remove residual solids. The total volume of water discharged from the CDF during hydraulic disposal is significantly greater then the volume associated with mechanical disposal.

4.4.6.2.4 The dissolved and total concentrations of chemical parameters in the discharge with hydraulic disposal are shown on table F-14. The PCB concentrations are shown for the TSCA, non-TSCA and maintenance disposal operations. For hydraulic disposal to the CDF the water quality impacts are site independent and therefore, the results shown in table F-14 also represent conditions for the ECI site.

4.4.6.2.5 A comparison of mechanical and hydraulic disposal shows that in the initial filling operations the water quality of the untreated effluent is less for all parameters with mechanical disposal. However, in the final filling stages the concentrations of ammonia nitrogen, TKN, phenol, and cyanide would be higher for mechanical disposal.

4.4.6.2.6 The simulated concentrations of some parameters in the hydraulic disposal analysis are considered highly conservative. Within the CDF pond, detention times will be far greater than used in laboratory analysis (elutriate tests). Metals and organic contaminants that are dissolved during the vigorous mixing accompanying slurry formation and hydraulic transport may form insoluble precipitates or adsorb onto particulate matter during a lengthy settling time. In addition, the formation of flocs following the addition of polymer flocculants will also remove some contaminants from solution.

4.4.6.2.7 As indicated above, hydraulic disposal methods may be utilized which require less additional water to transport the sediments. The results for hydraulic disposal shown here reflect an operation using a 4:1 ratio of added water to dredged material. The less water added, the more similar the water quality and quantity results of the hydraulic and mechanical disposal methods become.

4.4.6.2.8 The above results of the upland model simulation for mechanical and hydraulic disposal depict the quantity and quality of water drained from the CDF. This water will have had limited

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Table F-14: Predicted Untreated Effluent Characteristics, 141st Street Site - Hydraulic Disposal

		Concentration in Effluent					
		Dissolved		Suspended		Total	
Parameter		Avg.	Max.	Avg.	Max.	Avg.	Max.
TDS	mg/l	361	411	---	---	361	411
Total Solids	mg/l	---	---	411	461	411	461
Phosphorus	mg/l	0.33	0.37	0.13	0.13	0.46	0.50
TKN	mg/l	44	51	---	---	44	51
NH_3 (no nitrif.)	mg/l	41	49	---	---	41	49
NH_3 (w/ nitrif.)	mg/l	15	32	---	---	15	32
Arsenic	ug/l	3.1	3.7	2.7	2.7	5.7	6.3
Barium	ug/l	33	39	0.0	0.0	33	39
Cadmium	ug/l	2.0	2.4	0.6	0.6	2.6	3.0
Chromium	ug/l	15	18	19	19	33	36
Copper	ug/l	32	39	8	8	40	46
Iron	ug/l	1124	1342	7231	7231	8355	8573
Lead	ug/l	19	22	42	42	61	64
Manganese	ug/l	76	90	96	96	171	186
Mercury	ug/l	0.10	0.12	0.03	0.03	0.13	0.15
Nickel	ug/l	30	36	5	5	35	41
Zinc	ug/l	74	88	183	183	257	272
Cyanide	ug/l	32	38	0.1	0.1	32	38
Total Phenol	ug/l	31	37	0.1	0.1	31	37

All concentrations are operation independent, except PCBs. For PCBs, three different operations will results in the concentrations given below:

PCB (TSCA op)	ng/l	15	32	744	1500	759	1532
PCB (non-TSCA op)	ng/l	10	12	300	300	310	312
PCB (maintenance)	ng/l	8	10	100	100	108	108

treatment to this point. Water drained during mechanical disposal will have suspended solids filtered out by the sand surrounding the underdrain. Water drained during hydraulic disposal will have undergone primary settling, polymer flocculent addition, and secondary settling. Additional treatment required for this water prior to discharge is considered in section 6.3.4.

4.4.7 J-Pit Site CDF Alternative

4.4.7.1 Design and Operation

4.4.7.1.1 This plan consists of the construction of a CDF at a site located west of Colfax Avenue, east of the EJ & E Railroad, and south of 15th Avenue in the western edge of Gary (plate F-4). The site was a borrow pit, approximately 120 acres in area, which has been excavated to a depth of about 35 feet. The pit has been used intermittently for disposal of construction wastes.

4.4.7.1.2 The CDF would be constructed with a design capacity of 3.0 million cubic yards and an estimated design life of about 30 years. The CDF would be roughly rectangular in shape and divided into two or more cells of different sizes. A cross dike(s) would be constructed to separate the cells. The dike and side modifications would be constructed to an elevation of 35 feet above existing pit floor (figure F-6).

4.4.7.1.3 The proposed barrier system provides a 3 foot layer of compacted clay placed along the interior dike face. This clay liner is tied into a natural clay formation under the CDF floor. A soil/bentonite slurry wall would be placed in the existing slope tieing into the natural clay formation below the site. A sand and gravel drainage layer with drain pipe will be placed on the floor of the CDF and used to collect drainage and promote dewatering during filling.

4.4.7.1.4 Dredged sediments from Indiana Harbor must be transported 7.6 miles to the J-Pit site. This transport is one of the most costly features of this alternative. A transportation alternative considered and eliminated was hydraulic (pipeline). The construction of a 7.6 mile pipeline through an urban area would be cost prohibitive (easily exceeding all other cost including dredging and CDF construction combined). Trucking the material or using the rail system are the most cost-effective alternatives for transportation of dredged materials to the J-Pit site. An unloading site would be located along the canal.

4.4.7.1.5 If rail was used, spur rail lines would be needed to be constructed at both the rehandling area along the canal and at the CDF. The unloading process would be conducted using one or more cranes and small buckets.

4.4.7.1.6 Trucking would require less capital investment, but would present a number of logistical problems. A 40-ton truck can carry up to 25 cubic yards of sediments. However, the trucks could only be partially filled to prevent spillage during transport. Each truck would therefore carry approximately 15 cubic yards. In order to transport 250,000 cubic yards of dredged materials to the CDF a fleet of 20 trucks would have to operate continuously for the entire dredging operation (3 months).

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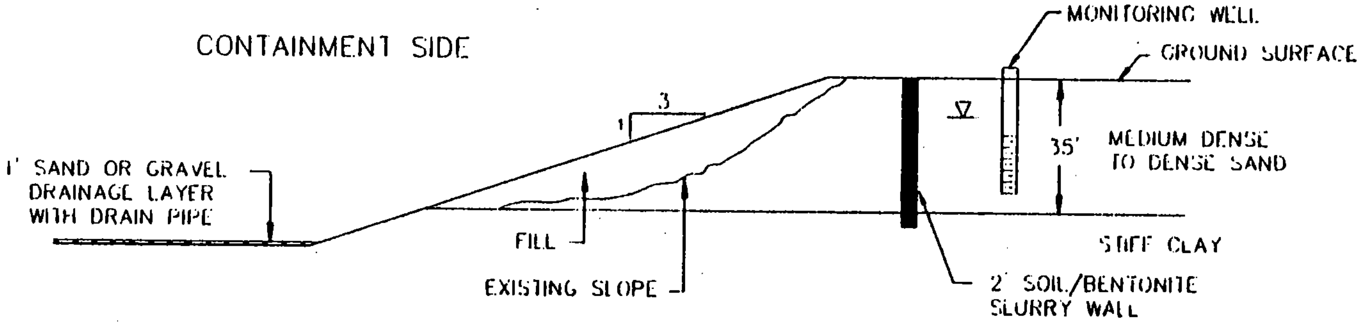
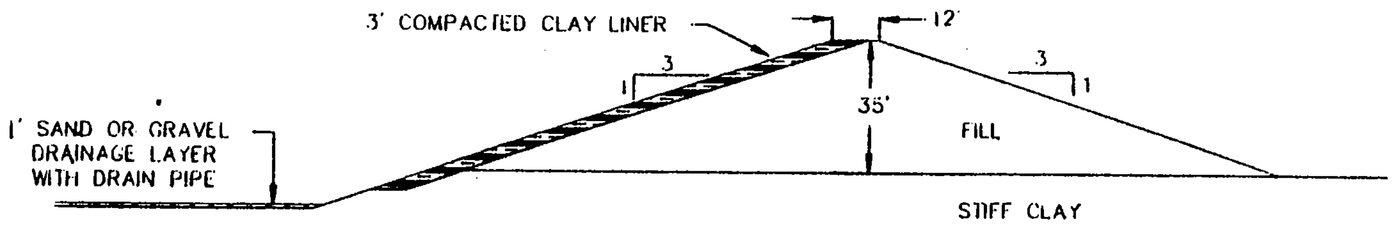
Figure F-6



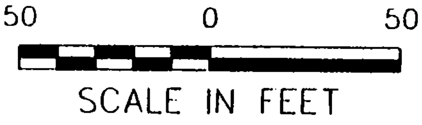
EXISTING SLOPE



DIKE

NOTES:

1. Drainage Layer and Drain Pipe will be sloped to Drain towards a dewatering sump.
2. Groundwater approximately 10' below ground surface.
3. Fill and compacted clay to come from excavating the bottom to the containment area.



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4.4.7.1.7 With this many trips and miles traveled, despite the most rigorous precautions, it is highly probable that there will be some accidents involving personal injuries and spillage of dredged material. The dredging contractor will be required to have proper insurance and a spill control plan.

4.4.7.1.8 Inside the CDF, dredged material will be reworked by use of earth moving equipment in order to facilitate dewatering. As with the 141st Street CDF, TSCA materials would be encapsulated in a "bowl" formed from non-TSCA materials. Once the entire CDF was filled drying and consolidation of the dredged materials would have to occur before the sediments could be fully covered and the cap constructed.

4.4.7.1.9 During an active filling operation, drainage from the sediments will be collected by the underdrainage system, treated, if needed, and discharged. There are no watercourses in the immediate vicinity of the J-Pit site and, therefore, the discharge would be routed to the Gary sanitary sewer. The treatment requirements for this discharge are discussed in section 6.3.3.4.

4.4.7.2 Results of Analysis

4.4.7.2.1 The water quality impacts associated with the upland CDF at the J-Pit site with mechanical disposal was simulated using the HELP model as described earlier. The quantity and quality of water pumped from the underdrain are shown in table F-15. To facilitate the water quality analysis and presentation the CDF was modeled as having three cells. Although, short term water quality impacts would change depending on the construction method (number of cells), the net water quality impacts would be similar. These results reflect the pumpage from the CDF at three stages of filling; the mid point of filling in cell 1, cell 2, and cell 3 respectively. The water quality results shown reflect the character of the pumpage without any post-treatment.

4.4.7.2.2 The trends in the water quality are similar to that seen with the 141st Street site CDF. The quantity of water pumped from the CDF diminishes as filling progresses, while the concentration of most constituents increase. The discharge flows are higher, and concentrations lower, then seen at the 141st Street site. This is a result of the increased surface area of the J-pit site which allows for more drainage and dilution. The drainage water is expected to have low levels of dissolved oxygen, and have a pH of between 6.5 and 7.0.

Table F-15: Predicted Untreated Effluent Characteristics, J-Pit Site - Mechanical Disposal

		Concentration in:			
			Cell #1	Cell #2	Cell #3
Parameter	Porewater	Precipitation	Outflow	Outflow	Outflow
TDS$^{1\ 2}$	302	107	112.1	116.8	137.8
Total Solids^{1}	352	283	284.8	286.5	293.9
Phosphorus	2.0	0.023	0.1	0.1	0.3
TKN	310	0.3	8.4	15.9	49.2
NH_3	305	0.435	8.4	15.7	48.5
Arsenic^{2}	0.014	0.0011	0.0014	0.0017	0.0031
Barium$^{1\ 2}$	0.025	0.021	0.021	0.021	0.0214
Cadmium	0.0047	0.0003	0.0004	0.001	0.001
Chromium^{2}	0.060	0.01	0.011	0.013	0.018
Copper	0.210	0.002	0.007	0.012	0.035
Iron	4.60	0.0528	0.17	0.28	0.77
Lead	0.089	0.0066	0.009	0.011	0.020
Manganese^{2}	0.021	0.20	0.19	0.19	0.17
Mercury^{2}	0.0002	0.000122	0.0001	0.0001	0.0001
Nickel	0.018	0.0004	0.005	0.009	0.029
Zinc	0.330	0.0195	0.028	0.035	0.069
Cyanide^{2}	0.190	0.005	0.010	0.014	0.034
PCB^{2} Cell #1	0.0016	0.00001	0.000051	---	---
Cell #2,#3	0.0002	0.00001	---	0.000020	0.0000
Total Phenol^{2}	0.200	0.0052	0.010	0.015	0.036

All concentrations in mg/l (ppm).
Outflow concentrations assume cells #1, #2 and #3 are 50% filled.
Outflow rates from cell #1 are 32.48 gallons per minute (gpm) from surface drainage and 0.87 gpm from porewater for a total of 33.35 gpm.
Outflow rates from cell #2 are 19.46 gpm from surface drainage and 1.03 gpm from porewater for a total of 20.49 gpm.
Outflow rates from cell #3 are 6.45 gpm from surface drainage and 1.21 gpm from porewater for a total of 7.66 gpm.
Notes:
1 Porewater data not available for parameter. Indiana Harbor Canal water quality concentration used (source IDEM 1986).
2 Precipitation data not available for parameter. Lake Michigan water concentration used (source IDEM 1986).

4.4.8 ECI Site CDF Alternative

4.4.8.1 Design and Operation

4.4.8.1.1 This plan consists of the construction of a CDF at a site bordered on the south by the Lake George Branch of the canal, on the east by Indianapolis Blvd., and on the north by Cline Avenue (plate F-5). The CDF is approximately 95 acres in area on the site of a former refinery.

4.4.8.1.2 The CDF would be constructed with a design capacity of about 3.0 million cubic yards and an estimated design life of about 30 to 40 years. The CDF would be roughly rectangular in shape and divided into 2 or more cells of different sizes. The CDF would be constructed of earthen dikes using offsite materials. Dikes would be constructed to an elevation of 25 feet above existing ground surface. The CDF dikes are trapezoidal in cross section (figure F-7) with a base width of about 185 feet and a crest width of 35 feet.

4.4.8.1.3 The proposed barrier system would be similar to the 141st Street CDF; a 3 foot layer of compacted clay placed along the dike face and a soil/bentonite slurry cutoff wall extending from the toe of the dike down approximately 33 feet to an existing clay formation. An underdrainage system trenched into the existing sand layer under the site will be used to collect drainage and promote dewatering during filling.

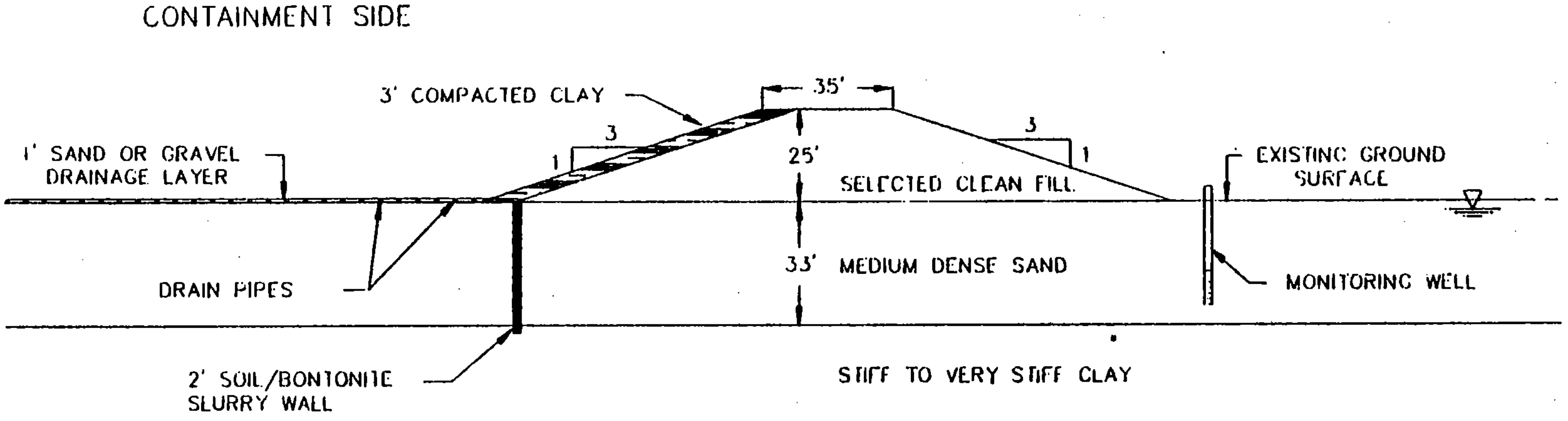
4.4.8.1.4 As with the 141st Street CDF, either mechanical or hydraulic disposal may be used. A 1,200 foot long pipeline or gravel roadway located entirely on the ECI property would be used to move the sediments from the canal to the CDF. Trucks would not have to use city or county roads to transport the dredgings.

4.4.8.1.5 Inside the CDF, dredged material would be reworked to construct a containment cell for the TSCA material in a similar fashion as noted above for the 141st Street site. Water would be collected from the CDF using the same methods described for the 141st Street site, depending on mechanical or hydraulic disposal. With hydraulic disposal, return water would be treated and discharged to the Lake George Branch of the canal. With mechanical disposal, treated water could be discharged to the Lake George Branch or to the East Chicago sanitary sewer system. The treatment requirements for the discharged water are discussed in section 6.3.3.5.

4.4.8.2 Results of Analysis

4.4.8.2.1 The water quality impacts associated with the upland CDF at the ECI site with mechanical disposal was simulated using the HELP model as described earlier. The quantity and quality of the water pumped from the underdrain are shown in table F-16. As for the J-Pit site the water quality and quantity was modeled assuming that the CDF was divided into three cells. This assumption would have little effect on the net water quality impacts of the CDF. These results reflect the pumpage from the CDF at three stages of filling; the midpoint of filling in cell 1, cell 2, and

Figure F-7



NOTES.

1. Drainage Layer and Drain Pipe will be sloped to Drain toward the dewatering cell.
2. Groundwater at approximately 3' Below Ground Surface.

50 0 50

SCALE IN FEET

INDIANA HARBOR CDF
ECI SITE
CONCEPTUAL CROSS-SECTION
(TYP)

JULY 1989

Table F-16: Predicted Untreated Effluent Characteristics, ECI Site - Mechanical Disposal

	Concentration in:				
Parameter	Porewater	Precipitation	Cell #1 Outflow	Cell #2 Outflow	Cell #3 Outflow
TDS[1 2]	302	107	112.2	116.8	137.8
Total Solids[1]	352	283	284.8	286.5	293.9
Phosphorus	2.0	0.023	0.1	0.1	0.3
TKN	310	0.3	8.5	15.9	49.2
NH_3	305	0.435	8.5	15.7	48.5
Arsenic[2]	0.014	0.0011	0.0014	0.0017	0.003
Barium[1 2]	0.025	0.021	0.021	0.021	0.021
Cadmium	0.0047	0.0003	0.0004	0.001	0.001
Chromium[2]	0.060	0.01	0.011	0.013	0.018
Copper	0.210	0.002	0.008	0.012	0.035
Iron	4.60	0.0528	0.17	0.28	0.77
Lead	0.089	0.0066	0.009	0.011	0.020
Manganese[2]	0.021	0.20	0.19	0.19	0.17
Mercury[2]	0.0002	0.000122	0.0001	0.0001	0.000
Nickel	0.018	0.0004	0.005	0.009	0.029
Zinc	0.330	0.0195	0.028	0.035	0.069
Cyanide[2]	0.190	0.005	0.010	0.014	0.034
PCB[2] Cell #1	0.0016	0.00001	0.000052	---	---
Cell #2,#3	0.0002	0.00001	---	0.000020	0.000
Total Phenol[2]	0.200	0.0052	0.010	0.015	0.036

All concentrations in mg/l (ppm).
Outflow concentrations assume cells #1, #2 and #3 are 50% filled.
Outflow rates from cell #1 are 34.51 gallons per minute (gpm) from surface drainage and 0.94 gpm from porewater for a total of 35.45 gpm.
Outflow rates from cell #2 are 21.1 gpm from surface drainage and 1.13 gpm from porewater for a total of 22.23 gpm.
Outflow rates from cell #3 are 6.85 gpm from surface drainage and 1.31 gpm from porewater for a total of 8.16 gpm.
Notes:
1 Porewater data not available for parameter. Indiana Harbor Canal water quality concentration used (source IDEM 1986).
2 Precipitation data not available for parameter. Lake Michigan water concentration used (source IDEM 1986).

cell 3 respectively. The water quality results shown reflect the character of the pumpage without any post treatment.

4.4.8.2.2 The trends in the water quality are similar to that seen with the J-Pit site CDF. The quantity of water pumped from the CDF diminishes as filling progresses, while the concentrations of most constituents increase. the drainage water is expected to have low levels of dissolved oxygen, and have a pH between 6.5 and 7.0.

4.4.8.2.3 The dissolved and total concentrations of chemical parameters in the discharge with hydraulic disposal are shown on table F-14. The PCB concentrations are shown for the TSCA, non-TSCA and maintenance disposal operations.

4.4.8.2.4 A comparison of mechanical and hydraulic disposal is similar to the 141st site. It shows that in the initial filling stages the water quality of the untreated effluent is less for all parameters with mechanical disposal. However, in the final filling stages the concentrations of ammonia nitrogen, TKN, phenol, and cyanide would be higher for mechanical disposal.

4.4.8.2.5 The simulated concentrations of some parameters in the hydraulic disposal analysis are considered highly conservative. Within the CDF pond, detention times will be far greater than used in laboratory analysis (elutriate tests). Metals and organic contaminants that are dissolved during the vigorous mixing accompanying slurry formation and hydraulic transport may form insoluble precipitates or adsorb onto particulate matter during a lengthy settling time. In addition, the formation of flocs following the addition of polymer flocculants will also remove some contaminants from solution.

4.4.8.2.6 As indicated above, hydraulic disposal methods may be utilized which require less additional water to transport the sediments. The results for hydraulic disposal shown here reflect an operation using a 4:1 ratio of added water to dredged material. The less water added, the more similar the water quality and quantity results of the hydraulic and mechanical disposal methods become.

4.4.8.2.7 The above results of the upland model simulation for mechanical and hydraulic disposal depict the quantity and quality of water drained from the CDF. This water will have had limited treatment to this point. Water drained during mechanical disposal will have suspended solids filtered out by the sand surrounding the underdrain. Water drained during hydraulic disposal will have undergone primary settling, polymer flocculent addition, and secondary settling. Additional treatment required for this water prior to discharge is considered in section 6.3.4.

5. VOLATILIZATION ANALYSIS

5.1 MODEL APPROACH

5.1.1 Volatilization is the process whereby a compound passes into the air from a solid or liquid surface. The degree of volatilization can be generally related to the Henry's constant of the compound: a compound with a high Henry's constant has a higher volatilization potential than one with a low Henry's constant.

5.1.2 The sediments in Indiana Harbor and canal are contaminated with volatile and semi-volatile compounds including PCBs and Polycyclic Aromatic Hydrocarbons (PAHs). Agitation of these sediments from a dredging project would invariably allow for volatilization to occur. As such, this contaminant pathway should be considered when describing environmental impacts of a dredging project at Indiana Harbor.

5.1.3 The model presented in this report is in the developmental stages and provides an estimate of the mass of PCBs lost from each of the alternative CDFs. PCB was the only compound considered due to its health significance and the complications of developing the model. It is anticipated that other semi-volatile and volatile compounds such as PAHs will be modeled in the future for sediments contaminated with these substances.

5.1.4 Pollutants are usually associated with the solid fraction of sediments, including volatile organic chemicals (VOCs). Fine-grained soils, such as silts and clays have a high affinity for pollutants. VOCs including hydrophobic contaminants, such as PCBs, have an especially high affinity for sediments containing organic matter (both natural and anthropogenic). The sediments in the Indiana Harbor Canal are composed of predominantly fine-grained materials, silts and clays. These sediments also contain a significant amount of oil and grease which has a strong affinity to hydrophobic contaminants.

5.1.5 With respect to dredging, VOCs can enter the air from either the water or sediment surfaces. For volatilization to occur from the water surface, the VOC must first desorb from the suspended solids phase and diffuse through the water before being emitted into the air. For this model, chemical equilibrium principles are used to determine the transfer of PCBs between the various phases. In the case of VOCs associated with sediment, three phases of matter are involved. These are the solid particles which constitute the sediment and include both organic matter and mineral matter comprising the particles. The two other primary phases include air and water.

5.1.6 The CDF air quality simulation accounts for PCB volatilization from exposed and submerged dredged materials. First a description of the locales associated with a dredging operation are presented, then the analyses is provided including assumptions applied to the model, and finally the models used for both the in-lake CDF and three upland CDFs are described.

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5.2 MODEL PURPOSE

5.2.1 Volatilization can involve a complicated interconnected number of transfer pathways. In order to quantify volatilization, one needs to address all sources, pathways and external parameters which effect the transfer. At this time lab and field verification of critical transfer coefficients is lacking, and therefore a complete quantification of PCB volatilization for all the activities associated with a dredging operation is beyond the scope of this report, if not impossible at this time. In light of this, the model should only be used as an indication of the relative significance of volatilization for various operational schemes. In this manner a ranking of potential PCB mass flux for different disposal options can be determined and viable options can be evaluated against each other and the no action plan.

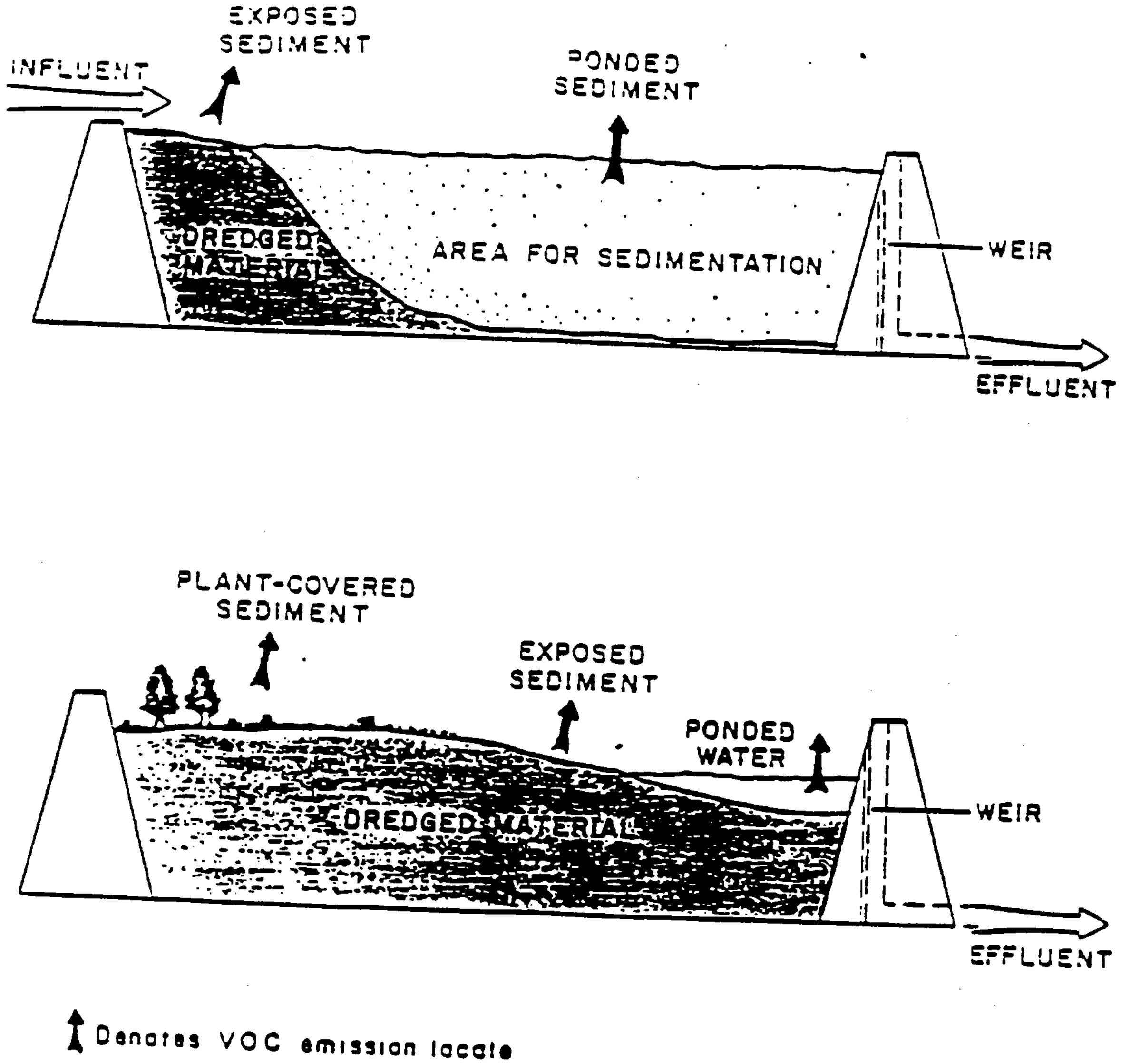
5.3 LOCALES FOR DREDGING OPERATION

5.3.1 A CDF with its associated operations comprises a complex framework in which to predict the generation of volatile organic chemicals and their resultant emission to the air. In light of this it is prudent to divide a CDF and its associated operations into four generalized emission locales. The first incorporates dredging, transporting, and any other related sediment handling operations. The second emission locale is the exposed sediment which is void of vegetation. The third emission locale is the area within the ponded zone, which includes the area of sedimentation during disposal. Finally, the fourth emission locale is that portion of the CDF that is covered with vegetation. The locales (excluding the dredging/transporting locale) are shown in figure F-8.

5.3.2 Removing and Transporting Sediments

5.3.2.1 Monitoring conducted by the Corps of Engineers during a dredge equipment demonstration at Calumet River and Harbor (Hayes et al., 1988) showed that the plume created by dredging contaminated sediment with a standard clamshell was approximately 500-800 feet in length. Samples collected near the bottom of the water column within 50 feet of the dredge ranged from 540 to 49 mg/l suspended solids. Samples collected farther from the dredge and higher in the water column contained levels of suspended solids only 2-4 mg/l greater then background. For the operations at Indiana Harbor mechanical dredging will be used with a closed bucket which should lower the concentration of suspended solids in the vicinity of the dredge during dredging operations.

5.3.2.2 Due to the variability of suspended solids concentration for this locale a quantification of PCB mass flux into the air would be at best difficult. At the present time there is some



VOC emission locales: ponded, exposed, and plant-covered

Figure F-8

603-04

theory covering this topic (Thibodeaux, 1987) however, the mechanisms are complex and critical transfer coefficients and rates need to be lab and/or field verified before they could be put to practical use in a mathematical model. Secondly, the relative amount of volatilization, from this locale, for either an in-lake or upland CDF would be about the same since the removal technique employed should be identical. For reasons stated above the volatilization model for the Indiana Harbor CDF does not consider losses from the removing and transporting locale.

5.3.3 Exposed Sediment Void Of Vegetation

5.3.3.1 This VOC emission locale is characterized by sediment that is exposed directly to air and void of any vegetation. For all practical purposes it can be considered the area within a CDF where sediments are in a unsaturated state with respect to water. The evaporation process begins as soon as dredge materials break the water surface in an in-lake CDF, or are deposited into an upland CDF. Water and VOCs are quickly depleted from the top microlayer of sediments, and continuing losses come from the pore spaces within the dredged material beneath the surface. PCB volatilization from this locale is considered in the model and details are given later in this appendix.

5.3.4 Exposed Sediments With Vegetation

5.3.4.1 This locale includes "aged" exposed sediments which have vegetative cover. By aged it is meant material that is exposed directly to air for a relatively long period of time, so that eventually it becomes a true soil. The existence of vegetation causes changes in the sediment (soil) environment, as compared to the exposed sediment locale, which effects the VOC emission rate.

5.3.4.2 Vegetation will cause the upper soil layers to be more porous. This and bioturbation process would tend to increase the porosity of the soil which increases the effective diffusivity of the soil and thereby increases the rate of mass flux into the air. With time the natural organic content of the soil would increase. The additional organic content of the soil retards VOC emission by providing absorption sites on soil particles for PCBs. Also, protrusion of the vegetation into the air boundary layer would increase the resistance to transport and lower volatilization rates. Finally, the overall path length that a contaminate sorbed onto a soil particle would need to travel in order to be released to the air would increase.

5.3.4.3 It appears that many complex variables need to be addressed when considering the effects of vegetation. However, the net effect of the above factors should result in a reduction in the VOC emission rate as compared to exposed sediments. Therefore, maintaining a conservative approach this locale is not considered in the model.

5.3.5 Ponded Area

5.3.5.1 This locale is similar to the "removing and transporting locale" in that sediments are in an agitated state compared to insitu conditions. The difference is that in this locale sediments are being deposited back into the water column. The pathway for volatilization involves desorption from the suspended solids, diffusion through the water phase followed by transport through the air-water interface. A variable to flux for this locale is the concentration of suspended solids. During an active filling operation a range of suspended solids exist in the ponded zone which is known from past experience, thus making quantification of PCB mass flux possible for this locale.

5.4 VOLATILIZATION ANALYSES AND ASSUMPTIONS

5.4.1 The impacts of PCB emission, through volatilization, from either an in-lake or upland CDF have been predicted using a mathematical model developed by the USACE, Chicago District. It should be noted that input to the model is highly dependent on the physical aspects of a particular CDF, the method of disposal, and the amount of time for a particular filling operation, as well as the lifetime of the CDF. This section will document the mechanics and assumptions of the model.

5.4.2 The model developed for the Indiana Harbor CDF was designed to provide information about the quantity of PCB mass flux into the air. To account for a complete analysis which could estimate flux from all potential emission sources is beyond the scope of this report. This model provides an indication of the relative flux, through volatilization, for various operational schemes. This information will be used, in turn, to assess impacts to the air.

5.4.3 Theoretical chemodynamic models for organic pollutants in dredged material are used to estimate potential emission rates of PCBs to the air. Although the chemodynamic models have not been verified experimentally for dredged material, studies of pesticide volatilization from soils, VOC emissions during refinery waste landfarming, and VOC emissions from hazardous waste lagoons indicate that theoretical chemodynamic models when properly formulated, provide realistic estimates (Thibodeaux and Hwang, 1982; Thibodeaux and Becker, 1982; Thibodeaux, Parker, and Heck, 1984; Eklund, Nelson, and Wetherold, 1987).

5.4.4 The model developed for the CDFs at Indiana Harbor accounts for volatilization of PCBs primarily through two locales: volatilization from exposed sediments, and volatilization from the submerged sediments within the ponded water.

5.4.5 Submerged Sediments (in-lake CDF only)

5.4.5.1 Submerged sediments occur when dredgings are placed into an in-lake CDF previous to delta formation. The experience from other CDFs (Miller, 1987) has shown that the levels of suspended solids are elevated immediately around the disposal operation, but that these increases are highly localized and diminished when the sediment delta extends above the waterline. Monitoring data for the Chicago CDF indicates that in the immediate vicinity of dredged material disposal, the upper limit on suspended solids concentration is approximately 100 mg/l. Away from the zone influenced by disposal, suspended solids concentrations are in the range of 10 to 20 mg/l.

5.4.5.2 In order to calculate mass flux from the ponded water locale it was necessary to delineate it into three zones: an active filling zone, which is in the immediate vicinity of the dredged material disposal; an active non-filling zone, which covers the remainder of the pond during a filling operation; and a nonactive zone, which is the entire pond in between filling operations.

5.4.5.3 The suspended solids concentration in the "active non-filling zone" will increase as the pond area and volume decrease over time. The effect would be to increase the pond concentrations above the background level. A similar effect will occur in the pond water concentration of PCBs in between filling operations (non-active zone). The concentration of suspended solids having sorbed PCBs is related to the dissolved concentration of PCBs in the pond. Reasonable estimates for the dissolved PCB concentrations are given in table F-17.

Table F-17: Dissolved PCB Concentrations for Submerged Sediments

	CDF Zone:		
Operation	Active Filling	Active Non-filling	Non-active[1]
1	16	12	7
2	16	13	8
3	16	14	11
4	16	15	NA[2]

All concentrations are ng/l (ppt)

1 The dissolved concentration is the mean of the background concentration and the ending concentration of the previous filling operation.

2 The CDF cell is filled after the fourth operation, therefore a concentration value is not applicable.

5.4.6 Exposed Sediment

5.4.6.1 VOC emission from the exposed sediment source is a function of the sediment mass transfer coefficient, surface area, and time in which the sediments remain exposed to the air. The transfer coefficient is primarily a function of sediment properties, while the surface area and exposure time are dependent on the volume deposited and CDF design life. Exposed sediments occur in an in-lake CDF once the dredgings break the water surface and a delta is formed, while all of the dredgings deposited into an upland CDF are considered exposed.

5.4.6.2 Calculation of mass transfer coefficients are given later in this appendix. The method used to calculate the surface area of exposed sediments for an in-lake CDF was discussed in the Delta Volume section (4.3.3) of this appendix. For an upland CDF the model treats the filling process as occurring in layers. This should approximate the actual situation since: the dredged material is placed in a semi-saturated state and will flow; as material begins to pile up mud flows would tend to push the mass outward; and sediments inside the CDF will need to be reworked in order to construct an interior dike used to partition the TSCA material.

5.4.6.3 Exposure time is the most complicated parameter to define. As noted earlier, vegetation, cracks, and sediment age are only a few factors which confound matters. Also, as will be seen later, the PCB flux is time dependent which means that the model must account for exposure time of the sediments for each operation.

5.5 OPERATIONS (FILLING PARAMETERS)

5.5.1 Currently there is a backlog of 1,000,000 cubic yards to be dredged from Indiana Harbor. Of this quantity approximately 70,000 cubic yards has been determined to be toxic under the Toxic Substance Control Act (TSCA). Once dredging operations begin the backlog volume is expected to be removed and placed into the CDF in the first 3 or 4 years of operation. Additional maintenance dredging totals about 1,000,000 cubic yards for the 141st site, and about 2,000,000 cubic yards for all of the other proposed designs. It is estimated that maintenance dredging would occur about every 3-4 years until the CDF was filled.

5.5.2 The objective of the model is to simulate PCB mass flux from a CDF over the design life of the structure. In order to use the model it is necessary to enter the projected volumes, durations, and the number of operations to fill the CDF. At this time only basic design parameters are known for the CDF or the encompassing filling operations, hence, only a general approach should be taken when inputting data to the model. The simulated filling parameters are given in table F-18.

Table F-18: Operating Parameters Simulated for Indiana Harbor CDF

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1. All operations will consist of dredging 250,000 cubic yards.

2. An operation will last 16 weeks.

3. A cell is capped two years after it has been filled.

4. The TSCA material is placed into the CDF during the fourth operation. At this time approximately 750,000 cubic yards will already have been placed.

   - TSCA material is completely submerged for an in-lake CDF
   - TSCA material is exposed for twice the time of placement for upland CDF
   - For calculations a value of 80,000 cubic yards of TSCA material was used instead of 70,000.
   - An additional 180,000 cubic yards of non-TSCA material (to total 250,000 cubic yards) will placed to encapsulate TSCA material

5. An in-lake CDF is designed to have three separate cells. Each cell would contain 1,000,000 cubic yards, and therefore would require 4 operations to fill.

6. Filling for an upland CDF would begin with one large cell. Enough material would be deposited in order to provide a liner to surround the TSCA material. At this time the sediments would be reworked to construct an interior cross dike to separate a cell for placement of the TSCA material.

7. During the year in which an operation is completed, exposed sediments are assumed to be subject to volatilization for 6 months. The TSCA material is assumed to be exposed for 2 months (upland sites only).

5.6 SUBMERGED DREDGED MATERIAL (POND VOLATILIZATION) ALGORITHMS

5.6.1 The pathway for volatilization in the case of submerged dredged material involves desorption from the suspended solids phase, diffusion through the water, and transport through the air-water interface. Assuming a constant suspended solids concentration, the steady-state flux of an organic chemical through the air-water interface is given by the following equation (Thibodeaux, 1988):

$$n_A = {}^1K_{A2}'\left(\frac{W_A}{K_d+1/P_{32}} - P_{A2}^{**}\right)\left(\frac{1}{1000}\right) \qquad (1)$$

Where:

A = organic chemical of interest

n_A = flux of A through air-water interface, mg A/cm^2 hr concentration of A, mg A/L

P_{A2}^{**} = hypothetical concentration in water for air side concentration of A, mg/L

${}^1K_{A2}'$ = over-all liquid phase mass transfer coefficient, cm/hr

W_A = concentration of A in the original bed sediment, mg/kg

P_{32} = concentration of suspended solids, kg/L

K_d = sediment-water distribution coefficient for A, L/kg

5.6.2 With respect to the over-all liquid-phase mass transfer coefficient when the emission rate is liquid-phase resistance controlled as it is for hydrophobic organics, ${}^1K_{A2}'$ depends on wind speed and molecular diffusivity of A in water, and can be estimated using the following equation (Lunney, Springer, and Thibodeaux, 1985):

$${}^1K_{A2}' = 19.6 * V_x^{2.23} * D_{A2}^{2/3} \qquad (2)$$

Where

V_x = wind speed, miles per hour (mph)

D_{A2} = molecular diffusivity of A in water, cm^2 /sec

If the diffusivity of A in water is not known, it can be estimated using the following equation (Thibodeaux, 1979):

$$D_{A2} = D_{B2}(M_B/M_A)^{0.6} \qquad (3)$$

Where:

B = model organic chemical of known molecular diffusivity

D_{B2} = molecular diffusivity of B in water, cm^2 /sec

M_A = molecular weight of A

M_B = molecular weight of B

5.6.3 The quantity $\frac{W_A}{K_d+1/P_{32}}$ is the dissolved concentration of A in the pond water and can be thought of as the dissolved concentration of A at the water-air interface. The difference between it and P_{A2}^{**} is the driving force which causes the flux of A into the air.

5.6.4 P_{A2}^{**} is derived from the existing concentration of A in the air. This value is very small compared to the water concentration and therefore if assumed to be zero would have little effect on the driving force. This is a conservative assumption that maximizes volatilization.

5.6.5 Equilibrium partitioning uses the relative chemical solubilities of hydrophobic organic compounds (like PCBs) in sediment and water to estimate the concentrations of the compound in these two media at equilibrium. PCBs are poorly soluble in water and have a high affinity for sediments, particularly those with much organic matter. The ratio of PCB concentrations in sediment and water at equilibrium is referred to as K_d. This partitioning coefficient (K_d) can be calculated from chemical properties of the contaminant (PCB) and information about the organic content (TOC) of the sediment or through a number of laboratory procedures. The K_d for PCBs in the Indiana Harbor sediments was determined by the Waterways Experiment Station (WES) as 256,000 L/kg (USACE, 1987).

5.6.6 Equation 1 can be used for calculating flux from submerged sediments during filling, however, in between operations the suspended solids concentration in the pond would not indicate the potential for PCB mass flux to the air. Sediments containing sorbed PCBs, deposited during filling, settle rapidly after a filling operation stops. For this case it is better to use the dissolved concentration in the water column as an indication of flux. The rate of mass flux across the phase boundary can be expressed by (Thibodeaux, 1979):

$$n_A = {}^{1}K_{A2}'(C_{A2} - C_{A2}^{*})M_A \qquad (4)$$

Where:

C_{A2} = bulk liquid molar dissolved concentration of A, mol/cm^3

$C_{A2}{}^*$ = hypothetical concentration in water for air side concentration of A, mol/cm^3

5.7 EXPOSED DREDGED MATERIAL ALGORITHMS

5.7.1 The volatilization pathway in the case of exposed dredged material incorporates a number of steps. Although sediments are placed in a semi-saturated state, water and VOCs become quickly depleted from the surface layer, and continuing losses come from the pore spaces within the dredged material beneath the surface. At this point VOC emission is dredged material-side vapor phase diffusion controlled. The emission pathway involves desorption from particle surfaces into the a water film surrounding the particles, diffusion through the water film, desorption from the water film into the pore gas, diffusion through the pore gas prior to emerging into the atmosphere. This last step is apparently the limiting step in soil systems (Dupont, 1986), and this condition is thought to apply to the top layers of dredged material in a CDF (Thibodeaux, 1988). Fick's second law with an effective diffusivity that accounts for tortuosity of the diffusion path and other factors that affect diffusion is an appropriate mathematical model. Due to the depth of the dredged material and the relatively flat surface, a semi-infinite solution to Fick's second law can be applied without serious error. (The semi-infinite solution is conservative; that is, flux is maximized). The instantaneous flux is given by (Thibodeaux, 1988):

$$n_{A,t} = \left[\frac{D_{A3}(E_1+(K_d*P_B/H)}{\pi *t}\right]^{1/2}\left(\frac{W_A*H}{1000*K_d} - P_{A1i}\right) \qquad (5)$$

Where:

E_1 = air filled porosity, dimensionless

D_{A3} = effective diffusivity, cm^2 /sec

P_B = bulk density of dredged material, kg/L

H = Henry's Law constant, dimensionless

P_{A1i} = background concentration in air at dredged material surface, usually assumed to be zero, mg/ cm^3

$n_{A,t}$ = instantaneous flux of A through dredged material-air interface at time t, mg A /cm^2 sec

t = time since initial exposure, sec

The average flux over a given time t is given by

$$\bar{n}_A = \frac{\int_0^t n_A dt}{\int_0^t dt} \tag{6}$$

It can be shown that

$$\bar{n}_A = 2n_{A,t} \tag{7}$$

5.7.2 The above equation is an idealized diffusion transport model that describes chemical movement in the unsaturated pore spaces near the surface of exposed dredged material. It does not account for the development of cracks as the dredged material dewaters by evaporative drying.

5.7.3 Effective diffusivity is a constant diffusion coefficient that characterizes the movement of chemical A as a vapor within the porous solid. It is one parameter for which there is no information available. To calculate the flux, it is therefore necessary to estimate D_{A3}. As an approximation, tortuosity can be accounted for using the equation below (Thibodeaux, 1988):

$$D_{A3} = D_{A1}\frac{(E_1^{10/3})}{E^2} \tag{8}$$

Where:

D_{A1} = molecular diffusivity of chemical A in air, cm^2/sec

E = total porosity, dimensionless

5.7.4 Henry's law constant (H) applies for dilute solutions of chemicals in air and water. It is an equilibrium partition coefficient for chemical A between the air and water phase. Henry's Law constant can be estimated using the equation below (Dilling, 1977):

$$H = 16.04\frac{(P_A^{o} * M_A)}{T * P_{A2}^{*}} \tag{9}$$

Where:

P_A^o = vapor pressure of A as pure solute, mm Hg

P_{A2}^* = solubility of A in pure water, mg/l

T = temperature, degree Kelvin

5.7.5 The background concentration P_{ai} in air has an analogous meaning to P_{A2}^{**} and also is assumed to be zero. This is a conservative assumption that maximizes volatilization.

5.8 APPLICATION AND RESULTS OF VOLATILIZATION MODEL

5.8.1 The volatilization model was applied to the Indiana Harbor CDF by assigning values to input variables based on published information, laboratory analysis, engineering analysis and judgment, and operating experience from other CDFs. Definitions of parameters, values used in the model, and sources are given in attachment F-2. The model was executed using a by-operation time step. The products of the model execution include time-series simulation of potential PCB flux, through volatilization, from submerged and exposed sediments. This simulation covers the design life of both an in-lake and upland CDF.

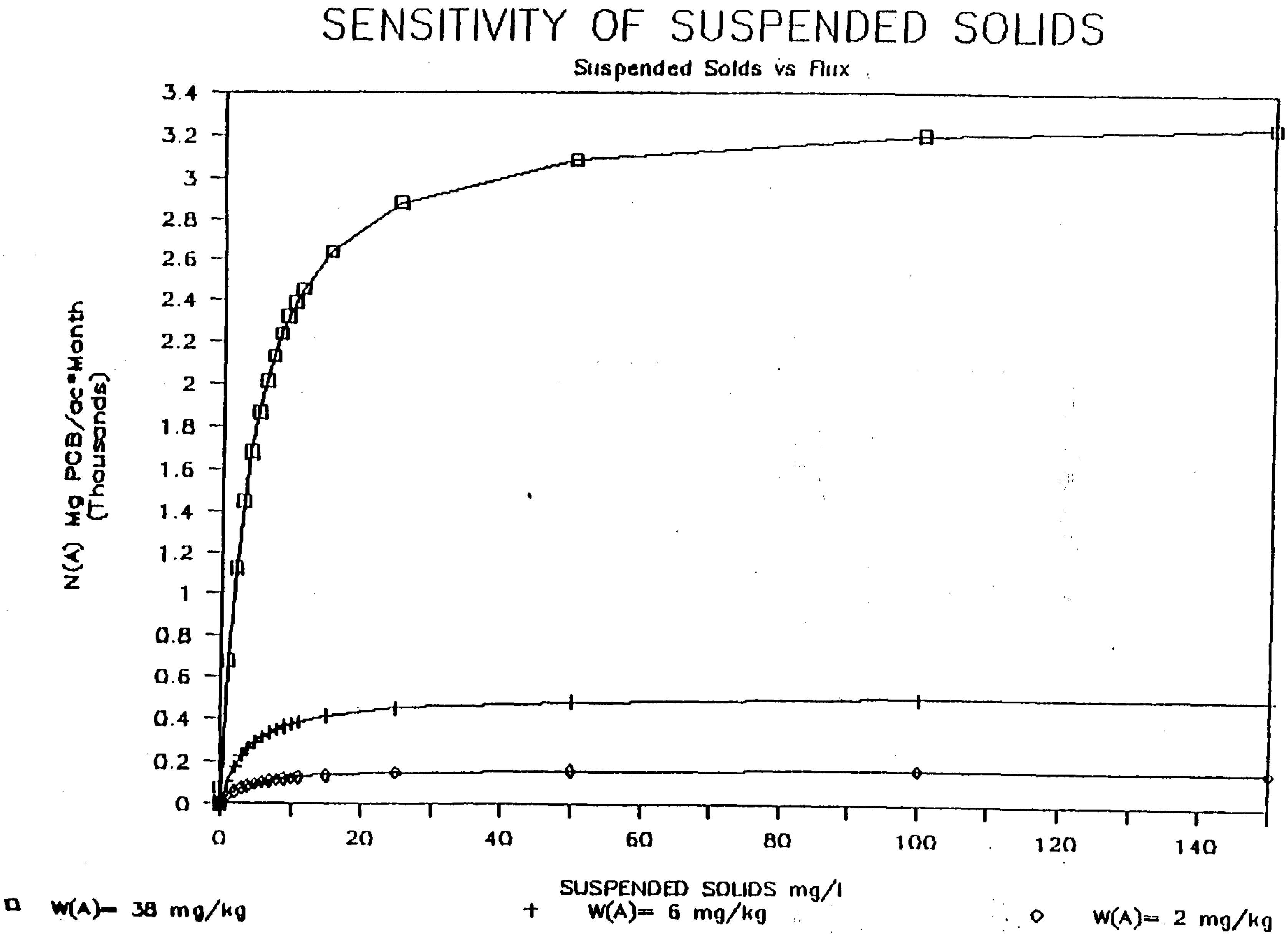
5.8.2 A sensitivity analysis was completed on the flux equations in order to determine the effects of varying parameters, such as, wind speed, and water and air temperatures. Results of this analysis are given in attachment F-2. The three parameters which are used directly to calculate flux are the liquid phase mass transfer coefficient (${}^1K_{A2}$), effective diffusivity (D_{A3}), and Henry's law constant (H). A sensitivity analysis was also done on suspended solids. A plot of suspended solids verses PCB mass flux is shown in figure F-9. As shown in the figure, flux is fairly insensitive to suspended solids concentrations greater then 50 mg/l.

5.8.3 The complexities involved in accounting for a monthly variation, with respect to dredging operations, in the aforementioned parameters is beyond the scope of this report. As can be seen from the sensitivity analysis on the flux equations the variation in the effective diffusivity and Henry's law constant is not significant. However, the mass transfer coefficient varies from a high of 1.010 cm/hr in April to a low of 0.565 cm/hr in August. In any case the mean values, shown in the table, were used to calculate PCB flux.

5.8.4 Inland Steel Site

5.8.4.1 Detailed results including exposed surface area, duration of exposure, and PCB mass loss from exposed and submerged

Figure F-9


SENSITIVITY OF SUSPENDED SOLIDS
Suspended Solds vs Flux
N(A) Mg PCB/ac*Month (Thousands)
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
SUSPENDED SOLIDS mg/l
□ W(A)= 38 mg/kg
+ W(A)= 6 mg/kg
◇ W(A)= 2 mg/kg

sediments are given in attachment F-2. A graphical representation of the PCB flux is given in figure F-10.

5.8.5 J-Pit Site

5.8.5.1 During the disposal of sediments to an upland CDF a small pond will form in the low areas. The pond is a result of surface drainage from the deposited dredgings. This ponded area would occupy a small area relative to the CDF surface area and be short lived after the completion of an operation. Table F-19 gives the operating parameters for this pond.

Table F-19: Upland Pond Parameters

Area	1.5 acres
Life of Pond After Operation is completed	3 months
PCB Dissolved Concentrations[1]	
Backlog material	
Non-TSCA	23 ng/l
TSCA[2]	63 ng/l
Maintenance Material	8 ng/l

---

[1] This is the pore water concentration of the sediments.

[2] The TSCA concentration is volume weighted.

5.8.5.2 Detailed results including exposed surface area, duration of exposure, and PCB mass loss from exposed sediments are shown in attachment F-2. The volatile mass loss of PCBs from submerged sediments is simulated to be 0.021 Kg. A graphical representation of the PCB flux is given in figure F-11 (the figure does not account for volatilization from submerged sediments).

5.8.6 141st Street Site

5.8.6.1 The PCB flux model was developed to simulate flux from a mechanical dredging and disposal operation. Although the actual removal of material will be done by mechanical means, hydraulic disposal is being considered for the 141st street due to its close proximity to the canal.

5.8.6.2 The volatile loss of PCBs from a hydraulic disposal operation would be very hard to model. The consequences of slurring the sediments and the transient mode of the CDF; cycles of being near completely ponded to wholly exposed would have an

Figure F-10

YEARLY VOLATILE PCB MASS FLUX

PLAN 1 (INLAND STEEL SITE)

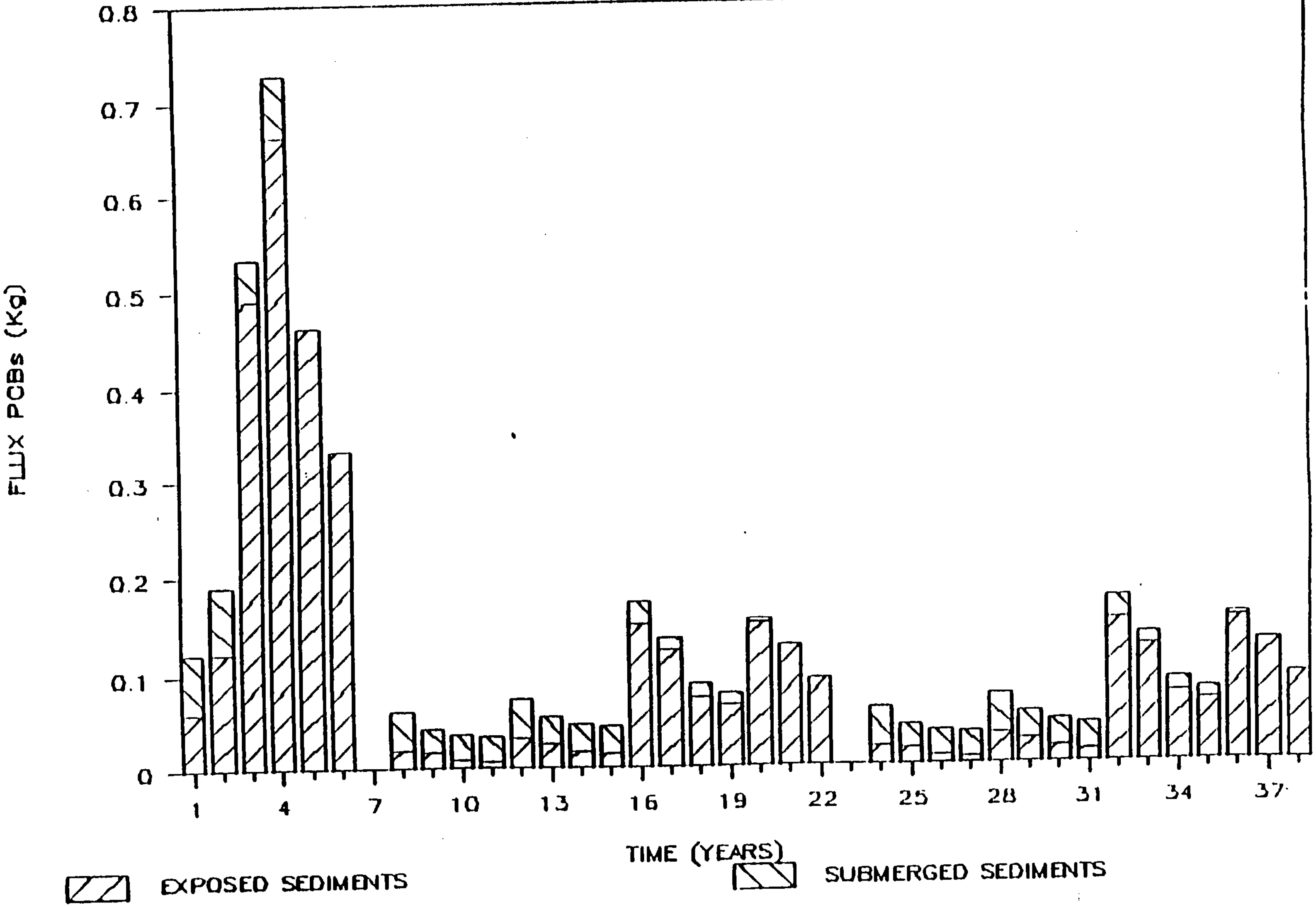
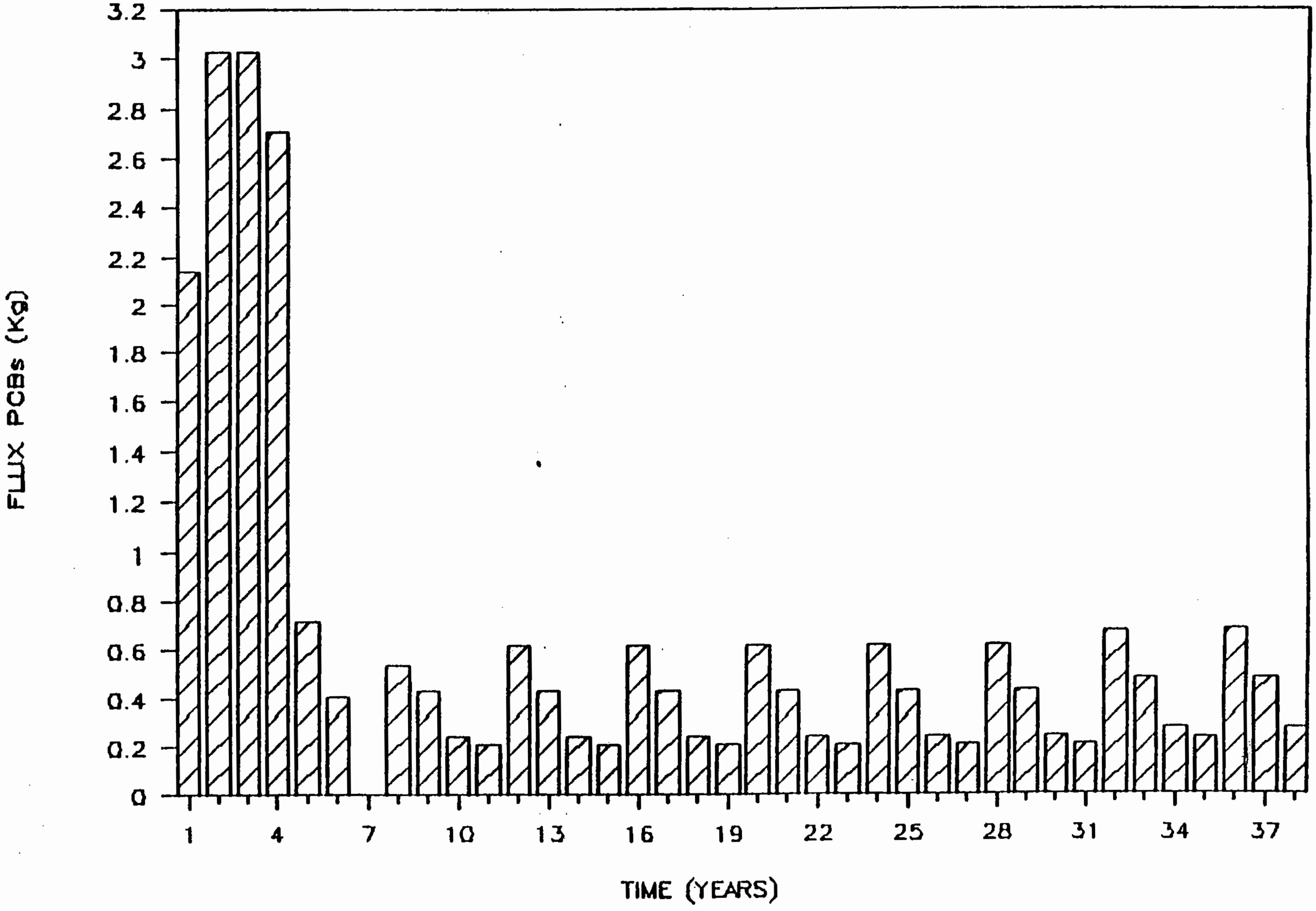


Figure F-11

YEARLY VOLATILE PCB MASS FLUX

PLAN 3 (J-PIT)



unknown effect on the overall mass transfer coefficient. Also, delineation of submerged verses exposed sediments, at any time in the CDF, would be difficult.

5.8.6.3 A reasonable approximation of flux for hydraulic disposal is to assume that the surface area within the CDF is either exposed or completely ponded during any given time. For this analysis it was assumed that during the year of any filling operation the CDF would be ponded for 9 months and exposed for 3 months. Calculations of flux for hydraulic disposal are given in attachment F-3.

5.8.6.4 For a mechanical disposal operation the detailed results including exposed surface area, duration of exposure, and PCB mass loss from exposed sediments are given in attachment F-2. The volatile mass loss of PCBs from submerged sediments is simulated to be 0.017Kg. A graphical representation of the PCB flux is given in figure F-12 (this figure does not account for volatilization from submerged sediments).

5.8.7 ECI Site

5.8.7.1 The simulation for the ECI site is similar to that of the 141st site. Likewise, hydraulic disposal is being considered for this site due to its close proximity to the canal. Calculations for flux from hydraulic disposal are given in attachment F-3.

5.8.7.2 For a mechanical disposal operation the detailed results including exposed surface area, duration of exposure, and PCB mass loss from exposed sediments are given in attachment F-2. The volatile mass loss of PCBs from submerged sediments is simulated to be 0.021 Kg. A graphical representation of the PCB flux is given in figure F-13 (this figure does not account for volatilization from submerged sediments).

5.9 SUMMARY AND DISCUSSION

5.9.1 The sediments to be dredged from Indiana Harbor contain levels of PCBs which range from less than 1 ppm to 115 ppm. Currently there is a backlog of approximately 1,000,000 cubic yards of material. An additional 1,000,000 or 2,000,000 (depending on the proposed CDF) cubic yards is estimated for maintenance dredging. 70,000 cubic yards of backlog material are considered TSCA in that the sediments contain PCB levels exceeding 50 ppm. However, the volume-weighted concentration of this material is 38 ppm, while that of the non-TSCA sediments is 6 ppm. The maintenance sediments have a mean concentration of 2 ppm.

5.9.2 The volatilization model simulates the PCB mass flux, over a CDF design life, into the air. Since this model is limited in coverage of possible source emission locales it should be used to

Figure F-12

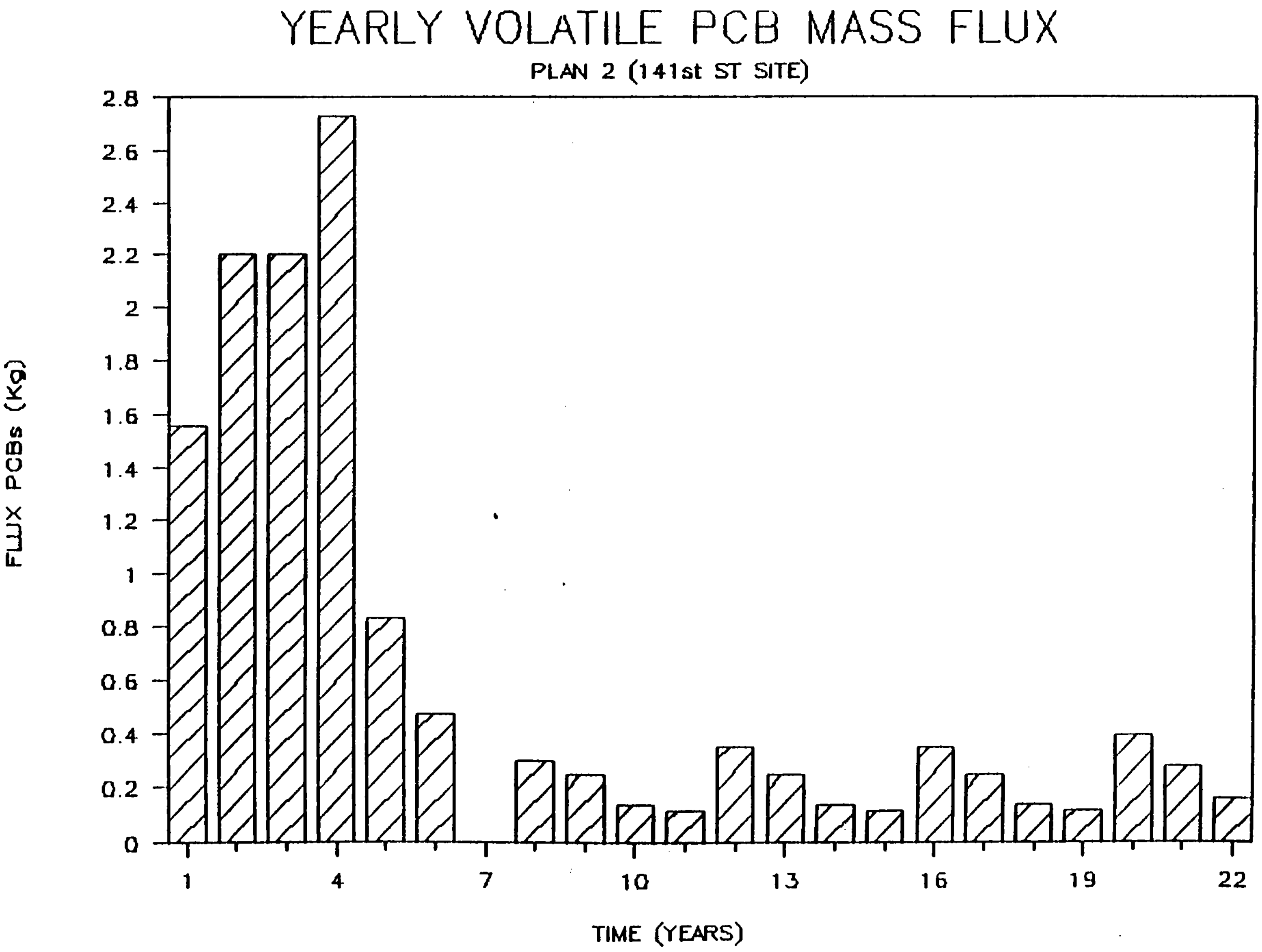
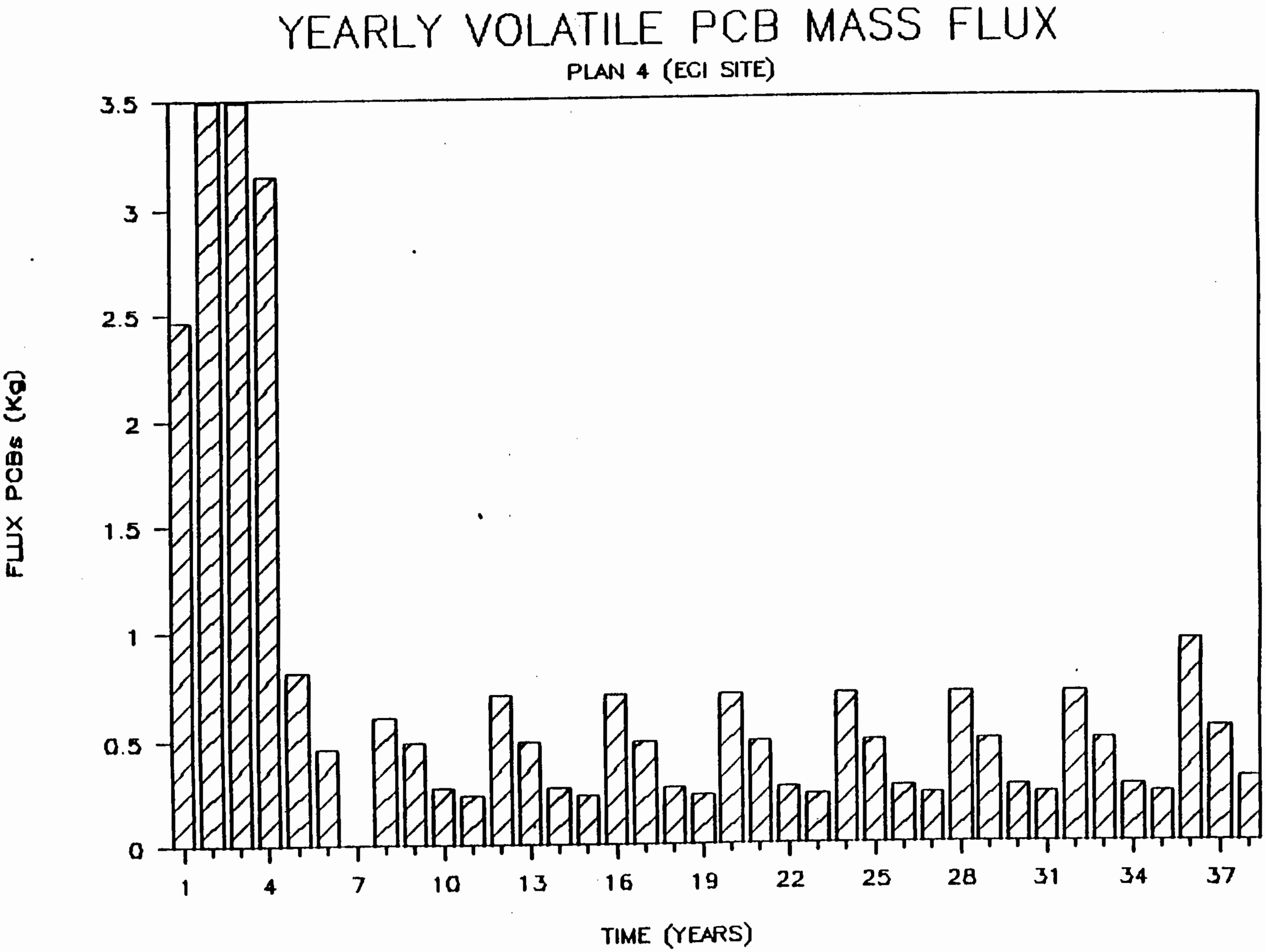

YEARLY VOLATILE PCB MASS FLUX
PLAN 2 (141st ST SITE)
FLUX PCBs (Kg)
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
4
7
10
13
16
19
22
TIME (YEARS)

Figure F-13


YEARLY VOLATILE PCB MASS FLUX
PLAN 4 (ECI SITE)
FLUX PCBs (Kg)
3.5
3
2.5
2
1.5
1
0.5
0
1
4
7
10
13
16
19
22
25
28
31
34
37
TIME (YEARS)

develop a relative ranking of PCB mass flux for different disposal options and not to quantify absolute quantities of flux. In this manner viable options can be evaluated against each other and the no action plan. Attachment F-2 gives a summary of PCB loss for each site. Shown below is a portion of that table giving only totals:

Simulated PCB Loss
Mechanical Disposal

Site	Exposed Sediments (kg)	Submerged Sediments (kg)	Total (kg)
Plan 1 Inland Steel Site	4.0	0.90	5
Plan 2 141st Site	13.3	0.02	13
Plan 3 J-Pit Site	24.1	0.02	24
Plan 4 ECI Site	27.5	0.02	28

Simulated PCB Loss
Hydraulic Disposal

Site	Exposed Sediments (kg)	Submerged Sediments (kg)	Total (kg)
Plan 2 141st Site	9.9	1.1	11
Plan 4 ECI Site	21.2	2.6	24

5.9.3 As can be seen from these results the PCB mass flux is less when the sediments are maintained in a submerged state. This is due to the hydrophobic nature of PCBs as pointed out earlier in this appendix. In either case the flux is highly dependent on two factors; the exposure time of the sediments, and the surface area of the sediments.

5.9.4 The exposure time for submerged sediments encompasses the entire time a pond is in contact with PCB contaminated sediments. However, the rate of volatilization is directly related to the concentration of dissolved PCBs in the pond which is derived from the mass fraction of PCBs in the sediments. The rate of volatilization changes over time, since the pond dissolved concentration of PCBs varies over time with the highest rate during an active filling operation. The surface area is that area of the pond which is in direct contact with the air and is dependent on the volume of dredgings being deposited.

5.9.5 The exposure time for exposed sediments encompasses the time in which unsaturated sediments are in direct contact with the air, while the surface area is that area which is in direct contact at any given time.

5.9.6 The in-lake CDF shows the least amount of volatilization. This is because over the filling life of the CDF the exposed surface area is much less than an upland CDF. During most of the filling the dredgings are placed and remain submerged. However, when a cell is nearly filled, the ponded area is very small, and the flux rate is wholly derived from exposed sediments. Likewise, the upland site (ECI) with the largest surface area is showing the highest PCB mass flux.

5.9.7 Interpretation of Results

5.9.7.1 The major emission locales for a CDF and its inherent operations are as follows:

Dredging and Transporting
Exposed sediments void of vegetation
Ponded Zone
Sediments with vegetative cover

Secondary emission sources include entry of VOCs to air from droplets created by bursting bubbles and wind blown sediment dust or other means of particle generation. This model only considers the "exposed sediment void of vegetation," and "ponded zone" locales as emission sources for PCB flux.

5.9.7.2 The equation used to calculate flux from exposed sediments describes chemical movement in the unsaturated pore spaces near the exposed surface. Although, the initially placed sediments are in a semi-saturated state, it is short lived and surface layers will approximate the unsaturated situation soon after placement. In any case this initial transient state is not accounted for by the model. Also, wetting and drying cycles generated by rainfall were not considered.

5.9.7.3 In summary the approach taken in model formulation was conservative in nature in that it simulated a worst case scenario. For instance, the exposed sediments were assumed to be completely void of vegetation throughout the life of the CDF. However, from past experience a vegetative cover will form over the exposed sediments over time. Although there is no quantitative theory predicting the effects of vegetation on flux it is anticipated that the cover would reduce the flux rate. Also, the surface area of exposed sediments was simulated as a layer covering the entire cell (only for upland CDFs). Realistically, the deposited sediments would flow outward, but probably not far enough to cover the entire cell of an upland CDF. Finally, the suspended solids concentrations in the ponded areas (used during filling operations) and the dissolved PCB concentrations (used between filling operations) were based on conservative estimates. For the reasons stated above the actual PCB mass flux from a CDF could be substantially lower then what is predicted by the model simulation.

5.9.7.4 Theoretical models must be tested against and adjusted to both laboratory and field data prior to their acceptance and use as predictive tools. Preliminary model calculations can be made for the submerged sediment locale and the exposed sediment locale void of vegetation at this time. However, some aspects are based on very crude equations and further development is needed. At this time laboratory and field testing must be performed to build a higher degree of confidence in the predictive capability of the PCB volatilization model.

5.9.7.5 Laboratory analysis has been completed by WES (USACE 1989b) on New Bedford Harbor sediments in order to determine the volatile emission rates of PCBs from freshly placed drying sediments. Although, these results only supply one data set, it appears that the theory (used for model development) is in the range of actual lab results for freshly drying sediments. It should be noted that the lab tests were only done on fresh sediments and ran under laminar conditions. A substantial amount of work in lab and field testing and verification needs to be completed before any conclusive results can be made on PCB flux simulation from an active CDF.

6. ENVIRONMENTAL CONTROLS

6.1 The <u>Management Strategy for Disposal of Dredged Materials</u>, (Francingues et al, 1985) provides a framework for decision making to select the best possible disposal alternatives and to identify appropriate control measures to offset problems associated with the presence of contaminants.

6.2 Confined disposal of contaminated sediments must be planned to contain dredged material within the site and restrict the contaminant mobility out of the site in order to control or minimize potential environmental impacts. There are basically six possible mechanisms for transport of contaminants from confined disposal sites that should be considered:

a. Release of contaminants in the effluent during disposal operations.
b. Surface runoff of contaminants in either dissolved or suspended particulate form following disposal.
c. Leaching of contaminants into groundwater.
d. Plant and animal uptake of contamination from deposited sediments.
e. Contaminant uptake by animals foraging on vegetation growing on deposited sediments.
f. Wind-blown or volatile loss of contaminants during and after placement of dredged material.

6.3 EFFLUENT CONTROLS

6.3.1 According to the management strategy effluent controls at conventional CDFs are generally limited to chemical clarification. There are several physical and chemical treatment processes available that will dramatically reduce the level of contaminants in the CDF effluent. Settling of suspended solids naturally occurs when there is adequate detention time supplied to a wastewater. This settling process can be further enhanced by the addition of a chemical coagulant or polymer. The polymer will physically bridge smaller suspended solid particles into a larger mass of sufficient size to settle out of the water. The polymer will also cause some of the dissolved contaminants to combine into a suspended solid particle that can be physically removed. Dissolved pollutants can also be further removed by adsorption on activated carbon. The activated carbon supplies a large number of sites for adsorption of dissolved contaminants at the molecular level. This sorption process will remove some of the trace organic compounds, including PCB.

6.3.2 Inland Steel CDF Controls

6.3.2.1 There are several parameters whose total concentrations exceed the Indiana state water quality standards for Lake Michigan for all cases. These chemical parameters include: total dissolved solids (TDS), phosphorous, ammonia nitrogen, dissolved iron, phenols and PCBs. Chromium, cyanide, and lead exceed water quality standards for some of the final operations.

6.3.2.2 As stated, these results depict the quality of pumpage from the in-lake CDF, prior to any post-treatment. However, the actual concentration of some parameters will be different from the simulated results because of chemical or biological processes not simulated by the model and discussed in section 4.3.5.2.

6.3.2.3 As a result of these biological and chemical reactions within the CDF pond, the only chemical parameters which should have dissolved concentrations exceeding Indiana water quality standards for Lake Michigan are total dissolved solids, ammonia nitrogen, and PCBs. Other parameters may exceed the whole water standards only if the levels of suspended solids are elevated.

6.3.2.4 The in-lake CDF is divided into three separate cells. The last cell filled (Cell #3) will also be subdivided into two settling basins. The large primary basin will receive the dredged sediments from the disposal operations for Cell #3 and will provide adequate storage of material and sufficient detention time for sedimentation to occur. The smaller secondary basin receives only clarified supernatant water from the primary basin. As the filling operations progress, the pond volume will decrease thus allowing for less detention time for settling to occur. In order to achieve the same suspended solids level during these later operations, it will probably be necessary to add a polymer to the supernatant water once it enters the secondary basin.

6.3.2.5 The supernatant water will be pumped or will flow over a weir from the primary basin into the secondary basin. Polymer added to this water will induce both chemical coagulation and physical flocculation of the pollutants. These processes will result in greater containment of the contaminants within the CDF. The effluent from the secondary basin will be pumped to a permanent treatment structure that may include a dual media filter similar to the one used at the Chicago CDF. A package treatment system was also considered and rejected because the flow would be too high for such a system to handle.

6.3.2.6 The anticipated suspended solids removal efficiency is 80% for a sand filtration system. The use of a carbon sorption system will result in about a 35% removal efficiency for dissolved organics (including PCB). These treatment processes would not reduce the concentrations of dissolved solids or ammonia nitrogen. An air stripping process for removal of ammonia nitrogen from the effluent may also be necessary.

6.3.2.7 By following the treatment process outlined above, the vast majority of contaminants are removed from the CDF effluent prior to discharge and nearly all of the sediments are retained within the in-lake CDF. Routes of escape for contaminants in the effluent are subsequently monitored to ensure that water treatment is sufficient to satisfy state water quality standards.

6.3.2.8 The effluent from Cell #3 has the highest concentrations of chemical contaminants as there are no dilution effects associated with it. Therefore, this effluent will require the greatest level of treatment to meet state water quality standards for the in-lake CDF. The addition of a polymer may be necessary for all four operations in Cell #3. Based on the results of coagulation tests performed by WES (USACE, 1979), several of these parameters will meet state standards by the use of polymer addition alone. These conclusions were attained by applying the removal efficiencies as determined by WES to the chemical contaminant concentrations of the pond for Cell #3 operations before discharge from the secondary basin. The chemical contaminants that will not meet state water quality standards by use of a coagulant in Cell #3 are ammonia nitrogen, phenols, cyanide, total dissolved solids, and PCB. Although there is no quantitative standard for oil and grease, the last three operations for this cell will require further removal of this parameter to achieve the ambient lake concentration. Aeration will also be needed for the last two operations in Cell #3 to achieve the mandated dissolved oxygen level, particularly during the final disposal operation.

6.3.2.9 The discharge water quality for Cell #2 is somewhat better than that for Cell #3 due to the dilution of this effluent by the pond volume in Cell #3 before discharge. A polymer may be needed to satisfy state standards for Cell #2. The pollutants that will not be in compliance with state standards after use of a polymer in this cell are ammonia nitrogen, phenols, cyanide, total dissolved solids, and PCB. The oil and grease level in this effluent is comparable to the ambient lake concentration.

6.3.2.10 The effluent from Cell #1 is the most dilute for the in-lake CDF since it is diluted by the pond volumes of Cells #3 and #2. The use of a polymer may also be necessary for Cell #1. The contaminants that will exceed state water quality standards after polymer addition in this cell are ammonia nitrogen, phenols, total dissolved solids, and PCB. The oil and grease levels in this effluent will be lower than the ambient lake concentration.

6.3.2.11 The approach used to predict the chemical contaminant levels for the in-lake CDF is a conservative application of the water quality model. This conservativeness is especially pronounced for the dissolved iron concentrations reported in the various tables. These elevated concentrations of dissolved iron are expected under reducing, anaerobic conditions. The in-lake water quality model utilized for this analysis does not take into account the natural precipitation reaction of iron with hydroxide ions in the water under the pH ranges and oxidizing conditions present. This reaction will significantly reduce the level of dissolved iron in the CDF discharge water for all three cells. For the above reasons, the actual levels of iron present in the CDF effluent will be far less than shown on all data tables and will approach the ambient lake concentration.

6.3.2.12 The conservative approach of this water quality model overestimates the concentrations of the other parameters as well as for iron. Actual concentrations and post-treatment requirements will have to be verified in the field. Further treatment may bring some of the chemical parameters into compliance with state water quality standards.

6.3.3 Upland CDF Sites (Mechanical Disposal) Controls

6.3.3.1 Although there are physical differences between the three proposed disposal sites, the water quality and flow rate of the effluent discharged from these sites is dependent upon the surface area of the CDF. The J-Pit site and the ECI site have similar predicted water quality and flow rates due to similar size. The 141st site has the smallest predicted flow rates but the highest concentrations. Because it has less surface area there is less rain water drainage to dilute sediment drainage and thus results in higher concentrations with a lower flow.

6.3.3.2 All of the upland sites would have several parameters whose total concentrations exceed the Indiana state water quality standards for the Grand Calumet River/Indiana Harbor Canal for all cases. These chemical parameters include: phosphorus, ammonia nitrogen, PCBs, and Phenol. Iron, lead, and Cyanide would exceed the water quality standards for some of the final operations.

6.3.3.3 The option of on site treatment and discharge to Indiana Harbor Canal was considered for the ECI and 141st Sites for mechanical disposal. However, substantial treatment of the effluent would be needed to meet the Indiana Harbor and Canal standards making it cost prohibitive and therefore this option was eliminated from further consideration.

6.3.3.4 J-Pit CDF Controls

6.3.3.4.1 The effluent from the CDF will be discharged to the Gary Sanitary District Wastewater Treatment Plant. Ammonia nitrogen would probably be the only contaminant of concern for the treatment plant operations due to low flow conditions of mechanical disposal. If required, for PCB removal, a two stage filtration system, composed of a sand/anthracite filter followed by an activated carbon filter would be employed at the CDF site. Also, the effluent could be recycled (to cause evaporation and oxidation of ammonia) through the CDF to lower the ammonia nitrogen concentration. For more details on pretreatment see appendix I.

6.3.3.5 ECI CDF Controls

6.3.3.5.1 The effluent from the CDF will be discharged to the East Chicago Wastewater Treatment Plant. Ammonia nitrogen would probably be the only contaminant of concern for the treatment plant operations. The same pretreatment options are applicable as for the J-Pit site. For more details on pretreatment see appendix I.

6.3.3.6 141st Street CDF Controls

6.3.3.6.1 The effluent from the CDF will be discharged to the East Chicago Wastewater Treatment Plant. Ammonia nitrogen would probably be the only contaminant of concern for the treatment plant operations. The same pretreatment options are applicable as for the J-Pit site. For more details on pretreatment see appendix I.

6.3.4 Upland CDF Sites (Hydraulic) Controls

6.3.4.1 Hydraulic disposal is only viable at two of the upland sites due to their close proximity to Indiana Harbor Canal. These are the ECI site and the 141st Site. The model results for hydraulic disposal at these sites are the same for each CDF except for differences in PCB concentrations for disposal of TSCA and non-TSCA (backlog material) and maintenance sediments. These similarities occur because the effluent concentration is dependent on the quality of sediment pore water, the quality of the sluice water, and the amount of pore water released to the pond. The concentration of PCB in the backlog sediment pore water is greater for the TSCA material than for the non-TSCA material, and least for the maintenance material, but is the same for all other parameters. Thus, the only difference in effluent contaminant concentrations is for PCB when comparing disposal of TSCA and non-TSCA (backlog material) and maintenance sediments.

6.3.4.2 Several parameters total concentrations would exceed the Indiana state water quality standards for the Grand Calumet River/Indiana Harbor Canal. These chemical parameters include: TDS, phosphorus, ammonia nitrogen, chromium, iron, lead, phenol,and PCBs.

6.3.4.3 Due to the high flow rate consistent with hydraulic disposal the effluent could not be treated by a on-site package treatment plant. This flow rate would also tax any of the wastewater treatment plants available for discharge and thereby preclude discharge to a sanitary sewer. For the hydraulic disposal option to work the contractor must be able to slurry the material and transport it using substantially less then a 4:1 ratio of water to sediment.

6.3.4.4 The use of a polymer for coagulation and flocculation is necessary for treatment of effluent from hydraulically disposed sediments due to the high suspended solids concentration associated with this disposal option. The pollutants that will exceed state water quality standards after polymer addition are ammonia nitrogen, total dissolved solids, phenols, and PCB. The level of phenols is barely above the state standard, and further treatment will bring this parameter into compliance. The maximum concentration of PCB for hydraulic disposal of non-TSCA sediment is 300 ppt for hydraulic disposal of non-TSCA (backlog) material, 1900 ppt for hydraulic disposal of TSCA sediments, and 100 for hydraulic disposal of maintenance material.

6.4 SURFACE RUNOFF

6.4.1 Following the management strategy, runoff controls consist of measures to prevent the erosion of contaminated dredge material and the dissolution and discharge of contaminants from the oxidized dredged material surface. Surface runoff quality problems for an in-lake CDF can be mitigated by surrounding heavily contaminated sediments with cleaner ones. Also, no runoff will occur if the sediments are placed below the water level.

6.4.2 A major difference between an upland and inlake CDF is the amount and quality of water to be removed. In an in-lake CDF the water within the facility at the start of disposal must be gradually removed. This water provides significant dilution for the sediment pore water released during disposal. In an upland CDF there is no water inside the facility at the beginning of operations. Hence, the volume of water to be removed from the CDF is much less.

6.4.3 The effects of evaporation and precipitation will be similar for an upland or in-lake CDF. Evaporation of water from both the exposed sediment surface and CDF pond is a natural process, accelerated by high temperatures, low humidity, and strong winds. Evaporative loss is countered by precipitation which returns water to the CDF. The evaporation loss from shallow ponds and wet soils is generally estimated as 70% of measured pan evaporation. The average precipitation and adjusted pan evaporation rates for the Chicago-Midway and Valparaiso areas are shown in table F-20.

6.4.4 Indiana Harbor is situated between Midway and Valparaiso, and therefore, the amount of precipitation and evaporation should be somewhere between the values shown in table F-20. Due to the lack of information for the Valparaiso area, and assuming (a conservative assumption) that the 8 month dredging season depicts the water balance for this area, a net gain of 3.84 inches per year is seen in Valparaiso while a net loss of 7.23 inches per year is seen for Midway.

6.4.5 If there is evaporative drying (net loss) occurring it would have a relatively minor effect on the water balance of a CDF (in-lake or upland) during disposal operations. However, evaporative drying will be important in the drying and consolidation of the dredged sediments following disposal.

6.4.6 A net gain will be a direct source of water to the CDF. Only a portion of the precipitation falling on unsaturated areas of the CDF will runoff to the pond. The rest will be retained on the unsaturated area surface in depressions, and cracks or leach into the underlying sediments.

6.4.7 Both sources of water would need to be pumped from the CDF and be treated as effluent. The runoff water would have little time to sorb contaminants from exposed sediments as it moves to the CDF pond. The major impacts would be to the volume of pond water that needs to be pumped rather then any significant water

Table F-20: Average Monthly Precipitation and Evaporation at Two Meteorological Stations in Vicinity of Indiana Harbor

	Precipitation (in)[1]		Evaporation (in)[1]	
Month	Valparaiso	Midway	Valparaiso	Midway
January	2.30	1.93	---	0.76
February	1.79	1.78	---	0.96
March	2.91	2.73	1.26	1.88
April	3.46	3.17	2.55	3.19
May	3.59	3.46	3.61	4.83
June	3.67	3.72	4.07	5.75
July	3.34	3.44	4.09	5.71
August	3.43	3.23	3.48	4.87
September	3.31	3.14	2.37	3.85
October	2.92	2.56	1.58	2.68
November	2.76	2.31	0.89	1.38
December	2.61	2.12	---	0.83
Annual	36.09	33.59	---	36.69
8 month dredging season (Apr-Nov)	26.48	25.03	22.64	32.26

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[1] Source: US West Optical Publishing, 1988

quality impact. The water leaching through the sediments would eventually enter the CDF pond, and although this water would have higher contaminant concentrations the volume would be much less. In either case the total mass loading, to the effluent stream from precipitation would be small compared to other sources. Once the CDF has been capped, any runoff generated would not contain contaminates from the deposited dredge material.

6.5 LEACHATE CONTROLS

6.5.1 Subsurface drainage from confined disposal sites in an upland environment may reach adjacent aquifers. Fine-grained dredged material tends to form its own disposal-area liner as particles settle, but the settlement process may require some time for self-sealing to develop. Since most contaminants potentially present in dredged materials are closely adsorbed to particles, only the dissolved fraction will be present as leachate. A potential for leachate impacts exists when dredge material is placed in a confined site adjacent to freshwater aquifers. The site-specific nature of subsurface conditions is the major factor in determining the possible impact.

6.5.2 Inland Steel CDF Controls

6.5.2.1 The quantity of water that may seep through a completed in-lake CDF is very small. The dredged material spreads across the bottom of the CDF and eventually consolidates to form a layer of very low permeability. Consolidated dredge materials can have a permeability as low as 10E-09 cm/s. Also, the driving force for seepage is very small since the difference in height between the water in a CDF and the lake levels is likely to be small. When both water levels are equal, there is no pressure gradient acting to push water through the CDF. To prevent migration of seepage from the site a slurry wall will be placed around the perimeter of the CDF.

6.5.2.2 Covering the contaminated sediments with a cap will reduce leachate production by decreasing the amount of precipitation reaching the dredged material. Covers can also prevent the loss of contaminants through surface runoff and plant and animal uptake. Potential covers were evaluated using the HELP (Hydrologic Evaluation of Landfill Performance) model to determine the reduction in precipitation reaching the sediment. A 3 ft compacted clay layer covered with a 1.5 ft layer of topsoil could prevent over 98% of the amount of precipitation from reaching the dredged material. In order to maintain its effectiveness, the cover should be planted with vegetation to control erosion. Woody species should be prevented from taking root in the topsoil because their roots might penetrate the liner and release contaminants.

6.5.2.3 Until the material in the CDF reaches the desired degree of consolidation, various control measures can minimize the quantity and improve the quality of the leachate. These measures include encapsulation, filtering and operational controls. Encapsulating the heavily contaminated materials with clean materials will adsorb contaminants from the leachate before it reaches the lake.

6.5.3 Upland CDF Site(s) Control(s)

6.5.3.1 The same control measures mentioned for the in-lake CDF also apply for the upland CDFs. Control measures are also required to restrict seepage of leachate from the site. Leachate is produced from both the drainage of initially saturated dredged material and from precipitation infiltration through the cover. A drainage system will be employed in the upland CDFs which will collect leachate from saturated dredgings in initial operations. Eventually, due to the fine grained nature of the sediments the drainage system will lose efficiency in it's capability to transport leachate. However, by this time the deposited dredged material shall provide a barrier layer over the CDF floor with an effective permeability of 10^{-8} cm/sec, thus reducing the production of leachate. Additional surface drainage will than be used to dewater the dredged material.

6.5.3.2 J-Pit Site Leachate Controls

6.5.3.2.1 To prevent migration of leachate (seepage) from the CDF site, a slurry wall will be used around the perimeter of the existing slope and a compacted clay liner will be placed on the constructed dike. The floor of this site overlies an existing clay formation. A sand and gravel drainage layer with drain pipe will be placed on the CDF floor. This drainage system will also function as the leachate collection system as the CDF becomes filled.

6.5.3.2.2 The leachate collected from the CDF would be routed to the Gary Wastewater Treatment Plant. Ammonia nitrogen and possibly oil and grease would be the only parameters of concern to the treatment plant operations. Pretreatment methods could include striping and aeration to reduce the ammonia nitrogen concentration.

6.5.3.3 ECI Site Leachate Controls

6.5.3.3.1 A slurry wall will be placed around the perimeter of the site which will tie into an existing clay formation beneath the site. Also, a compacted clay liner will be placed along the dike face to seal off the CDF.

6.5.3.3.2 The seepage collected from the CDF and groundwater will be contained by the surrounding slurry wall. A groundwater collection system will be installed to maintain an inward gradient.

6.5.3.3.3 Prior to construction, the District would perform testing on the existing groundwater. The leachate and groundwater collected would be routed to the East Chicago Wastewater Treatment Plant. Depending on the results of the groundwater characterization, it may be necessary to pretreat the stream before discharging to the wastewater treatment plant. Analyis during the project design phase will determine if pretreatment is required to meet the pretreatment standards of the East Chicago Wastewater Treatment Plant.

6.5.3.4 141st Street Site Leachate Controls

6.5.3.4.1 The controls for this site are the same as the ECI site.

6.6 PLANT AND ANIMAL UPTAKE CONTROLS

6.6.1 Of immediate concern in an upland disposal of dredged sediments would be the potential for acute toxicity to soil invertebrates due to volatile PAHs, especially naphthalene. These compounds would be expected to decrease rapidly with time through a combination of volatilization, microbial activity and photodegradation. Following the loss of more labile organic compounds, the sediments possibly would be colonized by earthworms and other soil-dwelling invertebrates. Bioaccumulation of metals and the less labile organic compounds then would be the major concern, as indicated by the earthworm bioassay.

6.6.2 Plant bioassay test indicate that organic contaminants were not found in plant tissues and, apparently, are not being mobilized into the environment through plant uptake. However, cadmium and lead were quite high in the plants grown on the upland sediments (14.5 ug/g and 47.0 ug/g, respectively). The cadmium value is above the FDA allowable level of 10 ug/g. Uptake and subsequent mobilization of cadmium and lead can be minimized by maintaining the sediment under a flooded reduced condition.

6.6.3 Encapsulating the PCB contaminated dredged material should prevent long-term plant and animal uptake from the CDF. Also, capping the CDF would provide a barrier between the contaminated sediment and the zone of uptake.

6.7 VOLATILIZATION CONTROLS

6.7.1 Volatile contaminants are released to the atmosphere when they are exposed to air. Volatilization can be minimized by a number of control options. These options include submersion and encapsulation, temporary cover and capping, operational controls to reduce dust, and use of a wind fence.

6.7.2 Volatilization (in an in-lake CDF) can be minimized by placing the sediments below lake level to keep the sediments saturated and by encapsulating the contaminated materials in cleaner sediments. This option would be extremely effective for hydrophobic materials such as PCBs.

6.7.3 For control measures to effectively reduce volatilization they must reduce the number of wetting and drying cycles. Although quantification of flux through these cycles is unknown for a CDF, it is known that wetting and drying cycles have a substantial effect on the rate of volatilization. Minimizing these cycles can be best accomplished by keeping the sediments permanently saturated. Unfortunately, in an upland CDF this would encourage leachate movement and preclude the use of a low permeability cap. If hydraulic disposal is used, the sediments should be pumped to the CDF through a submerged inlet to minimize turbulence at the surface.

6.7.4 Temporary cover placed during filling operations could reduce volatile losses. This would increase the pathway a contaminant travels in order to escape to the air. If the cover material has organic matter present, this will also increase the number of adsorption sites for PCBs. Covering the exposed material with geofabrics, or vegetation such as grasses and shrubs would also reduce emissions to air. A cap placed after the CDF has been filled would have a similar effect in that the volatilization of persistent contaminants, such as PCBs, would be effectively eliminated.

6.7.5 A wind fence is another control option which may reduce volatile loss. In the case of surface impoundments, fences appear to be an effective volatile chemical control device in the presence of wind. A perimeter fence of solid construction (i.e., non-porous) can give up to approximately 40 % volatile emission reduction (Thibodeaux, Springer, Parker,___).

6.8 PCB BIODEGRADATION

6.8.1 Prior to 1980 anaerobic environments were thought to be long-term sinks for PCBs. Today evidence indicates that PCBs do undergo some degradation or transformation in anaerobic environments. According to a report (USACE, 1989A) done on PCB biodegradation by the Waterways Experiment Station (WES) for the Chicago District, the only degradation of PCBs under anaerobic conditions is reductive dehalogenation. This process will reduce the average degree of chlorination of PCBs in flooded soil or sediment, but will not change the overall amount of PCBs. The dehalogenation process is also sensitive to substrate concentration. PCB levels of 50 ppm or higher seem to be required for significant dehalogenation to occur, and little or no dehalogenation will take place at PCB concentrations of 5 ppm or less.

6.8.2 As of April 1989, research has not reached a point to predict the theory or formulation of degradation equations for predicating the fate of PCBs in an anaerobic environment. However, the literature does provide a range of values for the half-life of given Arochlors. For instance, the half-life of Arochlor 1242 has been estimated to be 10 years, while a half-life of an Arochlor 1242-1248 mixture present in Indiana Harbor has been estimated as 70 days or less.

6.8.3 The majority of the sediments placed into a CDF would remain in an anaerobic condition. From the aforementioned discussion, an initial level of 50 mg/kg of Arochlor 1248 can be expected to decrease under anaerobic conditions, while a starting level of 5 mg/kg will change little, if at all. The disappearance of Arochlor 1248 will not, however, be a true disappearance of PCBs. Instead, the original 1248 will appear as congeners having lower levels of chlorination. A reasonable range for the half-life of this degradation appears to be from 2 months to 10 years.

6.8.4 As a result of the dehalogenation process the sediments contained within the capped CDF should become less persistent over time. Also, it seems that this natural process occurs most efficiently with high concentrations of PCBs (such as TSCA material).

6.9 CDF CLOSURE

6.9.1 The closure of a CDF refers to its final cap and cover. These are important features of the CDF's environmental design. The purpose of a cap and cover is to promote positive drainage of precipitation from the CDF surface and to inhibit infiltration and percolation of water into the CDF after closure.

6.9.2 Two alternate cap and cover designs were evaluated for the in-lake CDF using a computer model developed by the Corps' Waterways Experiment Station (WES) for the USEPA. The Hydrologic Evaluation of Landfill Performance (HELP) model calculates the amount of drainage from and percolation through a design cap and cover. This model is fully documented elsewhere (Schroeder et al, 1984).

6.9.3 The HELP model was used to evaluate two different cap designs. The input and output summaries for the proposed cap and cover design are provided in attachment F-4. A summary of the average annual volume of water penetrating both the cover and cap is given in table F-21.

6.9.4 Inland Steel Site

6.9.4.1 It is assumed that each cell would be filled in approximately four operations. The final cover would probably not be spread out until at least a year or two after disposal was completed for a cell to allow the sediments within the CDF to undergo drying and consolidation. The first step in cap construction would be to regrade the surface sediments in the CDF to provide a slope for positive drainage.

6.9.4.2 The recommended closure design is shown on figure F-14. This design consists of a cover of topsoil (18 inches) seeded with grass, over a lateral drainage layer of gravel (6 inches), over a cap of compacted clay (3 feet). The average annual volume of water penetrating both cover and cap is 0.69 inches, or 6,100 cubic yards.

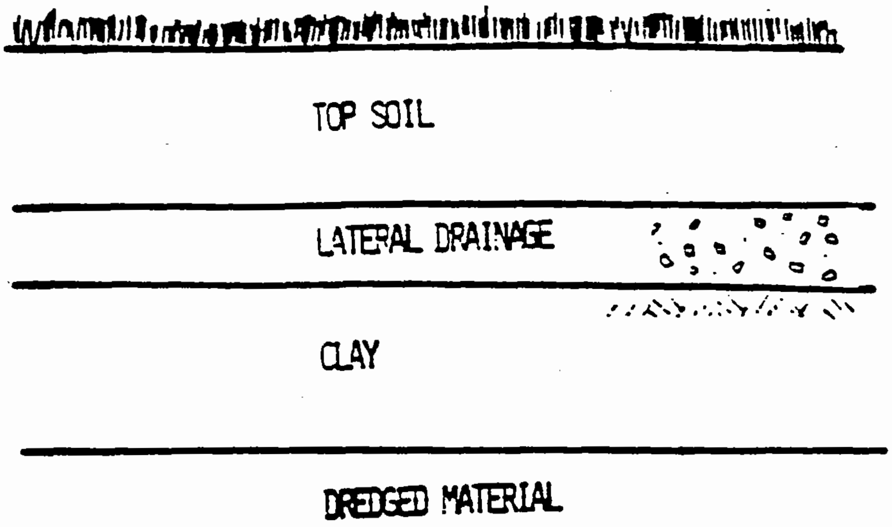

Figure F-14: Indiana Harbor CDF Closure Design

Table F-21: Average Annual Percolation Through Cover and Cap

Cap Design	Layer Thickness (inches)	Average Annual Percolation Through Cap (inches)
#1		
Topsoil	24	
Clay	36	1.06
#2		
Topsoil	18	
Lateral drainage- gravel	6	
Clay	36	0.69

Site	Surface Area at Dike Crest (acres)	Annual Percolation #1 (gal/yr)	Annual Percolation #2 (gal/yr)
Inland Steel	66	1,898,800	1,232,200
J-Pit	72	2,020,000	1,353,400
ECI	77	2,222,000	1,434,200
141st Street	56	1,616,000	1,050,400

6.9.4.3 The amount of seepage from the CDF (post-closure) is directly related to the effectiveness of the cap and cover. Lab test indicate that the sediments from Indiana Harbor have a permeability on the order of 10^{-8} cm/sec. Due to this low permeability and the high storage capacity of fine grain material only a very small head would develop within the dredge material. For these reasons the amount of percolation through the dredged material would be significantly less than through the cap and cover. The HELP model was used to predict the seepage through the dredged material and the results are shown in table F-22. This seepage would (in the long term) pass through the dredgings into the dike core and become mixed with Lake Inland waters before reaching Lake Michigan. This seepage would have the quality of pore water as shown in table F-9. In this manner Lake Inland acts as a mixing zone for any seepage leaving the CDF. The rate of seepage is so slow that there would be no change to the water quality of Lake Michigan immediately adjacent to Lake Inland and the enclosed CDF.

Table F-22: Average Annual Seepage from CDFs

Site	Surface Area at Dike Crest (acres)	Annual Seepage (gal/yr)
Inland Steel	66	242,400
J-Pit	72	262,600
ECI	77	282,800
141st Street	56	199,980

6.9.5 Upland Sites

6.9.5.1 The design of the cap and cover for all of the upland CDFs was conducted using the methods employed for the in-lake CDF. The only difference between the sites is the difference in surface area each occupies. The cap and cover design proposed for all CDFs is the same (figure F-14).

6.9.5.2 The quantity of seepage from the upland CDFs will be determined by the rate of penetration of the cap, cover and leachate collection system. The HELP model was used to simulate production of seepage from the CDF. The underdrain system was assumed to be functioning at 30 percent of its initial capacity. A summary of the average annual seepage for each site is shown in table F-22. As expected the underdrain system has little effect on leachate collection in the long term. The seepage shown in table F-22 would (in the long term) pass through the dredgings, leave the CDF and enter the shallow groundwater below the CDF. No site specific information was available at the time of this report on the movement, quality, or use of the ground water below each site.

6.10 RECOMMENDED CONTROLS

6.10.1 Following the management strategy gives various control measures which ensure that any escaping contaminants are controlled and properly treated. The proposed disposal facilities are thus able to comply with all applicable environmental standards. Contaminant pathways, along with their correspondent control measures are summarized in table F-23 for different disposal alternatives.

7. COMPARISON OF CONFINED DISPOSAL ALTERNATIVES

7.1 The bottom sediments (predominantly silt and clay materials) in the Grand Calumet River and Indiana Harbor Canal reflect the history of waste discharges into the waterway. The sources of

Table F-23: Possible Control Measures

Contaminant Pathway	Control Measures	
	In-Lake CDF	Upland CDF
Effluent	settling filtration chemical clarification	settling filtration chemical clarification carbon adsorption
Surface Runoff	encapsulation submerge sediments below lake level cap	encapsulation carbon adsorption cap
Leachate	filtration operational controls encapsulation cap	leachate collection and treatment liner cap
Plant/Animal Uptake	encapsulation cap	encapsulation cap
Volatilization	encapsulation submerge sediments below lake level cap	encapsulation temporary cover wind fence cap

these sediments include point discharges, combined sewer overflows, and urban runoff from the Grand Calumet River/Indiana Harbor Canal watershed. The results of recent sampling events do not indicate any vertical trends for most parameters (see Appendix H). The exposed sediment is characteristically similar to the deeper sediments located below project depth. The bottom sediments to be dredged and disposed to a CDF are "moderately to heavily polluted" according to USEPA criteria. Laboratory analysis of Indiana Harbor sediments has included physical properties, bulk chemistry, settling tests, standard elutriate tests, leachate tests, filtration tests, coagulation tests, surface runoff, and permeability tests. The results of laboratory analysis with Indiana Harbor sediments are in agreement with the Dredged Material Research Program; that most contaminants associated with bottom sediments are tightly bound to the sediment particles, and that the confinement of the sediment particles is the key to the containment of the adsorbed contaminants.

7.2 The in-lake CDF water quality was determined by applying the physical characteristics and disposal methods to the water quality model. The water quality is much better during the earlier operations for each cell and for the first cells filled as compared to the last cell filled. Treatment of the effluent will result in compliance with state standards for most parameters. Contaminants not in compliance will achieve ambient lake concentrations within a small mixing zone. More treatment is needed during the last filling operation of the third cell filled than during any other in-lake disposal operation. The state water quality standards for the in-lake CDF are the most stringent of any Indiana waterway since the discharge is to Lake Michigan.

7.3 As a basis of comparison, mechanical disposal to an upland CDF appears to produce the lowest effluent concentration of most parameters and has the lowest flow. Compared to hydraulic disposal all parameters are lower except ammonia nitrogen, TKN, phenols, and cyanide and this occurs only in the final filling stages. A comparison with mechanical disposal to the in-lake CDF shows all parameters to be lower except ammonia nitrogen, TKN, phenols, cyanide, TS, and manganese. However, in the final stages of filling all of the parameters are lower for mechanical disposal to an upland CDF.

7.4 In order to complete the analysis of the impacts of the proposed project on the water quality of Lake Michigan, the effects of the maintenance of the navigation channel on the yield of suspended solids by the Grand Calumet River/Indiana Harbor Canal watershed to the lake were examined. This is necessary because the maintenance of the navigation channel and the construction/operation of the proposed CDF come as a package. The annual loadings of suspended solids by the watershed was estimated from available information on point sources, combined sewer overflows, and urban runoff. The rates of sediment deposition in the navigation channel were based on dredging records and bathymetric surveys. This analysis indicates that the maintenance of the navigation channel at authorized depths could trap an estimated 75-105 million pounds of sediments annually, or about 50%-70% of the total suspended solids loading by the watershed. The mass of contaminants associated with these sediments was estimated from the bulk chemistry of sediments already deposited in the channel.

7.5 Table F-24 gives a comparison of the contaminant transfer from the GCR/IHC to Lake Michigan for no-action and with project conditions. The numbers represent the mass of contaminants lost over the project lifetime which is approximately 40 years. The mass loss is based on current conditions within the project area remaining constant, and does not account for any future changes to land use within the project area. As can be seen in table F-24 the project should reduce the annual sediment and sediment contaminant loadings from GCR/IHC to Lake Michigan from 50% to 70%. Table F-25 gives the contaminant loss for average operating conditions and capped conditions from each CDF site. It should be noted that the effluent contaminant pathway, defined in table 25, is not a true loss pathway to the environment since this flow stream will be directed to further treatment.

7.6 Clearly, the positive effects of maintaining the navigation channel, and its impact as a sediment trap far out weighs the unavoidable discharges from the proposed CDF.

Table 24: Comparison of Contaminant Loss for No-Action and With-Project Conditions

Sediment and Sediment Contaminant Loadings to Lake Michigan
from GCR/IHC and Upland CDF Over Active Life of CDF (pounds)

Constituent	No-Action	With-Project[1]		Contaminant losses from Upland CDF[2]
Total Suspended Solids	7,000,000,000	2,000,000,000 -	3,000,000,000	110,000
Arsenic	250,000	75,000	120,000	7
Cadmium	76,000	23,000	38,000	2
Chromium	2,600,000	770,000	1,300,000	49
Copper	940,000	280,000	470,000	49
Iron	660,000,000	200,000,000	330,000,000	1,100
Lead	3,800,000	1,100,000	1,900,000	42
Manganese	7,600,000	2,300,000	3,800,000	81
Mercury	4,800	1,400	2,400	0.50
Nickel	500,000	150,000	250,000	37
Zinc	20,000,000	6,000,000	10,000,000	140
Ammonia	5,800,000	1,800,000	3,000,000	62,000
Phosphorous	18,000,000	5,300,000	8,800,000	480
Oil & Grease	390,000,000	118,000,000	200,000,000	---
PCBs	14,000	4,200	7,000	61[3]

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[1] Assuming a 70 and 50% reduction from no-action conditions.

[2] Losses are through seepage, effluent, and volatilization over 38 year active life.

[3] 60.5 lbs volatile loss and .01 lbs seepage and effluent loss.

Table 25: Contaminant Loss for Average Operating Conditions and Capped Conditions (lbs/yr)[1]

Inland Steel Site

	Average Operating Conditions				Capped Operating Conditions			
Constituent	Seepage	Effluent	Volatile	Total	Seepage	Effluent	Volatile	Total
Arsenic	0.033	0.49		0.52	0.029	0.032		0.061
Cadmium	0.014	0.83		0.84	0.010	0.0090		0.019
Chromium	0.15	4.5		4.7	0.13	0.29		0.42
Copper	0.49	5.4		5.9	0.44	0.087		0.53
Iron	10	89		99	10	2.1		12
Lead	0.21	4.4		4.6	0.19	0.20		0.39
Manganese	0.085	9.0		9.1	0.044	0.58		0.62
Mercury	0.0006	0.055		0.056	0.00042	0.0034		0.0038
Nickel	0.41	4.1		4.5	0.38	0.038		0.42
Zinc	0.79	14		15	0.69	0.59		1.3
Ammonia	670	71		740	640	58		700
Phosphorous	4.0	17		21	4.20	0.93		5.1
PCBs	0.000068	0.00045	0.28	0.28	0.000021	0.000029	---	0.000050

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[1] Average operating conditions represent the situation when the CDF is at 1/2 capacity.
Capped conditions represent long term losses.
Seepage is the mass loss from passage through the CDF.
Effluent is the mass loss, prior to any pretreatment, which is routed to waste water treatment.
Volatile is the mass loss from exposed and ponded sediment.

(continued)

Table 25 (cont'd): Contaminant Loss for Average Operating Conditions and Capped Conditions (lbs/yr)[1]

J-Pit Site

	Average Operating Conditions				Capped Operating Conditions			
Constituent	Seepage	Effluent	Volatile	Total	Seepage	Effluent	Volatile	Total
Arsenic	0.063	0.094		0.16	0.032	0.035		0.067
Cadmium	0.021	0.026		0.047	0.011	0.010		0.021
Chromium	0.27	0.85		1.1	0.14	0.31		0.45
Copper	0.95	0.17		1.1	0.48	0.094		0.57
Iron	21	4.5		26	10	2.3		12
Lead	0.40	0.56		0.96	0.20	0.21		0.41
Manganese	0.095	1.7		1.8	0.048	0.61		0.66
Mercury	0.00090	0.010		0.011	0.00046	0.0037		0.0042
Nickel	0.81	0.03		0.84	0.41	0.041		0.45
Zinc	1.5	1.7		3.2	0.75	0.64		1.4
Ammonia	1400	37		1400	700	63		760
Phosphorous	9.0	2.0		11	4.6	1.0		5.6
PCBs	0.000045	0.000085	1.4	1.4	0.000023	0.000032	---	0.000055

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[1] Average operating conditions represent the situation when the CDF is at 1/2 capacity.
Capped conditions represent long term losses.
Seepage is the mass loss from passage through the CDF.
Effluent is the mass loss, prior to any pretreatment, which is routed to waste water treatment.
Volatile is the mass loss from exposed and ponded sediment.

(continued)

Table 25 (cont'd): Contaminant Loss for Average Operating Conditions and Capped Conditions (lbs/yr)[1]

141st Street Site

	Average Operating Conditions				Capped Operating Conditions			
Constituent	Seepage	Effluent	Volatile	Total	Seepage	Effluent	Volatile	Total
Arsenic	0.069	0.06		0.12	0.02	0.03		0.050
Cadmium	0.023	0.02		0.038	0.008	0.008		0.016
Chromium	0.29	0.50		0.80	0.11	0.24		0.35
Copper	1.0	0.10		1.1	0.37	0.07		0.44
Iron	23	3.0		26	8.2	1.8		10
Lead	0.44	0.33		0.77	0.16	0.17		0.33
Manganese	0.10	1.0		1.1	0.040	0.47		0.51
Mercury	0.0010	0.0061		0.0071	0.0004	0.003		0.0034
Nickel	0.88	0.020		0.90	0.32	0.03		0.35
Zinc	1.6	1.0		2.6	0.59	3.2		0.59
Ammonia	1500	22		1500	540	49		590
Phosphorous	10	1.0		11	3.5	0.8		4.3
PCBs	0.000071	0.000072	1.3	1.3	0.000020	0.000020	---	0.000040

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[1] Average operating conditions represent the situation when the CDF is at 1/2 capacity.
Capped conditions represent long term losses.
Seepage is the mass loss from passage through the CDF.
Effluent is the mass loss, prior to any pretreatment, which is routed to waste water treatment.
Volatile is the mass loss from exposed and ponded sediment.

(continued)

Table 25 (cont'd): Contaminant Loss for Average Operating Conditions and Capped Conditions (lbs/yr)[1]

ECI Site

	Average Operating Conditions				Capped Operating Conditions			
Constituent	Seepage	Effluent	Volatile	Total	Seepage	Effluent	Volatile	Total
Arsenic	0.07	0.10		0.17	0.034	0.038		0.072
Cadmium	0.023	0.028		0.051	0.011	0.010		0.021
Chromium	0.30	0.92		1.2	0.15	0.33		0.48
Copper	1.0	0.18		1.2	0.51	0.10		0.61
Iron	23	4.9		28	11	2.5		14
Lead	0.44	0.61		1.1	0.22	0.23		0.45
Manganese	0.10	1.9		2.0	0.050	0.68		0.73
Mercury	0.0010	0.011		0.012	0.00049	0.0040		0.0045
Nickel	0.89	0.037		0.93	0.44	0.044		0.48
Zinc	1.6	1.8		3.4	0.80	0.69		1.49
Ammonia	1500	40		1500	740	67		810
Phosphorous	10	2.1		12	4.9	1.1		6.0
PCBs	0.000049	0.000092	1.6	1.6	0.000024	0.000034	---	0.000058

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[1] Average operating conditions represent the situation when the CDF is at 1/2 capacity.
Capped conditions represent long term losses.
Seepage is the mass loss from passage through the CDF.
Effluent is the mass loss, prior to any pretreatment, which is routed to waste water treatment.
Volatile is the mass loss from exposed and ponded sediment.

PART B

8. CURRENT PROPOSED PLAN

8.1 The preceding sections (2 through 7) presented the water and air quality impacts of CDF operations at four proposed sites. The preceding sections of the appendix were written during the third phase of the project (mid 1980's to late 1990) when the ECI site was one of four alternative sites. During the fourth phase of the plan formulation, the ECI alternative was chosen and the design was revised according to the changes itemized in the CMP. The revised proposal is discussed in this section, Part B, of the appendix. Part B presents the same impact analysis for the revised ECI proposal as was included in the preceding sections. The earlier proposal (third phase) and revised proposal (fourth phase) will be referred to as "initial" and "current," respectively.

8.2 The current proposal uses the same location as the initial proposal but there are changes in the size, design, and filling sequence of the CDF. The current proposal is 130 acres in size and made up of three separate cells as shown in Plate F-6. One of the cells, the southwest, would be subdivided into two subcells to separate the TSCA material. The southwest and southeast cells would occupy an area of approximately 88 acres and the north cell would occupy an area of approximately 43 acres, making a total of 130 acres for the current CDF. In the initial proposal, the CDF size has been 90 to 95 acres.

8.3 Many aspects of the current proposal are the same as the initial proposal so that only the differences between the two plans will be presented in Part B. Also, since the southern cells of the current proposal are of the same approximate capacity as the initial proposal, the discussion will focus on the south cells. In the current proposal, the north cell is approximately half the combined size of the southern cells and the design of the north cell, with the exception of the TSCA subcell, is identical to the south cells. Therefore, the environmental impacts of the north cell would be similar to but of less magnitude (about half that of the south cells). The same environmental controls would be applicable to both ECI site proposals as required.

9. EXISTING CONDITIONS

9.1 GROUNDWATER QUALITY

9.1.1 The ECI CDF site is located between the Lake George Branch of the Indiana Harbor Canal and Lake Michigan. Groundwater flow as this site may be influenced by pumping from nearby petrochemical tank farms surrounding the site and the Lake George Branch of the canal immediately south of the site. A discussion of five groundwater wells in the vicinity is included in section 2.2.2.7.

9.1.2 Since demolition of the refinery in the mid-1980's, several site assessments have been conducted on the property. One of the investigations was done by Ecology & Environment, Inc., and a report summarizing the field activities was submitted in February, 1991. The report confirmed the existence of a hydrocarbon layer floating above the groundwater. The thickness of the layer was measured at monitoring wells during three field site visits from October, 1990 through January, 1991. Of five wells on parcels I, IIA, and IIB, the hydrocarbon thickness varied from zero to 4.4 feet.

9.1.3 As stated in the CMP, RCRA clsure will be required on parcel I which contained the hazardous waste management units and RCRA corrective action will be required on parcels IIA and IIB due to extensive on-site surface and groundwater contamination. The engineering requirements for RCRA closure/corrective action will contain and prevent the contamination from leaving the site. These include an in-place clay cap system, slurry wall (or high density polyethylene membrane) around the perimeter of the site, and an inward gradient groundwater control system.

9.2 AIR QUALITY

9.2.1 A general discussion of the air quality in northwest Indiana is included in section 2.3. As stated in the CMP, the ECI site was owned and occupied by Energy Cooperative Industries as an oil refinery. After ECI filed for bankruptcy, all building and above ground structures were razed and several inches of clean topsoil were placed on the site. No soil or groundwater cleanup has taken place since demolition.

9.2.2 Volatilization and wind-born particulate matter are two potential contaminant loss pathways from exposed petroleum-contaminated soil. Without a cap covering the exposed soil, volatile organic compounds and fugitive particles can be emitted from the site. In an inhalation risk assessment, the USEPA investigated the magnitude of the emission loadings from the ECI site (Appendix T). The site emission loadings were approximated from soil samples chacterizing the ECI site (ERM, 1992).

9.2.3 The construction of the CDF will serve to cap the site, removing the site as a source of emissions. However, once dredging begins, the CDF will replace the soil on the site as the emission source. A volatilization analysis of the CDF is presented in section 11.

10. WATER QUALITY ANALYSIS

10.1 WATER QUALITY MODEL FOR CURRENT PROPOSED PLAN

10.1.1 Hydraulic disposal will not be discussed due to the large volume of water currently required to transport and slurry the material. If future techniques are developed to substantially reduce this water requirement, the water quality impacts would approximate those from a mechanical operation as will be presented in this section. Unlike the initial ECI site proposal, two lobes would be filled concurrently throughout the design life of the current proposal. The current proposal revises the filling sequence so that at the half-filled point, the sediment in both lobes will be divided evenly between new and aged material. The half-way filling point designed for the initial proposal was that one third of the CDF would be capped, one third would be empty, and the last third wuld be divided between new and aged material. This operational difference will change the sequence and eliminate some of the surface conditions presented for the initial ECI site proposal.

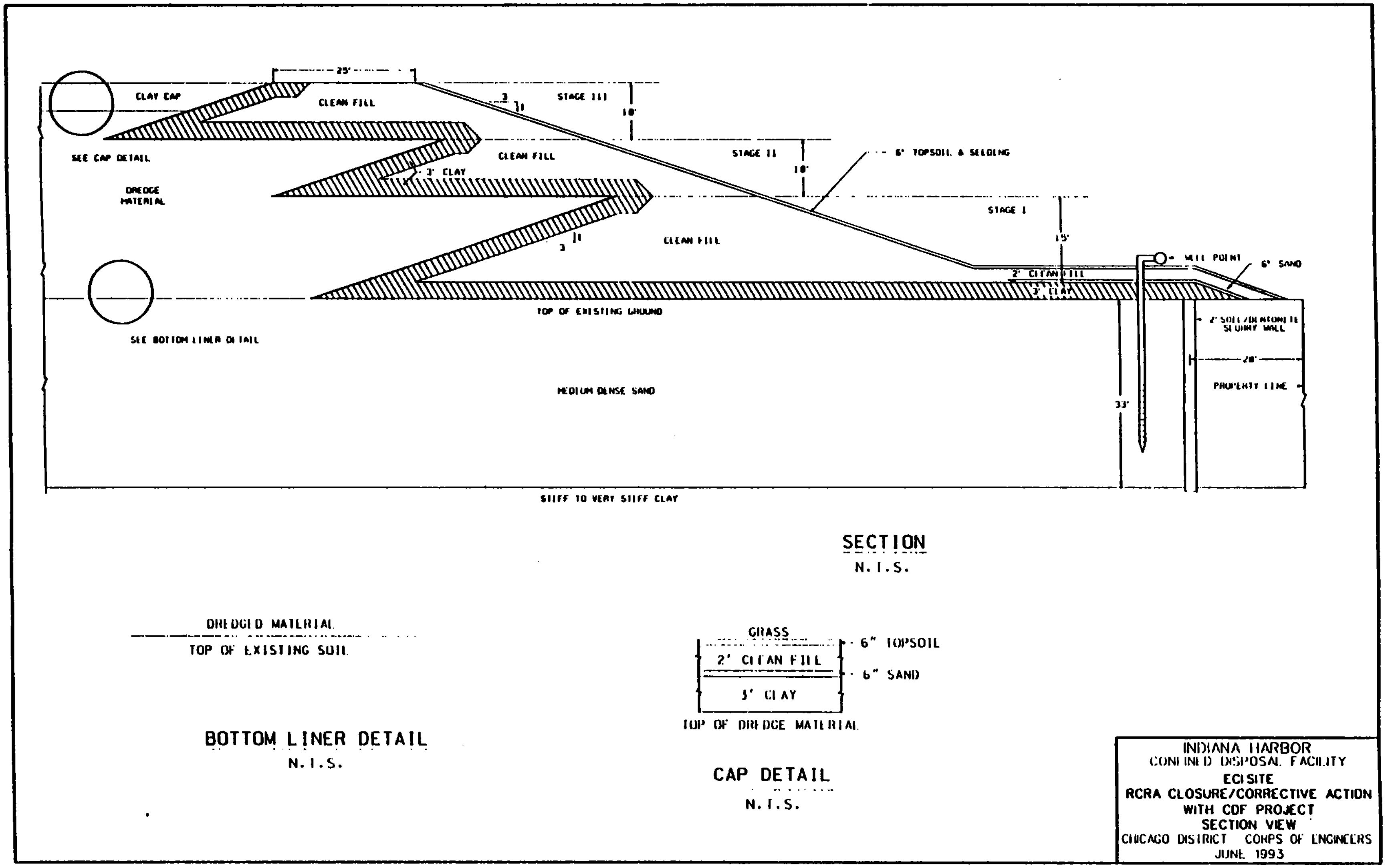
10.2 DESIGN AND OPERATION

10.2.1 This plan consists of the construction of a three lobed CDF. The two southern lobes of the current proposal (Plate F-6) are slightly smaller in surface area than the single lobe of the initial proposal (Plate F-5). The north lobe is about half the size of the south lobes. The foot print of the CDF (north and south lobes) is approximately 131 acres in area and is shown in Plate F-6.

10.2.2 The CDF would be constructed with a design capacity of about 4.0 million cubic yards and an estimated design life of approximately 38 years. The CDF would be roughly rectangular in shape and would be constructed of earthen dikes using off site materials. Dikes would be built using staged construction to elevations of 15, 25, and 35 feet above existing ground surface. The CDF dikes are trapezoidal in cross section (figure F-15) with a final crest width of 35 feet.

10.2.3 The proposed barrier system (figure F-15) would consist of a bentonite slurry wall, two feet thick, placed around the perimeter of the CDF. The slurry wall would extend from the ground surface down to approximately 33 feet and be tied into the hard till which underlies the site. Well points would be installed in order to maintain a inward hydraulic gradient into the subsurface below the CDF. In addition, monitoring wells would be installed along the outside face of the slurry wall in order to determine if any contaminates are seeping through the slurry wall and leaving the site.

Figure F-15



INDIANA HARBOR
CONFINED DISPOSAL FACILITY
ECI SITE
RCRA CLOSURE/CORRECTIVE ACTION
WITH CDF PROJECT
SECTION VIEW
CHICAGO DISTRICT CORPS OF ENGINEERS
JUNE 1993

10.2.4 Dredging would be performed using a closed bucket mechanical dredge. The dredged material would be loaded into barges or scows and transferred into trucks in a rehandling zone located next to the CDF. Splash guards would be required by the contractor to prevent spillage from entering into the canal during rehandling. The trucks would then transport the dredged material to the CDF by use of haul roads placed around the site and on top of the dikes. Trucks would not have to use city or county roads to transport the dredgings.

10.2.5 Dredge material would be placed in the CDF in lifts of approximately 3 feet. Such limited lifts would promote greater efficiency of natural drying and greatly enhance potential gains in CDF capacity. To allow for natural drying, not more than one 3 - foot lift would be placed on top of the previous lift in each cell. Once placed inside the CDF, dredged material would be reworked to construct a containment cell for the TSCA material, heighten the interior dike, and build a platform for heightening of the perimeter dikes. Lifts would continue to be placed until 2-3 feet of freeboard remained, at which time the containment dikes would be raised.

10.2.6 Each cell would be graded towards a dewatering sump to avoid ponding of water. Placement would begin at the high end of each cell and continue towards the sump. The first placement of dredged material is expected to be "windrowed" on the bottom of the CDF. Windrows are long parallel piles with space in between for vehicle access. Dump trucks would drive into the CDF and dump the dredge material on the bottom into rows 3-4 feet high. Subsequent lifts would be windrowed if possible or dumped from the edge and mechanically distributed.

10.2.7 Water would be collected from within the CDF and subsurface, pretreated if required, and discharged to the East Chicago sanitary sewer system. The treatment requirements for the discharged water are discussed in section 12.1.

10.3 RESULTS OF ANALYSIS

10.3.1 Water quality impacts for the current ECI site were simulated using the HELP model as described earlier. The impact for the north lobe is assumed to be half that of the south lobe. The quantity and quality of the CDF effluent, for average or mid-CDF life, are shown in table F-26. For comparison, the results for the initial ECI site proposal are also included in the table.

10.3.2 The existing water quality beneath the site is expected to have similar characteristics to the predicted effluent. Infiltration through the slurry wall from the site perimeter is estimated to be approximately 0.5 gpm for the entire site. Hence, the average outflow rates are expected to be about 20 and

10 gpm for the south lobe and north lobe, respectively. The water quality is expected to be similar to that shown in table F-26.

10.3.3 The water quality and quantity was modeled assuming that the CDF was divided into a northern and southern cell. This assumption would have little effect on the net water quality impacts of the CDF. Also, as stated above, the cells were assumed to be filled concurrently. For this operational scheme the water quality impacts would be very similar to the initial ECI site proposal in the beginning filling stages. This means that, unlike the initial proposal, water quality and quantity would be fairly static after the beginning filling stages. The results shown in table F-26 reflect the pumpage from the CDF throughout the majority of the CDF life, without any post treatment.

10.3.4 There are two noticeable differences in water quality trends between the initial ECI site plan and the current proposed Plan as shown below:

Initial ECI Site Plan	Current ECI Site Plan
Outflow decreases over time	Outflow constant after initial filling
Concentration increases over time	Concentration constant after initial filling

The differences occur from the way the CDFs are filled: for the initial proposal, each cell is filled separately. Thus at any given time, part of the CDF would be capped, empty, or partially filled. In the current proposed plan, the cells are filled concurrently.

10.3.5 The results in table F-26 depict the quantity and quality of the water drained from the CDF and water infiltrating through the slurry wall. This water will have had limited treatment to this point---filtered out by the insitu sand beneath the site. Additional treatment required for this water prior to discharge is considered in section 11.1.

Table F-26: Predicted Untreated Effluent Characteristics,
Initial and Current ECI Site Proposal - Mechanical Disposal

	Concentration in:		Initial ECI Site Proposal			Current ECI
			Cell #1	Cell #2	Cell #3	Site Proposal
Parameter	Porewater	Precipitation	Outflow	Outflow	Outflow	Outflow
TDS[1,2]	302	107	112.2	116.8	137.8	142.9
Total Solids[1]	352	283	284.8	286.5	293.9	295.7
Phosphorus	2.0	0.023	0.1	0.1	0.3	0.4
TKN	310	0.3	8.5	15.9	49.2	57.3
NH_3	305	0.435	8.5	15.7	48.5	56.5
Arsenic[2]	0.014	0.0011	0.0014	0.0017	0.0031	0.0035
Barium[1,2]	0.025	0.021	0.021	0.021	0.0214	0.0215
Cadmium	0.0047	0.0003	0.0004	0.001	0.001	0.001
Chromium[2]	0.060	0.01	0.011	0.013	0.018	0.019
Copper	0.210	0.002	0.008	0.012	0.035	0.040
Iron	4.60	0.0528	0.17	0.28	0.77	0.89
Lead	0.089	0.0066	0.009	0.011	0.020	0.022
Manganese[2]	0.021	0.20	0.19	0.19	0.17	0.16
Mercury[2]	0.0002	0.000122	0.0001	0.0001	0.0001	0.0001
Nickel	0.018	0.0004	0.005	0.009	0.029	0.033
Zinc	0.330	0.0195	0.028	0.035	0.069	0.077
Cyanide[2]	0.190	0.005	0.010	0.014	0.034	0.039
PCB[2] TSCA Cell	0.0016	0.00001	0.000052	---	---	---
Cell #2,#3	0.0002	0.00001	---	0.000020	0.000040	0.00004
Total Phenol[2]	0.200	0.0052	0.010	0.015	0.036	0.041

All concentrations in mg/l (ppm).
See Table F-16 for Outflow rates for the initial proposal of the ECI site.
The outflow rates for the south and north lobes of the current proposal are 14.75 gallons per minute (gpm) and 7.38 gpm from surface drainage and 3.33 gpm and 1.67 gpm from porewater for a total of 18.08 gpm and 9.05 gpm respectively. Note the effluent concentrations are equal for the two lobes since the north lobe outflow is half of the south lobe outflow.

Notes:
1 Porewater data not available for parameter. Indiana Harbor and Canal water quality concentration used (source IDEM 1986).
2 Precipitation data not available for parameter. Lake Michigan water concentration used (source IDEM 1986).

11. VOLATILIZATION ANALYSIS

11.1 OPERATIONS (FILLING PARAMETERS)

11.1.2 The operational parameters for the current proposal are somewhat different than for the initial ECI site plan. A brief summary is provided describing these filling parameters. Currently there is a backlog of 1,000,000 cubic yards to be dredged from Indiana Harbor. Of this quantity approximately 70,000 cubic yards has been determined to be toxic under the Toxic Substance Control Act (TSCA). Once dredging operations begin the backlog volume is expected to be removed and placed into the CDF in the first 3 or 4 years of operation. Additional maintenance dredging totals about 3,000,000 cubic yards. It is estimated that maintenance dredging would occur every 2 years until the CDF was filled. The simulated filling parameters are given in table F-27.

Table F-27: Operating Parameters Simulated for Proposed CDF

1. Operations will consist of dredging anywhere from 100,000 to 170,00 cubic yards.

2. An operation will last 16 weeks.

3. A cell is capped two years after it has been filled.

4. The TSCA material is placed into the CDF during the fourth operation. At this time approximately 500,000 cubic yards will already have been placed.

   -TSCA material = 70,000 cubic yards
   -An additional 100,000 cubic yards of non-TSCA material will be placed to encapsulate TSCA material

5. During the year in which an operation is completed, exposed sediments are assumed to be subject to volatilization for 6 months. The TSCA material is assumed to be exposed for 2 months.

11.2 APPLICATION AND RESULTS OF VOLATILIZATION MODEL

11.2.1 Figure F-16 compares the simulated PCB volatilization results for the south lobes of the current proposal to the initial ECI site proposal. The total mass flux of PCBs from the south lobes of the current proposal and from the initial proposal are 32 Kg (31.8 Kg exposed and 0.02 Kg submerged) and 28 Kg (27.5 Kg exposed and 0.03 submerged), respectively. The total mass flux of PCBs from the north lobe would be about 16 Kg.

11.2.2 Both proposals have a similar flux patternin figure F-16 although the current proposal has about 14% higher overall mass flux distributed over the lifetime of the CDF. The detailed results for both plans are provided in attachment F-2.

12. ENVIRONMENTAL CONTROLS

12.1 EFFLUENT CONTROLS

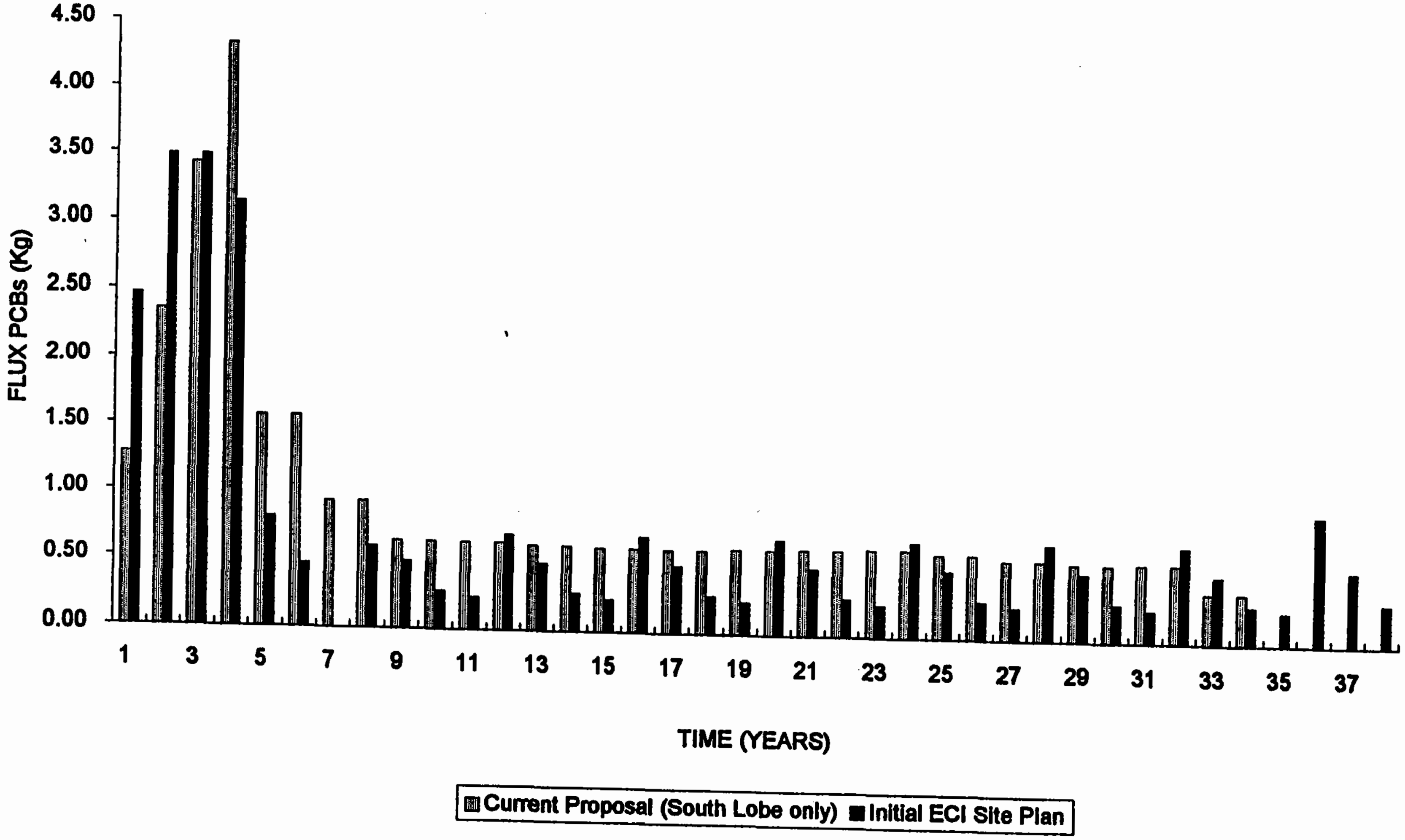
12.1.1 The effluent consisting of surface drainage and seepage collected from the CDF will be discharged to the East Chicago Wastewater Treatment Plant. Ammonia Nitrogen and possibly oil and grease would probably be the only contaminants of concern for the treatment plant operations. If required, a two stage filtration system would be employed at the CDF site for PCB removal. The system would be composed of a sand/anthracite filter followed by an activated carbon filter. For more details on pretreatment see appendix I.

12.2 LEACHATE CONTROLS

12.2.1 A barrier system around the perimeter of the site would consist of a slurry wall which would tie into an existing clay formation beneath the site. Also, a 3 foot layer of compacted clay would be placed along the dike face to seal off the CDF. The seepage collected from the active CDF and groundwater collected from the subsurface would be routed to the East Chicago Wastewater Treatment Plant.

12.2.2 If required, a facility would be installed on-site to provide initial treatment in order to meet the City of East Chicago's pretreatment standards. Analysis of the stream during the project design phase will determine if pretreatment is required to meet the plant's pretreatment standards.

Figure F-16. Yearly Volatile PCB Mass Flux
South Lobes of Current Proposal



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12.3 CDF CLOSURE

12.3.1 The HELP model was used to evaluate two different cap designs. The input and output summaries for the proposed cap and cover design are provided in attachment F-4. The average annual percolation through the cap and cover for both the initial and current ECI site proposals are shown below:

Site	Surface Area at Dike Crest (acres)	Annual Percolation Design #1 (gal/yr)	Annual Percolation Design #2 (gal/yr)
Initial Proposal	77	2,222,000	1,434,200
Current Proposal			
South lobe	63	1,818,000	1,173,400
North lobe[1]	32	909,000	586,700
TOTAL	95	2,727,000	1,760,100

---

[1] North lobe is half the size of the south lobe.

12.3.2 The quantity of seepage migrating from the CDF site will be determined by the rate of penetration of the cap, cover and inward gradient system. The HELP model was used to simulate production of seepage from the CDF. The CDF has a multiple liner/pumpage monitoring system to minimize any seepage from occurring.

12.3.3 In summary, contaminant loss through both the effluent and volatile pathways would be slightly higher for the south lobes of the current proposal relative to the initial proposal during average operating conditions. Losses from the north lobe would increase the total losses for the current proposal by approximately 50%. During capped conditions, the two plans would have essentially the same amount of loss. The same control measure outlined in table F-23 for the upland CDF will be applicable for the current ECI site proposal.

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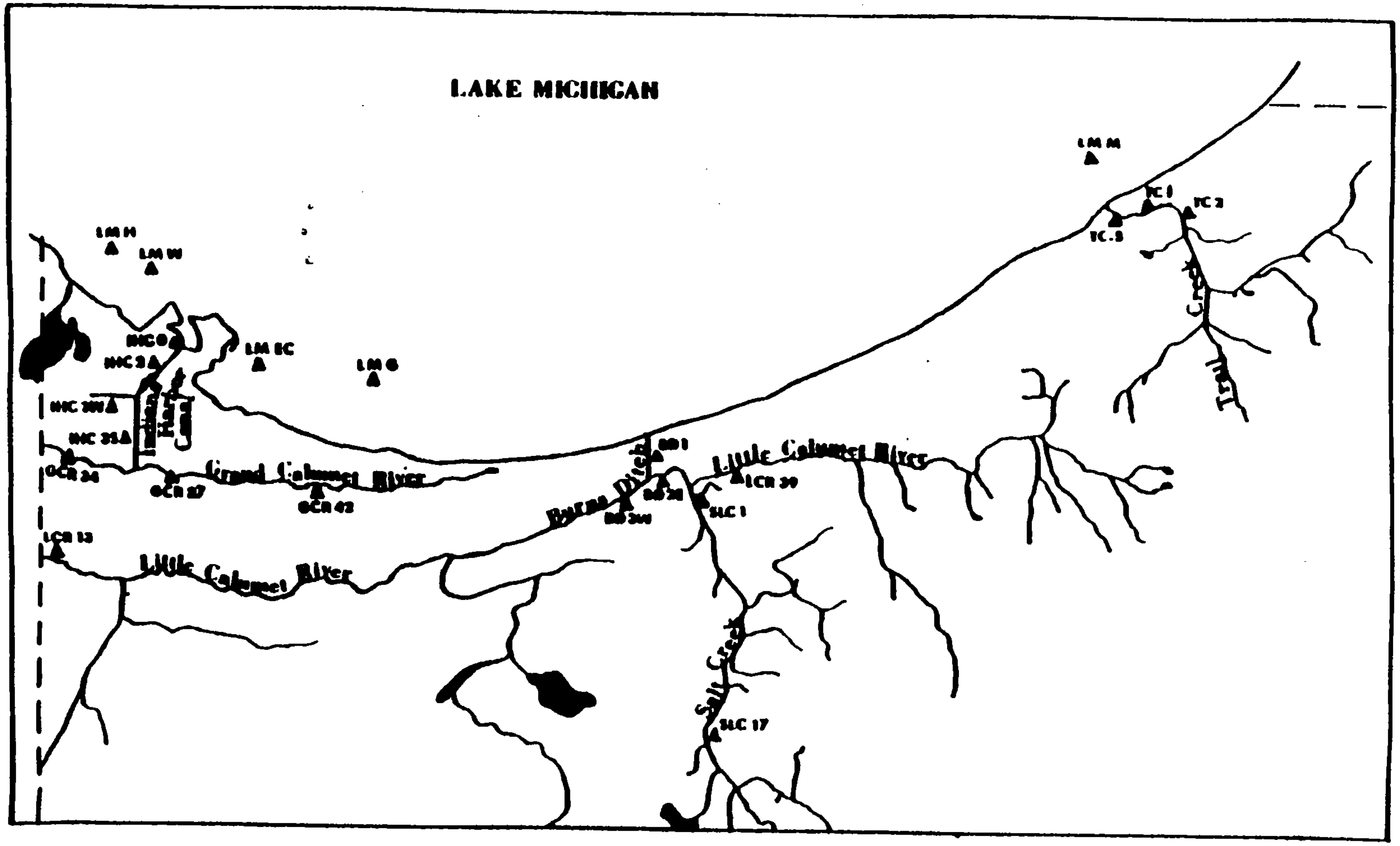
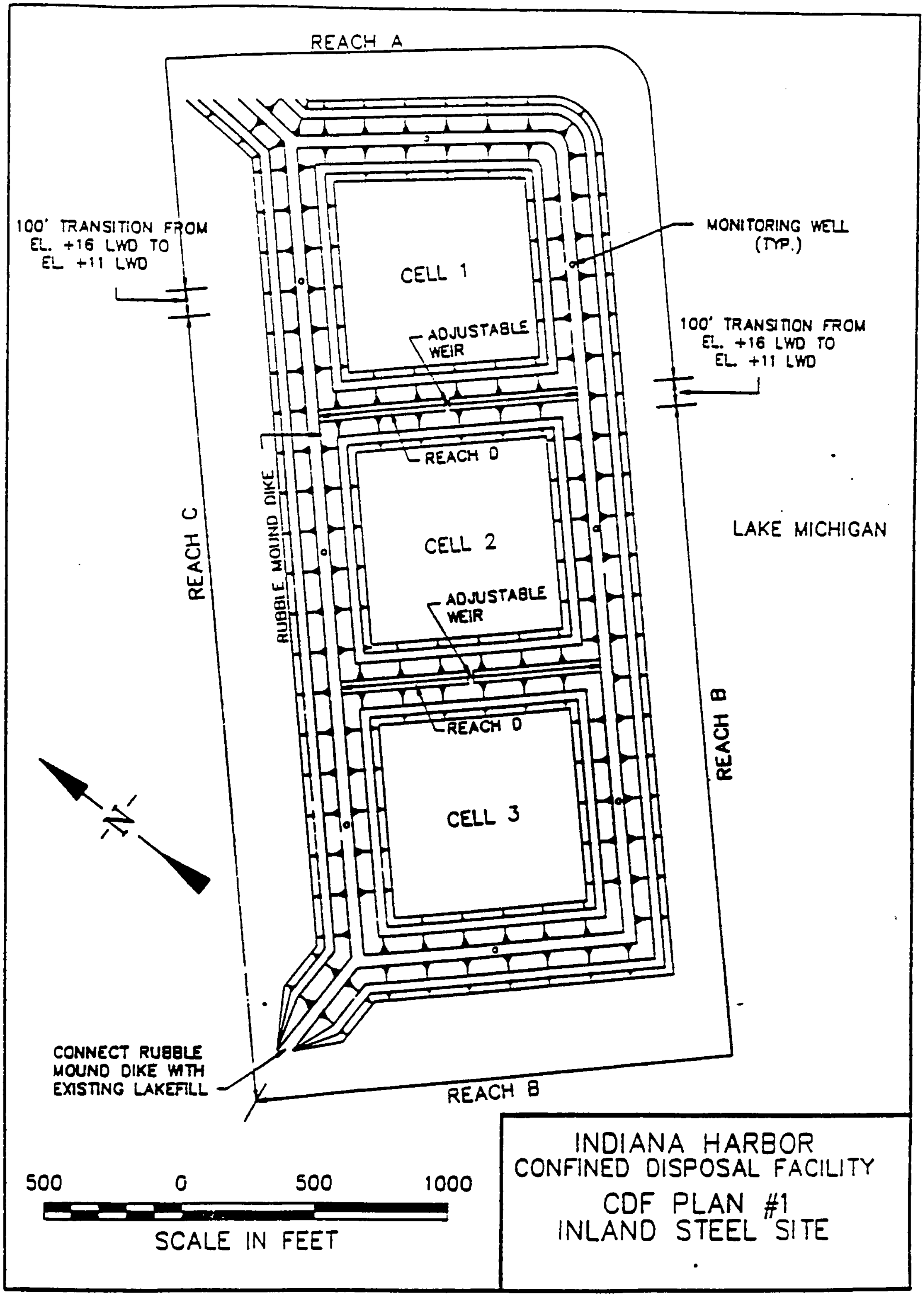
Plate F-1

IDEM LAKE MICHIGAN MONITORING STATIONS IN AND NEAR INDIANA HARBOR AND CANAL




REACH A
100' TRANSITION FROM
EL. +16 LWD TO
EL. +11 LWD
MONITORING WELL
(TYP.)
CELL 1
ADJUSTABLE
WEIR
100' TRANSITION FROM
EL. +16 LWD TO
EL. +11 LWD
REACH D
LAKE MICHIGAN
REACH C
RUBBLE MOUND DIKE
CELL 2
ADJUSTABLE
WEIR
REACH D
REACH B
N
CELL 3
CONNECT RUBBLE
MOUND DIKE WITH
EXISTING LAKEFILL
REACH B
500
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SCALE IN FEET
INDIANA HARBOR
CONFINED DISPOSAL FACILITY
CDF PLAN #1
INLAND STEEL SITE

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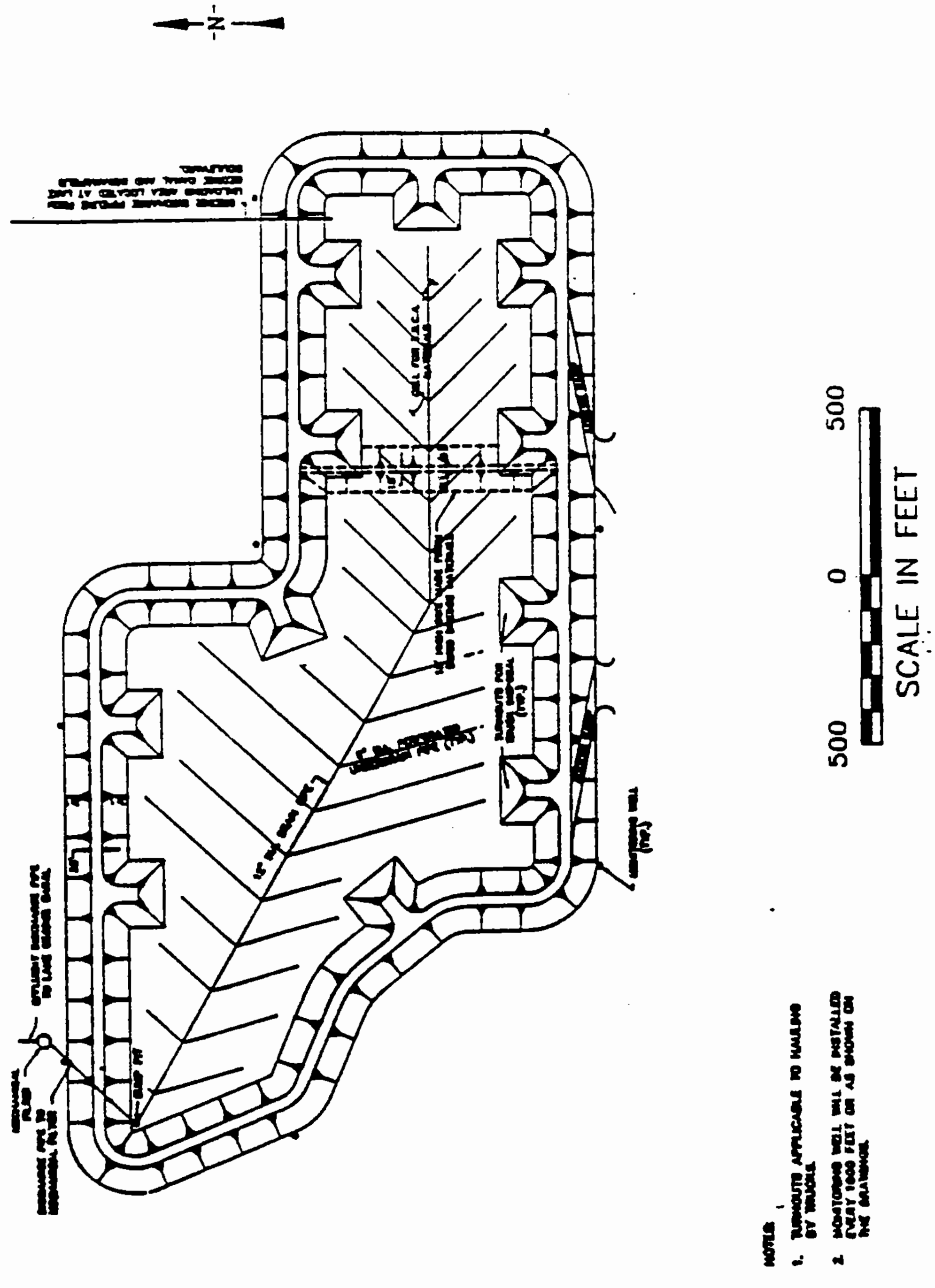

INDIANA HARBOR
CONFINED DISPOSAL FACILITY
CDF PLAN #2
141st STREET SITE

Plate F-4

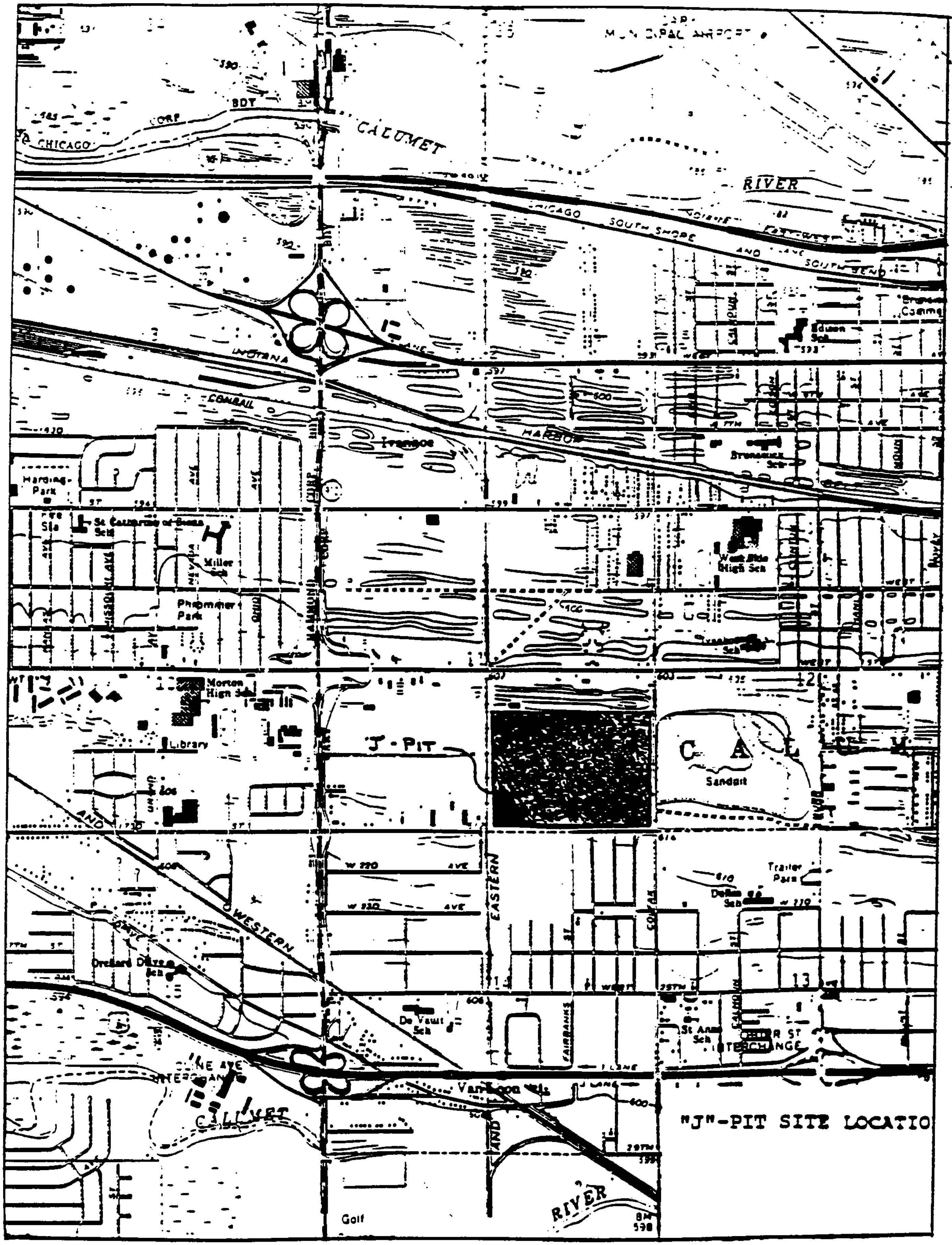

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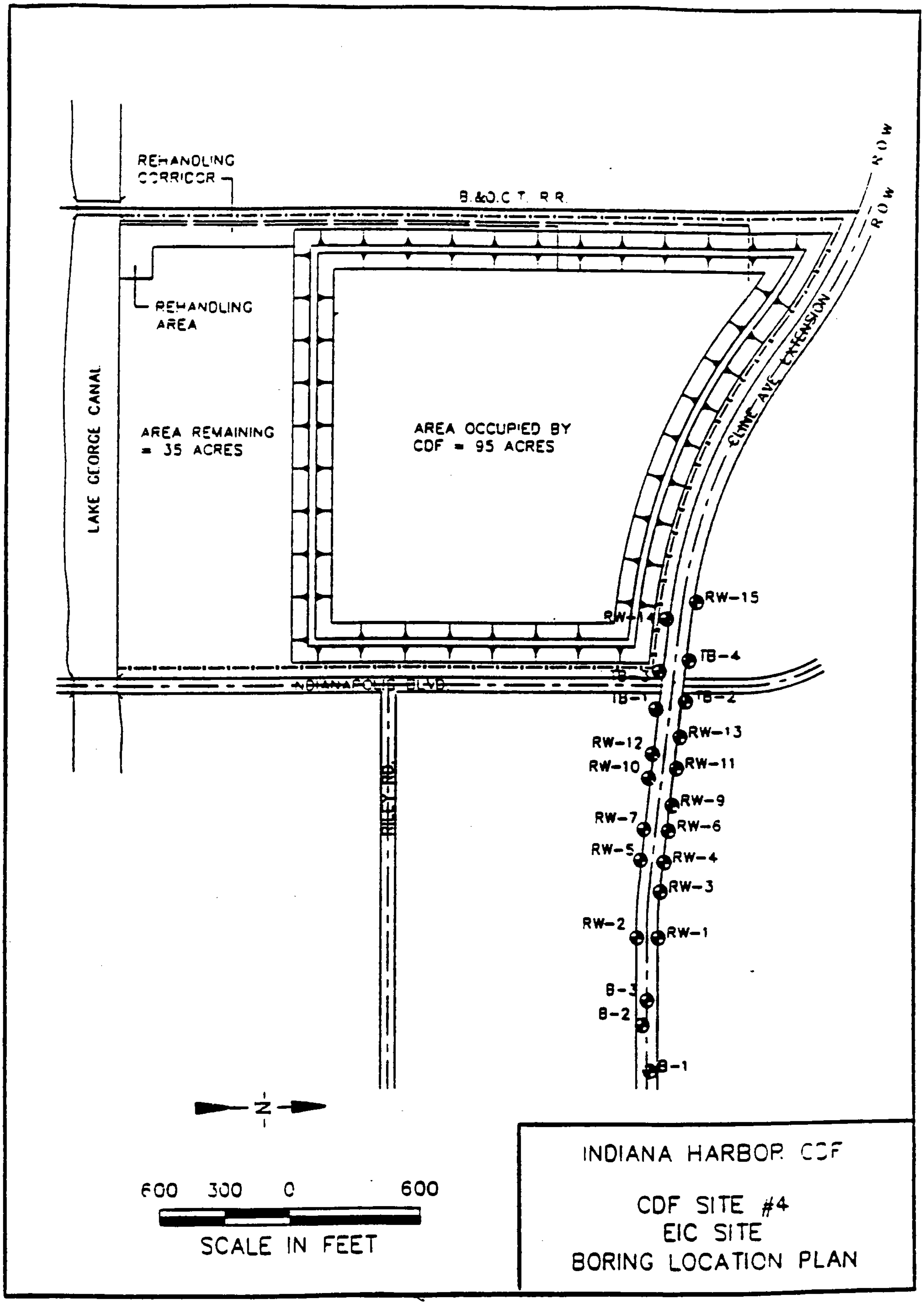
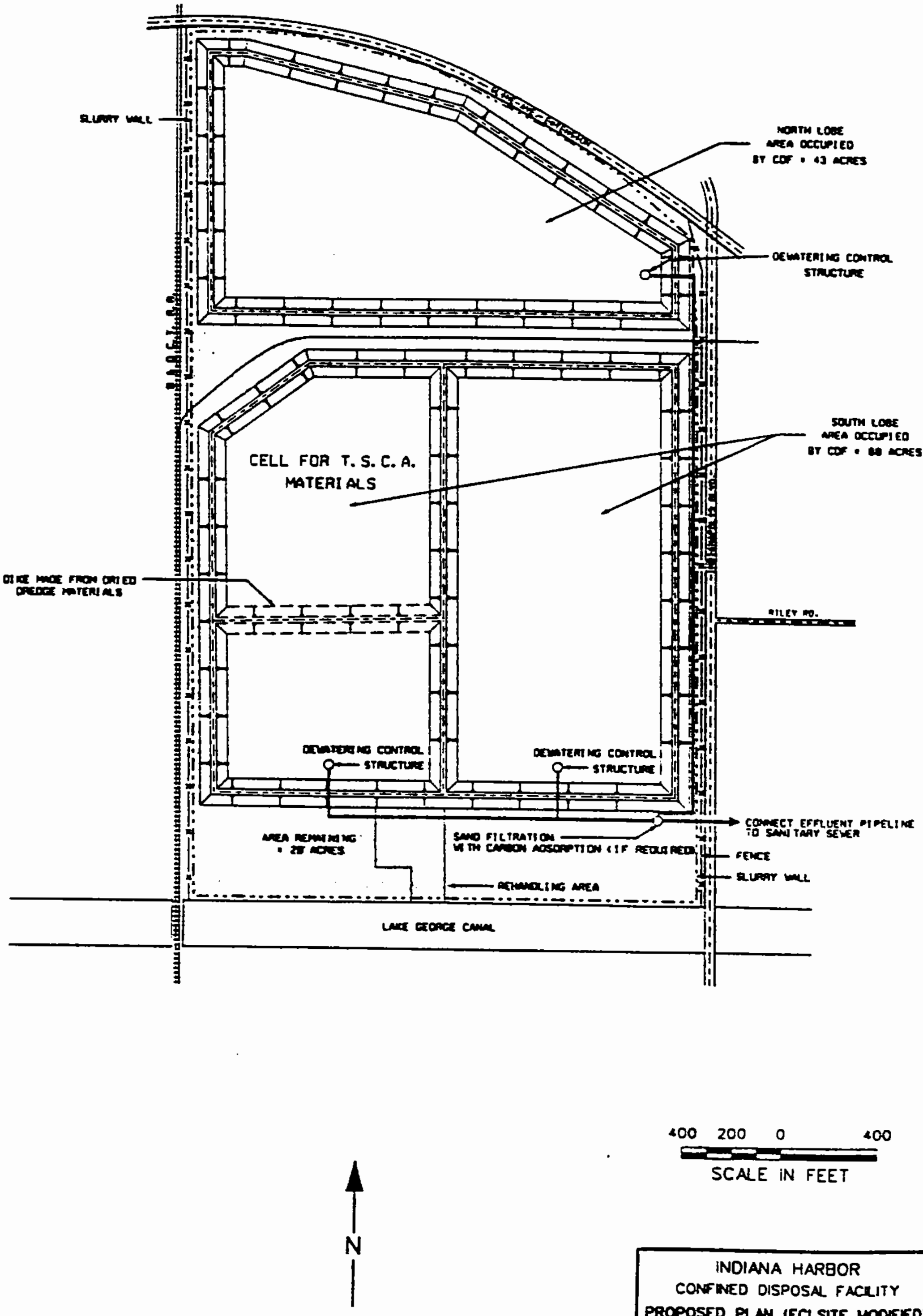
Plate F-5



INDIANA HARBOR CDF

CDF SITE #4
EIC SITE
BORING LOCATION PLAN

Plate F-6



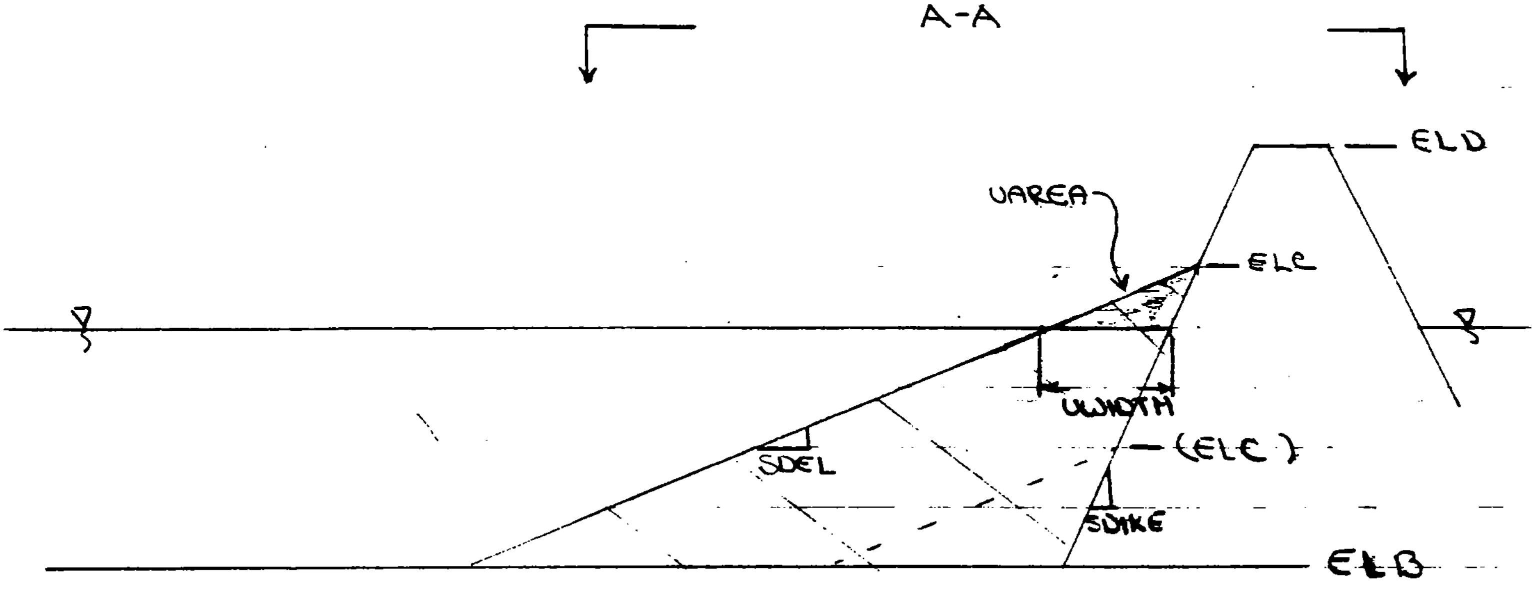
INDIANA HARBOR
CONFINED DISPOSAL FACILITY
PROPOSED PLAN (ECI SITE MODIFIED)
SITE PLAN
CHICAGO DISTRICT CORPS OF ENGINEERS
JUNE 1993

ATTACHMENT F-1

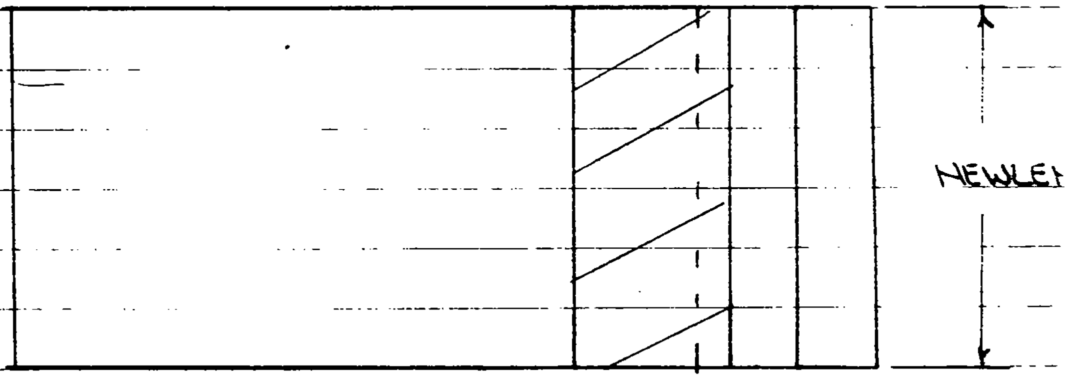
Delta Volume Model

- Delta Volume Algorithms
- Trapezoidal Prism Model
- Delta Height Reductions
- Layout of Filling Sequence
- Sensitivity Checks to Delta Volume Model
- Comparison of Simulation and Sensitivity Values for the Delta Formation Model
- In-lake CDF Operation Parameters - Results

DELTA VOLUME ALGORITHMS



SECTION "A-A"



▨ - UAREA

$$UWIDTH = (SDEL - SDIKE)(ELC - ELP(0))$$

SDEL = SLOPE OF SEDIMENT DELTA (H:V)
SDIKE = SLOPE OF CDF DIKE (H:V)
ELC = ELEVATION OF DREDGINGS AT CAPACITY
ELP(0) = POND WATER SURFACE ELEVATION @ TIME ZERO
UWIDTH = AVE WIDTH OF DELTA @ WATERLINE

$$UAREA = \frac{(ELC - ELP(0))}{\sin\left[\arctan \frac{1}{SDEL}\right]} \; \frac{(TLEN(0))}{43{,}560}$$

TLEN(0) = INITIAL LENGTH OF MOUNDED DELTA @ WATERLINE
UAREA = SURFACE AREA OF MOUNDED SEDIMENTS @ WATERLINE

$$NEWLEN = \frac{4\,TVOL}{(ELC - ELBAVE)^2 \left[(SDEL - SDIKE)_{i-1} + (SDEL - SDIKE)_{i} \right]}$$

TVOL = TOTAL VOLUME OF DREDGINGS DISPOSED
ELBAVE = AVE BASE ELEV OF MOUNDED SEDIMENTS @ TIME ZERO
i = CURRENT OPERATION
$i-1$ = PREVIOUS OPERATION
NEWLEN = LENGTH OF NEW DELTA

$$IUNSAT = \frac{(ELC - ELP(0))^2}{(ELC - ELB)^2}$$

$$PVOL(0) = \frac{\frac{(LCELL)^2}{43{,}560} + [LCELL - 2SDIKE(ELP(0) - ELB)]^2}{2} [ELP(0) - ELB]$$

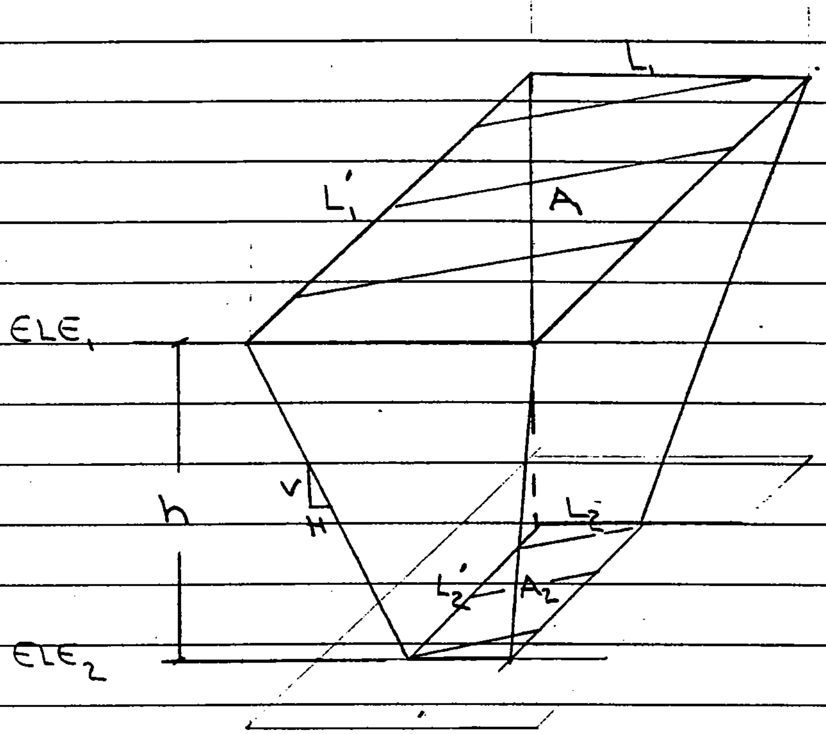
$$- [IVOL(1 - IUNSAT)]$$

PVOL(0) = POND VOLUME @ TIME ZERO
LCELL = LENGTH OF CELL @ ELP(0)
IVOL = VOLUME OF SEDIMENTS IN CDF @ TIME ZERO
IUNSAT = PERCENT OF SEDIMENTS IN CDF ABOVE WATERLINE

$$PAREA(0) = \left[(LCELL - 2(SDIKE)(ELP(0)_{i-1} - ELP(0)_i))^2 \right.$$

$$\left. - (TLEN(0))(UWIDTH) \right] \frac{1}{43{,}560}$$

TRAPEZOIDAL PRISM MODEL



$\text{VOLUME} \approx \frac{A_1 + A_2}{2}(h)$; $S = \frac{H}{V}$

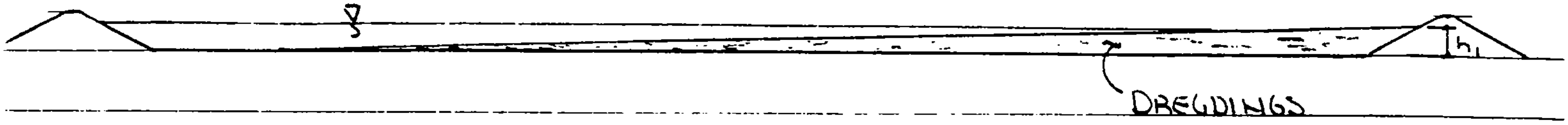
$L_2 = L_1 - 2Sh$

$L_2' = L_1' - 2Sh$ $A_2 = (L_2)(L_2')$

IF $L_1 = L_1'$

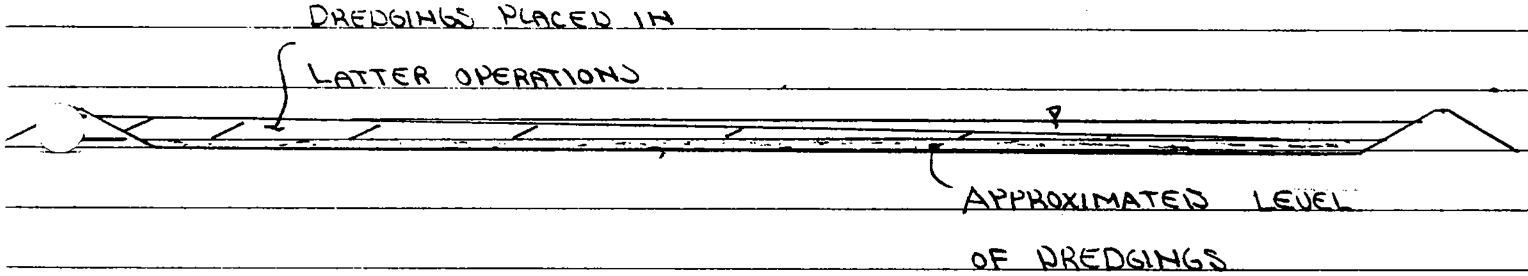
$L_2 = L_2' = L_1 - 2Sh$ $A_2 = (L_1)^2$

DELTA HEIGHT REDUCTIONS



INTIAL OPERATIONS

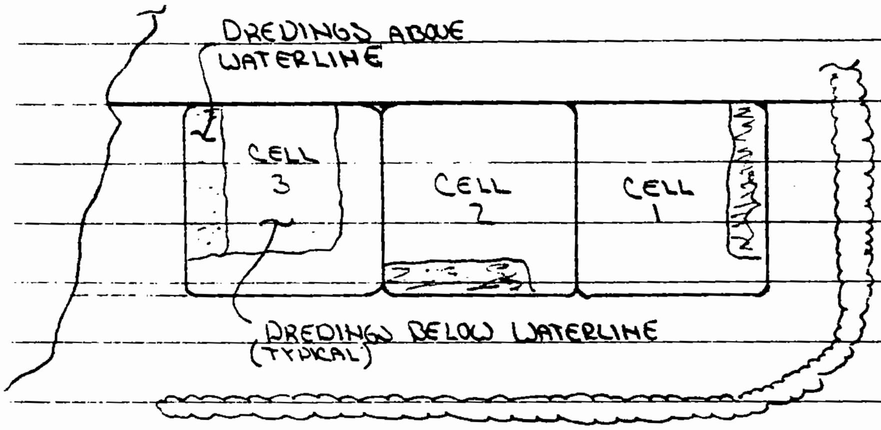
(Material To Line one side of a Cell)



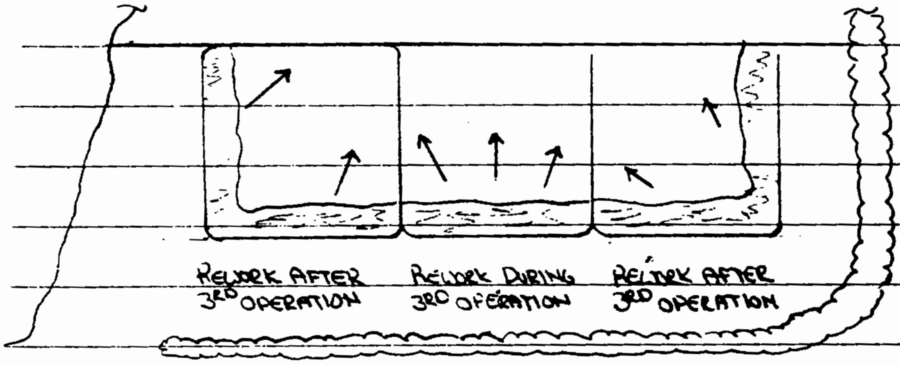
Note $h_1 > h_2$

FINAL OPERATIONS

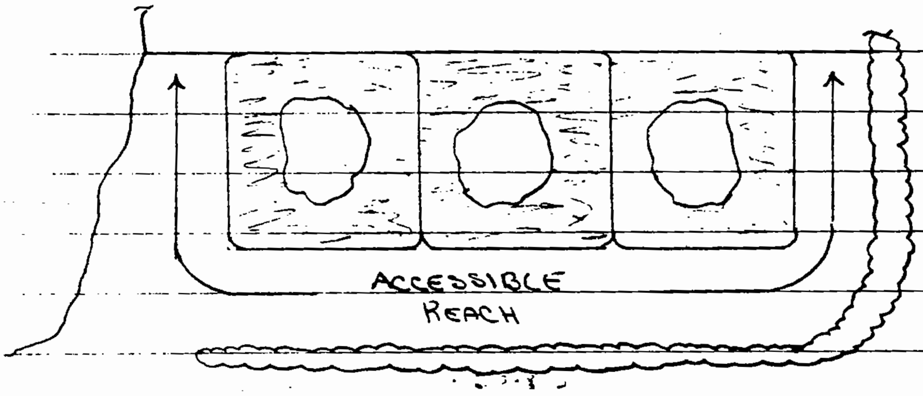
LAYOUT OF FILLING SEQUENCE - INLAKE CDF



FILLING FOR FIRST TWO OPERATIONS OF EACH CELL (500,000 YD³ EACH)



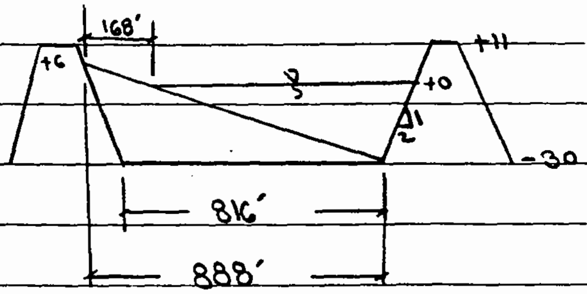
FILLING FOR THIRD OPERATION



FILLING FOR FOURTH OPERATION

** THE ABOVE SHOW FILLING FOR EACH CELL, HOWEVER THE SEQUENCE IS TO FILL CELL 1 COMPLETELY, THEN CELL 2, THEN CELL 3.

SENSITIVITY to DELTA VOLUME Model (IN-lake CDF)



Cell = 980ft @ dike Crest

Empty Length = 980' - 2(2)(41) = 816'

Length @ Water Line = 980 - 2(2)(11) = 936'

NOTE MEAN LENGTH (BETWEEN +6 AND -30) = 888'

Assume Typical Cross-section shown above will apply for one Side of Cell @ Waterline

$$\text{Volume} = \frac{1}{2}(888')(36')(888') \cdot 1/27 = \underline{\underline{525,696\ \text{yd}^3}}$$

For this volume the exposed sediments would be

$$\frac{(168')(936')}{43,560} = \underline{\underline{3.6\ \text{AC}}}$$

SINCE AN operation would dispose 250,000 yd^3, the Area of exposed Sediments should be slightly lower then 3.6 AC after two operations are completed.

SENSITIVITY to Water Quality Model - CONTINUED

2. It is assumed that after 3 operations the material is reworked with a resulting bowl shaped Configuration.

The diameter of the Ponded area would be approximately:

960 (Length when full of dredgings) - 2(168') = 624'

Area of pond $\sim \pi\left[\frac{624'}{2}\right]^2 \cdot \frac{1}{43{,}560} \sim 7.02$ Ac

The resulting Exposed Sediments would be $21.2 - 7.02 \sim 14.2$ Ac

3. To Account for overlaping of Dredge material a factor is used to adjust the bottom elevation. However, there will be little effect until one Side of a Cell is lined with material. As shown above this is after aproximately 526,000 Yd have been placed (or a little more then 2 operations worth of disposal)

The mean length of a Cell is 888 ft. At 500,000 Yd³ Placed, the length of dredging should be a little smaller then this Value. ($\frac{888}{526{,}000} \sim \frac{x}{500{,}000}$: $x \sim 844$ ft)

1 of 1

CDF OPERATIONAL PARAMETERS - RESULTS
(Conditions specific to given operations)

VARIABLE	DEFINITION	UNITS	OPERATION # 0	¦--ENTER OPERATIONS HERE --¦ 1	2	3	4
TVOL	TOTAL VOLUME OF DREDGINGS DISPOSED	CY	0	250,000	250,000	250,000	0
DUR	DURATION OF OPERATION	DAYS	0	80	80	80	0
SDEL	SLOPE OF SEDIMENT DELTA (H:V)		0	30	30	30	30
ELB	ELEV OF CDF FLOOR AT DISPOSAL SITE	FT LWD	-30.0	-30.0	-30.0	-30.0	-30.0
ELC	CREST ELEV OF NEW DREDGINGS (ELF)	FT LWD	6.0	6.0	6.0	6.0	6.0
NEWLEN	LENGTH OF NEW DELTA	FT	0	372	459	2,532	0
UWIDTH	AVE WIDTH OF DELTA @ WATERLINE	FT	0	168	168	168	168
UAREA	SURFACE AREA OF MOUNDED SEDIMENTS @ WATERLINE	ACRES	0.00	0.00	1.54	3.44	13.30
IVOL	VOLUME OF SEDIMENTS IN CDF @ TIME ZERO	CY	0	0	250,000	500,000	750,000
TLEN(0)	INITIAL LENGTH OF MOUNDED DELTA @ WATERLINE	LIN-FT	0	0	372	831	3363
IUNSAT	PERCENT OF SEDIMENTS IN CDF ABOVE WATERLINE		0.0%	2.8%	2.8%	2.8%	2.8%
ELCAVE	AVE CREST ELEV OF MOUNDED SEDIMENTS @ TIME 0	FT-LWD	0.0	6.0	6.0	6.0	6.0
ELBAVE	AVE BASE ELEV OF MOUNDED SEDIMENTS @ TIME 0	FT-LWD	-30	-30.0	-26.4	-7.8	-6.0
SAVE	WEIGHTED AVE OF DELTA SLOPES	FT/FT	0	0	30	30	30
ELP(0)	POND WATER SURFACE ELEVATION @ TIME ZERO	FT-LWD	0	0	0.0	0	0
PVOL(0)	POND VOLUME @ TIME ZERO	CY	856,640	856,640	613,584	370,529	127,473
PAREA(0)	WETTED POND SURFACE AREA @ TIME ZERO	ACRES	20.11	20.11	18.68	16.91	7.14
COPP	OPERATION SEQUENCE		0	1	2	3	4
FACT	FACTOR FOR ADJUSTMENT OF ELBAVE			0.1	0.12	0.74	0.8
LCELL	LENGTH OF CELL @ ELP(0)	FT	936	936	936	936	936
UAMAX	SURFACE AREA OF MOUNDED SEDIMENTS @ CAPACITY	ACRES	21.2				

617-7

Comparison of Simulation and Calibration Values for the Delta Formation Model

Description	Simulated value	* Values derived from design/ operating conditions used for calibration
Exposed surface area after two operations are completed	3.4 acres	3.6 acres
Ponded area after 3 operations are completed	7.1 acres	7.0 acres
Surface area of exposed sediments after three operations are completed	13.9 acres	14.2 acres
Length of dredgings after two operations	831 feet	844 feet

ATTACHMENT F-2

Volatilization Parameters and Results

- Indiana Harbor PCB Volatilization Model Definitions
- Sensitivity Analysis for Flux Equations
- Volatile Mass Loss of PCBs From Exposed Sediment
    - Inland Steel Site
    - J-Pit Site
    - 141st Site
    - ECI Site
    - Proposed Plan (ECI Site Modified)
- Summary of PCB Mass Loss for Each Site

```
                                        INDIANA HARBOR PCB VOLATILIZATION MODEL
                                        ******************************************************************************
                                        N(A)=Flux of A through air-water interface,mg A/ac mo
                                        N(A,t)=instant. flux of A through dredged material-air interface
                                               at time t, mg A/ac mo
                                        N(A,t)avg=average flux over agiven time t
                                        1K('A2)=over-all liquid phase mass transfer coefficient, cm/hr
                                        W(A)=concentration of A in the orginal bed sediment, mg/kg
                                        P(32)=concentration of suspended solids, kg/L
                                        K(d)=sediment-water distribution coefficient for A, L/kg
                                        D(A1)=moleclar diffusivity of A in air cm(2)/sec
                                        D(A2)=molecular diffusivity of A in water cm(2)/sec
                                        D(A3)=effective diffusivity, cm(2)/sec
                                        P(B)=bulk density of dredged material, kg/L
                                        V(X)=wind speed, miles per hour (mph)
                                        U(i)=vicosity of water at temperature T
                                        E=total porosity, dimensionless
                                        E(1)=air filled porosity, dimensionless
                                        P(A)=vapor pressure of A as pure solute, mm Hg
                                        P(A2*)=solubility of A in pure water, mg/L
                                        H=henry's law constant,dimensionless
                                         PCB(D)=Dissolved PCB concentration (ug/L)

PARAMETERS:
                         units                                                                        Source
********************************************************************************************************************************************************************************
1. K(d)=          256000 L/kg                                                                         Waterways Experiment Station
2. W(A)=              38 mg/kg (TSCA material)                                                        Volume-weighted average done by Chicago District COE
3. W(A)=               6 mg/kg (Non-TSCA material)                                                    "                               "
4. W(A)=               9 mg/kg (Volume-weighted mean for all material)                                "                               "
5. W(A)=               2 mg/kg (Maintanence material)
6. P(32)=      1.00E-04 Kg/L (SS in immediate vicinity of disposal-100ft radius Zone1)                Experence with other CDFs
7. P(32)=      1.00E-05 Kg/L (SS in zone away from influace of dredge material Zone2)                 "               "
8. D(A2)=      4.20E-06 cm(2)/sec (for phenol @20 deg C-reference diffusivity)                        Thibdoeaux 1979
9. W(1)=          2.112 lb*sec/ft(2) (reference vicosity for phenol @ 20 deg C)                       "           "
10. T(1)=           293 deg K (reference temp for phenol)                                             "           "
11. D(A1)=     4.90E-02 cm(2)/sec (for biphenyl @25 deg C-reference diffusivity)                      "           "
12. E(1)=          0.30                                                                               Myers 1988
13. E=             0.70                                                                               "      "
14. T(1')=          298 deg K (reference temp for biphenyl)
15. P(A)=      4.94E-04 mm Hg                                                                         Jaffe, ferrara 1983
16. P(A2*)=       0.054 mg/L                                                                          "           "
17. M(A)=        300.00 Molecular Weight of PCB                                                       Myers 1988
18. P(B)=          1.20 Kg/L                                                                          Myers 1988
```

SENSITIVITY ANALYSIS FOR FLUX EQUATIONS

****

Month	D(A1) cm(2)/sec	D(A2) cm(2)/sec	D(A3) cm(2)/sec	Temp deg. F (Water)	Temp deg. K (Water)	Temp deg. F (Air)	Temp deg. K (Air)	U(i) lb sec/ft	V(X) mph	1k('A2) cm/hr	H
Jan	4.14E-02	2.34E-06	1.53E-03	35.0	274.67	20.30	266.50	3.552	11.5	0.801	0.165
Feb	4.21E-02	2.34E-06	1.55E-03	35.0	274.67	25.60	269.44	3.552	11.7	0.833	0.163
Mar	4.35E-02	2.43E-06	1.61E-03	40.5	277.72	36.40	275.44	3.462	11.9	0.886	0.160
Apr	4.52E-02	3.04E-06	1.67E-03	46.5	281.06	48.70	282.28	2.799	11.8	1.010	0.156
May	4.66E-02	3.51E-06	1.72E-03	55.5	285.36	59.00	288.00	2.397	10.5	0.873	0.153
June	4.78E-02	4.13E-06	1.76E-03	55.0	291.33	68.30	293.17	2.103	9.3	0.736	0.150
July	4.85E-02	4.49E-06	1.79E-03	67.5	292.72	73.10	295.83	1.972	8.3	0.598	0.149
Aug	4.83E-02	4.47E-06	1.78E-03	74.0	296.33	71.80	295.11	2.005	8.1	0.565	0.143
Sep	4.73E-02	4.00E-06	1.74E-03	69.0	293.56	64.50	291.06	2.220	9.0	0.663	0.151
Oct	4.57E-02	3.31E-06	1.69E-03	58.0	287.44	52.90	284.61	2.628	9.8	0.707	0.155
Nov	4.40E-02	2.64E-06	1.62E-03	49.0	282.44	39.80	277.33	3.242	11.4	0.851	0.153
Dec	4.23E-02	2.65E-06	1.56E-03	41.0	278.00	27.00	270.22	3.180	11.2	0.820	0.163
		MEAN	1.67E-03						MEAN	0.779	0.156

RANGE 9

PLAN 1 (INLAND STEEL SITE)
VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A1	1.54	6	1		0.06
A2	1.90	6			0.07
A1	1.54	18			0.11
			2		0.18
A3	10.46	6			0.40
A2	1.90	18			0.13
A1	1.54	30			0.13
			3		0.67
A5	7.20	6			0.28
A4	0.00	2		*	0.00
A3	10.46	18			0.73
A2	1.90	30			0.17
A1	1.54	42			0.16
			4		1.33
A5	7.20	18			0.50
A4	0.00	2		*	0.00
A3	10.46	30			0.92
A2	1.90	42			0.20
A1	1.54	54			0.18
			5		1.79
A5	7.20	30			0.63
A4	0.00	2		*	0.00
A3	10.46	42			1.08
A2	1.90	54			0.22
A1	1.54	66			0.20
FIRST CELL CAPPED			6		2.12
YEAR 7 NO VOLATILIZATION					
A6	1.54	6			0.02
BEGIN FILLING CELL #2			8		0.02
A6	1.54	18			0.04
			9		0.04

RANGE 9

PLAN 1 (INLAND STEEL SITE)
VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A6	1.54	30			0.04
			10		0.04
A6	1.54	42			0.05
			11		0.05
A7	1.90	6			0.02
A6	1.54	54			0.06
			12		0.08
A7	1.90	18			0.04
A6	1.54	66			0.07
			13		0.11
A7	1.90	30			0.06
A6	1.54	78			0.07
			14		0.13
A7	1.90	42			0.07
A6	1.54	90			0.08
			15		0.14
A8	10.46	6			0.13
A7	1.90	54			0.07
A6	1.54	102			0.08
			16		0.29
A8	10.46	18			0.24
A7	1.90	66			0.08
A6	1.54	114			0.09
			17		0.41
A8	10.46	30			0.31
A7	1.90	78			0.09
A6	1.54	126			0.09
			18		0.48
A8	10.46	42			0.36
A7	1.90	90			0.09

```
RANGE 9                    PLAN 1 (INLAND STEEL SITE)
          VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT
*****************************************************************
AREA #   AREA               TIME    OPPERATN TSCA     MASS PCBs
         (Ac)              (MONTHS) (YEARS)  (*)      (Kg)

A6           1.54              138                         0.09

                                         19                0.55
-----------------------------------------------------------------
A9           7.20                6                         0.09
A8          10.46               54                         0.41
A7           1.90              102                         0.10
A6           1.54              150                         0.10

                                         20                0.70
-----------------------------------------------------------------
A9           7.20               18                         0.17
A8          10.46               66                         0.45
A7           1.90              114                         0.11
A6           1.54              162                         0.10

                                         21                0.82
-----------------------------------------------------------------
A9           7.20               30                         0.21
A8          10.46               78                         0.49
A7           1.90              126                         0.11
A6           1.54              174                         0.11

SECOND CELL CAPPED                       22                0.91
-----------------------------------------------------------------
YEAR 23 NO VOLATILIZATION

-----------------------------------------------------------------
A10          1.54                6                         0.02

BEGIN FILLING CELL #3                    24                0.02
-----------------------------------------------------------------
A10          1.54               18                         0.04

                                         25                0.04
-----------------------------------------------------------------
A10          1.54               30                         0.04

                                         26                0.04


-----------------------------------------------------------------
A10          1.54               42                         0.05

                                         27                0.05
-----------------------------------------------------------------
A11          1.90                6                         0.02
A10          1.54               54                         0.06

                                         28                0.08
```

645.66

```
RANGE 9                    PLAN 1 (INLAND STEEL SITE)
          VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT
*******************************************************************
AREA #   AREA                TIME     OPPERATN TSCA      MASS PCBs
         (Ac)               (MONTHS) (YEARS)   (*)       (Kg)

-------------------------------------------------------------------
A11            1.90              18                         0.04
A10            1.54              66                         0.07

                                             29             0.11
-------------------------------------------------------------------
A11            1.90              30                         0.06
A10            1.54              76                         0.07

                                             30             0.13
-------------------------------------------------------------------
A11            1.90              42                         0.07
A10            1.54              90                         0.08

                                             31             0.14
-------------------------------------------------------------------
A12           10.46               6                         0.13
A11            1.90              54                         0.07
A10            1.54             102                         0.08

                                             32             0.29
-------------------------------------------------------------------
A12           10.46              18                         0.24
A11            1.90              66                         0.08
A10            1.54             114                         0.09

                                             33             0.41
-------------------------------------------------------------------
A12           10.46              30                         0.31
A11            1.90              78                         0.09
A10            1.54             126                         0.09

                                             34             0.48
-------------------------------------------------------------------


A12           10.46              42                         0.36
A11            1.90              90                         0.09
A10            1.54             138                         0.09

                                             35             0.55
-------------------------------------------------------------------
A13            7.20               6                         0.09
A12           10.46              54                         0.41
A11            1.90             102                         0.10
A10            1.54             150                         0.10

                                             36             0.70
-------------------------------------------------------------------
A13            7.20              18                         0.17
```

RANGE 9 PLAN 1 (INLAND STEEL SITE)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A12	10.46	66			0.45
A11	1.90	114			0.11
A10	1.54	162			0.10
			37		0.82
A13	7.20	30			0.21
A12	10.46	78			0.49
A11	1.90	126			0.11
A10	1.54	174			0.11
THIRD CELL CAPPED			38		0.91

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```
RANGE 5
***NOTE IF FILLING OPPERATIONS CHANGE THIS RANGE HAS TO BE ADJUSTED

                                   VOLATILE MASS LOSS OF PCBs FROM SUBMERGED SEDIMENT
*******************************************************************************************************************************
*******************************************************************************************************************************
                                                  INLAKE CDF
*******************************************************************************************************************************************
                                                  ACTIVE                 ACTIVE                NON-ACTIVE            ACTIVE        NON-ACTIVE
       WQMODEL                                    FILLING ZONE (0.72 Ac) NON-FILLING ZONE      ZONE                  FILLING ZONE ZONE
        DATA                      YR    OPPERATION [P(32)]1=100Mg/l]   **[P(32)2=]           ***[CONCENTRATION=]
-----------------------------  :                  AREA     MASS PCB      AREA     MASS PCB     AREA     MASS PCB     TIME EXPOSED TIME EXPOSED
                  PAREA        :        (Ai)      (AC)     (Kg)          (AC)     (Kg)         (AC)     (Kg)         (MO)         (MO)
OPPERATION PAREA(0) AVERAGE    :  -----------------------------------------------------------------------------------------------------
(Ai)       (AC)    (AC)        :   1    1             0.72    0.002        18.68    0.042       18.68    0.018            6            6
1,6,10        20.11   19.395   :   2    2             0.72    0.002        17.08    0.047       16.91    0.018            6            6
2,7,11        18.68   17.795   :   3    3             0.72    0.002        11.31    0.031        7.14    0.011            6            6
3,8,12        16.91   12.025   :   4    4,5  *        0.72    0.014         2.85    0.053        0.00    0.000            6            0
4,5,9,13       7.14    3.57    :                              ---------              ---------            ---------
               0.00                       CELL 1 FILLED       0.020                  0.173                0.047

                                                                                                SUBTOTAL=    0.24

*TSCA OPPERATION                   8  6                0.72    0.001        18.68    0.014       18.68    0.107            6           42
**ACTIVE                          12  7                0.72    0.001        17.08    0.013       16.91    0.113            6           42
  NON-FILLING ZONE                16  8                0.72    0.001        11.31    0.009        7.14    0.054            6           42
      10 Mg/l OPERATION 1,6,10    20  9                0.72    0.001         2.85    0.002        0.00    0.000            6            0
      15 Mg/l OPERATION 2,7,11                                 ---------              ---------            ---------
      25 Mg/l OPERATION 3,8,12                CELL 2 FILLED    0.003                  0.038                0.274
      50 Mg/l OPERATION 4,5,9,13
                                                                                                SUBTOTAL=    0.31

***NON-ACTIVE                     24 10                0.72    0.001        18.68    0.014       18.68    0.107            6           42
   ZONE                           28 11                0.72    0.001        17.08    0.013       16.91    0.113            6           42
       6 ng/l OPERATION   6,10    32 12                0.72    0.001        11.31    0.009        7.14    0.054            6           42
       7 ng/l OPERATION 1,7,11    36 13                0.72    0.001         2.85    0.002        0.00    0.000            6            0
       8 ng/l OPERATION 2,8,12                                 ---------              ---------            ---------
      11 ng/l OPERATION 3                     CELL 3 FILLED    0.003                  0.038                0.274

                                                                                                SUBTOTAL=    0.31


                                                                   TOTAL MASS OF PCBs FROM
                                                                   S  RGED SEDIMENTS (Kg) =                  0.9
                                                                                                          ---------
```

RANGE 11 PLAN 3 (J-PIT SITE)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A1	55.5	6	1		2.14
A2	55.5	6			2.14
A1	55.5	12			3.03
			2		5.17
A3	55.5	6			2.14
A2	55.5	12			3.03
A1	55.5	12			3.03
			3		8.19
A5	23.0	6			0.89
A4	6.6	2		*	0.93
A3	55.5	12			3.03
A2	55.5	12			3.03
A1	55.5	12			3.03
			4		10.90
A5	23.0	18			1.61
A4	6.6	2		*	0.93
A3	55.5	12			3.03
A2	55.5	12			3.03
A1	55.5	12			3.03
			5		11.61
A5	23.0	30			2.01
A4	6.6	2		*	0.93
A3	55.5	12			3.03
A2	55.5	12			3.03
A1	55.5	12			3.03
FIRST CELL CAPPED			6		12.02
YEAR 7 NO VOLATILIZATION					
A6	41.5	6			0.53
BEGIN FILLING CELL #2			8		0.53
A6	41.5	18			0.97
			9		0.97

689.91

RANGE 11 PLAN 3 (J-PIT SITE)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

****

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A6	41.5	30			1.21
			10		1.21
A6	41.5	42			1.42
			11		1.42
A7	41.5	6			0.53
A6	41.5	48			1.51
			12		2.04
A7	41.5	18			0.97
A6	41.5	48			1.51
			13		2.47
A7	41.5	30			1.21
A6	41.5	48			1.51
			14		2.72
A7	41.5	42			1.42
A6	41.5	48			1.51
			15		2.93
A8	41.5	6			0.53
A7	41.5	48			1.51
A6	41.5	48			1.51
			16		3.55
A8	41.5	18			0.97
A7	41.5	48			1.51
A6	41.5	48			1.51
			17		3.98
A8	41.5	30			1.21
A7	41.5	48			1.51
A6	41.5	48			1.51
			18		4.23
A8	41.5	42			1.42
A7	41.5	48			1.51
A6	41.5	48			1.51
			19		4.44
A9	41.5	6			0.53

RANGE 11 PLAN 3 (J-PIT SITE)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51
			20		5.06
A9	41.5	18			0.97
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51
			21		5.49
A9	41.5	30			1.21
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51
			22		5.74
A9	41.5	42			1.42
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51
			23		5.95
A10	41.5	6			0.53
A9	41.5	48			1.51
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51
			24		6.57
A10	41.5	18			0.97
A9	41.5	48			1.51
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51
			25		7.00
A10	41.5	30			1.21
A9	41.5	48			1.51
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51

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```
RANGE 11            PLAN 3 (J-PIT SITE)
        VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT
***************************************************************
AREA #   AREA                TIME     OPERATN  TSCA     MASS PCBs
          (Ac)               (MONTHS) (YEARS)  (*)      (Kg)

                                         26                7.24
-----------------------------------------------------------------
A10            41.5               42                       1.42
A9             41.5               48                       1.51
A8             41.5               48                       1.51
A7             41.5               48                       1.51
A6             41.5               48                       1.51

                                         27                7.46
-----------------------------------------------------------------
A11            41.5                6                       0.53
A10            41.5               48                       1.51
A9             41.5               48                       1.51
A8             41.5               48                       1.51
A7             41.5               48                       1.51
A6             41.5               48                       1.51

                                         28                8.08
-----------------------------------------------------------------
A11            41.5               18                       0.97
A10            41.5               48                       1.51
A9             41.5               48                       1.51
A8             41.5               48                       1.51
A7             41.5               48                       1.51
A6             41.5               48                       1.51

                                         29                8.51
-----------------------------------------------------------------
A11            41.5               30                       1.21
A10            41.5               48                       1.51
A9             41.5               48                       1.51
A8             41.5               48                       1.51
A7             41.5               48                       1.51
A6             41.5               48                       1.51

                                         30                8.75
-----------------------------------------------------------------
A11            41.5               42                       1.42
A10            41.5               48                       1.51
A9             41.5               48                       1.51
A8             41.5               48                       1.51
A7             41.5               48                       1.51
A6             41.5               48                       1.51

                                         31                8.96
-----------------------------------------------------------------
A12            46.0                6                       0.59
A11            41.5               48                       1.51
A10            41.5               48                       1.51
A9             41.5               48                       1.51
```

```
RANGE 11            PLAN 3 (J-PIT SITE)
         VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT
*******************************************************************
AREA #   AREA                TIME     OPERATN  TSCA     MASS PCBs
         (Ac)               (MONTHS)  (YEARS)  (*)      (Kg)

A8            41.5               48                         1.51
A7            41.5               48                         1.51
A6            41.5               48                         1.51

                                         32                 9.64
-----------------------------------------------------------------------
A12           46.0               18                         1.07
A11           41.5               48                         1.51
A10           41.5               48                         1.51
A9            41.5               48                         1.51
A8            41.5               48                         1.51
A7            41.5               48                         1.51
A6            41.5               48                         1.51

                                         33                10.12
-----------------------------------------------------------------------
A12           46.0               30                         1.34
A11           41.5               48                         1.51
A10           41.5               48                         1.51
A9            41.5               48                         1.51
A8            41.5               48                         1.51
A7            41.5               48                         1.51
A6            41.5               48                         1.51

                                         34                10.39
-----------------------------------------------------------------------
A12           46.0               42                         1.58
A11           41.5               48                         1.51
A10           41.5               48                         1.51
A9            41.5               48                         1.51
A8            41.5               48                         1.51
A7            41.5               48                         1.51
A6            41.5               48                         1.51

                                         35                10.63
-----------------------------------------------------------------------
A13           46.0                6                         0.59
A12           46.0               48                         1.67
A11           41.5               48                         1.51
A10           41.5               48                         1.51
A9            41.5               48                         1.51
A8            41.5               48                         1.51
A7            41.5               48                         1.51
A6            41.5               48                         1.51

                                         36                11.31
-----------------------------------------------------------------------
A13           46.0               18                         1.07
A12           46.0               48                         1.67
A11           41.5               48                         1.51
```

RANGE 11 PLAN 3 (J-PIT SITE)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A10	41.5	48			1.51
A9	41.5	48			1.51
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51
			37		11.79
A13	46.0	30			1.34
A12	46.0	48			1.67
A11	41.5	48			1.51
A10	41.5	48			1.51
A9	41.5	48			1.51
A8	41.5	48			1.51
A7	41.5	48			1.51
A6	41.5	48			1.51
SECOND CELL CAPPED			38		12.07

RANGE 10

PLAN 2 (141 ST SITE)
VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A1	40.4	6	1		1.56
A2	40.4	6			1.56
A1	40.4	12			2.20
			2		3.76
A3	40.4	6			1.56
A2	40.4	12			2.20
A1	40.4	12			2.20
			3		5.96
A5	26.6	6			1.03
A4	7.5	2		*	1.06
A3	40.4	12			2.20
A2	40.4	12			2.20
A1	40.4	12			2.20
			4		8.69
A5	26.6	18			1.86
A4	7.5	2		*	1.06
A3	40.4	12			2.20
A2	40.4	12			2.20
A1	40.4	12			2.20
			5		9.52
A5	26.6	30			2.33
A4	7.5	2		*	1.06
A3	40.4	12			2.20
A2	40.4	12			2.20
A1	40.4	12			2.20
FIRST CELL CAPPED			6		9.99
YEAR 7 NO VOLATILIZATION					
A6	23.4	6			0.30
BEGIN FILLING CELL #2			8		0.30
A6	23.4	18			0.54
			9		0.54

RANGE 10

PLAN 2 (141 ST SITE)
VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A6	23.4	30			0.68
			10		0.68
A6	23.4	42			0.80
			11		0.80
A7	23.4	6			0.30
A6	23.4	48			0.85
			12		1.15
A7	23.4	18			0.54
A6	23.4	48			0.85
			13		1.40
A7	23.4	30			0.68
A6	23.4	48			0.85
			14		1.53
A7	23.4	42			0.80
A6	23.4	48			0.85
			15		1.65
A8	23.4	6			0.30
A7	23.4	48			0.85
A6	23.4	48			0.85
			16		2.00
A8	23.4	18			0.54
A7	23.4	48			0.85
A6	23.4	48			0.85
			17		2.25
A8	23.4	30			0.68
A7	23.4	48			0.85
A6	23.4	48			0.85
			18		2.38
A8	23.4	42			0.80
A7	23.4	48			0.85

RANGE 10 PLAN 2 (141 ST SITE)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A6	23.4	48			0.85
			19		2.50
A9	26.6	6			0.34
A8	23.4	48			0.85
A7	23.4	48			0.85
A6	23.4	48			0.85
			20		2.89
A9	26.6	18			0.62
A8	23.4	48			0.85
A7	23.4	48			0.85
A6	23.4	48			0.85
			21		3.17
A9	26.6	30			0.78
A8	23.4	48			0.85
A7	23.4	48			0.85
A6	23.4	48			0.85
SECOND CELL CAPPED			22		3.33

RANGE 12 PLAN 4 (ECI SITE)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A1	64.0	6	1		2.47
A2	64.0	6			2.47
A1	64.0	12			3.49
			2		5.96
A3	64.0	6			2.47
A2	64.0	12			3.49
A1	64.0	12			3.49
			3		9.45
A5	26.0	6			1.00
A4	8.0	2		*	1.13
A3	64.0	12			3.49
A2	64.0	12			3.49
A1	64.0	12			3.49
			4		12.60
A5	26.0	18			1.82
A4	8.0	2		*	1.13
A3	64.0	12			3.49
A2	64.0	12			3.49
A1	64.0	12			3.49
			5		13.41
A5	26.0	30			2.28
A4	8.0	2		*	1.13
A3	64.0	12			3.49
A2	64.0	12			3.49
A1	64.0	12			3.49
FIRST CELL CAPPED			6		13.87
YEAR 7 NO VOLATILIZATION					
A6	47.0	6			0.60
			8		0.60
A6	47.0	18			1.09
			9		1.09
A6	47.0	30			1.37

```
RANGE 12          PLAN 4 (ECI SITE)
         VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT
***************************************************************
AREA #   AREA              TIME     OPERATN  TSCA     MASS PCBs
         (Ac)              (MONTHS) (YEARS)  (*)      (Kg)

                                          10              1.37
--------------------------------------------------------------------
A6           47.0                42                       1.61

                                          11              1.61
--------------------------------------------------------------------
A7           47.0                 6                       0.60
A6           47.0                48                       1.71

                                          12              2.31
--------------------------------------------------------------------
A7           47.0                18                       1.09
A6           47.0                48                       1.71

                                          13              2.80
--------------------------------------------------------------------
A7           47.0                30                       1.37
A6           47.0                48                       1.71

                                          14              3.08
--------------------------------------------------------------------
A7           47.0                42                       1.61
A6           47.0                48                       1.71

                                          15              3.32
--------------------------------------------------------------------
A8           47.0                 6                       0.60
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          16              4.02
--------------------------------------------------------------------
A8           47.0                18                       1.09
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          17              4.51
--------------------------------------------------------------------
A8           47.0                30                       1.37
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          18              4.79
--------------------------------------------------------------------
A8           47.0                42                       1.61
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          19              5.03
--------------------------------------------------------------------
```

RANGE 12 PLAN 4 (ECI SITE)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A9	47.0	6			0.60
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			20		5.73
A9	47.0	18			1.09
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			21		6.22
A9	47.0	30			1.37
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			22		6.50
A9	47.0	42			1.61
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			23		6.74
A10	47.0	6			0.60
A9	47.0	48			1.71
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			24		7.44
A10	47.0	18			1.09
A9	47.0	48			1.71
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			25		7.93
A10	47.0	30			1.37
A9	47.0	48			1.71
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71

#01-02

```
RANGE 12          PLAN 4 (ECI SITE)
         VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT
***************************************************************
AREA #   AREA              TIME     OPERATN  TSCA     MASS PCBs
         (Ac)              (MONTHS) (YEARS)  (*)      (Kg)

                                          26              8.21
--------------------------------------------------------------------
A10          47.0                42                       1.61
A9           47.0                48                       1.71
A8           47.0                48                       1.71
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          27              8.44
--------------------------------------------------------------------
A11          47.0                 6                       0.60
A10          47.0                48                       1.71
A9           47.0                48                       1.71
A8           47.0                48                       1.71
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          28              9.15
--------------------------------------------------------------------
A11          47.0                18                       1.09
A10          47.0                48                       1.71
A9           47.0                48                       1.71
A8           47.0                48                       1.71
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          29              9.64
--------------------------------------------------------------------
A11          47.0                30                       1.37
A10          47.0                48                       1.71
A9           47.0                48                       1.71
A8           47.0                48                       1.71
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          30              9.91
--------------------------------------------------------------------
A11          47.0                42                       1.61
A10          47.0                48                       1.71
A9           47.0                48                       1.71
A8           47.0                48                       1.71
A7           47.0                48                       1.71
A6           47.0                48                       1.71

                                          31             10.15
--------------------------------------------------------------------
A12          47.0                 6                       0.60
A11          47.0                48                       1.71
A10          47.0                48                       1.71
A9           47.0                48                       1.71
```

RANGE 12

PLAN 4 (ECI SITE)
VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

****

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			32		10.85
A12	47.0	18			1.09
A11	47.0	48			1.71
A10	47.0	48			1.71
A9	47.0	48			1.71
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			33		11.34
A12	47.0	30			1.37
A11	47.0	48			1.71
A10	47.0	48			1.71
A9	47.0	48			1.71
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			34		11.62
A12	47.0	42			1.61
A11	47.0	48			1.71
A10	47.0	48			1.71
A9	47.0	48			1.71
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			35		11.86
A13	52.0	6			0.67
A12	52.0	48			1.89
A11	47.0	48			1.71
A10	47.0	48			1.71
A9	47.0	48			1.71
A8	47.0	48			1.71
A7	47.0	48			1.71
A6	47.0	48			1.71
			36		12.81
A13	52.0	18			1.21
A12	52.0	48			1.89
A11	47.0	48			1.71

703-07

```
RANGE 12          PLAN 4 (ECI SITE)
         VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT
*****************************************************************
AREA #   AREA                TIME     OPERATN  TSCA     MASS PCBs
         (Ac)                (MONTHS) (YEARS)  (*)      (Kg)

A10          47.0                48                          1.71
A9           47.0                48                          1.71
A8           47.0                48                          1.71
A7           47.0                48                          1.71
A6           47.0                48                          1.71

                                          37                13.35
----------------------------------------------------------------------
A13          52.0                30                          1.52
A12          52.0                48                          1.89
A11          47.0                48                          1.71
A10          47.0                48                          1.71
A9           47.0                48                          1.71
A8           47.0                48                          1.71
A7           47.0                48                          1.71
A6           47.0                48                          1.71

SECOND CELL CAPPED                        38                13.66
----------------------------------------------------------------------
```

Proposed Plan (ECI Site Modified)

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT

AREA #	AREA (Ac)	TIME (MONTHS)	OPERATN (YEARS)	TSCA (*)	MASS PCBs (Kg)
A1	33.2	6	1		1.28
A2	34.2	6			1.32
A1	33.2	18			2.32
			2		3.64
A4	34.2	6			1.32
A3	34.2	6			1.32
A2	34.2	12			1.86
A1	33.2	24			2.56
			3		7.06
A6	35.3	4			1.11
A5	11.4	2		*	1.61
A4	34.2	18			2.39
A3	34.2	12			1.86
A2	34.2	12			1.86
A1	33.2	24			2.56
			4		11.40
A7	35.3	6			0.45
A6	35.3	28			2.97
A5	11.4	2		*	1.61
A4	34.2	36			3.23
A3	34.2	12			1.86
A2	34.2	12			1.86
A1	33.2	24			2.56
			6		14.55
A8	36.4	6			0.47
A7	35.3	30			1.03
A6	35.3	46			3.79
A5	11.4	2		*	1.61
A4	34.2	36			3.23
A3	34.2	12			1.86
A2	34.2	12			1.86
A1	33.2	24			2.56
			8		16.41

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT - CONTINUED

A9	34.3	6		0.44
A8	36.4	30		1.06
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			10	17.70
A10	35.4	6		0.45
A9	34.3	30		1.00
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			12	18.98
A11	32.6	6		0.42
A10	35.4	30		1.03
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			14	20.22
A12	33.7	6		0.43
A11	32.6	30		0.95
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT - CONTINUED

A2	34.2	12		1.86
A1	33.2	24		2.56
			16	21.44
A13	33.7	6		0.43
A12	33.7	30		0.98
A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			18	22.66
A14	34.7	6		0.45
A13	33.7	30		0.98
A12	33.7	48		1.22
A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			20	23.89
A15	34.7	6		0.45
A14	34.7	30		1.01
A13	33.7	48		1.22
A12	33.7	48		1.22
A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86

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VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT - CONTINUED

A2	34.2	12		1.86
A1	33.2	24		2.56
			22	25.15
A16	35.8	6		0.46
A15	34.7	30		1.01
A14	34.7	48		1.26
A13	33.7	48		1.22
A12	33.7	48		1.22
A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			24	26.42
A17	30.1	6		0.39
A16	35.8	30		1.04
A15	34.7	48		1.26
A14	34.7	48		1.26
A13	33.7	48		1.22
A12	33.7	48		1.22
A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			26	27.64
A18	31.0	6		0.40
A17	30.1	30		0.88
A16	35.8	48		1.30
A15	34.7	48		1.26
A14	34.7	48		1.26
A13	33.7	48		1.22
A12	33.7	48		1.22

VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT - CONTINUED

A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			28	28.79

A19	30.8	6		0.40
A18	31.0	30		0.90
A17	30.1	48		1.09
A16	35.8	48		1.30
A15	34.7	48		1.26
A14	34.7	48		1.26
A13	33.7	48		1.22
A12	33.7	48		1.22
A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			30	29.91

A20	31.7	6		0.41
A19	30.8	30		0.90
A18	31.0	48		1.13
A17	30.1	48		1.09
A16	35.8	48		1.30
A15	34.7	48		1.26
A14	34.7	48		1.26
A13	33.7	48		1.22
A12	33.7	48		1.22
A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32

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VOLATILE MASS LOSS OF PCBs FROM EXPOSED SEDIMENT - CONTINUED

A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
			32	31.04

A20	31.7	30		0.93
A19	30.8	48		1.12
A18	31.0	48		1.13
A17	30.1	48		1.09
A16	35.8	48		1.30
A15	34.7	48		1.26
A14	34.7	48		1.26
A13	33.7	48		1.22
A12	33.7	48		1.22
A11	32.6	48		1.18
A10	35.4	48		1.29
A9	34.3	48		1.25
A8	36.4	48		1.32
A7	35.3	48		1.28
A6	35.3	46		3.79
A5	11.4	2	*	1.61
A4	34.2	36		3.23
A3	34.2	12		1.86
A2	34.2	12		1.86
A1	33.2	24		2.56
CDF CAPPED			34	31.78

RANGE 15 MECHCANICAL DISPOSAL

SUMMARY TABLE FOR PCB MASS LOSS - IN-LAKE CDF

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		EXPOSED SEDIMENTS			SUBMERGED SEDIMENTS	
	TIME (YEARS)	MASS LOSS (Kg)	YEARLY MASS LOSS (Kg)	(CUM) MASS LOSS (Kg)	MASS LOSS (Kg)	(CUM) MASS LOSS (Kg)
	1	0.06	0.059	0.06	0.06	0.06
	2	0.18	0.121	0.18	0.07	0.13
	3	0.67	0.490	0.67	0.04	0.17
	4	1.33	0.662	1.33	0.07	0.24
CELL 1	5	1.79	0.460	1.79	0.00	0.24
CAPPED---	6	2.12	0.331	2.12	0.00	0.24
	7	0.00	0.000	0,00	0.00	0.24
	8	0.02	0.020	2.14	0.04	0.28
	9	0.04	0.016	2.16	0.03	0.31
	10	0.04	0.009	2.17	0.03	0.33
	11	0.05	0.008	2.18	0.03	0.36
	12	0.08	0.031	2.21	0.04	0.40
	13	0.11	0.026	2.23	0.03	0.43
	14	0.13	0.017	2.25	0.03	0.46
	15	0.14	0.015	2.27	0.03	0.49
	16	0.29	0.148	2.41	0.02	0.51
	17	0.41	0.121	2.53	0.01	0.52
	18	0.48	0.073	2.61	0.01	0.54
	19	0.55	0.064	2.67	0.01	0.55
	20	0.70	0.149	2.82	0.00	0.55
CELL 2	21	0.82	0.127	2.95	0.00	0.55
CAPPED---	22	0.91	0.090	3.04	0.00	0.55
	23	0.00	0.000	0.00	0.00	0.55
	24	0.02	0.020	3.06	0.04	0.60
	25	0.04	0.016	3.07	0.03	0.62
	26	0.04	0.009	3.08	0.03	0.65
	27	0.05	0.008	3.09	0.03	0.68
	28	0.08	0.031	3.12	0.04	0.72
	29	0.11	0.026	3.15	0.03	0.75
	30	0.13	0.018	3.17	0.03	0.77
	31	0.14	0.014	3.18	0.03	0.80
	32	0.29	0.148	3.33	0.02	0.83
	33	0.41	0.121	3.45	0.01	0.84
	34	0.48	0.073	3.52	0.01	0.85
	35	0.55	0.064	3.59	0.01	0.87
	36	0.70	0.149	3.74	0.00	0.87
	37	0.82	0.127	3.86	0.00	0.87
	38	0.91	0.090	3.95	0.00	0.87
CELL 3 CAPPED						
				4.0 Kg		0.9 Kg

TOTAL = 5 Kg

SUMMARY TABLE FOR PCB MASS LOSS - UPLAND CDFS (MECHANICAL DISPOSAL)

PLAN 2 (141 ST SITE)
EXPOSED SEDIMENTS

	TIME (YEARS)	MASS LOSS (Kg)	YEARLY MASS LOSS (Kg)	(CUM) MASS LOSS (Kg)
	1	1.56	1.56	1.56
	2	3.76	2.20	3.76
	3	5.96	2.20	5.96
	4	8.69	2.73	8.69
CELL 1	5	9.52	0.83	9.52
CAPPED---	6	9.99	0.47	9.99
	7	0.00	0.00	0.00
	8	0.30	0.30	10.29
	9	0.54	0.24	10.54
	10	0.68	0.14	10.68
	11	0.80	0.12	10.80
	12	1.15	0.35	11.15
	13	1.40	0.24	11.39
	14	1.53	0.14	11.53
	15	1.65	0.12	11.65
	16	2.00	0.35	12.00
	17	2.25	0.24	12.24
	18	2.38	0.14	12.38
	19	2.50	0.12	12.50
	20	2.89	0.39	12.89
	21	3.17	0.28	13.16
	22	3.33	0.16	13.32

CELL 2 CAPPED

EXPOSED= 13.3 Kg

SUBMERGED SEDIMENTS

OPERATIONS=	8
POND AREA=	1.5 Ac
TIME/OPERATION	3 MO
TOTAL TIME	24 MO
NON-TSCA CONC.	23 Mg/l (9 MO)
TSCA CONC.	63 Mg/l (3 MO)
MAINTANENCE CONC.	8 Mg/l (12 MO)

SUBMERGED= 0.017 Kg

TOTAL = 13 Kg

SUMMARY TABLE FOR PCB MASS LOSS - UPLAND CDFS (MECHANICAL DISPOSAL)

PLAN 3 (J-PIT SITE)
EXPOSED SEDIMENTS

	TIME (YEARS)	MASS LOSS (Kg)	YEARLY MASS LOSS (Kg)	(CUM) MASS LOSS (Kg)
	1	2.14	2.14	2.14
	2	5.17	3.03	5.17
	3	8.19	3.03	8.19
	4	10.90	2.70	10.90
CELL 1	5	11.61	0.72	11.61
CAPPED--	6	12.02	0.41	12.02
	7	0.00	0.00	12.02
	8	0.53	0.53	12.56
	9	0.97	0.43	12.99
	10	1.21	0.25	13.23
	11	1.42	0.21	13.44
	12	2.04	0.62	14.06
	13	2.47	0.43	14.50
	14	2.72	0.25	14.74
	15	2.93	0.21	14.95
	16	3.55	0.62	15.57
	17	3.98	0.43	16.00
	18	4.23	0.25	16.25
	19	4.44	0.21	16.46
	20	5.06	0.62	17.08
	21	5.49	0.43	17.51
	22	5.74	0.25	17.76
	23	5.95	0.21	17.97
	24	6.57	0.62	18.59
	25	7.00	0.43	19.02
	26	7.24	0.25	19.27
	27	7.46	0.21	19.48
	28	8.08	0.62	20.10
	29	8.51	0.43	20.53
	30	8.75	0.25	20.78
	31	8.96	0.21	20.99
	32	9.64	0.68	21.66
	33	10.12	0.48	22.14
	34	10.39	0.27	22.42
	35	10.63	0.23	22.66
	36	11.31	0.69	23.34
	37	11.79	0.48	23.82
	38	12.07	0.27	24.09

CELL 2 CAPPED

EXPOSED= 24.1 Kg

SUBMERGED SEDIMENTS

OPERATIONS=	12
POND AREA=	1.5 Ac
TIME/OPERATION	3 MO
TOTAL TIME	36 MO
NON-TSCA CONC.	23 Mg/l (9 MO)
TSCA CONC.	63 Mg/l (3 MO)
MAINTAINENCE CONC.	8 Mg/l (24 MO)

SUBMERGED= 0.021 Kg

TOTAL = 24 Kg

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4 OF 5

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SUMMARY TABLE FOR PCB MASS LOSS - UPLAND CDF (MECHANICAL DISPOSAL)


                PLAN 4 (ECI SITE)
             EXPOSED SEDIMENTS
                               YEARLY     (CUM)
         TIME     MASS LOSS MASS LOSS  MASS LOSS
         (YEARS)  (Kg)      Kg)        (Kg)
               1      2.47         2.47      2.47
               2      5.96         3.49      5.96
               3      9.45         3.49      9.45
               4     12.60         3.15     12.60
CELL 1         5     13.41         0.81     13.41
CAPPED---      6     13.87         0.46     13.87
               7      0.00         0.00      0.00
               8      0.60         0.60     14.48
               9      1.09         0.49     14.97
              10      1.37         0.28     15.24
              11      1.61         0.24     15.48
              12      2.31         0.70     16.18
              13      2.80         0.49     16.67
              14      3.08         0.28     16.95
              15      3.32         0.24     17.19
              16      4.02         0.70     17.89
              17      4.51         0.49     18.38
              18      4.79         0.28     18.66
              19      5.03         0.24     18.90
              20      5.73         0.70     19.60
              21      6.22         0.49     20.09
              22      6.50         0.28     20.37
              23      6.74         0.24     20.61
              24      7.44         0.70     21.31
              25      7.93         0.49     21.80
              26      8.21         0.28     22.08
              27      8.44         0.24     22.32
              28      9.15         0.70     23.02
              29      9.64         0.49     23.51
              30      9.91         0.28     23.79
              31     10.15         0.24     24.02
              32     10.85         0.70     24.72
              33     11.34         0.49     25.22
              34     11.62         0.28     25.49
              35     11.86         0.24     25.73
              36     12.81         0.95     26.68
              37     13.35         0.54     27.22
              38     13.66         0.31     27.53
         CELL 2 CAPPED
         ----------------------------------------
                            EXPOSED=         27.5 Kg

         SUBMERGED SEDIMENTS

         OPERATIONS=                 12
         POND AREA=                 1.5 Ac
         TIME/OPERATION               3 Mo
         TOTAL TIME                  36 Mo
         NON-TSCA CONC.              23 Mg/l (9 MO)
         TSCA CONC.                  63 Mg/l (3 MO)
         MAINTAINENCE CONC.           8 Mg/l (24 MO)
         ------------------------------------------------------
               SUBMERGED=      0.021 Kg


         TOTAL =         28 Kg
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Proposed Plan (ECI Site Modified)

EXPOSED SEDIMENTS

		TIME (YEARS)	(CUM) MASS LOSS (Kg)	YEARLY MASS LOSS (Kg)
		1	1.28	1.28
		2	3.64	2.36
		3	7.06	3.43
		4	11.40	4.33
	*	5	12.97	1.57
		6	14.55	1.57
	*	7	15.48	0.93
		8	16.41	0.93
	*	9	17.06	0.64
		10	17.70	0.64
	*	11	18.34	0.64
		12	18.98	0.64
	*	13	19.60	0.62
		14	20.22	0.62
	*	15	20.83	0.61
		16	21.44	0.61
	*	17	22.05	0.61
		18	22.66	0.61
	*	19	23.27	0.62
		20	23.89	0.62
	*	21	24.52	0.63
		22	25.15	0.63
	*	23	25.79	0.64
		24	26.42	0.64
	*	25	27.03	0.61
		26	27.64	0.61
	*	27	28.22	0.57
		28	28.79	0.57
	*	29	29.35	0.56
		30	29.91	0.56
	*	31	30.47	0.57
CDF		32	31.04	0.57
	*	33	31.41	0.37
CAPPED->		34	31.78	0.37

EXPOSED= 31.78 Kg

* Interpolated value

SUBMERGED SEDIMENTS

OPERATIONS=	12
POND AREA=	1.5 Ac
TIME/OPERATION	3 Mo
TOTAL TIME	36 Mo
NON-TSCA CONC.	23 Ng/l (9 MO)
TSCA CONC.	63 Ng/l (3 MO)
MAINTANENCE CONC.	8 Ng/l (42 MO)

SUBMERGED= 0.026 Kg

TOTAL = 32 Kg (Exposed + Submerged)

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ATTACHMENT F-3

Hydraulic Disposal Mass Flux Calculations

HYDRAULIC DISPOSAL MASS FLUX

PLAN 2 (141 St. SITE)

	NUMBER	EXPOSED SEDIMENTS	SUBMERGED SEDIMENTS
YEARLY OPERATION	4	$\frac{3\,mo}{yr} \cdot 4 = 12\,mo$	$\frac{9\,mo}{yr} \cdot 4 = 36\,mo$
4 YEAR CYCLES	3	$\frac{39\,mo}{Cycle} \cdot 3 = 117\,mo$	$\frac{9\,mo}{Cycle} \cdot 3 = 27\,mo$
2 YEAR CAPPING	2	$\frac{24\,mo}{cycle} \cdot 2 = 48\,mo$	$\frac{0\,mo}{cycle} \cdot 2 = 0\,mo$
2 YEAR GAP BETWEEN FILLING CELLS (YR 6 - YR 8)	1	0 mo	0 mo
		177 mo	63 mo

Effective LIFE = 20 YR (240 mo)

% EXPOSED SEDIMENTS = $\frac{177}{240} = 0.74$

% SUBMERGED SEDIMENTS: $\frac{63}{240} = 0.26$

MASS FLUX

EXPOSED SEDIMENTS ≐ 0.74 (TOTAL FOR MECHANICAL DISPO

= 0.74 (13.3)

= 9.8 Kg

7/9 - [illegible]

HYDRAULIC DISPOSAL

PLAN 2 (191 St. SITE)

SUBMERGED SEDIMENTS $= 0.26\, n_A$ (MEAN AREA)(EFFECTIVE LIFE)

$$n_A = K'_{A2}\left(\frac{W_a}{K_d + 1/e_{32}} - e'^{**}_{A2}\right)\frac{1}{1000}$$

$$= \frac{0.26(0.779)\left[\left(\frac{41.2}{256{,}000 + 1/0.009} - 0\right)\left(\frac{1}{1000}\right)\right](40.47E+6\ \frac{cm^2}{Ac})(720\ \frac{hr}{mo})(240\ mo)(468\ Ac)}{10^6}$$

$= 1.09$ Kg

TOTAL $= 9.3 + 1.09$ 10.9 SAY $\underline{\underline{11\ Kg}}$

Volume Wieght W_a

BACKLOG - 1,000,000 yd^3 total 80,000 yd^3 @ 38 mg/Kg, 920,000 yd^3 @ 6 mg/Kg

MAINTENANCE - 2,000,000 yd^3 total 2,000,000 yd^3 @ 2 mg/Kg

$$W_a = \frac{80{,}000(38) + 920{,}000(6) + 2{,}000{,}000(2)}{3{,}000{,}000}$$

$W_a = 4.2$ mg/Kg

HYDRAULIC DISPOSAL MASS FLUX

PLAN 4 (ECI SITE)

	NUMBER	EXPOSED SEDIMENTS	SUBMERGED SEDIMENTS
YEARLY OPERATION	4	$\frac{3\,mo}{yr} \cdot 4 = 12\,mo$	$\frac{9\,mo}{yr} \cdot 4 = 36\,mo$
4 YEAR CYCLES	7	$\frac{39\,mo}{cycle} \cdot 7 = 273\,mo$	$\frac{9\,mo}{cycle} \cdot 7 = 63\,mo$
2 YEAR CAPPING	2	$\frac{24\,mo}{cycle} \cdot 2 = 48\,mo$	$\frac{0\,mo}{cycle} = 0\,mo$
2 YEAR GAP BETWEEN FILLING CELLS (YR6-YR8)		0 mo	0 mo
		333 mo	99 mo

EFFECTIVE LIFE = 36 YR (432 mo)

$$\%\text{ EXPOSED SEDIMENTS} = \frac{333}{432} = 0.77$$

$$\%\text{ SUBMERGED SEDIMENTS} = \frac{99}{432} = 0.23$$

MASS FLUX

EXPOSED SEDIMENTS = 0.77 (TOTAL FOR MECHANICAL DISPOSAL

= 0.77 (27.5)

= 21.2 Kg

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HYDRAULIC DISPOSAL

PLAN 4 (ECI SITE)

SUBMERGED SEDIMENTS $= 0.23\, n_a$ (MEAN AREA)(EFFECTIVE LIFE)

$$= \frac{0.23(0.779)\left[\left(\frac{4.2}{256000+\frac{1}{0.009}} - 0\right)\left(\frac{1}{1000}\right)\right]\left(40.47E+6\,\frac{cm^2}{AC}\right)\left(720\,\frac{hr}{mo}\right)(432\,mo)(70.8)}{10^6}$$

$= 2.62$ Kg

TOTAL = $21.2 + 2.62 = 23.8$ SAY **24 Kg**

$W_a = 4.2$ mg/Kg

SUMMARY TABLE FOR PCB MASS LOSS - UPLAND CDFS (HYDRAULIC DISPOSAL)

HYDRAULIC DISPOSAL

	EXPOSED SEDIMENT Kg	SUBMERGED SEDIMENT Kg	TOTAL
PLAN 2(141ST SITE)	9.9	1.1	11
PLAN 4 (ECI SITE)	21.2	2.6	24

723-2

ATTACHMENT F-4

Input and Output Summaries for Cap and Cover Designs

```
*************************************************************************
*************************************************************************


 INDIANA HARBOR CDF
 CAP DESIGN #1
                VERTICAL PERCOLATION LAYER - TOP SOIL
                BARRIER SOIL LINER - CLAY
                VERTICAL PERCOLATION LAYER - DREDGED MATERIAL
 6 JUNE 1989


*************************************************************************
*************************************************************************




                              LAYER  1
                              --------

           VERTICAL PERCOLATION LAYER - TOP SOIL
  THICKNESS                            =      24.00 INCHES
  POROSITY                             =       0.4370 VOL/VOL
  FIELD CAPACITY                       =       0.1310 VOL/VOL
  WILTING POINT                        =       0.0580 VOL/VOL
  INITIAL SOIL WATER CONTENT           =       0.2029 VOL/VOL
  SATURATED HYDRAULIC CONDUCTIVITY     =       0.001  CM/SEC


                              LAYER  2
                              --------

                 BARRIER SOIL LINER - CLAY
  THICKNESS                            =      36.00 INCHES
  POROSITY                             =       0.4300    VOL/VOL
  FIELD CAPACITY                       =       0.3660    VOL/VOL
  WILTING POINT                        =       0.2800    VOL/VOL
  INITIAL SOIL WATER CONTENT           =       0.4300    VOL/VOL
  SATURATED HYDRAULIC CONDUCTIVITY     =       0.0000001 CM/SEC
```

```
                              LAYER  3
                              --------

         VERTICAL PERCOLATION LAYER - DREDGED MATERIAL
   THICKNESS                              =     240.00 INCHES
   POROSITY                               =       0.7033      VOL/VOL
   FIELD CAPACITY                         =       0.4660      VOL/VOL
   WILTING POINT                          =       0.2510      VOL/VOL
   INITIAL SOIL WATER CONTENT             =       0.7033      VOL/VOL
   SATURATED HYDRAULIC CONDUCTIVITY       =       0.00000001 CM/SEC


                       GENERAL SIMULATION DATA
                       -----------------------

   SCS RUNOFF CURVE NUMBER                =       48.00
   TOTAL AREA OF COVER                    =    43560. SQ FT
   EVAPORATIVE ZONE DEPTH                 =       28.00 INCHES
   UPPER LIMIT VEG. STORAGE               =       10.4880 INCHES
   INITIAL VEG. STORAGE                   =        4.8696 INCHES
              SOIL WATER CONTENT INITIALIZED BY USER.


                         CLIMATOLOGICAL DATA
                         -------------------

   DEFAULT RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND
   SOLAR RADIATION FOR      CHICAGO               ILLINOIS


   MAXIMUM LEAF AREA INDEX                  = 3.30
   START OF GROWING SEASON (JULIAN DATE)    =  128
   END OF GROWING SEASON (JULIAN DATE)      =  282


          NORMAL MEAN MONTHLY TEMPERATURES, DEGREES  FAHRENHEIT

  JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
  -------     -------     -------     -------     -------     -------

   21.40       26.00       36.00       48.80       59.10       68.60
   73.00       71.90       64.70       53.50       39.80       27.70


*************************************************************************
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```
       AVERAGE MONTHLY VALUES IN INCHES FOR   74 THROUGH   78
-------------------------------------------------------------------------

                          JAN/JUL FEB/AUG MAR/SEP APR/OCT MAY/NOV JUN/DEC
                          ------- ------- ------- ------- ------- -------
 PRECIPITATION
 -------------
   TOTALS                   1.98    1.52    3.03    4.08    3.25    4.36
                            3.05    3.67    3.18    1.74    1.95    2.27

   STD. DEVIATIONS          1.43    0.90    1.84    1.02    1.42    0.99
                            1.57    2.52    2.68    0.36    0.77    1.06

 RUNOFF
 ------
   TOTALS                   0.000   0.000   0.405   0.737   0.359   0.243
                            0.000   0.000   0.000   0.000   0.000   0.000

   STD. DEVIATIONS          0.000   0.000   0.907   1.010   0.512   0.357
                            0.000   0.000   0.000   0.000   0.000   0.000

 EVAPOTRANSPIRATION
 ------------------
   TOTALS                   0.504   0.959   1.619   2.944   3.231   5.729
                            7.064   2.963   2.303   1.359   0.990   0.646

   STD. DEVIATIONS          0.066   0.222   0.345   0.222   0.963   0.496
                            2.561   1.057   1.354   0.318   0.347   0.151

 PERCOLATION FROM LAYER  2
 ------------------------
   TOTALS                   0.0949  0.0977  0.1247  0.1251  0.1488  0.1286
                            0.0859  0.0057  0.0317  0.0679  0.0697  0.0792

   STD. DEVIATIONS          0.0537  0.0557  0.0707  0.0709  0.0350  0.0500
                            0.0573  0.0122  0.0479  0.0637  0.0643  0.0673

 PERCOLATION FROM LAYER  3
 ------------------------
   TOTALS                   0.0105  0.0096  0.0105  0.0102  0.0105  0.0102
                            0.0105  0.0105  0.0102  0.0105  0.0102  0.0105

   STD. DEVIATIONS          0.0000  0.0002  0.0000  0.0000  0.0000  0.0000
                            0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

*************************************************************************


*************************************************************************

   AVERAGE ANNUAL TOTALS (AND STD. DEVIATIONS) FOR   74 THROUGH   78
```

729-30

```
---------------------------------------------------------------------------
                                     (INCHES)         (CU. FT.)    PERCENT
                                   ---------------    ----------   -------
  PRECIPITATION                    34.08   ( 4.915)     123718.     100.00

  RUNOFF                            1.744  ( 2.074)       6332.       5.12

  EVAPOTRANSPIRATION               30.312  ( 3.300)     110033.      88.94

  PERCOLATION FROM LAYER  2         1.0599 ( 0.4113)      3848.       3.11

  PERCOLATION FROM LAYER  3         0.1242 ( 0.0000)       451.       0.36
***************************************************************************


***************************************************************************
              PEAK DAILY VALUES FOR   74 THROUGH   78
     --------------------------------------------------------------
                                           (INCHES)     (CU. FT.)
                                           --------     ---------
       PRECIPITATION                         3.48        12632.4

       RUNOFF                                1.915        6952.1

       PERCOLATION FROM LAYER  2             0.0057         20.7

       HEAD ON LAYER  2                     24.6

       PERCOLATION FROM LAYER  3             0.0003          1.2

       HEAD ON LAYER  3                     12.5

       SNOW WATER                            4.00        14528.5


       MAXIMUM VEG. SOIL WATER (VOL/VOL)         0.4370

       MINIMUM VEG. SOIL WATER (VOL/VOL)         0.0579
***************************************************************************
***************************************************************************
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**********************************************************************
**********************************************************************

 INDIANA HARBOR CDF
 CAP DESIGN #2
                VERTICAL PERCOLATION LAYER - TOPSOIL
                LATERAL DRAINAGE LAYER - GRAVEL
                BARRIER SOIL LAYER - CLAY
                VERTICAL PERCOLATION LAYER - DREDGED MATERIAL
 6 JUNE 1989

**********************************************************************
**********************************************************************



                               LAYER  1
                               --------

              VERTICAL PERCOLATION LAYER - TOPSOIL
   THICKNESS                              =     18.00   INCHES
   POROSITY                               =      0.4370 VOL/VOL
   FIELD CAPACITY                         =      0.1310 VOL/VOL
   WILTING POINT                          =      0.0580 VOL/VOL
   INITIAL SOIL WATER CONTENT             =      0.2029 VOL/VOL
   SATURATED HYDRAULIC CONDUCTIVITY       =      0.001  CM/SEC


                               LAYER  2
                               --------

                LATERAL DRAINAGE LAYER - GRAVEL
   THICKNESS                              =      6.00 INCHES
   POROSITY                               =      0.4170 VOL/VOL
   FIELD CAPACITY                         =      0.0450 VOL/VOL
   WILTING POINT                          =      0.0200 VOL/VOL
   INITIAL SOIL WATER CONTENT             =      0.0521 VOL/VOL
   SATURATED HYDRAULIC CONDUCTIVITY       =      0.01   CM/SEC
   SLOPE                                  =      1.50   PERCENT
   DRAINAGE LENGTH                        =    100.0    FEET
```

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```
                        LAYER  3
                        --------

                BARRIER SOIL LINER - CLAY
THICKNESS                           =     36.00 INCHES
POROSITY                            =      0.4300    VOL/VOL
FIELD CAPACITY                      =      0.3660    VOL/VOL
WILTING POINT                       =      0.2800    VOL/VOL
INITIAL SOIL WATER CONTENT          =      0.4300    VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY    =      0.0000001 CM/SEC


                        LAYER  4
                        --------

      VERTICAL PERCOLATION LAYER - DREDGED MATERIAL
THICKNESS                           =    240.00 INCHES
POROSITY                            =      0.7033     VOL/VOL
FIELD CAPACITY                      =      0.4660     VOL/VOL
WILTING POINT                       =      0.2510     VOL/VOL
INITIAL SOIL WATER CONTENT          =      0.7033     VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY    =      0.00000001 CM/SEC



                 GENERAL SIMULATION DATA
                 -----------------------

SCS RUNOFF CURVE NUMBER             =      48.00
TOTAL AREA OF COVER                 =   43560. SQ FT
EVAPORATIVE ZONE DEPTH              =      28.00 INCHES
UPPER LIMIT VEG. STORAGE            =      10.3680 INCHES
INITIAL VEG. STORAGE                =       3.9648 INCHES
           SOIL WATER CONTENT INITIALIZED BY USER.


                   CLIMATOLOGICAL DATA
                   -------------------

DEFAULT RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND
SOLAR RADIATION FOR      CHICAGO            ILLINOIS


MAXIMUM LEAF AREA INDEX                = 3.30
START OF GROWING SEASON (JULIAN DATE)  =  128
END OF GROWING SEASON (JULIAN DATE)    =  282
```

```
          NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

  JAN/JUL      FEB/AUG      MAR/SEP      APR/OCT      MAY/NOV      JUN/DEC
  -------      -------      -------      -------      -------      -------

   21.40        26.00        36.00        48.80        59.10        68.60
   73.00        71.90        64.70        53.50        39.80        27.70


***********************************************************************

        AVERAGE MONTHLY VALUES IN INCHES FOR   74 THROUGH   78
-----------------------------------------------------------------------

                        JAN/JUL FEB/AUG MAR/SEP APR/OCT MAY/NOV JUN/DEC
                        ------- ------- ------- ------- ------- -------
 PRECIPITATION
 -------------
   TOTALS                 1.98    1.52    3.03    4.08    3.25    4.36
                          3.05    3.67    3.18    1.74    1.95    2.27

   STD. DEVIATIONS        1.43    0.90    1.84    1.02    1.42    0.99
                          1.57    2.52    2.68    0.36    0.77    1.06

 RUNOFF
 ------
   TOTALS                0.000   0.000   0.000   0.000   0.000   0.000
                         0.000   0.000   0.000   0.000   0.000   0.000

   STD. DEVIATIONS       0.000   0.000   0.000   0.000   0.000   0.000
                         0.000   0.000   0.000   0.000   0.000   0.000

 EVAPOTRANSPIRATION
 ------------------
   TOTALS                0.506   0.963   1.626   2.930   3.223   5.153
                         3.594   2.554   2.294   1.377   1.023   0.657

   STD. DEVIATIONS       0.067   0.223   0.352   0.240   0.975   0.909
                         1.690   0.979   1.367   0.340   0.355   0.163

 LATERAL DRAINAGE FROM LAYER  2
 ------------------------------
   TOTALS               0.8423  0.7605  1.9815  0.7979  0.9199  0.1794
                        0.0221  0.0340  0.7839  0.3024  0.0233  0.6927

   STD. DEVIATIONS      0.8388  0.5868  2.1783  0.6349  0.5875  0.2776
                        0.0494  0.0759  1.2732  0.5764  0.0407  0.6335

 PERCOLATION FROM LAYER  3
 -------------------------
   TOTALS               0.0847  0.0772  0.0851  0.0961  0.1059  0.0591
```

```
                  0.0066  0.0005  0.0278  0.0420  0.0409  0.06


  STD. DEVIATIONS 0.0474  0.0432  0.0476  0.0142  0.0001  0.0311
                  0.0149  0.0012  0.0425  0.0575  0.0560  0.0458

PERCOLATION FROM LAYER  4
-------------------------
  TOTALS          0.0105  0.0096  0.0105  0.0102  0.0105  0.0102
                  0.0105  0.0105  0.0102  0.0105  0.0102  0.0105

  STD. DEVIATIONS 0.0000  0.0002  0.0000  0.0000  0.0000  0.0000
                  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

***********************************************************************


***********************************************************************

 AVERAGE ANNUAL TOTALS (AND STD. DEVIATIONS) FOR   74 THROUGH   78
-----------------------------------------------------------------------
                                (INCHES)           (CU. FT.)    PERCENT
                            ----------------     -----------    -------
 PRECIPITATION               34.08   ( 4.915)       123718.      100.00

 RUNOFF                       0.000  ( 0.000)            0.        0.0

 EVAPOTRANSPIRATION          25.900  ( 3.282)        94017.       75.99

 LATERAL DRAINAGE FROM        7.3400 ( 2.8607)       26644.       21.54
    LAYER  2

 PERCOLATION FROM LAYER  3    0.6921 ( 0.1818)        2512.        2.03

 PERCOLATION FROM LAYER  4    0.1242 ( 0.0000)         451.        0.36
***********************************************************************



***********************************************************************

             PEAK DAILY VALUES FOR   74 THROUGH   78
    ---------------------------------------------------------------
                                            (INCHES)     (CU. FT.)
                                            --------     ---------
     PRECIPITATION                           3.48         12632.4

     RUNOFF                                  0.000            0.0

     LATERAL DRAINAGE FROM LAYER  2          0.7283        2643.7
```

```
          PERCOLATION FROM LAYER  3              0.0036          13.2
          HEAD ON LAYER  3                       2.6
          PERCOLATION FROM LAYER  4              0.0003           1.2
          HEAD ON LAYER  4                       1.5
          SNOW WATER                             3.99         14476.5

          MAXIMUM VEG. SOIL WATER (VOL/VOL)          0.2726
          MINIMUM VEG. SOIL WATER (VOL/VOL)          0.0484
**************************************************************************
**************************************************************************
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INDIANA HARBOR & CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES
IN LAKE COUNTY, INDIANA

APPENDIX G

APPLICATION OF SEDIMENT TREATMENT TECHNOLOGIES TO CONTAMINATED SEDIMENTS

March 1995
Environmental Engineering Section
Chicago District
U.S. Army Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606

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Table of Contents (continued)

List of Tables

1. PURPOSE AND OBJECTIVE

1.1 This appendix will review the potential for the application of sediment treatment technologies to dredged material from maintenance dredging of the Indiana Harbor and Canal (IHC). A portion of the sediments to be dredged from the canal has been classified as toxic, as defined in the Toxic Substances Control Act (TSCA), due to the presence of polychlorinated biphenyls (PCBs) in levels exceeding 50 parts per million (ppm). TSCA mandates that three alternatives be considered for the disposal of these materials: incineration, disposal in a licensed landfill, or an alternative disposal method that must be approved by the Regional Administrator of USEPA. A formal application for a TSCA permit for the navigation project is contained in Appendix J.

1.2 This appendix is divided into seven major sections. The first provides background material on the historical practices employed for the disposal of dredged material. The second section discusses the physical and chemical nature of the dredged material, compares it to traditional wastes, reviews dredging and handling techniques for sediments, discusses the role a CDF will play in any dredging scenario, discusses specific technologies examined in previous and ongoing studies, and examines the goals and rationale for treatment. The third section provides descriptions of the treatment technologies being considered. The fourth section presents the technical criteria used to evaluate the different technologies. The fifth section describes the results of laboratory tests of selected treatment technologies on Indiana Harbor sediments. The sixth section details cost estimates for four treatment technologies. The appendix ends with a summary section.

1.3 The information sources used to prepare this appendix include institutional knowledge and experience in the Chicago District and the Waterways Experiment Station (WES), discussions with experts outside the Corps of Engineers, reports produced by the Dredged Material Research Program and other research conducted by the WES, reports dealing with the Superfund sites at Waukegan and New Bedford Harbors, reports and discussions with experts from the USEPA, Proceedings from the US/Japan Experts Meetings on Management of Bottom Sediments Containing Toxic Substances, reports by Carpenter (1986, 1987) and Cullinane et al. (1986), and discussions with manufacturers, operators, and designers of proprietary technologies. The work being performed under the USEPA's Assessment and Remediation of Contaminated Sediments (ARCS) Program has been closely monitored by the Chicago District, and advances and information provided by the program have been included in this appendix. All sources consulted are listed in the literature cited. The other published sources of information, except those to which specific reference is made, are listed in the bibliography.

2. DREDGED MATERIAL DISPOSAL BACKGROUND

2.1 Dredging of navigable waters in the Great Lakes dates back to the early 19th century. Early efforts were usually limited to the removal of material deposited at the mouth of rivers by littoral drift and delta formation. Dredged material was either cast to one side of the channel or dumped in deeper water. The advent of steel use in ship building brought about larger vessels and increased the capability for greater and more efficient waterborne commerce. These larger ships demanded further improvements to harbors and the construction of connecting channels. The new, larger, harbors and channels filled with sediments more often, increasing the need for maintenance dredging. Dredging was now being performed on a more regular schedule in order to maintain safe, navigable waterways. The primary means of disposing of dredged materials was still unconfined, open-water disposal.

2.2 As the nation grew and expanded, the harbors on the Great Lakes found themselves surrounded by urban and industrial developments. Associated with the rise of these developments was an increase in the load of pollutants to the nearby waterways. The environmental consciousness of the early 1960's led to the development of a series of studies by the Corps, including the 1969 report entitled Dredging and Water Quality Problems in the Great Lakes. Although this report could not conclusively show harmful effects of open water disposal of dredged materials, the Board of Consultants for the study concluded that "in lake disposal of heavily polluted dredging must be considered presumptively undesirable." Subsequently, Congress authorized the "Diked Disposal Program for the Great Lakes" with the passage of PL 91-611. The Diked Disposal Program authorized the Corps to construct, operate, and maintain contained dredged material disposal facilities. Since the passage of PL 91-611 the Corps has constructed 30 confined disposal facilities, or CDFs, on the Great Lakes.

2.3 With the passage of PL 91-611 Congress authorized the Dredged Material Research Program (DMRP) to expand and refine the technical base developed through the Dredging and Water Quality on the Great Lakes reports. The Corps undertook this program in response to the need for more basic information on all types of dredged material disposal and possible alternatives to existing methods. The program was directed by the WES at Vicksburg, Mississippi and completed in the planned 5-year time frame at a cost of $32.8 million. Through Research Task 6B the DMRP specifically addressed the issue of treatment of contaminated dredged material.

2.4 In general, the CDF program provided a solution to the problem of where to dispose of contaminated sediments. But as industrial development has continued and environmental consciousness has increased, the problems associated with disposing of sediments from certain areas of the Great Lakes have grown more complex. New legislation has been developed since the passage of the Clean Water Act and the National Environmental Policy Act of the early 1970s, legislation that addresses the issues of toxic waste control. These laws provide strict regulations and controls over potentially dangerous substances and provide for environmental remediation at sites with uncontrolled contamination.

3. DISPOSAL ALTERNATIVES

3.1 PHYSICAL CHARACTERISTICS OF DREDGED MATERIALS

3.1.1 It is necessary to understand the physical and chemical composition of dredged materials, and how they compare with the characteristics of traditional waste materials, in order to evaluate the effectiveness of applying sediment treatment technologies to them.

3.1.2 The sediments to be dredged at the IHC are similar in some aspects to those found throughout many Great Lakes harbors. The sediments at the IHC consist primarily of silts and clays, with 65 percent of the material classified as "fines". The materials are 50 percent solids by weight on average, and the organics content, measured as total volatile solids, has a mean value of 16 percent. The sediments are contaminated with a wide variety of pollutants to levels that are classified as moderately to heavily polluted by the USEPA. A thorough chemical and physical description of the harbor sediments is given in Appendix E.

3.1.3 Dredged materials are often referred to, incorrectly, as "sludge". Shown in table G-1 are the physical and chemical characteristics of sewage sludge and how they differ from those of dredged materials. Also shown in table G-1 are the physical/chemical components of municipal solid waste (garbage). Dredged materials are distinctly different from these two common waste materials, and disposing of contaminated sediments poses a unique set of problems.

3.2 DREDGED MATERIAL HANDLING REQUIREMENTS

3.2.1 Sediments can be dredged mechanically, hydraulically, or by some combination of the two methods. Mechanical dredging, using a clamshell or dipper dredge, allows for the removal of sediments at a solids content near their in-place value. There is little or no volume increase associated with mechanical dredging. Hydraulic dredging (using a suction or draghead dredge) allows for the actual dredging to take place faster and with less

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Table G-1: Physical/Chemical Characteristics of Dredged Sediments, Municipal Solid Waste, and Sewage Sludge

	Municipal Solid Waste	Dredged Sediment	Sewage Sludge
Specific Wt. (lb/ft^3)	8	90	65
Solids (% by wt)	80	50	5
Organic (% by wt)	53	16	65
Total Nitrogen (ppm)	11,060	2,929	40,000
Total Phosphorus (ppm)	-	2,555	20,000
Iron (ppm)	20,000	144,623	25,000

From Tchobanoglous 1977, Metcalf and Eddy 1979, and USACE.

resuspension of bottom materials than occurs with mechanical dredges. However, hydraulic dredges create a slurry with the sediments that is only 10-20% solids, resulting in an increase of 300-400% over the in-place sediment volume. This excess water usually has to be removed from the dredged sediments before they can be treated and/or disposed of. This problem does not occur to the same magnitude with mechanically removed materials. A detailed discussion of dredging technologies is presented in Appendix H.

3.2.2 The handling requirements for dredged materials depend on the type of dredge used and the location of the dewatering/ holding facility, CDF, treatment facility, and final disposal site. Hydraulic dredges have the ability to pump the sediment slurry as it is being removed directly to a nearby dewatering/ holding facility. Mechanical dredges have to use scows or barges to transport the sediment material from the dredging site to the dewatering/holding facility. If the dewatering/holding facility is located on a distant upland site the materials have to be transported from the pipeline or scows to the site by truck or rail transport. From a dewatering/holding facility the materials have to be transported to the treatment facility, and then to the final disposal site. Rehandling requires time, space, material, and money.

3.2.3 For any feasible dredging scenario, a CDF will be used in one capacity or another. In the past, CDFs have been used as both dewatering and final disposal facilities. As part of an sediment treatment technology process, an upland CDF could be used as a dewatering and holding facility to allow temporary storage of materials as they are dredged and before they can be treated. (This is a consequence of the fact that dredging can be accomplished much faster than treatment). This same CDF, or another facility, could then be used as a final disposal site for the treated materials. In all cases, a CDF is necessary.

3.3 PREVIOUS TREATABILITY EVALUATIONS FOR DREDGED MATERIALS

3.3.1 The 1969 report, Dredging and Water Quality Problems on the Great Lakes explored alternatives to the open-water disposal of contaminants that included treatment technologies. The report examined the application of then current sewage sludge treatment technologies to contaminated sediments. Some of the treatment technologies were tested on a bench or pilot scale. It is useful to examine the results and conclusions reached from those tests.

3.3.2 One of the simplest treatment technologies tested in 1969 was the introduction of dredged materials directly into the intercepting sewer system of the Metropolitan Water Reclamation District of Greater Chicago (then called the Metropolitan Sanitary District of Greater Chicago). The dredged materials were transported by gravity through the sewers to the treatment plants, where they were mixed with incoming raw sewage and treated along with the normal plant flow. The effects that the sediments had on the sewer pipes themselves and on the operations of the treatment plants were both monitored. It was concluded that sediments would have to be removed from the waterway hydraulically and introduced into the sewer system in a very dilute slurry. Some effects were seen on the sewer pipes, primarily from the sediments that were removed mechanically. These effects were eliminated when hydraulic dredging was used. At the treatment plant itself, the dredged materials did produce a small increase in incoming flow, and they did cause some interference with the primary and secondary treatment processes. The problems encountered in the primary and secondary processes, combined with the tremendous volumes of diluted sediments that would flow into the plant, led to the conclusion that using the existing capabilities of a municipal wastewater district's treatment facility was inappropriate for the disposal of dredged materials.

3.3.3 The 1969 report also examined the treatment of dredged materials by aerobic and anaerobic biodegradation processes. Bench-scale tests of anaerobic digestion were conducted, and the amount of gas produced by the digesting sediments was measured. The report concluded that since less than 1 cubic foot of gas was produced per pound of volatile solids in the dredged materials, anaerobic digestion of such materials would not approach the efficiency of the anaerobic digestion of sewage sludge (which produces typically 10 cubic feet of gas per pound of volatile solids). The examination of aerobic stabilization of dredged materials concluded that the variability in organic content of sediments within a single harbor was so wide that process upsets could be a regular occurrence, leading to inefficient operations.

3.3.4 Chemical oxidation, by the addition of high levels of chlorine, was also examined, as was the application of a wet oxidation process. The chlorine oxidation, called the Purifax process, was tested on the bench scale, and reductions in oxygen demand for the dredged materials were seen. The products from the process contained high levels of chlorine residuals, which

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are unacceptable under current regulatory frameworks. The wet oxidation process, referred to later in this report as wet air oxidation, was also tested on a bench-scale. While the oxygen demand of the dredged solids was reduced by the process, it appeared that the demand was transferred to the liquid fractions that emerged from the treatment process. Wet oxidation was recommended only as a conditioner for soils to be used as land fill materials.

3.3.5 The 1969 report also performed a series of cost estimations for the construction and use of a fluid bed incinerator and a multiple hearth incinerator. Actual burn tests were not performed on dredged materials. The report estimated that an incinerator plant that could burn 220,000 cubic yards of dredged materials in one year would cost between $9.8 and 11.0 million (1993 dollars), and would cost from $1.7 to 3.9 million to operate for that year. These costs must be taken in the perspective of when they were generated. In 1968 the regulation and permitting of incinerators was not as extensive as it is now.

3.3.6 In the mid-1970s, the Chicago District proposed that research be conducted examining the use of a cone-like net to provide a fabric cover for dredged materials being deposited in the open waters of Lake Michigan (USACE 1975). At the time, the research was highly innovative, but the particular proposal by the Chicago District was not acted upon. Since that time others (primarily the USACE) have extensively examined different underwater capping techniques for the disposal of dredged materials in open waters. These techniques are now a common practice in many coastal areas, though they have only been demonstrated on the Great Lakes in a pilot scale (Hayes, et al., 1988).

3.3.7 The Corps has also evaluated using dredged materials for a number of beneficial applications. These uses included reclamation of strip mined areas, making bricks, mechanically densifying the material, drying the material, and using the material as a sanitary landfill cover. Some of these applications were tried by the Chicago District and others, most notably the Waterways Experiment Station. All these particular techniques hold promise for use with cleaner dredged materials, but the use of contaminated materials like those at the IHC has not been encouraged.

3.3.8 As discussed above, the Corps has been examining alternatives to open-water disposal of dredged materials since the mid 1960s. This examination of alternatives has been brought more to the forefront with recent projects that not only involve the Corps. Some of these projects are discussed in the following section.

3.4 CURRENT TREATABILITY EVALUATIONS WITH DREDGED MATERIALS

3.4.1 The Corps is not the only agency which has had to deal with the disposal of sediments contaminated with a wide variety of substances. The USEPA has identified a number of sites nationwide at which environmental remediation of in-place contaminated sediments is warranted. At New Bedford Harbor, Massachusetts; Waukegan Harbor, Illinois; Fields Brook, Ashtabula, Ohio; Sheboygan River, Wisconsin; and Messina River, New York PCBs have contaminated the sediments to such high levels that parts of these waterways have been designated Superfund sites.

3.4.2 As part of its Superfund efforts, the USEPA has conducted numerous investigations on treatability and containment of contaminated sediments. For the New Bedford Superfund cleanup, the USEPA has recently constructed a CDF for dredging and disposal pilot demonstrations. Bench- and pilot-scale demonstrations of extraction and vitrification technologies have also been conducted. The Corps has been involved by providing technical support. In addition, at three of these harbors, Waukegan, Ashtabula, and Sheboygan, the Corps also has an adjacent Federal navigation project that must be maintained. Although the sediments in these Federal channels are not as heavily contaminated as those in the Superfund sites, they are contaminated to levels higher than background concentrations. The disposal of these sediments poses unique design requirements.

3.4.2.1 <u>Treatment Considered for Waukegan Harbor Superfund Site</u>

3.4.2.2 A wide variety of treatment alternatives have been investigated by the USEPA in relation to the Superfund project at Waukegan Harbor. The sediments in the Superfund project were contaminated with levels of PCBs thousands of times greater than those found in the IHC. Some sediments in slip 3 of the Superfund area contained greater than 100,000 ppm PCBs. Even though the concentrations of PCBs in the Waukegan Harbor Superfund project were greater than those present in Indiana Harbor, it is appropriate to examine the technologies considered by USEPA for the Waukegan Superfund project.

3.4.2.3 Remediation alternatives examined by USEPA have varied from simple removal of the contaminated sediments and disposal offsite to an alternative involving removal of the sediments, treatment with an extraction process, and subsequent incineration of the extracted PCBs. The USEPA contracted with various consulting firms to produce feasibility studies on the Harbor.

3.4.2.4 Prior to the passage of the Superfund Amendments and Reauthorization Act (SARA) in 1986 the primary method of cleaning up NPL sites was to remove the contaminated materials and dispose of them offsite, in a permitted chemical waste landfill. Early alternatives identified for the site at Waukegan Harbor reflected this line of thought. Alternatives considered included removing all the material contaminated with PCBs above 50 ppm and disposing of the material in a chemical waste landfill, either offsite or to be constructed near the harbor. Other early alternatives considered sealing off and filling various parts of the harbor, including one scenario that would have sealed off and filled it entirely.

3.4.2.5 After the passage of SARA the focus on cleanups at Superfund sites shifted from removal and redisposal to reduction in volume and toxicity of contaminants. Likewise, a shift occurred in the alternatives being investigated for Waukegan. Later studies examined a group of technologies that included most of those identified later in this appendix. The technologies were evaluated for their ability to treat the sediments both in-place and after removal. Scenarios were developed involving the use of slip 3 and/or parts of the Upper Harbor as a disposal site for the sediments in the Superfund areas. Some alternatives included using various extraction techniques for removal of the PCBs, which would then be destroyed by incineration or another destructive technology, followed by containment of the treated sediments in slip 3.

3.4.2.6 In October 1988 the USEPA Region 5 announced that an agreement had been reached with Outboard Marine Corporation and a clean-up plan was developed for the harbor. The clean-up involved the removal of a small quantity (less than 10,000 cubic yards) of highly PCB-contaminated sediments (concentrations greater than 500 ppm) which was treated by a thermal extraction process (the Taciuk Process) in which the PCBs were removed and disposed of off site. The majority of the contaminated sediments (about 30,000 cubic yards) were placed in an on-site contained disposal facility. The Chicago District has provided technical review and construction oversight support to this project.

3.4.3 A harbor may still be a source of heavily contaminated sediments even if it is not declared a Superfund site. There are a number of industrial/urban harbors in the United States that contain sediments contaminated with such a variety of pollutants at levels greater than normal that traditional disposal methods are being questioned. This reexamination of dredged material disposal techniques is taking place at the Hudson River, where the New York Department of Environmental Conservation is investigating the feasibility of applying innovative treatment technologies to river sediments contaminated with PCBs.

3.4.4 Assessment and Remediation of Contaminated Sediments Program (ARCS)

3.4.4.1 USEPA was authorized under Section 118(c)(3) of the Clean Water Act to conduct a five-year study and demonstration project on assessment and remediation techniques for contaminated sediments in the Great Lakes. USEPA was directed to focus its efforts on five areas of concern in the Great Lakes: Ashtabula River, Ohio; Buffalo River, New York; Saginaw River and Bay, Michigan; Sheboygan River, Wisconsin; and the Grand Calumet

River/Indiana Harbor Canal, Indiana. The ARCS Program is being administered by USEPA's Great Lakes National Program Office (GLNPO).

3.4.4.2 GLNPO has established four technical work groups to conduct the activities under the ARCS Program. The Corps of Engineers is represented on all four work groups: Toxicity/Chemistry, Risk Assessment/Modeling, Engineering/Technology, and Communication/Liaison. Chicago District personnel have participated on and provided key support to the Engineering/Technology Work Group, which is responsible for the development and testing of innovative sediment treatment technologies.

3.4.4.3 A number of activities have taken place through the ARCS Program using GCR/IHC sediments. These activities include extensive sediment chemical and biological testing, the development of a sediment exposure human health risk assessment, and the bench- and pilot-scale testing of several treatment technologies (USEPA, 1991).

3.4.4.4 Several of the ARCS Program activities build upon the work done by the Chicago District for the Indiana Harbor navigation project. Therefore, those ARCS Program activities that closely follow or compliment actions taken in support of the Corps project are discussed in the following sections, where the Chicago District effort is first discussed. Requests for information concerning the ARCS Program should be directed the Great Lakes National Program Office of USEPA.

4. SEDIMENT TREATMENT ALTERNATIVES CONSIDERED

4.1 RATIONALE FOR TREATABILITY EVALUATION

4.1.1 A variety of treatment technologies may be applicable to contaminants in dredged material solids from the IHC, depending on status of development, process effectiveness, and other factors that affect implementation. Before we consider the feasibility of these technologies, we must examine the reasons and justification for making this evaluation. What is the need for sediment treatment? Or, what do we hope to achieve through these technologies?

4.1.2 The environmental concerns over landfilling and the loss or migration of contaminants from active, inactive and abandoned landfills has been the prime motivation behind the creation of strict standards and environmental remediation laws. The volume of waste created by man is staggering. Treatment and recycling are processes that are intended to reduce the volume of this waste which must be disposed and make this disposal more manageable. In addition, the presence of many toxic or persistent chemicals in wastes have led to increasing concerns about their leaching or migration from conventional landfills.

4.1.3 A waste stream (a flow or supply of waste material) is handled and treated in a manner determined by its physical and chemical characteristics. For example, typical municipal household waste contains a heterogeneous mixture of many materials; paper, plastic, glass, iron, tin, aluminum, solvents (including toxic chemicals), food wastes, etc. A technology which can handle one part may do little to, or may be limited by the presence of others. Industrial wastes may also be of many types and components.

4.1.4 The goals of waste treatment are varied, including: to remove and recycle usable materials; to reduce the volume of waste for disposal; to destroy specific contaminants; or to make disposal of the waste more manageable and efficient. They all share the common goal of protecting human health and the environment. The treatment of contaminated sediments can be viewed in light of these goals. Generally, sediments do not contain any one or group of contaminants in high enough concentrations for recovery or recycling to be workable. Even when a particular contaminant is present in high levels, such as iron at the IHC, the presence of the many other contaminants found along with the iron makes recovery impossible or impractical. This goal is therefore not applicable. Since dredged sediments are made of relatively inert material (Indiana Harbor sediments are 84 percent soil particles), there is little that can be done to reduce the volume for disposal. This second goal is therefore not applicable.

4.1.5 The last two goals for treatment identified above <u>may be applicable</u> to many contaminated sediments; the destruction of specific contaminants, and to provide for more manageable disposal. These goals are designed to reduce the amount of contaminants of concern which are disposed and/or to make the disposal of remaining contaminants more effective. In order to determine when treatment is justified and appropriate, we must consider the benefits provided and the costs associated with treatment. These benefits and costs must be quantified and compared with a baseline condition (no treatment).

4.1.6 The goals to be met by a Corps of Engineers maintenance activity such as dredging contaminated sediments from a Federal navigation project are stated in 33 CFR 335.4: "The Corps of Engineers undertakes operations and maintenance activities where appropriate and environmentally acceptable. All practicable and reasonable alternatives are fully considered on an equal basis. This includes the discharge of dredged or fill material into waters of the U.S. or ocean waters in the least costly and most practicable location, and consistent with engineering and environmental requirements." The alternative that meets these criteria is called the "Federal Standard."

4.1.7 The expansion of the list of treatment technologies worthy of consideration as alternatives to open-water disposal of contaminated dredged materials does not make the selection of a technology implicit. The goals of the Corps were stated above as they appear in the Code of Federal Regulations. Restated, the recommended alternative, or Federal Standard, is the least costly alternative that satisfies all environmental requirements and is sound from an engineering standpoint. This goal must remain in the forefront of any evaluation of innovative technologies.

4.2 PROCESS DESCRIPTIONS

4.2.1 Brief descriptions of the four major types of technologies (degradation, extraction, immobilization, and immobilization/ degradation) are provided below. The literature cited and the bibliography should be consulted for detailed descriptions of the technologies. The following information was originally compiled in 1986-88. Many new technologies have been developed or marketed since 1988, since this is a rapidly developing field. Under the ARCS Program, Averett (1990) conducted a thorough literature search of the this same topic. In order to expedite preparation of this document,the Averett report should be consulted for more information on this subject.

4.2.2 Degradation Technologies

4.2.2.1 Degradation technologies are based on thermal, chemical, or biological processes that act to alter the chemical form or properties of contaminants. Degradation technologies are capable of breaking down organic contaminants into a mixture of simple molecules and intermediates that are less toxic or non-toxic, but they cannot degrade metals. Short of nuclear fission, elemental metals cannot be destroyed. Metals can, however, be mineralized or complexed and rendered more or less reactive in aqueous media. Many of the processes described here will alter the mineral form of the metals present in the sediments.

4.2.2.2 Thermal degradation technologies use heat as the primary means to alter the chemical form of waste constituents. Organic compounds can be degraded by a wide variety of thermal methods. Incineration, super critical water oxidation, pyrolysis and wet air oxidation are briefly described below.

4.2.2.2.1 <u>Incineration</u>. Incineration uses high temperature (700 to 1,700 degrees C) thermal oxidation to convert organic wastes to ash and gaseous combustion products. The end product gas of incineration contains primarily carbon dioxide and water vapor plus hydrogen chloride, nitrogen oxides, phosphoric pentoxide, sulfur dioxide, particulates, and products of incomplete combustion. Air pollution control equipment is required. The types of incinerators capable of handling dredged material include multiple hearth, rotary kiln, and fluidized bed incinerators. An onsite rotary kiln is the type of incinerator with the greatest potential for application to dredged material from the IHC.

4.2.2.2.2 The destruction and removal efficiency of an incinerator depends on three factors: temperature, the amount of mixing which occurs between the air and the waste material, and the residence time of the waste material in contact with air in the incinerator. Temperature is affected by the amount of mixing, heating value of the waste, and feed rates for the waste, fuel, and air. Since the heating value (BTU content) of dredged material is too low to sustain combustion, special pretreatment such as dewatering and blending with fuel oil may be required to make incineration feasible. Gravity dewatering requires long holding periods in containment facilities. The alternative, mechanical dewatering may not be practical for high volume projects, such as the IHC deep-draft navigation project. Thus, dewatering requirements significantly impact the technical feasibility of incineration and could be prohibitive.

4.2.2.2.3 Although inorganic materials (metals/salts) oxidize to an extent during incineration, in general they are not destroyed. Consequently, the inorganic materials fed to an incinerator will not be degraded and will require disposal as ash. Oxidation during incineration could render the metals in dredged material more mobile or more reactive in the environment. Since IHC sediments contain elevated levels of cadmium, chromium, lead, and zinc, the ash resulting from incineration could be classified as a hazardous waste. There are two types of ash produced during incineration: fly ash and bottom ash. Fly ash is the ash (particulate matter) entrained in exhaust gases leaving the incinerator and which is usually captured in air pollution control equipment. Bottom ash is the ash remaining in the combustion chamber after incineration. The amount of ash produced during incineration of hazardous wastes is usually very small (< 3 percent) in relation to the total mass of waste incinerated. Dredged material, however, consists primarily of inorganic material. The inorganic material in the IHC sediment is estimated to be one-half of the in-situ sediment volume (Environmental Laboratory 1987). This level of non-destructible reside would result in an enormous amount of bottom ash formation as well as particulate emissions that must be disposed, possibly as a hazardous waste.

4.2.2.2.4 In addition to the potential for generating hazardous waste, other factors to consider about incineration involve system development. Developing the most efficient incineration system with optimal design parameters is a difficult task. At a minimum, an incinerator for the IHC sediments will have to meet the destruction and removal efficiencies established by the USEPA. Compliance is generally determined by a trial burn. Trial burns are expensive and time consuming, and they provide information only on how well the incinerator operates under the conditions of the trial burn. No information is obtained about how performance fluctuates with future changes in operating conditions or waste feed characteristics. Thus, once a unit is approved, there is a need for real-time monitoring to insure effective operation and provisions for corrective action if performance specifications are not met.

4.2.2.2.5 The potential formation and release of dioxin and dibenzofurans, highly toxic organic compounds, in ash and air emissions, is another factor to consider. Recent research addressing the source and fate of dioxins and dibenzofurans in the environment has suggested that incinerators may be a major source of these toxic contaminants (Crummett 1981; Czucza and Hites 1986). Other researchers disagree (Wilson 1986; Eduljee 1987). Thus, monitoring for dioxin and dibenzofurans will probably be required during a trial burn for dredged material from the IHC and possibly during full-scale implementation.

4.2.2.2.6 Pyrolysis. Pyrolysis is the decomposition of organic molecules by heat (1000 to 2000 degrees C) in an oxygen-starved or oxygen-free environment. The process produces a noncondensible gas that is combustible, liquids (pyrolytic oils), and a solid carbonaceous char. The product gases are hydrogen, carbon dioxide, carbon monoxide, methane, and other hydrocarbon gases. Since the product gas is combustible, it can be used as a low BTU fuel. Alternately, the gas can be cleaned with air pollution control equipment (scrubbers and adsorbers) and vented. Pyrolytic oils are complex mixtures of organic compounds that have potential for use as a fuel or chemical feedstock. The char is a combination of carbon and inorganic ash, which for dredged material will be a significant percentage of the feedstock. Pilot-scale experience with soils indicate PCB destruction efficiencies of 99.9995 per cent or better (Carpenter, 1986). The soil in these tests was dried to a moisture content of 3 per cent or less and ground to a 35 mesh particle size. If these values for moisture content and particle size are operational limits for full-scale units, pyrolysis of dredged material will probably not be practical. As with incineration, preprocessing requirements significantly impact the technical feasibility of pyrolysis and could be prohibitive. In addition, the properties and quantity of pyrolytic oils and char cannot be determined without testing of specific dredged material. Disposal of these materials is another factor to consider.

4.2.2.2.7 Supercritical water oxidation. Supercritical water oxidation combines thermal and chemical degradation processes in a technology that utilizes temperatures and pressures of supercritical water (above 374 degrees C and over 22 MPa) to break down organics to primarily carbon dioxide and water. The process is a low-temperature technology compared to incineration and pyrolysis. Chlorine atoms from chlorinated organics are liberated as chloride ions. Normally water-insoluble organics become highly soluble in supercritical water. In addition, oxygen is completely miscible with supercritical water. In contrast, inorganic salts become only sparingly soluble. Laboratory-scale tests conducted with contaminated soils have shown PCB reduction to background levels. One advantage of supercritical water oxidation is chemical processing in a closed system with minimal air emissions. The other major factors to consider include solids disposal after treatment and process equipment development and design. The mobility of the metals in the IHC sediments after supercritical water oxidation is unknown and could present a problem for solids disposal. For full-scale implementation of the technology to dredged material from the IHC, the processing rate must be higher than in presently available equipment. The need for a high processing rate combined with the high operating pressures will require thick wall reaction vessels, special metals for construction, and complex reactor interiors to provide for proper mass transfer and reaction kinetics.

4.2.2.2.8 Wet air oxidation. Wet air oxidation is another technology based on aqueous phase oxidation of contaminants at elevated temperature and pressure. Like supercritical water oxidation, contaminants are oxidized at temperatures that are significantly lower than incineration temperatures. Air emissions are also lower. Wet air oxidation uses temperatures of 250 to 325 degrees C and pressures from 1,000 to 2,000 psig. The process produces a vent gas that may contain volatile organics (requiring removal in air pollution control equipment) and a slurry containing inorganic ash and partially degraded organics. In a typical configuration, multistage reactors are connected in series with the number of units determined by the specific application. Compressed air is pumped into the waste feed which is heated to the level necessary to support oxidation before entry into the reactor. A catalyst can be used to facilitate dissolution of oxygen. Conventional wet air oxidation uses heat and pressure to drive the dissolution of oxygen from air and the reaction with dissolved contaminants. Systems that use a catalyst to enhance oxygen transfer operate at lower temperatures, 150 to 200 degrees C. Lower temperatures mean lower fuel costs and lower capital costs.

4.2.2.2.9 Unlike supercritical water oxidation, the operating conditions for wet air oxidation are below the critical point of water. The lower temperature and pressure result in lower capital costs and fewer operational problems. Wet air oxidation, however, is not as effective in treating relatively insoluble organic chemicals, such as PCBs. Destruction efficiencies for PCBs are around 60 percent. In addition, the process has not been demonstrated for soils or dredged material. Demonstration is important because the contaminants in dredged material must first desorb before they can be oxidized. Although the same is true for supercritical water oxidation, non-polar organics, such as PCBs, are more soluble at supercritical conditions and, thus, more easily oxidized. The other factors to consider for implementation of wet air oxidation to dredged material from the IHC are the same as those for supercritical water oxidation.

4.2.2.3 Chemical degradation processes use oxidation-reduction reactions to break down organic compounds. Sometimes the energy to drive the reactions is supplied in the form of elevated temperature or as ultra-violet light. Metals undergo oxidation-reduction reactions also, but the products still contain metals in a new valence state that may or may not be more toxic or mobile than in the untreated valence state.

4.2.2.3.1 Alkali-polyethylene glycol (APEG) process. APEG dechlorination of PCBs and other organochlorines is a novel chemical degradation technology under investigation by the USEPA. The process involves mixing soil with a hot reagent in a rotating mixer. The reagent is a mixture of polyglycols, alkali hydroxide, and dimethyl sulfoxide. The exact volume and formulation of reagent is varied according to specific soil and contaminant conditions. The dimethyl sulfoxide does not take part in the dechlorination reaction but acts as a catalyst and phase transfer agent to extract PCB from the soil. The dechlorination reaction which involves nucleophilic substitution and free radical formation proceeds rapidly at 70 to 150 degrees C. Non-organochlorine contaminants are not treated. Temperature and reaction time can be adjusted to optimize effectiveness. Reaction times used in laboratory studies range from 30 to 120 minutes. Water content of the dredged material does appear to be a problem, as it affects the viability of the reactants. The water is evaporated, and this affects fuel costs for heating. Several potential problems have been identified that must be worked out before APEG processing technology is feasible for dredged material on a large scale. These include problems with mixer design (mass transfer, reaction kinetics, and solids separation), reagent recovery and disposal, and solids disposal. In addition, the reaction product from APEG dechlorination is organic. Thus, treatment and disposal of the organic contamination remaining in the solids after APEG dechlorination is another factor to consider.

4.2.2.4 Biological degradation technologies use the action of microorganisms or enzymes prepared from microbial extracts to break down organic compounds into presumably less toxic compounds. Many bacterial and fungal strains have been shown to breakdown PCBs, pesticides, and other organic contaminants. The microorganisms may be indigenous microorganisms, conventional mutants, or recombinant DNA products. Varying degrees of treatment have been reported in laboratory studies. These studies, however, have emphasized one target contaminant in otherwise clean material, not degradation of a mixture of contaminants, such as present in the IHC sediments. In a mixture, treatment effectiveness can be significantly reduced by toxicity effects from other contaminants. Degradation rates as indicated by studies conducted on relatively simple systems are not, therefore, reliable indicators of full-scale treatment effectiveness for the mixture of contaminants in the IHC sediments. Biological degradation proceeds at slower rates than thermal or chemical degradation and, therefore, requires longer treatment periods. For slow treatment rates, the residence time in a treatment plant may be longer than is practical with dredged material.

4.2.2.4.1 Biological treatment systems are notoriously susceptible to process upset by a variety of factors ranging from things as simple as a change in flow rates to toxicity effects from other contaminants. Biological treatment processes also require a start-up or adjustment period before the process attains optimum efficiency. During this period process efficiency is usually poor, and organics are only partially degraded. Disposal of the residues remaining after biological degradation is another factor to consider. The residue will contain both organics in varying concentrations (depending on the degree of treatment achieved) and metals at approximately the same level as before treatment. Biological degradation in a treatment plant did not score very high in the rankings because processing rate is low, potential for process upset is high, degradation efficiency for dredged material is unknown, and the technology has not advanced very far beyond the conceptual stage of development.

4.2.2.4.2 There is evidence that PCBs and other organic contaminants are slowly biodegraded in in-situ (anaerobic) sediments (Brown et al, 1987). Biodegradation could, therefore, be important in evaluation of the long-term effectiveness of the containment provided by disposal in a CDF. Conceptually it seems possible to manage and operate a CDF to enhance biodegradation, but this technology is currently undeveloped.

4.2.3 Extraction Technologies

4.2.3.1 Extraction is the removal of chemical constituents from contaminated material with the goal of producing an uncontaminated residue. Extraction technologies use physical and chemical processes to transfer contaminants to another medium, generally a fluid, for treatment and disposal by another set of processes. Stripping, for example, involves transfer of volatile contaminants to a gas stream, and solvent extraction involves transfer to a liquid. Since metals cannot be degraded, they can only be removed and relocated. Sometimes treatment of organic contaminants after extraction can be carried out under more favorable conditions, at lower risk, and at reduced costs.

4.2.3.2 Solvent extraction is the transfer of contaminants from a solid or a liquid to another liquid. Solvent extraction has primarily been used to recover certain organic chemicals from wastewater (liquid-liquid extraction). Application of solvent extraction to mixtures of solids and water such as dredged material is still developmental. For the most part, solvent extraction is based on differential affinity (solubility) of an organic chemical between solvent and the material being extracted. For certain chemicals, a chemical reaction, such as complexation, with the solvent may be possible.

4.2.3.3 Various solvents are potentially applicable to dredged material including alcohols, amines, ketones, glycols, benzene, toluene, kerosene, Freon, and others. The selection of a solvent is a critical element in the design of a solvent extraction process. Finding a solvent that meets all criteria for an optimal system design is a difficult task. Desired qualities include low cost, high extraction efficiency, easy separation from dredged material, no tendency for emulsion formation, nonreactive, and nonhazardous. No one solvent will meet all criteria. For complex solids-water mixtures such as dredged material from Indiana harbor and Canal, laboratory studies are required to determine the best compromise among desired qualities and the best ratio of solvent to material to be extracted.

4.2.3.4 Multiple contact and counter-current flow are necessary design elements for solvent extraction because only a certain degree of removal is possible in a single step. Solvent recovery and ultimate disposal of extracted contaminants are also integral parts of a system design. Solvent recovery, in particular, affects cost and technical efficiency. The other major factor to consider is that solvent extraction, at best, is a process that relocates contaminants to another medium for treatment and disposal by another set of processes. Unless degradation of organics after solvent extraction is more feasible than direct application of degradation processes to contaminated dredged material, solvent extraction may not be cost effective.

4.2.4 Immobilization Technologies

4.2.4.1 Immobilization is physical, chemical, or combined physical/chemical conversion of contaminated material and waste constituents to a form that is resistant to leaching, erosion, biological attack, and other transport process responsible for movement of contaminants in the environment. Solidification/stabilization (S/S) is a technology designed to provide physical immobilization (solidification) by entrapment of contaminated solids in a hardened mass with reduced accessibility of water and chemical immobilization (stabilization) by alteration of the chemical form of contaminants so that they are less soluble and/or less leachable.

4.2.4.2 Solidification is accomplished by adding setting agents that react with water to form a hardened mass, somewhat like concrete. Material converted from a plastic to a solid state is expected to be less susceptible to leaching due to reduced accessibility of water to the contaminated solids within the hardened mass. Typical setting agents include portland cement, lime, fly ash, kiln dust, slag, and combinations of these materials. Co-additives such as clay minerals, soluble silicates, and sorbents are sometimes used with the setting agents to give special properties to the final products.

4.2.4.3 Solidification systems are usually formulated to minimize the solubility of metals by controlling pH and alkalinity. Anions are more difficult to convert to insoluble forms, and most S/S systems rely on entrapment to immobilize anions. Stabilization (chemical immobilization) of organic contaminants against aqueous leaching is generally not thought to occur when portland cement and pozzolan-based systems are used. However, current studies at WES with highly contaminated sediments indicate that these systems may actually reduce the leachability of PCBs. The stabilization processes responsible for reduced leachability are poorly understood at this time.

4.2.4.4 Solidification/stabilization technologies have been field tested in Japan for in-situ treatment of sediments with limited success. The Japanese work has primarily been oriented towards physical immobilization (solidification), not stabilization (chemical immobilization) of toxic chemicals. Although S/S has been applied at field scale to hazardous wastes, there have been no field demonstrations of the technology in the United States using dredged material.

4.2.4.5 Solidification/stabilization systems with potentially useful application to IHC sediments were investigated in laboratory scale studies at WES (Environmental Laboratory 1987). The laboratory studies at WES showed that S/S processing can convert the IHC sediments to a hardened mass. No major technical obstacles to applying S/S technology were found. Chemical leach data showed that S/S reduced the mobility of most metals, depending on the type of setting agents(s) and additive dosages used. Leachability of PCBs, long-term durability of solidified/stabilized products, and factors related to full-scale implementation were not investigated.

4.2.4.6 The use of locally-available industrial byproducts as setting agents for solidifying IHC sediments was investigated by Indiana University Northwest (IUNW) (Unger, in preparation). This study was designed to test whether materials available from local steel mills and power plants could be used to stabilize IHC sediments. These two studies (WES and IUNW) are discussed later in this report.

4.2.4.7 With the completion of the WES and IUNW studies, data gaps will remain to be filled before solidification can be recommended for full-scale application. Areas for additional work include scale-up factors, long-term durability, immobilization potential for PCBs, and local availability of setting agents. Because long-term records on the durability of solidified/stabilized wastes are not available, the major other factor to consider for S/S processing of dredged material from the IHC is the potential for contaminant release due to deterioration of the solidified/stabilized product.

4.2.5 Immobilization/Destruction Technologies

4.2.5.1 Immobilization/destruction technologies are primarily designed to immobilize contaminants but because of unusual aspects of waste processing they also degrade and remove some organic contaminants during the immobilization process. There are two immobilization/destruction technologies considered in this appendix -- vitrification and asphaltic encapsulation.

4.2.5.2 <u>Vitrification</u>

4.2.5.2.1 Vitrification is an emerging treatment technology that is being developed for in-place treatment of soils contaminated with radioactive, transuranic wastes at Department of Energy facilities. The technology uses an electric melt process to convert contaminated soils into a stable glass (vitrification) that has chemical durability properties similar to glass. Implementation involves inserting molybdenum electrodes into soil, placing a conductive mixture of flaked graphite just beneath the soil surface for initial electrical conductance, and applying a voltage of around 4,000 volts. The applied voltage quickly heats the graphite mixture to soil-melting temperatures (1,600 to 2,000 degrees C), and the waste is vitrified as the molten soil zone grows downward. As the soil melts, organic contaminants are pyrolyzed and oxidized, at least in part, on the surface of the hot melt when they come in contact with air. Metals remain in the molten glass and become part of the vitrified product.

4.2.5.2.2 A field-scale unit has been developed and tested that includes a specially engineered electrical power system and an off-gas collection and treatment system. Mathematical simulations predict that the unit can vitrify to a 2 meter depth at 5.5 meter electrode separation and 13 meter depth at 3.5 meter electrode separation. These projections are for soil which is dry compared to dredged material. Vitrification of mechanically dredged material at in-situ water content is thought to be feasible but has not been investigated in laboratory or field tests.

4.2.5.2.3 Vitrification offers significant advantages over the other technologies reviewed in this appendix. It degrades organics while simultaneously immobilizing inorganics in a crystalline form that is resistant to chemical leaching. There are, however, some significant process limitations that must be overcome before vitrification can be implemented. The configuration that has been tested with soils is not applicable to the IHC unless the dredged material is in a confined disposal facility and probably an upland confined disposal facility. This significantly impacts processing rate, cost-effectiveness, and feasibility.

4.2.5.2.4 A plant configuration in which dredged material is vitrified in a batch or continuous flow reactor may be feasible, but this type of application of vitrification technology is in the conceptual stage of development. Other factors to consider for vitrification include the potential for thermal pollution. It may take several months for the vitrified mass to cool, and very little is known about the potential environmental impacts of the cooling process.

4.2.5.3 Asphaltic microencapsulation

4.2.5.3.1 Asphaltic microencapsulation is another technology initially developed for nuclear waste disposal that has been proposed for hazardous waste disposal. Asphaltic encapsulation techniques consist of mixing heated asphalt with contaminated materials to coat (microencapsulate) solids with asphalt. Water and volatile organics are evaporated, and after cooling the processed material is rigid but deformable and resistant to weathering. Asphaltic microencapsulation requires complex, specialized mixing equipment and a trained operations staff to ensure safe, consistent operation. Although no studies have been conducted with dredged material, the limitations of the technology that have been documented for waste processing in the nuclear industry do not appear to apply to dredged material.

5. TECHNICAL SCREENING PROCESS

5.1 TECHNICAL CRITERIA FOR TECHNOLOGY ASSESSMENT

5.1.1 A variety of treatment technologies may be applicable to contaminants in dredged material solids from the IHC, depending on status of development, process effectiveness, and other factors that affect implementation. The status of development ranges from primarily conceptual with little or no experimental basis to ready for field testing with dredged material. Some technologies are specifically designed for contaminants other than PCBs, a contaminant of major concern in the IHC sediment. Some of the technologies involve processes that are ineffective in the presence of water, and some use processes that are ineffective in the presence of turbidity (solids). Since the candidate treatment alternatives differ in their potential applicability to dredged material, a set of factors was selected for comparing and ranking different technologies according to technical feasibility. The selected factors are as follows:

- Safety
- Engineering Feasibility
  - Availability
  - Process Limitations
  - Processing Rate
  - Effectiveness/Efficiency
- Contaminant Specificity
- Reliability
- Other Factors

5.1.2 **Safety** is always an important factor in Corps of Engineers projects. The safety evaluation factor considers those direct hazards associated with implementation of a technology. Both onsite personnel and the general public are part of a safety evaluation. With regard to public health and safety, the major areas of concern are risks associated with hauling material on public roads, accidental releases of chemicals used in treatment processes, and emissions from treatment processes.

5.1.3 The **engineering feasibility** factors address dredged material and process specific factors that impact implementation of a specific treatment technology to dredged material from the IHC. Engineering feasibility is important because of the potential for misapplication of a technology with poor engineering feasibility for dredged material. The important aspects of each engineering feasibility factor identified above are discussed below.

5.1.3.1 **Availability** refers to the status of process development. Implementation of innovative technologies usually requires significant research and development involving bench-, pilot-, and field-scale testing. Data from these tests provide the information needed to design, operate, and maintain full-scale systems.

5.1.3.2 The **process limitations** evaluation factor addresses tolerance for water and limits on contaminant concentrations that can be treated. Bench and pilot-scale testing is needed to determine the impact of these parameters on process performance. Technologies that are conceptually viable alternatives, may be shown to be impractical in bench-scale testing due to process limitations. For example, processes normally applicable to wastewater are usually not feasible for dredged material solids, and processes normally applicable to soils may require dewatering beyond that technically feasible for dredged material.

5.1.3.3 **Processing rate** is also an important factor to consider. Technologies with slow processing rates will require storage of dredged material in containment facilities. Technologies, such as biodegradation, that require holding materials in reaction vessels for times ranging from several days to several weeks may be impractical for dredged material. The effectiveness/efficiency evaluation factor addresses the ability of a technology to accomplish specific process objectives to degrade, remove, or immobilize contaminants. Technologies vary in both theoretical and practical operating efficiency. Theoretical removal efficiency may be very high, but full-scale designs that approach the theoretical may be impractical for dredged material. Important to evaluation of process effectiveness/efficiency is the status of development. Without the appropriate test data, the technical effectiveness/efficiency factor is difficult to evaluate.

5.1.4 **Contaminant specificity** is an important factor because PCBs are not the only contaminants in high concentration in IHC sediments. Technologies that degrade PCBs may not effectively treat other organic contaminants, and technologies specific for metals are not practical alternatives unless the organic contaminants are removed/degraded in a pretreatment process. A series of treatment processes, such as removal/degradation of organic contaminants including PCBs followed by immobilization of metals, will probably be needed to fully treat dredged material from the IHC.

5.1.5 The **reliability factor** addresses the difficulty of operating and maintaining a treatment process. This factor is different from the technical effectiveness/efficiency factor in that a process may be very efficient when it is on line and performing as designed, but due to operational and maintenance difficulties may be on line a small percentage of the time. The potential for process upset and unanticipated contaminant release with subsequent environmental impacts is a major concern for technologies that have not been adequately researched and developed. Since complicated processes are, in general, more difficult to operate and maintain than simple processes, reliability is related to the complexity of the processes that a technology is based on.

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5.1.6 Factors other than those presented above may affect full-scale implementation of a technology. These factors are **technology specific** factors that relate to inherent strengths and weaknesses that are not covered in one of the other technical factors. For example, vitrification produces a hot melt that may take months to cool. Thus, the thermal pollutant potential of vitrified dredged material is a factor that should be considered, but is not explicitly identified in any of the listed factors.

5.2 RANKING OF TREATMENT TECHNOLOGIES

5.2.1 Ranking of alternatives necessitates relative numeric rating of alternatives according to the factors previously described. Ranking also necessitates subjective evaluation of each alternative against an arbitrary ideal meeting all criteria (Carpenter 1986; Cullinane et al. 1986). Overall ranking was accomplished through the use of weighting factors assigned to each rated factor. The weighting factors were as follows:

Factor	Weight
Safety	10
Availability	5
Process Limitations	10
Processing Rate	10
Effectiveness/Efficiency	5
Specificity	5
Reliability	2
Other Factors	5

Guidelines for evaluating the alternatives against the weighted factors were developed to provide a consistent approach to ranking. These guidelines are described in table G-2.

5.2.2 Rankings according to the scheme described above for eighteen (18) selected technologies are provided in table G-3. The rankings fall into four distinct groups as shown in table G-4. The highest ranked group had scores ranging from 79 to 89 out of a possible 150 points. Technologies included in this group were immobilization by solidification/stabilization, solvent extraction, and incineration. The second group (scores from 59 to 67 out of a possible 150 points) included wet air oxidation, polyethylene glycol dehalogenation, supercritical water oxidation, asphaltic encapsulation, pyrolysis, and vitrification. The remaining technologies fell into two groups, group three with scores ranging from 45 to 55 and group four with scores ranging from 25 to 32. In terms of rating factors, the technologies in the highest ranked group differ from the other technologies primarily in terms of availability, process limitations, and

Table G-2: Guidelines for Rating Treatment Alternatives for Dredged Material From Indiana Harbor and Canal

Factor	Rating	Guidelines
Safety	3	Process can be safely constructed and operated without special personnel protection. Process does not involve transportation of materials on public roads. Process operations do not pose public health and safety risks.
	2	Process can be safely constructed and operated. Transportation of materials will not endanger public safety. Process operations do not pose public health and safety risks.
	1	Process can be safely constructed. Material transportation involves low risk hazard to public safety. Process operations involve low level public health and safety risks.
	0	Process cannot be safely constructed and operated or public safety will be endangered. Process operations involve significant public health and safety risks.
Availability	3	Full-scale process commercially available. Proven technology for contaminated soils.
	2	Field demonstrated: has been applied to contaminated soils in full-scale or pilot-scale demonstration projects.
	1	Demonstrable: laboratory studies indicate technology should be considered for field demonstration with dredged material. Additional laboratory and engineering studies may be needed to design and implement the technology.
	0	Conceptual: In theory would treat dredged material contaminants.

(continued)

Table G-2 (continued)

Factor	Rating	Guidelines
Process Limitations	3	Insensitive to moisture content and contaminant limitations or other constituent concentrations.
	2	Slightly sensitive to moisture content and/or contaminant or other constituent concentrations.
	1	Moderately sensitive to moisture content and/or contaminant or other constituent concentrations.
	0	Very sensitive to water content and/or contaminant or other constituent concentrations.
Process Rate	3	Capable of processing mechanically dredged material at dredge production rate.
	2	Capable of processing 200,000 yds of mechanically dredged material in less than one year.
	1	Requires more than one year to process 200,000 yds of mechanically dredged material.
	0	Insufficient information available to estimate process rate.
Effectiveness	3	Demonstrated ability to achieve Effectiveness/ 99.9 per cent of treatment objectives Efficiency/ to degrade, extract, or immobilize contaminants.
	2	Likely to achieve 99.9 percent of treatment objectives to degrade, extract, or immobilize contaminants with proper design, operation, and maintenance.
	1	Not likely to achieve 99.9 percent of treatment objectives to degrade, extract, or immobilize contaminants.
	0	Efficiency unknown or potential efficiency cannot be estimated.

(continued)

Table G-2 (Continued)

Factor	Rating	Guidelines
Specificity	3	None selective, applicable to PCBs, other organics, and metals.
	2	Primarily applicable to organics and partially applicable to metals or vice-versa.
	1	Applicable to metals only or organics only.
	0	Applicable to only one contaminant.
Reliability	3	No probability of process upset when applied to dredged material.
	2	Low probability of process upset when applied to dredged material.
	1	Moderate probability of process upset when applied to dredged material.
	0	High probability of process upset when applied to dredged material.
Other Factors	3	Other factors not applicable or neutral.
	2	Technical factors not covered by factors identified above limit applicability.
	1	Technical factors not covered by factors identified above limit applicability and must be evaluated in engineering studies.
	0	Technical obstacles not covered by factors identified above seriously limit applicability.

Table G-3: Technical Feasibility Ranking of Selected Treatment Technologies for Dredged Material From Indiana Harbor and Canal

-- Evaluation Factors --

Process	Safety (10)	Availability (5)	Process Limitations (10)	Process Rate (10)	Effectiveness (5)	Specificity (5)	Reliability (2)	Other Factors (5)	Total Score
EXTRACTION									
Steam Stripping	2	1	1	0	2	1	1	0	52
Solvent Extraction	2	2	1	1	2	3	2	1	84
Metal Extraction	1	0	1	0	0	1	0	0	25
DEGREDATION									
(Thermal)									
Incineration	2	3	0	1	3	1	2	2	79
Molten Salt	2	1	0	0	2	1	0	1	45
Pyrolysis	2	3	0	0	3	1	0	1	60
Supercritical Water Oxidation	1	1	1	1	2	1	1	2	62
Wet Air Oxidation	2	2	1	1	1	1	1	1	67
(Chemical)									
Ozonation	1	0	0	1	1	1	1	0	32
APEG Dechlorination	2	1	1	1	2	0	1	1	62
UV/Ozone	1	0	0	1	1	1	1	0	32
UV/Hydrogen	1	0	0	1	1	1	1	0	32
(Biological)									
Digestion	3	1	0	0	1	1	0	2	55
Composting	2	1	0	0	1	1	2	2	49
Enzymatic Degredation	3	0	0	0	1	1	0	2	50
IMMOBILIZATION									
Solidification/Stabilization	2	2	2	2	1	2	2	0	89
IMMOBILIZATION/DEGREDATION									
Vitrification	2	2	0	0	2	3	2	0	59
Asphaltic Encapsulation	2	1	1	0	2	3	1	0	62

Table G-4: Rankings By Group

Technology	Group	Rank	Score
Solid/Stab	I	1	89
Solvent Extraction	I	2	84
Incineration	I	3	79
Wet Air Oxidation	II	4	67
APEG Dechlor	II	5	62
Supercritical Water	II	5	62
Asphaltic Encap	II	5	62
Pyrolysis	II	8	60
Vitrification	II	9	59
Biodegradation	III	10	55
Steam Stripping	III	11	52
Enzyme Degradation	III	12	50
Composting	III	13	49
Molten Salt	III	14	45
UV/Ozone	IV	15	32
Ozonation	IV	15	32
UV/Hydrogen	IV	15	32
Metal Extraction	IV	18	25

process rate. The qualities that separate the highly ranked group from the others include demonstrated effectiveness at pilot or field-scale for contaminated soil, practical process rates, and no technical limitations or other factors that bar implementation to dredged material. Technologies in the lowest ranked groups, groups three and four, are characterized by lack of field-scale testing, significant process limitations, impractical processing rates, and poor or unknown reliability. There is no single characteristic or set of characteristics that separates the technologies in the second group from the other technologies. Factors that resulted in a score in the second group were technology specific.

6. LABORATORY TESTING OF SELECTED CANDIDATES

6.1 SELECTED CANDIDATES

6.1.1 Following the completion of the technical screening process described above, four treatment technologies were selected as having the greatest potential for application to sediments from the IHC. The selected candidates included all three members of group I as shown on table G-4, and the highest ranking technology from group II. These final four candidates were chosen based on their high rankings, which in turn were primarily a result of their demonstrated effectiveness at treating contaminated soils on a pilot or field-scale.

6.1.2 Of the four technologies, three were selected for laboratory testing with Indiana Harbor sediments: wet air oxidation, solvent extraction, and solidification/stabilization. Vendors of a wet air oxidation and a solvent extraction process were contacted and arrangements made for bench-scale tests to be performed. Solidification/stabilization studies with Indiana Harbor sediments had been conducted previously by the WES (USACE 1987). Indiana University Northwest (IUN) was contracted to collect sediment samples from the harbor and canal and to perform the solidification tests. Incineration tests were considered, and vendors were contacted, but due to the extremely high costs being predicted for full-scale applications, and the complexity necessary even in a small, laboratory scale test, incineration tests were not conducted.

6.1.3 Sediment samples were collected from the harbor and canal in June 1988 by IUN. A sample representative of the harbor and canal was composited from three samples taken throughout the project. The sediments used in the laboratory tests were taken from this composite sample. A description of this sampling event is given in Appendix E, Sediment Quality.

6.2 BENCH-SCALE TESTS

6.2.1 Wet Air Oxidation Tests

6.2.1.1 Zimpro/Passavant, Inc of Rothschild, Wisconsin was contracted to perform the laboratory tests of the wet air oxidation process on Indiana Harbor sediments. The wet air oxidation process was developed in the late 1950s and early 1960s, and has been primarily used to treat municipal sludges. Other full scale applications have included treatment of paper mill byproducts, explosives, acrylonitrile, and metallurgical coking wastes. Destruction efficiencies for PCBs have ranged from 63 to over 99 percent according to literature on wet air oxidation.

6.2.1.2 Samples were sent to Zimpro in July 1988, and tests were run during August and September. The elevated temperatures and pressures of the wet air oxidation process were simulated in the laboratory by an autoclave. The sediment sample was mixed and then diluted to a slurry concentration that could be input to the autoclave. An optimum temperature for oxidation tests of 320 °C was determined with initial screenings tests, and a series of tests was then run to collect enough end product for analysis. The results of the PCB destruction efficiency tests are summarized in table G-5.

6.2.1.3 The treated solids were then tested according to the EP-Toxicity and TCLP methods, and results demonstrated that they would not exhibit EP-Toxicity characteristics.

Table G-5: Results of Wet Air Oxidation Tests on Indiana Harbor and Canal Sediments

PCB Concentration of Input to Autoclave[1]	PCB Concentration of Output from Autoclave	Destruction Efficiency
619 ug/l	297 ug/l	52 %

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[1] Note: this represents the PCB concentration of the slurried sediment sample input to the autoclave. Zimpro measured the PCB concentration in the bulk sediment sample at 5.1 mg/kg prior to diluting it for test purposes.

6.2.2 Solvent Extraction Tests

6.2.2.1 Resources Conservation Corporation (RCC), of Bellevue, Washington was contracted to perform laboratory tests of their patented solvent extraction technology called the Basic Extraction Sludge Treatment (BEST). RCC developed and patented the BEST process in the mid 1970s, originally intending to use the process to dewater municipal sludges. Recovered solids were high enough in nutrients to be sold as animal feed or fertilizer. The products, however, were not economically competitive and the process was shelved until 1984.

6.2.2.2 Environmental regulation under RCRA caused disposal costs to increase to the point that the BEST process became advantageous from an economic standpoint. RCC began investigating the use of BEST as a method for the treatment of oily sludges, and built its first full scale (100 tons/day) unit in 1985. The BEST process has been tested on sludges from several oil refineries, and was used to clean up PCB contaminated soils and sludge from the General Refining Superfund site near Savannah, Georgia in 1986-87. The BEST process has also been considered for use in the sediment cleanups at New Bedford Harbor, Waukegan Harbor, and Hudson River.

6.2.2.3 The BEST process employs the inverse miscibility properties of aliphatic amines (specifically triethylamine, or TEA) to breakdown suspensions and emulsions in sludges and contaminated soils. This enhances the separation of these materials into distinct fractions: water, oil, and solids. Extraction efficiencies of PCBs from sludges, out of the solid fraction, of over 98 percent have been demonstrated.

6.2.2.4 Bench-scale tests were performed on sediment samples collected from the IHC in June 1988 by Indiana University Northwest. The results of the extraction tests are shown in table G-6.

Table G-6: Results of Solvent Extraction Tests on Indiana Harbor and Canal Sediments

	Concentration measured in:			
Parameter	Raw Sediment	Solid Fraction	Water Fraction	Oil Fraction
Oil (ppm)	20,000	1,000	210	--
PCB (ppm)	7.6	0.5	<0.03	200
Triethylamine (ppm)	--	50	120	2,500

6.2.2.2 The solid fraction product of the extraction test was analyzed according to the EP-Toxicity methods. Results indicate that the treated solids would not exhibit EP-Toxicity characteristics.

6.2.3 Solidification Tests

6.2.3.1 Bench-scale tests of solidification were conducted by the WES in 1985 and by Indiana University Northwest (IUN) in 1989. The two testing programs were conducted to determine if Indiana Harbor sediments could be solidified, if the solidification process helped reduce the leachability of contaminants in the sediments, and if locally available materials could be used as solidification agents.

6.2.3.2 <u>WES Solidification Tests</u>

6.2.3.2.1 The technical feasibility of reducing contaminant mobility in Indiana Harbor sediment by solidification/stabilization was investigated in a series of laboratory-scale applications conducted by the WES in 1985. The processes evaluated differed primarily in the selection of additives used as setting or fixating agents. The additives evaluated were: portland cement, portland cement with fly ash, portland cement with fly ash and/or sodium silicate, portland cement with Firmix (a proprietary additive), Firmix, portland cement with WEST-P (a proprietary polymer), Firmix with WEST-P, and lime with fly ash.

6.2.3.2.2 Sediment samples collected from the harbor in 1985 were mixed with the various additives and cast into different shapes, depending on the analysis to be performed. Each process was applied in three formulations, except for the portland cement mixtures, with four formulations tested. The mixtures were cast into 2 inch cube molds for stabilization tests (unconsolidated strength and strength-time curves), standard USACE 4 inch diameter compaction molds for trafficability tests, and 2.8 inch diameter cylindrical molds for permeability testing.

6.2.3.2.3 Chemical leach tests on the solidified sediments were conducted according to protocols developed during these analysis (Environmental Laboratory, 1987). The leach tests were run on samples taken from the center of the compaction molds, which were broken apart in order to obtain the samples for testing. The samples were ground up to pass a 0.5 mm screen before testing. The leach procedure consisted of contacting solidified sediment samples with distilled-deionized water on a mechanical shaker for 24 hours at varying liquid to solids ratios. After shaking, the mixtures were filtered through a 0.45-micron membrane filters and analyzed for arsenic, cadmium, chromium, lead, zinc, and organic carbon.

6.2.3.2.4 A major drawback in this type of leach testing is inherent in the procedure. The grinding of the solidified sediments down to a particle size less than 0.5 mm in diameter for the preparation of the leachate represents an absolutely worst case scenario that would not occur in the field. A solidified mass of sediments could not realistically be expected to completely breakdown into 0.5 mm particles even under the most adverse environmental conditions. The results of these tests, therefore, must be interpreted as being extremely conservative in their estimation of the amount of contaminants that could leach from solidified dredged material.

6.2.3.2.5 The results of the WES solidification tests demonstrated the feasibility of solidifying Indiana harbor sediments. The 28-day unconfined compressive strength values ranged from 48.5 psi to 682 psi, depending on the additive and dosage used. This indicates that Indiana Harbor sediments can be immobilized into a form similar to soft concrete. The strength versus time curves showed that while the sediments can be solidified, evidence of retardation in set time was being caused by the contaminants in the sediments, most likely the oil and grease. The trafficability tests indicate that the solidified dredged materials could be driven on by tracked vehicles after one day of consolidation. The permeability of the solidified sediments was found to range from 0.000014 to 0.0000067 cm/sec, indicating that the solidification process actually made the sediments more permeable than if they were allowed to consolidate naturally, with no additives.

6.2.3.2.6 The leach test results demonstrated the ability of solidification process to reduce the leachability of arsenic, cadmium, chromium, lead, and zinc. Cadmium and zinc were completely immobilized by some processes, while the leachability of lead and zinc were increased by the fly ash with lime process. No conclusions regarding the ability of solidification to reduce the leachability of organic carbon could be made.

6.2.3.3 IUN Solidification Tests

6.2.3.3.1 Following on the conclusion from the WES tests that solidification of Indiana Harbor sediments was feasible, IUN was contracted to investigate the availability of process waste materials (such as slags or kiln dust) from local industries and to test the feasibility of using these locally obtained materials as additives, with portland cement, for solidifying Indiana Harbor sediments (Unger, et al., in preparation).

6.2.3.3.2 Researchers from IUN contacted various steel making and power producing industries in the northwest Indiana area and collected a database of the types and quantities of their by-products that showed potential for use as solidification additives. From this database of potential additives, two mixtures were selected for testing with Indiana harbor sediments: steel making slag with lime fines, and fly ash with slag and lime fines. The steel making slag was obtained from USX and the fly ash from the Northern Indiana Power Supply Company.

6.2.3.3.3 The solidification additives were mixed with sediment samples collected from the harbor in 1988 and formed into 2-inch cube molds for unconfined compressive strength (UCS) tests and 4-inch diameter molds for durability testing (wet/dry and freeze/thaw tests). The mixtures tested differed in the ratio of sediment to additives and portland cement used. Since the WES tests had demonstrated the ability for solidification processes with similar materials to reduce the leachability of contaminants from the sediments, no leach tests were performed by IUN.

6.2.3.3.4 The IUN report is in preparation. Preliminary results indicate that the locally available materials can be used to achieve strengths of 200 to 400 psi for the UCS tests.

6.2.4 Bench-Scale Tests Conducted Under the ARCS Program

6.2.4.1 The ARCS Program, through the Chicago District, collected 100 gallons of sediment from the upstream-most portion of the navigation channel (where Columbus Drive crosses the Calumet River Branch) for laboratory technology tests. Tests were conducted using the afore-mentioned wet air oxidation and BEST (solvent extraction) processes, as well as the Taciuk thermal desorption process (the technology to be used at Waukegan Harbor Superfund site). Additionally, the Bureau of Mines' Salt Lake City Research Center conducted a series of physical separation tests and metal recovery processes to determine if the volume of contaminated material present at Indiana Harbor could be reduced.

6.2.5 Summary of Bench-Scale Test Results

6.2.5.1 The results of the bench-scale tests conducted on Indiana Harbor sediments indicate that both solvent extraction (BEST process) and solidification are feasible in the laboratory. The BEST process produced a solid fraction with 0.5 ppm PCBs, a reduction of 97.5 percent from the raw sediment levels, and an oil fraction with 200 ppm PCBs. The solid fraction did not exhibit the characteristics of EP-Toxicity. The soldification tests conducted by the WES show that the sediments can be turned into a material similar in strength to soft concrete, and that the potential for leaching of contaminants can be substantially reduced. Research conducted by IUN identified a number of local sources for additives that can be used to produce solidified sediments that have unconfined compressive strengths of 200-400 psi. The test results from the wet air oxidation tests, however, were less than satisfactory, and would not provide the level of PCB reduction that may be desired.

6.3 PILOT-SCALE TECHNOLOGY DEMONSTRATION

6.3.1 The ARCS Program, through the Chicago District, demonstrated a pilot-scale, truck-mounted version of the solvent extraction (BEST) process at Indiana Harbor in July 1992. The treatment unit operated on property provided by USX Gary Works, and the sediments processed through this demonstration project were collected from areas of the Grand Calumet River adjacent to USX property. The results from this pilot-scale demonstration on approximately 250 gallons of GCR sediments is applicable to both the Corps navigation project and the sediment remediation project under the consent decree between USX and USEPA Region 5. Results from the pilot demonstration showed the BEST process was effective at reducing PCB concentrations in the feed sediment by greater than 99 percent.

7. COST ESTIMATES

7.1. Economic considerations play an important role in assessing the feasibility of a sediment treatment technology. As mentioned above, the Corps' regulations on maintenance dredging require consideration of all reasonable disposal alternatives. The recommended disposal alternative will be the least costly option which is consistent with all engineering and environmental requirements.

7.2 The estimation of costs for the application of these technologies to dredged materials has rarely been attempted. The costs given here were developed by the Chicago District and are a compilation of information from reports by Carpenter (1986,1987), Cullinane et al. (1986), and Ebasco (1987).

7.3 BREAKDOWN OF SEDIMENT REMEDIATION COSTS

7.3.1 Traditionally, costs for dredging and disposal projects are given as unit costs, usually dollars per cubic yard of material dredged. This use of unit costs has been followed in previous efforts by Carpenter and Ebasco in development of cost estimates for the treatment technologies presented above, and will also be used here.

7.3.2 This section on cost estimates must be prefaced with a caveat and discussion of the different elements presented herein. A detailed cost estimate of this type, for an entire sediment remediation process, has not been attempted for a project of the magnitude of the IHC. Cost estimates produced for USEPA at hazardous and toxic waste cleanup projects where similar treatment technologies are used typically have an acceptable accuracy of plus or minus 50 percent. The cost estimates provided in this appendix are within this acceptable range of plus or minus 50 percent.

7.3.3 The accuracy of the overall cost estimates depends entirely on the accuracy of the estimates developed for each individual element. The different elements that make up a complete dredging and disposal process are discussed below, and it should be understood that for some of these elements our cost estimating abilities are excellent, due primarily to experience with such operations. For other elements, where little or no experience exists, estimates must be developed based on the best engineering judgment of the cost estimator.

7.3.4 The process of removing contaminated sediments from a waterway and their subsequent treatment and final disposal can be broken down into four basic steps:

a. Dredging
b. Pretreatment
c. Treatment technology
d. Post-treatment

Each of these four steps is absolutely necessary in any treatment process, and each of these steps has costs that impact the overall cost of the project.

7.3.5 Dredging Cost Factors

7.3.5.1 Of the four steps identified above as being part of a treatment process, the costs associated with dredging are the best known and most easily identifiable. This is primarily due to the extensive experience developed by the Corps over the past 100 years of navigation maintenance. The cost of dredging is effected by four variables: the volume and pollution level of the material to be removed, the accessibility of the material, the distance to be traveled during dredging and disposal, and any restrictions that may be placed on the dredging. A more detailed discussion of dredging technologies is provided in Appendix H.

7.3.5.2 Volume of Material Removed

7.3.5.2.1 Economies of scale apply to dredging operations; the larger the absolute quantity of material being removed, the less expensive per cubic yard it is to dredge. The level of contamination of the material being dredged also affects the unit cost; clean material is usually dredged with standard equipment that is readily available, while highly contaminated materials are sometimes removed with specialty dredges and additional contamination control devices such as sorbents and oil booms may be used. The more specialized or complicated the equipment, the greater the unit cost.

7.3.5.3 Accessibility

7.3.5.3.1 Dredging is a mechanical process involving the use of large equipment. The goal of the dredge operator is to spend as little time as possible simply moving the dredge from one location to the next, and to spend the most time in the act of dredging. In waterways with large numbers of obstructions that must be avoided, or great depths from which materials must be removed, or where the areas to be dredged are not contiguous, but instead are isolated pockets located some distance apart, the unit cost of dredging will be greater than a waterway where the materials are easy to reach and close together.

7.3.5.4 Travel Distance

7.3.5.4.1 As mentioned above, the dredge operator wants to spend as much time as possible dredging and as little time not dredging. The distance that must be traveled to unload or dispose of the dredged material directly affects the amount of "downtime" the dredge must incur. When a disposal site is located in close proximity to the dredging site, the travel time is reduced and unit costs are less.

7.3.5.5 Restrictions

7.3.5.5.1 Dredging unit costs are also affected by the time of the year that dredging is allowed to take place. Obviously, weather conditions have a great impact on the ability to dredge. Some waterways may have restrictions placed on them as to when dredging must not take place due to the presence of migratory fish (such as salmon), while others are closed over with ice in winter months. The greater the limitations placed on when dredging can occur, the greater the unit cost.

7.3.6 Pretreatment Cost Factors

7.3.6.1 As with the costs associated with dredging, the costs for the pretreatment of the dredged materials are fairly well known. This is because the processes that may be used to prepare the dredged materials for treatment are existing handling techniques that have been used for manipulating materials similar to dredgings, such as sludges, waste slags, or soils. A certain amount of uncertainty arises from the application of these processes to dredged materials, which have unique physical and chemical properties. The unit costs for the pretreatment of dredged material are affected by storage requirements, the amount of dewatering required, any debris removal, and the rehandling and transportation of materials that may be required.

7.3.6.2 Storage

7.3.6.2.1 As has been discussed above, dredging can be performed most efficiently at a pace that exceeds the rate that the materials can be treated by any of the technologies. A storage facility will have to be constructed to stockpile the dredged materials as they are dredged and before they can be treated. The costs for building confined disposal facilities, which are this type of structure, are well known.

7.3.6.3 Dewatering

7.3.6.3.1 Some treatment technologies, particularly those that involve heat, require that the moisture content of the dredged materials be reduced as much as possible before treatment. This may be accomplished by allowing the materials to air dry as they are held in the storage facility and may be augmented by mechanical methods. The greater the reduction in moisture required, the greater the unit cost.

7.3.6.4 Debris Removal

7.3.6.4.1 Several of the treatment technologies are very sensitive to the size of particle that can enter the reactor or unit. Materials dredged from typical urban and industrial harbors contain a great deal of debris, ranging in size from old cans to large pieces of timber and even car bodies. The dredged materials may have to be sorted and perhaps even ground up to reduce all the particles to a small size. The unit cost will increase with the number of sorting steps and amount of grinding required.

7.3.6.5 Other Rehandling and Transportation

7.3.6.5.1 Depending on the layout and location of the storage facility, the dredged materials may need to be rehandled before being placed into the treatment unit. If the treatment unit and the storage facility are not located adjacent to each other the materials may have to be trucked or trained to the treatment unit. Also, the dredged materials may have to placed in special containers, such as barrels, before being input to the treatment unit. The more extensive the rehandling or the greater the distance traveled, the greater the unit cost.

7.3.7 Treatment Technology Cost Factors

7.3.7.1 The costs associated with the construction and operation of the individual treatment technologies are the least well known when compared to the costs of dredging, pretreatment and post treatment, because none of the technologies under consideration have ever been executed on the scale of the Indiana Harbor project. Experience from the areas of hazardous waste remediation and from traditional civil engineering construction projects can be used in developing the unit costs for the different technologies. These unit costs are affected by the complexity of the process, the size of the physical plant required, the amount and chemical nature of any additives or reagents used, the controls required for any process discharges, the amount of energy used, the size of the labor force needed, and any safety precautions necessary.

7.3.7.2 Complexity

7.3.7.2.1 Some treatment technologies are much more exotic and complicated than others, and will involve the construction of large support facilities including chemical holding areas, different reaction tanks or units, or complex control structures. Other technologies are relatively simple to construct and operate, and are basically modifications or new applications of current technologies (such as solidification).

7.3.7.3 Physical Plant

7.3.7.3.1 The size of the physical plant constructed will vary from one treatment technology to another, and will also depend on the number of different technologies being used at one site. The unit cost of the physical plant will increase with increasing plant size and complexity, and the accuracy of this cost estimate is directly dependent on the similarity of the plant to existing types of plants.

7.3.7.4 Additives and Reagents

7.3.7.4.1 The different treatment technologies depend on the use of chemical reagents or additives in varying degrees. Those that are chemical-intensive (such as solidification) will have a higher unit cost in this area than those that use no chemical additives at all (such as incineration).

7.3.7.5 Discharge Controls

7.3.7.5.1 All of the treatment technologies produce byproducts and discharges that will require some form of control. Complex process involving heat (such as vitrification) will require complicated control devices that will trap any gaseous releases from the treatment unit. Other processes will use chemical reagents that must be carefully contained when being reacted, while others will produce a wastewater stream that must be captured and treated. The more discharge controls required, the greater the cost.

7.3.7.6 Energy

7.3.7.6.1 All of the treatment technologies require some form of energy input to operate them, with some relying extensively on it for the treatment itself (incineration). The amount and form of energy required will determine the cost incurred.

7.3.7.7 Labor

7.3.7.7.1 Larger and more complex process, or treatment processes that involve a great deal of material rehandling will require a larger labor force than those that are more simple or more easily automated. The local availability of labor with the necessary and appropriate skill level will also impact the unit cost.

7.3.7.8 Safety

7.3.7.8.1 Due to their nature, some of the treatment technologies present a greater safety risk to workers or the general public than others. Extensive safety precautions required by a certain technology will increase the unit cost.

7.3.8 Post-Treatment Cost Factors

7.3.8.1 None of the treatment technologies under consideration can completely destroy or remove all of the contaminants present in dredged material. All of the technologies will produce one or more end product that will have to be disposed of or require further treatment before being disposed or discharged. The unit cost for post-treatment will depend on the amount of water treatment required, any air or volatile treatment necessary, the final disposal of the solid material that will always be left over, the treatment of any other fractions or residues that may be produced, and any rehandling or transportation of these end products that must occur.

7.3.8.2 Water Treatment

7.3.8.2.1 Some of the treatment technologies will produce a wastewater that will require treatment before it can be discharged. This treatment may be as simple as filtration to remove suspended solids, or may involve some form or activated carbon adsorption or biological treatment to remove chemical contaminants. Any treatment technology that adds water to the sediments will result in more water needing treatment, increasing the cost per cubic yard of dredged material. Treatment will also be required for the water removed during the storage/dewatering stage.

7.3.8.3 Air or Volatile Treatment

7.3.8.3.1 Most of the treatment technologies will require controls be placed on their gaseous emissions, and the cost of such controls will depend on the nature of the gas stream being contained. Incinerator controls are well developed and the costs for them are known, while the composition of the gases released during the vitrification process is unknown and the controls and treatment of those gases may be costly.

7.3.8.4 Solids Disposal

7.3.8.4.1 Dredged materials are mostly soil particles, and none of the treatment technologies will make those soil particles disappear. One end product that will result from every technology process is a solid fraction requiring final disposal. The type of disposal required will depend on the nature of the solid fraction, which in turn is dependent on the treatment technology. Each of the technologies will produce a solids product that is contaminated with various levels of different chemical parameters. The more contaminated the solids still are after treatment, the more extensive the final disposal will be.

7.3.8.5 Rehandling and Transportation

7.3.8.5.1 As was discussed above for pretreatment, the amount of rehandling required and the distance the final products must be transported for disposal will affect the unit cost. If the storage facility is also used as the final disposal location a substantial cost savings can be incurred by reducing transportation costs. If the end products are in different forms and must be rehandled into discrete packaging material the costs will increase.

7.4 POSSIBLE TREATMENT TECHNOLOGY PROCESSES

7.4.1 Depending on the treatment technology selected, the number and type of supporting processes needed will vary. This section details four possible technologies that could be employed to treat the sediments from the IHC. Each of the processes are centered around each of the four treatment technologies selected earlier as the candidates most likely to be effective with the IHC sediments. The following descriptions identify the different steps that must be taken to remove, prepare, and treat the sediments, and then dispose of the treated end products. Typically technologies are designed to deal with organic (such as PCBs and PAHs) or heavy-metal contaminants. The sediment within the IHC is heavily contaminated with both organic and heavy-metal contaminants, and therefore, it is unlikely that any single treatment technology can adequately treat these sediments.

7.4.2 Incineration Process

7.4.2.1 There are nine different steps that would be taken to incinerate sediments from the IHC. They are identified and detailed as follows:

7.4.2.2 Dredge material

7.4.2.2.1 This step is common to all four processes, with the dredging method potentially differing depending on the treatment technology that forms the center of the process. For the incineration process, mechanical dredging would be a necessity, due to the requirement that the sediments be as dry as possible before being burned. Mechanical dredges can remove sediments from the waterway at or very near their in-place water content, unlike hydraulic dredges, which add up to four times as much water to form a slurry. This would greatly reduce the amount of dewatering that must occur during storage.

7.4.2.3 Store material in CDF

7.4.2.3.1 This step is also common to all four processes, and is necessary because dredging can be most efficiently performed at a rate that exceeds the treatment rate of the different technologies. With mechanical dredging being used, the CDF size will be smaller than that used for storing hydraulically dredged materials.

7.4.2.4 Remove large debris (>12")

7.4.2.4.1 This step, common to all four processes, actually takes place partly during the rehandling of material from the scows and into the CDF, when the unloading crane can be used to separate very large debris (timbers, rocks, car bodies) from the bulk of the dredged material. Further screening of large debris can be done after the materials have consolidated and before or as they are removed from the CDF.

7.4.2.5 Dewater material through underdrain system

7.4.2.5.1 This step is inherent in the operation of any CDF: as the materials are allowed to consolidate during storage in the CDF, the interstitial water that drains from them will be collected in a series of underdrain pipes for treatment and discharge.

7.4.2.6 Treat drained water

7.4.2.6.1 The water collected by the underdrain system will require some form of treatment before being discharged back into any waterway. This treatment may be accomplished with an on-site wastewater treatment facility, or by pumping the water into a nearby sanitary sewer for treatment at the local treatment plant. The treatment of the collected drainage water is common to all the processes, and an on-site plant will be assumed.

7.4.2.7 Rehandle material into incinerator

7.4.2.7.1 This process is centered on an on-site incinerator, built for the burning of Indiana Harbor sediments. Rehandling will involve the removal of the dried dredged material from the CDF by standard earth moving equipment either into trucks or onto a conveyor system for transport to the incinerator.

7.4.2.8 Incinerate material

7.4.2.8.1 The incinerator will be built on site, with a capacity for burning 292 cubic yards of sediments per day. The incinerator and the other three treatment technologies are sized to treat 4 million cubic yards of sediments over thirty years. The incinerator will be a rotary kiln type (see earlier discussion of incinerators). Scrubbers and/or a bag house will be employed to control the gaseous emissions.

7.4.2.9 Solidify ash

7.4.2.9.1 Since sediments are mostly soil particles, a large amount of ash will be left over after incineration. This ash

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will require proper disposal, and since the exposure of the sediments to the high temperatures of incineration may oxidize some of the metals, making them more leachable, the ash will be solidified. A process similar to those considered for the solidification of the raw sediments will be used, employing portland cement and/or additives. The solid materials collected by the air pollution control system (bag house fines, scrubber sludges, etc) will also be solidified along with the ash, and may in fact aid the solidification process.

7.4.2.10 Rehandle solidified materials into disposal site

7.4.2.10.1 The solidified end products will be disposed of in the CDF originally used as the storage and dewatering facility. Rehandling will involve moving the material either by truck or conveyor from the solidification plant to the CDF. The CDF will be capped after filling in all the processes.

7.4.3 Solidification Process

7.4.3.1 Solidification of IHC sediments would be accomplished in nine steps. Those steps, and how they differ from the nine identified earlier for the incineration process, are described below.

7.4.3.2 Dredge material

7.4.3.2.1 While mechanical dredging is not as necessary for the solidification process as it is for incineration, its advantages of delivering the dredged materials to the storage site with minimal added water will be utilized here. The lower water content of the mechanically dredged material will reduce the amount of drainage water collected, and the amount of water that must be treated on-site.

7.4.3.3 Store material in CDF

7.4.3.3.1 This step is the same as described for the incineration process.

7.4.3.4 Remove large debris (>12")

7.4.3.4.1 This step is the same as described for the incineration process.

7.4.3.5 Remove medium debris (>2")

7.4.3.5.1 In addition to removing all large debris, the dewatered dredged materials will be screened to remove any remaining debris larger than 2 inches. Items such as rocks or waste iron scraps could damage the mixers used to blend the sediments with the portland cement and additives.

7.4.3.6 Dewater material through underdrain system

7.4.3.6.1 This step is the same as described for the incineration process.

7.4.3.7 Treat removed water

7.4.3.7.1 This step is the same as described for the incineration process.

7.4.3.8 Rehandle material into solidification plant

7.4.3.8.1 This step is the same as described for the incineration process, with the difference being that the materials will be rehandled into an on-site solidification plant.

7.4.3.9 Solidify material

7.4.3.9.1 A solidification plant will be built on-site with the capacity to solidify 292 cubic yards of dredged material per day. The dredged material will be mixed with portland cement and at least one additional additive, either a locally available product such as slag or fly ash, or a proprietary additive. Testing will be conducted to determine the best additive and the proper ratio of dredged material to cement to additive.

7.4.3.10 Rehandle solidified materials into disposal site

7.4.3.10.1 The solidified dredged materials will not be cast into molds, but instead will be transported back to the CDF in a semi-solid state by trucks, where they will be allowed to harden in layers. This will minimize the amount of surface area exposed, thereby reducing the potential for breakdown or leaching or the solidified material.

7.4.4 Solvent Extraction Process

7.4.4.1 Eleven steps make up the solvent extraction process. The steps, and how they differ from those described earlier for the incineration and solidification processes are detailed below.

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7.4.4.2 Dredge material

7.4.4.2.1 Mechanical dredging will be used for the solvent extraction process, for the same reasons as given in the solidification process description.

7.4.4.3 Store material in CDF

7.4.4.3.1 This step is the same as described for the incineration and solidification processes.

7.4.4.4 Remove large debris (>12")

7.4.4.4.1 This step is the same as described for the incineration and solidification processes.

7.4.4.5 Remove medium sized debris (>2")

7.4.4.5.1 The solvent extraction reactors are also sensitive to large particles, and the dredged materials will have to be screened as they were in the solidification process.

7.4.4.6 Remove small sized debris (>1/2")

7.4.4.6.1 Current configurations of solvent extraction units cause them to be very intolerant of more than pea-gravel sized particles. Therefore, a third screening step must take place to ensure the sensitive extraction equipment will not be damaged.

7.4.4.7 Dewater material through underdrain system

7.4.4.7.1 This step is the same as described for the incineration and solidification processes.

7.4.4.8 Rehandle material into extraction unit

7.4.4.8.1 This step is the same as described for the incineration and solidification processes, with the material being rehandled into an on-site extraction reactor.

7.4.4.9 Extract material

7.4.4.9.1 The extraction plant built on-site will employ the BEST technology, described in the section on bench-scale tests. A plant will be built on-site capable of extracting 292 cubic yards of dredged materials per day. The plant will produce three fractions of material that will be disposed of as described below.

7.4.4.10 Incinerate oil fraction

7.4.4.10.1 IHC sediments have an average oil content of 6.4 percent: at a processing rate of 292 cubic yards per day of dredged material, the extraction plant will produce 3800 gallons per day of PCB-contaminated oil. This oil fraction will be placed into tank trucks and transported off-site, where it will be incinerated.

7.4.4.11 Rehandle solid fraction into disposal site

7.4.4.11.1 The solid fraction from the extraction plant will be handled in a similar fashion to the ash product from the incineration process: it will be solidified with portland cement and/or additives and disposed of in the CDF on-site.

7.4.4.12 Treat effluent and drainage water

7.4.4.12.1 The drainage water collected from the CDF during storage of the dredged materials will require some form of treatment, as it did in the incineration and solidification processes. The extraction plant will produce a water fraction that will also require treatment before disposal. The treatment of both the drainage water and the extracted water will be accomplished with an on-site wastewater treatment plant.

7.4.5 Wet Air Oxidation Process

7.4.5.1 The wet air oxidation of sediments dredged from the IHC will take place in ten steps, detailed below.

7.4.5.2 Dredge material

7.4.5.2.1 The wet air oxidation process can handle input materials that vary widely in solids content from very dilute slurries to relatively dense materials such as mechanically dredged materials. Mechanical dredging will be used for the wet air oxidation process, for the same reasons as detailed in the solidification process.

7.4.5.3 Store material in CDF

7.4.5.3.1 This step is the same as described for the other processes.

7.4.5.4 Remove large debris (>12")

7.4.5.4.1 This step is the same as described for the other processes.

7.4.5.5 Remove medium sized debris (>2")

7.4.5.5.1 This step is the same as described for the other processes that are sensitive to larger particles, solidification and solvent extraction.

7.4.5.6 Remove small sized debris (>1/2")

7.4.5.6.1 As with the solvent extraction units, the wet air oxidation processor is intolerant of larger than pea-gravel sized particles.

7.4.5.7 Dewater material through underdrain system

7.4.5.7.1 This step is the same as described for the other processes.

7.4.5.8 Rehandle material into wet air oxidation unit

7.4.5.8.1 This step is the same as described for the other processes, with the dredged materials being transported into an on-site wet air oxidation plant.

7.4.5.9 Oxidize material

7.4.5.9.1 A wet air oxidation plant capable of treating 292 cubic yards per day of dredged materials will be constructed on-site.

7.4.5.10 Rehandle treated slurry into disposal site

7.4.5.10.1 The product from the wet air oxidation plant will be a slurry of solids and water. This slurry will be pumped into the CDF where it will be dewatered through the underdrain system. The dewatered, treated solids will remain in the CDF for final disposal.

7.4.5.11 Treat effluent and drainage water

7.4.5.11.1 Similar to what will happen in the solvent extraction process, the water collected by the underdrain system and the water effluent from the treatment technology will require treatment before disposal. This treatment will be accomplished by an on-site wastewater plant.

7.5 COST ESTIMATES OF TREATMENT TECHNOLOGY PROCESSES

7.5.1 This section presents cost estimates for each of the elements identified above, and sums them to produce a unit cost for each of the four treatment technology processes evaluated. Before giving each of those unit costs, however, it is important to reiterate that the precision of cost estimates prepared at this stage of a project may fall in a wide range. The USEPA guidance on preparation of feasibility studies allows cost estimates to fall within plus or minus 50 percent. In some instances, the estimates may end up being very accurate when compared to costs incurred. The plus or minus factor is meant to convey the fact that there are a number of uncertainties in the estimates that may not be accounted for (i.e., technological problems, permitting, etc).

7.5.2 As discussed above, the cost estimate on some items, such as dredging, transport, and CDF construction, may be very accurate, due primarily to the extensive experience in constructing these types of facilities the Corps has gained in the past 100 years. On the opposite side, most of the treatment process have never been attempted on either the scale or for the type of materials at Indiana Harbor. In developing these estimates we have attempted to use a mid range figure for the costs. Finally, it is important to note that cost estimates of this type are more suitable for comparing one process to another than for estimating bottom-line costs. We can definitely tell that alternative A is more costly than alternative B, and we have a good idea of the ballpark that both costs are in.

7.5.3 Unit Costs

7.5.3.1 Although some of the treatment processes have common elements such as "Rehandling" or "Treat water", the unit cost may vary from one process to the next because the unit process described in that step may be more complex or involved in one context than it is in another. Also, all of these unit costs include both the capital cost required to build the necessary structures and facilities as well as the operation and maintenance costs that will be incurred as they are in use. Original costs were developed in 1989, and updated to 1993 dollars.

7.5.3.2 <u>Incineration Unit Costs</u>

7.5.3.2.1 The unit costs for each of the elements in the incineration process are:

		<u>$ per cu. yd.</u>
1.	Dredge material	7.59
2.	Store material in CDF	11.93
3.	Remove large debris (>12")	2.17
4.	Dewater material through underdrain system	3.26
5.	Treat removed water	5.42
6.	Rehandle material into incinerator	2.17
7.	Incinerate material	238.50
8.	Solidify ash	53.11
9.	Rehandle solidified materials into disposal site	1.09
	Subtotal	325.24

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7.5.3.3 Solidification Unit Costs

7.5.3.3.1 The unit costs for each of the elements in the solidification process are:

		$ per cu. yd.
1.	Dredge material	7.59
2.	Store material in CDF	11.93
3.	Remove large debris (>12")	2.17
4.	Remove medium debris (>2")	3.26
5.	Dewater material through underdrain system	1.09
6.	Treat removed water	3.26
7.	Rehandle material into solidification plant	2.17
8.	Solidify material	65.04
9.	Rehandle solidified materials into disposal site	1.09
	Subtotal	97.60

7.5.3.4 Solvent Extraction Unit Costs

7.5.3.4.1 The unit costs for each of the elements in the solvent extraction process are:

		$ per cu. yd.
1.	Dredge material	7.59
2.	Store material in CDF	11.93
3.	Remove large debris (>12")	2.17
4.	Remove medium sized debris (>2")	2.17
5.	Remove small sized debris (>1/2")	2.17
6.	Dewater material through underdrain system	1.09
7.	Rehandle material into extraction unit	2.17
8.	Extract material	105.15
9.	Incinerate oil fraction	46.61
10.	Rehandle solid fraction into disposal site	2.17
11.	Treat effluent and drainage water	5.42
	Subtotal	188.64

7.5.3.5 Wet Air Oxidation Unit Costs

7.5.3.5.1 The unit costs for each of the elements in the wet air oxidation process are:

		$ per cu. yd.
1.	Dredge material	7.59
2.	Store material in CDF	11.93
3.	Remove large debris (>12")	2.17
4.	Remove medium sized debris (>2")	2.17
5.	Remove small sized debris (>1/2")	2.17
6.	Dewater material through underdrain system	1.09
7.	Rehandle material into wet air oxidation unit	2.17
8.	Oxidize material	111.66
9.	Rehandle solid materials into disposal site	2.17
10.	Treat effluent and drainage water	8.67
	Subtotals	151.79

7.6 OTHER COSTS

7.6.1 The costs given above for each of the treatment technology processes were summed as a subtotal, indicating that there are other costs in addition to those directly related to the treatment technology that must be considered. These costs are those associated with ordinary engineering or construction projects, and are discussed below.

7.6.2 The additional costs that are calculated as a percentage of the subtotal and added to determine a final total cost are shown on table G-7.

Table G-7: Additional Costs for Treatment Technology Processes

Cost Item	Percentage of Subtotal
Mobilization/Demobilization	25
Engineering & Design	15
Supervision & Administration	8
Process Development	7
Contingency	25

7.6.3 Mobilization/demobilization is the cost incurred during the transportation of necessary equipment to the project site and the setup and breakdown of the equipment. Some equipment may become contaminated during operation and require special handling and disposal after breakdown. Engineering and design is the cost of the design work that will go into the plans for all of the components of the process- the treatment plants, the storage facility, the treatment operation, etc. The eight percent allocated for supervision and administration is a fixed percentage for Corps projects and covers the costs for the personnel who will supervise the overall project to assure that the operation is conducted in accordance with the specifications and administer the contracts.

7.6.4 The final two costs, process development and the contingency fee are the two least well-known of all the costs discussed to date. The costs that will be incurred for process development are very dependent on the specific process being used and the current state of development of that process. This cost will be significant for all the technologies because they all will need to be scaled up to sizes they have never been operated at before. Extensive testing will also have to be done with Indiana Harbor sediments to determine the proper amounts of reagents and chemicals necessary to make the technology work. The contingency fee, which is set at 25 percent, is an attempt to make allowances for any of the other costs being grossly in error. It does not guarantee, however, that the actual costs will be below the estimated total cost.

7.6.5 The unit costs of the four treatment technology processes with these additional costs included are summarized in table G-8. These costs are for the treatment of total dredged material volumes of 4 million cubic yards over 30 years. The Costs for treating smaller volumes would be significantly higher.

Table G-8: Total Unit and Project Costs for Treatment Technology Processes

Technology process	Total Unit Cost, $/cy	Project Cost,$mil[1]
Incineration	585	2,340
Solidification	176	704
Solvent Extraction	340	1,360
Wet Air Oxidation	273	1,092

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[1] Cost for treating and disposing 4 million cubic yards of dredged materials.

8. SUMMARY AND CONCLUSIONS

8.1 The application of sediment treatment technologies to contaminated sediments from the IHC has been examined in detail in this appendix. The technologies have been evaluated and ranked according to their technical feasibility, and the top four candidates were selected for further analysis.

8.2 Three of the top four technologies were tested on a bench-scale in the laboratory with sediment samples from the IHC. The test results indicate that the solvent extraction process known as the BEST process removed 97.5 percent (>99% in pilot demonstration) of the PCBs present in the sediments as dredged and concentrated them in an oil fraction that can be more easily destroyed through a secondary process. Test results also indicate that IHC sediments can be solidified with a number of locally available industrial by-products as potential setting agents. Tests showed that the wet air oxidation process destroyed only 52 percent of the PCBs in the sediments and does not appear to be a suitable candidate for a full-scale process.

8.3 Cost estimates were developed for sediment remediation processes that were centered on each of the four candidate technologies. This cost estimation exercise was the first of its kind to include the complete costs of remediation, from the removal of the material from the waterway by dredging through the final disposal of the treated end products. Costs were shown to range from $176-$585 per cubic yard of dredged material, and are accurate within plus or minus 50 percent.

8.4 In summary, the entire contaminated sediment remediation process must be seen in terms of improving the overall quality of the aquatic ecosystem. The addition of "treatment" to a disposal process will not make environmental impacts go away. Treatment technology applications will have many of the same impacts associated with confined disposal alternatives. Some new impacts may be created by these technologies. The environmental impacts of sediment treatment technologies with dredged sediments have not been fully assessed in any studies completed to date, however, some of the types of impacts can be described.

8.5 As stated above, a CDF will be used in one capacity or another with almost any treatment application. The impacts associated with the construction and operation of a CDF for the IHC maintenance dredgings has been fully described in Appendix F of this EIS. The short-term impacts associated with a CDF would appear to be a starting point for most treatment alternatives. Several treatment technologies require extensive rehandling of the sediments after dewatering. This rehandling may aggravate the contaminant loss from wind blown dust and volatilization of PCBs.

8.6 Some treatment technologies utilize solvents and chemicals which may be reactive, explosive, or toxic. Most of these technologies work under the principle of recycling solvents and chemicals. Some systems are "closed" so that reactive chemicals are contained. All will have some degree of loss and the associated impacts will depend on the amount and the nature of the chemical.

8.7 All treatment technologies will produce a residue which must be disposed. The physical and chemical nature of this residue will vary with the process. Some processes that destroy organic matter may oxidize the inorganic metals which remain and render them more mobile. Others such as vitrification can create a residue which is highly resistant to weathering. The long-term impacts associated with the disposal of the treated residue can therefore vary considerably.

8.8 Since the first consideration of alternatives to open-water disposal of contaminated dredged materials in 1969, the Corps has considered and evaluated the applicability of a wide variety of disposal alternatives for its navigation maintenance projects. The inclusion of technologies that in some way alter or treat contaminated sediments as alternatives for consideration is not as recent a development as it may appear. Other more recent developments, such as the increasing number of remedial actions taking place at Superfund sites throughout the country has brought forth many new and innovative technologies that have expanded the list of alternatives for consideration.

8.9 The underlying reason for considering sediment treatment of contaminated sediments is to improve the environmental performance of their disposal. This might be done either through the destruction and removal of contaminants of concern or by altering the material to make their disposal more efficient. Sediment treatment of these sediments is not required under federal law

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and is appropriate only if found to be the least costly alternative that is consistent with engineering and environmental requirements.

8.10 The environmental impacts associated with any treatment alternative will begin with the same short-term impacts associated with confined disposal. Additional short-term impacts will be dependent on the technology. All technologies will produce a residue requiring confined disposal. The long-term impacts of the disposal of this residue are undetermined.

8.11 Due to the developmental nature of the treatment technologies considered in this appendix, there are no alternatives to confined disposal that are available as "off the shelf" technologies. Most of the technologies reviewed in this appendix do not treat organic and inorganic contaminants in one treatment process, wherein the problem with application of a technology to contaminated sediments lies. A single technology that will completely treat all the contaminants present in IHC sediments does not exist at this time. A series of treatment processes to remove/degrade contaminants would be needed to convert dredged material from the IHC to clean sand and silt. The technologies that do exist can modify or destroy one or more contaminants, but at the same time they produce discharges that may need further treatment, or that are more difficult to deal with than the original contaminated sediment material.

8.12 To date, innovative technologies like those described in this appendix have not been applied on a scale as large as the maintenance dredging proposed for the IHC. Significant time and funds would have to be expended for further development before these technologies could be applied on this scale. Even projects such as the Waukegan Harbor Superfund cleanup only represent a step in the development of technologies large enough to remediate the volumes of material under consideration for remediation at Indiana Harbor.

8.13 The only alternative that meets the requirements of the Corps' regulation, the Federal Standard, is a confined disposal facility. A CDF satisfies the applicable environmental regulations, is sound from an engineering standpoint, and has economic demands that are appropriate for an operations and maintenance activity. The development of new technologies and the refinement and economizing of existing ones is occuring now in both the private and public sectors. As work continues in the cleanup of Superfund and RCRA sites, the efficiency and capabilities of these technologies may become more fully developed. Until such time, the use of innovative treatment technologies for the treatment of the large volumes of contaminated sediments associated with a navigation project will remain unlikely. However, if in the future these technologies are shown to be both effective from the standpoint of treatment and cost, they would be considered for implementation in future disposal operations.

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INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES
IN LAKE COUNTY, INDIANA

APPENDIX H

DREDGING TECHNOLOGIES AND IMPACTS

March 1994
Environmental Engineering Section
Chicago District
U.S. Army Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606

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1. PURPOSE AND OBJECTIVE

1.1 This appendix will describe the history of maintenance dredging at the Indiana Harbor and Canal project, discuss the available dredging technologies, identify the recommended dredging method(s), and define the environmental impacts of maintenance dredging on water quality and aquatic life.

2. HISTORY OF DREDGING

2.1 The U.S. Army Corps of Engineers is authorized by Congress to operate and maintain some 131 navigation projects around the Great Lakes. These projects include major commercial and industrial ports, smaller commercial and fishing harbors, and recreational harbors. Project features that must be maintained include breakwaters and piers which provide shelter from high waves, locks, and navigation channels. The depths and widths to which navigation channels are maintained are prescribed in the Congressional authorization for specific projects. Dredging beyond these channel limits must be done in accordance with all applicable laws and regulations. The Water Resources Development Act of 1990 (PL 101-640), in Section 312, gave the Corps the authority to dredge outside the navigation channel for "the purpose of environmental enhancement and water quality improvement." This section also requires that a local, non-federal, sponsor must provide the funds for 50 percent of the dredging costs and 100 percent of the disposal costs for the dredged material. Aside from projects conducted under Section 312, any other dredging outside the federal channel must be funded by other sources or specifically authorized by Congress.

2.2 In order to maintain navigation channels at authorized depths, the Corps must dredge bottom sediments which accumulate in these channels. Sediments are soils that have eroded from land surfaces, washed off streets and paved areas, or moved along shorelines by littoral processes. Around the Great Lakes the Corps dredges about 4 million cubic yards of sediments annually from authorized federal projects.

2.3 Indiana Harbor and Canal is a deep-draft navigation project located in East Chicago, Indiana. The project features and authorization are described in the EIS. The navigation channel at Indiana Harbor and Canal was dredged almost every year since its authorization as a federal project, in 1910, until 1972. This dredging was performed by the Corps (or its contractors) and by local industries whose docks line the harbor and canal. A summary of maintenance dredging between 1955 and 1972 is shown on table H-1.

2.4 Two trends are evident in the maintenance dredging summary. First, the volume of private dredging at Indiana Harbor and Canal

Table H-1: Summary of Maintenance Dredging at Indiana Harbor and Canal (1955 - 1972)

Year	Dredged Quantity (cubic yards[1]) Corps	Private	Total
1955	105,000	211,000	316,000
1956	105,000	311,000	416,000
1957		215,000	215,000
1958	127,000	433,000	560,000
1959		117,000	117,000
1960		164,000	164,000
1961	262,000	135,000	397,000
1962	141,000	7,000	148,000
1963	163,000	86,000	249,000
1964	91,000	25,000	116,000
1965		201,000	201,000
1966	135,000	90,000	225,000
1967	213,000	290,000	503,000
1972	269,000		269,000
Totals	1,611,000	2,285,000	3,896,000

1 All quantities rounded to nearest thousand.

was more than double the amount of Corps dredging through the late 50's and diminished during the 60's. Secondly, the average annual maintenance dredging volumes decreased from 325,000 cy (1955-1959) to 215,000 cy (1960-1964) to 150,000 cy (1965-1972). There are many possible causes for these trends. Industrial production declined during this period. Also, discharge limitations on industries became more stringent during this period. In 1968 the sediment was characterized as unsuitable for open water disposal. 1967 was the last year that the dredged material was disposed of in Lake Michigan. The 1972 dredged material was placed in the Inland Steel Landfill.

2.5 Maintenance dredging of Indiana Harbor and Canal has not been conducted by the Corps since 1972 because of the lack of an acceptable disposal facility. Since 1972, approximately 1 million cubic yards of sediment have deposited in the navigation channel. Bathymetric surveys of the navigation channel are prepared by the Corps every year. These surveys show that most of the sediment deposition occurred within the first five years, with successive years having less and less additional deposition. In the last few years, very little new deposition has occurred. Sediments are, however, moved from one area to another by river currents and passing ships. During storm events, sediments are "flushed out" into Lake Michigan.

2.6 These depositional trends are typical of the "settling basin" effect of most deep-draft channels located at the mouth of a tributary. The deeper the channel, the more efficiently it acts as a sediment trap. The Calumet Branch of the Canal is the area which receives sediment deposits most rapidly, and 10 to 15 feet of sediments have been deposited there. The main portion of the Canal and Harbor area also have sediment deposits of 5 to 10 feet.

2.7 Once the existing backlog of sediments is dredged from Indiana Harbor and Canal, future sediment deposits will require maintenance dredging. Forecasting future maintenance dredging requirements is typically based on past dredging rates. For Indiana Harbor and Canal this process is complicated by the long time since the last dredging and the many changes to the watershed.

2.8 A crude mass balance model of sediment yield for the GCR/IHC watershed, developed by the Chicago District, is described in Appendix C, No Action Alternative. This model was used to project sediment loadings to the waterway and estimate the settling efficiency of the navigation channel. The annual sediment loading to the GCR/IHC estimated by this method has decreased from 280 million pounds to 182 million pounds due to reductions from point source discharges since the early 1970's. It is estimated that 94% of the total sediment loading to the GCR/IHC is captured by the federal navigation channel, when maintained at authorized depths. From this information, the future sediment deposition in the federal navigation channel (after backlog dredging is completed) is estimated to be between 50,000 and 100,000 cubic yards per year.

3. AVAILABLE DREDGING TECHNOLOGIES

3.1 Dredging is the excavation of soils from the bottom of a waterway. Maintenance dredging may be performed using a variety of different equipment. There are two basic types of dredges; mechanical and hydraulic. Mechanical dredging physically removes sediments by the use of a large bucket or shovel. Hydraulic dredges move the sediments in a water slurry. In addition, there are a number of special purpose dredges for specific applications.

3.2 MECHANICAL DREDGES

3.2.1 Mechanical dredges include the dipper and bucket varieties. Sediments excavated with a mechanical dredge are placed into a barge, hopper, or scow for transport to the disposal location. Mechanical dredging removes sediment with little or no change in water content.

3.2.2 The dipper dredge is basically a barge-mounted power shovel. The dipper is a heavy duty excavator, useful for new work dredging and breaking up hard, compacted material (USACE, 1969). It is not typically used for removing contaminated materials.

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3.2.3 The bucket type of dredge is so named because it utilizes a bucket to excavate dredged material. Different types of buckets can be used to meet differing dredging requirements. For example, dragline dredging is typically a land-based operation, where a bucket scrapes material from the waterway onto the river bank. Draglines are not typically used for removing contaminated materials. Another bucket example is the clamshell dredge used, for the most part, to excavate soft or cohesive sediments and especially useful for deep digging and dredging in close quarters (USACE, 1969). A typical clamshell dredge is shown on figure H-1.

3.2.4 Mechanical dredges will cause sediment resuspension. The physical force of the bucket or dipper impacting the bottom, and the loss of sediments as the bucket or dipper is raised through the water column and emptied into a scow, will cause sediment resuspension. The closed bucket is a Japanese designed modification to the standard clamshell which has been demonstrated to reduce sediment resuspension by 30 to 70 percent (Barnard, 1978). This inexpensive modification involves the welding of plates on the top of the bucket and gaskets or seals on the sides to reduce the loss of sediments as the bucket is raised and moved over the scow. When used by an experienced operator, the amount of sediments resuspended by a closed bucket clamshell can be reduced to levels similar to those caused by a hydraulic dredge.

3.3 HYDRAULIC DREDGES

3.3.1 Hydraulic dredges remove and transport sediment in a liquid slurry form. They are usually barge or ship mounted, and carry diesel or electric powered centrifugal pumps. Cutterhead, suction, dustpan, hopper, and special-purpose dredges are types of hydraulic dredges. In order to move the sediments, hydraulic dredges typically add four or more volumes of water for each volume of in-place sediment removed.

3.3.2 The cutterhead dredge excavates with a revolving cutter surrounding the intake end of a suction pipe (figure H-1). The cutterhead cuts the sediment, which is then drawn into the pipe with a large volume of water. The sediment slurry is transported in a pipeline to the disposal site. Booster pumps are used when the pipeline length exceeds the dredge pump capacity or when a higher pump rate is needed. A suction dredge is simply a cutterhead dredge with the cutterhead removed. Suction dredges are only applicable for removing soft, unconsolidated sediments, with little or no debris (Cullinane et al, 1986).

3.3.3 The dustpan dredge is a hydraulic suction dredge which uses a widely flared dredging head along which are mounted pressure water jets. The jets loosen and agitate the sediment, which is then captured in the dustpan head as the dredge advances (Cullinane et al, 1986). The dustpan dredge is typically used for shallow water dredging in large river channels.

3.3.4 The hopper dredge is a self-propelled seagoing ship with large containers (hoppers) used to store and transport dredged materials (figure H-1). Dredged material is pumped through drag-

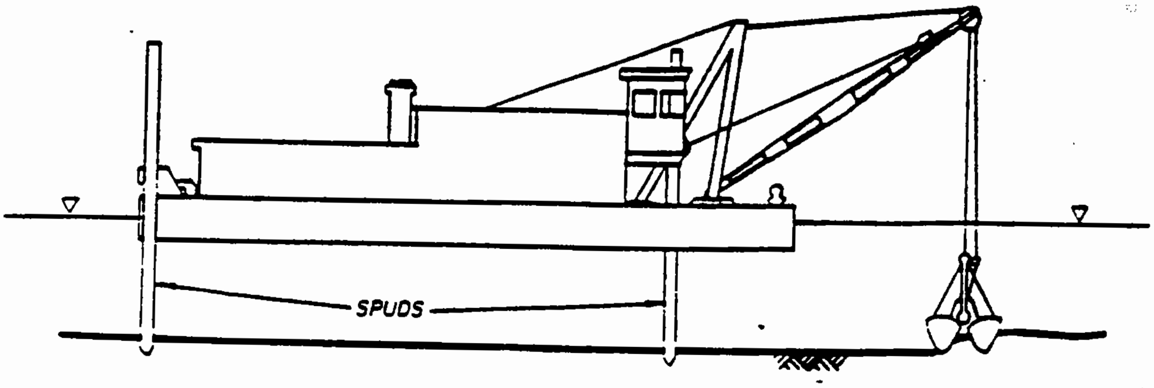

Figure H-1a: Clamshell Bucket Dredge

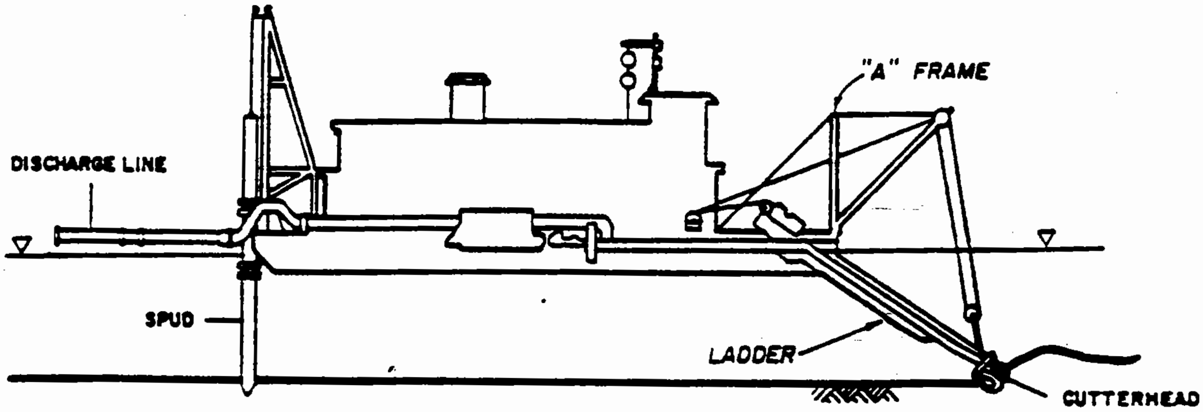

Figure H-1b: Hydraulic Pipeline Cutterhead Dredge

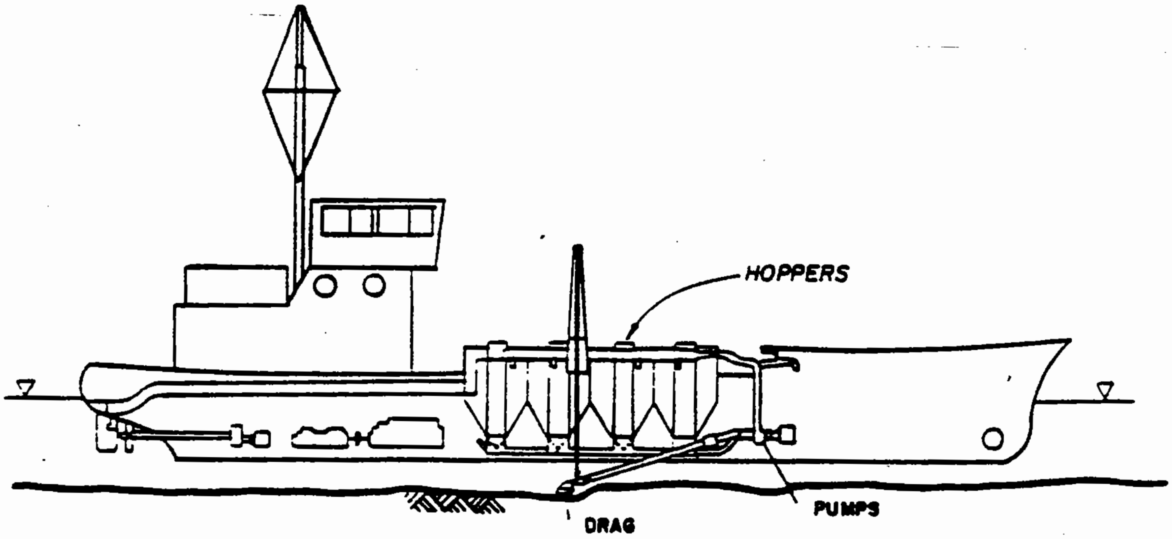

Figure H-1c: Self-propelled Hopper Dredge

Figure H-1: Schematics of Dredging Equipment.

arms and discharged into the hoppers. Hopper dredges are used to dredge large harbors and rivers with ample area to maneuver.

3.4 SPECIAL PURPOSE DREDGES

3.4.1 There are a number of special-purpose hydraulic dredges that have been developed in the U.S. and overseas to pump dredged material slurry with a high solids content and/or minimize the resuspension of sediment (Cullinane et al, 1986). Examples of special-purpose dredges include:

Mud cat dredge
Clean-Up system
Refresher system
Pneuma pump
Oozer pump
Match box suction head

3.4.2 Most of these special-purpose dredges are not designed for use on typical maintenance operations; however, they may provide alternative methods for unusual dredging projects such as those with contaminated sediments. Some have received limited testing or use in this country. Most are capable of very limited production rates (measured in cubic yards per hour) as compared to other conventional dredges.

3.4.3 The Mud Cat is a small, portable hydraulic dredge designed for projects where a 50 to 120 cubic yard per hour production rate is desired (Cullinane et al, 1986). Mud Cat dredges are commonly used for dredging solids from small reservoirs, impoundments, and lagoons. A Mud Cat dredge was field tested at the New Bedford Harbor Superfund site. The results from that demonstration indicated that the Mud Cat may not be more effective in reducing sediment resuspension than a cutterhead hydraulic dredge (Palermo et al, 1988). Field tests of a modified Mud Cat dredge were conducted by Environment Canada in the Welland River during the fall of 1991. A personal communication (Ian Orchard, Environmental Canada) indicated that modification to the Mud Cat did not always reduce resuspension. In some cases, they increased resuspension.

3.4.4 The Pneuma system uses compressed air instead of centrifugal motion to pump a sediment slurry through a pipeline (Cullinane et al, 1986). Although it has been used extensively in Europe and Japan, only one Pneuma-type dredge is available in the U.S. The Oozer pump operates in a manner similar to the Pneuma pump system. The Pneuma and Oozer pumps have capacities similar to smaller, conventional hydraulic dredges.

3.4.5 The Clean-Up, Refresher, and Matchbox are modifications to the cutterhead of a hydraulic dredge. All were designed to reduce sediment resuspension. The Clean-Up and Refresher dredge heads were developed in Japan. The Matchbox is a Dutch designed dredge head.

3.4.6 The Chicago District conducted a dredging equipment demonstration at Calumet Harbor which compared the Match box, suction, and cutterhead dredges for turbidity and production (Hayes et al, 1988). The Match box and suction dredges had comparable results, in terms of turbidity and production.

3.4.7 The performance of any dredge (turbidity and production) is highly dependent on the dredging contract specifications and the skill of the dredge operator. Having more sophisticated equipment does not assure better results than standard equipment used by a skilled operator.

3.5 ENVIRONMENTAL CONTROLS

3.5.1 Dredging causes the resuspension of bottom sediments and associated impacts on water quality and aquatic life. The significance of dredging related impacts vary with the method of dredging, characteristics of the sediments, and the hydraulic and environmental characteristics of the waterway. The impacts of the proposed dredging operations will be discussed later in this appendix. Methods to reduce the impacts caused by dredging will be discussed and their applicability to the IHC considered.

3.5.2 Silt curtains (or turbidity curtains), as the name implies, are large sheets of plastic or synthetic fabric suspended in the water to restrict the lateral movement of sediments resuspended during construction or dredging in a waterway. Silt curtains typically have buoys at the surface and weights at the bottom. Silt curtains are sometimes deployed around the dredge; are not usually extended to the bottom of the channel; and only limit the movement of sediments in the surface layer of the water column.

3.5.3 The application of silt curtains is very difficult in waterways that are narrow or have swift currents. With mechanical dredging operations, the curtains must be repeatedly opened to allow barges to move to and from the dredge.

3.5.4 Because of the narrow channel and highly variable currents in the IHC and the difficulties with deployment around the dredging operation, it is unlikely that silt curtains will have much effect in restricting the movement of resuspended sediment. The potential benefits from the use of silt curtains during the dredging at the IHC, therefore, appear minimal and are not recommended.

3.5.5 Because of the high levels of oil and grease in the IHC sediments, it is likely that an oil film will be produced during dredging. The use of an oil boom and adsorbents to remove this oil from the water are recommended for the IHC dredging.

3.5.6 Oil booms are routinely used to contain oil spills or films on the surface of the water. Oil booms are very similar to silt curtains, except that the boom extends only a foot or two deep in the water. The deployment of oil booms around a dredging operation is problematic but because they do not restrict channel flow like silt curtains, they are viable to contain potentially released oil from dredging.

3.5.7 There are a number of proprietary products available for adsorbing oil or grease contained by an oil boom. These products include bags and pads of granular chemicals that attract oil and

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grease (and associated contaminants), but do not absorb water. If an oil film is expected during a dredging operation, these products could be placed within the area enclosed by the oil boom and periodically replaced as they become saturated with oil.

3.6 SELECTION OF DREDGING EQUIPMENT

3.6.1 The selection of dredging equipment is usually based on a number of factors, including:

Quantity of material to be removed
Character of material (particle size, compaction, etc.)
Physical site restrictions (water depths, channel widths, obstructions, etc.)
Distance to disposal site
Compatibility with disposal operations
Availability of equipment
Cost of equipment use

These criteria will be used to determine the recommended dredging method(s) for Indiana Harbor and Canal.

3.6.2 Quantity of Material to be Dredged

3.6.2.1 There are about 1 million cubic yards of bottom sediments to be dredged from Indiana Harbor and Canal in order to restore navigable depths. This backlog will be dredged in four to six operations on successive years. A typical maintenance dredging operation will remove between 200,000 and 400,000 cubic yards in three to four months. This will require a production rate of about 3,000 to 5,000 cubic yards a day (assuming a six-day a week operation). Conventional mechanical and hydraulic dredges can operate at much higher rates than this if necessary. Most special purpose dredges cannot operate consistently at these production rates.

3.6.3 Character of Material

3.6.3.1 The sediments to be dredged from Indiana Harbor and Canal are predominantly fine-grained soil particles (silt and clay), and are not dense or firmly compacted. All types of dredges could excavate such materials. Aside from the sediments, considerable amounts of debris are expected in the dredged materials. This may include large rock, broken concrete, and wooden pilings from deteriorating embankments, bulkheads, or discarded construction materials. Around docks and unloading areas, pockets of iron ore pellets, coal, or other raw materials can be expected. Many other types of debris are commonly encountered in dredging urban canals, including abandoned cars. The presence of such debris can present significant problems for all types of hydraulic dredges (i.e. clogged intakes and pipes).

3.6.4 Physical Site Restrictions

3.6.4.1 The Indiana Harbor Canal has six bridge crossings, including: three railroad crossings (the first is a cluster of railroad crossings); Dickey Place; Cline Avenue; and Indianapolis Boulevard. The navigation channel, which is generally 130 to 280 feet wide narrows to only 50 feet between the embankments at all railroad crossings and at Canal Street. The channel dimensions of Indiana Harbor Canal would prevent the use of most hopper dredges. The use of a floating or submerged pipeline with any type of hydraulic dredge could create a navigational hazard, especially at narrow bridge crossings. Channel depths would also limit the ability to use a dustpan dredge.

3.6.5 Distance to Disposal Site

3.6.5.1 The distance and mode of transportation to the disposal facility are interrelated. Sediments that are mechanically dredged may be transported to the CDF mechanically (by truck or rail with most upland CDFs or by barges when the CDF is located adjacent or near the water) or may be slurried and transported by pipeline. Hydraulically dredged materials must be piped directly to the CDF. Transporting hydraulically dredged materials by tank truck or rail is prohibitively expensive. If the CDF site is not in the immediate area of the navigation channel, hydraulic dredging or pipeline transportation are generally not feasible. The cost of constructing a lengthy pipeline, coupled with the costs of crossing roads, railroads, and private properties is prohibitive.

3.6.6 Compatibility With Disposal Operation

3.6.6.1 The selected disposal method may limit the applicability of some dredging technologies. For instance, the disposal of clean dredged materials to a nearby beach may be far more easily accomplished with a hydraulic dredge and pipeline than by any mechanical dredge; or, a small CDF may not have sufficient storage volume to allow adequate settling with hydraulic dredging or disposal.

3.6.7 Availability of Equipment

3.6.7.1 The Corps no longer has a fleet of dredges operating on the Great Lakes. As a result, Corps dredging is almost entirely performed by private contractors. A summary of dredging equipment currently in operation on, or staged to be on sites within the Great Lakes is provided in table H-2.

Table H-2: Summary of Available Dredging Equipment on the Great Lakes[1]

Mechanical (bucket size)	Number
< 5 cy	44
5 - 10	18
11 - 15	10
> 15	5
Hydraulic (pump size)	
8 inches	4
10	2
12	5
14	5
16	5
18	1
20	1
> 20	10
Hopper (capacity)	
3600 cy	1
16000	5

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[1] Source: Dredgenet retrieval 6/89.

3.6.8 Cost of Equipment Use

3.6.8.1 Corps dredging contracts are advertised to all dredging contractors and the lowest qualified bidder awarded the contract. The actual costs of dredging bid by contractors takes into consideration all of the factors described above. Dredging costs are usually compared in units of $/cubic yard. Recent costs from Great Lakes dredging are given in table H-3.

3.6.9 Proposed Dredging Equipment

3.6.9.1 Mechanical clamshell dredges are the recommended dredging equipment for the Indiana Harbor and Canal navigation project. Clamshell dredges can have high production rates, are able to remove both sediments and debris, and can navigate in the IHC. Mechanical dredging is compatible with the distance to and operation at all CDF sites considered. Mechanical dredging is especially suited to CDF disposal because it minimizes the amount of water disposed. Clamshell dredging is not the least costly dredging method, but is the most commonly available dredging equipment on the Great Lakes. As a result, there is more competition for such dredging contracts, and more competitive bids.

Table H-3: Comparison of Dredging Costs

Volume (1,000 cy)	Disposal Method*	No. of Operations	Unit Cost $/cu yd
		Hopper	
<100	O	2	9.02
>100	O/C	3	5.96
		Pipeline	
<50	B/C	8	13.49
50-100	B/C	4	8.61
>100	B/C	1	6.74
		Mechanical	
<50	O/U	2	12.61
50-100	C	4	11.93
>100	O/C	4	11.58

Source: USACE Division, North Central. Actual 1989 Costs are updated to 1994 dollars and include contracts for dredging and transportation, preparation of plans and specifications, contract management, and monitoring. Costs do not include confined disposal facility construction/operation/maintenance.

* Code definitions: O = open lake, B = beach nourishment, U = upland, unconfined, C = confined.

3.6.9.2 Mechanical clamshell is the recommended dredging method. Historically, it is the only dredging method used at Indiana Harbor and Canal according to available records. Other dredging methods are not excluded from later consideration and use, if these methods can be made to transport sediments at near insitu water contents, as is the case for mechanical dredging. The Corps will continue to test and evaluate innovative dredging equipment, and demonstrations of such equipment by the Corps are also possible.

3.6.9.3 Environmental controls which are recommended for the IHC dredging include the use of closed-bucket clamshells to reduce the resuspension of sediments, deployment of oil booms when oil slicks are produced by the dredging, and use of adsorbents to remove oil and grease contained by the oil booms. The sorbent materials will be disposed with the dredged materials. As with dredging technologies, the Corps will make every attempt to evaluate and test new and innovative controls as they develop. It is believed that through the implementation of these controls, including the use of experienced dredge operators, the resuspension of sediments can be minimized to levels associated with hydraulic dredges.

4. IMPACTS OF MAINTENANCE DREDGING

4.1 This section will describe the environmental impacts of maintenance dredging of the IHC using the methods described above. Clamshell dredging is the most likely method to be used at IHC for the reasons described above. However, the Corps may use alternate dredging methods depending on equipment availability, changing conditions, or for purposes of demonstrating new or innovative equipment. The Corps will select alternate dredging methods and controls to assure that the impacts are comparable (or less adverse) to those described below. In addition, private industries or other agencies may dredge sediments from the IHC adjacent to the navigation channel for disposal to the Corps proposed CDF. Such dredging will have impacts comparable with those described below.

4.2 Dredging will cause the resuspension of bottom sediments, increase the turbidity and levels of suspended solids in the water column. These impacts are unavoidable, but will be greatly reduced by the use of a closed bucket clamshell. Dredging will remove in-place sediment down to navigation depth and expose the underlying sediment to the water column. Sediment sampling results show that the contaminant concentration within the IHC does not indicate any significant change with depth, except for PCB levels in two reaches. The adverse impact of increased sediment contamination will be short-lived because new sediment will deposit on top of the existing sediment.

4.3 Most dredging impacts are short-term and are localized in the area being dredged. Dredging is not a continuous process. Most dredging operations last about three months and may not occur every year. In addition, dredging is usually confined to one or two locations in the channel at any given time.

4.4 Impacts on Sediments

4.4.1 Dredging will have long-term beneficial impacts and may have short-term detrimental effects on sediment quality in the Indiana Harbor and Canal and adjacent Lake Michigan. The dredging of sediments from the IHC will remove those contaminants associated with the sediments from the aquatic ecosystem. This will eliminate the ability of these in-place contaminants to be resuspended and transported into Lake Michigan.

4.4.2 Restoring the navigation channel to authorized depths will create a sediment-trap capable of capturing and preventing between 50,000 and 100,000 cubic yards of future contaminated sediments from reaching the lake annually. This sediment-trap effect is more fully described in Appendix C, No Action Alternative. The removal of existing contaminated sediment from the IHC and reduction of sediment contamination transported to Lake Michigan should significantly reduce the level of sediment contamination in southern Lake Michigan.

4.4.3 Sediment resuspension caused by dredging will cause some sediment contamination to move downstream. Although resuspension is a contaminant transport mechanism, the resuspended sediment from dredging will likely settle out within 500 to 800 feet of the dredge (USACE, 1988). This is discussed in more detail in impacts on water quality. Most resuspended sediment will be deposited further downstream in the canal or harbor and will be removed by future dredging operation.

4.4.4 A small percentage of resuspended sediments may be transported to Lake Michigan and contribute to the overall sediment transport from the GCR/IHC. The amount of material that may be transported to Lake Michigan during the dredging operation will be insignificant when compared to the amount of material leaving the harbor due to natural sediment transport processes and resuspension from storm events and ship traffic. The adverse impacts from dredging are localized, short-term, and will be minimized by the use of the closed bucket clamshell.

4.4.5 Dredging will remove in-place sediment down to the navigation depth. The existing sediment below this depth will be exposed to the water column. Sampling has been conducted to determine the characteristics of the dredged sediment and the sediment which will be exposed after dredging. Between 1979 and 1984, core samples were collected along the length of IHC from the approach channel to the two branches. The top of the core samples were approximately four feet above project depth on average and the bottom of the cores were approximately five feet below project depth on average. To compare the existing sediments to the surficial sediments exposed after dredging, averages for the sediment concentration above and below project depth were computed. The sediment concentrations for the separate vertical zones (above and below project depth) are shown in table H-4. The results show that the contaminant concentrations within the IHC do not indicate any consistent vertical trends for most parameters, except for PCBs. A general lateral trend of decreasing concentrations from the branches to the harbor is evident as discussed in appendix E. For most parameters, the lateral decrease in concentration is apparent for the sediment above project depth as well as below project depth. As shown in table H-4, the PCB levels in two areas (within the Calumet River Branch and the Canal) have higher concentrations below project depth compared to above project depth. These two areas correspond to the two reaches with TSCA-regulated sediment. The database for PCBs exhibits both vertical and lateral trends.

4.4.6 Additional sampling events have taken place since 1984. The results from samples collected in 1992 and 1993 are shown in table H-5. Only two areas of IHC were sampled in the recent sampling events. Table H-5 compares the recent data with the

Table H-4: Average Concentration Above and Below Project Depth

Area of	Lake George		Calumet River		Forks		Canal		Entrance		Harbor		Approach	
Harbor/	Branch		Branch						channel				channel	
Parameter	APD Ave	BPD Ave	APD Ave	BPD Ave	APD Ave	BPD Ave	APD Ave	BPD Ave	APD Ave	BPD Ave	APD Ave	BPD Ave	APD Ave	BPD Ave
Total Solids, %	60	No Data	34	45	26	46	48	61	60	68	49	64	71	74
Volatile Solids, %	16	No Data	25	15	28	21	21	18	13	11	14	8.3	6.7	3.0
TOC	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	93,000	35,000	40,000	16,000	18,000	11,000
COD	180,000	No Data	230,000	160,000	310,000	210,000	270,000	200,000	42,000	130,000	240,000	130,000	78,000	32,000
TKN	2,000	No Data	8,900	4,100	9,100	5,000	3,800	2,600	390	1,200	1,300	1,100	780	420
Ammonia Nit	340	No Data	3,000	1,800	1,900	1,200	600	590	410	300	380	220	130	14
Total Phosphorus	2,100	No Data	7,800	5,200	7,900	6,100	3,300	2,600	570	910	1,000	800	600	250
Oil & Grease	100,000	No Data	60,000	45,000	97,000	91,000	82,000	64,000	21,000	15,000	53,000	17,000	10,000	430
As	43	No Data	59	40	39	53	66	68	25	26	61	35	15	11
Ba	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	83	71	61	65	43	49
Cd	23	No Data	14	17	12	10	14	13	5.0	4.8	4.7	4.8	4.3	1.0
Cr	300	No Data	1,200	980	850	1,000	330	240	330	120	240	180	120	31
Cu	205	No Data	300	190	380	260	290	170	270	110	250	110	70	30
Fe	81,000	No Data	200,000	330,000	170,000	220,000	200,000	150,000	230,000	180,000	230,000	120,000	72,000	25,000
Pb	3,000	No Data	1,200	1,200	1,000	1,100	1,100	840	610	230	530	260	230	22
Mg	23,000	No Data	9,400	6,000	11,000	9,600	14,000	18,000	No Data	17,000	8,200	19,000	23,000	25,000
Mn	923	No Data	2,700	4,200	2,000	2,500	2,000	1,700	2,000	1,700	2,200	1,100	970	410
Hg	0.8	No Data	1.9	1.0	2.2	1.3	1.8	1.2	0.64	0.43	0.42	0.25	0.18	0.11
Ni	115	No Data	203	80	220	140	96	55	69	51	89	54	30	29
Zn	6,510	No Data	6,200	8,400	4,900	6,600	4,800	4,100	3,300	2,100	3,000	2,000	1,400	94
CN	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	2.2	1.4	1.7	0.61	0.70	0.21
PHENOL	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0.58	0.31	0.24	0.43	0.25	0.45
TOTAL PCBs	3.0	No Data	38	54	23	28	15	33	19	8.2	6.4	3.9	2.6	0.1

Units are mg/kg unless otherwise stated.

"APD Ave" signifies the average sediment concentration for above project depth (sediment to project depth plus 1' overdepth).

"BPD Ave" signifies the average sediment concentration for below project depth. The average sample depth was 2 ft for Calumet River Branch and Canal, 4 to 5 ft for Entrance channel, Harbor, and Approach channel, and 6 ft for the Forks.

The data is derived from core samples collected from 1979 to 1984. Various stratifications of the core samples were analyzed and the analytical results for each sample were averaged for above and below project depths. This table calculates an overall mean for each area of IHC based on the individual sample mean.

Table H-5: Comparison of Sediment Concentration Between Two Sampling Events

	Calumet River Branch				Forks			
	1979-84 Data		1992 & 1993 Data		1979-84 Data		1992 & 1993 Data	
	APD Ave	BPD Ave	APD Ave	BPD Ave	APD Ave	BPD Ave	APD Ave	BPD Ave
As	59	40	66	72	39	53	200	150
Cd	14	17	17	31	12	10	23	15
Cr	1,200	980	650	3,120	850	1,000	190	1,100
Pb	1,200	1,200	1,100	1,400	1,000	1,100	2,200	1,500
Hg	1.9	1.0	1.6	2.1	2.2	1.3	3.0	2.3
Total PCBs	38	54		40*	23	28		36*

Notes:

Units of mg/kg.

"APD Ave" signifies the average sediment concentration for above project depth (sediment to project depth plus 1 foot overdepth).

"BPD Ave" signifies the average sediment concentration for below project depth.

* These concentrations are for the sediment layer below project depth and above till. The till has a substantially lower PCB concentration which ranges from nondetect to 4 mg/kg.

All the data is derived from core samples. The '92 data is a composite obtained from a core sample. For the rest of the data, various stratifications of core sample were analyzed and the analytical results reported above are an average of the stratifications as divided into above and below project depths.

older data for the two areas sampled. With the exception of the parameter chromium and confirmation of PCBs in the Calumet River Branch, the results confirm that no apparent vertical trend is demonstrated in the recent sampling events as with the older data set. The levels of chromium for below project depth is somewhat elevated in comparison to above project depth. Generally, the levels of sediment contamination do not appear to have changed since the time samples were collected over ten years ago.

4.4.7 The adverse impacts of exposure from increased bottom sediment contamination in the PCB areas will be short-lived. A limited number of ways exist in which contaminants associated with sediment can become mobile. Three mechanisms controlling contaminant migration determine the impact of the exposed sediment on water quality. The three ways that contaminants can migrate are by resuspension of the contaminated sediment through storm events and ship traffic, desorption of soluble contaminants from resuspended sediments, and diffusion of soluble contaminants from the in-place sediment interstitial water into the overlying water. The Waterways Experiment Station (WES) investigated and ranked the influence of the three contaminant migration mechanisms on the water quality in the GCR/IHC (USACE, 1989) as discussed below.

4.4.8 Contaminant movement is the greatest from the resuspension mechanism because suspended sediments have a larger surface area than deposited sediment and the migration pathway is more effective. In addition, the activity of resuspension occurs in appreciable quantities in the IHC due to ship traffic and storm events. The second transport mechanism, desorption from resuspended sediments, is a function of the first mechanism because resuspension must occur before desorption can take place. Contaminant transport by diffusion is minimal compared to the other two mechanisms because the contaminant must desorb into the sediment pore water and slowly diffuse through pore spaces into the overlying water column (Lerman 1979, Berner 1971). The mechanisms in order of relative importance to contaminant migration are 1) Resuspension, 2) desorption from resuspended solids, and 3) diffusion. The WES study determined that release of contaminants from newly exposed sediment after dredging, which models the diffusion mechanism, provides the least impact on water quality.

4.4.9 As mentioned above, dredging and maintaining the navigation channel will cause the canal to act as a sediment trap and reduce the sediment loadings to the lake. Maintaining the channel at project depths will eliminate resuspension from ship traffic and reduce the effects from storm events. These two actions create the largest amount of contaminant transport which is caused by the resuspension mechanism and desorption from resuspended solids mechanism. It is estimated that after dredging the IHC, 50 to 70% of the loadings will settle in the IHC and be removed by future maintenance dredging activities rather than migrate into the lake. Although dredging will not lessen the impacts from the third mechanism, diffusion is the least effective contaminant transport mechanism and minimal compared to the other two. In addition, sedimentation in the IHC will relatively quickly cover the elevated PCB areas, as discussed below, thereby preventing migration of PCBs into the water column.

4.4.10 The restoration of the channel to authorized depths will promote the settling of sediment coming from upstream and local sources. Bathymetric soundings of the navigation channel since the last dredging in 1972 indicate that 10 feet of sediments deposited in the Calumet River Branch of the canal within the first four years (see figure C-2, Appendix C, Not Action Alternative). The expected rates of sedimentation in the IHC system after dredging was calculated from examining historical soundings. Based on the historical information, exposed sediment should be covered by more than 2 inches of new material in one year. Further discussion is presented in appendix Q, Sediment Investigation and Dredging Plans.

4.4.11 In conjunction with USEPA, the Chicago District developed a continuous period simulation model to analyze hydrologic and hydraulic impacts of dredging the Grand Calumet River. The model calculated velocity profiles of the system. Using this information, it was determined that dredging will not cause upstream sediment to erode and be subsequently transported and deposited in the Federal channel (see appendix Q). Having the same sediment sources after dredging as before, the contaminant levels in the new sediments which enter and deposit in the recently dredged channel are expected to be similar to those of the in-place surficial sediments. In the short-term, with implementation of more stringent source controls and upstream remediation under the Remedial Action Plan (RAP) for the IHC/GCR, future sediments will become even less contaminated than existing surface deposits. Dredging and other planned remedial activities will remove the source of contamination which is the sediments. In addition to activities in the RAP, USEPA enforcement actions have been implemented to ensure that regulatory compliance and desired environmental improvement are attained in the IHC. In the long term, with the completion of remedial activities, the depositing sediment should be substantially cleaner than the existing sediment.

4.5 Rationale for Dredging TSCA-Regulated Sediment

4.5.1 Dealing with TSCA-material is problematic and experience in dredging and confined disposal of such material is limited. The option of leaving the material in-place was considered. However, dredging is likely to impact the nature of the exposed sediment by causing physical movement of sediment. Sloughage or movement of sediment from outside the dredging area into the dredged channel will occur when the shoaled area is cut into. The material bordering the dredged area becomes unstable and slides into the dredged channel. Therefore, it is impractical to leave the TSCA-material in place. In addition, a remediation benefit is gained by removing these sediments from potential migration to Lake Michigan. A systematic approach has been established to remove the sediment from the two reaches containing TSCA-regulated PCBs.

4.6 Impacts on Water Quality

4.6.1 The dredging of the IHC and maintenance of the channel at authorized depths will remove about 1 million cubic yards of existing, in-place contaminated sediments and prevent the transport of 50,000 to 100,000 cubic yards of future contaminated sediments to Lake Michigan each year. The levels of suspended contaminants in the IHC and ultimate transport to nearshore Lake Michigan will be reduced by the sediment-trap effect. These reductions will be most prominent during rainfall events. Secondary impacts include long-term improvements to the water quality of nearshore Lake Michigan resulting from the reduced loadings of sediment contaminants. The adverse impacts of no action which will be reduced by maintenance dredging are more fully described in Appendix C.

4.6.2 Dredging will cause temporary and localized increases in the levels of suspended solids and turbidity in Indiana Harbor and Canal. The turbidity plume created by a dredge is influenced by the dredging methods and the hydraulics of the waterway. Monitoring conducted by the Corps during a dredge equipment demonstration at Calumet River and Harbor (USACE, 1988) showed that the plume created by dredging contaminated sediment with a standard clamshell was approximately 500-800 feet long. Samples collected near the bottom of the water column within 50 feet of the dredge ranged from 540 to 49 mg/l suspended solids. Samples collected farther from the dredge and higher in the water column contained levels of suspended solids only 2-4 mg/l greater than background. Because the physical parameters of sediment from Calumet Harbor and IHC and the hydrodynamic conditions at both sites were similar, the field evaluations should be directly applicable to Indiana Harbor.

4.6.3 The length of the turbidity plume caused by dredging at the IHC is difficult to predict because of the highly variable flows in this waterway which are composed largely of industrial discharges, municipal discharges, and lake water (see Appendix Q). Based on available information, it is expected that turbidity should approach background in a distance of less than 1,000 feet. The use of a closed bucket clamshell will reduce the turbidity caused from dredging by an additional 30 to 70 percent over that of a standard clamshell (USACE, 1978). The turbidity of the water column around the dredging operation will be monitored to determine if the dredging operation is causing any unacceptable levels of resuspension. If necessary, modifications could be made to the operation to lower the levels if unacceptable levels are reached. A discussion of monitoring is included in appendix N, Monitoring Plan.

4.6.4 Sediment resuspension will cause increase in the levels of particulate contaminants proportionate to the levels of suspended solids. Relatively few sediment pollutants are readily released into solution during resuspension. The levels of dissolved nitrogen compounds (predominantly ammonia) may be increased to five or more times the background level immediately around the dredge. Some metals (manganese and iron) and trace organics (phenol) may exhibit smaller increases in dissolved concentrations. Dissolved concentrations should rapidly diminish downstream of the dredge.

4.6.5 The dredging may increase the oxygen demand upon the water column in two ways. Sediments that are uncovered by dredging to navigation depths may exert a higher sediment oxygen demand than the existing surface sediments. This impact will continue until the new surface sediments are oxidized or are covered by incoming sediments. Sediment resuspension will increase oxygen demand in the vicinity of the dredge, which may result in localized dissolved oxygen reductions.

4.6.6 A small amount of the oil and grease in the sediments will be released by resuspension during dredging and form a film or sheen on the water surface. Hydrophobic contaminants, such as PAHs and PCBs, will be dissolved in this oil and grease. The migration of this oil film will be minimized by the use of an oil boom and adsorbents to remove the contained oil and dissolved contaminants.

4.6.7 The impacts to water quality from the dredging operation as described here will not be significantly different than those already occurring during storm events and from ship traffic. However, the impacts from dredging cause localized effects in the vicinity of the dredge, whereas the other two impact a much larger area. The new, long-term benefits to the water quality of the IHC and Lake Michigan far outweigh any short-term impacts.

4.7 Impacts on Aquatic Life

4.7.1 Maintenance dredging will remove 1 million cubic yards of existing, in-place contaminated sediments from the IHC and prevent the transport of 50,000 to 100,000 cubic yards of future contaminated sediments to Lake Michigan each year. The overall exposure level of the aquatic life of nearshore Lake Michigan to sediment contaminants should be significantly reduced. The adverse impacts of no action which are reduced by maintenance dredging are more fully described in Appendix C.

4.7.2 The excavation of bottom sediments will permanently remove existing benthic organisms from the IHC. This benthic community is generally composed of pollution-tolerant organisms in high abundance and low diversity. Recolonization would occur within a few years in the newly exposed sediments and the future deposition. With implementation of the RAP, future deposits will be less contaminated and be able to support less pollution-tolerant benthic organisms. This may enable the harbor and canal benthos to achieve a higher diversity of aquatic species.

4.7.3 The physical operation of the dredge (noise and increased turbidity) may disturb the activities of local fish populations, attracting some species, and dispersing others. In particular, Carp and Gizzard shad may be attracted to the dredging operation for the food particles resuspended. Some fish may be captured, injured or killed by physical contact with the dredging equipment. Turbidity alone is not a significant stress to the fish species commonly found in the IHC. The resuspension of sediment and food particles will increase the availability of contaminants to visiting and local fish populations and subsequently result it a temporary increase of the potential for bioaccumulation and toxic effects.

4.7.4 Localized degradation of water quality around the dredge may be severe enough to cause death of some fish. In particular, increased levels of ammonia and reduction of dissolved oxygen may cause acute toxicity effects to some fish. However, those fish more likely to be attracted to the dredging activity are more pollution-tolerant. Less pollution tolerant fish are likely to avoid the disturbances of the dredge and its localized water quality impairments.

4.7.5 Oil released by sediment disturbance will cause some surface slicks. These slicks would not be thick, but would be a thin film (monolayer) and should be contained in the immediate area encircled by the oil boom. Fish should not be affected by these slicks to any significant degree and the removal of the oil by the use of absorbents should minimize effects on other organisms.

4.7.6 Dredging to navigation depths will expose sediments having higher levels of a few contaminants (specifically PCBs) than the existing surface sediments. Benthic organisms that recolonize these sediments may accumulate higher levels of PCBs. This impact will be short-lived for a number of reasons. Exposed sediments should be covered with a thin layer (inches) of "new" sediments within one year. The ability of benthos to recolonize the exposed sediments and accumulate contaminants in such a short time is limited. With the implementation of the RAP, future sediment deposits should have less contamination. Benthos and fish populations in the IHC should be less exposed to toxic and bioaccumulative sediment contaminants.

4.8 Secondary and Cumulative Impacts

4.8.1 Maintenance dredging will remove sediment deposits from dockage and unloading areas around local industries. This will enable vessels to reach dockside before unloading, reducing the amount of raw materials spilled. Currently, ships and barges must "plow" through sediment deposits to approach docks. This causes significant resuspension of contaminated sediments. Dredging to authorized depths will greatly reduce the amount of sediment resuspension caused by all ship traffic.

4.8.2 The maintenance of the navigation channel will restore an important resource to local industries. The existing navigation use of the channel and the value of this resource to local industries is more fully described in Appendix B, Waterborne Commerce. A secondary impact of the maintenance of this navigation channel is the potential growth and development of new commerce and industry in this area. This additional commerce/industry may create new discharges to the air and the waterway. These discharges would have to comply with federal and state environmental regulations, and should therefore have no significant impact.

4.8.3 The cumulative impacts of maintenance dredging will be significant reductions to the amount of sediment contamination in southern Lake Michigan. In conjunction with other source controls and remediation planned as part of the RAP, the environmental quality and beneficial uses of the IHC and Lake Michigan will be restored.

5. SUMMARY

5.1 Dredging is necessary to remove sediments that accumulate in channels in order to maintain adequate depths for navigation. Between 1955 and 1972, nearly 3.5 million cubic yards of bottom sediments were dredged from Indiana Harbor and Canal by the Crops and private industry. Presently there is about 1 million cubic yards of sediment in the navigation channel which must be dredged to restore the channel to authorized depths. Once this backlog is dredged, an additional 3 to 4 million cubic yards of sediments will require maintenance dredging over the next 30 years.

5.2 Available dredging technologies and environmental controls have been examined and their feasibility at the Indiana Harbor project considered using a number of criteria including, quantity and character of sediments to be removed, site restrictions and distance to disposal area, compatibility with disposal operations, availability of equipment, and cost.

5.3 The recommended dredging method for the IHC is by closed bucket clamshell. This method can work at high production rates, removes both fine-grained sediment and debris, is able to work in close quarters and around bridges, and requires equipment readily available on the Great Lakes. This method is especially suited to use with an upland CDF, since mechanical dredging can deliver sediments with a minimal amount of water. The less water associated with the sediments, the less water has to be collected and removed from the disposal site. The closed bucket modification is designed to reduce sediment resuspension. Environmental controls to be employed around the dredging include the use of an oil boom and adsorbents to contain and remove any surface oil film.

5.4 The impacts of maintenance dredging on sediment and water quality and aquatic life have been described above. Unavoidable adverse impacts include short-term, localized increases in suspended solids, turbidity, and dissolved pollutants (most significantly ammonia), and reductions in dissolved oxygen. However, resuspension caused by dredging is minimal when compared to resuspension which occurs presently due to storm events and ship traffic. Generally during dredging, resuspended sediment will settle out within 500 to 800 feet of the dredge.

5.5 These water quality impacts from maintenance dredging may result in short-term, localized adverse impacts on aquatic biota. Benthic organisms currently inhabiting bottom sediment will be removed. However, most of these adverse impacts will be minimized by the use of proper environmental controls (closed bucket, oil boom, and adsorbents).

5.6 Dredging will remove in-place sediment down to navigation depth, thus exposing the underlying sediment. Sediment sampling results show that the contaminant concentration within the IHC does not indicate any significant change with depth, except for PCB levels in two reaches. The sediment in these two reaches are TSCA-regulated because the PCB concentrations are greater than 50 ppm. Because experience in dredging and confined disposal of TSCA-material is limited, leaving the material in-place was considered. However, dredging is likely to impact the nature of the exposed sediment by causing physical movement of sediment due to sloughage. To prevent the potential migration to Lake Michigan, a systematic approach has been established to remove the TSCA-regulated sediment.

5.7 After dredging, the exposed sediments will exert a higher oxygen demand and expose benthic organisms recolonizing the area to higher levels of PCB contamination. These impacts will be short-lived due to the rapid sedimentation in the channel which should cover the exposed sediments with more than two inches of new sediments within one year.

5.8 The proposed dredging will have highly significant, long-term beneficial impacts on the environmental quality of the IHC and adjacent Lake Michigan. Dredging will remove 1 million cubic yards of existing and 3 to 4 million cubic yards of future contaminated sediments from the aquatic ecosystem. If the channel is not dredged, some of the existing sediments and nearly all of the future sediments would migrate out of the IHC and be dispersed in Lake Michigan.

5.9 Maintenance dredging will prevent the release of hundreds of thousands of pounds of sediment pollutants to Lake Michigan. The magnitude of these benefits to the Lake environment are difficult to measure. However, it is clear that these benefits out weigh the unavoidable, adverse impacts caused by the dredging.

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INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES
IN LAKE COUNTY, INDIANA

APPENDIX I

EFFLUENT PRETREATMENT

March 1994
Environmental Engineering Section
Chicago District
U.S. Army Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

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INDIANA HARBOR & CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES IN LAKE COUNTY, INDIANA

APPENDIX J

TOXIC SUBSTANCES CONTROL ACT APPLICATION PROCEDURE FOR A 40 CFR 761.60 (a) (5) ALTERNATIVE DISPOSAL APPROVAL

April 1995
Environmental Engineering Section
Chicago District
111 North Canal Street
Chicago, Illinois 60606

8.39

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1. PURPOSE

1.1 This appendix will describe the environmental impacts of discharging the CDF effluent to the Wastewater Treatment Plant (WWTP) at East Chicago, Indiana. The effluent is comprised of drainage from sediments mechanically disposed into the proposed CDF at the ECI site. The treatment processes utilized at the East Chicago WWTP and the permit requirements for discharge to this plant will be described. The predicted quality of the effluent prior to any treatment is presented in Appendix F. This information will be compared to the pretreatment limitations for the East Chicago WWTP to determine the level of treatment necessary before discharge to the sanitary sewer. A waste stream will not be permitted unless it is in complete compliance with the district limitations.

1.2 Several treatment process options which may be used, if required to bring the effluent quality into compliance with the pretreatment limitations will be described. The impacts of the proposed discharge upon the processes used at the East Chicago WWTP will also be described. Attached to this appendix is the completed application to be submitted to the East Chicago Sanitary District by the U.S. Army Corps of Engineers, Chicago District (USACE), for a wastewater discharge permit for the effluent from the CDF.

2. OVERVIEW OF THE EAST CHICAGO WWTP

2.1 The WWTP located in the City of East Chicago, IN receives both sanitary and stormwater flows from this municipality. The effluent from this plant is discharged to the West Branch of the Grand Calumet River which flows to Lake Michigan and to the Calumet River, with most of the flow going to Lake Michigan. The East Chicago WWTP has undergone recent construction which has brought the plant into compliance with the discharge limitations as specified in the National Pollutant Discharge Elimination System (NPDES) permit issued to the East Chicago Sanitary District on October 25, 1987. These discharge standards include a monthly average for total suspended solids (8.5 mg/l), carbonaceous BOD_5 (7.1 mg/l), ammonia-nitrogen (1.5 mg/l), and total phosphorus (0.1 mg/l).

2.2 The East Chicago WWTP is a Class IV activated sludge facility with an average flow of 15 million gallons per day (mgd). The peak hourly design flow is 27 mgd and the maximum instantaneous flow is 36 mgd. The various plant processes are described below.

2.3 Upon entering the plant, the wastewater flows totally by gravity. Screening of large objects and debris is provided by two influent climber bar screens with a manually cleaned bar screen as a backup. After screening, the influent velocity is slowed within two aerated pista grit chambers for removal of quickly settling particles (grit). The grit is deposited in a storage hopper and is dewatered by the use of a grit screw conveyor. The screenings and dewatered grit are transferred by conveyor belts to truck loading areas for ultimate disposal to a landfill.

2.4 The wastewater is directed through two oxidation ditches, along with return activated sludge, to provide biological treatment. This process utilizes the action of bacteria to consume organic contaminants. These oxidation ditches are capable of holding 8.4 million gallons. The oxidation process results in the removal of BOD and the elimination of ammonia-nitrogen through nitrification.

2.5 The effluent from the oxidation ditches is transferred to final clarifiers for the settling of solids. There are five 100-foot diameter final clarifiers which slow the wastewater flow to allow for sedimentation. These final clarifiers are peripherally-fed and the solids settle out to the bottom of the tanks by gravity. The clarified effluent is discharged over a V-notch weir system at the top of the clarifier. Part of the settled sludge is returned to the oxidation ditches to maintain the bacteria population needed for the biological treatment of the wastewater. The excess clarified sludge is sent to two belt press filters for dewatering. These belt press filters squeeze excess water from the sludge to a dry solids content of about 20%. The dewatered sludge is transferred by conveyor belts to the truck loading area for ultimate disposal in a landfill. The belt press filters have the total capacity to process 11,000 pounds of dry solids per day. Scum removal is provided at the final clarifiers and separated in the dewatering building by use of a gravity separator.

2.6 The wastewater flows from the final clarifiers to sand filters for further polishing treatment. There are six sand filters which furnish a total filter area of nearly 6,000 square feet. These sand filters are backwashed automatically.

2.7 The effluent from the sand filters is disinfected for the destruction of pathogenic (disease-causing) organisms before discharge to the Grand Calumet River. This disinfection is accomplished through the use of ultra-violet light. The use of an ultra-violet disinfection system is preferable over utilizing chlorine for a variety of reasons. One disadvantage with chlorine disinfection is that it requires the maintenance of a chlorine residual in the plant effluent, which results in the introduction of free chlorine into the natural waterway. Free chlorine is highly toxic to most forms of aquatic life, and also has a tendency to form other compounds, some of which are carcinogenic (cancer-causing), such as chloramines. The storage and use of chlorine is also a hazardous situation that requires special safety precautions. The disinfection system consists of two ultra-violet units, each designed to disinfect a maximum flow rate of 36 mgd. The dosage of ultra-violet radiation is varied, according to the disinfection demand, by adjusting the UV intensity with flow rate through these two units.

2.8 There are several locations within the East Chicago WWTP where chemical addition takes place for the enhancement of solids settling and for the precipitation of phosphorus. A flocculent is used to promote settling of solids in the final clarifiers. Ferric sulfate is added to the wastewater flow at several points as needed to comply with the phosphorus standard for this plant (0.1 mg/l).

3. PERMIT PROCESS AND REQUIREMENTS

3.1 The U.S. Army Corps of Engineers, Chicago District will submit a wastewater discharge permit application to the East Chicago Sanitary District. This wastewater discharge permit must be issued before any flow will be accepted for treatment at the plant. The completed application submitted to the East Chicago Sanitary District for a wastewater discharge permit for the effluent and subsurface seepage from the CDF operation is included with this appendix as attachment I-1. This application will be submitted to the East Chicago Sanitary District upon completion of the Final EIS.

3.2 The information provided by the Corps in this permit application will include a proposed plan of action that will describe the operation of the CDF. This information will include details concerning the pretreatment processes, if required, that the effluent will undergo prior to discharge to the East Chicago WWTP.

3.3 Effluent from CDF operations is derived from two sources. The first source consists of runoff from the surface of the active CDF face. The second source consists of pumapage from well points placed in the subsurface beneath the site. Both sources of effluent will be directed to the WWTP. The Corps will be responsible for monitoring the flow to the sanitary sewer. The flow will be controlled to achieve a discharge rate acceptable to the East Chicago WWTP. The predicted effluent flow rates from the CDF are given on table I-1. A flow monitoring plan will be included in the plan of action for the wastewater discharge permit application. This flow monitoring plan will specify how the Corps will record the discharge quantities.

Table I-1: Predicted Effluent Flow Rates

Mode of Operation	[1]Maximum Flow Rate
[2]Initial Volume	21 million gallons
Active CDF	80 gpm
Capped CDF	5 gpm

Notes:

[1] Flow rates given are maximum expected during a period. They include surface runoff collected from the active CDF face, and seepage infiltrating through the slurry wall around site perimeter into subsurface.

[2] Estimated volume of water required to be removed to create a 2' inward gradient. Pumpage would occur between placement of slurry wall and initial disposal operations.

3.4 The information provided in the wastewater discharge permit application will be evaluated by the East Chicago Sanitary District. If the application is approved, a permit will be issued by the Sanitary District to the Corps for the discharge of effluent from the CDF to the sanitary sewer. The wastewater discharge permit will specifically indicate all of the requirements and limitations associated with the discharge and will list the user rate and any other surcharges (if applicable). This permit will remain in effect for five years, at which time renewal will be necessary.

4. PRETREATMENT

4.1 The East Chicago Sanitary District is responsible for maintaining an industrial pretreatment program as a condition of their NPDES permit. The pretreatment program assures that no industrial user will discharge an effluent with a high enough concentration of pollutants to upset the treatment processes or solids disposal options at the East Chicago WWTP. The Sanitary District requires each industrial customer to monitor their flow to the plant and verifies that the flow monitoring equipment is accurate and reliable. The Sanitary District also regularly analyzes samples of the user's discharge to determine if the pretreatment standards are being met.

4.2 The predicted levels of contaminants in the effluent from the proposed CDF from mechanically disposed sediments prior to any additional treatment is presented in Appendix F (table F-26). It is assumed that subsurface water quality would be of a similar nature. The pretreatment limitations for the East Chicago WWTP are shown in table I-2. There are several parameters listed in the pretreatment limitations that are not included in table F-

26. These contaminants are silver, fluoride, FOG (fats, oils, grease), thallium, methylene chloride, fluoranthene, and bis (2-ethylhexy) pthalate. The Corps will test for the presence of these pollutants in the effluent, as necessary, prior to any discharge to the East Chicago WWTP. Details of the proposed monitoring that will take place at the CDF site are given in Appendix N, Monitoring Plan. According to the analysis performed and described in Appendix F, none of the constituent concentrations in the effluent from the CDF are expected to exceed the pretreatment standards.

Table I-2: Pretreatment Discharge Limitations for the East Chicago Wastewater Treatment Plant

Parameter	Standard (mg/l)
Ammonia-Nitrogen	77
Cadmium	0.140
Chromium	0.282
Copper	0.170
Cyanide (total)	0.407
Iron (soluble)	2.40
Lead	0.224
Mercury	0.003
Nickel	0.390
Silver	0.05
Zinc	5.5
Total Phosphorus	5.5
Fluoride	2.9
Oil & Grease (FOG)	50
Phenolics (4-AAP)	14
Thallium	4.3
Methylene Chloride	0.960
Fluoranthene	0.690
bis(2-ethylhexy)phthalate	1.03

4.3 Although none of the constituents in the effluent from the CDF are expected to exceed the sanitary district's pretreatment standards, there is some concern regarding the levels of PCB that will reach the WWTP. The vast majority of PCB in the water drained from the sediments will be associated with the suspended solids. If needed, nearly all of the PCB could be removed by a two step filtration system.

4.4 The first step in the filtration system would be a sand/anthracite filter, designed to remove as much of the suspended material as possible. This filter has been used at other CDFs on the Great Lakes and has been shown to remove greater than

85 percent of the suspended solids from the effluent water. The sand/anthracite filter will be followed by an activated carbon treatment unit. This type of filter system is identical to those used in the treatment of municipal drinking and waste waters.

4.5 There are several pretreatment options that may be utilized to reduce the concentration of organic contaminants (such as ammonia-nitrogen or BOD) in the CDF effluent prior to discharge to the sanitary sewer. The first option is to use a storage tank to detain the effluent and provide aeration by mechanical or other means. Aerating the effluent will reduce the levels of organic contaminants by accelerating the naturally-occurring processes of oxidation. Detention of the effluent will also provide a method of flow control if the discharge rate from the CDF is higher than that allowed by the operating permit. A method for achieving nitrification is through the use of a cascading tower system. The effluent would flow over this tower by gravity and would obtain oxygen from the air by turbulent action.

4.6 The second pretreatment option is the recirculation of the effluent over the CDF. Recirculation would achieve a limited degree of aeration, reduce the volume of effluent discharged by evaporating some of the drained water, and provide another method of flow regulation. A third pretreatment option is the use of an ammonia air stripping system. This system would first require raising the pH of the effluent by adding lime. Air-water contact would then have to be provided by circulation of large quantities of air through the stripping tower, usually from the bottom to the top. The effluent would travel in the opposite direction by gravity.

5. SUMMARY

5.1 The discharge of water drained from sediments mechanically disposed to the proposed CDF located at the ECI site will not have a significant impact on the East Chicago WWTP. The USACE will submit a wastewater discharge permit application to the East Chicago Sanitary District after completion of the Final EIS. The Sanitary District is directly responsible for approval of the wastewater discharge permit.

5.2 The effluent from the CDF is expected to meet all of the pretreatment standards set by the East Chicago Sanitary District. If needed, to meet pretreatment standards a two-stage filtration system, composed of a sand/anthracite filter followed by an activated carbon filter would be employed at the CDF site. This two-stage filter system is not necessary to bring the CDF effluent into compliance, but would be employed to reduce the amount of PCBs that reach the WWTP to a minimum.

5.3 The wastewater discharge permit issued to the U.S. Army Corps of Engineers, Chicago District, will clearly define all of the requirements for compliance with the terms of this permit. These activities will include reliable flow monitoring. Any other special actions or terms required under this wastewater discharge permit will also be detailed. The wastewater discharge permit is valid for a period of five years, after which time renewal will be necessary.

6. REFERENCES

City of East Chicago, IN Ordinance No. 3403; July 3, 1985 "An Ordinance Approving the Wastewater Discharge Resolution for the East Chicago Sanitary District"

East Chicago Sanitary District; Wastewater Treatment Plant Fact Sheets

Indiana Department of Environmental Management; October 25, 1987 Final NPDES Permit No. IN 0022829 for the East Chicago Sanitary District

East Chicago Sanitary District

Wastewater Discharge Permit Application

I GENERAL INFORMATION

1. Company Name: U.S. Army Corps of Engineers, Chicago District
2. Facility Address:
3. Mailing Address: 111 North Canal Street, Chicago, IL 60606-7206
4. Name and Title of Signing Official: David M. Reed, District Engineer
5. Name, title and telephone number of person to contact concerning information contained in this permit:

Name: James E. Evans Telephone Number: (312) 353-6435

Title: Chief, Construction/Operations Division

The information contained in this permit application is true, complete and accurate.

DATE

SIGNATURE OF OFFICIAL

II PRODUCT INFORMATION

1. SIC Code:
2. Brief description of production generating wastestream(s): Operation of confined disposal facility (CDF) for contaminated sediments dredged from Indiana Harbor and Canal. CDF design and operation described in attached EIS/Letter Report.
3. Raw materials utilized in #2: None
4. Materials present in production area not directly involved with the production as described in #2 but may be discharged to the sewer system:

None

Please use additional sheets if necessary to complete the above items.

(See reverse side)

III DISCHARGE INFORMATION

1. Time of day of discharge: Intermittant
2. Duration of discharge: Intermittant
3. Average daily wastewater flow rates: See table I-1 gpd (include daily, monthly or seasonal variations if any)
4. Description of flow measuring equipment: Venturi meter installed in discharge line from filter system.
5. Wastewater constituents and characteristics:

Compound	Present	Suspected	Concentration
1) Ammonia-Nitrogen	X		57
2) Cadmium	X		0.001
3) Chromium	X		0.019
4) Copper	X		0.040
5) Cyanide (Total)	X		0.039
6) Iron (Soluble)	X		0.89
7) Lead	X		0.022
8) Mercury	X		0.0001
9) Nickel	X		0.033
10) Silver	X		0.010
11) Zinc	X		0.077
12) Total Phosphorus	X		0.40
13) Fluoride	X		0.5
14) Oil & Grease	X		5
15) phenolics (4-AAP)	X		0.036
16) Thallium			
17) Methylene Chloride			
18) Fluoranthene		X	
19) bis(2-ethylhexy)Phthalate			
20) Others, please specify on additional sheet			

6. Please provide the appropriate information in accordance with Sections 5.02.2 (f), 5.02.2 (h) and 5.02.2 (i) of Wastewater Discharge Resolution No. S85-08.

1. BACKGROUND

1.1 The Indiana Harbor and Canal, which were constructed around the turn of the twentieth century, are part of a small, highly industrialized water shed in northwestern Indiana. The Harbor and Canal were routinely dredged until dredging slowed in the late 1960s and eased in 1972 due to environmental concerns with respect to disposal of the contaminated sediment.

1.2 Currently there is one million cubic yards of sediment that needs to be removed from this waterway to restore the Federal Channel to authorized depths. Seventy thousand cubic yards of this sediment contains PCBs, in concentrations greater than or equal to 50 parts per million (ppm) and is regulated for disposal under the Toxic Substance Control Act (TSCA). These regulated sediments are located in two separate reaches of the waterway. One is located in the main canal, along the north bank between the first (most downstream) two bridges and the other in the Calumet River Branch. For the locations, refer to the figure labeled Alternative Dredging Plans in the Comprehensive Management Plan.

1.3 PCB contaminated sediment must be disposed of in an incinerator that complies with 40 CFR 761.70 of the PCB regulations, in a chemical waste landfill that complies with 40 CFR 761.75 of the PCB regulations, or by an Environmental Protection Agency (EPA) approved alternative disposal method. Disposal of the contaminated sediment in an incinerator or chemical waste landfill has been considered and eliminated for economic and environmental reasons.

1.4 The recommended method for disposal of the PCB contaminated sediment from Indiana Harbor and Canal is the construction and operation of a TSCA cell within an upland confined disposal facility (CDF). Disposal of the sediments in a CDF is an alternative disposal method which must be approved by the EPA.

2. APPLICATION PROCEDURE

2.1 The application for approval of a CDF as an alternative method for the disposal of PCB contaminated sediments will be submitted to the EPA Regional Administrator in Region 2 at least two years prior to the construction of the TSCA cell within the CDF. The cell is tentatively scheduled to be constructed around 2004. An application for approval of the alternative disposal method is not being submitted at this time since these approvals expire five years from the date of signature by the Regional Administrator.

2.2 The application will contain detailed technical, environmental and economic information establishing that disposal in an incinerator or chemical waste landfill is not reasonable and appropriate, and that the alternative disposal method will provide adequate protection to health and the environment. In addition, the application will contain detailed technical information about the CDF including a detailed description of the facility consisting of general site plans and design drawings.

2.3 Additional information necessary for the evaluation of the alternative disposal method such as a traffic plan, waste acceptance and handling plan, surface water handling plan, air monitoring plan, worker protection plan, sampling and monitoring plan, site security plan and TSCA records maintenance and reporting plan will be part of the application.

INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES

APPENDIX K

COST ESTIMATES

June 1993
Revised August 1998

Cost Engineering Branch
Chicago District
U.S. Army Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

84.-4

APPENDIX K
COST ESTIMATES

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APPENDIX K

COST ESTIMATES

SUMMARY

This appendix includes the cost estimates for the alternatives considered in the fourth and fifth phases of plan formulation, including the selected plan. The estimates for the alternatives investigated in the previous phases of plan formulation are on file in the Chicago District Office. The estimates for the fourth phase of plan formulation are based on October 1993 prices. The fifth phase estimates are based on October 1997 prices. Extensive work was completed in preparing these estimates which are considered appropriate for the feasibility level of the comprehensive management plan. An M-CACES estimate was prepared for the selected plan and is included in this appendix as Attachment K-1, starting on page K-31.

This appendix contains estimates for the following:

- Plan 1, Partial Federal Channel Dredging/ECI Site CDF (Fourth Phase Plan Formulation)
- Plan 2, Complete Federal Channel/ECI Site CDF (Fourth Phase Plan Formulation)
- Plan 3, Cooperative Dredging Program/ECI Site CDF (Fourth Phase Plan Formulation)
- Plan 4, Complete Federal Channel Dredging/Generic Clean Upland CDF Site (Fourth Phase Plan Formulation)
- Selected Plan, Cooperative Dredging Program, Construction and O&M (Fifth Phase Plan Formulation)
- ECI Site RCRA Closure/Corrective Action, Without CDF (Fourth & Fifth Phases Plan Formulation)

An overall contingency factor of 15 percent was used on all items in the four plans considered on the fourth phase of plan formulation, except the slurry wall in Plans 1, 2, and 3. The slurry wall contingency was 30 percent since existing abandoned underground piping might significantly impact the slurry trench progress. Engineering and design and construction management costs were each based on an estimate of five percent of the total construction cost. A more detailed analysis of the required contingencies was undertaken in the fifth phase of plan formulation during preparation of the M-CACES estimate which is contained in Attachment K-1 to this appendix.

30 JUNE 1993

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TABLE K-1
PLAN 1
PARTIAL FEDERAL CHANNEL DREDGING – ESTIMATED RCRA FEATURES COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
1.	PRESENT SITE RCRA CLOSURE					
A.	**Slurry Wall**					
1)	Bentonite Slurry Wall – Site Perimeter	380,100	SF	$12.00	$4,561,200	$4,561,200
2)	Bridging Under RR	2	Loc	$15,600.00	$31,200	$31,200
3)	Cement Slurry Wall – Under RR	1,400	SF	$13.72	$19,202	$19,200
	SUBTOTAL				$4,611,602	$4,611,600
	Contingencies	30%			$1,383,481	$1,383,500
	TOTAL CONSTRUCTION COST				$5,995,083	$5,995,100
	Planning, Engrg. & Design	5%			$299,754	$299,800
	Construction Management	5%			$299,754	$299,800
	TOTAL SLURRY WALL				**$6,594,591**	**$6,594,700**
B.	**Seal Peripheral Areas (3' Clay)**	302,200	CY	$12.50	$3,777,500	$3,777,500
	Chem. Grout Railroad Spur to 3' Depth	32,000	CY	32.75	$1,048,000	$1,048,000
	SUBTOTAL				$4,825,500	$4,825,500
	Contingencies	15%			$723,825	$723,800
	TOTAL CONSTRUCTION COST				$5,549,325	$5,549,300
	Planning, Engrg. & Design	5%			$277,466	$277,500
	Construction Management	5%			$277,466	$277,500
	TOTAL CLAY LAYER				**$6,104,258**	**$6,104,300**
C.	**Hydraulic Gradient Control**					
1)	Well Points	221	EA	$90.00	$19,890	$19,900
2)	Header Piping	11,025	LF	$53.40	$588,735	$588,700
3)	Pumps	11	EA	$1,800.00	$19,800	$19,800
4)	Misc. Fittings	1	LS		$10,206	$10,200
5)	Ground Water Monitoring Wells	12	EA	$3,000.00	$36,000	$36,000
6)	Discharge Pipe to Indianapolis Ave.	4,000	LF	$86.40	$345,600	$345,600
	SUBTOTAL				$1,020,231	$1,020,200
	Contingencies	15%			$153,035	$153,000
	TOTAL CONSTRUCTION COST				$1.173,266	$1,173,200
	Planning, Engrg. & Design	5%			$58,663	$58,700
	Construction Management	5%			$58,663	$58,700
	TOTAL GRADIENT CONTROL				**$1,290,592**	**$1,290,600**
D.	**Water Treatment System (25%)**	1	LS		$375,000	$375,000
	Contingencies	15%			$56,250	$56,300
	TOTAL CONSTRUCTION COST				$431,250	$431,300
	Planning, Engrg. & Design	5%			$21,563	$21,600
	Construction Management	5%			$21,563	$21,600
	TOTAL GRADIENT CONTROL				**$474,375**	**$474,500**
E.	**Erosion Control (Perimeter Site Finishing)**					
1)	6" Sand	50,400	CY	$15.75	$793,800	$793,800
2)	2' Clean Fill	201,500	CY	$7.80	$1,571,700	$1,571,700
3)	6" Topsoil	50,400	CY	$12.60	$635,040	$635,000
4)	Seeding	63.0	ACR	$2,724.00	$171,612	$171,600
	SUBTOTAL				$3,172,152	$3,172,100
	Contingencies	15%			$475,823	$475,800
	TOTAL CONSTRUCTION COST				$3,647,975	$3,647,900
	Planning, Engrg. & Design	5%			$182,399	$182,400
	Construction Management	5%			$182,399	$182,400
	TOTAL EROSION CONTROL				**$4,012,772**	**$4,012,700**
	TOTAL RCRA FEATURES				**$18,476,588**	**$18,476,800**

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TABLE K-1

PLAN 1
PARTIAL FEDERAL CHANNEL DREDGING – ESTIMATED RCRA O & M COST

Item No.	*Description*	*Esitmated Yearly Amount*
2.	O & M COSTS	
A.	**Water Treatment**	$5,500
B.	**Gradient Control Water Monitoring**	
1)	Pumping	$1,680
2)	Monitoring ECI Discharge	$30,000
C.	Ground Water Monitoring	$82,500
D.	**Monitoring CDF Discharge**	
E.	**Mowing**	$1,292
TOTAL O & M COSTS: RCRA FEATURES		**$120,972**

TABLE K-2
PLAN 1
PARTIAL FEDERAL CHANNEL DREDGING – ESTIMATED CDF AND DREDGING COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
1.	**DREDGING, STAGES I, II & III**					
A.	**Dredging Including Barge to Site & Mechanical Rehandling**	4,247,000	CY	$12.00	$50,964,000	$50,964,000
B.	**Pumping & Treatment of Effluent**	28	PDS	$12,480.00	$349,440	$349,400
	SUBTOTAL				**$51,313,440**	**$51,313,400**
	Contingencies	15%			$7,697,016	$7,697,000
	TOTAL CONSTRUCTION COST				**$59,010,456**	**$59,010,400**
	Planning, Engrg. & Design	5%			$2,950,523	$2,950,500
	Construction Management	5%			$2,950,523	$2,950,500
	TOTAL DREDGING				**$64,911,502**	**$64,911,400**
2.	**Water Treatment System (75 % CDF)**	1	LS		$1,125,000	$1,125,000
	Contingencies	15%			$168,750	$168,800
	TOTAL CONSTRUCTION COST				$1,293,750	$1,293,800
	Planning, Engrg. & Design	5%			$64,688	$64,700
	Construction Management	5%			$64,688	$64,700
	TOTAL WATER TREATMENT				**$1,423,125**	**$1,423,200**
3.	**CDF DRAINAGE SYSTEM**					
	Decant Structure	4	EA	$6,240.00	$24,960	$25,000
	Contingencies	15%			$3,744	$3,700
	TOTAL CONSTRUCTION COST				**$28,704**	**$28,700**
	Planning, Engrg. & Design	5%			$1,435	$1,400
	Construction Management	5%			$1,435	$1,400
	TOTAL DRAINAGE SYSTEM				**$31,574**	**$31,500**
4.	**PERIMETER SITE FINISHING**					
A.	**6" Sand**	7,200	CY	$15.75	$113,400	$113,400
B.	**2' Clean Fill**	29,000	CY	$7.80	$226,200	$226,200
C.	**6" Topsoil**	7,200	CY	$12.60	$90,720	$90,700
D.	**Seeding**	9	ACR	$2,724.00	$24,516	$24,500
	SUBTOTAL				**$454,836**	**$454,800**
	Contingencies	15%			$68,225	$68,200
	TOTAL CONSTRUCTION COST				**$523,061**	**$523,000**
	Planning, Engrg. & Design	5%			$26,153	$26,200
	Construction Management	5%			$26,153	$26,200
	TOTAL PERIMETER FINISHING				**$575,368**	**$575,400**

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TABLE K-2
PLAN 1
PARTIAL FEDERAL CHANNEL DREDGING – ESTIMATED CDF AND DREDGING COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
5.	**CDF DIKE SYSTEMS & CAP**					
A.	**DIKE SYSTEMS, STAGES I, II & III**					
1)	Embankment	503,040	CY	$6.70	$3,370,368	$3,370,400
2)	3' Clay Slope Liner	352,390	CY	$12.50	$4,404,875	$4,404,900
3)	Cross Dike w/Dredged Material	64,300	CY	$4.15	$266,845	$266,800
4)	6" Topsoil	19,650	CY	$10.50	$206,325	$206,300
5)	Seed	25	ACR	$2,270.00	$56,500	$56,500
6)	Ramp & Road	1	LS		$2,458,823	$2,458,800
	SUBTOTAL				$10,763,737	$10,763,700
	Contingencies	15%			$1,614,561	$1,614,600
	TOTAL CONSTRUCTION COST				$12,378,297	$12,378,300
	Planning, Engrg. & Design	5%			$618,915	$618,900
	Construction Management	5%			$618,915	$618,900
	TOTAL DIKE SYSTEMS				**$13,616,127**	**$13,616,100**
B.	**Seal Base of Dikes (3' Clay)**	151,000	CY	$12.50	$1,887,500	$1,887,500
	Contingencies	15%			$283,125	$283,100
	SUBTOTAL				**$2,170,625**	$2,170,600
	Planning, Engrg. & Design	5%			$108,531	$108,500
	Construction Management	5%			$108,531	$108,500
	TOTAL				**$2,387,688**	**$2,387,600**
C.	**EARTH CAP**					
1)	2' Clay Liner	209,700	CY	$14.22	$2,981,934	$2,981,900
2)	2' Clean Fill	212,600	CY	$7.80	$1,658,280	$1,658,300
3)	6" Sand Drainage Layer	53,600	CY	$15.75	$844,200	$844,200
4)	6" Topsoil	53,800	CY	$12.60	$677,880	$677,900
5)	Seed	71	ACR	$2,724.00	$193,404	$193,400
	SUBTOTAL				$6,355,698	$6,355,700
	Contingencies	15%			$953,355	$953,400
	TOTAL CONSTRUCTION COST				$7,309,053	$7,309,100
	Planning, Engrg. & Design	5%			$365,453	$365,500
	Construction Management	5%			$365,453	$365,500
	TOTAL EARTH CAP				**$8,039,958**	**$8,040,100**
TOTAL					**$90,985,341**	**$90,985,300**

TABLE K-2
PLAN 1
PARTIAL FEDERAL CHANNEL DREDGING – ESTIMATED O & M COST

Item No.	*Description*	*Esitmated Yearly Amount*
	O & M COSTS:	
A.	**Water Treatment**	$16,500
B.	**Gradient Control Water Monitoring**	
1)	Pumping	$1,120
2)	Monitoring ECI Discharge	$20,000
C.	**Ground Water Monitoring**	$82,500
D.	**Monitoring CDF Discharge**	$55,000
E.	**Mowing**	$2,508
F.	**Dredge Material Management**	$213,210
TOTAL O & M COSTS		**$390,838**

TABLE K-3
PLAN 2
COMPLETE FEDERAL CHANNEL DREDGING–ESTIMATED RCRA FEATURES COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
1.	PRESENT SITE RCRA CLOSURE					
A.	**Slurry Wall**					
1)	Bentonite Slurry Wall – Site Perimeter	380,100	SF	$12.00	$4,561,200	$4,561,200
2)	Bridging Under RR	2	Loc	$15,600.00	$31,200	$31,200
3)	Cement Slurry Wall – Under RR	1,400	SF	$13.72	$19,202	$19,200
	SUBTOTAL				$4,611,602	$4,611,600
	Contingencies	30%			$1,383,481	$1,383,500
	TOTAL CONSTRUCTION COST				$5,995,083	$5,995,100
	Planning, Engrg. & Design	5%			$299,754	$299,800
	Construction Management	5%			$299,754	$299,800
	TOTAL SLURRY WALL				**$6,594,591**	**$6,594,700**
B.	**Seal Peripheral Areas**	94,600	CY	$12.50	$1,182,500	$1,182,500
	Chem. Grout Railroad Spur to 3' Depth	32,000	CY	32.75	$1,048,000	$1,048,000
	SUBTOTAL				$2,230,500	$2,230,500
	Contingencies	15%			$334,575	$334,600
	TOTAL CONSTRUCTION COST				$2,565,075	$2,565,100
	Planning, Engrg. & Design	5%			$128,254	$128,300
	Construction Management	5%			$128,254	$128,300
	TOTAL CLAY LAYER				**$2,821,583**	**$2,821,700**
C.	**Hydraulic Gradient Control**					
1)	Well Points	221	EA	$90.00	$19,890	$19,900
2)	Header Piping	11,025	LF	$53.40	$588,735	$588,700
3)	Pumps	11	EA	$1,800.00	$19,800	$19,800
4)	Misc. Fittings	1	LS		$10,206	$10,200
5)	Ground Water Monitoring Wells	12	EA	$3,000.00	$36,000	$36,000
6)	Discharge Pipe to Indianapolis Ave.	4,000	LF	$86.40	$345,600	$345,600
	SUBTOTAL				$1,020,231	$1,020,200
	Contingencies	15%			$153,035	$153,000
	TOTAL CONSTRUCTION COST				$1,173,266	$1,173,200
	Planning, Engrg. & Design	5%			$58,663	$58,700
	Construction Management	5%			$58,663	$58,700
	TOTAL GRADIENT CONTROL				**$1,290,592**	**$1,290,600**
D.	**Water Treatment System (24%)**	1	LS		$360,000	$360,000
	Contingencies	15%			$54,000	$54,000
	TOTAL CONSTRUCTION COST				$414,000	$414,000
	Planning, Engrg. & Design	5%			$20,700	$20,700
	Construction Management	5%			$20,700	$20,700
	TOTAL GRADIENT CONTROL				**$455,400**	**$455,400**
E.	**Erosion Control (Perimeter Site Finishing)**					
1)	6" Sand	15,800	CY	$15.75	$248,850	$248.900
2)	2' Clean Fill	63,100	CY	$7.80	$492,180	$492.200
3)	6" Topsoil	15,800	CY	$12.60	$199,080	$199.100
4)	Seeding	20.0	ACR	$2,724.00	$54,480	$54.500
	SUBTOTAL				$994,590	$994.700
	Contingencies	15%			$149,189	$149.200
	TOTAL CONSTRUCTION COST				$1,143,779	$1,143 900
	Planning, Engrg. & Design	5%			$57,189	$57 200
	Construction Management	5%			$57,189	$57 200
	TOTAL EROSION CONTROL				**$1,258,156**	**$1,258.300**
	TOTAL RCRA FEATURES				**$12,420,322**	**$12,420,700**

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TABLE K-3
PLAN 2
COMPLETE FEDERAL CHANNEL DREDGING-ESTIMATED RCRA O & M COST

Item No.	*Description*	*Esitmatec Yearly Amount*
2.	O & M COSTS:	
A.	**Water Treatment**	$5,280
B.	**Gradient Control Water Monitoring**	
1)	Pumping	$1,596
2)	Monitoring ECI Discharge	$28,500
C.	Ground Water Monitoring	$82,500
D.	**Monitoring CDF Discharge**	
E.	**Mowing**	$380
F.	**Dredged Material Management**	
TOTAL O & M COSTS: RCRA FEATURES		**$118,256**

TABLE K–4
PLAN 2
COMPLETE FEDERAL CHANNEL DREDGING–ESTIMATED CDF & DREDGING COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
1.	DREDGING, STAGES I, II & III					
A.	**Dredging Including Barge to Site & Mechanical Rehandling**	4,674,000	CY	$12.00	$56,088,000	$56,088,000
B.	**Pumping & Treatment of Effluent**	26	PDS	$12,480.00	$324,480	$324,500
	SUBTOTAL				**$56,412,480**	**$56,412,500**
	Contingencies	15%			$8,461,872	$8,461,900
	TOTAL CONSTRUCTION COST				**$64,874,352**	**$64,874,400**
	Planning, Engrg. & Design	5%			$3,243,718	$3,243,700
	Construction Management	5%			$3,243,718	$3,243,700
	TOTAL DREDGING				**$71,361,787**	**$71,361,800**
2.	**Water Treatment System (76%)**	1	LS		$1,140,000	$1,140,000
	Contingencies	15%			$171,000	$171,000
	TOTAL CONSTRUCTION COST				$1,311,000	$1,311,000
	Planning, Engrg. & Design	5%			$65,550	$65,600
	Construction Management	5%			$65,550	$65,600
	TOTAL WATER TREATMENT				**$1,442,100**	**$1,442,200**
3.	CDF DRAINAGE SYSTEM					
	Decant Structure	4	EA	$6,240.00	$24,960	$25,000
	Contingencies	15%			$3,744	$3,700
	TOTAL CONSTRUCTION COST				**$28,704**	**$28,700**
	Planning, Engrg. & Design	5%			$1,435	$1,400
	Construction Management	5%			$1,435	$1,400
	TOTAL DRAINAGE SYSTEM				**$31,574**	**$31,500**
4.	PERIMETER SITE FINISHING					
A.	**6" Sand**	12,650	CY	$15.75	$199,238	$199,200
B.	**2' Clean Fill**	50,600	CY	$7.80	$394,680	$394,700
C.	**6" Topsoil**	12,650	CY	$12.60	$159,390	$159,400
D.	**Seeding**	16	ACR	$2,724.00	$42,767	$42,800
	SUBTOTAL				**$796,074**	**$796,100**
	Contingencies	15%			$119,411	$119,400
	TOTAL CONSTRUCTION COST				**$915,485**	**$915,500**
	Planning, Engrg. & Design	5%			$45,774	$45,800
	Construction Management	5%			$45,774	$45,800
	TOTAL PERIMETER FINISHING				**$1,007,034**	**$1,007,100**

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TABLE K-4
PLAN 2
COMPLETE FEDERAL CHANNEL DREDGING-ESTIMATED CDF & DREDGING COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approxim Esitmated Amount*
5.	**CDF DIKE SYSTEMS & CAP**					
A.	**DIKE SYSTEMS, STAGES I, II & III**					
1)	Embankment	676,600	CY	$6.70	$4,533,220	$4,533,200
2)	3' Clay Slope Liner	474,400	CY	$12.50	$5,930,000	$5,930,000
3)	Cross Dike w/Dredged Material	64,300	CY	$4.15	$266,845	$266,800
4)	6" Topsoil	26,200	CY	$10.50	$275,100	$275,100
5)	Seed	33	ACR	$2,270.00	$74,002	$74,000
6)	Ramp & Road	1	LS		$2,458,823	$2,458,800
	SUBTOTAL				$13,537,990	$13,537,900
	Contingencies	15%			$2,030,699	$2,030,700
	TOTAL CONSTRUCTION COST				$15,568,689	$15,568,600
	Planning, Engrg. & Design	5%			$778,434	$778,400
	Construction Management	5%			$778,434	$778,400
	TOTAL DIKE SYSTEMS				**$17,125,558**	**$17,125,400**
B.	**Seal Base of Dikes (3' Clay)**	265,800	CY	$12.50	$3,322,500	$3,322,500
	Contingencies	15%			$498,375	$498,400
	SUBTOTAL				**$3,820,875**	$3,820,900
	Planning, Engrg. & Design	5%			$191,044	$191,000
	Construction Management	5%			$191,044	$191,000
	TOTAL				**$4,202,963**	**$4,202,900**
C.	**EARTH CAP**					
1)	2' Clay Liner	292,000	CY	$14.22	$4,152,240	$4,152,200
2)	2' Clean Fill	297,200	CY	$7.80	$2,318,160	$2,318,200
3)	6" Sand Drainage Layer	75,100	CY	$15.75	$1,182,825	$1,182,800
4)	6" Topsoil	75,400	CY	$12.60	$950,040	$950,000
5)	Seed	100	ACR	$2,724.00	$273,490	$273,500
	SUBTOTAL				$8,876,755	$8,876,700
	Contingencies	15%			$1,331,513	$1,331,500
	TOTAL CONSTRUCTION COST				$10,208,268	$10,208,200
	Planning, Engrg. & Design	5%			$510,413	$510,400
	Construction Management	5%			$510,413	$510,400
	TOTAL EARTH CAP				**$11,229,095**	**$11,229,000**
	TOTAL CDF & DREDGING COST				**$106,400,111**	**$106,399,900**

TABLE K-4

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PLAN 2

COMPLETE FEDERAL CHANNEL DREDGING—ESTIMATED O & M COST

Item No.	*Description*	*Esitmated Yearly Amount*
	O & M COSTS:	
A.	**Water Treatment**	$16,720
B.	**Gradient Control Water Monitoring**	
1)	Pumping	$1,204
2)	Monitoring ECI Discharge	$21,500
C.	**Ground Water Monitoring**	$82,500
D.	**Monitoring CDF Discharge**	$55,000
E.	**Mowing**	$3,420
F.	**Dredged Material Management**	$213,210
TOTAL O & M COSTS		**$393,554**

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TABLE K–5
Page 1

PLAN–3

COOPERATIVE DREDGING PROGRAM – ESTIMATED RCRA FEATURES COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
1.	PRESENT SITE RCRA CLOSURE					
A.	**Slurry Wall**					
1)	Bentonite Slurry Wall – Site Perimeter	380,100	SF	$12.00	$4,561,200	$4,561,200
2)	Bridging Under RR	2	Loc	$15,600.00	$31,200	$31,200
3)	Cement Slurry Wall – Under RR	1,400	SF	$13.72	$19,202	$19,200
	SUBTOTAL				$4,611,602	$4,611,600
	Contingencies	30%			$1,383,481	$1,383,500
	TOTAL CONSTRUCTION COST				$5,995,083	$5,995,100
	Planning, Engrg. & Design	5%			$299,754	$299,800
	Construction Management	5%			$299,754	$299,800
	TOTAL SLURRY WALL				**$6,594,591**	**$6,594,700**
B.	**Seal Peripheral Areas**	94,600	CY	$12.50	$1,182,500	$1,182,500
	Chem. Grout Railroad Spur to 3' Depth	32,000	CY	32.75	$1,048,000	$1,048,000
	SUBTOTAL				$2,230,500	$2,230,500
	Contingencies	15%			$334,575	$334,600
	TOTAL CONSTRUCTION COST				$2,565,075	$2,565,100
	Planning, Engrg. & Design	5%			$128,254	$128,300
	Construction Management	5%			$128,254	$128,300
	TOTAL CLAY LAYER				**$2,821,583**	**$2,821,700**
C.	**Hydraulic Gradient Control**					
1)	Well Points	221	EA	$90.00	$19,890	$19,900
2)	Header Piping	11,025	LF	$53.40	$588,735	$588,700
3)	Pumps	11	EA	$1,800.00	$19,800	$19,800
4)	Misc. Fittings	1	LS		$10,206	$10,200
5)	Ground Water Monitoring Wells	12	EA	$3,000.00	$36,000	$36,000
6)	Discharge Pipe to Indianapolis Ave.	4,000	LF	$86.40	$345,600	$345,600
	SUBTOTAL				$1,020,231	$1,020,200
	Contingencies	15%			$153,035	$153,000
	TOTAL CONSTRUCTION COST				$1,173,266	$1,173,200
	Planning, Engrg. & Design	5%			$58,663	$58,700
	Construction Management	5%			$58,663	$58,700
	TOTAL GRADIENT CONTROL				**$1,290,592**	**$1,290,600**
D.	**Water Treatment System (24%)**	1	LS		$360,000	$360,000
	Contingencies	15%			$54,000	$54,000
	TOTAL CONSTRUCTION COST				$414,000	$414,000
	Planning, Engrg. & Design	5%			$20,700	$20,700
	Construction Management	5%			$20,700	$20,700
	TOTAL GRADIENT CONTROL				**$455,400**	**$455,400**
E.	**Erosion Control (Perimeter Site Finishing)**					
1)	6" Sand	15,800	CY	$15.75	$248,850	$248,900
2)	2' Clean Fill	63,100	CY	$7.80	$492,180	$492,200
3)	6" Topsoil	15,800	CY	$12.60	$199,080	$199,100
4)	Seeding	20.0	ACR	$2,724.00	$54,480	$54,500
	SUBTOTAL				$994,590	$994,700
	Contingencies	15%			$149,189	$149,200
	TOTAL CONSTRUCTION COST				$1,143,779	$1,143,900
	Planning, Engrg. & Design	5%			$57,189	$57,200
	Construction Management	5%			$57,189	$57,200
	TOTAL EROSION CONTROL				**$1,258,156**	**$1,258,300**
	TOTAL RCRA FEATURES COST				**$12,420,322**	**$12,420,700**

963.867

TABLE K–5
PLAN–3
COOPERATIVE DREDGING PROGRAM – ESTIMATED RCRA FEATURES COST

Item No.	*Description*	*Esitmated Yearly Amount*
2.	O & M COSTS	
A.	**Water Treatment**	$5,280
B.	**Gradient Control Water Monitoring**	
1)	Pumping	$1,596
2)	Monitoring ECI Discharge	$28,500
C.	Ground Water Monitoring	$82,500
D.	**Monitoring CDF Discharge**	
E.	**Mowing**	$380
	TOTAL O & M COSTS: RCRA FEATURES	**$118,256**

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TABLE K-6
PLAN-3
COOPERATIVE DREDGING PROGRAM – ESTIMATED CDF & DREDGING COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
1.	DREDGING, STAGES I, II & III					
A.	**Dredging Including Barge to Site & Mechanical Rehandling**	4,675,000	CY	$12.00	$56,100,000	$56,100,000
B.	**Pumping & Treatment of Effluent**	25	PDS	$12,480.00	$312,000	$312,000
	SUBTOTAL				**$56,412,000**	**$56,412,000**
	Contingencies	15%			$8,461,800	$8,461,800
	TOTAL CONSTRUCTION COST				**$64,873,800**	**$64,873,800**
	Planning, Engrg. & Design	5%			$3,243,690	$3,243,700
	Construction Management	5%			$3,243,690	$3,243,700
	TOTAL DREDGING				**$71,361,180**	**$71,361,200**
2.	**Water Treatment System (76%)**	1	LS		$1,140,000	$1,140,000
	Contingencies	15%			$171,000	$171,000
	TOTAL CONSTRUCTION COST				$1,311,000	$1,311,000
	Planning, Engrg. & Design	5%			$65,550	$65,600
	Construction Management	5%			$65,550	$65,600
	TOTAL WATER TREATMENT				**$1,442,100**	**$1,442,200**
3.	CDF DRAINAGE SYSTEM					
	Decant Structure	4	EA	$6,240.00	$24,960	$25,000
	Contingencies	15%			$3,744	$3,700
	TOTAL CONSTRUCTION COST				**$28,704**	**$28,700**
	Planning, Engrg. & Design	5%			$1,435	$1,400
	Construction Management	5%			$1,435	$1,400
	TOTAL DRAINAGE SYSTEM				**$31,574**	**$31,500**
4.	PERIMETER SITE FINISHING					
A.	**6" Sand**	12,650	CY	$15.75	$199,238	$199,200
B.	**2' Clean Fill**	50,600	CY	$7.80	$394,680	$394,700
C.	**6" Topsoil**	12,650	CY	$12.60	$159,390	$159,400
D.	**Seeding**	16	ACR	$2,724.00	$42,767	$42,800
	SUBTOTAL				**$796,074**	**$796,100**
	Contingencies	15%			$119,411	$119,400
	TOTAL CONSTRUCTION COST				**$915,485**	**$915,500**
	Planning, Engrg. & Design	5%			$45,774	$45,800
	Construction Management	5%			$45,774	$45,800
	TOTAL PERIMETER FINISHING				**$1,007,034**	**$1,007,100**

TABLE K-[illegible]
PL[illegible]-3
COOPERATIVE DREDGING PROGRAM — ESTIMATED CDF & DREDGING COST

Item No.	Description	Quantity	Unit	Unit Price	Estimated Amount	Approximate Estimated Amount
5.	**CDF DIKE SYSTEMS & CAP**					
A.	**DIKE SYSTEMS, STAGES I, II & III**					
1)	Embankment	67[illegible]500	CY	$6[illegible]	$4,5[illegible]220	$4[illegible]33,2[illegible]
2)	[illegible] Clay Slope Liner	47[illegible]400	CY	$12[illegible]	$5,9[illegible]000	$5[illegible]30,0[illegible]
3)	Cross Dike w/Dredged Material	6[illegible]300	CY	$4[illegible]	$2[illegible]345	[illegible]56,8[illegible]
4)	[illegible] Topsoil	2[illegible]200	CY	$10[illegible]	$2[illegible]100	[illegible]75,1[illegible]
5)	Seed	33	ACR	$[illegible]2,270[illegible]	$[illegible]4,002	[illegible]74,0[illegible]
6)	Ramp & Road		LS		$2[illegible]823	$[illegible]58,8[illegible]
	SUBTOTAL				$13,[illegible]990	$13[illegible]37,9[illegible]
	Contingencies	15%			$2,0[illegible]699	$2[illegible]30,7[illegible]
	TOTAL CONSTRUCTION COST				$15,5[illegible]689	$15[illegible]68,6[illegible]
	Planning, Engrg. & Design	5%			$7[illegible]434	[illegible]78,4[illegible]
	Construction Management	5%			$7[illegible]434	[illegible]78,4[illegible]
	TOTAL DIKE SYSTEMS				$17,12[illegible]558	$17[illegible]25,4[illegible]
B.	**Seal Base of Dikes (3' Clay)**	2[illegible]300	CY	$1[illegible]	$3,3[illegible]500	$[illegible]22,5[illegible]
	Contingencies	15%			$4[illegible]375	[illegible]98,4[illegible]
	SUBTOTAL				$3,82[illegible]875	$[illegible]20,9[illegible]
	Planning, Engrg. & Design	5%			$1[illegible]044	[illegible]91,[illegible]
	Construction Management	5%			$1[illegible]044	[illegible]91,[illegible]
	TOTAL				$4,2[illegible]963	$4[illegible]02,9[illegible]
C.	**EARTH CAP**					
1)	[illegible] Clay Liner	29[illegible]300	CY	$14[illegible]	$4,[illegible]240	$[illegible]52,2[illegible]
2)	[illegible] Clean Fill	29[illegible]200	CY	$[illegible]	$2,[illegible]160	$[illegible]18,2[illegible]
3)	[illegible] Sand Drainage Layer	7[illegible]1[illegible]	CY	$1[illegible]	$1,[illegible]825	$[illegible]82,8[illegible]
4)	[illegible] Topsoil	7[illegible]4[illegible]	CY	$1[illegible]	$9[illegible]040	[illegible]50,0[illegible]
5)	Seed	1[illegible]	ACR	$[illegible]2,724[illegible]	$2[illegible]490	[illegible]273,5[illegible]
	SUBTOTAL				$8,[illegible]755	$[illegible]76,7[illegible]
	Contingencies	15[illegible]			$1,[illegible]513	$[illegible]31,5[illegible]
	TOTAL CONSTRUCTION COST				$10,2[illegible]268	$1[illegible]08,2[illegible]
	Planning, Engrg. & Design	5[illegible]			$5[illegible]413	[illegible]10,4[illegible]
	Construction Management	5[illegible]			$5[illegible]413	[illegible]10,4[illegible]
	TOTAL EARTH CAP				$11,22[illegible]095	$1[illegible]29,0[illegible]
	TOTAL CDF DIKE SYSTEMS & CAP				$28,354,653	$2[illegible]54,4[illegible]
	TOTAL CDF & DREDGING COST				$[illegible]6,3[illegible]503	$10[illegible]99,3[illegible]

TABLE K–6
PLAN–3
COOPERATIVE DREDGING PROGRAM – ESTIMATED CDF & DREDGING COST

Item No.	*Description*	*Esitmated Yearly Amount*
	O & M COSTS:	
A.	**Water Treatment**	$16,720
B.	**Gradient Control Water Monitoring**	
1)	Pumping	$1,204
2)	Monitoring ECI Discharge	$21,500
C.	**Ground Water Monitoring**	$82,500
D.	**Monitoring CDF Discharge**	$55,000
E.	**Mowing**	$3,420
F.	**Dredged Material Management**	$213,210
TOTAL ANNUAL COSTS		**$393,554**

TABLE K-7
PLAN 4
GENERIC CLEAN UPLAND CDF SITE – ESTIMATED CDF AND DREDGING COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
1.	**DREDGING, STAGES I, II & III**					
A.	**Dredging Including Barge to Site & Mechanical Rehandling**	4,674,000	CY	$17.50	$81,795,000	$81,795,000
B.	**Pumping & Treatment of Effluent**	26	PDS	$12,480.00	$324,480	$324,000
	SUBTOTAL				**$82,119,480**	**$82,119,000**
	Contingencies	15%			$12,317,922	$12,318,000
	TOTAL CONSTRUCTION COST				**$94,437,402**	**$94,437,000**
	Planning, Engrg. & Design	5%			$4,721,870	$4,722,000
	Construction Management	5%			$4,721,870	$4,722,000
	TOTAL DREDGING				**$103,881,142**	**$103,881,000**
2.	**WATER TREATMENT SYSTEM**	1	LS		$1,000,000	$1,000,000
	Contingencies	15%			$150,000	$150,000
	TOTAL CONSTRUCTION COST				**$1,150,000**	**$1,150,000**
	Planning, Engrg. & Design	5%			$57,500	$58,000
	Construction Management	5%			$57,500	$58,000
	TOTAL WATER TREATMENT SYSTEM				**$1,265,000**	**$1,266,000**
3.	CDF SEPARATION & MONITORING LAYERS					
).	**2' Sand Drainage Layer**	367,840	CY	$15.75	$5,793,480	$5,793,000
B.	**6" Dia. Perforated Pipe**	38,040	LF	$18.60	$707,544	$708,000
C.	**12" Dia. Drain Pipe**	4,560	LF	$37.20	$169,632	$170,000
D.	**40 mil HDPE Liner**	4,959,000	SF	$0.66	$3,272,940	$3,273,000
E.	**60 mil HDPE Liner**	4,959,000	SF	$0.75	$3,719,250	$3,719,000
F.	**1 Layer Drainage Media**	551,000	SY	$1.26	$694,260	$694,000
G.	**1' Sand Monitoring Layer**	211,347	CY	$15.75	$3,328,710	$3,329,000
H.	**Decant Structure**	4	EA	$6,240.00	$24,960	$25,000
	SUBTOTAL				**$17,710,776**	**$17,711,000**
	Contingencies	15%			$2,656,616	$2,657,000
	TOTAL CONSTRUCTION COST				**$20,367,392**	**$20,368,000**
	Planning, Engrg. & Design	5%			$1,018,370	$1,018,000
	Construction Management	5%			$1,018,370	$1,018,000
	TOTAL SEPARATION & MONITORING				**$22,404,132**	**$22,404,000**
4.	PERIMETER SITE FINISHING					
A.	**6" Topsoil**	12,650	CY	$12.60	$159,390	$159,000
B.	**Seeding**	16	ACR	$2,724.00	$43,584	$44,000
	SUBTOTAL				**$202,974**	**$203,000**
	Contingencies	15%			$30,446	$30,000
	TOTAL CONSTRUCTION COST				**$233,420**	**$233,000**
	Planning, Engrg. & Design	5%			$11,671	$12,000
	Construction Management	5%			$11,671	$12,000
	TOTAL PERIMETER FINISHING				**$256,762**	**$257,000**

TABLE K-7
PLAN 4
GENERIC CLEAN UPLAND CDF SITE – ESTIMATED CDF AND DREDGING COST

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
5.	**CDF DIKE SYSTEMS & CAP**					
A.	**DIKE SYSTEMS, STAGES I, II & III**					
1)	Embankment	1,038,000	CY	$8.04	$8,345,520	$8,346,000
2)	2' Clay Slope Liner	185,500	CY	$15.00	$2,782,500	$2,783,000
3)	Cross Dike w/Dredged Material	64,300	CY	$4.98	$320,214	$320,000
4)	1 Layer HDPE Liner – Slopes	2,503,800	SF	$0.60	$1,502,280	$1,502,000
5)	1 Layer Drainage Media	725,400	SF	$1.26	$914,004	$914,000
6)	1' Sand Drainage Layer	79,400	CY	$15.75	$1,250,550	$1,251,000
7)	6" Dia. Perforated Pipe	22,770	LF	$18.60	$423,522	$424,000
8)	6" Topsoil	26,240	CY	$12.60	$330,624	$331,000
9)	Seed	33	ACR	$2,724.00	$88,802	$89,000
10)	Ramp & Road	1	LS		$2,658,338	$2,658,000
	SUBTOTAL				$18,616,354	$18,618,000
	Contingencies	15%			$2,792,453	$2,793,000
	TOTAL CONSTRUCTION COST				$21,408,808	$21,411,000
	Planning, Engrg. & Design	5%			$1,070,440	$1,071,000
	Construction Management	5%			$1,070,440	$1,071,000
	TOTAL DIKE SYSTEMS				**$23,549,688**	**$23,553,000**
B.	**EARTH CAP**					
1)	2' Clay Liner	292,000	CY	$14.22	$4,152,240	$4,152,[illegible]
2)	2' Clean Fill	297,200	CY	$7.80	$2,318,160	$2,318,000
3)	6" Sand Drainage Layer	75,100	CY	$15.75	$1,182,825	$1,183,000
4)	6" Topsoil	75,400	CY	$12.60	$950,040	$950,000
5)	Seed	89	ACR	$2,724.00	$242,436	$242,000
	SUBTOTAL				$8,845,701	$8,845,000
	Contingencies	15%			$1,326,855	$1,327,000
	TOTAL CONSTRUCTION COST				$10,172,556	$10,172,000
	Planning, Engrg. & Design	5%			$508,628	$509,000
	Construction Management	5%			$508,628	$509,000
	TOTAL EARTH CAP				**$11,189,812**	**$11,190,000**
	TOTAL CDF DIKE SYSTEMS & CAP				**$34,739,500**	**$34,743,000**
6.	**LANDS & DAMAGES**				$6,000,000	$6,000,000
	Contingencies	15%			$900,000	$900,000
	TOTAL LANDS & DAMAGES				**$6,900,000**	**$6,900,000**
7.	**PERIMETER FENCING AND GATES**				$176,000	$176,000
	Contingencies	15%			$26,400	$26,000
	SUBTOTAL				**$202,400**	**$202,000**
	Planning, Engrg. & Design	5%			$10,120	$10,000
	Construction Management	5%			$10,120	$10,000
	TOTAL FENCING & GATES				**$222,640**	**$222,000**
	TOTAL CDF AND DREDGING COST				**$169,669,176**	**$169,673,[illegible]0**

TABLE K–7
PLAN 4
GENERIC CLEAN UPLAND CDF SITE – ESTIMATED CDF AND DREDGING COST

m No.	Description	Esitmated Yearly Amount
	O & M COSTS:	
A.	**Water Treatment**	$22,000
B.	**Gradient Control Water Monitoring**	
1)	Pumping	$2,800
2)	Monitoring	$27,500
C.	**Ground Water Monitoring**	$82,500
D.	**CDF Water Monitoring**	$55,000
E.	**Mowing**	$3,800
F.	**Dredged Material Management**	$213,210
TOTAL O & M COSTS		**$406,810**

TABLE K-9
ECI SITE RCRA CLOSURE/CORRECTIVE ACTION WITHOUT CDF
ESTIMATED RCRA FEATURES COST

Page 1

Item No.	*Description*	*Quantity*	*Unit*	*Unit Price*	*Estimated Amount*	*Approximate Esitmated Amount*
1.	**PRESENT SITE RCRA CLOSURE**					
A.	**Slurry Wall**					
1)	Bentonite Slurry Wall – Site Perimeter	380,100	SF	$12.00	$4,561,200	$4,561,200
2)	Bridging Under RR	2	LOC	$15,600.00	$31,200	$31,200
3)	Cement Slurry Wall – Under RR	1,400	SF	$13.72	$19,208	$19,200
	SUBTOTAL				$4,611,608	$4,611,600
	Contingencies	30%			$1,383,482	$1,383,500
	TOTAL CONSTRUCTION COST				$5,995,090	$5,995,100
	Planning, Engrg. & Design	5%			$299,755	$299,800
	Construction Management	5%			$299,755	$299,800
	TOTAL SLURRY WALL				**$6,594,599**	**$6,594,700**
B.	**RCRA Cap**					
1)	Site Grading – 1%	360,400	CY	$7.80	$2,811,120	$2,811,100
2)	3' Clay Layer (10^–7)	813,120	CY	$12.50	$10,164,000	$10,164,000
	SUBTOTAL				$12,975,120	$12,975,100
	Contingencies	15%			$1,946,268	$1,946,300
	TOTAL CONSTRUCTION COST				$14,921,388	$14,921,400
	Planning, Engrg. & Design	5%			$746,069	$746,100
	Construction Management	5%			$746,069	$746,100
	TOTAL CLAY LAYER				**$16,413,527**	**$16,413,600**
C.	**Hydraulic Gradient Control**					
1)	Well Points	221	EA	$90.00	$19,890	$19,900
2)	Header Piping	11,025	LF	$53.40	$588,735	$588,700
3)	Pumps	11	EA	$1,800.00	$19,800	$19,800
4)	Misc. Fittings	1	LS		$10,200	$10,200
5)	Ground Water Monitoring Wells	12	EA	$3,000.00	$36,000	$36,000
6)	Discharge Pipe to Indianapolis Ave.	4,000	LF	$86.40	$345,600	$345,600
	SUBTOTAL				$1,020,225	$1,020,200
	Contingencies	15%			$153,034	$153,000
	TOTAL CONSTRUCTION COST				$1,173,259	$1,173,200
	Planning, Engrg. & Design	5%			$58,663	$58,700
	Construction Management	5%			$58,663	$58,700
	TOTAL GRADIENT CONTROL				**$1,290,585**	**$1,290,600**
D.	**Water Treatment System**	1	LS		$1,275,000	$1,275,000
	Contingencies	15%			$191,250	$191,300
	TOTAL CONSTRUCTION COST				$1,466,250	$1,466,300
	Planning, Engrg. & Design	5%			$73,313	$73,300
	Construction Management	5%			$73,313	$73,300
	TOTAL WATER TREATMENT				**$1,612,875**	**$1,612,900**
E.	**Erosion Control**					
1)	6" Sand	135,520	CY	$15.78	$2,138,506	$2,138,500
2)	2' Clean Fill	542,080	CY	$7.80	$4,228,224	$4,228,200
3)	6" Topsoil	135,520	CY	$12.60	$1,707,552	$1,707,600
4)	Seeding	168	ACR	$2,724.00	$457,632	$457,600
	SUBTOTAL				$8,531,914	$8,531,900
	Contingencies	15%			$1,279,787	$1,279,800
	TOTAL CONSTRUCTION COST				$9,811,701	$9,811,700
	Planning, Engrg. & Design	5%			$490,585	$490.600
	Construction Management	5%			$490,585	$490,600
	TOTAL EROSION CONTROL				**$10,792,871**	**$10,792.900**
	TOTAL FIRST COSTS: RCRA CLOSURE, WITHOUT CDF				**$36,704,457**	**$36,704,700**

TABLE K-9
ECI SITE RCRA CLOSURE/CORRECTIVE ACTION WITHOUT CDF
ESTIMATED RCRA FEATURES COST

Item No.	*Description*	*Esitmated Yearly Amount*
2.	**O & M COSTS:**	
A.	Water Treatment	$22,000
B.	Gradient Control Water Monitoring	
1)	Pumping	$2,800
2)	Monitoring ECI Discharge	$50,000
C.	Ground Water Monitoring	$165,000
D.	Mowing	$3,800
TOTAL O & M COSTS: RCRA FEATURES, WITHOUT CDF		**$243,600**

TABLE K - 10
SELECTED PLAN

COOPERATIVE DREDGING PROGRAM - ESTIMATED RCRA FEATURES COST

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	ESTIMATED AMOUNT
					EPC Oct 96
	PRESENT SITE RCRA CLOSURE				
	A. Slurry Wall				
	1. Bentonite Slurry Wall- Site Perimeter	341,715	SF	$7.40	$2,528,691
	2. Rail Road Relocation	1	LS		$943,962
	3. Inspection Trench	5,200	LF	$17.20	$89,440
	4. Initial Groundwater Drawdown				
	a. Pumping	1	LS		$8,400
	b. Treatment Surcharge	1	LS		$34,020
	c. Analytical Testing	1	LS		$25,000
	d. Sample Collection	1	LS		$800
	SUBTOTAL				$3,630,313
	Contingencies	20%			$726,063
	TOTAL CONSTRUCTION COST				$4,356,376
	Planning Engrg. & Design	12%			$522,765
	Construction Management	7.5%			$326,728
	TOTAL COST SLURRY WALL				**$5,205,869**
	B. Seal Peripheral Areas (Buffer Zone)				
	1. 3' Clay Layer	158,620	CY	$15.64	$2,480,817
	2. 6" Sand	26,440	CY	$15.30	$404,532
	3. 2' Clean Fill	105,750	CY	$9.70	$1,025,775
	4. 6" Topsoil	26,440	CY	$13.43	$355,089
	5. Seeding	20	AC	$3,430	$68,600
	SUBTOTAL				$4,334,813
	Contingencies	15%			$650,222
	TOTAL CONSTRUCTION COST				$4,985,035
	Planning Engrg. & Design	12%			$598,204
	Construction Management	7.5%			$373,878
	TOTAL COST SEAL PERIPHERAL AREAS & EROSION CONTROL				**$5,957,117**
	C. Hydraulic Gradient Control				
	1. Well Points	221	EA	$349.50	$77,240
	2. Header Piping	11,025	LF	$54.90	$605,273
	3. Pumps	11	EA	$12,482	$137,302
	5. Ground Water Monitor. Wells	12	EA	$3,245	$38,940
	6. Discharge Pipe Indiana. Ave.	500	LF	$74.90	$37,450
	SUBTOTAL				$896,204
	Contingencies	15%			$134,431
	TOTAL CONSTRUCTION COST				$1,030,635
	Planning Engrg. & Design	12%			$123,676
	Construction Management	7.5%			$77,298
	TOTAL COST HYDRAULIC GRADIENT CONTROL				**$1,231,609**

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TABLE K - 10
SELECTED PLAN
COOPERATIVE DREDGING PROGRAM - ESTIMATED RCRA FEATURES COST

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	ESTIMATED AMOUNT
	D. Water Treatment System (24%)	1	LS		$1,557,937
	SUBTOTAL				$1,557,937
	Contingencies	15%			$233,691
	TOTAL CONSTRUCTION COST				$1,791,628
	Planning Engrg. & Design	12%			$214,995
	Construction Management	7.5%			$134,372
	TOTAL COST WATER TREATMENT SYSTEM				**$2,140,995**
	SUB-TOTAL RCRA FEATURES COST				**$14,535,590**
	ESCALATION FROM OCT 96 TO OCT 97 - 2.3%				**$334,319**
	TOTAL RCRA FEATURES COST				**$14,869,909**

TABLE K - 11
SELECTED PLAN
COOPERATIVE DREDGING PROGRAM - ESTIMATED CDF & DREDGING COST

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	ESTIMATED AMOUNT
					EPC Oct 96
1.	**DREDGING STAGES I, & II**				
	A. Dredging including Barge to Site & Mechanical Rehandling	4,675,000	CY	$11.82	$55,258,500
	SUBTOTAL				$55,258,500
	Contingencies	15%			$8,288,775
	TOTAL CONSTRUCTION COST				$63,547,275
	Planning Engrg. & Design	12%			$7,625,673
	Construction Management	7.5%			$4,766,046
	TOTAL COST DREDGING				**$75,938,994**
2.	**A. WATER TREATMENT SYSTEM (76%)**	1	LS		$4,933,467
	SUBTOTAL				$4,933,467
	Contingencies	15%			$740,020
	TOTAL CONSTRUCTION COST				$5,673,487
	Planning Engrg. & Design	12%			$680,818
	Construction Management	7.5%			$425,512
	TOTAL COST WATER TREATMENT SYSTEM				**$6,779,817**
3.	**CDF SURFACE DRAINAGE SYSTEM**				
	A. Decant Structure	5	EA	$7,796	$38,980
	B. Piping	1	LS		$34,000
	SUBTOTAL				$72,980
	Contingencies	15%			$10,947
	TOTAL CONSTRUCTION COST				$83,927
	Planning Engrg. & Design	12%			$10,071
	Construction Management	7.5%			$6,295
	TOTAL DRAINAGE SYSTEM				**$100,293**
	TOTAL COST ITEMS 1 THRU 3				**$82,819,104**

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TABLE K - 11
SELECTED PLAN
COOPERATIVE DREDGING PROGRAM - ESTIMATED CDF & DREDGING COST

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	ESTIMATED AMOUNT
4.	**CDF DIKE SYSTEMS & CAP**				
	A. Dike Systems, Stages I, & II				
	1. Embankment	575,620	CY	$10.35	$5,957,667
	2. 3' Clay Slope Liner	38,510	CY	$18.00	$693,180
	3. Cross Dikes 8' Ht.				
	a. Existing On-Site Fill	31,500	CY	$8.27	$260,505
	b. Dried Sediments	21200	CY	$8.27	$175,324
	c. Stripping	68,500	CY	$3.75	$256,875
	4. 6" Topsoil	18,500	CY	$13.43	$248,455
	5. Seeding	23	AC	$3,243.00	$74,589
	6. Ramps & Roads	1	LS		$2,850,369
	SUBTOTAL				$10,516,964
	Contingencies	15%			$1,577,545
	TOTAL CONSTRUCTION COST				$12,094,509
	Planning Engrg. & Design	12%			$1,451,341
	Construction Management	7.5%			$907,088
	TOTAL COST DIKE SYSTEMS				**$14,452,938**
	B. Seal Base of Dikes (3' Clay)	123,280	CY	$16.36	$2,016,861
	SUBTOTAL				$2,016,861
	Contingencies	15%			$302,529
	TOTAL CONSTRUCTION COST				$2,319,390
	Planning Engrg. & Design	12%			$278,327
	Construction Management	7.5%			$173,954
	TOTAL COST SEAL BASE				**$2,771,671**
	C. Final Cap				
	1. 3' Clay Liner	474,000	CY	$15.64	$7,413,360
	2. 2' Clean Fill	316,000	CY	$10.35	$3,270,600
	3. 6" Sand Drainage Layer	79,000	CY	$15.30	$1,208,700
	4. 6" Topsoil	79,000	CY	$13.43	$1,060,970
	5. Seed	100	AC	$3,240	$324,000
	SUBTOTAL				$13,277,630
	Contingencies	15%			$1,991,645
	TOTAL CONSTRUCTION COST				$15,269,275
	Planning Engrg. & Design	12%			$1,832,313
	Construction Management	7.5%			$1,145,196
	TOTAL COST EARTH CAP				**$18,246,784**
	TOTAL CDF DIKE SYSTEMS & CAP (ITEM 4)				**$35,471,393**
	TOTAL CDF & DREDGING COST				**$118,290,497**
	ESCALATION FROM OCT 96 TO OCT 97 - 2.3%				**$2,720,681**
	TOTAL CDF & DREDGING COST				**$121,011,178**
	TOTAL RCRA FEATURES COST (K-10, Page 2)				**$14,869,909**
	LANDS AND DAMAGES (See Appendix W for Detail)				**$42,746**
	TOTAL PROJECT COST				**$135,923,833**

TABLE K - 12
SELECTED PLAN
COOPERATIVE DREDGING PROGRAM - ESTIMATED RCRA FEATURES O & M

ITEM NO	DESCRIPTION		ESTIMATED YEARLY AMOUNT
	PRE - CLOSURE O & M COST		
	A. Water Treatment System		$389,490
	B. Gradient Control System		
	1. Pumping		$288
	2. Analytical Testing		$8,640
	3. Sample Collection		$1,008
	C. Ground Water Monitoring		
	1. Analytical Testing		$82,500
	2. Sample Collection		$6,300
	D. CDF Surface Water Collection		
	1. Pumping		$1,452
	2. Analytical Testing		$11,368
	3. Sample Collection		$1,326
	E. Erosion Control Repair, Mowing		$380
	Sub-total		**$502,752**
	Escalation OCT 93 to OCT 97	11%	**$55,303**
	TOTAL		**$558,055**
	TOTAL PRE - CLOSURE O & M COST		**$558,100**
	POST CLOSURE O & M COSTS		
	A. Water Treatment System		$76,000
	B. Gradient Control System		
	1. Pumping		$456
	2. Treatment Surcharge		$1,786
	3. Analytical Testing		$13,680
	4. Sample Collection		$1,596
	C. Ground Water Monitoring		
	1. Analytical Testing		$41,250
	2. Sample Collection		$3,150
	D. Erosion Control Repair, Mowing		$1,710
	Sub-total		**$139,628**
	Escalation OCT 93 to OCT 97	11%	**$15,359**
	TOTAL		**$154,987**
	TOTAL POST CLOSURE O & M COSTS		**$154,990**

TABLE K - 13
SELECTED PLAN
COOPERATIVE DREDGING PROGRAM - ESTIMATED CDF & DREDGING O & M

ITEM NO	DESCRIPTION		ESTIMATED YEARLY AMOUNT
	PRE - CLOSURE O & M COSTS		
	A. Water Treatment		$1,233,370
	B. Gradient Control System		
	1. Pumping		$912
	2. Analytical Testing		$27,360
	3. Sample Collection		$3,192
	C. Ground Water Monitoring		
	1. Analytical Testing		$82,500
	2. Sample Collection		$6,300
	D. CDF Surface Water Collection		
	1. Pumping		$4,600
	2. Analytical Testing		$36,000
	3. Sample Collection		$4,200
	E. Erosion Control Repair, Mowing		$3,420
	F. Dredged Material Management		$185,400
	G. Air Monitoring Plan Implementation		$30,000
	Subtotal		**$1,617,254**
	Escalation OCT 93 TO OCT 97	**11%**	**$177,898**
	TOTAL		**$1,795,152**
	TOTAL PRE-CLOSURE O & M COSTS		**$1,795,150**
	POST CLOSURE COSTS		
	A. Water Treatment System		$24,000
	B. Gradient Control System		
	1. Pumping		$144
	2. Analytical Testing		$4,320
	3. Sample Collection		$504
	C. Ground Water Monitoring		
	1. Analytical Testing		$41,250
	2. Sample Collection		$3,150
	D. Erosion Control Repair, Mowing		$190
	Sub-total		**$73,558**
	Escalation OCT 93 TO OCT 97	**11%**	**$8,091**
	TOTAL		**$81,649**
	TOTAL POST CLOSURE O & M COSTS		**$81,700**

Table K-15 Indiana Harbor Confined Disposal Facility
Sequence of Construction and Dredging

Dates	Activity	Amount $(000)[1]
Sep 99 - Aug 00	Railroad Relocation (Includes lands & damages)	$1,367
Apr 00 - Jun 01	Cut Off Wall (Includes Fed real estate costs)	4,002
Jul 00 - Jun 01	Hydraulic Gradient Control	1,260
Apr 00 - Mar 02	Treatment Plant	9,126
Apr 01 - Sep 01	Seal Stage I Dike Base	2,835
Jun 01 - Nov 02	Stage I Dikes	6,872
	West Lobe - dikes, drainage, roads, cross dikes	
	East Lobe - dikes, drainage, roads, cross dikes	
	North Lobe - dikes, drainage, roads, cross dikes	
	Seal Permeter Areas	
Apr 01 - Nov 01	ECI Parcel I	2,986
May 02 - Jun 03	ECI Parcels IIA & IIB	3,108
May 02 - Sep 02	Dredging (Yr. 1)	2,641
May 03 - Sep 03	Dredging (Yr. 2)	4,965
May 04 - Sep 04	Dredging (Yr. 3)	2,693
May 05 - Sep 05	TSCA Dredging	5,100
May 06 - Sep 10	Dredging (Yearly 2006 - 2010)	19,262
May 10 - Sep 11	Stage II Dikes	8,016
	West Lobe - dikes, roads, cross dikes	
	East Lobe - dikes, roads, cross dikes	
	North Lobe - dikes, roads, cross dikes	
May 12 - Sep 18	Dredging [2]	20,723
May 20 - Sep 30	Dredging [2]	22,302
May 31 - Sep 31	CDF CAP	18,666
TOTAL		$ 135,924

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[1] Based on October 1997 price levels.

[2] Based on a 4-year dredging cycle of three consecutive years of dredging followed by one year of no dredging.

881-82

24 SEP 1998

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ATTACHMENT K - 1

MCACES SUMMARY
INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL ACTIVITIES

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	ESTIMATED AMOUNT
1	**TOTAL INDIANA HARBOR AND CANAL CONSTRUCTION COST** (FROM SUMMARY PAGE 1, PROJECT OWNER SUMMARY, MCACES ESTIMATE DATED 24 SEPTEMBER 1998)	1	LS	-	**$111,148,392**
2	PLANNING ENGINEERING & DESIGN	12%			$13,337,807
3	CONSTRUCTION MANAGEMENT	7.5%			$8,336,129
	SUB TOTAL				$132,822,328
	ESCALATION	2.30%			$3,054,914
	SUBTOTAL				$135,877,242
	LANDS & DAMAGES				$42,746
	TOTAL PROJECT COST				**$135,919,988**

Note :

The minor difference in " Total Project Cost ", ($3845), between the above summary and Table K - 11, the Selected Plan, is due to the rounding of numbers process associated with MCACES program.

smd

Indiana Harbor and Canal

Maintenance Dredging and Disposal Activities

Designed By: Chicago District
Estimated By: M.O.E., W.R.L., S.M.D. & C.T.A.

Prepared By: Chicago District
M.O.E., W.R.L., S.M.D. & C.T.A.

Preparation Date: 10/20/97
Effective Date of Pricing: 10/01/97

Sales Tax: 0.00%

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Release 5.30A

SUMMARY REPORTS — SUMMARY PAGE

DETAILED ESTIMATE — DETAIL PAGE

DETAILED ESTIMATE — DETAIL PAGE

	QUANTY	UOM	CONTRACT	CONTINGN	ESCALATN	TOTAL COST	UNIT COST
01 Present Site RCRA Closure	1.00	EA	10,417,287	1,744,110	0	12,161,397	12161396.52
02 Dredging & CDF	1.00	EA	86,075,648	12,911,347	0	98,986,995	98986995.35
TOTAL Indiana Harbor and Canal	1.00	EA	96,492,935	14,655,457	0	111,148,392	111148392

	QUANTY	UOM	CONTRACT	CONTINGN	ESCALATN	TOTAL COST	UNIT COST
01 Present Site RCRA Closure							
01_01 Slurry Wall							
01_01.01 Bentonite Slurry Wall-Site Peri.							
01_01.01.01 Mobilization & Site Preparation	1.00	EA	124,838	24,968	0	149,806	149805.99
TOTAL Mobilization & Site Preparation	1.00	EA	124,838	24,968	0	149,806	149805.99
01_01.01.02 Bentonite Slurry Trench							
01_01.01.02_ 01 Initial Slurry Placement	733.60	CY	3,711	742	0	4,453	6.07
01_01.01.02_ 02 Remainder Slurry Trench	43469	CY	1,979,374	395,875	0	2,375,249	54.64
TOTAL Bentonite Slurry Trench	1.00	EA	1,983,085	396,617	0	2,379,702	2379702.25
01_01.01.03 Slurry Trench Excav. & Disposal	39197	CY	115,155	23,031	0	138,186	3.53
01_01.01.04 Borrow for Slurry Trench Fill	39269	CY	292,793	58,559	0	351,352	8.95
01_01.01.05 Disposal of Excess Slurry	863.00	CY	12,836	2,567	0	15,404	17.85
TOTAL Bentonite Slurry Wall-Site Peri.	341715	SF	2,528,708	505,742	0	3,034,450	8.88
01_01.02 Railroad Relocation							
01_01.02.01 Clearing and Grubbing	7.00	AC	40,804	8,161	0	48,965	6994.96
01_01.02.02 Topsoil Stripping	6296.00	CY	19,018	3,804	0	22,822	3.62
01_01.02.03 Roadbed Earthfill	18350	CY	190,796	38,159	0	228,955	12.48
01_01.02.04 Ditches and Swales			20,100	4,020	0	24,120	
01_01.02.05 Sub-Ballast	4320.00	TN	69,452	13,890	0	83,343	19.29
01_01.02.06 Duo-Rail, Single Side Track	3400.00	LF	375,883	75,177	0	451,060	132.66
01_01.02.07 Turnouts #10, incl. Rails, Frog			105,631	21,126	0	126,757	
01_01.02.08 RR Crossing Rubber Mat & Traf. S			51,255	10,251	0	61,506	
01_01.02.09 Topsoil Replacement	6296.00	CY	37,958	7,592	0	45,549	7.23
01_01.02.10 Seeding	5.00	AC	16,281	3,256	0	19,537	3907.44
01_01.02.11 Relocate Light Pole			2,764	553	0	3,316	
01_01.02.12 Relocate Surface Discharge Pipe			1,508	302	0	1,809	
01_01.02.13 Brick Masonry Wall Relocation			10,363	2,073	0	12,435	
01_01.02.14 Replace Gate			2,157	431	0	2,588	
TOTAL Railroad Relocation			943,968	188,794	0	1,132,762	
01_01.04 Inspection Trench							
01_01.04.01 Trench Excavation	5200.00	LF	50,425	10,085	0	60,510	11.64
01_01.04.02 Trench Backfill	5200.00	LF	39,015	7,803	0	46,818	9.00

	QUANTY	UOM	CONTRACT	CONTINGN	ESCALATN	TOTAL COST	UNIT COST
TOTAL Inspection Trench	5200.00	LF	89,440	17,888	0	107,328	20.64
01_01.05 Initial Groundwater Drawdown							
01_01.05.01 Pumping			8,420	1,684	0	10,104	
01_01.05.02 Treatment Surcharge			34,000	6,800	0	40,800	
01_01.05.03 Analytical Testing			25,000	5,000	0	30,000	
01_01.05.04 Sample Collection			800	160	0	960	
TOTAL Initial Groundwater Drawdown			68,221	13,644	0	81,865	
TOTAL Slurry Wall	1.00	EA	3,630,337	726,067	0	4,356,405	4356404.95
01_02 Seal Peripheral Areas							
01_02.01 3' Clay Layer							
01_02.01.01 Excavate & Haul Clay	158620	CY	1,549,437	232,416	0	1,781,853	11.23
01_02.01.02 Spread & Compact Clay	158620	CY	931,527	139,729	0	1,071,256	6.75
TOTAL 3' Clay Layer	158620	CY	2,480,964	372,145	0	2,853,108	17.99
01_02.03 6" Sand							
01_02.03.01 Spread Sand	26440	CY	404,263	60,639	0	464,902	17.58
TOTAL 6" Sand	26440	CY	404,263	60,639	0	464,902	17.58
01_02.04 2' Clean Fill							
01_02.04.01 Excavate & Haul Clean Fill	105750	CY	822,856	123,428	0	946,285	8.95
01_02.04.02 Spread & Compact Clean Fill	105750	CY	200,930	30,139	0	231,069	2.19
TOTAL 2' Clean Fill	105750	CY	1,023,786	153,568	0	1,177,354	11.13
01_02.05 6" Topsoil							
01_02.05.01 Spread Topsoil	26440	CY	354,963	53,244	0	408,208	15.44
TOTAL 6" Topsoil	26440	CY	354,963	53,244	0	408,208	15.44
01_02.06 Seeding							
01_02.06.01 Spread Seedings	20.00	AC	68,596	10,289	0	78,885	3944.27

	QUANTY	UOM	CONTRACT	CONTINGN	ESCALATN	TOTAL COST	UNIT COST
TOTAL Seeding	20.00	AC	68,596	10,289	0	78,885	3944.27
TOTAL Seal Peripheral Areas	1.00	EA	4,332,572	649,886	0	4,982,458	4982457.62
01_03 Hydraulic Gradient Control							
01_03.01 Well Points	221.00	EA	77,239	11,586	0	88,825	401.92
01_03.02 Header Piping	11025	LF	605,506	90,826	0	696,332	63.16
01_03.03 Pumps	11.00	EA	137,303	20,595	0	157,898	14354.40
01_03.04 Ground Water Monitoring Wells	12.00	EA	38,944	5,842	0	44,786	3732.14
01_03.05 Disch. Pipe to Indianapolis Ave.	500.00	LF	37,446	5,617	0	43,063	86.13
TOTAL Hydraulic Gradient Control	1.00	EA	896,438	134,466	0	1,030,904	1030904.14
01_04 Water Treatment System (24%)			1,557,939	233,691	0	1,791,630	
TOTAL Present Site RCRA Closure	1.00	EA	10,417,287	1,744,110	0	12,161,397	12161396.52
02 Dredging & CDF							
02_01 Dredging Stages I, & II							
02_01.01 Dredging Incl. Barge to Site	4675000	CY	55,260,999	8,289,150	0	63,550,149	13.59
TOTAL Dredging Stages I, & II	1.00	EA	55,260,999	8,289,150	0	63,550,149	63550148.58
02_02 Water Treatment System (76%)							
02_02.01 Costs of Water Treatment System			4,933,470	740,021	0	5,673,491	
TOTAL Water Treatment System (76%)			4,933,470	740,021	0	5,673,491	
02_03 Sediment Dewatering System							
02_03.01 Decant Structure	5.00	EA	38,981	5,847	0	44,828	8965.64
TOTAL Decant Structure	5.00	EA	38,981	5,847	0	44,828	8965.64
02_03.02 Piping							
02_03.02.01 Concrete Pipe	1000.00	LF	33,558	5,034	0	38,592	38.59
TOTAL Piping			33,558	5,034	0	38,592	
TOTAL Sediment Dewatering System	1.00	EA	72,539	10,881	0	83,420	83420.08

	QUANTY	UOM	CONTRACT	CONTINGN	ESCALATN	TOTAL COST	UNIT COST
02_05 Dike Systems, Stages I & II							
02_05.01 Embankment							
02_05.01.01 Embankment Stage I	232711	CY	2,408,012	361,202	0	2,769,213	11.90
02_05.01.02 Embankment Stage II	342909	CY	3,548,302	532,245	0	4,080,547	11.90
TOTAL Embankment	575620	CY	5,956,313	893,447	0	6,849,760	11.90
02_05.02 3' Clay Slope Liner							
02_05.02.01 Excavate & Haul Clay Liner	38510	CY	448,420	67,263	0	515,683	13.39
02_05.02.02 Spread & Compact Clay Liner	38510	CY	244,782	36,717	0	281,499	7.31
TOTAL 3' Clay Slope Liner	38510	CY	693,202	103,980	0	797,183	20.70
02_05.03 Cross Dikes 8' Ht.							
02_05.03.01 Existing On-Site Fill	31500	CY	260,682	39,102	0	299,784	9.52
02_05.03.02 Dried Sediments	21200	CY	175,443	26,316	0	201,760	9.52
02_05.03.03 Stripping	68500	CY	256,507	38,476	0	294,983	4.31
TOTAL Cross Dikes 8' Ht.	115000	CY	692,632	103,895	0	796,527	6.93
02_05.04 6" Topsoil							
02_05.04.01 Spread Topsoil	18500	CY	248,367	37,255	0	285,622	15.44
TOTAL 6" Topsoil	18500	CY	248,367	37,255	0	285,622	15.44
02_05.05 Seeding							
02_05.05.01 Spread Seeding	23.00	AC	74,579	11,187	0	85,766	3728.96
TOTAL Seeding	23.00	AC	74,579	11,187	0	85,766	3728.96
02_05.06 Ramp & Road							
02_05.06.01 Curbs	94064	LF	1,426,398	213,960	0	1,640,358	17.44
02_05.06.02 8" Base Course	78387	SY	680,011	102,002	0	782,013	9.98
02_05.06.03 6" CA - 6	13064	CY	358,745	53,812	0	412,557	31.58
02_05.06.04 Rehandling Pad	1111.00	SY	14,769	2,215	0	16,984	15.29
02_05.06.05 Ramp	29978	CY	370,446	55,567	0	426,013	14.21
TOTAL Ramp & Road			2,850,369	427,555	0	3,277,924	

	QUANTY	UOM	CONTRACT	CONTINGN	ESCALATN	TOTAL COST	UNIT COST
TOTAL Dike Systems, Stages I & II	1.00	EA	10,515,463	1,577,319	0	12,092,782	12092782.29
02_06 Seal Base of Dikes (3' Clay)							
02_06.01 Excavate & Haul Clay	123280	CY	1,303,641	195,546	0	1,499,187	12.16
02_06.03 Spread & Compact Clay	123280	CY	712,696	106,904	0	819,600	6.65
TOTAL Seal Base of Dikes (3' Clay)	123280	CY	2,016,336	302,450	0	2,318,787	18.81
02_07 Final Cap							
02_07.01 3' Clay Liner							
02_07.01.01 Excavate & Haul Clay Liner	474000	CY	4,630,143	694,521	0	5,324,664	11.23
02_07.01.02 Spread & Compact Clay Liner	474000	CY	2,783,657	417,549	0	3,201,205	6.75
TOTAL 3' Clay Liner	474000	CY	7,413,799	1,112,070	0	8,525,869	17.99
02_07.02 2' Clean Fill							
02_07.02.01 Excavate & Haul Clean Fill	316000	CY	2,669,881	400,482	0	3,070,363	9.72
02_07.02.02 Spread & Compact Clean Fill	316000	CY	600,414	90,062	0	690,477	2.19
TOTAL 2' Clean Fill	316000	CY	3,270,295	490,544	0	3,760,840	11.90
02_07.03 6" Sand Drainage Layer							
02_07.03.01 Spread Sand	79000	CY	1,207,895	181,184	0	1,389,080	17.58
TOTAL 6" Sand Drainage Layer	79000	CY	1,207,895	181,184	0	1,389,080	17.58
02_07.04 6" Topsoil							
02_07.04.01 Spread Topsoil	79000	CY	1,060,593	159,089	0	1,219,682	15.44
TOTAL 6" Topsoil	79000	CY	1,060,593	159,089	0	1,219,682	15.44
02_07.05 Seeding							
02_07.05.01 Spread Seeds	100.00	AC	324,257	48,639	0	372,896	3728.96
TOTAL Seeding	100.00	AC	324,257	48,639	0	372,896	3728.96
TOTAL Final Cap	1.00	EA	13,276,841	1,991,526	0	15,268,367	15268366.58

	QUANTY	UOM	CONTRACT	CONTINGN	ESCALATN	TOTAL COST	UNIT COST
TOTAL Dredging & CDF	1.00	EA	86,075,648	12,911,347	0	98,986,995	98986995.35
TOTAL Indiana Harbor and Canal	1.00	EA	96,492,935	14,655,457	0	111,148,392	111148392

** PROJECT INDIRECT SUMMARY - Contract **

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 Present Site RCRA Closure	1.00	EA	8,345,791	584,205	446,500	937,650	103,141	10,417,287	10417286.65
02 Dredging & CDF	1.00	EA	68,959,351	4,827,155	3,689,325	7,747,583	852,234	86,075,648	86075648.13
TOTAL Indiana Harbor and Canal	1.00	EA	77,305,142	5,411,360	4,135,825	8,685,233	955,376	96,492,935	96492934.78
Contingency (15%)								14,655,457	
TOTAL INCL OWNER COSTS								111,148,392	

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 Present Site RCRA Closure									
01_01 Slurry Wall									
01_01.01 Bentonite Slurry Wall-Site Peri.									
01_01.01.01 Mobilization & Site Preparation	1.00	EA	100,014	7,001	5,351	11,237	1,236	124,838	124838.32
TOTAL Mobilization & Site Preparation	1.00	EA	100,014	7,001	5,351	11,237	1,236	124,838	124838.32
01_01.01.02 Bentonite Slurry Trench									
01_01.01.02_ 01 Initial Slurry Placement	733.60	CY	2,973	208	159	334	37	3,711	5.06
01_01.01.02_ 02 Remainder Slurry Trench	43469	CY	1,585,772	111,004	84,839	178,162	19,598	1,979,374	45.54
TOTAL Bentonite Slurry Trench	1.00	EA	1,588,745	111,212	84,998	178,496	19,635	1,983,085	1983085.21
01_01.01.03 Slurry Trench Excav. & Disposal	39197	CY	92,256	6,458	4,936	10,365	1,140	115,155	2.94
01_01.01.04 Borrow for Slurry Trench Fill	39269	CY	234,571	16,420	12,550	26,354	2,899	292,793	7.46
01_01.01.05 Disposal of Excess Slurry	863.00	CY	10,284	720	550	1,155	127	12,836	14.87
TOTAL Bentonite Slurry Wall-Site Peri.	341715	SF	2,025,870	141,811	108,384	227,606	25,037	2,528,708	7.40
01_01.02 Railroad Relocation									
01_01.02.01 Clearing and Grubbing	7.00	AC	32,690	2,288	1,749	3,673	404	40,804	5829.13
01_01.02.02 Topsoil Stripping	6296.00	CY	15,236	1,067	815	1,712	188	19,018	3.02
01_01.02.03 Roadbed Earthfill	18350	CY	152,856	10,700	8,178	17,173	1,889	190,796	10.40
01_01.02.04 Ditches and Swales			16,103	1,127	862	1,809	199	20,100	
01_01.02.05 Sub-Ballast	4320.00	TN	55,642	3,895	2,977	6,251	688	69,452	16.08
01_01.02.06 Duo-Rail, Single Side Track	3400.00	LF	301,138	21,080	16,111	33,833	3,722	375,883	110.55
01_01.02.07 Turnouts #10, incl. Rails, Frog			84,626	5,924	4,527	9,508	1,046	105,631	
01_01.02.08 RR Crossing Rubber Mat & Traf. S			41,063	2,874	2,197	4,613	507	51,255	
01_01.02.09 Topsoil Replacement	6296.00	CY	30,410	2,129	1,627	3,417	376	37,958	6.03
01_01.02.10 Seeding	5.00	AC	13,044	913	698	1,465	161	16,281	3256.20
01_01.02.11 Relocate Light Pole			2,214	155	118	249	27	2,764	
01_01.02.12 Relocate Surface Discharge Pipe			1,208	85	65	136	15	1,508	
01_01.02.13 Brick Masonry Wall Relocation			8,302	581	444	933	103	10,363	
01_01.02.14 Replace Gate			1,728	121	92	194	21	2,157	
TOTAL Railroad Relocation			756,259	52,938	40,460	84,966	9,346	943,968	
01_01.04 Inspection Trench									
01_01.04.01 Trench Excavation	5200.00	LF	40,398	2,828	2,161	4,539	499	50,425	9.70
01_01.04.02 Trench Backfill	5200.00	LF	31,257	2,188	1,672	3,512	386	39,015	7.50

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                                                             QUANTY UOM      DIRECT    FIELD OH    HOME OFC      PROFIT        BOND  TOTAL COST   UNIT COST
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                    TOTAL Inspection Trench                  5200.00 LF      71,655       5,016       3,834       8,050         886      89,440       17.20


           01_01.05  Initial Groundwater Drawdown

           01_01.05.01  Pumping                                               6,746         472         361         758          83       8,420
           01_01.05.02  Treatment Surcharge                                  27,239       1,907       1,457       3,060         337      34,000
           01_01.05.03  Analytical Testing                                   20,029       1,402       1,072       2,250         248      25,000
           01_01.05.04  Sample Collection                                       641          45          34          72           8         800
                                                                        ----------- ----------- ----------- ----------- ----------- -----------
                    TOTAL Initial Groundwater Drawdown                       54,655       3,826       2,924       6,140         675      68,221
                                                                        ----------- ----------- ----------- ----------- ----------- -----------
                    TOTAL Slurry Wall                           1.00 EA   2,908,438     203,591     155,601     326,763      35,944   3,630,337  3630337.46


           01_02  Seal Peripheral Areas

           01_02.01  3' Clay Layer

           01_02.01.01  Excavate & Haul Clay                  158620 CY   1,241,329      86,893      66,411     139,463      15,341   1,549,437        9.77
           01_02.01.02  Spread & Compact Clay                 158620 CY     746,291      52,240      39,927      83,846       9,223     931,527        5.87
                                                                        ----------- ----------- ----------- ----------- ----------- -----------
                    TOTAL 3' Clay Layer                        158620 CY   1,987,620     139,133     106,338     223,309      24,564   2,480,964       15.64


           01_02.03  6" Sand

           01_02.03.01  Spread Sand                            26440 CY     323,874      22,671      17,327      36,387       4,003     404,263       15.29
                                                                        ----------- ----------- ----------- ----------- ----------- -----------
                    TOTAL 6" Sand                              26440 CY     323,874      22,671      17,327      36,387       4,003     404,263       15.29


           01_02.04  2' Clean Fill

           01_02.04.01  Excavate & Haul Clean Fill            105750 CY     659,230      46,146      35,269      74,064       8,147     822,856        7.78
           01_02.04.02  Spread & Compact Clean Fill           105750 CY     160,975      11,268       8,612      18,085       1,989     200,930        1.90
                                                                        ----------- ----------- ----------- ----------- ----------- -----------
                    TOTAL 2' Clean Fill                       105750 CY     820,204      57,414      43,881      92,150      10,136   1,023,786        9.68


           01_02.05  6" Topsoil

           01_02.05.01  Spread Topsoil                         26440 CY     284,378      19,906      15,214      31,950       3,514     354,963       13.43
                                                                        ----------- ----------- ----------- ----------- ----------- -----------
                    TOTAL 6" Topsoil                           26440 CY     284,378      19,906      15,214      31,950       3,514     354,963       13.43


           01_02.06  Seeding

           01_02.06.01  Spread Seedings                          20.00 AC      54,956       3,847       2,940       6,174         679      68,596     3429.80
```

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Seeding	20.00	AC	54,956	3,847	2,940	6,174	679	68,596	3429.80
TOTAL Seal Peripheral Areas	1.00	EA	3,471,032	242,972	185,700	389,970	42,897	4,332,572	4332571.85
01_03 Hydraulic Gradient Control									
01_03.01 Well Points	221.00	EA	61,880	4,332	3,311	6,952	765	77,239	349.50
01_03.02 Header Piping	11025	LF	485,100	33,957	25,953	54,501	5,995	605,506	54.92
01_03.03 Pumps	11.00	EA	110,000	7,700	5,885	12,359	1,359	137,303	12482.09
01_03.04 Ground Water Monitoring Wells	12.00	EA	31,200	2,184	1,669	3,505	386	38,944	3245.34
01_03.05 Disch. Pipe to Indianapolis Ave.	500.00	LF	30,000	2,100	1,605	3,371	371	37,446	74.89
TOTAL Hydraulic Gradient Control	1.00	EA	718,180	50,273	38,423	80,688	8,876	896,438	896438.38
01_04 Water Treatment System (24%)			1,248,140	87,370	66,775	140,229	15,425	1,557,939	
TOTAL Present Site RCRA Closure	1.00	EA	8,345,791	584,205	446,500	937,650	103,141	10,417,287	10417286.65
02 Dredging & CDF									
02_01 Dredging Stages I, & II									
02_01.01 Dredging Incl. Barge to Site	4675000	CY	44,272,250	3,099,058	2,368,565	4,973,987	547,139	55,260,999	11.82
TOTAL Dredging Stages I, & II	1.00	EA	44,272,250	3,099,058	2,368,565	4,973,987	547,139	55,260,999	55260998.76
02_02 Water Treatment System (76%)									
02_02.01 Costs of Water Treatment System			3,952,441	276,671	211,456	444,057	48,846	4,933,470	
TOTAL Water Treatment System (76%)			3,952,441	276,671	211,456	444,057	48,846	4,933,470	
02_03 Sediment Dewatering System									
02_03.01 Decant Structure	5.00	EA	31,230	2,186	1,671	3,509	386	38,981	7796.21
TOTAL Decant Structure	5.00	EA	31,230	2,186	1,671	3,509	386	38,981	7796.21
02_03.02 Piping									
02_03.02.01 Concrete Pipe	1000.00	LF	26,885	1,882	1,438	3,021	332	33,558	33.56
TOTAL Piping			26,885	1,882	1,438	3,021	332	33,558	
TOTAL Sediment Dewatering System	1.00	EA	58,115	4,068	3,109	6,529	718	72,539	72539.20

	QUANTY UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
02_05 Dike Systems, Stages I & II								
02_05.01 Embankment								
02_05.01.01 Embankment Stage I	232711 CY	1,929,174	135,042	103,211	216,743	23,842	2,408,012	10.35
02_05.01.02 Embankment Stage II	342909 CY	2,842,716	198,990	152,085	319,379	35,132	3,548,302	10.35
TOTAL Embankment	575620 CY	4,771,890	334,032	255,296	536,122	58,973	5,956,313	10.35
02_05.02 3' Clay Slope Liner								
02_05.02.01 Excavate & Haul Clay Liner	38510 CY	359,251	25,148	19,220	40,362	4,440	448,420	11.64
02_05.02.02 Spread & Compact Clay Liner	38510 CY	196,107	13,727	10,492	22,033	2,424	244,782	6.36
TOTAL 3' Clay Slope Liner	38510 CY	555,358	38,875	29,712	62,394	6,863	693,202	18.00
02_05.03 Cross Dikes 8' Ht.								
02_05.03.01 Existing On-Site Fill	31500 CY	208,845	14,619	11,173	23,464	2,581	260,682	8.28
02_05.03.02 Dried Sediments	21200 CY	140,556	9,839	7,520	15,791	1,737	175,443	8.28
02_05.03.03 Stripping	68500 CY	205,500	14,385	10,994	23,088	2,540	256,507	3.74
TOTAL Cross Dikes 8' Ht.	115000 CY	554,901	38,843	29,687	62,343	6,858	692,632	6.02
02_05.04 6" Topsoil								
02_05.04.01 Spread Topsoil	18500 CY	198,979	13,929	10,645	22,355	2,459	248,367	13.43
TOTAL 6" Topsoil	18500 CY	198,979	13,929	10,645	22,355	2,459	248,367	13.43
02_05.05 Seeding								
02_05.05.01 Spread Seeding	23.00 AC	59,749	4,182	3,197	6,713	738	74,579	3242.57
TOTAL Seeding	23.00 AC	59,749	4,182	3,197	6,713	738	74,579	3242.57
02_05.06 Ramp & Road								
02_05.06.01 Curbs	94064 LF	1,142,756	79,993	61,137	128,389	14,123	1,426,398	15.16
02_05.06.02 8" Base Course	78387 SY	544,790	38,135	29,146	61,207	6,733	680,011	8.68
02_05.06.03 6" CA - 6	13064 CY	287,408	20,119	15,376	32,290	3,552	358,745	27.46
02_05.06.04 Rehandling Pad	1111.00 SY	11,832	828	633	1,329	146	14,769	13.29
02_05.06.05 Ramp	29978 CY	296,782	20,775	15,878	33,343	3,668	370,446	12.36
TOTAL Ramp & Road		2,283,568	159,850	122,171	256,559	28,221	2,850,369	

	QUANTY	UOM	DIRECT	FIELD OH	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
TOTAL Dike Systems, Stages I & II	1.00	EA	8,424,444	589,711	450,708	946,486	104,113	10,515,463	10515462.86
02_06 Seal Base of Dikes (3' Clay)									
02_06.01 Excavate & Haul Clay	123280	CY	1,044,409	73,109	55,876	117,339	12,907	1,303,641	10.57
02_06.03 Spread & Compact Clay	123280	CY	570,975	39,968	30,547	64,149	7,056	712,696	5.78
TOTAL Seal Base of Dikes (3' Clay)	123280	CY	1,615,384	113,077	86,423	181,488	19,964	2,016,336	16.36
02_07 Final Cap									
02_07.01 3' Clay Liner									
02_07.01.01 Excavate & Haul Clay Liner	474000	CY	3,709,431	259,660	198,455	416,755	45,843	4,630,143	9.77
02_07.01.02 Spread & Compact Clay Liner	474000	CY	2,230,122	156,109	119,312	250,554	27,561	2,783,657	5.87
TOTAL 3' Clay Liner	474000	CY	5,939,552	415,769	317,766	667,309	73,404	7,413,799	15.64
02_07.02 2' Clean Fill									
02_07.02.01 Excavate & Haul Clean Fill	316000	CY	2,138,970	149,728	114,435	240,313	26,434	2,669,881	8.45
02_07.02.02 Spread & Compact Clean Fill	316000	CY	481,021	33,671	25,735	54,043	5,945	600,414	1.90
TOTAL 2' Clean Fill	316000	CY	2,619,991	183,399	140,170	294,356	32,379	3,270,295	10.35
02_07.03 6" Sand Drainage Layer									
02_07.03.01 Spread Sand	79000	CY	967,703	67,739	51,772	108,721	11,959	1,207,895	15.29
TOTAL 6" Sand Drainage Layer	79000	CY	967,703	67,739	51,772	108,721	11,959	1,207,895	15.29
02_07.04 6" Topsoil									
02_07.04.01 Spread Topsoil	79000	CY	849,692	59,478	45,459	95,463	10,501	1,060,593	13.43
TOTAL 6" Topsoil	79000	CY	849,692	59,478	45,459	95,463	10,501	1,060,593	13.43
02_07.05 Seeding									
02_07.05.01 Spread Seeds	100.00	AC	259,778	18,184	13,898	29,186	3,210	324,257	3242.57
TOTAL Seeding	100.00	AC	259,778	18,184	13,898	29,186	3,210	324,257	3242.57
TOTAL Final Cap	1.00	EA	10,636,717	744,570	569,064	1,195,035	131,454	13,276,841	13276840.50

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                                                                                  QUANTY UOM      DIRECT    FIELD OH    HOME OFC      PROFIT        BOND  TOTAL COST   UNIT COST
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                                       TOTAL Dredging & CDF                         1.00 EA   68,959,351   4,827,155   3,689,325   7,747,583     852,234  86,075,648 86075648.13
                                                                                            ----------- ----------- ----------- ----------- ----------- -----------
                                       TOTAL Indiana Harbor and Canal               1.00 EA   77,305,142   5,411,360   4,135,825   8,685,233     955,376  96,492,935 96492934.78

                              Contingency (15%)                                                                                                           14,655,457
                                                                                                                                                          -----------
                                TOTAL INCL OWNER COSTS                                                                                                   111,148,392
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                                                               QUANTY UOM      LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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                          01  Present Site RCRA Closure          1.00 EA   3,294,351  2,374,348  1,683,179    993,913  8,345,791 8345790.50
                          02  Dredging & CDF                     1.00 EA  10,610,635  8,827,588  2,965,310 46,555,818 68,959,351 68959351.05
                                                                          ----------- ----------- ----------- ----------- -----------
                        TOTAL Indiana Harbor and Canal           1.00 EA  13,904,986 11,201,935  4,648,489 47,549,731 77,305,142 77305141.55

                            Field Office Overhead (7%)                                                                  5,411,360
                                                                                                                      -----------
                              SUBTOTAL                                                                                 82,716,501
                            Home Office Overhead (5%)                                                                   4,135,825
                                                                                                                      -----------
                              SUBTOTAL                                                                                 86,852,327
                            Profit (10%)                                                                                8,685,233
                                                                                                                      -----------
                              SUBTOTAL                                                                                 95,537,559
                            Bond (1%)                                                                                     955,376
                                                                                                                      -----------
                              TOTAL INCL INDIRECTS                                                                     96,492,935
                            Contingency (15%)                                                                          14,655,457
                                                                                                                      -----------
                              TOTAL INCL OWNER COSTS                                                                  111,148,392
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	QUANTY	UOM	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01 Present Site RCRA Closure								
01_01 Slurry Wall								
01_01.01 Bentonite Slurry Wall-Site Peri.								
01_01.01.01 Mobilization & Site Preparation	1.00	EA	0	0	0	100,014	100,014	100014.00
TOTAL Mobilization & Site Preparation	1.00	EA	0	0	0	100,014	100,014	100014.00
01_01.01.02 Bentonite Slurry Trench								
01_01.01.02_ 01 Initial Slurry Placement	733.60	CY	1,569	1,404	0	0	2,973	4.05
01_01.01.02_ 02 Remainder Slurry Trench	43469	CY	688,317	420,705	476,750	0	1,585,772	36.48
TOTAL Bentonite Slurry Trench	1.00	EA	689,886	422,110	476,750	0	1,588,745	1588745.16
01_01.01.03 Slurry Trench Excav. & Disposal	39197	CY	41,935	50,321	0	0	92,256	2.35
01_01.01.04 Borrow for Slurry Trench Fill	39269	CY	81,697	109,194	0	43,680	234,571	5.97
01_01.01.05 Disposal of Excess Slurry	863.00	CY	1,112	297	0	8,875	10,284	11.92
TOTAL Bentonite Slurry Wall-Site Peri.	341715	SF	814,630	581,921	476,750	152,569	2,025,870	5.93
01_01.02 Railroad Relocation								
01_01.02.01 Clearing and Grubbing	7.00	AC	19,614	13,076	0	0	32,690	4670.00
01_01.02.02 Topsoil Stripping	6296.00	CY	7,492	7,744	0	0	15,236	2.42
01_01.02.03 Roadbed Earthfill	18350	CY	74,868	77,988	0	0	152,856	8.33
01_01.02.04 Ditches and Swales			7,890	8,213	0	0	16,103	
01_01.02.05 Sub-Ballast	4320.00	TN	7,776	10,584	37,282	0	55,642	12.88
01_01.02.06 Duo-Rail, Single Side Track	3400.00	LF	69,258	15,062	216,818	0	301,138	88.57
01_01.02.07 Turnouts #10, incl. Rails, Frog			9,309	3,385	71,932	0	84,626	
01_01.02.08 RR Crossing Rubber Mat & Traf. S			0	0	0	41,063	41,063	
01_01.02.09 Topsoil Replacement	6296.00	CY	14,922	15,488	0	0	30,410	4.83
01_01.02.10 Seeding	5.00	AC	1,957	1,304	9,783	0	13,044	2608.70
01_01.02.11 Relocate Light Pole			0	0	0	2,214	2,214	
01_01.02.12 Relocate Surface Discharge Pipe			0	0	0	1,208	1,208	
01_01.02.13 Brick Masonry Wall Relocation			0	0	0	8,302	8,302	
01_01.02.14 Replace Gate			0	0	0	1,728	1,728	
TOTAL Railroad Relocation			213,085	152,844	335,814	54,515	756,259	
01_01.04 Inspection Trench								
01_01.04.01 Trench Excavation	5200.00	LF	18,981	7,422	0	13,994	40,398	7.77
01_01.04.02 Trench Backfill	5200.00	LF	24,560	6,697	0	0	31,257	6.01

	QUANTY	UOM	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
TOTAL Inspection Trench	5200.00	LF	43,541	14,120	0	13,994	71,655	13.78
01_01.05 Initial Groundwater Drawdown								
01_01.05.01 Pumping			0	0	0	6,746	6,746	
01_01.05.02 Treatment Surcharge			0	0	0	27,239	27,239	
01_01.05.03 Analytical Testing			0	0	0	20,029	20,029	
01_01.05.04 Sample Collection			0	0	0	641	641	
TOTAL Initial Groundwater Drawdown			0	0	0	54,655	54,655	
TOTAL Slurry Wall	1.00	EA	1,071,256	748,885	812,564	275,733	2,908,438	2908438.34
01_02 Seal Peripheral Areas								
01_02.01 3' Clay Layer								
01_02.01.01 Excavate & Haul Clay	158620	CY	556,312	685,017	0	0	1,241,329	7.83
01_02.01.02 Spread & Compact Clay	158620	CY	466,120	280,171	0	0	746,291	4.70
TOTAL 3' Clay Layer	158620	CY	1,022,432	965,188	0	0	1,987,620	12.53
01_02.03 6" Sand								
01_02.03.01 Spread Sand	26440	CY	29,233	17,021	277,620	0	323,874	12.25
TOTAL 6" Sand	26440	CY	29,233	17,021	277,620	0	323,874	12.25
01_02.04 2' Clean Fill								
01_02.04.01 Excavate & Haul Clean Fill	105750	CY	283,520	375,709	0	0	659,230	6.23
01_02.04.02 Spread & Compact Clean Fill	105750	CY	105,109	55,866	0	0	160,975	1.52
TOTAL 2' Clean Fill	105750	CY	388,629	431,575	0	0	820,204	7.76
01_02.05 6" Topsoil								
01_02.05.01 Spread Topsoil	26440	CY	23,993	22,425	237,960	0	284,378	10.76
TOTAL 6" Topsoil	26440	CY	23,993	22,425	237,960	0	284,378	10.76
01_02.06 Seeding								
01_02.06.01 Spread Seedings	20.00	AC	9,923	2,033	43,000	0	54,956	2747.78

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                                                                 QUANTY UOM       LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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                    TOTAL Seeding                                 20.00 AC        9,923       2,033      43,000           0      54,956     2747.78
                                                                            ----------- ----------- ----------- ----------- -----------
                    TOTAL Seal Peripheral Areas                    1.00 EA    1,474,211   1,438,242     558,580           0   3,471,032  3471032.16


          01_03  Hydraulic Gradient Control

          01_03.01  Well Points                                  221.00 EA            0           0           0      61,880      61,880      280.00
          01_03.02  Header Piping                                 11025 LF            0           0           0     485,100     485,100       44.00
          01_03.03  Pumps                                         11.00 EA            0           0           0     110,000     110,000    10000.00
          01_03.04  Ground Water Monitoring Wells                 12.00 EA            0           0           0      31,200      31,200     2600.00
          01_03.05  Disch. Pipe to Indianapolis Ave.             500.00 LF            0           0           0      30,000      30,000       60.00
                                                                            ----------- ----------- ----------- ----------- -----------
                    TOTAL Hydraulic Gradient Control               1.00 EA            0           0           0     718,180     718,180   718180.00

          01_04  Water Treatment System (24%)                                   748,884     187,221     312,035           0   1,248,140
                                                                            ----------- ----------- ----------- ----------- -----------
                    TOTAL Present Site RCRA Closure                1.00 EA    3,294,351   2,374,348   1,683,179     993,913   8,345,791  8345790.50


          02  Dredging & CDF

          02_01  Dredging Stages I, & II

          02_01.01  Dredging Incl. Barge to Site                4675000 CY            0           0           0  44,272,250  44,272,250        9.47
                                                                            ----------- ----------- ----------- ----------- -----------
                    TOTAL Dredging Stages I, & II                  1.00 EA            0           0           0  44,272,250  44,272,250 44272250.00


          02_02  Water Treatment System (76%)

          02_02.01  Costs of Water Treatment System                           2,370,000     594,331     988,110           0   3,952,441
                                                                            ----------- ----------- ----------- ----------- -----------
                    TOTAL Water Treatment System (76%)                        2,370,000     594,331     988,110           0   3,952,441


          02_03  Sediment Dewatering System

          02_03.01  Decant Structure                               5.00 EA       11,237       1,793      18,200           0      31,230     6245.92
                                                                            ----------- ----------- ----------- ----------- -----------
                    TOTAL Decant Structure                         5.00 EA       11,237       1,793      18,200           0      31,230     6245.92


          02_03.02  Piping

          02_03.02.01  Concrete Pipe                             1000.00 LF       16,218       4,667       6,000           0      26,885       26.89
                                                                            ----------- ----------- ----------- ----------- -----------
                    TOTAL Piping                                                 16,218       4,667       6,000           0      26,885
                                                                            ----------- ----------- ----------- ----------- -----------
                    TOTAL Sediment Dewatering System               1.00 EA       27,455       6,460      24,200           0      58,115    58114.65
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	QUANTY	UOM	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
02_05 Dike Systems, Stages I & II								
02_05.01 Embankment								
02_05.01.01 Embankment Stage I	232711	CY	944,807	984,368	0	0	1,929,174	8.29
02_05.01.02 Embankment Stage II	342909	CY	1,392,211	1,450,505	0	0	2,842,716	8.29
TOTAL Embankment	575620	CY	2,337,017	2,434,873	0	0	4,771,890	8.29
02_05.02 3' Clay Slope Liner								
02_05.02.01 Excavate & Haul Clay Liner	38510	CY	161,001	198,250	0	0	359,251	9.33
02_05.02.02 Spread & Compact Clay Liner	38510	CY	122,485	73,622	0	0	196,107	5.09
TOTAL 3' Clay Slope Liner	38510	CY	283,486	271,872	0	0	555,358	14.42
02_05.03 Cross Dikes 8' Ht.								
02_05.03.01 Existing On-Site Fill	31500	CY	102,375	106,470	0	0	208,845	6.63
02_05.03.02 Dried Sediments	21200	CY	68,900	71,656	0	0	140,556	6.63
02_05.03.03 Stripping	68500	CY	100,695	104,805	0	0	205,500	3.00
TOTAL Cross Dikes 8' Ht.	115000	CY	271,970	282,931	0	0	554,901	4.83
02_05.04 6" Topsoil								
02_05.04.01 Spread Topsoil	18500	CY	16,788	15,691	166,500	0	198,979	10.76
TOTAL 6" Topsoil	18500	CY	16,788	15,691	166,500	0	198,979	10.76
02_05.05 Seeding								
02_05.05.01 Spread Seeding	23.00	AC	11,411	2,338	46,000	0	59,749	2597.78
TOTAL Seeding	23.00	AC	11,411	2,338	46,000	0	59,749	2597.78
02_05.06 Ramp & Road								
02_05.06.01 Curbs	94064	LF	0	0	0	1,142,756	1,142,756	12.15
02_05.06.02 8" Base Course	78387	SY	0	0	0	544,790	544,790	6.95
02_05.06.03 6" CA - 6	13064	CY	0	0	0	287,408	287,408	22.00
02_05.06.04 Rehandling Pad	1111.00	SY	0	0	0	11,832	11,832	10.65
02_05.06.05 Ramp	29978	CY	0	0	0	296,782	296,782	9.90
TOTAL Ramp & Road			0	0	0	2,283,568	2,283,568	

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                                                               QUANTY UOM       LABOR   EQUIPMNT    MATERIAL       OTHER TOTAL COST  UNIT COST
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                                  TOTAL Dike Systems, Stages I & II      1.00 EA   2,920,672  3,007,704     212,500   2,283,568  8,424,444 8424444.20

                          02_06  Seal Base of Dikes (3' Clay)

                          02_06.01  Excavate & Haul Clay         123280 CY     458,881    585,529           0           0  1,044,409       8.47
                          02_06.03  Spread & Compact Clay        123280 CY     335,663    235,312           0           0    570,975       4.63
                                                                          ----------- ----------- ----------- ----------- -----------
                                  TOTAL Seal Base of Dikes (3' Clay)     123280 CY     794,543    820,841           0           0  1,615,384      13.10

                          02_07  Final Cap

                          02_07.01  3' Clay Liner

                          02_07.01.01  Excavate & Haul Clay Liner     474000 CY   1,662,413  2,047,018           0           0  3,709,431       7.83
                          02_07.01.02  Spread & Compact Clay Liner    474000 CY   1,392,894    837,227           0           0  2,230,122       4.70
                                                                          ----------- ----------- ----------- ----------- -----------
                                  TOTAL 3' Clay Liner                    474000 CY   3,055,307  2,884,245           0           0  5,939,552      12.53

                          02_07.02  2' Clean Fill

                          02_07.02.01  Excavate & Haul Clean Fill     316000 CY     919,925  1,219,046           0           0  2,138,970       6.77
                          02_07.02.02  Spread & Compact Clean Fill    316000 CY     314,084    166,937           0           0    481,021       1.52
                                                                          ----------- ----------- ----------- ----------- -----------
                                  TOTAL 2' Clean Fill                    316000 CY   1,234,009  1,385,982           0           0  2,619,991       8.29

                          02_07.03  6" Sand Drainage Layer

                          02_07.03.01  Spread Sand                     79000 CY      87,347     50,857     829,500           0    967,703      12.25
                                                                          ----------- ----------- ----------- ----------- -----------
                                  TOTAL 6" Sand Drainage Layer            79000 CY      87,347     50,857     829,500           0    967,703      12.25

                          02_07.04  6" Topsoil

                          02_07.04.01  Spread Topsoil                  79000 CY      71,689     67,004     711,000           0    849,692      10.76
                                                                          ----------- ----------- ----------- ----------- -----------
                                  TOTAL 6" Topsoil                        79000 CY      71,689     67,004     711,000           0    849,692      10.76

                          02_07.05  Seeding

                          02_07.05.01  Spread Seeds                   100.00 AC      49,613     10,165     200,000           0    259,778    2597.78
                                                                          ----------- ----------- ----------- ----------- -----------
                                  TOTAL Seeding                          100.00 AC      49,613     10,165     200,000           0    259,778    2597.78
                                                                          ----------- ----------- ----------- ----------- -----------
                                  TOTAL Final Cap                          1.00 EA   4,497,965  4,398,252   1,740,500           0 10,636,717 10636716.95
                                                                          ----------- ----------- ----------- ----------- -----------
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	QUANTY	UOM	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
TOTAL Dredging & CDF	1.00	EA	10,610,635	8,827,588	2,965,310	46,555,818	68,959,351	68959351.05
TOTAL Indiana Harbor and Canal	1.00	EA	13,904,986	11,201,935	4,648,489	47,549,731	77,305,142	77305141.55
Field Office Overhead (7%)							5,411,360	
SUBTOTAL							82,716,501	
Home Office Overhead (5%)							4,135,825	
SUBTOTAL							86,852,327	
Profit (10%)							8,685,233	
SUBTOTAL							95,537,559	
Bond (1%)							955,376	
TOTAL INCL INDIRECTS							96,492,935	
Contingency (15%)							14,655,457	
TOTAL INCL OWNER COSTS							111,148,392	

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01_01. Slurry Wall                                         QUANTY UOM CREW ID    OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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   01. Present Site RCRA Closure
      01_01. Slurry Wall
         01_01.01. Bentonite Slurry Wall-Site Peri.

            01_01.01.01. Mobilization & Site Preparation

            USR AA <         >                                                    0.00       0.00       0.00  100014.00  100014.00
                                                             1.00 LS              0.00          0          0          0    100,014    100,014  100014.00
                                                                                      ----------- ----------- ----------- ----------- -----------
                       TOTAL Mobilization & Site Preparation    1.00 EA                          0          0          0    100,014    100,014  100014.00

            01_01.01.02. Bentonite Slurry Trench

               01_01.01.02_ 01. Initial Slurry Placement (ZQAA)

            MIL AA <         > CRANE,DRAG/CLAM, 2.0CY / 65'BOOM                   0.00      65.09       0.00       0.00      65.09
                               REF. EP 1110-1-8             21.58 HR  C85AM002    1.00          0      1,404          0          0      1,404      65.09
                               2.00 CY DRAGLINE/CLAM (ADD BUCKE
                               T) WITH 65' BOOM

            USR AA <         > EQUIPMENT OPERATOR GRP 1                          38.55       0.00       0.00       0.00      38.55
                                                            21.58 HR  Z-EQUIPOPB  1.00        832          0          0          0        832      38.55

            USR AA <         > EQUIPMENT OPERATOR GRP 5, OILER                   34.15       0.00       0.00       0.00      34.15
                                                            21.58 HR  Z-EQUIPOPF  1.00        737          0          0          0        737      34.15
                                                                                      ----------- ----------- ----------- ----------- -----------
                       TOTAL Initial Slurry Placement       733.60 CY                       1,569      1,404          0          0      2,973       4.05

               01_01.01.02_ 02. Remainder Slurry Trench (ZOAA)

            MIL AA <         > HYD EXCAV,CRWLR, 1 CY BKT,HYD-SC                   0.00      51.61       0.00       0.00      51.61
                               REF. EP 1110-1-8           1241.97 HR  H25BA002    1.00          0     64,102          0          0     64,102      51.61
                               1.00 CY BUCKET, HYDRO-SCOPIC

            USR AA <         > Slurry Mixer Pump & Sump                           0.00      10.00       0.00       0.00      10.00
                                                          1241.97 HR  XX0XX020    1.00          0     12,420          0          0     12,420      10.00

            USR AA <         > Air Lift Pump w/ Compressor                        0.00      10.00       0.00       0.00      10.00
                                                          1241.97 HR  XX0XX021    1.00          0     12,420          0          0     12,420      10.00

            USR AA <         > Trash Pumps                                        0.00       2.60       0.00       0.00       2.60
                                                          2483.95 HR  XX0XX012    1.00          0      6,458          0          0      6,458       2.60

            USR AA <         > Cyclone                                            0.00       5.00       0.00       0.00       5.00
                                                          1241.97 HR  XX0XX013    1.00          0      6,210          0          0      6,210       5.00

            UPB AA <         > DOZER,CWLR, D-6H,PS  (ADD BLADE)                   0.00      39.58       0.00       0.00      39.58
                               REF. EP 1110-1-8           1241.97 HR  T15CA010    1.00          0     49,153          0          0     49,153      39.58
                               POWERSHIFT (ADD BLADE)
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01_01. Slurry Wall		QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
UPB AA <	> BLADE, STRAIGHT, HYDR (FOR D6 REF. EP 1110-1-8 BLADE, STRAIGHT,HYDRAULIC, FOR D 6	1241.97	HR	T10CA009	1.00	0.00 0	3.66 4,539	0.00 0	0.00 0	3.66 4,539	3.66
USR AA <	> Motor Boats	2483.95	HR	XX0XX014	1.00	0.00 0	3.50 8,694	0.00 0	0.00 0	3.50 8,694	3.50
USR AA <	> Water Tanks	3725.92	HR	XX0XX015	1.00	0.00 0	9.26 34,502	0.00 0	0.00 0	9.26 34,502	9.26
UPB AA <	> TRK,WTR,OF-HY, 6000GAL,W/CAT621E REF. EP 1110-1-8 6,000 GALLON,WITH CAT 621E TRACTOR	2483.95	HR	T60KI002	1.00	0.00 0	63.75 158,361	0.00 0	0.00 0	63.75 158,361	63.75
USR AA <	> Silos 3,410 CF, 160 Ton	1241.97	HR	XX0XX016	1.00	0.00 0	8.07 10,023	0.00 0	0.00 0	8.07 10,023	8.07
USR AA <	> Screw Feeder 9", 20 Hp	1241.97	HR	XX0XX017	1.00	0.00 0	2.92 3,627	0.00 0	0.00 0	2.92 3,627	2.92
USR AA <	> Scales and Batcher	1241.97	HR	XX0XX018	1.00	0.00 0	2.00 2,484	0.00 0	0.00 0	2.00 2,484	2.00
USR AA <	> Bin Vibrator	1241.97	HR	XX0XX019	1.00	0.00 0	5.00 6,210	0.00 0	0.00 0	5.00 6,210	5.00
MIL AA <	> CRANE,HYD,S/P,RT,4WD,22T/70'BOOM REF. EP 1110-1-8 22 TON, ROUGH TERRAIN, 4WD	1241.97	HR	C75GV007	1.00	0.00 0	33.42 41,503	0.00 0	0.00 0	33.42 41,503	33.42
USR AA <	> CRAFT FOREMAN	1241.97	HR	Z-EQUIPOPA	1.00	39.80 49,430	0.00 0	0.00 0	0.00 0	39.80 49,430	39.80
USR AA <	> EQUIP. OPERATOR GROUP 1, BACKHOE	1241.97	HR	Z-EQUIPOPB	1.00	38.55 47,873	0.00 0	0.00 0	0.00 0	38.55 47,873	38.55
USR AA <	> EQUIPMENT OPERATOR GRP 5, OILER	1241.97	HR	Z-EQUIPOPF	1.00	34.15 42,414	0.00 0	0.00 0	0.00 0	34.15 42,414	34.15
USR AA <	> EQUIPMENT OPERATOR GRP 2, PUMP	2483.95	HR	Z-EQUIPOPC	1.00	37.90 94,143	0.00 0	0.00 0	0.00 0	37.90 94,143	37.90
USR AA <	> EQUIPMENT OPERATOR GRP 2, BOAT	1241.97	HR	Z-EQUIPOPC	1.00	37.90 47,071	0.00 0	0.00 0	0.00 0	37.90 47,071	37.90
USR AA <	> EQUIPMENT OPERATOR GRP 2, MIXER	1241.97	HR	Z-EQUIPOPC	1.00	37.90 47,071	0.00 0	0.00 0	0.00 0	37.90 47,071	37.90

01_01. Slurry Wall		QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
USR AA <	> EQUIPMENT OPERATOR GRP 1, DOZER					38.55	0.00	0.00	0.00	38.55	
		1241.97	HR	Z-EQUIPOPB	1.00	47,873	0	0	0	47,873	38.55
USR AA <	> EQUIPMENT OPERATOR GRP 1, CRANE					38.55	0.00	0.00	0.00	38.55	
		1241.97	HR	Z-EQUIPOPB	1.00	47,873	0	0	0	47,873	38.55
USR AA <	> GROUP 3, GENERAL LABORER					26.40	0.00	0.00	0.00	26.40	
		7451.85	HR	Z-LABORERD	1.00	196,759	0	0	0	196,759	26.40
USR AA <	> TEAMSTER, GROUP 1					27.30	0.00	0.00	0.00	27.30	
		2483.95	HR	Z-TEAMSTEA	1.00	67,811	0	0	0	67,811	27.30
USR AA <	> Bentonite					0.00	0.00	100.00	0.00	100.00	
		4763.00	TON		0.00	0	0	476,300	0	476,300	100.00
USR AA <	> Water					0.00	0.00	0.05	0.00	0.05	
		9000.00	MG		0.00	0	0	450	0	450	0.05
	TOTAL Remainder Slurry Trench	43469	CY			688,317	420,705	476,750	0	1,585,772	36.48
	TOTAL Bentonite Slurry Trench	1.00	EA			689,886	422,110	476,750	0	1,588,745	1588745.16
01_01.01.03. Slurry Trench Excav. & Disposal (ZPAA)											
UPB AA <	> LDR,FE, CRWLR, 3.75 CY REF. EP 1110-1-8 3.75 CY					0.00	75.41	0.00	0.00	75.41	
		244.53	HR	L35CA007	1.00	0	18,440	0	0	18,440	75.41
UPB AA <	> DOZER,CWLR, D-6H,PS (ADD BLADE) REF. EP 1110-1-8 POWERSHIFT (ADD BLADE)					0.00	39.58	0.00	0.00	39.58	
		244.53	HR	T15CA010	1.00	0	9,678	0	0	9,678	39.58
UPB AA <	> BLADE, STRAIGHT, HYDR (FOR D6 REF. EP 1110-1-8 BLADE, STRAIGHT,HYDRAULIC, FOR D 6					0.00	3.66	0.00	0.00	3.66	
		244.53	HR	T10CA009	1.00	0	894	0	0	894	3.66
USR AA <	> CRAFT FOREMAN					39.80	0.00	0.00	0.00	39.80	
		244.53	HR	Z-EQUIPOPA	1.00	9,732	0	0	0	9,732	39.80
USR AA <	> EQUIPMENT OPERATOR GRP 1					38.55	0.00	0.00	0.00	38.55	
		489.06	HR	Z-EQUIPOPB	1.00	18,851	0	0	0	18,851	38.55
USR AA <	> TEAMSTER, GROUP 1					27.30	0.00	0.00	0.00	27.30	
		489.06	HR	Z-TEAMSTEA	1.00	13,351	0	0	0	13,351	27.30
MIL AA <	> TRK,OFF-HWY,R-DUMP, 13-17CY, 25T REF. EP 1110-1-8 13-17 CY, 25 TON, 6X6, REAR DUMP					0.00	43.57	0.00	0.00	43.57	
		489.06	HR	T55VO003	1.00	0	21,310	0	0	21,310	43.57

01_01. Slurry Wall		QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
	TOTAL Slurry Trench Excav. & Disposal	39197	CY			41,935	50,321	0	0	92,256	2.35
01_01.01.04. Borrow for Slurry Trench Fill (ZRAA)											
UPB AA <	> LDR,FE, CRWLR, 3.75 CY					0.00	75.41	0.00	0.00	75.41	
	REF. EP 1110-1-8	215.76	HR	L35CA007	1.00	0	16,270	0	0	16,270	75.41
	3.75 CY										
MIL AA <	> TRK,HWY, 33,000 GVW, 4X2, 2 AXLE					0.00	31.41	0.00	0.00	31.41	
	REF. EP 1110-1-8	2373.40	HR	T50KE002	1.00	0	74,539	0	0	74,539	31.41
	33,000 GVW, 76,800 GCW, 2 AXLE										
UPB AA <	> TRLR,END DUMP, 20CY, 24T(ADD TRK					0.00	7.75	0.00	0.00	7.75	
	REF. EP 1110-1-8	2373.40	HR	T45XX008	1.00	0	18,384	0	0	18,384	7.75
	20 CY, 24 TON										
USR AA <	> CRAFT FOREMAN					39.80	0.00	0.00	0.00	39.80	
		215.76	HR	Z-EQUIPOPA	1.00	8,587	0	0	0	8,587	39.80
USR AA <	> Loader Operator					38.55	0.00	0.00	0.00	38.55	
		215.76	HR	Z-EQUIPOPB	1.00	8,317	0	0	0	8,317	38.55
USR AA <	> Truck Driver					27.30	0.00	0.00	0.00	27.30	
		2373.40	HR	Z-TEAMSTEA	1.00	64,793	0	0	0	64,793	27.30
USR AA <	> Borrow Silty Sand					0.00	0.00	0.00	1.00	1.00	
		43680	CY		0.00	0	0	0	43,680	43,680	1.00
	TOTAL Borrow for Slurry Trench Fill	39269	CY			81,697	109,194	0	43,680	234,571	5.97
01_01.01.05. Disposal of Excess Slurry (ZSAA)											
UPB AA <	> PUMP,CENTRF,DW,6"D, 100GPM/40'HD					0.00	16.28	0.00	0.00	16.28	
	REF. EP 1110-1-8	7.19	HR	P60ML003	1.00	0	117	0	0	117	16.28
	1100 GPM AT 40' HEAD										
USR AA <	> CRAFT FOREMAN					39.80	0.00	0.00	0.00	39.80	
		7.19	HR	Z-EQUIPOPA	1.00	286	0	0	0	286	39.80
USR AA <	> EQUIPMENT OPERATOR GRP 4					35.60	0.00	0.00	0.00	35.60	
		7.19	HR	Z-EQUIPOPE	1.00	256	0	0	0	256	35.60
USR AA <	> GROUP 3, GENERAL LABORER					26.40	0.00	0.00	0.00	26.40	
		21.58	HR	Z-LABORERD	1.00	570	0	0	0	570	26.40
USR AA <	> Pipeline, 6"					0.00	25.00	0.00	0.00	25.00	
		7.19	HR	XX0XX030	1.00	0	180	0	0	180	25.00

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01_01. Slurry Wall                                               QUANTY UOM CREW ID    OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER  TOTAL COST  UNIT COST
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             USR AA <          > Containment Dike                                                0.00       0.00       0.00       2.50        2.50
                                                                3550.00 CY              0.00        0          0          0      8,875       8,875       2.50
                                                                                            ----------- ----------- ----------- ----------- -----------
                          TOTAL Disposal of Excess Slurry        863.00 CY                       1,112        297          0      8,875      10,284      11.92

                                                                                            ----------- ----------- ----------- ----------- -----------
                          TOTAL Bentonite Slurry Wall-Site Peri. 341715 SF                     814,630    581,921    476,750    152,569   2,025,870       5.93
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01_01. Slurry Wall	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01_01.02. Railroad Relocation										
01_01.02.01. Clearing and Grubbing										
USR AA < > Clearing and Grubbing					2802.00	1868.00	0.00	0.00	4670.00	
	7.00	AC		0.00	19,614	13,076	0	0	32,690	4670.00
TOTAL Clearing and Grubbing	7.00	AC			19,614	13,076	0	0	32,690	4670.00
01_01.02.02. Topsoil Stripping										
USR AA < > Topsoil Stripping					1.19	1.23	0.00	0.00	2.42	
	6296.00	CY		0.00	7,492	7,744	0	0	15,236	2.42
TOTAL Topsoil Stripping	6296.00	CY			7,492	7,744	0	0	15,236	2.42
01_01.02.03. Roadbed Earthfill										
USR AA < > Roadbed Earthfill					4.08	4.25	0.00	0.00	8.33	
	18350	CY		0.00	74,868	77,988	0	0	152,856	8.33
TOTAL Roadbed Earthfill	18350	CY			74,868	77,988	0	0	152,856	8.33
01_01.02.04. Ditches and Swales										
USR AA < > Ditches and Swales					7890.00	8213.00	0.00	0.00	16103.00	
	1.00	LS		0.00	7,890	8,213	0	0	16,103	16103.00
TOTAL Ditches and Swales					7,890	8,213	0	0	16,103	
01_01.02.05. Sub-Ballast										
USR AA < > Sub-Ballast					1.80	2.45	8.63	0.00	12.88	
	4320.00	TN		0.00	7,776	10,584	37,282	0	55,642	12.88
TOTAL Sub-Ballast	4320.00	TN			7,776	10,584	37,282	0	55,642	12.88
01_01.02.06. Duo-Rail, Single Side Track										
USR AA < > Duo-Rail, Single Side Track					20.37	4.43	63.77	0.00	88.57	
	3400.00	LF		0.00	69,258	15,062	216,818	0	301,138	88.57
TOTAL Duo-Rail, Single Side Track	3400.00	LF			69,258	15,062	216,818	0	301,138	88.57

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01_01. Slurry Wall                                               QUANTY UOM CREW ID    OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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            01_01.02.07. Turnout■ #10, incl. Rails, Frog

            USR AA <         > Turnouts #10, incl. Rails, Frog                                 9309.00    3385.00   71932.00       0.00   84626.00
                                                                   1.00 LS             0.00      9,309      3,385     71,932          0     84,626   84626.00
                                                                                           ----------- ----------- ----------- ----------- -----------
                       TOTAL Turnouts #10, incl. Rails, Frog                                     9,309      3,385     71,932          0     84,626

            01_01.02.08. RR Cros■ing Rubber Mat & Traf. S

            USR AA <         > RR Crossing Rubber Mat & Traffic                                   0.00       0.00       0.00   41063.00   41063.00
                                                                   1.00 LS             0.00          0          0          0     41,063     41,063   41063.00
                                                                                           ----------- ----------- ----------- ----------- -----------
                       TOTAL RR Cros■ing Rubber Mat & Traf. S                                        0          0          0     41,063     41,063

            01_01.02.09. Topsoil Replacement

            USR AA <         > Topsoil Replacement                                                2.37       2.46       0.00       0.00       4.83
                                                                6296.00 CY             0.00     14,922     15,488          0          0     30,410       4.83
                                                                                           ----------- ----------- ----------- ----------- -----------
                       TOTAL Topsoil Replacement                6296.00 CY                      14,922     15,488          0          0     30,410       4.83

            01_01.02.10. Seeding

            USR AA <         > Seeding                                                          391.30     260.87    1956.53       0.00    2608.70
                                                                   5.00 AC             0.00      1,957      1,304      9,783          0     13,044    2608.70
                                                                                           ----------- ----------- ----------- ----------- -----------
                       TOTAL Seeding                               5.00 AC                       1,957      1,304      9,783          0     13,044    2608.70

            01_01.02.11. Relocate Light Pole

            USR AA <         > Relocate Light Pole                                                0.00       0.00       0.00    2214.00    2214.00
                                                                   1.00 LS             0.00          0          0          0      2,214      2,214    2214.00
                                                                                           ----------- ----------- ----------- ----------- -----------
                       TOTAL Relocate Light Pole                                                     0          0          0      2,214      2,214

            01_01.02.12. Relocate Surface Discharge Pipe

            USR AA <         > Relocate Surface Discharge Pipe                                    0.00       0.00       0.00    1208.00    1208.00
                                                                   1.00 LS             0.00          0          0          0      1,208      1,208    1208.00
                                                                                           ----------- ----------- ----------- ----------- -----------
                       TOTAL Relocate Surface Discharge Pipe                                         0          0          0      1,208      1,208
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01_01. Slurry Wall                                         QUANTY UOM CREW ID     OUTPUT       LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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            01_01.02.13. Brick Masonry Wall Relocation

            USR AA <          > Brick Masonry Wall Relocation                          0.00       0.00       0.00    8302.00    8302.00
                                                              1.00 LS           0.00          0          0          0      8,302      8,302    8302.00
                                                                                    ----------- ----------- ----------- ----------- -----------
                        TOTAL Brick Masonry Wall Relocation                             0          0          0      8,302      8,302

            01_01.02.14. Replace Gate

            USR AA <          > Replace Gate                                           0.00       0.00       0.00    1728.00    1728.00
                                                              1.00 LS           0.00          0          0          0      1,728      1,728    1728.00
                                                                                    ----------- ----------- ----------- ----------- -----------
                        TOTAL Replace Gate                                              0          0          0      1,728      1,728

                                                                                    ----------- ----------- ----------- ----------- -----------
                        TOTAL Railroad Relocation                                 213,085    152,844    335,814     54,515    756,259
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01_01. Slurry Wall                                          QUANTY UOM CREW ID     OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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         01_01.04. Inspection Trench

            01_01.04.01. Trench Excavation (ZLBB)

            MIL AA <          > HYD EXCAV, CRWLR, 0.75 CY BKT                               0.00      51.29       0.00       0.00      51.29
                                REF. EP 1110-1-8              144.73 HR  H25GA002     1.00          0      7,422          0          0      7,422      51.29
                                .750 CY BUCKET

            USR AA <          > CRAFT FOREMAN                                               39.80       0.00       0.00       0.00      39.80
                                                              144.73 HR  Z-EQUIPOPA   1.00      5,760          0          0          0      5,760      39.80

            USR AA <          > EQUIPMENT OPERATOR GRP 1                                    38.55       0.00       0.00       0.00      38.55
                                                              144.73 HR  Z-EQUIPOPB   1.00      5,579          0          0          0      5,579      38.55

            USR AA <          > GROUP 3, GENERAL LABORER                                    26.40       0.00       0.00       0.00      26.40
                                                              289.45 HR  Z-LABORERD   1.00      7,643          0          0          0      7,643      26.40

            USR AA <          > Remove Obstruction                                           0.00       0.00       0.00     349.85     349.85
                                                               40.00 HR               0.00          0          0          0     13,994     13,994     349.85
                                                                                          ----------- ----------- ----------- ----------- -----------
                          TOTAL Trench Excavation            5200.00 LF                        18,981      7,422          0     13,994     40,398       7.77

            01_01.04.02. Trench Backfill (ZMBB)

            MIL AA <          > LDR,FE, CRWLR, 2.25 CY                                       0.00      35.06       0.00       0.00      35.06
                                REF. EP 1110-1-8              144.73 HR  L35JD005     1.00          0      5,074          0          0      5,074      35.06
                                2.25 CY

            MIL AA <          > ROLLER,VIB,DD,S/P, 2.7T, 47.25"W                             0.00      11.22       0.00       0.00      11.22
                                REF. EP 1110-1-8              144.73 HR  R45BO001     1.00          0      1,623          0          0      1,623      11.22
                                47.2" WIDE X 26.6" DIA.,HYDROSTA
                                TIC

            USR AA <          > CRAFT FOREMAN                                               39.80       0.00       0.00       0.00      39.80
                                                              144.73 HR  Z-EQUIPOPA   1.00      5,760          0          0          0      5,760      39.80

            USR AA <          > EQUIPMENT OPERATOR GRP 1                                    38.55       0.00       0.00       0.00      38.55
                                                              289.45 HR  Z-EQUIPOPB   1.00     11,157          0          0          0     11,157      38.55

            USR AA <          > GROUP 3, GENERAL LABORER                                    26.40       0.00       0.00       0.00      26.40
                                                              289.45 HR  Z-LABORERD   1.00      7,643          0          0          0      7,643      26.40
                                                                                          ----------- ----------- ----------- ----------- -----------
                          TOTAL Trench Backfill              5200.00 LF                        24,560      6,697          0          0     31,257       6.01

                                                                                          ----------- ----------- ----------- ----------- -----------
                          TOTAL Inspection Trench            5200.00 LF                        43,541     14,120          0     13,994     71,655      13.78
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01_01. Slurry Wall                                                    QUANTY UOM CREW ID     OUTPUT      LABOR   EQUIPMNT   MATERIAL       OTHER  TOTAL COST  UNIT COST
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           01_01.05. Initial Groundwater Drawdown

               01_01.05.01. Pumping

               USR AA <          > Costs of Pumping                                                    0.00       0.00       0.00     6746.00     6746.00
                                                                        1.00 LS              0.00         0          0          0       6,746       6,746    6746.00
                                                                                                  ---------- ---------- ---------- ---------- ----------
                              TOTAL Pumping                                                               0          0          0       6,746       6,746

               01_01.05.02. Treatment Surcharge

               USR AA <          > Costs of Treatment Surcharge                                        0.00       0.00       0.00    27239.00    27239.00
                                                                        1.00 LS              0.00         0          0          0      27,239      27,239   27239.00
                                                                                                  ---------- ---------- ---------- ---------- ----------
                              TOTAL Treatment Surcharge                                                   0          0          0      27,239      27,239

               01_01.05.03. Analytical Testing

               USR AA <          > Costs of Analytical Testing                                         0.00       0.00       0.00    20029.00    20029.00
                                                                        1.00 LS              0.00         0          0          0      20,029      20,029   20029.00
                                                                                                  ---------- ---------- ---------- ---------- ----------
                              TOTAL Analytical Testing                                                    0          0          0      20,029      20,029

               01_01.05.04. Sample Collection

               USR AA <          > Costs of Sample Collection                                          0.00       0.00       0.00      641.00      641.00
                                                                        1.00 LS              0.00         0          0          0         641         641     641.00
                                                                                                  ---------- ---------- ---------- ---------- ----------
                              TOTAL Sample Collection                                                     0          0          0         641         641

                                                                                                  ---------- ---------- ---------- ---------- ----------
                              TOTAL Initial Groundwater Drawdown                                           0          0          0      54,655      54,655
                                                                                                  ---------- ---------- ---------- ---------- ----------
                              TOTAL Slurry Wall                         1.00 EA                   1,071,256    748,885    812,564     275,733   2,908,438 2908438.34
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01_02. Seal Peripheral Areas                                QUANTY UOM CREW ID     OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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      01_02. Seal Peripheral Areas
            (Buffer Zone)
         01_02.01. 3' Clay Layer

            01_02.01.01. Excavate & Haul Clay (ZKAA)

            UPB AA <        > TRLR,END DUMP, 20CY, 24T(ADD TRK                          0.00       7.75       0.00       0.00       7.75
                              REF. EP 1110-1-8             14981 HR  T45XX008    1.00          0    116,038          0          0    116,038       7.75
                              20 CY,   24 TON

            MIL AA <        > TRK,HWY, 33,000 GVW, 4X2, 2 AXLE                          0.00      29.75       0.00       0.00      29.75
                              REF. EP 1110-1-8             14981 HR  T50KE001    1.00          0    445,654          0          0    445,654      29.75
                              33,000 GVW, 76,800 GCW, 2 AXLE

            MIL AA <        > Outside Equip. Operators, Heavy                          38.55       0.00       0.00       0.00      38.55
                                                         1762.44 HR  X-EQOPRHVY  1.00     67,943          0          0          0     67,943      38.55

            MIL AA <        > Craft Foreman                                            39.80       0.00       0.00       0.00      39.80
                                                          881.22 HR  X-LABORER   1.00     35,072          0          0          0     35,072      39.80

            MIL AA <        > Outside Truck Drivers, Heavy                             27.30       0.00       0.00       0.00      27.30
                                                           14981 HR  X-TRKDVRHV  1.00    408,971          0          0          0    408,971      27.30

            MIL AA <        > Flagmen                                                  25.15       0.00       0.00       0.00      25.15
                                                         1762.44 HR  X-TRKDVRLT  1.00     44,326          0          0          0     44,326      25.15

            UPB AA <        > LDR,FE, CRWLR, 3.75 CY                                    0.00      75.41       0.00       0.00      75.41
                              REF. EP 1110-1-8            881.22 HR  L35CA007    1.00          0     66,451          0          0     66,451      75.41
                              3.75 CY

            MIL AA <        > BLADE, STRAIGHT, HYDR    (FOR D7                          0.00       5.23       0.00       0.00       5.23
                              REF. EP 1110-1-8            881.22 HR  T10CA012    1.00          0      4,608          0          0      4,608       5.23
                              BLADE, STRAIGHT,HYDRAULIC, FOR D
                              7

            UPB AA <        > DOZER,CWLR, D-7H,PS  (ADD BLADE)                          0.00      59.31       0.00       0.00      59.31
                              REF. EP 1110-1-8            881.22 HR  T15CA013    1.00          0     52,265          0          0     52,265      59.31
                              POWERSHIFT (ADD BLADE)
                                                                                  ----------- ----------- ----------- ----------- -----------
                       TOTAL Excavate & Haul Clay         158620 CY                  556,312    685,017          0          0  1,241,329       7.83

            01_02.01.02. Spread & Compact Clay (ZKB)

            MIL AA <        > BLADE, STRAIGHT, HYDR    (FOR D7                          0.00       5.23       0.00       0.00       5.23
                              REF. EP 1110-1-8           1724.13 HR  T10CA012    1.00          0      9,015          0          0      9,015       5.23
                              BLADE, STRAIGHT,HYDRAULIC, FOR D
                              7
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	01_02. Seal Peripheral Areas	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
UPB AA <	> DOZER,CWLR, D-7H,PS (ADD BLADE)					0.00	59.31	0.00	0.00	59.31	
	REF. EP 1110-1-8	1724.13	HR	T15CA013	1.00	0	102,259	0	0	102,259	59.31
	POWERSHIFT (ADD BLADE)										
UPB AA <	> GRADER,MOTOR, ARTIC, CAT 140-G					0.00	30.67	0.00	0.00	30.67	
	REF. EP 1110-1-8	1724.13	HR	G15CA004	1.00	0	52,878	0	0	52,878	30.67
	ARTICULATED FRAME, POWERSHIFT										
UPB AA <	> ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W					0.00	22.70	0.00	0.00	22.70	
	REF. EP 1110-1-8	1724.13	HR	R40SO001	1.00	0	39,132	0	0	39,132	22.70
	72" WIDE X 56" DIA., 25.5 TON										
MIL AA <	> TRACTOR,WH,FARM, JD-2755, 2WD					0.00	9.22	0.00	0.00	9.22	
	REF. EP 1110-1-8	1724.13	HR	T25JD004	1.00	0	15,892	0	0	15,892	9.22
	INDUSTRIAL 2WD (NO ATTACHMENTS)										
MIL AA <	> TRK,WTR,OF-HY, 5000GAL,W/CAT613C					0.00	35.38	0.00	0.00	35.38	
	REF. EP 1110-1-8	1724.13	HR	T60KI001	1.00	0	60,995	0	0	60,995	35.38
	5,000 GALLON,WITH CAT 613C TRACTOR										
MIL AA <	> Outside Equip. Operators, Heavy					38.55	0.00	0.00	0.00	38.55	
		5172.39	HR	X-EQOPRHVY	1.00	199,397	0	0	0	199,397	38.55
MIL AA <	> Outside Equip. Operators, Light					37.30	0.00	0.00	0.00	37.30	
		1724.13	HR	X-EQOPRLT	1.00	64,310	0	0	0	64,310	37.30
MIL AA <	> Craft Foreman					39.80	0.00	0.00	0.00	39.80	
		1724.13	HR	X-LABORER	1.00	68,620	0	0	0	68,620	39.80
MIL AA <	> Outside Truck Drivers, Heavy					27.30	0.00	0.00	0.00	27.30	
		1724.13	HR	X-TRKDVRHV	1.00	47,068	0	0	0	47,068	27.30
MIL AA <	> Flagmen					25.15	0.00	0.00	0.00	25.15	
		3448.26	HR	X-TRKDVRLT	1.00	86,725	0	0	0	86,725	25.15
	TOTAL Spread & Compact Clay	158620	CY			466,120	280,171	0	0	746,291	4.70
	TOTAL 3' Clay Layer	158620	CY			1,022,432	965,188	0	0	1,987,620	12.53

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01_02. Seal Peripheral Areas                                  QUANTY UOM CREW ID     OUTPUT       LABOR   EQUIPMNT   MATERIAL      OTHER  TOTAL COST  UNIT COST
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          01_02.03. 6" Sand

             01_02.03.01. Spread Sand (ZMAA)

             UPB AA <          > GRADER,MOTOR, ARTIC, CAT 140-G                                0.00      30.67       0.00       0.00       30.67
                                 REF. EP 1110-1-8           188.86 HR  G15CA004      1.00          0      5,792          0          0       5,792      30.67
                                 ARTICULATED FRAME, POWERSHIFT

             MIL AA <          > ROLLER,STATIC,DD,S/P,14T, 54"W                                0.00      16.14       0.00       0.00       16.14
                                 REF. EP 1110-1-8           188.86 HR  R30FR010      1.00          0      3,047          0          0       3,047      16.14
                                 10-14 TON, TANDEM, HYDROSTATIC

             UPB AA <          > BLADE, STRAIGHT, HYDR   (FOR D6                               0.00       3.66       0.00       0.00        3.66
                                 REF. EP 1110-1-8           188.86 HR  T10CA009      1.00          0        690          0          0         690       3.65
                                 BLADE, STRAIGHT,HYDRAULIC, FOR D
                                 6

             MIL AA <          > DOZER,CWLR, D-6D,SA  (ADD BLADE)                              0.00      39.67       0.00       0.00       39.67
                                 REF. EP 1110-1-8           188.86 HR  T15CA009      1.00          0      7,491          0          0       7,491      39.67
                                 SPECIAL APPLICATION (ADD BLADE)

             USR AA <          > CRAFT FOREMAN                                                39.80       0.00       0.00       0.00       39.80
                                                            188.86 HR  Z-EQUIPOPA    1.00      7,516          0          0          0       7,516      39.80

             USR AA <          > EQUIPMENT OPERATOR GRP 1                                     38.55       0.00       0.00       0.00       38.55
                                                            377.71 HR  Z-EQUIPOPB    1.00     14,559          0          0          0      14,559      38.55

             USR AA <          > EQUIPMENT OPERATOR GRP 2                                     37.90       0.00       0.00       0.00       37.90
                                                            188.86 HR  Z-EQUIPOPC    1.00      7,158          0          0          0       7,158      37.90

             USR AA <          > Costs of Sand                                                 0.00       0.00      10.50       0.00       10.50
                                                             26440 CY                0.00          0          0    277,620          0     277,620      10.50
                                                                                        ----------- ---------- ---------- ---------- -----------
                         TOTAL Spread Sand                   26440 CY                         29,233     17,021    277,620          0     323,874      12.25

                                                                                        ----------- ---------- ---------- ---------- -----------
                         TOTAL 6" Sand                       26440 CY                         29,233     17,021    277,620          0     323,874      12.25
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01_02. Seal Peripheral Areas                                QUANTY UOM CREW ID     OUTPUT       LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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         01_02.04. 2' Clean Fill

            01_02.04.01. Excavate & Haul Clean Fill (ZIBB)

            MIL AA <         > TRK,HWY, 33,000 GVW, 4X2, 2 AXLE                                  0.00      31.41       0.00       0.00      31.41
                               REF. EP 1110-1-8               8553.31 HR  T50KE002     1.00         0    268,626          0          0    268,626      31.41
                               33,000 GVW, 76,800 GCW, 2 AXLE

            UPB AA <         > TRLR,END DUMP, 20CY, 24T(ADD TRK                                  0.00       7.75       0.00       0.00       7.75
                               REF. EP 1110-1-8               8553.31 HR  T45XX008     1.00         0     66,252          0          0     66,252       7.75
                               20 CY,    24 TON

            USR AA <         > CRAFT FOREMAN                                                    39.80       0.00       0.00       0.00      39.80
                                                               388.79 HR  Z-EQUIPOPA   1.00    15,474          0          0          0     15,474      39.80

            MIL AA <         > Outside Equip. Operators, Heavy                                  38.55       0.00       0.00       0.00      38.55
                                                               388.79 HR  X-EQOPRHVY   1.00    14,988          0          0          0     14,988      38.55

            MIL AA <         > Outside Truck Drivers, Heavy                                     27.30       0.00       0.00       0.00      27.30
                                                              8553.31 HR  X-TRKDVRHV   1.00   233,503          0          0          0    233,503      27.30

            MIL AA <         > Flagmen                                                          25.15       0.00       0.00       0.00      25.15
                                                               777.57 HR  X-TRKDVRLT   1.00    19,556          0          0          0     19,556      25.15

            MIL AA <         > HYD EXCAV, CRWLR, 3.75 CY BKT                                     0.00     105.02       0.00       0.00     105.02
                               REF. EP 1110-1-8                388.79 HR  H25IS006     1.00         0     40,831          0          0     40,831     105.02
                               3.75 CY BUCKET
                                                                                          ----------- ----------- ----------- ----------- -----------
                        TOTAL Excavate & Haul Clean Fill       105750 CY                      283,520    375,709          0          0    659,230       6.23

            01_02.04.02. Spread & Compact Clean Fill (ZHAA)

            UPB AA <         > ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W                                  0.00      22.70       0.00       0.00      22.70
                               REF. EP 1110-1-8                388.79 HR  R40SO001     1.00         0      8,824          0          0      8,824      22.70
                               72" WIDE X 56" DIA., 25.5 TON

            MIL AA <         > TRACTOR,WH,FARM, JD-2755, 2WD                                     0.00       9.22       0.00       0.00       9.22
                               REF. EP 1110-1-8                388.79 HR  T25JD004     1.00         0      3,584          0          0      3,584       9.22
                               INDUSTRIAL 2WD (NO ATTACHMENTS)

            MIL AA <         > Outside Equip. Operators, Heavy                                  38.55       0.00       0.00       0.00      38.55
                                                              1166.36 HR  X-EQOPRHVY   1.00    44,964          0          0          0     44,964      38.55

            MIL AA <         > Craft Foreman                                                    39.80       0.00       0.00       0.00      39.80
                                                               388.79 HR  X-LABORER    1.00    15,474          0          0          0     15,474      39.80

            MIL AA <         > Outside Truck Drivers, Heavy                                     27.30       0.00       0.00       0.00      27.30
                                                               388.79 HR  X-TRKDVRHV   1.00    10,614          0          0          0     10,614      27.30
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01_02. Seal Peripheral Areas		QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
MIL AA <	> Outside Equip. Operators, Light	388.79	HR	X-EQOPRLT	1.00	37.30 14,502	0.00 0	0.00 0	0.00 0	37.30 14,502	37.30
MIL AA <	> Flagmen	777.57	HR	X-TRKDVRLT	1.00	25.15 19,556	0.00 0	0.00 0	0.00 0	25.15 19,556	25.15
UPB AA <	> BLADE, STRAIGHT, HYDR (FOR D6 REF. EP 1110-1-8 BLADE, STRAIGHT,HYDRAULIC, FOR D 6	388.79	HR	T10CA009	1.00	0.00 0	3.66 1,421	0.00 0	0.00 0	3.66 1,421	3.66
UPB AA <	> DOZER,CWLR, D-6H,PS (ADD BLADE) REF. EP 1110-1-8 POWERSHIFT (ADD BLADE)	388.79	HR	T15CA010	1.00	0.00 0	39.58 15,387	0.00 0	0.00 0	39.58 15,387	39.58
UPB AA <	> GRADER,MOTOR, ARTIC, CAT 140-G REF. EP 1110-1-8 ARTICULATED FRAME, POWERSHIFT	388.79	HR	G15CA004	1.00	0.00 0	30.67 11,924	0.00 0	0.00 0	30.67 11,924	30.67
MIL AA <	> TRK,WTR,OF-HY, 5000GAL,W/CAT613C REF. EP 1110-1-8 5,000 GALLON,WITH CAT 613C TRACTOR	388.79	HR	T60KI001	1.00	0.00 0	35.38 13,754	0.00 0	0.00 0	35.38 13,754	35.38
USR AA <	> Discs	388.79	HR	XX0XX022	1.00	0.00 0	2.50 972	0.00 0	0.00 0	2.50 972	2.50
	TOTAL Spread & Compact Clean Fill	105750	CY			105,109	55,866	0	0	160,975	1.52
	TOTAL 2' Clean Fill	105750	CY			388,629	431,575	0	0	820,204	7.76

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1_02. Seal Peripheral Areas                                 QUANTY UOM CREW ID      OUTPUT       LABOR   EQUIPMNT   MATERIAL      OTHER  TOTAL COST  UNIT COST
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          01_02.05. 6" Topsoil

             01_02.05.01. Spread Topsoil (ZNAA)

             MIL AA <            > BLADE, STRAIGHT, HYDR    (FOR D7                            0.00       5.23       0.00       0.00       5.23
                                   REF. EP 1110-1-8         132.20 HR  T10CA012     1.00          0        691          0          0        691        5.23
                                   BLADE, STRAIGHT,HYDRAULIC, FOR D
                                   7

             UPB AA <            > DOZER,CWLR, D-7H,PS  (ADD BLADE)                                0.00      59.31       0.00       0.00      59.31
                                   REF. EP 1110-1-8         132.20 HR  T15CA013     1.00          0      7,841          0          0      7,841       59.31
                                   POWERSHIFT (ADD BLADE)

             UPB AA <            > GRADER,MOTOR, ARTIC, CAT 140-G                                  0.00      30.67       0.00       0.00      30.67
                                   REF. EP 1110-1-8         132.20 HR  G15CA004     1.00          0      4,054          0          0      4,054       30.67
                                   ARTICULATED FRAME, POWERSHIFT

             MIL AA <            > TRACTOR,WH,FARM, JD-2755, 2WD                                   0.00       9.22       0.00       0.00       9.22
                                   REF. EP 1110-1-8         132.20 HR  T25JD004     1.00          0      1,219          0          0      1,219        9.22
                                   INDUSTRIAL 2WD (NO ATTACHMENTS)

             UPB AA <            > SMALL TOOLS                                                     0.00       1.45       0.00       0.00       1.45
                                                            132.20 HR  XMIXX020     1.00          0        192          0          0        192        1.45

             UPB AA <            > TRK,WTR,OF-HY, 6000GAL,W/CAT621E                                0.00      63.75       0.00       0.00      63.75
                                   REF. EP 1110-1-8         132.20 HR  T60KI002     1.00          0      8,428          0          0      8,428       63.75
                                   6,000 GALLON,WITH CAT 621E TRACT
                                   OR

             USR AA <            > CRAFT FOREMAN                                                  39.80       0.00       0.00       0.00      39.80
                                                            132.20 HR  Z-EQUIPOPA   1.00      5,262          0          0          0      5,262       39.80

             USR AA <            > EQUIPMENT OPERATOR GRP 1                                       38.55       0.00       0.00       0.00      38.55
                                                            264.40 HR  Z-EQUIPOPB   1.00     10,191          0          0          0     10,191       38.55

             USR AA <            > EQUIPMENT OPERATOR GRP 3                                       37.30       0.00       0.00       0.00      37.30
                                                            132.20 HR  Z-EQUIPOPD   1.00      4,931          0          0          0      4,931       37.30

             USR AA <            > TEAMSTER, GROUP 1                                              27.30       0.00       0.00       0.00      27.30
                                                            132.20 HR  Z-TEAMSTEA   1.00      3,609          0          0          0      3,609       27.30

             USR AA <            > Costs of Topsoil                                                0.00       0.00       9.00       0.00       9.00
                                                             26440 CY               0.00          0          0    237,960          0    237,960        9.00
                                                                                            ----------- ----------- ----------- ----------- -----------
                            TOTAL Spread Topsoil             26440 CY                        23,993     22,425    237,960          0    284,378       10.76

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                            TOTAL 6" Topsoil                 26440 CY                        23,993     22,425    237,960          0    284,378       10.76
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1_02. Seal Peripheral Areas                       QUANTY UOM CREW ID    OUTPUT      LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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         01_02.06. Seeding

            01_02.06.01. Spread Seedings (ZLAA)

            UPB AA <          > MISC. POWER TOOLS                                   0.00        5.90        0.00        0.00        5.90
                                                   80.00 HR  XMIXX010     1.00          0         472           0           0         472        5.90

            UPB AA <          > SMALL TOOLS                                         0.00        1.45        0.00        0.00        1.45
                                                   80.00 HR  XMIXX020     1.00          0         116           0           0         116        1.45

            USR AA <          > LABOR FOREMAN                                      27.10        0.00        0.00        0.00       27.10
                                                   80.00 HR  Z-LABORERA   1.00      2,168           0           0           0       2,168       27.10

            USR AA <          > GROUP 3, GENERAL LABORER                           26.40        0.00        0.00        0.00       26.40
                                                  160.00 HR  Z-LABORERD   1.00      4,225           0           0           0       4,225       26.40

            MIL AA <          > TRACTOR,WH,FARM, JD-2755, 2WD                       0.00        9.22        0.00        0.00        9.22
                                REF. EP 1110-1-8   80.00 HR  T25JD004     1.00          0         737           0           0         737        9.22
                                INDUSTRIAL 2WD (NO ATTACHMENTS)

            USR AA <          > EQUIPMENT OPERATOR GRP 3                           37.30        0.00        0.00        0.00       37.30
                                                   80.00 HR  Z-EQUIPOPD   1.00      2,984           0           0           0       2,984       37.30

            MIL AA <          > TRK,WTR,OF-HY, 5000GAL,W/CAT613C                    0.00       35.38        0.00        0.00       35.38
                                REF. EP 1110-1-8   20.00 HR  T60KI001     1.00          0         708           0           0         708       35.38
                                5,000 GALLON,WITH CAT 613C TRACT
                                OR

            USR AA <          > TEAMSTER, GROUP 1                                  27.30        0.00        0.00        0.00       27.30
                                                   20.00 HR  Z-TEAMSTEA   1.00        546           0           0           0         546       27.30

            USR AA <          > Costs of Seeds                                      0.00        0.00     2150.00        0.00     2150.00
                                                   20.00 AC               0.00          0           0      43,000           0      43,000     2150.00
                                                                              ----------- ----------- ----------- ----------- -----------
                       TOTAL Spread Seedings       20.00 AC                         9,923       2,033      43,000           0      54,956     2747.78

                                                                              ----------- ----------- ----------- ----------- -----------
                       TOTAL Seeding               20.00 AC                         9,923       2,033      43,000           0      54,956     2747.78
                                                                              ----------- ----------- ----------- ----------- -----------
                       TOTAL Seal Peripheral Areas  1.00 EA                     1,474,211   1,438,242     558,580           0   3,471,032  3471032.16
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1_03. Hydraulic Gradient Control                              QUANTY UOM CREW ID     OUTPUT        LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST  UNIT COST
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      01_03. Hydraulic Gradient Control
         01_03.01. Well Points
                 Costs of Well Points is based on Quotation from Subcontractor for
                 Griffin Well Point Systems.

            USR AA <         > Cost of Well Points                                     0.00        0.00        0.00      280.00      280.00
                                                              221.00 EA               0.00            0           0           0      61,880      61,880      280.00
                                                                                          ----------- ----------- ----------- ----------- -----------
                         TOTAL Well Points                    221.00 EA                               0           0           0      61,880      61,880      280.00
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1_03. Hydraulic Gradient Control                                      QUANTY UOM CREW ID     OUTPUT       LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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           01_03.02. Header Piping
                    Costs of Header Piping is based on Quotation from Subcontractor for
                    Griffin Well Point Systems.

               USR AA <          > Costs of Header Piping                                                  0.00        0.00        0.00       44.00       44.00
                                                                       11025 LF                0.00           0           0           0     485,100     485,100       44.00
                                                                                                    ----------- ----------- ----------- ----------- -----------
                              TOTAL Header Piping                      11025 LF                               0           0           0     485,100     485,100       44.00
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1_03. Hydraulic Gradient Control                              QUANTY UOM CREW ID     OUTPUT       LABOR   EQUIPMNT   MATERIAL      OTHER  TOTAL COST  UNIT COST
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          01_03.03. Pumps
                  Costs of Pumps is based on Quotation from Subcontractor for
                  Griffin Well Point Systems.

             USR AA <          > Costs of Pumps                                           0.00       0.00       0.00   10000.00   10000.00
                                                               11.00 EA              0.00          0          0          0    110,000    110,000   10000.00
                                                                                          ---------- ---------- ---------- ---------- ----------
                          TOTAL Pumps                          11.00 EA                            0          0          0    110,000    110,000   10000.00
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1_03. Hydraulic Gradient Control                                   QUANTY UOM CREW ID     OUTPUT       LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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          01_03.04. Ground Water Monitoring Wells
                  Costs of Monitoring Wells is based on Quotation from Subcontractor
                  for Griffin Well Point Systems.

              USR AA <          > Costs of Monitoring Wells                                          0.00        0.00        0.00     2600.00     2600.00
                                                                   12.00 EA                 0.00        0           0           0      31,200      31,200     2600.00
                                                                                               ----------- ----------- ----------- ----------- -----------
                             TOTAL Ground Water Monitoring Wells   12.00 EA                             0           0           0      31,200      31,200     2600.00
```

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1_03. Hydraulic Gradient Control                          QUANTY UOM CREW ID     OUTPUT       LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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          01_03.05. Disch. Pipe to Indianapolis Ave.
                  Costs of Discharge Pipe to Indianapolis Ave. is based on Quotation
                  from Subcontractor for Griffin Well Point Systems.

             USR AA <          > Costs of Discharge Pipe                                     0.00        0.00        0.00       60.00       60.00
                                                          500.00 LF                0.00         0           0           0      30,000      30,000       60.00
                                                                                       ----------- ----------- ----------- ----------- -----------
                         TOTAL Disch. Pipe to Indianapolis Ave.  500.00 LF                      0           0           0      30,000      30,000       60.00

                                                                                       ----------- ----------- ----------- ----------- -----------
                         TOTAL Hydraulic Gradient Control    1.00 EA                            0           0           0     718,180     718,180   718180.00
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1_04. Water Treatment System (24%)                           QUANTY UOM CREW ID     OUTPUT        LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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       01_04. Water Treatment System (24%)

              USR AA <          > Costs of Water Treatment System                          748884.00   187221.00   312035.00        0.00  1248140.00
                                                               1.00 LS                0.00     748,884     187,221     312,035           0   1,248,140  1248140.00
                                                                                          ----------- ----------- ----------- ----------- -----------
                         TOTAL Water Treatment System (24%)                                   748,884     187,221     312,035           0   1,248,140

                                                                                          ----------- ----------- ----------- ----------- -----------
                         TOTAL Present Site RCRA Closure          1.00 EA                   3,294,351   2,374,348   1,683,179     993,913   8,345,791  8345790.50
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2_01. Dredging Stages I, & II                              QUANTY UOM CREW ID     OUTPUT       LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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  02. Dredging & CDF
     02_01. Dredging Stages I, & II
        02_01.01. Dredging Incl. Barge to Site

           USR AA <         > Costs of Dredging                                            0.00        0.00        0.00        9.47        9.47
                                                          4675000 CY                0.00          0           0           0  44,272,250  44,272,250        9.47
                                                                                        ----------- ----------- ----------- ----------- -----------
                      TOTAL Dredging Incl. Barge to Site  4675000 CY                              0           0           0  44,272,250  44,272,250        9.47

                                                                                        ----------- ----------- ----------- ----------- -----------
                      TOTAL Dredging Stages I, & II          1.00 EA                              0           0           0  44,272,250  44,272,250 44272250.00
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2_02. Water Treatment System (76%)                   QUANTY UOM CREW ID   OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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     02_02. Water Treatment System (76%)
        02_02.01. Costs of Water Treatment System

           USR AA <          > Costs of Water Treatment System                  2370000.00  594331.00  988110.00       0.00 3952441.00
                                                       1.00 LS              0.00  2,370,000    594,331    988,110          0  3,952,441 3952441.00
                                                                                 ----------- ---------- ---------- ---------- ----------
                      TOTAL Costs of Water Treatment System                       2,370,000    594,331    988,110          0  3,952,441

                                                                                 ----------- ---------- ---------- ---------- ----------
                      TOTAL Water Treatment System (76%)                          2,370,000    594,331    988,110          0  3,952,441
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2_03. Sediment Dewatering System                          QUANTY UOM CREW ID     OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER  TOTAL COST  UNIT COST
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      02_03. Sediment Dewatering System
         02 03.01. Decant Structure (ZBBB)

             USR AA <        > Small Tools                                                 0.00       8.20       0.00       0.00       8.20
                                                        40.00 HR  XX0XX025      1.00          0        328          0          0        328       8.20

             MIL AA <        > WELDER, 250 AMP, W/1 AXLE TRLR                              0.00       3.05       0.00       0.00       3.05
                               REF. EP 1110-1-8         40.00 HR  W35XX001      1.00          0        122          0          0        122       3.05
                               250 AMP WITH 1 AXLE TRLR

             UPB AA <        > HYD EXCAV,CRWLR, 0.91CY BKT,LONG                            0.00      33.58       0.00       0.00      33.58
                               REF. EP 1110-1-8         40.00 HR  H25CA003      1.00          0      1,343          0          0      1,343      33.58
                               .91 CY BUCKET, LONG CARRIAGE

             USR AA <        > EQUIPMENT OPERATOR GRP 1                                   38.55       0.00       0.00       0.00      38.55
                                                        40.00 HR  Z-EQUIPOPB    1.00      1,542          0          0          0      1,542      38.55

             USR AA <        > LABOR FOREMAN                                              27.10       0.00       0.00       0.00      27.10
                                                        40.00 HR  Z-LABORERA    1.00      1,084          0          0          0      1,084      27.10

             USR AA <        > GROUP 3, GENERAL LABORER                                   26.40       0.00       0.00       0.00      26.40
                                                       160.00 HR  Z-LABORERD    1.00      4,225          0          0          0      4,225      26.40

             USR AA <        > WELDER                                                     36.85       0.00       0.00       0.00      36.85
                                                        80.00 HR  Z-LABORERC    1.00      2,948          0          0          0      2,948      36.85

             USR AA <        > MASON                                                      35.95       0.00       0.00       0.00      35.95
                                                        40.00 HR  Z-LABORERF    1.00      1,438          0          0          0      1,438      35.95

             USR AA <        > Miscellaneous Materials                                     0.00       0.00    3640.00       0.00    3640.00
                                                         5.00 EA                0.00          0          0     18,200          0     18,200    3640.00
                                                                                    ----------- ---------- ---------- ---------- ----------
                       TOTAL Decant Structure            5.00 EA                         11,237      1,793     18,200          0     31,230    6245.92
```

2_03. Sediment Dewatering System		QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
02_03.02. Piping											
02_03.02.01. Concrete Pipe (ZHCA)											
UPB AA <	> HYD EXCAV, CRWLR, 1.25 CY BKT					0.00	45.63	0.00	0.00	45.63	
	REF. EP 1110-1-8	59.99	HR	H25CA006	1.00	0	2,737	0	0	2,737	45.63
	1.25 CY BUCKET										
MIL AA <	> LDR,FE, CRWLR, 2.00 CY					0.00	30.63	0.00	0.00	30.63	
	REF. EP 1110-1-8	59.99	HR	L35CS003	1.00	0	1,837	0	0	1,837	30.63
	2.00 CY, POWERSHIFT/TC										
MIL AA <	> COMPACTOR, RAMMER, 9"X13.8" SHOE					0.00	1.54	0.00	0.00	1.54	
	REF. EP 1110-1-8	59.99	HR	C10BO001	1.00	0	92	0	0	92	1.54
	VIBRATORY TAMPER, 9" RAMMER										
USR AA <	> EQUIPMENT OPERATOR GRP 1					38.55	0.00	0.00	0.00	38.55	
		119.98	HR	Z-EQUIPOPB	1.00	4,625	0	0	0	4,625	38.55
USR AA <	> EQUIPMENT OPERATOR GRP 5, OILER					34.15	0.00	0.00	0.00	34.15	
		59.99	HR	Z-EQUIPOPF	1.00	2,049	0	0	0	2,049	34.15
USR AA <	> LABOR FOREMAN					27.10	0.00	0.00	0.00	27.10	
		59.99	HR	Z-LABORERA	1.00	1,626	0	0	0	1,626	27.10
USR AA <	> GROUP 3, GENERAL LABORER					26.40	0.00	0.00	0.00	26.40	
		299.94	HR	Z-LABORERD	1.00	7,920	0	0	0	7,920	26.40
USR AA <	> Sewer Pipe w/ Ring Gaskets					0.00	0.00	6.00	0.00	6.00	
		1000.00	LF		0.00	0	0	6,000	0	6,000	6.00
	TOTAL Concrete Pipe	1000.00	LF			16,218	4,667	6,000	0	26,885	26.89
	TOTAL Piping					16,218	4,667	6,000	0	26,885	
	TOTAL Sediment Dewatering System	1.00	EA			27,455	6,460	24,200	0	58,115	58114.65

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2_05. Dike Systems, Stages I & II                            QUANTY UOM CREW ID     OUTPUT       LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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       02_05. Dike Systems, Stages I & II
           02_05.01. Embankment

               02_05.01.01. Embankment Stage I

               USR AA <           > Embankment Stage I                                       4.06        4.23        0.00        0.00        8.29
                                                              232711 CY               0.00     944,807     984,368           0           0   1,929,174        8.29
                                                                                           ----------- ----------- ----------- ----------- -----------
                              TOTAL Embankment Stage I        232711 CY                        944,807     984,368           0           0   1,929,174        8.29

               02_05.01.02. Embankment Stage II

               USR AA <           > Embankment Stage II                                      4.06        4.23        0.00        0.00        8.29
                                                              342909 CY               0.00   1,392,211   1,450,505           0           0   2,842,716        8.29
                                                                                           ----------- ----------- ----------- ----------- -----------
                              TOTAL Embankment Stage II       342909 CY                      1,392,211   1,450,505           0           0   2,842,716        8.29

                                                                                           ----------- ----------- ----------- ----------- -----------
                              TOTAL Embankment                575620 CY                      2,337,017   2,434,873           0           0   4,771,890        8.29
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2_05. Dike Systems, Stages I & II                    QUANTY UOM CREW ID     OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER  TOTAL COST  UNIT COST
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        02_05.02. 3' Clay Slope Liner

           02_05.02.01. Excavate & Haul Clay Liner (ZKAA)

           UPB AA <           > TRLR,END DUMP, 20CY, 24T(ADD TRK                     0.00       7.75       0.00       0.00       7.75
                                REF. EP 1110-1-8              4335.56 HR  T45XX008      1.00          0     33,582          0          0     33,582       7.75
                                20 CY,    24 TON

           MIL AA <           > TRK,HWY, 33,000 GVW, 4X2, 2 AXLE                     0.00      29.75       0.00       0.00      29.75
                                REF. EP 1110-1-8              4335.56 HR  T50KE001      1.00          0    128,976          0          0    128,976      29.75
                                33,000 GVW, 76,800 GCW, 2 AXLE

           MIL AA <           > Outside Equip. Operators, Heavy                     38.55       0.00       0.00       0.00      38.55
                                                               510.07 HR  X-EQOPRHVY    1.00     19,663          0          0          0     19,663      38.55

           MIL AA <           > Craft Foreman                                       39.80       0.00       0.00       0.00      39.80
                                                               255.03 HR  X-LABORER     1.00     10,150          0          0          0     10,150      39.80

           MIL AA <           > Outside Truck Drivers, Heavy                        27.30       0.00       0.00       0.00      27.30
                                                              4335.56 HR  X-TRKDVRHV    1.00    118,360          0          0          0    118,360      27.30

           MIL AA <           > Flagmen                                             25.15       0.00       0.00       0.00      25.15
                                                               510.07 HR  X-TRKDVRLT    1.00     12,828          0          0          0     12,828      25.15

           UPB AA <           > LDR,FE, CRWLR, 3.75 CY                               0.00      75.41       0.00       0.00      75.41
                                REF. EP 1110-1-8               255.03 HR  L35CA007      1.00          0     19,232          0          0     19,232      75.41
                                3.75 CY

           MIL AA <           > BLADE, STRAIGHT, HYDR   (FOR D7                      0.00       5.23       0.00       0.00       5.23
                                REF. EP 1110-1-8               255.03 HR  T10CA012      1.00          0      1,333          0          0      1,333       5.23
                                BLADE, STRAIGHT,HYDRAULIC, FOR D
                                7

           UPB AA <           > DOZER,CWLR, D-7H,PS  (ADD BLADE)                     0.00      59.31       0.00       0.00      59.31
                                REF. EP 1110-1-8               255.03 HR  T15CA013      1.00          0     15,126          0          0     15,126      59.31
                                POWERSHIFT (ADD BLADE)
                                                                                  ----------- ----------- ----------- ----------- -----------
                      TOTAL Excavate & Haul Clay Liner          38510 CY                      161,001    198,250          0          0    359,251       9.33

           02_05.02.02. Spread & Compact Clay Liner (ZKB)

           MIL AA <           > BLADE, STRAIGHT, HYDR   (FOR D7                      0.00       5.23       0.00       0.00       5.23
                                REF. EP 1110-1-8               453.06 HR  T10CA012      1.00          0      2,369          0          0      2,369       5.23
                                BLADE, STRAIGHT,HYDRAULIC, FOR D
                                7

           UPB AA <           > DOZER,CWLR, D-7H,PS  (ADD BLADE)                     0.00      59.31       0.00       0.00      59.31
                                REF. EP 1110-1-8               453.06 HR  T15CA013      1.00          0     26,871          0          0     26,871      59.31
                                POWERSHIFT (ADD BLADE)
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2_05. Dike Systems, Stages I & II                          QUANTY UOM CREW ID      OUTPUT        LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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            UPB AA <          > GRADER,MOTOR, ARTIC, CAT 140-G                                    0.00       30.67        0.00        0.00       30.67
                                REF. EP 1110-1-8             453.06 HR  G15CA004       1.00          0      13,895           0           0      13,895       30.67
                                ARTICULATED FRAME, POWERSHIFT

            UPB AA <          > ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W                                  0.00       22.70        0.00        0.00       22.70
                                REF. EP 1110-1-8             453.06 HR  R40SO001       1.00          0      10,283           0           0      10,283       22.70
                                72" WIDE X 56" DIA., 25.5 TON

            MIL AA <          > TRACTOR,WH,FARM, JD-2755, 2WD                                     0.00        9.22        0.00        0.00        9.22
                                REF. EP 1110-1-8             453.06 HR  T25JD004       1.00          0       4,176           0           0       4,176        9.22
                                INDUSTRIAL 2WD (NO ATTACHMENTS)

            MIL AA <          > TRK,WTR,OF-HY, 5000GAL,W/CAT613C                                  0.00       35.38        0.00        0.00       35.38
                                REF. EP 1110-1-8             453.06 HR  T60KI001       1.00          0      16,028           0           0      16,028       35.38
                                5,000 GALLON,WITH CAT 613C TRACT
                                OR

            MIL AA <          > Outside Equip. Operators, Heavy                                  38.55        0.00        0.00        0.00       38.55
                                                            1359.18 HR  X-EQOPRHVY     1.00     52,397           0           0           0      52,397       38.55

            MIL AA <          > Outside Equip. Operators, Light                                  37.30        0.00        0.00        0.00       37.30
                                                             453.06 HR  X-EQOPRLT      1.00     16,899           0           0           0      16,899       37.30

            MIL AA <          > Craft Foreman                                                    39.80        0.00        0.00        0.00       39.80
                                                             453.06 HR  X-LABORER      1.00     18,032           0           0           0      18,032       39.80

            MIL AA <          > Outside Truck Drivers, Heavy                                     27.30        0.00        0.00        0.00       27.30
                                                             453.06 HR  X-TRKDVRHV     1.00     12,368           0           0           0      12,368       27.30

            MIL AA <          > Flagmen                                                          25.15        0.00        0.00        0.00       25.15
                                                             906.12 HR  X-TRKDVRLT     1.00     22,789           0           0           0      22,789       25.15
                                                                                           ----------- ----------- ----------- ----------- -----------
                        TOTAL Spread & Compact Clay Liner      38510 CY                        122,485      73,622           0           0     196,107        5.09

                                                                                           ----------- ----------- ----------- ----------- -----------
                        TOTAL 3' Clay Slope Liner              38510 CY                        283,486     271,872           0           0     555,358       14.42
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2_05. Dike Systems, Stages I & II	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
02_05.03. Cross Dikes 8' Ht.										
02_05.03.01. Existing On-Site Fill										
USR AA < > Existing On-Site Fill					3.25	3.38	0.00	0.00	6.63	
	31500	CY		0.00	102,375	106,470	0	0	208,845	6.63
TOTAL Existing On-Site Fill	31500	CY			102,375	106,470	0	0	208,845	6.63
02_05.03.02. Dried Sediments										
USR AA < > Dried Sediments					3.25	3.38	0.00	0.00	6.63	
	21200	CY		0.00	68,900	71,656	0	0	140,556	6.63
TOTAL Dried Sediments	21200	CY			68,900	71,656	0	0	140,556	6.63
02_05.03.03. Stripping										
USR AA < > Stripping					1.47	1.53	0.00	0.00	3.00	
	68500	CY		0.00	100,695	104,805	0	0	205,500	3.00
TOTAL Stripping	68500	CY			100,695	104,805	0	0	205,500	3.00
TOTAL Cross Dikes 8' Ht.	115000	CY			271,970	282,931	0	0	554,901	4.83

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2_05. Dike Systems, Stages I & II                        QUANTY UOM CREW ID     OUTPUT       LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST  UNIT COST
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        02_05.04. 6" Topsoil

           02_05.04.01. Spread Topsoil (ZNAA)

           MIL AA <        > BLADE, STRAIGHT, HYDR   (FOR D7                            0.00        5.23        0.00        0.00        5.23
                             REF. EP 1110-1-8           92.50 HR  T10CA012      1.00           0         484           0           0         484       5.23
                             BLADE, STRAIGHT,HYDRAULIC, FOR D
                             7

           UPB AA <        > DOZER,CWLR, D-7H,PS  (ADD BLADE)                           0.00       59.31        0.00        0.00       59.31
                             REF. EP 1110-1-8           92.50 HR  T15CA013      1.00           0       5,486           0           0       5,486      59.31
                             POWERSHIFT (ADD BLADE)

           UPB AA <        > GRADER,MOTOR, ARTIC, CAT 140-G                             0.00       30.67        0.00        0.00       30.67
                             REF. EP 1110-1-8           92.50 HR  G15CA004      1.00           0       2,837           0           0       2,837      30.67
                             ARTICULATED FRAME, POWERSHIFT

           MIL AA <        > TRACTOR,WH,FARM, JD-2755, 2WD                              0.00        9.22        0.00        0.00        9.22
                             REF. EP 1110-1-8           92.50 HR  T25JD004      1.00           0         853           0           0         853       9.22
                             INDUSTRIAL 2WD (NO ATTACHMENTS)

           UPB AA <        > SMALL TOOLS                                                0.00        1.45        0.00        0.00        1.45
                                                        92.50 HR  XMIXX020      1.00           0         134           0           0         134       1.45

           UPB AA <        > TRK,WTR,OF-HY, 6000GAL,W/CAT621E                           0.00       63.75        0.00        0.00       63.75
                             REF. EP 1110-1-8           92.50 HR  T60KI002      1.00           0       5,897           0           0       5,897      63.75
                             6,000 GALLON,WITH CAT 621E TRACT
                             OR

           USR AA <        > CRAFT FOREMAN                                             39.80        0.00        0.00        0.00       39.80
                                                        92.50 HR  Z-EQUIPOPA    1.00       3,681           0           0           0       3,681      39.80

           USR AA <        > EQUIPMENT OPERATOR GRP 1                                  38.55        0.00        0.00        0.00       38.55
                                                       185.00 HR  Z-EQUIPOPB    1.00       7,131           0           0           0       7,131      38.55

           USR AA <        > EQUIPMENT OPERATOR GRP 3                                  37.30        0.00        0.00        0.00       37.30
                                                        92.50 HR  Z-EQUIPOPD    1.00       3,450           0           0           0       3,450      37.30

           USR AA <        > TEAMSTER, GROUP 1                                         27.30        0.00        0.00        0.00       27.30
                                                        92.50 HR  Z-TEAMSTEA    1.00       2,525           0           0           0       2,525      27.30

           USR AA <        > Costs of Topsoil                                           0.00        0.00        9.00        0.00        9.00
                                                        18500 CY                0.00           0           0     166,500           0     166,500       9.00
                                                                                     ----------- ----------- ----------- ----------- -----------
                      TOTAL Spread Topsoil              18500 CY                          16,788      15,691     166,500           0     198,979      10.76

                                                                                     ----------- ----------- ----------- ----------- -----------
                      TOTAL 6" Topsoil                  18500 CY                          16,788      15,691     166,500           0     198,979      10.76
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)2_05. Dike Systems, Stages I & II		QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
02_05.05. Seeding											
02_05.05.01. Spread Seeding (ZLAA)											
UPB AA <	> MISC. POWER TOOLS					0.00	5.90	0.00	0.00	5.90	
		92.00	HR	XMIXX010	1.00	0	543	0	0	543	5.90
UPB AA <	> SMALL TOOLS					0.00	1.45	0.00	0.00	1.45	
		92.00	HR	XMIXX020	1.00	0	133	0	0	133	1.45
USR AA <	> LABOR FOREMAN					27.10	0.00	0.00	0.00	27.10	
		92.00	HR	Z-LABORERA	1.00	2,493	0	0	0	2,493	27.10
USR AA <	> GROUP 3, GENERAL LABORER					26.40	0.00	0.00	0.00	26.40	
		184.00	HR	Z-LABORERD	1.00	4,858	0	0	0	4,858	26.40
MIL AA <	> TRACTOR,WH,FARM, JD-2755, 2WD					0.00	9.22	0.00	0.00	9.22	
	REF. EP 1110-1-8	92.00	HR	T25JD004	1.00	0	848	0	0	848	9.22
	INDUSTRIAL 2WD (NO ATTACHMENTS)										
USR AA <	> EQUIPMENT OPERATOR GRP 3					37.30	0.00	0.00	0.00	37.30	
		92.00	HR	Z-EQUIPOPD	1.00	3,432	0	0	0	3,432	37.30
MIL AA <	> TRK,WTR,OF-HY, 5000GAL,W/CAT613C					0.00	35.38	0.00	0.00	35.38	
	REF. EP 1110-1-8	23.00	HR	T60KI001	1.00	0	814	0	0	814	35.38
	5,000 GALLON,WITH CAT 613C TRACT										
	OR										
USR AA <	> TEAMSTER, GROUP 1					27.30	0.00	0.00	0.00	27.30	
		23.00	HR	Z-TEAMSTEA	1.00	628	0	0	0	628	27.30
USR AA <	> Costs Seeds, Fertilizer, Mulch					0.00	0.00	2000.00	0.00	2000.00	
		23.00	AC		0.00	0	0	46,000	0	46,000	2000.00
	TOTAL Spread Seeding	23.00	AC			11,411	2,338	46,000	0	59,749	2597.78
	TOTAL Seeding	23.00	AC			11,411	2,338	46,000	0	59,749	2597.78

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2_05. Dike Systems, Stages I & II                    QUANTY UOM CREW ID    OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER  TOTAL COST  UNIT COST
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        02_05.06. Ramp & Road

           02_05.06.01. Curbs

           USR AA <          > Costs of Curbs                                      0.00       0.00       0.00      12.15       12.15
                                                      94054 LF              0.00          0          0          0  1,142,756   1,142,756      12.15
                                                                                ----------- ----------- ----------- ----------- -----------
                      TOTAL Curbs                     94064 LF                            0          0          0  1,142,756   1,142,756      12.15

           02_05.06.02. 8" Base Course

           USR AA <          > Costs of 8" Base Course                             0.00       0.00       0.00       6.95        6.95
                                                      78387 SY              0.00          0          0          0    544,790     544,790       6.95
                                                                                ----------- ----------- ----------- ----------- -----------
                      TOTAL 8" Base Course            78387 SY                            0          0          0    544,790     544,790       6.95

           02_05.06.03. 6" CA - 6

           USR AA <          > Costs of 6" CA - 6                                  0.00       0.00       0.00      22.00       22.00
                                                      13064 CY              0.00          0          0          0    287,408     287,408      22.00
                                                                                ----------- ----------- ----------- ----------- -----------
                      TOTAL 6" CA - 6                 13064 CY                            0          0          0    287,408     287,408      22.00

           02_05.06.04. Rehandling Pad

           USR AA <          > Costs of Rehandling Pad                             0.00       0.00       0.00      10.65       10.65
                                                    1111.00 SY              0.00          0          0          0     11,832      11,832      10.65
                                                                                ----------- ----------- ----------- ----------- -----------
                      TOTAL Rehandling Pad          1111.00 SY                            0          0          0     11,832      11,832      10.65

           02_05.06.05. Ramp

           USR AA <          > Costs of Ramp                                       0.00       0.00       0.00       9.90        9.90
                                                      29978 CY              0.00          0          0          0    296,782     296,782       9.90
                                                                                ----------- ----------- ----------- ----------- -----------
                      TOTAL Ramp                      29978 CY                            0          0          0    296,782     296,782       9.90

                                                                                ----------- ----------- ----------- ----------- -----------
                      TOTAL Ramp & Road                                                   0          0          0  2,283,568   2,283,568
                                                                                ----------- ----------- ----------- ----------- -----------
                      TOTAL Dike Systems, Stages I & II  1.00 EA                  2,920,672  3,007,704    212,500  2,283,568   8,424,444 8424444.20
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2_06. Seal Base of Dikes (3' Clay)                      QUANTY UOM CREW ID     OUTPUT       LABOR  EQUIPMNT  MATERIAL     OTHER TOTAL COST  UNIT COST
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    02_06. Seal Base of Dikes (3' Clay)
       02_06.01. Excavate & Haul Clay (ZIBB)

          UPB AA <           > DOZER,CWLR, D-7H,PS  (ADD BLADE)                      0.00     59.31      0.00      0.00      59.31
                               REF. EP 1110-1-8          726.89 HR  T15CA013    1.00      0    43,112         0         0     43,112      59.31
                               POWERSHIFT (ADD BLADE)

          MIL AA <           > BLADE, STRAIGHT, HYDR   (FOR D7                       0.00      5.23      0.00      0.00       5.23
                               REF. EP 1110-1-8          726.89 HR  T10CA012    1.00      0     3,801         0         0      3,801       5.23
                               BLADE, STRAIGHT,HYDRAULIC, FOR D
                               7

          UPB AA <           > LDR,FE, CRWLR, 3.75 CY                                0.00     75.41      0.00      0.00      75.41
                               REF. EP 1110-1-8          726.89 HR  L35CA007    1.00      0    54,813         0         0     54,813      75.41
                               3.75 CY

          MIL AA <           > TRK,HWY, 33,000 GVW, 4X2, 2 AXLE                      0.00     31.41      0.00      0.00      31.41
                               REF. EP 1110-1-8           12357 HR  T50KE002    1.00      0   388,088         0         0    388,088      31.41
                               33,000 GVW, 76,800 GCW, 2 AXLE

          UPB AA <           > TRLR,END DUMP, 20CY, 24T(ADD TRK                      0.00      7.75      0.00      0.00       7.75
                               REF. EP 1110-1-8           12357 HR  T45XX008    1.00      0    95,715         0         0     95,715       7.75
                               20 CY,   24 TON

          USR AA <           > CRAFT FOREMAN                                        39.80      0.00      0.00      0.00      39.80
                                                         726.89 HR  Z-EQUIPOPA  1.00 28,930         0         0         0     28,930      39.80

          MIL AA <           > Outside Equip. Operators, Heavy                      38.55      0.00      0.00      0.00      38.55
                                                        1453.77 HR  X-EQOPRHVY  1.00 56,043         0         0         0     56,043      38.55

          MIL AA <           > Outside Truck Drivers, Heavy                         27.30      0.00      0.00      0.00      27.30
                                                          12357 HR  X-TRKDVRHV  1.00 337,344        0         0         0    337,344      27.30

          MIL AA <           > Flagmen                                              25.15      0.00      0.00      0.00      25.15
                                                        1453.77 HR  X-TRKDVRLT  1.00 36,563         0         0         0     36,563      25.15

                      TOTAL Excavate & Haul Clay         123280 CY                  458,881   585,529         0         0  1,044,409       8.47
```

SRC	LABOR ID	DESCRIPTION	TYPE	HOURS	*** DATABASE *** RATE	TOTAL	*** TO PRIME *** RATE	TOTAL
01_01.01. Bentonite Slurry Wall-Site Peri.								
USR	Z-EQUIPOPA	CRAFT FOREMAN	Laborer	1709.46	39.80	68036.07	39.80	68036.07
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	Laborer	4452.33	38.55	171618.09	38.55	171618.09
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	Laborer	4967.90	37.90	188285.33	37.90	188285.33
USR	Z-EQUIPOPE	EQUIPMENT OPERATOR GRP 4	Laborer	7.19	35.60	256.01	35.60	256.01
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	Laborer	1263.55	34.15	43150.40	34.15	43150.40
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	Laborer	7473.42	26.40	197328.25	26.40	197328.25
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	Laborer	5346.41	27.30	145955.50	27.30	145955.50
			Total	25220.27				814629.64
01_01.04. Inspection Trench								
USR	Z-EQUIPOPA	CRAFT FOREMAN	Laborer	289.45	39.80	11520.09	39.80	11520.09
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	Laborer	434.18	38.55	16735.68	38.55	16735.68
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	Laborer	578.90	26.40	15285.37	26.40	15285.37
			Total	1302.53				43541.14
01_02.01. 3' Clay Layer								
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	Laborer	6934.84	38.55	267340.00	38.55	267340.00
MIL	X-EQOPRLT	Outside Equip. Operators, Light	Laborer	1724.13	37.30	64309.55	37.30	64309.55
MIL	X-LABORER	Craft Foreman	Laborer	2605.35	39.80	103692.25	39.80	103692.25
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	Laborer	16704.91	27.30	456038.98	27.30	456038.98
MIL	X-TRKDVRLT	Flagmen	Laborer	5210.71	25.15	131051.32	25.15	131051.32
			Total	33179.93				1022432.10
01_02.03. 6" Sand								
USR	Z-EQUIPOPA	CRAFT FOREMAN	Laborer	188.86	39.80	7516.46	39.80	7516.46
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	Laborer	377.71	38.55	14559.26	38.55	14559.26

				*** DATABASE ***		*** TO PRIME ***	
SRC LABOR ID	DESCRIPTION	TYPE	HOURS	RATE	TOTAL	RATE	TOTAL
USR Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	Laborer	188.86	37.90	7157.76	37.90	7157.76
		Total	755.43				29233.48
01_02.04. 2' Clean Fill							
MIL X-EQOPRHVY	Outside Equip. Operators, Heavy	Laborer	1555.15	38.55	59951.39	38.55	59951.39
MIL X-EQOPRLT	Outside Equip. Operators, Light	Laborer	388.79	37.30	14501.63	37.30	14501.63
MIL X-LABORER	Craft Foreman	Laborer	388.79	39.80	15473.60	39.80	15473.60
MIL X-TRKDVRHV	Outside Truck Drivers, Heavy	Laborer	8942.10	27.30	244116.53	27.30	244116.53
MIL X-TRKDVRLT	Flagmen	Laborer	1555.15	25.15	39112.57	25.15	39112.57
USR Z-EQUIPOPA	CRAFT FOREMAN	Laborer	388.79	39.80	15473.60	39.80	15473.60
		Total	13218.75				388629.31
01_02.05. 6" Topsoil							
USR Z-EQUIPOPA	CRAFT FOREMAN	Laborer	132.20	39.80	5261.52	39.80	5261.52
USR Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	Laborer	264.40	38.55	10191.48	38.55	10191.48
USR Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	Laborer	132.20	37.30	4931.02	37.30	4931.02
USR Z-TEAMSTEA	TEAMSTER, GROUP 1	Laborer	132.20	27.30	3609.02	27.30	3609.02
		Total	661.00				23993.04
01_02.06. Seeding							
USR Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	Laborer	80.00	37.30	2983.98	37.30	2983.98
USR Z-LABORERA	LABOR FOREMAN	Laborer	80.00	27.10	2168.06	27.10	2168.06
USR Z-LABORERD	GROUP 3, GENERAL LABORER	Laborer	160.00	26.40	4224.64	26.40	4224.64
USR Z-TEAMSTEA	TEAMSTER, GROUP 1	Laborer	20.00	27.30	545.99	27.30	545.99
		Total	340.00				9922.67
02_03.01. Decant Structure							
USR Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	Laborer	40.00	38.55	1541.83	38.55	1541.83

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02_06. Seal Base of Dikes (3' Clay)                          QUANTY UOM CREW ID     OUTPUT       LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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         02_06.03. Spread & Compact Clay (ZHAA)

            UPB AA <          > DOZER,CWLR, D-7H,PS  (ADD BLADE)                                0.00      59.31       0.00       0.00      59.31
                                REF. EP 1110-1-8           1232.80 HR  T15CA013      1.00           0     73,118          0          0     73,118      59.31
                                POWERSHIFT (ADD BLADE)

            UPB AA <          > GRADER,MOTOR, ARTIC, CAT 140-G                                  0.00      30.67       0.00       0.00      30.67
                                REF. EP 1110-1-8           1232.80 HR  G15CA004      1.00           0     37,809          0          0     37,809      30.67
                                ARTICULATED FRAME, POWERSHIFT

            MIL AA <          > BLADE, STRAIGHT, HYDR   (FOR D7                                 0.00       5.23       0.00       0.00       5.23
                                REF. EP 1110-1-8           1232.80 HR  T10CA012      1.00           0      6,446          0          0      6,446       5.23
                                BLADE, STRAIGHT,HYDRAULIC, FOR D
                                7

            UPB AA <          > ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W                                0.00      22.70       0.00       0.00      22.70
                                REF. EP 1110-1-8           1232.80 HR  R40SO001      1.00           0     27,981          0          0     27,981      22.70
                                72" WIDE X 56" DIA., 25.5 TON

            MIL AA <          > TRACTOR,WH,FARM, JD-2755, 2WD                                   0.00       9.22       0.00       0.00       9.22
                                REF. EP 1110-1-8           1232.80 HR  T25JD004      1.00           0     11,363          0          0     11,363       9.22
                                INDUSTRIAL 2WD (NO ATTACHMENTS)

            UPB AA <          > TRK,WTR,OF-HY, 6000GAL,W/CAT621E                                0.00      63.75       0.00       0.00      63.75
                                REF. EP 1110-1-8           1232.80 HR  T60KI002      1.00           0     78,596          0          0     78,596      63.75
                                6,000 GALLON,WITH CAT 621E TRACT
                                OR

            MIL AA <          > Outside Equip. Operators, Heavy                                38.55       0.00       0.00       0.00      38.55
                                                           3698.40 HR  X-EQOPRHVY    1.00     142,574          0          0          0    142,574      38.55

            MIL AA <          > Craft Foreman                                                  39.80       0.00       0.00       0.00      39.80
                                                           1232.80 HR  X-LABORER     1.00      49,065          0          0          0     49,065      39.80

            MIL AA <          > Outside Truck Drivers, Heavy                                   27.30       0.00       0.00       0.00      27.30
                                                           1232.80 HR  X-TRKDVRHV    1.00      33,655          0          0          0     33,655      27.30

            MIL AA <          > Outside Equip. Operators, Light                                37.30       0.00       0.00       0.00      37.30
                                                           1232.80 HR  X-EQOPRLT     1.00      45,983          0          0          0     45,983      37.30

            MIL AA <          > Flagmen                                                        25.15       0.00       0.00       0.00      25.15
                                                           2560.00 HR  X-TRKDVRLT    1.00      64,385          0          0          0     64,385      25.15
                                                                                          ----------- ---------- ---------- ---------- ----------
                         TOTAL Spread & Compact Clay         123280 CY                        335,663    235,312          0          0    570,975       4.63

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                         TOTAL Seal Base of Dikes (3' Clay)  123280 CY                        794,543    820,841          0          0  1,615,384      13.10
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02_07. Final Cap                                                    QUANTY UOM CREW ID     OUTPUT      LABOR  EQUIPMNT  MATERIAL      OTHER TOTAL COST  UNIT COST
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       02_07. Final Cap
          02_07.01. 3' Clay Liner

             02_07.01.01. Excavate & Haul Clay Liner (ZKAA)

             UPB AA <          > TRLR,END DUMP, 20CY, 24T(ADD TRK                               0.00       7.75       0.00       0.00       7.75
                                 REF. EP 1110-1-8                  44767 HR  T45XX008     1.00         0    346,754          0          0    346,754       7.75
                                 20 CY,   24 TON

             MIL AA <          > TRK,HWY, 33,000 GVW, 4X2, 2 AXLE                               0.00      29.75       0.00       0.00      29.75
                                 REF. EP 1110-1-8                  44767 HR  T50KE001     1.00         0  1,331,737          0          0  1,331,737      29.75
                                 33,000 GVW, 76,800 GCW, 2 AXLE

             MIL AA <          > Outside Equip. Operators, Heavy                               38.55       0.00       0.00       0.00      38.55
                                                                 5266.67 HR  X-EQOPRHVY   1.00   203,032          0          0          0    203,032      38.55

             MIL AA <          > Craft Foreman                                                 39.80       0.00       0.00       0.00      39.80
                                                                 2633.33 HR  X-LABORER    1.00   104,806          0          0          0    104,806      39.80

             MIL AA <          > Outside Truck Drivers, Heavy                                  27.30       0.00       0.00       0.00      27.30
                                                                   44767 HR  X-TRKDVRHV   1.00 1,222,117          0          0          0  1,222,117      27.30

             MIL AA <          > Flagmen                                                       25.15       0.00       0.00       0.00      25.15
                                                                 5266.67 HR  X-TRKDVRLT   1.00   132,459          0          0          0    132,459      25.15

             UPB AA <          > LDR,FE, CRWLR, 3.75 CY                                         0.00      75.41       0.00       0.00      75.41
                                 REF. EP 1110-1-8                2633.33 HR  L35CA007     1.00         0    198,575          0          0    198,575      75.41
                                 3.75 CY

             MIL AA <          > BLADE, STRAIGHT, HYDR   (FOR D7                                0.00       5.23       0.00       0.00       5.23
                                 REF. EP 1110-1-8                2633.33 HR  T10CA012     1.00         0     13,769          0          0     13,769       5.23
                                 BLADE, STRAIGHT,HYDRAULIC, FOR D
                                 7

             UPB AA <          > DOZER,CWLR, D-7H,PS  (ADD BLADE)                               0.00      59.31       0.00       0.00      59.31
                                 REF. EP 1110-1-8                2633.33 HR  T15CA013     1.00         0    156,184          0          0    156,184      59.31
                                 POWERSHIFT (ADD BLADE)
                                                                                             ----------- ----------- ----------- ----------- -----------
                      TOTAL Excavate & Haul Clay Liner            474000 CY                    1,662,413  2,047,018          0          0  3,709,431       7.83

             02_07.01.02. Spread & Compact Clay Liner (ZKB)

             MIL AA <          > BLADE, STRAIGHT, HYDR   (FOR D7                                0.00       5.23       0.00       0.00       5.23
                                 REF. EP 1110-1-8                5152.17 HR  T10CA012     1.00         0     26,939          0          0     26,939       5.23
                                 BLADE, STRAIGHT,HYDRAULIC, FOR D
                                 7

             UPB AA <          > DOZER,CWLR, D-7H,PS  (ADD BLADE)                               0.00      59.31       0.00       0.00      59.31
                                 REF. EP 1110-1-8                5152.17 HR  T15CA013     1.00         0    305,576          0          0    305,576      59.31
                                 POWERSHIFT (ADD BLADE)
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02_07. Final Cap		QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
UPB AA <	> GRADER,MOTOR, ARTIC, CAT 140-G					0.00	30.67	0.00	0.00	30.67	
	REF. EP 1110-1-8	5152.17	HR	G15CA004	1.00	0	158,013	0	0	158,013	30.67
	ARTICULATED FRAME, POWERSHIFT										
UPB AA <	> ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W					0.00	22.70	0.00	0.00	22.70	
	REF. EP 1110-1-8	5152.17	HR	R40SO001	1.00	0	116,938	0	0	116,938	22.70
	72" WIDE X 56" DIA., 25.5 TON										
MIL AA <	> TRACTOR,WH,FARM, JD-2755, 2WD					0.00	9.22	0.00	0.00	9.22	
	REF. EP 1110-1-8	5152.17	HR	T25JD004	1.00	0	47,490	0	0	47,490	9.22
	INDUSTRIAL 2WD (NO ATTACHMENTS)										
MIL AA <	> TRK,WTR,OF-HY, 5000GAL,W/CAT613C					0.00	35.38	0.00	0.00	35.38	
	REF. EP 1110-1-8	5152.17	HR	T60KI001	1.00	0	182,270	0	0	182,270	35.38
	5,000 GALLON,WITH CAT 613C TRACT OR										
MIL AA <	> Outside Equip. Operators, Heavy					38.55	0.00	0.00	0.00	38.55	
		15457	HR	X-EQOPRHVY	1.00	595,854	0	0	0	595,854	38.55
MIL AA <	> Outside Equip. Operators, Light					37.30	0.00	0.00	0.00	37.30	
		5152.17	HR	X-EQOPRLT	1.00	192,175	0	0	0	192,175	37.30
MIL AA <	> Craft Foreman					39.80	0.00	0.00	0.00	39.80	
		5152.17	HR	X-LABORER	1.00	205,055	0	0	0	205,055	39.80
MIL AA <	> Outside Truck Drivers, Heavy					27.30	0.00	0.00	0.00	27.30	
		5152.17	HR	X-TRKDVRHV	1.00	140,653	0	0	0	140,653	27.30
MIL AA <	> Flagmen					25.15	0.00	0.00	0.00	25.15	
		10304	HR	X-TRKDVRLT	1.00	259,158	0	0	0	259,158	25.15
	TOTAL Spread & Compact Clay Liner	474000	CY			1,392,894	837,227	0	0	2,230,122	4.70
	TOTAL 3' Clay Liner	474000	CY			3,055,307	2,884,245	0	0	5,939,552	12.53

02_07. Final Cap		QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
02_07.02. 2' Clean Fill											
02_07.02.01. Excavate & Haul Clean Fill (ZIBB)											
MIL AA <	> TRK,HWY, 33,000 GVW, 4X2, 2 AXLE					0.00	31.41	0.00	0.00	31.41	
	REF. EP 1110-1-8	27752	HR	T50KE002	1.00	0	871,598	0	0	871,598	31.41
	33,000 GVW, 76,800 GCW, 2 AXLE										
UPB AA <	> TRLR,END DUMP, 20CY, 24T(ADD TRK					0.00	7.75	0.00	0.00	7.75	
	REF. EP 1110-1-8	27752	HR	T45XX008	1.00	0	214,965	0	0	214,965	7.75
	20 CY, 24 TON										
USR AA <	> CRAFT FOREMAN					39.80	0.00	0.00	0.00	39.80	
		1261.48	HR	Z-EQUIPOPA	1.00	50,206	0	0	0	50,206	39.80
MIL AA <	> Outside Equip. Operators, Heavy					38.55	0.00	0.00	0.00	38.55	
		1261.48	HR	X-EQOPRHVY	1.00	48,630	0	0	0	48,630	38.55
MIL AA <	> Outside Truck Drivers, Heavy					27.30	0.00	0.00	0.00	27.30	
		27752	HR	X-TRKDVRHV	1.00	757,635	0	0	0	757,635	27.30
MIL AA <	> Flagmen					25.15	0.00	0.00	0.00	25.15	
		2522.95	HR	X-TRKDVRLT	1.00	63,453	0	0	0	63,453	25.15
MIL AA <	> HYD EXCAV, CRWLR, 3.75 CY BKT					0.00	105.02	0.00	0.00	105.02	
	REF. EP 1110-1-8	1261.48	HR	H25IS006	1.00	0	132,483	0	0	132,483	105.02
	3.75 CY BUCKET										
	TOTAL Excavate & Haul Clean Fill	316000	CY			919,925	1,219,046	0	0	2,138,970	6.77
02_07.02.02. Spread & Compact Clean Fill (ZHAA)											
UPB AA <	> ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W					0.00	22.70	0.00	0.00	22.70	
	REF. EP 1110-1-8	1161.76	HR	R40SO001	1.00	0	26,368	0	0	26,368	22.70
	72" WIDE X 56" DIA., 25.5 TON										
MIL AA <	> TRACTOR,WH,FARM, JD-2755, 2WD					0.00	9.22	0.00	0.00	9.22	
	REF. EP 1110-1-8	1161.76	HR	T25JD004	1.00	0	10,709	0	0	10,709	9.22
	INDUSTRIAL 2WD (NO ATTACHMENTS)										
MIL AA <	> Outside Equip. Operators, Heavy					38.55	0.00	0.00	0.00	38.55	
		3485.29	HR	X-EQOPRHVY	1.00	134,359	0	0	0	134,359	38.55
MIL AA <	> Craft Foreman					39.80	0.00	0.00	0.00	39.80	
		1161.76	HR	X-LABORER	1.00	46,238	0	0	0	46,238	39.80
MIL AA <	> Outside Truck Drivers, Heavy					27.30	0.00	0.00	0.00	27.30	
		1161.76	HR	X-TRKDVRHV	1.00	31,716	0	0	0	31,716	27.30

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02_07. Final Cap                                    QUANTY UOM CREW ID    OUTPUT       LABOR   EQUIPMNT   MATERIAL      OTHER  TOTAL COST  UNIT COST
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             MIL AA <         > Outside Equip. Operators, Light                         37.30       0.00       0.00       0.00       37.30
                                                   1161.76 HR  X-EQOPRLT     1.00      43,333          0          0          0      43,333      37.30

             MIL AA <         > Flagmen                                                 25.15       0.00       0.00       0.00       25.15
                                                   2323.53 HR  X-TRKDVRLT    1.00      58,438          0          0          0      58,438      25.15

             UPB AA <         > BLADE, STRAIGHT, HYDR   (FOR D6                          0.00       3.66       0.00       0.00        3.66
                                REF. EP 1110-1-8   1161.76 HR  T10CA009      1.00           0      4,246          0          0       4,246       3.66
                                BLADE, STRAIGHT,HYDRAULIC, FOR D
                                6

             UPB AA <         > DOZER,CWLR, D-6H,PS  (ADD BLADE)                         0.00      39.58       0.00       0.00       39.58
                                REF. EP 1110-1-8   1161.76 HR  T15CA010      1.00           0     45,979          0          0      45,979      39.58
                                POWERSHIFT (ADD BLADE)

             UPB AA <         > GRADER,MOTOR, ARTIC, CAT 140-G                           0.00      30.67       0.00       0.00       30.67
                                REF. EP 1110-1-8   1161.76 HR  G15CA004      1.00           0     35,630          0          0      35,630      30.67
                                ARTICULATED FRAME, POWERSHIFT

             MIL AA <         > TRK,WTR,OF-HY, 5000GAL,W/CAT613C                         0.00      35.38       0.00       0.00       35.38
                                REF. EP 1110-1-8   1161.76 HR  T60KI001      1.00           0     41,100          0          0      41,100      35.38
                                5,000 GALLON,WITH CAT 613C TRACT
                                OR

             USR AA <         > Discs                                                    0.00       2.50       0.00       0.00        2.50
                                                   1161.76 HR  XX0XX022      1.00           0      2,904          0          0       2,904       2.50
                                                                                  ----------- ----------- ----------- ----------- -----------
                      TOTAL Spread & Compact Clean Fill     316000 CY                 314,084    166,937          0          0     481,021       1.52

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                      TOTAL 2' Clean Fill                   316000 CY               1,234,009  1,385,982          0          0   2,619,991       8.29
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02_07. Final Cap                                                   QUANTY UOM CREW ID     OUTPUT       LABOR    EQUIPMNT    MATERIAL       OTHER  TOTAL COST   UNIT COST
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          02_07.03. 6" Sand Drainage Layer

             02_07.03.01. Spread Sand (ZMAA)

             UPB AA <          > GRADER,MOTOR, ARTIC, CAT 140-G                                     0.00       30.67        0.00        0.00       30.67
                                 REF. EP 1110-1-8                  564.29 HR  G15CA004      1.00           0      17,306           0           0      17,306       30.67
                                 ARTICULATED FRAME, POWERSHIFT

             MIL AA <          > ROLLER,STATIC,DD,S/P,14T, 54"W                                     0.00       16.14        0.00        0.00       16.14
                                 REF. EP 1110-1-8                  564.29 HR  R30FR010      1.00           0       9,105           0           0       9,105       16.14
                                 10-14 TON, TANDEM, HYDROSTATIC

             UPB AA <          > BLADE, STRAIGHT, HYDR   (FOR D6                                    0.00        3.66        0.00        0.00        3.66
                                 REF. EP 1110-1-8                  564.29 HR  T10CA009      1.00           0       2,062           0           0       2,062        3.66
                                 BLADE, STRAIGHT,HYDRAULIC, FOR D
                                 6

             MIL AA <          > DOZER,CWLR, D-6D,SA  (ADD BLADE)                                   0.00       39.67        0.00        0.00       39.67
                                 REF. EP 1110-1-8                  564.29 HR  T15CA009      1.00           0      22,383           0           0      22,383       39.67
                                 SPECIAL APPLICATION (ADD BLADE)

             USR AA <          > CRAFT FOREMAN                                                     39.80        0.00        0.00        0.00       39.80
                                                                   564.29 HR  Z-EQUIPOPA    1.00      22,458           0           0           0      22,458       39.80

             USR AA <          > EQUIPMENT OPERATOR GRP 1                                          38.55        0.00        0.00        0.00       38.55
                                                                  1128.57 HR  Z-EQUIPOPB    1.00      43,502           0           0           0      43,502       38.55

             USR AA <          > EQUIPMENT OPERATOR GRP 2                                          37.90        0.00        0.00        0.00       37.90
                                                                   564.29 HR  Z-EQUIPOPC    1.00      21,387           0           0           0      21,387       37.90

             USR AA <          > Costs of Sand                                                      0.00        0.00       10.50        0.00       10.50
                                                                   79000                    0.00           0           0     829,500           0     829,500       10.50
                                                                                                 ----------- ----------- ----------- ----------- -----------
                         TOTAL Spread Sand                         79000 CY                           87,347      50,857     829,500           0     967,703       12.25

                                                                                                 ----------- ----------- ----------- ----------- -----------
                         TOTAL 6" Sand Drainage Layer              79000 CY                           87,347      50,857     829,500           0     967,703       12.25
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02_07. Final Cap                                               QUANTY UOM CREW ID     OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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          02_07.04. 6" Topsoil

             02_07.04.01. Spread Topsoil (ZNAA)

             MIL AA <        > BLADE, STRAIGHT, HYDR   (FOR D7                                0.00       5.23       0.00       0.00       5.23
                               REF. EP 1110-1-8                 395.00 HR  T10CA012     1.00          0      2,065          0          0      2,065       5.23
                               BLADE, STRAIGHT,HYDRAULIC, FOR D
                               7

             UPB AA <        > DOZER,CWLR, D-7H,PS  (ADD BLADE)                               0.00      59.31       0.00       0.00      59.31
                               REF. EP 1110-1-8                 395.00 HR  T15CA013     1.00          0     23,428          0          0     23,428      59.31
                               POWERSHIFT (ADD BLADE)

             UPB AA <        > GRADER,MOTOR, ARTIC, CAT 140-G                                 0.00      30.67       0.00       0.00      30.67
                               REF. EP 1110-1-8                 395.00 HR  G15CA004     1.00          0     12,114          0          0     12,114      30.67
                               ARTICULATED FRAME, POWERSHIFT

             MIL AA <        > TRACTOR,WH,FARM, JD-2755, 2WD                                  0.00       9.22       0.00       0.00       9.22
                               REF. EP 1110-1-8                 395.00 HR  T25JD004     1.00          0      3,641          0          0      3,641       9.22
                               INDUSTRIAL 2WD (NO ATTACHMENTS)

             UPB AA <        > SMALL TOOLS                                                    0.00       1.45       0.00       0.00       1.45
                                                                395.00 HR  XMIXX020     1.00          0        573          0          0        573       1.45

             UPB AA <        > TRK,WTR,OF-HY, 6000GAL,W/CAT621E                               0.00      63.75       0.00       0.00      63.75
                               REF. EP 1110-1-8                 395.00 HR  T60KI002     1.00          0     25,183          0          0     25,183      63.75
                               6,000 GALLON,WITH CAT 621E TRACT
                               OR

             USR AA <        > CRAFT FOREMAN                                                 39.80       0.00       0.00       0.00      39.80
                                                                395.00 HR  Z-EQUIPOPA   1.00     15,721          0          0          0     15,721      39.80

             USR AA <        > EQUIPMENT OPERATOR GRP 1                                      38.55       0.00       0.00       0.00      38.55
                                                                790.00 HR  Z-EQUIPOPB   1.00     30,451          0          0          0     30,451      38.55

             USR AA <        > EQUIPMENT OPERATOR GRP 3                                      37.30       0.00       0.00       0.00      37.30
                                                                395.00 HR  Z-EQUIPOPD   1.00     14,733          0          0          0     14,733      37.30

             USR AA <        > TEAMSTER, GROUP 1                                             27.30       0.00       0.00       0.00      27.30
                                                                395.00 HR  Z-TEAMSTEA   1.00     10,783          0          0          0     10,783      27.30

             USR AA <        > Costs of Topsoil                                               0.00       0.00       9.00       0.00       9.00
                                                                 79000 CY               0.00          0          0    711,000          0    711,000       9.00
                                                                                        ----------- ---------- ---------- ---------- ----------
                        TOTAL Spread Topsoil                     79000 CY                    71,689     67,004    711,000          0    849,692      10.76

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                        TOTAL 6" Topsoil                         79000 CY                    71,689     67,004    711,000          0    849,692      10.76
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02_07. Final Cap                                      QUANTY UOM CREW ID     OUTPUT      LABOR   EQUIPMNT   MATERIAL      OTHER TOTAL COST  UNIT COST
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         02_07.05. Seeding

            02_07.05.01. Spread Seeds (ZLAA)

            UPB AA <          > MISC. POWER TOOLS                                         0.00       5.90       0.00       0.00       5.90
                                                      400.00 HR  XMIXX010      1.00          0      2,360          0          0      2,360       5.90

            UPB AA <          > SMALL TOOLS                                               0.00       1.45       0.00       0.00       1.45
                                                      400.00 HR  XMIXX020      1.00          0        580          0          0        580       1.45

            USR AA <          > LABOR FOREMAN                                            27.10       0.00       0.00       0.00      27.10
                                                      400.00 HR  Z-LABORERA    1.00     10,840          0          0          0     10,840      27.10

            USR AA <          > GROUP 3, GENERAL LABORER                                 26.40       0.00       0.00       0.00      26.40
                                                      800.00 HR  Z-LABORERD    1.00     21,123          0          0          0     21,123      26.40

            MIL AA <          > TRACTOR,WH,FARM, JD-2755, 2WD                             0.00       9.22       0.00       0.00       9.22
                                REF. EP 1110-1-8      400.00 HR  T25JD004      1.00          0      3,687          0          0      3,687       9.22
                                INDUSTRIAL 2WD (NO ATTACHMENTS)

            USR AA <          > EQUIPMENT OPERATOR GRP 3                                 37.30       0.00       0.00       0.00      37.30
                                                      400.00 HR  Z-EQUIPOPD    1.00     14,920          0          0          0     14,920      37.30

            MIL AA <          > TRK,WTR,OF-HY, 5000GAL,W/CAT613C                          0.00      35.38       0.00       0.00      35.38
                                REF. EP 1110-1-8      100.00 HR  T60KI001      1.00          0      3,538          0          0      3,538      35.38
                                5,000 GALLON,WITH CAT 613C TRACT
                                OR

            USR AA <          > TEAMSTER, GROUP 1                                        27.30       0.00       0.00       0.00      27.30
                                                      100.00 HR  Z-TEAMSTEA    1.00      2,730          0          0          0      2,730      27.30

            USR AA <          > Costs of Seeds                                            0.00       0.00    2000.00       0.00    2000.00
                                                      100.00 AC                0.00          0          0    200,000          0    200,000    2000.00
                                                                                   ----------- ---------- ---------- ---------- ----------
                      TOTAL Spread Seeds              100.00 AC                        49,613     10,165    200,000          0    259,778    2597.78

                                                                                   ----------- ---------- ---------- ---------- ----------
                      TOTAL Seeding                   100.00 AC                        49,613     10,165    200,000          0    259,778    2597.78
                                                                                   ----------- ---------- ---------- ---------- ----------
                      TOTAL Final Cap                   1.00 EA                     4,497,965  4,398,252  1,740,500          0 10,636,717 10636716.95
                                                                                   ----------- ---------- ---------- ---------- ----------
                      TOTAL Dredging & CDF              1.00 EA                    10,610,635  8,827,588  2,965,310 46,555,818 68,959,351 68959351.05
                                                                                   ----------- ---------- ---------- ---------- ----------
                      TOTAL Indiana Harbor and Canal    1.00 EA                    13,904,986 11,201,935  4,648,489 47,549,731 77,305,142 77305141.55
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---------------------------------------------------------------------------------- *** DATABASE *** ------ *** TO PRIME ***-------------------------------------------
    SRC LABOR ID    DESCRIPTION                           TYPE              HOURS        RATE        TOTAL         RATE        TOTAL
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    USR Z-LABORERA  LABOR FOREMAN                         Laborer           40.00       27.10      1084.03        27.10      1084.03

    USR Z-LABORERC  WELDER                                Laborer           80.00       36.85      2948.02        36.85      2948.02

    USR Z-LABORERD  GROUP 3, GENERAL LABORER              Laborer          160.00       26.40      4224.64        26.40      4224.64

    USR Z-LABORERF  MASON                                 Laborer           40.00       35.95      1437.99        35.95      1437.99

                                                          ------------------------------------------------------------------------
                                                          Total            360.00                                             11236.51


02_03.02. Piping
    USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1              Laborer          119.98       38.55      4624.56        38.55      4624.56

    USR Z-EQUIPOPF  EQUIPMENT OPERATOR GRP 5, OILER       Laborer           59.99       34.15      2048.60        34.15      2048.60

    USR Z-LABORERA  LABOR FOREMAN                         Laborer           59.99       27.10      1625.72        27.10      1625.72

    USR Z-LABORERD  GROUP 3, GENERAL LABORER              Laborer          299.94       26.40      7919.62        26.40      7919.62

                                                          ------------------------------------------------------------------------
                                                          Total            539.89                                             16218.49


02_05.02. 3' Clay Slope Liner
    MIL X-EQOPRHVY  Outside Equip. Operators, Heavy       Laborer         1869.24       38.55     72059.87        38.55     72059.87

    MIL X-EQOPRLT   Outside Equip. Operators, Light       Laborer          453.06       37.30     16898.96        37.30     16898.96

    MIL X-LABORER   Craft Foreman                         Laborer          708.09       39.80     28181.85        39.80     28181.85

    MIL X-TRKDVRHV  Outside Truck Drivers, Heavy          Laborer         4788.62       27.30    130727.94        27.30    130727.94

    MIL X-TRKDVRLT  Flagmen                               Laborer         1416.18       25.15     35617.59        25.15     35617.59

                                                          ------------------------------------------------------------------------
                                                          Total           9235.20                                            283486.19


02_05.04. 6" Topsoil
    USR Z-EQUIPOPA  CRAFT FOREMAN                         Laborer           92.50       39.80      3681.47        39.80      3681.47

    USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1              Laborer          185.00       38.55      7130.95        38.55      7130.95

    USR Z-EQUIPOPD  EQUIPMENT OPERATOR GRP 3              Laborer           92.50       37.30      3450.22        37.30      3450.22

    USR Z-TEAMSTEA  TEAMSTER, GROUP 1                     Laborer           92.50       27.30      2525.22        27.30      2525.22

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SRC LABOR ID	DESCRIPTION	TYPE	HOURS	*** DATABASE *** RATE	TOTAL	*** TO PRIME *** RATE	TOTAL
		Total	462.50				16787.87
02_05.05. Seeding							
USR Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	Laborer	92.00	37.30	3431.57	37.30	3431.57
USR Z-LABORERA	LABOR FOREMAN	Laborer	92.00	27.10	2493.26	27.10	2493.26
USR Z-LABORERD	GROUP 3, GENERAL LABORER	Laborer	184.00	26.40	4858.34	26.40	4858.34
USR Z-TEAMSTEA	TEAMSTER, GROUP 1	Laborer	23.00	27.30	627.89	27.30	627.89
		Total	391.00				11411.07
02_06.01. Excavate & Haul Clay							
MIL X-EQOPRHVY	Outside Equip. Operators, Heavy	Laborer	1453.77	38.55	56043.41	38.55	56043.41
MIL X-TRKDVRHV	Outside Truck Drivers, Heavy	Laborer	12357.08	27.30	337344.45	27.30	337344.45
MIL X-TRKDVRLT	Flagmen	Laborer	1453.77	25.15	36562.99	25.15	36562.99
USR Z-EQUIPOPA	CRAFT FOREMAN	Laborer	726.89	39.80	28929.88	39.80	28929.88
		Total	15991.51				458880.73
02_06.03. Spread & Compact Clay							
MIL X-EQOPRHVY	Outside Equip. Operators, Heavy	Laborer	3698.40	38.55	142574.43	38.55	142574.43
MIL X-EQOPRLT	Outside Equip. Operators, Light	Laborer	1232.80	37.30	45983.07	37.30	45983.07
MIL X-LABORER	Craft Foreman	Laborer	1232.80	39.80	49065.07	39.80	49065.07
MIL X-TRKDVRHV	Outside Truck Drivers, Heavy	Laborer	1232.80	27.30	33655.07	27.30	33655.07
MIL X-TRKDVRLT	Flagmen	Laborer	2560.00	25.15	64385.02	25.15	64385.02
		Total	9956.80				335662.66
02_07.01. 3' Clay Liner							
MIL X-EQOPRHVY	Outside Equip. Operators, Heavy	Laborer	20723.19	38.55	798885.13	38.55	798885.13
MIL X-EQOPRLT	Outside Equip. Operators, Light	Laborer	5152.17	37.30	192174.54	37.30	192174.54
MIL X-LABORER	Craft Foreman	Laborer	7785.51	39.80	309860.85	39.80	309860.85

SRC LABOR ID	DESCRIPTION	TYPE	HOURS	*** DATABASE *** RATE	TOTAL	*** TO PRIME *** RATE	TOTAL
MIL X-TRKDVRHV	Outside Truck Drivers, Heavy	Laborer	49918.84	27.30	1362769.37	27.30	1362769.37
MIL X-TRKDVRLT	Flagmen	Laborer	15571.01	25.15	391617.24	25.15	391617.24
		Total	99150.72				3055307.14
02_07.02. 2' Clean Fill							
MIL X-EQOPRHVY	Outside Equip. Operators, Heavy	Laborer	4746.77	38.55	182989.45	38.55	182989.45
MIL X-EQOPRLT	Outside Equip. Operators, Light	Laborer	1161.76	37.30	43333.47	37.30	43333.47
MIL X-LABORER	Craft Foreman	Laborer	1161.76	39.80	46237.89	39.80	46237.89
MIL X-TRKDVRHV	Outside Truck Drivers, Heavy	Laborer	28914.26	27.30	789350.62	27.30	789350.62
MIL X-TRKDVRLT	Flagmen	Laborer	4846.48	25.15	121891.00	25.15	121891.00
USR Z-EQUIPOPA	CRAFT FOREMAN	Laborer	1261.48	39.80	50206.41	39.80	50206.41
		Total	42092.52				1234008.83
02_07.03. 6" Sand Drainage Layer							
USR Z-EQUIPOPA	CRAFT FOREMAN	Laborer	564.29	39.80	22458.40	39.80	22458.40
USR Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	Laborer	1128.57	38.55	43501.57	38.55	43501.57
USR Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	Laborer	564.29	37.90	21386.65	37.90	21386.65
		Total	2257.14				87346.63
02_07.04. 6" Topsoil							
USR Z-EQUIPOPA	CRAFT FOREMAN	Laborer	395.00	39.80	15720.88	39.80	15720.88
USR Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	Laborer	790.00	38.55	30451.10	38.55	30451.10
USR Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	Laborer	395.00	37.30	14733.38	37.30	14733.38
USR Z-TEAMSTEA	TEAMSTER, GROUP 1	Laborer	395.00	27.30	10783.38	27.30	10783.38
		Total	1975.00				71688.75
02_07.05. Seeding							
USR Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	Laborer	400.00	37.30	14919.88	37.30	14919.88

** LABOR COST TO PRIME SUMMARY - Sub Feat **

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--------------------------------------------------------------------------------------- *** DATABASE *** ------ *** TO PRIME ***---------------------------------------------
    SRC LABOR ID    DESCRIPTION                          TYPE                HOURS        RATE      TOTAL         RATE      TOTAL
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    USR Z-LABORERA  LABOR FOREMAN                        Laborer            400.00       27.10   10840.28        27.10   10840.28

    USR Z-LABORERD  GROUP 3, GENERAL LABORER             Laborer            800.00       26.40   21123.20        26.40   21123.20

    USR Z-TEAMSTEA  TEAMSTER, GROUP 1                    Laborer            100.00       27.30    2729.97        27.30    2729.97

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                                                         Total             1700.00                                       49613.33
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---------------------------------------------------------------------------   **** LABOR ****     **** EQUIP ****       TOTAL--------------------------------------------
SRC  ITEM ID    DESCRIPTION                              NO. UOM       RATE    HOURS      COST     HOURS      COST        COST
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     ITEM ID  DESCRIPTION
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01. Present Site RCRA Closure
02. Dredging & CDF
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ITEM ID	DESCRIPTION
0_01.	Prime Contractor
01_01.	Slurry Wall
01_02.	Seal Peripheral Areas
01_03.	Hydraulic Gradient Control
01_04.	Water Treatment System (24%)
02_01.	Dredging Stages I, & II
02_02.	Water Treatment System (76%)
02_03.	Sediment Dewatering System
02_05.	Dike Systems, Stages I & II
02_06.	Seal Base of Dikes (3' Clay)
02_07.	Final Cap

ITEM ID	DESCRIPTION
0_01. 0.	Overhead Items - AA
0_01.01.	Slurry Contractor
01_01.01.	Bentonite Slurry Wall-Site Peri.
01_01.02.	Railroad Relocation
01_01.04.	Inspection Trench
01_01.05.	Initial Groundwater Drawdown
01_02.01.	3' Clay Layer
01_02.03.	6" Sand
01_02.04.	2' Clean Fill
01_02.05.	6" Topsoil
01_02.06.	Seeding
01_03.01.	Well Points
01_03.02.	Header Piping
01_03.03.	Pumps
01_03.04.	Ground Water Monitoring Wells
01_03.05.	Disch. Pipe to Indianapolis Ave.
02_01.01.	Dredging Incl. Barge to Site
02_02.01.	Costs of Water Treatment System
02_03.01.	Decant Structure
02_03.02.	Piping
02_05.01.	Embankment
02_05.02.	3' Clay Slope Liner
02_05.03.	Cross Dikes 8' Ht.
02_05.04.	6" Topsoil
02_05.05.	Seeding
02_05.06.	Ramp & Road
02_06.01.	Excavate & Haul Clay
02_06.03.	Spread & Compact Clay
02_07.01.	3' Clay Liner
02_07.02.	2' Clean Fill
02_07.03.	6" Sand Drainage Layer
02_07.04.	6" Topsoil
02_07.05.	Seeding

ITEM ID	DESCRIPTION
0_01.01. 0.	Overhead Items - SC
01_01.01.01.	Mobilization & Site Preparation
01_01.01.02.	Bentonite Slurry Trench
01_01.01.03.	Slurry Trench Excav. & Disposal
01_01.01.04.	Borrow for Slurry Trench Fill
01_01.01.05.	Disposal of Excess Slurry
01_01.02.01.	Clearing and Grubbing
01_01.02.02.	Topsoil Stripping
01_01.02.03.	Roadbed Earthfill
01_01.02.04.	Ditches and Swales
01_01.02.05.	Sub-Ballast
01_01.02.06.	Duo-Rail, Single Side Track
01_01.02.07.	Turnouts #10, incl. Rails, Frog
01_01.02.08.	RR Crossing Rubber Mat & Traf. S
01_01.02.09.	Topsoil Replacement
01_01.02.10.	Seeding
01_01.02.11.	Relocate Light Pole
01_01.02.12.	Relocate Surface Discharge Pipe
01_01.02.13.	Brick Masonry Wall Relocation
01_01.02.14.	Replace Gate
01_01.04.01.	Trench Excavation
01_01.04.02.	Trench Backfill
01_01.05.01.	Pumping
01_01.05.02.	Treatment Surcharge
01_01.05.03.	Analytical Testing
01_01.05.04.	Sample Collection
01_02.01.01.	Excavate & Haul Clay
01_02.01.02.	Spread & Compact Clay
01_02.03.01.	Spread Sand
01_02.04.01.	Excavate & Haul Clean Fill
01_02.04.02.	Spread & Compact Clean Fill
01_02.05.01.	Spread Topsoil
01_02.06.01.	Spread Seedings
02_03.02.01.	Concrete Pipe
02_05.01.01.	Embankment Stage I
02_05.01.02.	Embankment Stage II
02_05.02.01.	Excavate & Haul Clay Liner
02_05.02.02.	Spread & Compact Clay Liner
02_05.03.01.	Existing On-Site Fill
02_05.03.02.	Dried Sediments
02_05.03.03.	Stripping
02_05.04.01.	Spread Topsoil
02_05.05.01.	Spread Seeding
02_05.06.01.	Curbs
02_05.06.02.	8" Base Course
02_05.06.03.	6" CA - 6
02_05.06.04.	Rehandling Pad
02_05.06.05.	Ramp
02_07.01.01.	Excavate & Haul Clay Liner
02_07.01.02.	Spread & Compact Clay Liner
02_07.02.01.	Excavate & Haul Clean Fill

ITEM ID	DESCRIPTION
02_07.02.02.	Spread & Compact Clean Fill
02_07.03.01.	Spread Sand
02_07.04.01.	Spread Topsoil
02_07.05.01.	Spread Seeds

ITEM ID	DESCRIPTION
01_01.01.02_ 01.	Initial Slurry Placement
01_01.01.02_ 02.	Remainder Slurry Trench

SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	**** TOTAL **** DEFAULT	HOURS
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	40981
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	10113
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	13882
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	122859
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	32613
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	5749
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	7792
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	5721
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	1192
USR	Z-EQUIPOPE	EQUIPMENT OPERATOR GRP 4	20.45	0.0%	36.0%	7.79	0.00	35.60	HR	12/26/95	0.00	7
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	19.40	0.0%	36.0%	7.77	0.00	34.15	HR	12/26/95	0.00	1324
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	672
USR	Z-LABORERC	WELDER	21.60	0.0%	36.0%	7.47	0.00	36.85	HR	03/09/96	0.00	80
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	9656
USR	Z-LABORERF	MASON	21.99	0.0%	36.0%	6.05	0.00	35.95	HR	03/09/96	0.00	40
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	6109

												**** TOTAL ****
SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	HOURS
01. Present Site RCRA Closure												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	8490
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	2113
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	2994
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	25647
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	6766
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	2709
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	5529
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	5157
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	212
USR	Z-EQUIPOPE	EQUIPMENT OPERATOR GRP 4	20.45	0.0%	36.0%	7.79	0.00	35.60	HR	12/26/95	0.00	7
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	19.40	0.0%	36.0%	7.77	0.00	34.15	HR	12/26/95	0.00	1264
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	80
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	8212
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	5499
02. Dredging & CDF												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	32491
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	8000
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	10888
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	97212
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	25847
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	3040
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	2264
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	564
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	980
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	19.40	0.0%	36.0%	7.77	0.00	34.15	HR	12/26/95	0.00	60
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	592
USR	Z-LABORERC	WELDER	21.60	0.0%	36.0%	7.47	0.00	36.85	HR	03/09/96	0.00	80
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	1444
USR	Z-LABORERF	MASON	21.99	0.0%	36.0%	6.05	0.00	35.95	HR	03/09/96	0.00	40
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	611

											**** TOTAL ****	
SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	HOURS
0_01. Prime Contractor												
01_01. Slurry Wall												
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	1999
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	4887
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	4968
USR	Z-EQUIPOPE	EQUIPMENT OPERATOR GRP 4	20.45	0.0%	36.0%	7.79	0.00	35.60	HR	12/26/95	0.00	7
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	19.40	0.0%	36.0%	7.77	0.00	34.15	HR	12/26/95	0.00	1264
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	8052
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	5346
01_02. Seal Peripheral Areas												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	8490
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	2113
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	2994
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	25647
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	6766
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	710
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	642
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	189
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	212
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	80
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	160
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	152
01_03. Hydraulic Gradient Control												
01_04. Water Treatment System (24%)												
02_01. Dredging Stages I, & II												
02_02. Water Treatment System (76%)												
02_03. Sediment Dewatering System												
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	160
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	19.40	0.0%	36.0%	7.77	0.00	34.15	HR	12/26/95	0.00	60
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	100
USR	Z-LABORERC	WELDER	21.60	0.0%	36.0%	7.47	0.00	36.85	HR	03/09/96	0.00	80
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	460
USR	Z-LABORERF	MASON	21.99	0.0%	36.0%	6.05	0.00	35.95	HR	03/09/96	0.00	40
02_05. Dike Systems, Stages I & II												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	1869
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	453
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	708
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	4789
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	1416
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	93
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	185
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	185
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	92
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	184
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	116
02_06. Seal Base of Dikes (3' Clay)												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	5152

											**** TOTAL ****	
SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	HOURS
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	1233
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	1233
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	13590
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	4014
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	727
02_07. Final Cap												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	25470
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	6314
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	8947
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	78833
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	20417
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	2221
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	1919
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	564
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	795
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	400
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	800
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	495

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------------------------------------------------------------------------------------------------------------ **** TOTAL **** ------------------------------------------
SRC LABOR ID   DESCRIPTION                           BASE   OVERTM TXS/INS  FRNG   TRVL    RATE UOM  UPDATE   DEFAULT    HOURS
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 0_01. 0. Overhead Items - AA
 0_01.01. Slurry Contractor
01_01.01. Bentonite Slurry Wall-Site Peri.
USR Z-EQUIPOPA  CRAFT FOREMAN                        23.45     0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95    0.00     1709
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1             22.55     0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95    0.00     4452
USR Z-EQUIPOPC  EQUIPMENT OPERATOR GRP 2             22.10     0.0%   36.0%  7.84   0.00   37.90 HR  12/26/95    0.00     4968
USR Z-EQUIPOPE  EQUIPMENT OPERATOR GRP 4             20.45     0.0%   36.0%  7.79   0.00   35.60 HR  12/26/95    0.00        7
USR Z-EQUIPOPF  EQUIPMENT OPERATOR GRP 5, OILER      19.40     0.0%   36.0%  7.77   0.00   34.15 HR  12/26/95    0.00     1264
USR Z-LABORERD  GROUP 3, GENERAL LABORER             16.34     0.0%   36.0%  4.18   0.00   26.40 HR  12/26/95    0.00     7473
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                    16.55     0.0%   36.0%  4.79   0.00   27.30 HR  12/26/95    0.00     5346

01_01.02. Railroad Relocation
01_01.04. Inspection Trench
USR Z-EQUIPOPA  CRAFT FOREMAN                        23.45     0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95    0.00      289
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1             22.55     0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95    0.00      434
USR Z-LABORERD  GROUP 3, GENERAL LABORER             16.34     0.0%   36.0%  4.18   0.00   26.40 HR  12/26/95    0.00      579

01_01.05. Initial Groundwater Drawdown
01_02.01. 3' Clay Layer
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy      22.55     0.0%   36.0%  7.88   0.00   38.55 HR  12/29/95   23.41     6935
MIL X-EQOPRLT   Outside Equip. Operators, Light      21.65     0.0%   36.0%  7.86   0.00   37.30 HR  12/29/95   15.96     1724
MIL X-LABORER   Craft Foreman                        23.45     0.0%   36.0%  7.91   0.00   39.80 HR  12/29/95    9.72     2605
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy         16.55     0.0%   36.0%  4.79   0.00   27.30 HR  12/29/95   19.23    16705
MIL X-TRKDVRLT  Flagmen                              15.39     0.0%   36.0%  4.22   0.00   25.15 HR  12/29/95   17.09     5211

01_02.03. 6" Sand
USR Z-EQUIPOPA  CRAFT FOREMAN                        23.45     0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95    0.00      189
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1             22.55     0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95    0.00      378
USR Z-EQUIPOPC  EQUIPMENT OPERATOR GRP 2             22.10     0.0%   36.0%  7.84   0.00   37.90 HR  12/26/95    0.00      189

01_02.04. 2' Clean Fill
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy      22.55     0.0%   36.0%  7.88   0.00   38.55 HR  12/29/95   23.41     1555
MIL X-EQOPRLT   Outside Equip. Operators, Light      21.65     0.0%   36.0%  7.86   0.00   37.30 HR  12/29/95   15.96      389
MIL X-LABORER   Craft Foreman                        23.45     0.0%   36.0%  7.91   0.00   39.80 HR  12/29/95    9.72      389
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy         16.55     0.0%   36.0%  4.79   0.00   27.30 HR  12/29/95   19.23     8942
MIL X-TRKDVRLT  Flagmen                              15.39     0.0%   36.0%  4.22   0.00   25.15 HR  12/29/95   17.09     1555
USR Z-EQUIPOPA  CRAFT FOREMAN                        23.45     0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95    0.00      389

01_02.05. 6" Topsoil
USR Z-EQUIPOPA  CRAFT FOREMAN                        23.45     0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95    0.00      132
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1             22.55     0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95    0.00      264
USR Z-EQUIPOPD  EQUIPMENT OPERATOR GRP 3             21.65     0.0%   36.0%  7.86   0.00   37.30 HR  12/26/95    0.00      132
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                    16.55     0.0%   36.0%  4.79   0.00   27.30 HR  12/26/95    0.00      132

01_02.06. Seeding
USR Z-EQUIPOPD  EQUIPMENT OPERATOR GRP 3             21.65     0.0%   36.0%  7.86   0.00   37.30 HR  12/26/95    0.00       80
USR Z-LABORERA  LABOR FOREMAN                        16.84     0.0%   36.0%  4.20   0.00   27.10 HR  12/26/95    0.00       80
USR Z-LABORERD  GROUP 3, GENERAL LABORER             16.34     0.0%   36.0%  4.18   0.00   26.40 HR  12/26/95    0.00      160
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                    16.55     0.0%   36.0%  4.79   0.00   27.30 HR  12/26/95    0.00       20

01_03.01. Well Points
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											**** TOTAL ****	
SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	HOURS
01_03.02. Header Piping												
01_03.03. Pumps												
01_03.04. Ground Water Monitoring Wells												
01_03.05. Disch. Pipe to Indianapolis Ave.												
02_01.01. Dredging Incl. Barge to Site												
02_02.01. Costs of Water Treatment System												
02_03.01. Decant Structure												
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	40
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	40
USR	Z-LABORERC	WELDER	21.60	0.0%	36.0%	7.47	0.00	36.85	HR	03/09/96	0.00	80
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	160
USR	Z-LABORERF	MASON	21.99	0.0%	36.0%	6.05	0.00	35.95	HR	03/09/96	0.00	40
02_03.02. Piping												
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	120
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	19.40	0.0%	36.0%	7.77	0.00	34.15	HR	12/26/95	0.00	60
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	60
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	300
02_05.01. Embankment												
02_05.02. 3' Clay Slope Liner												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	1869
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	453
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	708
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	4789
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	1416
02_05.03. Cross Dikes 8' Ht.												
02_05.04. 6" Topsoil												
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	93
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	185
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	93
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	93
02_05.05. Seeding												
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	92
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	92
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	184
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	23
02_05.06. Ramp & Road												
02_06.01. Excavate & Haul Clay												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	1454
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	12357
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	1454
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	727
02_06.03. Spread & Compact Clay												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	3698
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	1233
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	1233

											**** TOTAL ****	
SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	HOURS
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	1233
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	2560
02_07.01. 3' Clay Liner												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	20723
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	5152
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	7786
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	49919
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	15571
02_07.02. 2' Clean Fill												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	4747
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	1162
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	1162
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	28914
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	4846
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	1261
02_07.03. 6" Sand Drainage Layer												
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	564
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	1129
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	564
02_07.04. 6" Topsoil												
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	395
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	790
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	395
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	395
02_07.05. Seeding												
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	400
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	400
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	800
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	100

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SRC LABOR ID   DESCRIPTION                          BASE   OVERTM TXS/INS  FRNG   TRVL    RATE UOM  UPDATE   DEFAULT   HOURS
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 0_01.01. 0. Overhead Items - SC
01_01.01.01. Mobilization & Site Preparation
01_01.01.02. Bentonite Slurry Trench
USR Z-EQUIPOPA  CRAFT FOREMAN                       23.45    0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95   0.00     1242
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1            22.55    0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95   0.00     3748
USR Z-EQUIPOPC  EQUIPMENT OPERATOR GRP 2            22.10    0.0%   36.0%  7.84   0.00   37.90 HR  12/26/95   0.00     4968
USR Z-EQUIPOPF  EQUIPMENT OPERATOR GRP 5, OILER     19.40    0.0%   36.0%  7.77   0.00   34.15 HR  12/26/95   0.00     1264
USR Z-LABORERD  GROUP 3, GENERAL LABORER            16.34    0.0%   36.0%  4.18   0.00   26.40 HR  12/26/95   0.00     7452
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                   16.55    0.0%   36.0%  4.79   0.00   27.30 HR  12/26/95   0.00     2484

01_01.01.03. Slurry Trench Excav. & Disposal
USR Z-EQUIPOPA  CRAFT FOREMAN                       23.45    0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95   0.00      245
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1            22.55    0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95   0.00      489
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                   16.55    0.0%   36.0%  4.79   0.00   27.30 HR  12/26/95   0.00      489

01_01.01.04. Borrow for Slurry Trench Fill
USR Z-EQUIPOPA  CRAFT FOREMAN                       23.45    0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95   0.00      216
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1            22.55    0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95   0.00      216
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                   16.55    0.0%   36.0%  4.79   0.00   27.30 HR  12/26/95   0.00     2373

01_01.01.05. Disposal of Excess Slurry
USR Z-EQUIPOPA  CRAFT FOREMAN                       23.45    0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95   0.00        7
USR Z-EQUIPOPE  EQUIPMENT OPERATOR GRP 4            20.45    0.0%   36.0%  7.79   0.00   35.60 HR  12/26/95   0.00        7
USR Z-LABORERD  GROUP 3, GENERAL LABORER            16.34    0.0%   36.0%  4.18   0.00   26.40 HR  12/26/95   0.00       22

01_01.02.01. Clearing and Grubbing
01_01.02.02. Topsoil Stripping
01_01.02.03. Roadbed Earthfill
01_01.02.04. Ditches and Swales
01_01.02.05. Sub-Ballast
01_01.02.06. Duo-Rail, Single Side Track
01_01.02.07. Turnouts #10, incl. Rails, Frog
01_01.02.08. RR Crossing Rubber Mat & Traf. S
01_01.02.09. Topsoil Replacement
01_01.02.10. Seeding
01_01.02.11. Relocate Light Pole
01_01.02.12. Relocate Surface Discharge Pipe
01_01.02.13. Brick Masonry Wall Relocation
01_01.02.14. Replace Gate
01_01.04.01. Trench Excavation
USR Z-EQUIPOPA  CRAFT FOREMAN                       23.45    0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95   0.00      145
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1            22.55    0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95   0.00      145
USR Z-LABORERD  GROUP 3, GENERAL LABORER            16.34    0.0%   36.0%  4.18   0.00   26.40 HR  12/26/95   0.00      289

01_01.04.02. Trench Backfill
USR Z-EQUIPOPA  CRAFT FOREMAN                       23.45    0.0%   36.0%  7.91   0.00   39.80 HR  12/26/95   0.00      145
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1            22.55    0.0%   36.0%  7.88   0.00   38.55 HR  12/26/95   0.00      289
USR Z-LABORERD  GROUP 3, GENERAL LABORER            16.34    0.0%   36.0%  4.18   0.00   26.40 HR  12/26/95   0.00      289

01_01.05.01. Pumping
01_01.05.02. Treatment Surcharge
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---------------------------------------------------------------------------------------------------------- **** TOTAL **** -------------------------------------------
SRC LABOR ID    DESCRIPTION                               BASE   OVERTM TXS/INS  FRNG   TRVL     RATE UOM  UPDATE   DEFAULT    HOURS
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01_01.05.03. Analytical Testing
01_01.05.04. Sample Collection
01_02.01.01. Excavate & Haul Clay
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy          22.55     0.0%   36.0%  7.88   0.00    38.55 HR  12/29/95    23.41     1762
MIL X-LABORER   Craft Foreman                            23.45     0.0%   36.0%  7.91   0.00    39.80 HR  12/29/95     9.72      881
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy             16.55     0.0%   36.0%  4.79   0.00    27.30 HR  12/29/95    19.23    14981
MIL X-TRKDVRLT  Flagmen                                  15.39     0.0%   36.0%  4.22   0.00    25.15 HR  12/29/95    17.09     1762

01_02.01.02. Spread & Compact Clay
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy          22.55     0.0%   36.0%  7.88   0.00    38.55 HR  12/29/95    23.41     5172
MIL X-EQOPRLT   Outside Equip. Operators, Light          21.65     0.0%   36.0%  7.86   0.00    37.30 HR  12/29/95    15.96     1724
MIL X-LABORER   Craft Foreman                            23.45     0.0%   36.0%  7.91   0.00    39.80 HR  12/29/95     9.72     1724
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy             16.55     0.0%   36.0%  4.79   0.00    27.30 HR  12/29/95    19.23     1724
MIL X-TRKDVRLT  Flagmen                                  15.39     0.0%   36.0%  4.22   0.00    25.15 HR  12/29/95    17.09     3448

01_02.03.01. Spread Sand
USR Z-EQUIPOPA  CRAFT FOREMAN                            23.45     0.0%   36.0%  7.91   0.00    39.80 HR  12/26/95     0.00      189
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1                 22.55     0.0%   36.0%  7.88   0.00    38.55 HR  12/26/95     0.00      378
USR Z-EQUIPOPC  EQUIPMENT OPERATOR GRP 2                 22.10     0.0%   36.0%  7.84   0.00    37.90 HR  12/26/95     0.00      189

01_02.04.01. Excavate & Haul Clean Fill
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy          22.55     0.0%   36.0%  7.88   0.00    38.55 HR  12/29/95    23.41      389
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy             16.55     0.0%   36.0%  4.79   0.00    27.30 HR  12/29/95    19.23     8553
MIL X-TRKDVRLT  Flagmen                                  15.39     0.0%   36.0%  4.22   0.00    25.15 HR  12/29/95    17.09      778
USR Z-EQUIPOPA  CRAFT FOREMAN                            23.45     0.0%   36.0%  7.91   0.00    39.80 HR  12/26/95     0.00      389

01_02.04.02. Spread & Compact Clean Fill
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy          22.55     0.0%   36.0%  7.88   0.00    38.55 HR  12/29/95    23.41     1166
MIL X-EQOPRLT   Outside Equip. Operators, Light          21.65     0.0%   36.0%  7.86   0.00    37.30 HR  12/29/95    15.96      389
MIL X-LABORER   Craft Foreman                            23.45     0.0%   36.0%  7.91   0.00    39.80 HR  12/29/95     9.72      389
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy             16.55     0.0%   36.0%  4.79   0.00    27.30 HR  12/29/95    19.23      389
MIL X-TRKDVRLT  Flagmen                                  15.39     0.0%   36.0%  4.22   0.00    25.15 HR  12/29/95    17.09      778

01_02.05.01. Spread Topsoil
USR Z-EQUIPOPA  CRAFT FOREMAN                            23.45     0.0%   36.0%  7.91   0.00    39.80 HR  12/26/95     0.00      132
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1                 22.55     0.0%   36.0%  7.88   0.00    38.55 HR  12/26/95     0.00      264
USR Z-EQUIPOPD  EQUIPMENT OPERATOR GRP 3                 21.65     0.0%   36.0%  7.86   0.00    37.30 HR  12/26/95     0.00      132
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                        16.55     0.0%   36.0%  4.79   0.00    27.30 HR  12/26/95     0.00      132

01_02.06.01. Spread Seedings
USR Z-EQUIPOPD  EQUIPMENT OPERATOR GRP 3                 21.65     0.0%   36.0%  7.86   0.00    37.30 HR  12/26/95     0.00       80
USR Z-LABORERA  LABOR FOREMAN                            16.84     0.0%   36.0%  4.20   0.00    27.10 HR  12/26/95     0.00       80
USR Z-LABORERD  GROUP 3, GENERAL LABORER                 16.34     0.0%   36.0%  4.18   0.00    26.40 HR  12/26/95     0.00      160
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                        16.55     0.0%   36.0%  4.79   0.00    27.30 HR  12/26/95     0.00       20

02_03.02.01. Concrete Pipe
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1                 22.55     0.0%   36.0%  7.88   0.00    38.55 HR  12/26/95     0.00      120
USR Z-EQUIPOPF  EQUIPMENT OPERATOR GRP 5, OILER          19.40     0.0%   36.0%  7.77   0.00    34.15 HR  12/26/95     0.00       60
USR Z-LABORERA  LABOR FOREMAN                            16.84     0.0%   36.0%  4.20   0.00    27.10 HR  12/26/95     0.00       60
USR Z-LABORERD  GROUP 3, GENERAL LABORER                 16.34     0.0%   36.0%  4.18   0.00    26.40 HR  12/26/95     0.00      300
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---------------------------------------------------------------------------------------------------- **** TOTAL **** ------------------------------------------
SRC LABOR ID    DESCRIPTION                          BASE   OVERTM TXS/INS  FRNG   TRVL     RATE UOM  UPDATE   DEFAULT     HOURS
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02_05.01.01. Embankment Stage I
02_05.01.02. Embankment Stage II
02_05.02.01. Excavate & Haul Clay Liner
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy     22.55     0.0%    36.0%  7.88   0.00    38.55 HR  12/29/95    23.41       510
MIL X-LABORER   Craft Foreman                       23.45     0.0%    36.0%  7.91   0.00    39.80 HR  12/29/95     9.72       255
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy        16.55     0.0%    36.0%  4.79   0.00    27.30 HR  12/29/95    19.23      4336
MIL X-TRKDVRLT  Flagmen                             15.39     0.0%    36.0%  4.22   0.00    25.15 HR  12/29/95    17.09       510

02_05.02.02. Spread & Compact Clay Liner
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy     22.55     0.0%    36.0%  7.88   0.00    38.55 HR  12/29/95    23.41      1359
MIL X-EQOPRLT   Outside Equip. Operators, Light     21.65     0.0%    36.0%  7.86   0.00    37.30 HR  12/29/95    15.96       453
MIL X-LABORER   Craft Foreman                       23.45     0.0%    36.0%  7.91   0.00    39.80 HR  12/29/95     9.72       453
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy        16.55     0.0%    36.0%  4.79   0.00    27.30 HR  12/29/95    19.23       453
MIL X-TRKDVRLT  Flagmen                             15.39     0.0%    36.0%  4.22   0.00    25.15 HR  12/29/95    17.09       906

02_05.03.01. Existing On-Site Fill
02_05.03.02. Dried Sediments
02_05.03.03. Stripping
02_05.04.01. Spread Topsoil
USR Z-EQUIPOPA  CRAFT FOREMAN                       23.45     0.0%    36.0%  7.91   0.00    39.80 HR  12/26/95     0.00        93
USR Z-EQUIPOPB  EQUIPMENT OPERATOR GRP 1            22.55     0.0%    36.0%  7.88   0.00    38.55 HR  12/26/95     0.00       185
USR Z-EQUIPOPD  EQUIPMENT OPERATOR GRP 3            21.65     0.0%    36.0%  7.86   0.00    37.30 HR  12/26/95     0.00        93
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                   16.55     0.0%    36.0%  4.79   0.00    27.30 HR  12/26/95     0.00        93

02_05.05.01. Spread Seeding
USR Z-EQUIPOPD  EQUIPMENT OPERATOR GRP 3            21.65     0.0%    36.0%  7.86   0.00    37.30 HR  12/26/95     0.00        92
USR Z-LABORERA  LABOR FOREMAN                       16.84     0.0%    36.0%  4.20   0.00    27.10 HR  12/26/95     0.00        92
USR Z-LABORERD  GROUP 3, GENERAL LABORER            16.34     0.0%    36.0%  4.18   0.00    26.40 HR  12/26/95     0.00       184
USR Z-TEAMSTEA  TEAMSTER, GROUP 1                   16.55     0.0%    36.0%  4.79   0.00    27.30 HR  12/26/95     0.00        23

02_05.06.01. Curbs
02_05.06.02. 8" Base Course
02_05.06.03. 6" CA - 6
02_05.06.04. Rehandling Pad
02_05.06.05. Ramp
02_07.01.01. Excavate & Haul Clay Liner
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy     22.55     0.0%    36.0%  7.88   0.00    38.55 HR  12/29/95    23.41      5267
MIL X-LABORER   Craft Foreman                       23.45     0.0%    36.0%  7.91   0.00    39.80 HR  12/29/95     9.72      2633
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy        16.55     0.0%    36.0%  4.79   0.00    27.30 HR  12/29/95    19.23     44767
MIL X-TRKDVRLT  Flagmen                             15.39     0.0%    36.0%  4.22   0.00    25.15 HR  12/29/95    17.09      5267

02_07.01.02. Spread & Compact Clay Liner
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy     22.55     0.0%    36.0%  7.88   0.00    38.55 HR  12/29/95    23.41     15457
MIL X-EQOPRLT   Outside Equip. Operators, Light     21.65     0.0%    36.0%  7.86   0.00    37.30 HR  12/29/95    15.96      5152
MIL X-LABORER   Craft Foreman                       23.45     0.0%    36.0%  7.91   0.00    39.80 HR  12/29/95     9.72      5152
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy        16.55     0.0%    36.0%  4.79   0.00    27.30 HR  12/29/95    19.23      5152
MIL X-TRKDVRLT  Flagmen                             15.39     0.0%    36.0%  4.22   0.00    25.15 HR  12/29/95    17.09     10304

02_07.02.01. Excavate & Haul Clean Fill
MIL X-EQOPRHVY  Outside Equip. Operators, Heavy     22.55     0.0%    36.0%  7.88   0.00    38.55 HR  12/29/95    23.41      1261
MIL X-TRKDVRHV  Outside Truck Drivers, Heavy        16.55     0.0%    36.0%  4.79   0.00    27.30 HR  12/29/95    19.23     27752
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											**** TOTAL ****	
SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	HOURS
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	2523
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	1261
02_07.02.02. Spread & Compact Clean Fill												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/29/95	23.41	3485
MIL	X-EQOPRLT	Outside Equip. Operators, Light	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/29/95	15.96	1162
MIL	X-LABORER	Craft Foreman	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/29/95	9.72	1162
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/29/95	19.23	1162
MIL	X-TRKDVRLT	Flagmen	15.39	0.0%	36.0%	4.22	0.00	25.15	HR	12/29/95	17.09	2324
02_07.03.01. Spread Sand												
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	564
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	1129
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	564
02_07.04.01. Spread Topsoil												
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	395
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	790
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	395
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	395
02_07.05.01. Spread Seeds												
USR	Z-EQUIPOPD	EQUIPMENT OPERATOR GRP 3	21.65	0.0%	36.0%	7.86	0.00	37.30	HR	12/26/95	0.00	400
USR	Z-LABORERA	LABOR FOREMAN	16.84	0.0%	36.0%	4.20	0.00	27.10	HR	12/26/95	0.00	400
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	800
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	100

**** TOTAL ****

SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	HOURS
01_01.01.02_ 01. Initial Slurry Placement												
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	22
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	19.40	0.0%	36.0%	7.77	0.00	34.15	HR	12/26/95	0.00	22
01_01.01.02_ 02. Remainder Slurry Trench												
USR	Z-EQUIPOPA	CRAFT FOREMAN	23.45	0.0%	36.0%	7.91	0.00	39.80	HR	12/26/95	0.00	1242
USR	Z-EQUIPOPB	EQUIPMENT OPERATOR GRP 1	22.55	0.0%	36.0%	7.88	0.00	38.55	HR	12/26/95	0.00	3726
USR	Z-EQUIPOPC	EQUIPMENT OPERATOR GRP 2	22.10	0.0%	36.0%	7.84	0.00	37.90	HR	12/26/95	0.00	4968
USR	Z-EQUIPOPF	EQUIPMENT OPERATOR GRP 5, OILER	19.40	0.0%	36.0%	7.77	0.00	34.15	HR	12/26/95	0.00	1242
USR	Z-LABORERD	GROUP 3, GENERAL LABORER	16.34	0.0%	36.0%	4.18	0.00	26.40	HR	12/26/95	0.00	7452
USR	Z-TEAMSTEA	TEAMSTER, GROUP 1	16.55	0.0%	36.0%	4.79	0.00	27.30	HR	12/26/95	0.00	2484

** EQUIPMENT BACKUP **

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	** TOTAL ** TOTAL RATE	** TOTAL ** HOURS
MIL	C10BO001	COMPACTOR, RAMMER, 9"X13.8" SHOE	0.40	0.06	0.36	0.09			0.63	1.54 HR	60
MIL	C75GV007	CRANE,HYD,S/P,RT,4WD,22T/70'BOOM	10.93	3.74	4.88	1.45	0.94	0.14	11.33	33.42 HR	1242
MIL	C85AM002	CRANE,DRAG/CLAM, 2.0CY / 65'BOOM	24.99	8.34	3.26	1.10			27.40	65.09 HR	22
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	11486
MIL	H25BA002	HYD EXCAV,CRWLR, 1 CY BKT,HYD-SC	20.13	4.88	4.91	1.85			19.85	51.61 HR	1242
UPB	H25CA003	HYD EXCAV,CRWLR, 0.91CY BKT,LONG	12.98	3.15	3.38	1.27			12.80	33.58 HR	40
UPB	H25CA006	HYD EXCAV, CRWLR, 1.25 CY BKT	16.62	4.48	5.06	1.91			17.56	45.63 HR	60
MIL	H25GA002	HYD EXCAV, CRWLR, 0.75 CY BKT	19.94	4.84	4.97	1.87			19.66	51.29 HR	145
MIL	H25IS006	HYD EXCAV, CRWLR, 3.75 CY BKT	32.96	9.55	14.33	3.12			45.06	105.02 HR	1650
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	4957
MIL	L35CS003	LDR,FE, CRWLR, 2.00 CY	8.12	2.19	4.28	1.61			14.43	30.63 HR	60
MIL	L35JD005	LDR,FE, CRWLR, 2.25 CY	9.21	2.49	5.08	1.91			16.37	35.06 HR	145
UPB	P60ML003	PUMP,CENTRF,DW,6"D, 100GPM/40'HD	1.52	0.37	9.48	3.00			1.91	16.28 HR	7
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14 HR	753
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	10113
MIL	R45BO001	ROLLER,VIB,DD,S/P, 2.7T, 47.25"W	3.44	0.76	1.63	0.52			4.87	11.22 HR	145
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	3790
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	13678
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67 HR	753
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	3037
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	13678
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	11304
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	115119
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75 HR	64083
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	51036
MIL	T55VO003	TRK,OFF-HWY,R-DUMP, 13-17CY, 25T	14.95	4.65	4.91	1.65	5.43	0.81	11.18	43.57 HR	489
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	9023
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	4336
MIL	W35XX001	WELDER, 250 AMP, W/1 AXLE TRLR	0.67	0.18	1.13	0.27	0.04	0.01	0.76	3.05 HR	40
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	572
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	1192
USR	XX0XX012	Trash Pumps	0.73	0.09	0.35	0.11			1.32	2.60 HR	2484
USR	XX0XX013	Cyclone	2.37	0.58	0.50	0.30			1.25	5.00 HR	1242
USR	XX0XX014	Motor Boats	1.64	0.40	0.30	0.20			0.96	3.50 HR	2484
USR	XX0XX015	Water Tanks	5.02	0.40					3.84	9.26 HR	3726
USR	XX0XX016	Silos	5.02	0.40					2.65	8.07 HR	1242
USR	XX0XX017	Screw Feeder 9", 20 Hp	1.17	0.29	0.30	0.10			1.06	2.92 HR	1242
USR	XX0XX018	Scales and Batcher	0.72	0.07					1.21	2.00 HR	1242
USR	XX0XX019	Bin Vibrator	2.85	0.32					1.83	5.00 HR	1242
USR	XX0XX020	Slurry Mixer Pump & Sump	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX021	Air Lift Pump w/ Compressor	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	1551
USR	XX0XX025	Small Tools	5.02	0.40					2.78	8.20 HR	40
USR	XX0XX030	Pipeline, 6"	20.00	5.00						25.00 HR	7

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
01. Present Site RCRA Closure											
MIL	C75GV007	CRANE,HYD,S/P,RT,4WD,22T/70'BOOM	10.93	3.74	4.88	1.45	0.94	0.14	11.33	33.42 HR	1242
MIL	C85AM002	CRANE,DRAG/CLAM, 2.0CY / 65'BOOM	24.99	8.34	3.26	1.10			27.40	65.09 HR	22
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	2434
MIL	H25BA002	HYD EXCAV,CRWLR, 1 CY BKT,HYD-SC	20.13	4.88	4.91	1.85			19.85	51.61 HR	1242
MIL	H25GA002	HYD EXCAV, CRWLR, 0.75 CY BKT	19.94	4.84	4.97	1.87			19.66	51.29 HR	145
MIL	H25IS006	HYD EXCAV, CRWLR, 3.75 CY BKT	32.96	9.55	14.33	3.12			45.06	105.02 HR	389
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	1342
MIL	L35JD005	LDR,FE, CRWLR, 2.25 CY	9.21	2.49	5.08	1.91			16.37	35.06 HR	145
UPB	P60ML003	PUMP,CENTRF,DW,6"D, 100GPM/40'HD	1.52	0.37	9.48	3.00			1.91	16.28 HR	7
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14 HR	189
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	2113
MIL	R45BO001	ROLLER,VIB,DD,S/P, 2.7T, 47.25"W	3.44	0.76	1.63	0.52			4.87	11.22 HR	145
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	2064
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	2738
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67 HR	189
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	1875
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	2738
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	2325
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	25907
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75 HR	14981
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	10927
MIL	T55VO003	TRK,OFF-HWY,R-DUMP, 13-17CY, 25T	14.95	4.65	4.91	1.65	5.43	0.81	11.18	43.57 HR	489
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	2133
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	2616
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	80
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	212
USR	XX0XX012	Trash Pumps	0.73	0.09	0.35	0.11			1.32	2.60 HR	2484
USR	XX0XX013	Cyclone	2.37	0.58	0.50	0.30			1.25	5.00 HR	1242
USR	XX0XX014	Motor Boats	1.64	0.40	0.30	0.20			0.96	3.50 HR	2484
USR	XX0XX015	Water Tanks	5.02	0.40					3.84	9.26 HR	3726
USR	XX0XX016	Silos	5.02	0.40					2.65	8.07 HR	1242
USR	XX0XX017	Screw Feeder 9", 20 Hp	1.17	0.29	0.30	0.10			1.06	2.92 HR	1242
USR	XX0XX018	Scales and Batcher	0.72	0.07					1.21	2.00 HR	1242
USR	XX0XX019	Bin Vibrator	2.85	0.32					1.83	5.00 HR	1242
USR	XX0XX020	Slurry Mixer Pump & Sump	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX021	Air Lift Pump w/ Compressor	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	389
USR	XX0XX030	Pipeline, 6"	20.00	5.00						25.00 HR	7
02. Dredging & CDF											
MIL	C10BO001	COMPACTOR, RAMMER, 9"X13.8" SHOE	0.40	0.06	0.36	0.09			0.63	1.54 HR	60
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	9052
UPB	H25CA003	HYD EXCAV,CRWLR, 0.91CY BKT,LONG	12.98	3.15	3.38	1.27			12.80	33.58 HR	40
UPB	H25CA006	HYD EXCAV, CRWLR, 1.25 CY BKT	16.62	4.48	5.06	1.91			17.56	45.63 HR	60
MIL	H25IS006	HYD EXCAV, CRWLR, 3.75 CY BKT	32.96	9.55	14.33	3.12			45.06	105.02 HR	1261
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	3615
MIL	L35CS003	LDR,FE, CRWLR, 2.00 CY	8.12	2.19	4.28	1.61			14.43	30.63 HR	60
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14 HR	564
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	8000
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	1726

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	10941
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67 HR	564
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	1162
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	10941
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	8979
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	89212
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75 HR	49102
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	40110
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	6890
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	1720
MIL	W35XX001	WELDER, 250 AMP, W/1 AXLE TRLR	0.67	0.18	1.13	0.27	0.04	0.01	0.76	3.05 HR	40
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	492
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	980
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	1162
USR	XX0XX025	Small Tools	5.02	0.40					2.78	8.20 HR	40

0_01. Prime Contractor

01_01. Slurry Wall

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	** TOTAL ** TOTAL RATE	HOURS
MIL	C75GV007	CRANE,HYD,S/P,RT,4WD,22T/70'BOOM	10.93	3.74	4.88	1.45	0.94	0.14	11.33	33.42 HR	1242
MIL	C85AM002	CRANE,DRAG/CLAM, 2.0CY / 65'BOOM	24.99	8.34	3.26	1.10			27.40	65.09 HR	22
MIL	H25BA002	HYD EXCAV,CRWLR, 1 CY BKT,HYD-SC	20.13	4.88	4.91	1.85			19.85	51.61 HR	1242
MIL	H25GA002	HYD EXCAV, CRWLR, 0.75 CY BKT	19.94	4.84	4.97	1.87			19.66	51.29 HR	145
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	460
MIL	L35JD005	LDR,FE, CRWLR, 2.25 CY	9.21	2.49	5.08	1.91			16.37	35.06 HR	145
UPB	P60ML003	PUMP,CENTRF,DW,6"D, 100GPM/40'HD	1.52	0.37	9.48	3.00			1.91	16.28 HR	7
MIL	R45BO001	ROLLER,VIB,DD,S/P, 2.7T, 47.25"W	3.44	0.76	1.63	0.52			4.87	11.22 HR	145
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	1487
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	1487
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	2373
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	2373
MIL	T55VO003	TRK,OFF-HWY,R-DUMP, 13-17CY, 25T	14.95	4.65	4.91	1.65	5.43	0.81	11.18	43.57 HR	489
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	2484
USR	XX0XX012	Trash Pumps	0.73	0.09	0.35	0.11			1.32	2.60 HR	2484
USR	XX0XX013	Cyclone	2.37	0.58	0.50	0.30			1.25	5.00 HR	1242
USR	XX0XX014	Motor Boats	1.64	0.40	0.30	0.20			0.96	3.50 HR	2484
USR	XX0XX015	Water Tanks	5.02	0.40					3.84	9.26 HR	3726
USR	XX0XX016	Silos	5.02	0.40					2.65	8.07 HR	1242
USR	XX0XX017	Screw Feeder 9", 20 Hp	1.17	0.29	0.30	0.10			1.06	2.92 HR	1242
USR	XX0XX018	Scales and Batcher	0.72	0.07					1.21	2.00 HR	1242
USR	XX0XX019	Bin Vibrator	2.85	0.32					1.83	5.00 HR	1242
USR	XX0XX020	Slurry Mixer Pump & Sump	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX021	Air Lift Pump w/ Compressor	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX030	Pipeline, 6"	20.00	5.00						25.00 HR	7

01_02. Seal Peripheral Areas

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	** TOTAL ** TOTAL RATE	HOURS
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	2434
MIL	H25IS006	HYD EXCAV, CRWLR, 3.75 CY BKT	32.96	9.55	14.33	3.12			45.06	105.02 HR	389
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	881
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14 HR	189
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	2113
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	578
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	2738
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67 HR	189
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	389
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	2738
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	2325
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	23534
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75 HR	14981
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	8553
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	2133
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	132
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	80
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	212
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	389

01_03. Hydraulic Gradient Control

01_04. Water Treatment System (24%)

02_01. Dredging Stages I, & II
02_02. Water Treatment System (76%)
02_03. Sediment Dewatering System

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE		** TOTAL ** HOURS
MIL	C10BO001	COMPACTOR, RAMMER, 9"X13.8" SHOE	0.40	0.06	0.36	0.09			0.63	1.54	HR	60
UPB	H25CA003	HYD EXCAV,CRWLR, 0.91CY BKT,LONG	12.98	3.15	3.38	1.27			12.80	33.58	HR	40
UPB	H25CA006	HYD EXCAV, CRWLR, 1.25 CY BKT	16.62	4.48	5.06	1.91			17.56	45.63	HR	60
MIL	L35CS003	LDR,FE, CRWLR, 2.00 CY	8.12	2.19	4.28	1.61			14.43	30.63	HR	60
MIL	W35XX001	WELDER, 250 AMP, W/1 AXLE TRLR	0.67	0.18	1.13	0.27	0.04	0.01	0.76	3.05	HR	40
USR	XX0XX025	Small Tools	5.02	0.40					2.78	8.20	HR	40

02_05. Dike Systems, Stages I & II

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE		** TOTAL ** HOURS
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67	HR	546
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41	HR	255
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70	HR	453
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23	HR	801
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31	HR	801
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22	HR	638
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75	HR	4336
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75	HR	4336
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38	HR	476
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75	HR	93
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90	HR	92
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45	HR	185

02_06. Seal Base of Dikes (3' Clay)

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE		** TOTAL ** HOURS
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67	HR	1233
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41	HR	727
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70	HR	1233
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23	HR	1960
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31	HR	1960
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22	HR	1233
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75	HR	12357
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41	HR	12357
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75	HR	1233

02_07. Final Cap

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE		** TOTAL ** HOURS
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67	HR	7273
MIL	H25IS006	HYD EXCAV, CRWLR, 3.75 CY BKT	32.96	9.55	14.33	3.12			45.06	105.02	HR	1261
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41	HR	2633
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14	HR	564
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70	HR	6314
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66	HR	1726
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23	HR	8181
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67	HR	564
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58	HR	1162
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31	HR	8181
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22	HR	7109
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75	HR	72519
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75	HR	44767
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41	HR	27752
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38	HR	6414

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	395
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	400
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	795
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	1162

0_01. 0. Overhead Items - AA
0_01.01. Slurry Contractor
01_01.01. Bentonite Slurry Wall-Site Peri.

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE		** TOTAL ** HOURS
MIL	C75GV007	CRANE,HYD,S/P,RT,4WD,22T/70'BOOM	10.93	3.74	4.88	1.45	0.94	0.14	11.33	33.42	HR	1242
MIL	C85AM002	CRANE,DRAG/CLAM, 2.0CY / 65'BOOM	24.99	8.34	3.26	1.10			27.40	65.09	HR	22
MIL	H25BA002	HYD EXCAV,CRWLR, 1 CY BKT,HYD-SC	20.13	4.88	4.91	1.85			19.85	51.61	HR	1242
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41	HR	460
UPB	P60ML003	PUMP,CENTRF,DW,6"D, 100GPM/40'HD	1.52	0.37	9.48	3.00			1.91	16.28	HR	7
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66	HR	1487
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58	HR	1487
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75	HR	2373
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41	HR	2373
MIL	T55VO003	TRK,OFF-HWY,R-DUMP, 13-17CY, 25T	14.95	4.65	4.91	1.65	5.43	0.81	11.18	43.57	HR	489
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75	HR	2484
USR	XX0XX012	Trash Pumps	0.73	0.09	0.35	0.11			1.32	2.60	HR	2484
USR	XX0XX013	Cyclone	2.37	0.58	0.50	0.30			1.25	5.00	HR	1242
USR	XX0XX014	Motor Boats	1.64	0.40	0.30	0.20			0.96	3.50	HR	2484
USR	XX0XX015	Water Tanks	5.02	0.40					3.84	9.26	HR	3726
USR	XX0XX016	Silos	5.02	0.40					2.65	8.07	HR	1242
USR	XX0XX017	Screw Feeder 9", 20 Hp	1.17	0.29	0.30	0.10			1.06	2.92	HR	1242
USR	XX0XX018	Scales and Batcher	0.72	0.07					1.21	2.00	HR	1242
USR	XX0XX019	Bin Vibrator	2.85	0.32					1.83	5.00	HR	1242
USR	XX0XX020	Slurry Mixer Pump & Sump	3.27	0.88	1.17	0.32			4.36	10.00	HR	1242
USR	XX0XX021	Air Lift Pump w/ Compressor	3.27	0.88	1.17	0.32			4.36	10.00	HR	1242
USR	XX0XX030	Pipeline, 6"	20.00	5.00						25.00	HR	7

01_01.02. Railroad Relocation
01_01.04. Inspection Trench

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE		** TOTAL ** HOURS
MIL	H25GA002	HYD EXCAV, CRWLR, 0.75 CY BKT	19.94	4.84	4.97	1.87			19.66	51.29	HR	145
MIL	L35JD005	LDR,FE, CRWLR, 2.25 CY	9.21	2.49	5.08	1.91			16.37	35.06	HR	145
MIL	R45BO001	ROLLER,VIB,DD,S/P, 2.7T, 47.25"W	3.44	0.76	1.63	0.52			4.87	11.22	HR	145

01_01.05. Initial Groundwater Drawdown
01_02.01. 3' Clay Layer

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE		** TOTAL ** HOURS
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67	HR	1724
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41	HR	881
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70	HR	1724
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23	HR	2605
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31	HR	2605
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22	HR	1724
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75	HR	14981
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75	HR	14981
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38	HR	1724

01_02.03. 6" Sand

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE		** TOTAL ** HOURS
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67	HR	189
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14	HR	189
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66	HR	189
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67	HR	189

01_02.04. 2' Clean Fill

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	389
MIL	H25IS006	HYD EXCAV, CRWLR, 3.75 CY BKT	32.96	9.55	14.33	3.12			45.06	105.02 HR	389
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	389
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	389
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	389
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	389
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	8553
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	8553
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	389
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	389
01_02.05. 6" Topsoil											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	132
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	132
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	132
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	132
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	132
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	132
01_02.06. Seeding											
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	80
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	20
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	80
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	80
01_03.01. Well Points											
01_03.02. Header Piping											
01_03.03. Pumps											
01_03.04. Ground Water Monitoring Wells											
01_03.05. Disch. Pipe to Indianapolis Ave.											
02_01.01. Dredging Incl. Barge to Site											
02_02.01. Costs of Water Treatment System											
02_03.01. Decant Structure											
UPB	H25CA003	HYD EXCAV,CRWLR, 0.91CY BKT,LONG	12.98	3.15	3.38	1.27			12.80	33.58 HR	40
MIL	W35XX001	WELDER, 250 AMP, W/1 AXLE TRLR	0.67	0.18	1.13	0.27	0.04	0.01	0.76	3.05 HR	40
USR	XX0XX025	Small Tools	5.02	0.40					2.78	8.20 HR	40
02_03.02. Piping											
MIL	C10BO001	COMPACTOR, RAMMER, 9"X13.8" SHOE	0.40	0.06	0.36	0.09			0.63	1.54 HR	60
UPB	H25CA006	HYD EXCAV, CRWLR, 1.25 CY BKT	16.62	4.48	5.06	1.91			17.56	45.63 HR	60
MIL	L35CS003	LDR,FE, CRWLR, 2.00 CY	8.12	2.19	4.28	1.61			14.43	30.63 HR	60
02_05.01. Embankment											
02_05.02. 3' Clay Slope Liner											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	453
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	255
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	453
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	708
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	708
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	453
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	4336

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--------------------------------------------------------------------------------------------------** TOTAL **------------------------------------------
SRC ID.NO.     EQUIPMENT DESCRIPTION            DEPR   FCCM   FUEL    FOG  TR WR TR REP EQ REP TOTAL RATE  HOURS
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MIL T50KE001   TRK,HWY, 33,000 GVW, 4X2, 2 AXLE  8.63   1.92   9.00   2.49   0.25   0.04   7.42  29.75 HR   4336
MIL T60KI001   TRK,WTR,OF-HY, 5000GAL,W/CAT613C 10.84   3.72   5.86   1.86   2.62   0.39  10.09  35.38 HR    453

02_05.03. Cross Dikes 8' Ht.
02_05.04. 6" Topsoil
UPB G15CA004   GRADER,MOTOR, ARTIC, CAT 140-G   10.06   3.63   4.60   1.55   0.75   0.11   9.98  30.67 HR     93
MIL T10CA012   BLADE, STRAIGHT, HYDR  (FOR D7    2.22   0.60          0.08                 2.33   5.23 HR     93
UPB T15CA013   DOZER,CWLR, D-7H,PS  (ADD BLADE) 16.34   4.85   7.80   2.78                27.54  59.31 HR     93
MIL T25JD004   TRACTOR,WH,FARM, JD-2755, 2WD     2.47   0.52   2.91   0.81   0.35   0.05   2.11   9.22 HR     93
UPB T60KI002   TRK,WTR,OF-HY, 6000GAL,W/CAT621E 18.52   6.50  11.05   3.50   5.97   0.89  17.32  63.75 HR     93
UPB XMIXX020   SMALL TOOLS                       0.46   0.20   0.15   0.06                 0.58   1.45 HR     93

02_05.05. Seeding
MIL T25JD004   TRACTOR,WH,FARM, JD-2755, 2WD     2.47   0.52   2.91   0.81   0.35   0.05   2.11   9.22 HR     92
MIL T60KI001   TRK,WTR,OF-HY, 5000GAL,W/CAT613C 10.84   3.72   5.86   1.86   2.62   0.39  10.09  35.38 HR     23
UPB XMIXX010   MISC. POWER TOOLS                 2.00   0.70   0.55   0.25                 2.40   5.90 HR     92
UPB XMIXX020   SMALL TOOLS                       0.46   0.20   0.15   0.06                 0.58   1.45 HR     92

02_05.06. Ramp & Road
02_06.01. Excavate & Haul Clay
UPB L35CA007   LDR,FE, CRWLR, 3.75 CY           21.31   5.75   7.62   2.87                37.87  75.41 HR    727
MIL T10CA012   BLADE, STRAIGHT, HYDR  (FOR D7    2.22   0.60          0.08                 2.33   5.23 HR    727
UPB T15CA013   DOZER,CWLR, D-7H,PS  (ADD BLADE) 16.34   4.85   7.80   2.78                27.54  59.31 HR    727
UPB T45XX008   TRLR,END DUMP, 20CY, 24T(ADD TRK  3.34   0.88          0.09   0.64   0.09   2.71   7.75 HR  12357
MIL T50KE002   TRK,HWY, 33,000 GVW, 4X2, 2 AXLE  9.43   2.10   9.00   2.49   0.25   0.04   8.10  31.41 HR  12357

02_06.03. Spread & Compact Clay
UPB G15CA004   GRADER,MOTOR, ARTIC, CAT 140-G   10.06   3.63   4.60   1.55   0.75   0.11   9.98  30.67 HR   1233
UPB R40SO001   ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W  8.73   1.93   2.33   0.74                 8.98  22.70 HR   1233
MIL T10CA012   BLADE, STRAIGHT, HYDR  (FOR D7    2.22   0.60          0.08                 2.33   5.23 HR   1233
UPB T15CA013   DOZER,CWLR, D-7H,PS  (ADD BLADE) 16.34   4.85   7.80   2.78                27.54  59.31 HR   1233
MIL T25JD004   TRACTOR,WH,FARM, JD-2755, 2WD     2.47   0.52   2.91   0.81   0.35   0.05   2.11   9.22 HR   1233
UPB T60KI002   TRK,WTR,OF-HY, 6000GAL,W/CAT621E 18.52   6.50  11.05   3.50   5.97   0.89  17.32  63.75 HR   1233

02_07.01. 3' Clay Liner
UPB G15CA004   GRADER,MOTOR, ARTIC, CAT 140-G   10.06   3.63   4.60   1.55   0.75   0.11   9.98  30.67 HR   5152
UPB L35CA007   LDR,FE, CRWLR, 3.75 CY           21.31   5.75   7.62   2.87                37.87  75.41 HR   2633
UPB R40SO001   ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W  8.73   1.93   2.33   0.74                 8.98  22.70 HR   5152
MIL T10CA012   BLADE, STRAIGHT, HYDR  (FOR D7    2.22   0.60          0.08                 2.33   5.23 HR   7786
UPB T15CA013   DOZER,CWLR, D-7H,PS  (ADD BLADE) 16.34   4.85   7.80   2.78                27.54  59.31 HR   7786
MIL T25JD004   TRACTOR,WH,FARM, JD-2755, 2WD     2.47   0.52   2.91   0.81   0.35   0.05   2.11   9.22 HR   5152
UPB T45XX008   TRLR,END DUMP, 20CY, 24T(ADD TRK  3.34   0.88          0.09   0.64   0.09   2.71   7.75 HR  44767
MIL T50KE001   TRK,HWY, 33,000 GVW, 4X2, 2 AXLE  8.63   1.92   9.00   2.49   0.25   0.04   7.42  29.75 HR  44767
MIL T60KI001   TRK,WTR,OF-HY, 5000GAL,W/CAT613C 10.84   3.72   5.86   1.86   2.62   0.39  10.09  35.38 HR   5152

02_07.02. 2' Clean Fill
UPB G15CA004   GRADER,MOTOR, ARTIC, CAT 140-G   10.06   3.63   4.60   1.55   0.75   0.11   9.98  30.67 HR   1162
MIL H25IS006   HYD EXCAV, CRWLR, 3.75 CY BKT    32.96   9.55  14.33   3.12                45.06 105.02 HR   1261
UPB R40SO001   ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W  8.73   1.93   2.33   0.74                 8.98  22.70 HR   1162
UPB T10CA009   BLADE, STRAIGHT, HYDR  (FOR D6    1.54   0.42          0.08                 1.62   3.66 HR   1162
UPB T15CA010   DOZER,CWLR, D-6H,PS  (ADD BLADE) 10.55   3.13   5.98   2.13                17.78  39.58 HR   1162
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SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	1162
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	27752
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	27752
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	1162
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	1162
02_07.03. 6" Sand Drainage Layer											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	564
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14 HR	564
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	564
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67 HR	564
02_07.04. 6" Topsoil											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	395
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	395
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	395
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	395
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	395
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	395
02_07.05. Seeding											
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	400
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	100
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	400
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	400

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
0_01.01. 0. Overhead Items - SC											
01_01.01.01. Mobilization & Site Preparation											
01_01.01.02. Bentonite Slurry Trench											
MIL	C75GV007	CRANE,HYD,S/P,RT,4WD,22T/70'BOOM	10.93	3.74	4.88	1.45	0.94	0.14	11.33	33.42 HR	1242
MIL	C85AM002	CRANE,DRAG/CLAM, 2.0CY / 65'BOOM	24.99	8.34	3.26	1.10			27.40	65.09 HR	22
MIL	H25BA002	HYD EXCAV,CRWLR, 1 CY BKT,HYD-SC	20.13	4.88	4.91	1.85			19.85	51.61 HR	1242
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	1242
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	1242
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	2484
USR	XX0XX012	Trash Pumps	0.73	0.09	0.35	0.11			1.32	2.60 HR	2484
USR	XX0XX013	Cyclone	2.37	0.58	0.50	0.30			1.25	5.00 HR	1242
USR	XX0XX014	Motor Boats	1.64	0.40	0.30	0.20			0.96	3.50 HR	2484
USR	XX0XX015	Water Tanks	5.02	0.40					3.84	9.26 HR	3726
USR	XX0XX016	Silos	5.02	0.40					2.65	8.07 HR	1242
USR	XX0XX017	Screw Feeder 9", 20 Hp	1.17	0.29	0.30	0.10			1.06	2.92 HR	1242
USR	XX0XX018	Scales and Batcher	0.72	0.07					1.21	2.00 HR	1242
USR	XX0XX019	Bin Vibrator	2.85	0.32					1.83	5.00 HR	1242
USR	XX0XX020	Slurry Mixer Pump & Sump	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX021	Air Lift Pump w/ Compressor	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
01_01.01.03. Slurry Trench Excav. & Disposal											
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	245
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	245
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	245
MIL	T55VO003	TRK,OFF-HWY,R-DUMP, 13-17CY, 25T	14.95	4.65	4.91	1.65	5.43	0.81	11.18	43.57 HR	489
01_01.01.04. Borrow for Slurry Trench Fill											
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	216
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	2373
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	2373
01_01.01.05. Disposal of Excess Slurry											
UPB	P60ML003	PUMP,CENTRF,DW,6"D, 100GPM/40'HD	1.52	0.37	9.48	3.00			1.91	16.28 HR	7
USR	XX0XX030	Pipeline, 6"	20.00	5.00						25.00 HR	7
01_01.02.01. Clearing and Grubbing											
01_01.02.02. Topsoil Stripping											
01_01.02.03. Roadbed Earthfill											
01_01.02.04. Ditches and Swales											
01_01.02.05. Sub-Ballast											
01_01.02.06. Duo-Rail, Single Side Track											
01_01.02.07. Turnouts #10, incl. Rails, Frog											
01_01.02.08. RR Crossing Rubber Mat & Traf. S											
01_01.02.09. Topsoil Replacement											
01_01.02.10. Seeding											
01_01.02.11. Relocate Light Pole											
01_01.02.12. Relocate Surface Discharge Pipe											
01_01.02.13. Brick Masonry Wall Relocation											
01_01.02.14. Replace Gate											
01_01.04.01. Trench Excavation											
MIL	H25GA002	HYD EXCAV, CRWLR, 0.75 CY BKT	19.94	4.84	4.97	1.87			19.66	51.29 HR	145

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
01_01.04.02. Trench Backfill											
MIL	L35JD005	LDR,FE, CRWLR, 2.25 CY	9.21	2.49	5.08	1.91			16.37	35.06 HR	145
MIL	R45BO001	ROLLER,VIB,DD,S/P, 2.7T, 47.25"W	3.44	0.76	1.63	0.52			4.87	11.22 HR	145
01_01.05.01. Pumping											
01_01.05.02. Treatment Surcharge											
01_01.05.03. Analytical Testing											
01_01.05.04. Sample Collection											
01_02.01.01. Excavate & Haul Clay											
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	881
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	881
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	881
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	14981
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75 HR	14981
01_02.01.02. Spread & Compact Clay											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	1724
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	1724
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	1724
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	1724
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	1724
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	1724
01_02.03.01. Spread Sand											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	189
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14 HR	189
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	189
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67 HR	189
01_02.04.01. Excavate & Haul Clean Fill											
MIL	H25IS006	HYD EXCAV, CRWLR, 3.75 CY BKT	32.96	9.55	14.33	3.12			45.06	105.02 HR	389
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	8553
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	8553
01_02.04.02. Spread & Compact Clean Fill											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	389
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	389
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	389
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	389
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	389
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	389
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	389
01_02.05.01. Spread Topsoil											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	132
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	132
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	132
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	132
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	132
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	132

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
01_02.06.01. Spread Seedings											
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	80
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	20
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	80
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	80
02_03.02.01. Concrete Pipe											
MIL	C10BO001	COMPACTOR, RAMMER, 9"X13.8" SHOE	0.40	0.06	0.36	0.09			0.63	1.54 HR	60
UPB	H25CA006	HYD EXCAV, CRWLR, 1.25 CY BKT	16.62	4.48	5.06	1.91			17.56	45.63 HR	60
MIL	L35CS003	LDR,FE, CRWLR, 2.00 CY	8.12	2.19	4.28	1.61			14.43	30.63 HR	60
02_05.01.01. Embankment Stage I											
02_05.01.02. Embankment Stage II											
02_05.02.01. Excavate & Haul Clay Liner											
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	255
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	255
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	255
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	4336
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75 HR	4336
02_05.02.02. Spread & Compact Clay Liner											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	453
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	453
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	453
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	453
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	453
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	453
02_05.03.01. Existing On-Site Fill											
02_05.03.02. Dried Sediments											
02_05.03.03. Stripping											
02_05.04.01. Spread Topsoil											
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	93
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	93
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	93
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	93
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	93
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	93
02_05.05.01. Spread Seeding											
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	92
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	23
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	92
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	92
02_05.06.01. Curbs											
02_05.06.02. 8" Base Course											
02_05.06.03. 6" CA - 6											
02_05.06.04. Rehandling Pad											
02_05.06.05. Ramp											

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
02_07.01.01.	Excavate & Haul Clay Liner										
UPB	L35CA007	LDR,FE, CRWLR, 3.75 CY	21.31	5.75	7.62	2.87			37.87	75.41 HR	2633
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	2633
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	2633
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	44767
MIL	T50KE001	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	8.63	1.92	9.00	2.49	0.25	0.04	7.42	29.75 HR	44767
02_07.01.02.	Spread & Compact Clay Liner										
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	5152
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	5152
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	5152
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	5152
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	5152
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	5152
02_07.02.01.	Excavate & Haul Clean Fill										
MIL	H25IS006	HYD EXCAV, CRWLR, 3.75 CY BKT	32.96	9.55	14.33	3.12			45.06	105.02 HR	1261
UPB	T45XX008	TRLR,END DUMP, 20CY, 24T(ADD TRK	3.34	0.88		0.09	0.64	0.09	2.71	7.75 HR	27752
MIL	T50KE002	TRK,HWY, 33,000 GVW, 4X2, 2 AXLE	9.43	2.10	9.00	2.49	0.25	0.04	8.10	31.41 HR	27752
02_07.02.02.	Spread & Compact Clean Fill										
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	1162
UPB	R40SO001	ROLLR,VIB,SD,TOW,SHPF,25.5T,72"W	8.73	1.93	2.33	0.74			8.98	22.70 HR	1162
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	1162
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	1162
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	1162
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	1162
USR	XX0XX022	Discs	1.30	0.20					1.00	2.50 HR	1162
02_07.03.01.	Spread Sand										
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	564
MIL	R30FR010	ROLLER,STATIC,DD,S/P,14T, 54"W	5.58	1.51	2.68	0.64			5.74	16.14 HR	564
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	564
MIL	T15CA009	DOZER,CWLR, D-6D,SA (ADD BLADE)	10.58	3.14	5.98	2.13			17.83	39.67 HR	564
02_07.04.01.	Spread Topsoil										
UPB	G15CA004	GRADER,MOTOR, ARTIC, CAT 140-G	10.06	3.63	4.60	1.55	0.75	0.11	9.98	30.67 HR	395
MIL	T10CA012	BLADE, STRAIGHT, HYDR (FOR D7	2.22	0.60		0.08			2.33	5.23 HR	395
UPB	T15CA013	DOZER,CWLR, D-7H,PS (ADD BLADE)	16.34	4.85	7.80	2.78			27.54	59.31 HR	395
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	395
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	395
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	395
02_07.05.01.	Spread Seeds										
MIL	T25JD004	TRACTOR,WH,FARM, JD-2755, 2WD	2.47	0.52	2.91	0.81	0.35	0.05	2.11	9.22 HR	400
MIL	T60KI001	TRK,WTR,OF-HY, 5000GAL,W/CAT613C	10.84	3.72	5.86	1.86	2.62	0.39	10.09	35.38 HR	100
UPB	XMIXX010	MISC. POWER TOOLS	2.00	0.70	0.55	0.25			2.40	5.90 HR	400
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	400

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
01_01.01.02_ 01. Initial Slurry Placement											
MIL	C85AM002	CRANE,DRAG/CLAM, 2.0CY / 65'BOOM	24.99	8.34	3.26	1.10			27.40	65.09 HR	22
01_01.01.02_ 02. Remainder Slurry Trench											
MIL	C75GV007	CRANE,HYD,S/P,RT,4WD,22T/70'BOOM	10.93	3.74	4.88	1.45	0.94	0.14	11.33	33.42 HR	1242
MIL	H25BA002	HYD EXCAV,CRWLR, 1 CY BKT,HYD-SC	20.13	4.88	4.91	1.85			19.85	51.61 HR	1242
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	1242
UPB	T15CA010	DOZER,CWLR, D-6H,PS (ADD BLADE)	10.55	3.13	5.98	2.13			17.78	39.58 HR	1242
UPB	T60KI002	TRK,WTR,OF-HY, 6000GAL,W/CAT621E	18.52	6.50	11.05	3.50	5.97	0.89	17.32	63.75 HR	2484
USR	XX0XX012	Trash Pumps	0.73	0.09	0.35	0.11			1.32	2.60 HR	2484
USR	XX0XX013	Cyclone	2.37	0.58	0.50	0.30			1.25	5.00 HR	1242
USR	XX0XX014	Motor Boats	1.64	0.40	0.30	0.20			0.96	3.50 HR	2484
USR	XX0XX015	Water Tanks	5.02	0.40					3.84	9.26 HR	3726
USR	XX0XX016	Silos	5.02	0.40					2.65	8.07 HR	1242
USR	XX0XX017	Screw Feeder 9", 20 Hp	1.17	0.29	0.30	0.10			1.06	2.92 HR	1242
USR	XX0XX018	Scales and Batcher	0.72	0.07					1.21	2.00 HR	1242
USR	XX0XX019	Bin Vibrator	2.85	0.32					1.83	5.00 HR	1242
USR	XX0XX020	Slurry Mixer Pump & Sump	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX021	Air Lift Pump w/ Compressor	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
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MIL	C75GV007	CRANE,HYD,S/P,RT,4WD,22T/70'BOOM	10.93	3.74	4.88	1.45	0.94	0.14	11.33	33.42 HR	1242
MIL	H25BA002	HYD EXCAV,CRWLR, 1 CY BKT,HYD-SC	20.13	4.88	4.91	1.85			19.85	51.61 HR	1242
UPB	T10CA009	BLADE, STRAIGHT, HYDR (FOR D6	1.54	0.42		0.08			1.62	3.66 HR	1242
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USR	XX0XX014	Motor Boats	1.64	0.40	0.30	0.20			0.96	3.50 HR	2484
USR	XX0XX015	Water Tanks	5.02	0.40					3.84	9.26 HR	3726
USR	XX0XX016	Silos	5.02	0.40					2.65	8.07 HR	1242
USR	XX0XX017	Screw Feeder 9", 20 Hp	1.17	0.29	0.30	0.10			1.06	2.92 HR	1242
USR	XX0XX018	Scales and Batcher	0.72	0.07					1.21	2.00 HR	1242
USR	XX0XX019	Bin Vibrator	2.85	0.32					1.83	5.00 HR	1242
USR	XX0XX020	Slurry Mixer Pump & Sump	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242
USR	XX0XX021	Air Lift Pump w/ Compressor	3.27	0.88	1.17	0.32			4.36	10.00 HR	1242

INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL

APPENDIX L
SOILS AND GEOLOGY

June 1993
Geotechnical and Coastal Branch
Chicago District
U.S. Army Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

INDIANA HARBOR CDF
SOILS AND GEOLOGY
APPENDIX L

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INDIANA HARBOR CDF
SOILS AND GEOLOGY
APPENDIX L

INTRODUCTION

PURPOSE

1.1. The purpose of this appendix is to review existing soils data for the alternative sites selected for the Indiana Harbor Confined Disposal Facility. This evaluation will review the project plans at each individual site, local site descriptions, and review subsurface investigations. A review of the soil conditions will be performed to develop recommendations for design features. Items to be investigated in a detail design analysis will be summarized for each site.

1.2. In the Site Selection Study for Indiana Harbor (May 1983), fifteen (15) sites were identified as potential locations for a confined disposal facility. As a result of that study, Site 12, located southeast of the Inland Steel peninsula, was selected for further investigation as the location for the CDF, and a detailed study was undertaken. After completion of the Letter Report (Feb. 1986), public reaction against Site 12 was substantial and the Corps decided to reconsider other sites as possible confined dredged material disposal and treatment facilities.

1.3. At this time, four (4) sites are under review as potential CDF sites. Two of these sites were considered in the Site Selection Study: the first site within the Inland Steel breakwater (originally designated as Site 7), and the second, 141st Street Site (previously referred to as Site 14B), located at the southwest end of the Lake George Canal. Several subsurface investigations have been performed at the Inland Steel plant during the facility's lifetime. As a result, soils information was readily available. However, very little information for the 141st Street Site exists as the site is unimproved and located in a sparsely developed area. Two additional sites have been proposed as potential locations following the original Site Selection Study. One site, locally known as the "J"-Pit, is located in the city of Gary, Indiana about 4.5 miles southeast of Indiana Harbor. The "J"-Pit is currently being investigated by Waste Management, Inc. (WMI) as a potential landfill facility. Subsequently, extensive soils data have been acquired for this location, with assistance from WMI. The other site, referred to as the ECI Site, is located on the north side of the Lake George Canal and immediately west of Indianapolis Boulevard and south of the Cline Avenue Extension in the city of East Chicago, Indiana. The site was formerly an oil refinery which has been cleared of all facilities.

1.4. The findings presented in the review of the potential sites were of a preliminary nature and are only intended to provide general subsurface conditions for each site. As the scope of prior investigations varied greatly between the sites, it was not possible to review each site to the same level of detail. However, sufficient information is available to provide a basis for the development of a preliminary design of a CDF at each of the sites. The items necessary for a detailed design analysis are covered in sections discussing the individual sites.

1.5. Following review of the potential sites for constructing a CDF, a selection was made. Please refer to the discussion of site selection in the main report. The selected site was then reviewed in more detail and the design of the facility was developed to take into account more recent data that has become available.

REGIONAL CONDITIONS

Geology

1.6. Northwest Indiana, including the northern Lake County area has undergone a series of geologic events which shaped its current surface and subsurface features. Deposition and erosion of flat-lying sediments, followed by consolidation, account for the significant thicknesses of sedimentary rocks which underlie the region. Glaciation subsequently occurred, which led to erosion of the sedimentary rock surface and the deposition of glacial till moraines on top of the bedrock surface. Glaciation was followed by the formation of an ancient glacial lake, which laid down the lacustrine deposits that constitute much of the near-surface soils in the area. Finally, a lowering of the glacial lake occurred, and sand dunes formed along beaches associated with the lake as it receded to the north. Today, those sand dunes are expressed at the surface as arc-shaped ridges parallel to the existing shoreline of Lake Michigan.

1.7. The uppermost bedrock formations which underlie northern Lake County consist of Devonian and Silurian limestones, shales, and dolomites. Figure L-1 shows the distribution of the Devonian and Silurian formations throughout the region. No bedrock outcrops occur except for some scattered pinnacle reefs. The bedrock surface varies from an elevation of approximately 450 feet MSL in the northern part of the county to approximately 650 feet MSL in the southern part of Lake County. The limestone and dolomites may locally contain significant fractures and solution cavities due to the action of percolating groundwater when these rocks are at or near the surface. The formations of Silurian and Devonian age are underlain by Ordovician shales, sandstones, and limestones. Significant thicknesses of Cambrian sandstones and shales underlie the Ordovician age formations. The whole sequence of sedimentary rock formations rests upon Pre-Cambrian granite. The sedimentary rocks are generally flat-lying, but are gently sloped along the flank of a structural feature known as the Kankakee Arch. A typical geologic column, showing aquifer systems and hydrologic properties of the bedrock formations beneath the region, is presented on figure L-2.

1.8. The unconsolidated overburden materials which overlie the bedrock are the direct result of Wisconsinan age glaciation. When the Lake Michigan ice lobe began to retreat, several end moraines were superimposed on one another to form the regional formation known as the Valparaiso Moraine, a complex system of rolling hills which run roughly parallel to the southern end of Lake Michigan through the central portions of Lake and Porter Counties, (figure L-3). Ground moraine deposited on top of the pre-glacial bedrock surface as the glaciers melted, is classified as the Lagro Formation.

1.9. As the glaciers retreated, melting water trapped by the end moraine, formed the glacial Lake Chicago. This lake deposited fine sands, silts, and clays which today make up a regional physiographic unit called the Calumet Lacustrine Plain, shown on figure L-3. The fine-grained sediments that were laid down in Lake Chicago constitute the lacustrine deposits of the Atherton Formation. The proposed CDF site located at the Inland Steel plant, lies within this formation.

1.10. Subsequent to the formation of Lake Chicago, the Valparaiso Moraine was breached, causing water levels in the lake to lower. As the lake receded to the north, the water levels became somewhat stabilized during three time periods. During these periods, beaches and dunes formed along the newly exposed shorelines. These sands constitute the dune faces of the Atherton Formation. The youngest and northernmost of the relic beaches was formed when the lake was between 580 and 605 ft. MSL and has been named Toleston, in which the 141st Street Site and the ECI Site are located. The second youngest was formed when the lake elevation was at an elevation of 620 ft. MSL. The proposed site at the "J"-Pit is located along this relic beach which is known as Calumet.

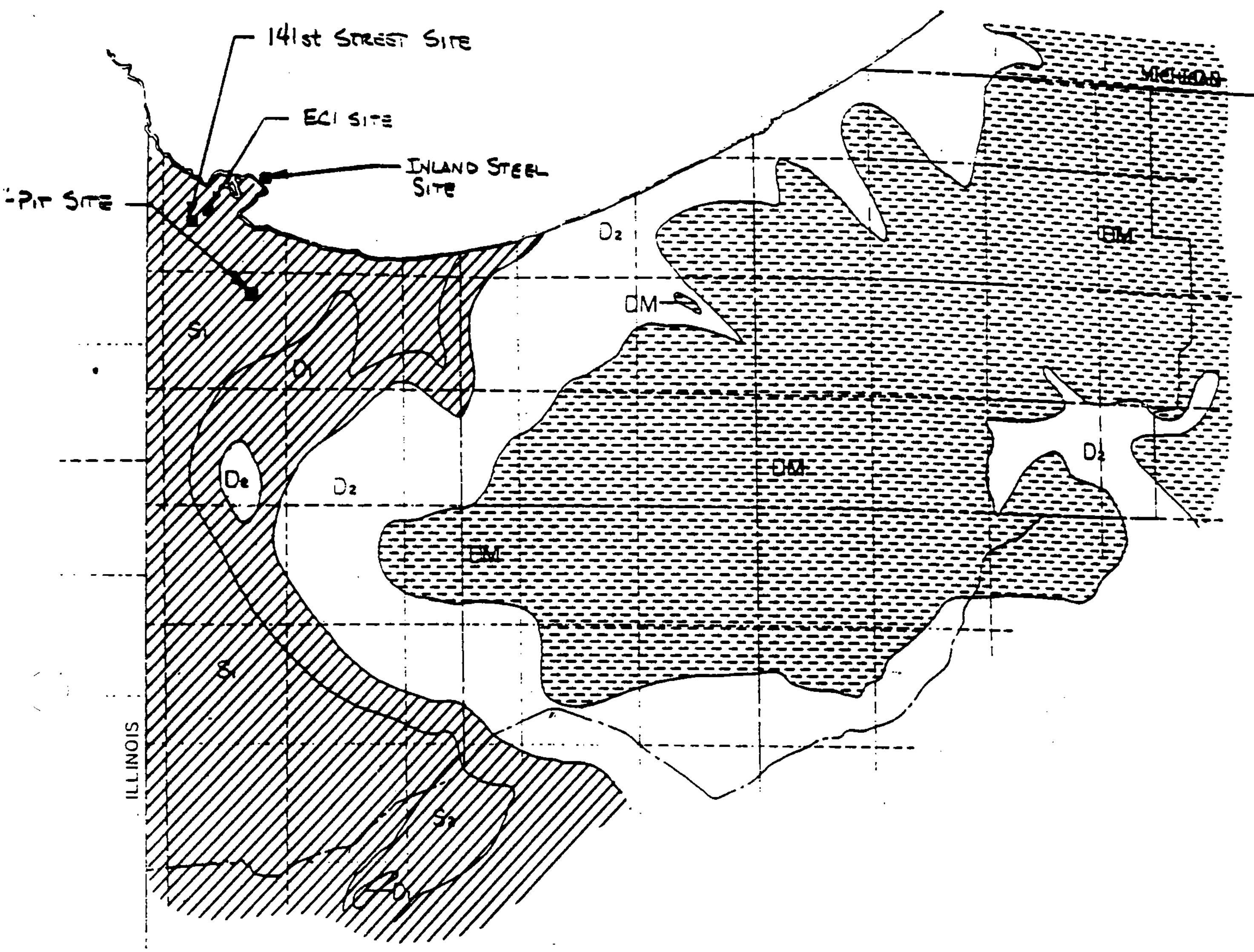
Groundwater

1.11. Three main aquifers are present in the unconsolidated overburden in Lake County. These sand and gravel units have been designated as the Calumet, the Valparaiso, and the Kankakee aquifers.

1.12. The Calumet aquifer, which underlies the northern part of Lake County, is isolated from the other two, which are hydraulically interconnected in the southern part of the county. The Calumet aquifer is recharged by direct infiltration of precipitation and discharges naturally into Lake Michigan. The aquifer is made up of water and wind deposited sands from the beaches and dunes associated with glacial Lake Chicago. Because the saturated thickness of the aquifer is generally thin and the aquifer is dependent upon direct infiltration for recharge, it is not typically used as a primary source of water for the region. The potentiometric surface of the unconsolidated overburden in the county varies from a low elevation of 580 feet MSL in the northern part to a high elevation of 740 feet MSL in the Valparaiso Moraine Area.

1.13. The major source of water for the municipalities located in the Calumet Lacustrine Plain is Lake Michigan. The main reasons for this usage are cost, availability, and the lack of significant groundwater sources in the unconsolidated soils, which are primarily fine silts and clays. Groundwater uses from the shallow bedrock aquifer are limited due to the cost of drilling wells over 200 to 300 feet deep and the availability of water from Lake Michigan.

1.14. Private water wells are scattered throughout the region. These wells are typically completed in sands less than 50 ft. deep, with water level elevations between 580 ft. and 590 ft. MSL. A few wells are completed in the bedrock with water levels typically between an elevation of 560 ft. and 570 ft. MSL. This indicates a regional downward hydraulic gradient between the unconsolidated overburden aquifer and the bedrock aquifer. Private wells drawing water from the overburden aquifer derive water from direct infiltration of rainfall and are the most susceptible to contamination by sources of surface pollution. Refer to Appendix F for information regarding groundwater quality.

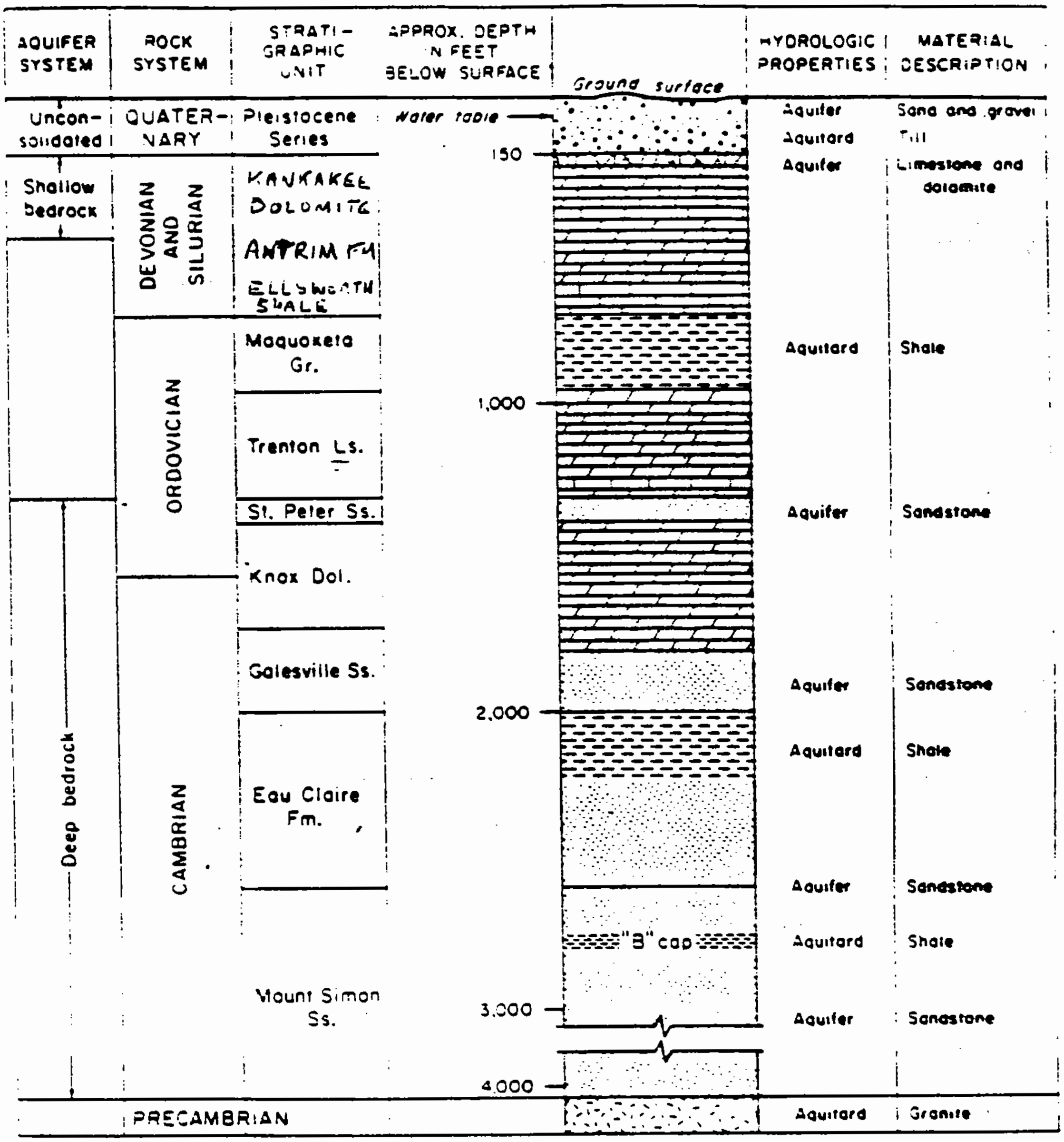


LEGEND:

SYMBOL	RELATIVE SUITABILITY	BEDROCK DESCRIPTION
▤	LOW TO NO RESTRICTIONS· HAS LOW POTENTIAL AS SOURCE OF GROUND WATER	DM· ELLSWORTH SHALE - GREEN SHALE WITH BLACK SHALE IN LOWER PART. AVERAGE THICKNESS 300-425'
☐	MODERATE RESTRICTIONS HAS MODERATE POTENTIAL AS SOURCE OF GROUND WATER	D2· ANTRIM SHALE - BLACK SHALE WITH GRAY SHALE AND LIMESTONE IN LOWER PART. AVERAGE THICKNESS 60-120'
▨	HIGH RESTRICTIONS HIGH POTENTIAL AS SOURCE OF GROUND WATER	D1· TRAVERSE AND DETROIT RIVER FORMATIONS - MOSTLY LIMESTONE AND DOLOMITE. AVERAGE THICKNESS 40-175' S2 SALINA FORMATION - LIMESTONE AND DOLOMITE. AVERAGE THICKNESS 0-150' S1· NIAGARAN SERIES - DOLOMITE. CHERTY LIMESTONE AND SOME SHALE AVERAGE THICKNESS 300-675'.

REGIONAL BEDROCK GEOLOGY

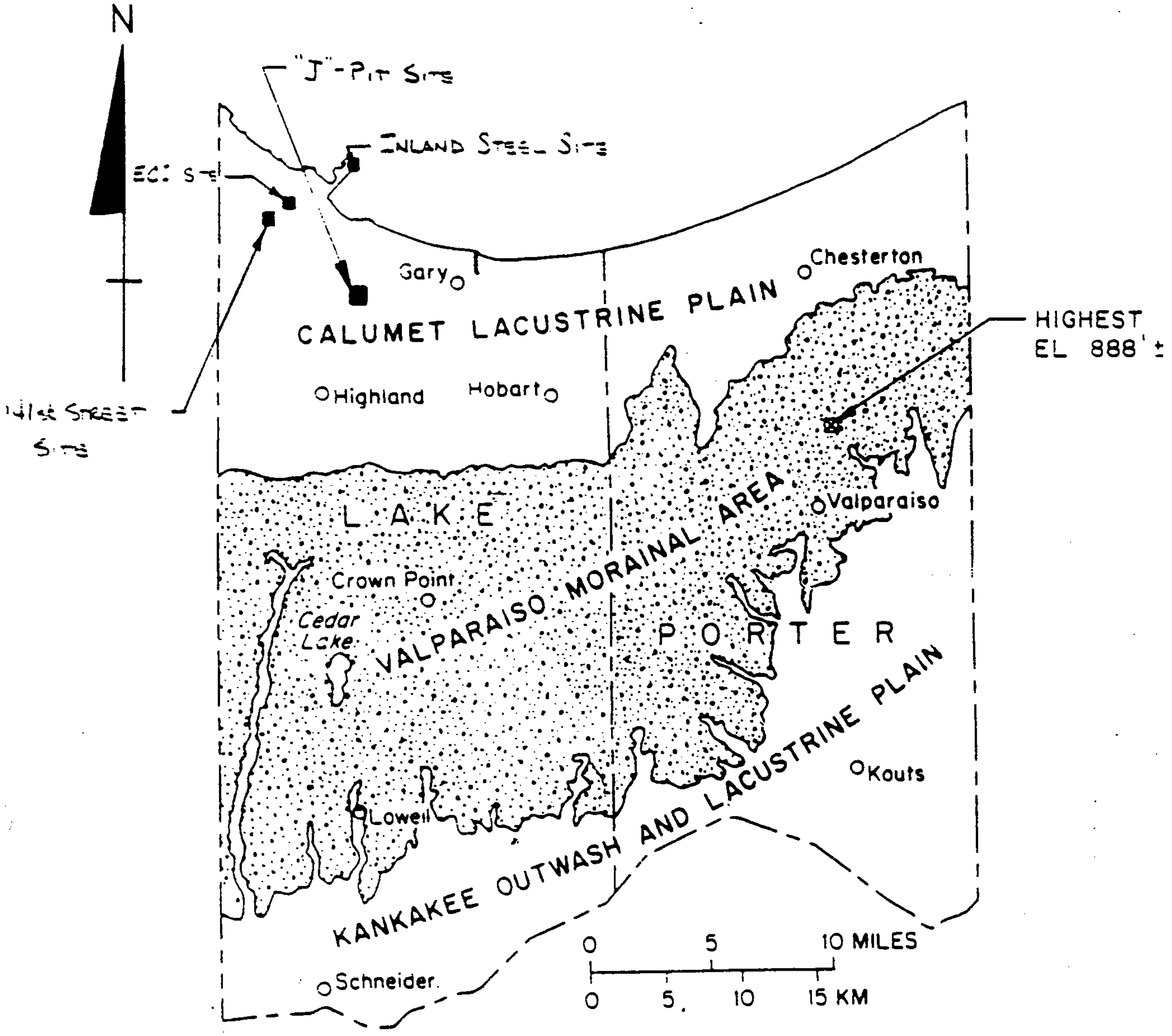
FIGURE L - 1



GEOLOGIC COLUMN SHOWING AQUIFER SYSTEMS AND HYDROLOGIC PROPERTIES

REFERENCES:
-"ENVIRONMENTAL GEOLOGY OF LAKE AND PORTER COUNTIES, INDIANA; AN AID TO PLANNING", SPECIAL REPORT 11, STATE OF INDIANA GEOLOGICAL SURVEY, 1975.

FIGURE L - 2



REGIONAL
PHYSIOGRAPHIC UNITS
LAKE AND PORTER COUNTIES

REFERENCES:
- "ENVIRONMENTAL GEOLOGY OF LAKE AND PORTER COUNTIES, INDIANA: AN AID TO PLANNING", SPECIAL REPORT II, STATE OF INDIANA GEOLOGICAL SURVEY, 1975.

FIGURE L - 3

1007-08

CDF PLAN #1 - INLAND STEEL SITE

INTRODUCTION

Site Description

2.1. CDF Plan #1 is proposed to be placed at the Inland Steel Plant in East Chicago, Indiana. The site is located at the northeastern tip of the Inland Steel peninsula within the existing cellular cofferdam breakwater. The area where the site is planned is currently being filled by Inland Steel with slag and other steel mill waste.

2.2. In 1968 and 1972, a portion of the area encompassed by the Inland Steel breakwater was used to dispose of dredged material from Indiana Harbor. This location was investigated during the preparation of the original Site Selection Study. However, the site was found to be unacceptable without the construction of new dikes at the time due to overtopping of the existing breakwater and water movement between the interior and exterior of the breakwater.

Plan #1 Description

2.3. The plan for constructing a CDF within the existing lakefill area is designated as Plan #1. The CDF would be located along the eastern side of the lakefill, which has received relatively little fill, and constructed with a design capacity of 3,000,000 cubic yards. This will yield an estimated design life of approximately thirty (30) years. The facility would be roughly rectangular in shape, 120 acres in size, and divided into 3 separate cells. Refer to figure L-4. The cells are intended to be part of the water treatment process to control turbidity and to allow settling and consolidation of the dredged material before the next filling. After the initial construction has been completed, the interior dikes may be constructed with coarse grained dredged material in order to reduce costs. The exterior dikes would be protected from wave forces by an armor stone exterior. The detailed design for the dike protection is discussed in Appendix M, Coastal Hydraulics/Engineering Analysis.

2.4. The proposed Plan #1 CDF would be to construct a diked disposal area with a barrier system to prevent the migration of the dredged material through the dike. The types of barrier systems that would be investigated include:

- A cement/bentonite slurry wall through the dike,
- A grouted mattress liner within the cells,
- A synthetic liner within the cells.

SUBSURFACE INVESTIGATIONS

General Remarks

2.5. Prior to the construction of the cellular sheet-pile breakwater, at the end of the Inland Steel plant, no subsurface investigations had been performed in the area. With the construction of the breakwater, Inland Steel contracted Soil Testing Services, Inc. (STS), to conduct a geotechnical investigation of the soil conditions that would be encountered during the construction of the sheet-pile breakwater. The investigation was conducted in the spring of 1968 and consisted of five (5) borings, numbers 200 to 204, drilled along the baseline of the planned breakwater.

2.6. While construction of the breakwater was taking place, a section of the cells was observed to be settling excessively. As a result, during the summer of 1971, Inland Steel again contracted STS to perform an investigation to discover the causes of the settlement and to recommend remedial measures to correct the problem. During this investigation, three (3) soil borings, 324-326, were drilled through the cells that were experiencing settlement.

2.7. Numerous other borings had been drilled for Inland Steel during the period of time that the site has been under development. However, only one additional boring, boring 418, was drilled near the location of the proposed CDF. This boring was drilled on 25 September 1978 through the slag fill. The only information available from this boring is included on the log. Copies of the boring logs are presented in attachment L-1.

2.8. The results of these investigations have been used within this section to approximate the subsurface conditions underlying the proposed CDF and develop conclusions about the site.

Soil Sampling Methods

2.9. In exploring the soil conditions along the breakwater, STS used a truck mounted drill rig. During the first investigation, the drill rig was carried on a barge in order to perform the drilling operations over open water, and for the second investigation, it was driven over the top of the breakwater to the designated boring locations. The borings were advanced using various drill bits and circulating water. Steel casing was used to keep the overlying fill and the upper sand from caving in.

2.10. Soil samples were obtained with a split-spoon and thin-walled Shelby tubes, in accordance with ASTM D 1586 and ASTM D 1587 procedures. Standard penetration test (SPT) values, obtained during split-spoon sampling, are noted on the boring logs and give an indication of the relative density of the in-situ soils. Sampling with the thin-walled Shelby tubes involved hydraulically advancing the sampling tubes through cohesive soil in order to obtain a relatively undisturbed sample.

2.11. All the soil samples acquired during the investigations by STS were sealed in the field and sent to a laboratory for additional examination and testing. The samples were classified in accordance with the Unified Soil Classification System (USCS).

LABORATORY TESTING PROGRAM

2.12. During the initial investigation, the laboratory testing consisted of unconfined compression, moisture content, and dry density determination tests on cohesive samples. In the second investigation, similar tests were performed and supplemented with in-situ Torvane shear tests on soft clays of less than one ton per square foot. These tests were performed in the field with a special apparatus. The Torvane test measures the torque required to exceed the shear strength of the soil. The results are plotted on the boring logs as double the shear strength measured so as to correlate to the unconfined compressive strength. The results of all these tests are included on the boring logs, presented in attachment L-1.

2.13. For the second investigation, additional classification and strength tests were performed on the samples obtained, different from those performed during the initial investigation. The tests included: organic content, Atterberg limits, consolidation, and triaxial compression tests. The results of the organic content and Atterberg limits tests are shown on the boring logs. The results of the consolidation and triaxial compressive tests are tabulated on tables L-1 and L-2, respectively, and presented in attachment L-1.

SUBSURFACE CONDITIONS

2.14. The soils described on the boring logs show a relatively consistent soils profile. Borings 324, 325, and 326, were drilled through the existing cellular breakwater, which was filled with crushed limestone. No samples of the limestone fill were taken, but it was estimated that the size of the material ranged from 0.75 to 12 inches in diameter. Boring 418 was drilled through the slag fill deposited by Inland Steel, and was measured to be 40 feet thick at the time of the boring.

2.15. The first layer of natural soil observed in the borings, was lake bottom sand. In boring 418, this layer was only 2 feet thick. However, the rest of the borings, had sand ranging from a thickness of 9 feet to 13 feet, with an average depth of 11 feet. The sand is described as medium to fine grained, with occasional fine gravel, and a trace of silt. The sand is medium dense to dense with "N" values ranging from 10 to 40 blows per 12 inches.

2.16. The next layer of material varied somewhat between the borings. Essentially this layer consisted of gray silty clay, soft to stiff consistency. The layer extends from a depth of approximately 40 feet to 85 feet, in borings 200, 201, 203, and 204. In borings 202, 324, 325, and 326, dark gray organic silty clay was discovered. In these cases, the organic material ranged from a depth of 43 feet to 58 feet with the soft silty clay continuing down to a depth of 85 feet. The organic material had an average dry unit weight of 64 pounds per cubic foot and an average moisture content of 68 percent.

2.17. Between approximately 90 feet and 115 feet, a very hard silty clay till was encountered. Within this layer, intermittent seams and lenses of silt and sand were observed. This material has been highly overconsolidated with "N" values commonly in excess of 100 blows and unconfined compressive strengths ranging between 5 and 12 tons per square foot. The moisture content averaged 11 percent within this layer.

2.18. Three (3) of the borings were drilled down to bedrock. In boring 418, bedrock was located at 130 feet below grade and in borings 200 and 201 at 113 feet and 118 feet, respectively. This corresponds to an approximate elevation of 460 feet MSL. The bedrock surface appears to be relatively level in the area described by the borings. No sampling of the bedrock was performed.

CONCLUSIONS AND RECOMMENDATIONS

Site Characterization

2.19. The borings along the Inland Steel breakwater indicate that the area is generally overlain by about 11 feet of fine sand. Below the sand, soft clay was encountered approximately 40 to 50 feet thick. In a few instances, organic clay was found below the sand. Excessive settlement of the breakwater occurred during construction as a result of bearing capacity failure of the organic silty clay.

2.20. Due to the fact that dredged material disposal has occurred within the breakwater, and most of the rainfall run-off from the Inland Steel plant has been contained inside the breakwater, in addition to the dumping of slag, a layer of soft sediment may be present overlying the lake bottom sand. If present, this layer would be unsuitable as a foundation for the CDF dikes. This material would need to be identified and possibly removed prior to construction of the CDF.

Design Recommendations

2.21. Construction of a CDF at the Inland Steel Site would entail building containment dikes up to an elevation of approximately +16 LWD. These dikes would be placed in a water depth of about 30 feet. Due to the soft underlying soils, it is recommended that the dikes be constructed using lightweight materials and placed at a maximum 2:1 slope. Toe berms are considered to be necessary at this time to provide additional stability. Refer to figure L-6 for a conceptual cross-section of the containment dikes.

2.22. A check on the bearing capacity of the underlying foundation soils revealed a safety factor of 1.4 against failure for the general site conditions. In areas where the organic clay was encountered, a safety factor of 0.7 resulted, indicating that failure will probably occur. Methods to increase the factor of safety would be to flatten the side slopes, reduce the dike height, use lightweight materials such as slag, and to stage the construction allowing the soil strength to increase before raising the crest to the next elevation. A workable solution to this problem would be arrived at during the detailed design analysis after more soil information became available and the problem area more thoroughly identified.

2.23. A barrier system is required to prevent migration of polluted materials into the lake. Three systems were considered:

> Design 1A - Bentonite/cement slurry wall. The slurry wall would be placed through the containment dikes and extend past the sand and keyed into the underlying clay. This system would provide an effective barrier to the migration of the dredged material. Windows may develop due to shifting of the material in the dikes. To prevent this, a grout wall may be necessary.
>
> Design 1B - Grout mattress liner. The mattress would be placed along the interior of the disposal area and then filled with grout. Placement of the mattress below water would be difficult. The bottom surface would be irregular because of the toe berms and gaps may develop allowing seepage to occur.
>
> Design 1C - Synthetic membrane liner. The liner would be placed from a floating plant and sunk to its required position on the bottom of the containment area. The liner itself would provide adequate protection against seepage. Gaps may develop if the overlap of the individual sheets were insufficient, causing seepage to occur. In addition, uplift forces would need to be controlled.

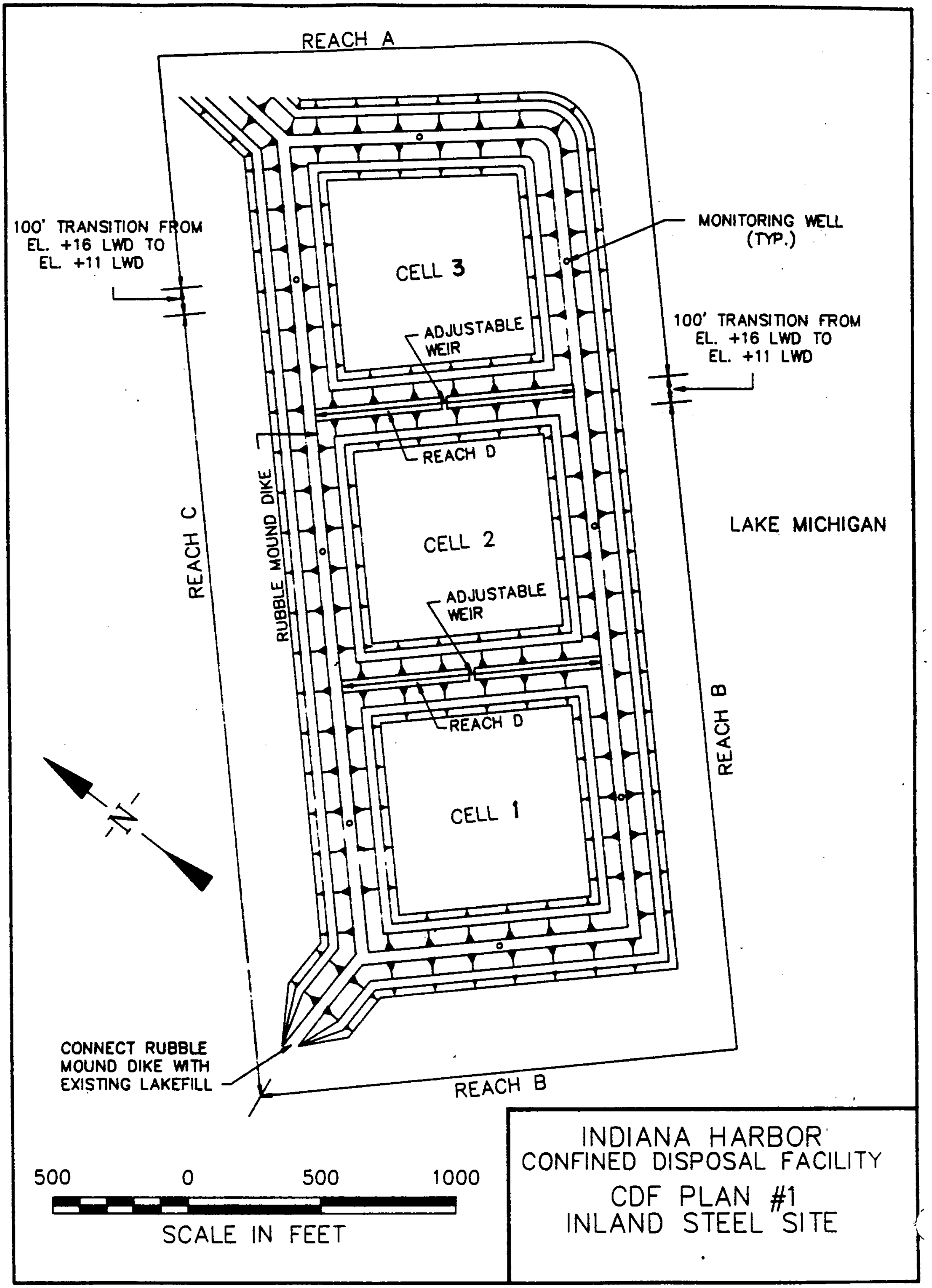
Detailed Design Requirements

2.24. To develop a detailed design of the site, a comprehensive subsurface investigation is needed. This investigation would have borings along the dike alignment and sampling of the sand and clay layers down to an approximate depth of -100 LWD or about 10 feet into the very hard silty clay till. Undisturbed samples of the clay are necessary to perform the laboratory testing required to establish the engineering properties of the soil.

2.25. A stability analysis of the dike would be performed. End-of-construction and steady seepage conditions would be studied to determine the final dike configuration. Sudden drawdown conditions do not apply to this situation.

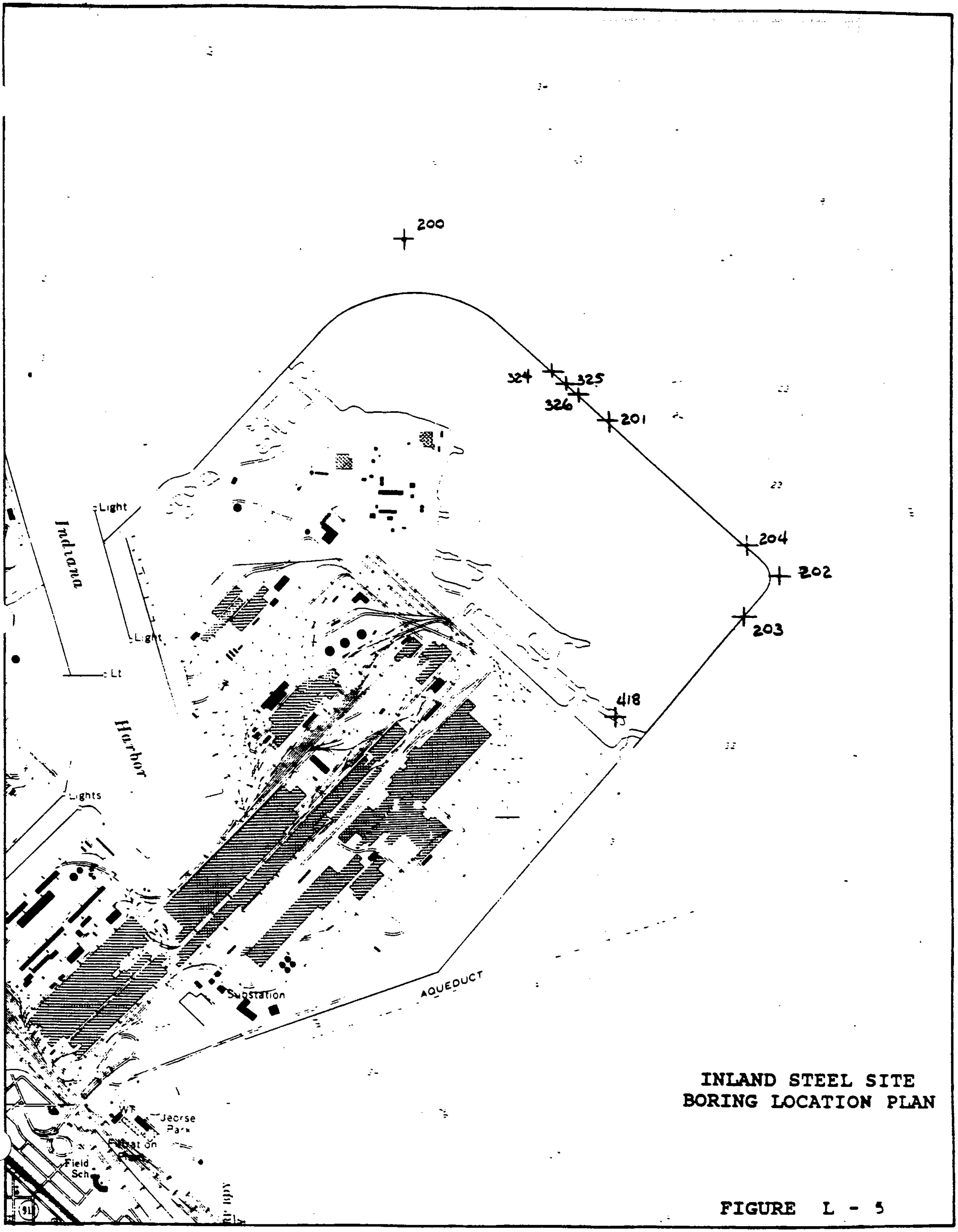
2.26. After the subsurface site conditions are established, the bearing capacity needs to be reevaluated to determine the dike configuration and develop methods to resolve weak conditions encountered.

2.27. The chosen barrier system would also be checked to make sure that it will provide suitable confinement of the dredge materials.



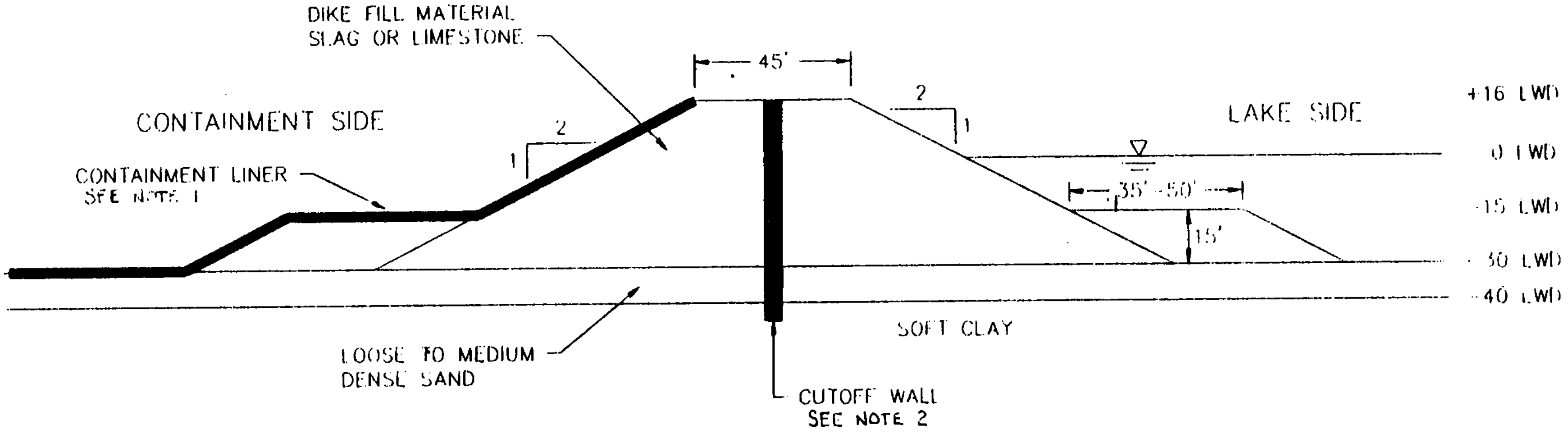
INDIANA HARBOR
CONFINED DISPOSAL FACILITY
CDF PLAN #1
INLAND STEEL SITE

FIGURE L-4



INLAND STEEL SITE
BORING LOCATION PLAN

FIGURE L - 5

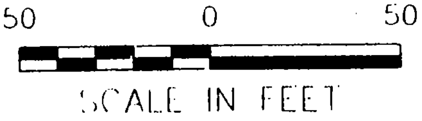


NOTES:

1. CONTAINMENT LINER OPTIONS INCLUDE: GROUT MATTRESS, ASPHALTIC GABION MATTRESS, AND SYNTHETIC MEMBRANE.

2. CUTOFF WALL OPTIONS INCLUDE: BENTONITE/CEMENT SLURRY OR CEMENT GROUT SLURRY.

3. UNDERLYING SOFT CLAY WAS NOTED TO BE OCCASSIONALLY ORGANIC FOR THAT CONDITION, THIS CROSS-SECTION MAY NEED TO BE ALTERED.



INDIANA HARBOR CDF
INLAND STEEL SITE
CONCEPTUAL CROSS-SECTION
(TYP)
FIGURE L-6

FEBRUARY 1989

Table L-1. Summary of Consolidation Tests - Inland Steel

BORING NO.	SAMPLE NO.	DEPTH ft.	ELEV. msl	Wo %	LL	PL	Eo	Po ksf	CONSOLIDATION INDICES	
									Cc	Ccr
200	8	55		24.3	37.0	18.0	0.650	3.6	0.182	0.032
202	4	50		56.6	60.0	28.0	1.532	2.0	0.570	0.100
324	6	55-57	526.9-524.9	44.3	47.8	24.2	1.263	1.1	0.350	0.085
324	8	65-68	516.6-513.9	30.0	35.5	21.7	0.808	3.4	0.180	0.040
324	10	75-77.8	506.9-504.1	26.6	30.3	20.5	0.830	3.0	0.155	0.033

1019-18

Table L-2. Summary of Tri-Axial Tests - Inland Steel

BORING NO.	SAMPLE NO.	DEPTH ft.	ELEV. msl	Po ksf	Qu tsf	INITIAL WATER	FINAL WATER	$\left(\frac{\sigma_1-\sigma_3}{2}\right)_f$ tsf	$\bar{\phi}^\circ$	c tsf
200	8	55		2.04	0.86	23.1	23.3	0.650	25.5	0.00
						21.6	16.9	1.480		
						23.8	20.0	1.930		
202	4	50		0.97	0.51	52.0	50.0	0.410	10.0	0.20
						52.5	46.1	0.6		
						53.3	32.8	1.080		
324	8	65	516.9	1.60	0.60	30.4	28.3	0.445	30.5	0.10
						28.3	26.1	1.035		
						26.1	24.4	1.850		
324	9	70	511.9	2.17	1.00	33.5	31.2	0.425	24.5	0.17
						31.2	30.7	0.940		
						30.7	29.2	1.550		
326	8	65	518.6	1.60	0.34	34.3	31.5	0.500	32.0	0.00
						31.5	29.2	0.750		
						29.2	27.9	1.500		
326	10	80	503.6	2.64	0.56	27.0	25.8	0.640	31.5	0.00
						25.8	24.7	1.120		
						24.7	23.6	1.930		

CDF PLAN #2 - 141st STREET SITE

INTRODUCTION

Site Description

3.1. The 141st Street Site is located in Hammond, Indiana in the South 1/2 of Section 19 of North Township, T37N, R10W, Lake County, Indiana. This is a land site of approximately 83 acres bordered on the south by 141st Street and on the west by the Indiana East-West Toll Road (I-90). The northern boundary is an existing wetland and the eastern border is an existing tree line marking the property limits of several petroleum companies. Refer to the site plan, figure L-7.

3.2. Previous use of the site is undetermined at this time, but it appears that it may have been a former wetland which has been filled in. The site is flat and essentially barren with a small amount of vegetation consisting of a few scrub trees and patches of wild grasses.

Plan #2 Description

3.3. Under Plan #2, the CDF would be constructed with a design capacity of two million cubic yards, giving an estimated design life of 15 years. Earthen dikes using off-site materials, would be built to an approximate elevation of 24.5 feet above grade. The CDF is to have a barrier layer of three feet of compacted clay along the bottom and up the side berms. A drainage layer is anticipated on top of the clay liner, consisting of one foot of sand or gravel with a network of perforated drain pipe. Refer to figure L-7 for the preliminary layout of the CDF at the 141st Street Site.

SUBSURFACE INVESTIGATIONS

3.4. Only one subsurface investigation was located as being performed near the 141st Street Site. This investigation was conducted by CASE Company, for DeLeuw, Cather, and Co. The purpose for the investigation was to obtain soils data for the design of the Indiana East-West Toll Road, running along the west side of the site. This investigation took place during the summer and fall of 1954. Five (5) bridge borings were drilled around the intersection of the tollroad and 141st Street. In addition, six (6) auger borings were taken along the alignment of the East-West Toll Road and the ramps connecting 141st Street near the proposed site. Refer to figure L-8 for the locations of these borings. The boring logs are included in attachment L-2.

3.5. The borings, S-75 through S-79 and S-92, were sampled using a split-spoon sampler and three inch diameter thin-walled Shelby tubes. The sampling occurred at five foot intervals. Standard penetration test (SPT) results are included on the boring logs. No laboratory testing of the samples appears to have been conducted. Borings S-78 and S-92 were drilled to a depth of 25 feet. The other borings were drilled to refusal approximately 60 feet below grade.

3.6. Six (6) auger borings were made near the 141st Street Site. Three of the borings were taken with a hand auger (HA-1, HA-2, and HA-3), and were made along the Tollroad alignment. The boring depths of probes HA-1 and HA-2 was 4 feet, and 5 feet for HA-3. The remaining three (3) augers borings were drilled using a power auger (PA-48, PA-49, and PA-50), and were taken along the alignments for the ramps connecting 141st Street and the Tollway. The borings were drilled to depths of 4.5 feet for PA-49 and PA-50, and 5 feet for PA-48. These borings were terminated due to flowing sand conditions.

SUBSURFACE CONDITIONS

3.7. The soils underlying the 141st Street Site can be identified as being divided into four (4) layers. These layers are as follows:

- Layer 1: Black Sandy Topsoil
- Layer 2: Fine Grained Sand
- Layer 3: Gray Silty Clay, Soft
- Layer 4: Gray Silty Clay, Hard

3.8. Layer 1. The Topsoil in the area ranges from non-existent to a thickness of three feet (Boring S-92). Where present, this layer occasionally contains an extensive root mat.

3.9. Layer 2. The strata of medium to fine grained sand grades from brown to gray with depth. The sand is loose to medium dense with "N"-values ranging from 7 to 20 blows per foot. This layer is approximately 23 feet thick and is saturated.

3.10. Layer 3. The soft clay extends from a depth of 23 feet to 46 feet below grade. "N"-values between 10 and 20 blows per foot were reported.

3.11. Layer 4. The hard clay was encountered below the soft upper clay and continued down until auger refusal. The layer had "N"-values of 30 to 100 blows per foot, increasing with depth. Auger refusal generally occurred around 60 feet. Bedrock is anticipated at an approximate depth of 100' below ground surface.

CONCLUSIONS AND RECOMMENDATIONS

3.12. The information obtained for the 141st Street Site indicates that the soil conditions on the site consists of approximately 23 feet of loose to medium dense fine sand, underlain by clay extending to the end of the borings at 60 feet. Groundwater on the site was found to be approximately 3 feet below ground surface.

Recommended Design

3.13. The recommended design for the CDF would be to construct earthen dikes up to about 24.5 feet above grade. These dikes should be built with 3:1 side slopes using off-site materials. Refer to figure L-9 for a conceptual cross-section of the 141st Street Site design. The use of off-site materials is recommended due to a high groundwater table which would cause considerable difficulty during excavation and potentially contaminated soils. The use of on-site materials would be reconsidered if future site investigations indicate no contamination.

3.14. A liner system would be necessary to prevent migration of pollutants from the dredge materials into the sand and groundwater. A three foot layer of compacted clay under an impermeable membrane would provide sufficient protection. The recommended alternative would be to construct a slurry wall at the interior toe of the containment dikes and to have the clay liner only on the dike slopes. This system would trap the groundwater within the diked area and eliminate the need for a clay liner across the bottom of the CDF. This may prove necessary as constructing the bottom liner could be difficult with the required machinery in the presence of the high groundwater table and underlying loose sand.

3.15. An underdrain system would be included in the design. This system would be necessary to help dewater the dredge material, thereby allowing consolidation of the dredged material to occur. The system would consist of a drainage layer of one foot of sand and gravel with perforated drain pipe embedded in it, leading to the dewatering cell.

3.16. Groundwater monitoring wells need to be installed around the perimeter of the dikes. These wells are necessary to monitor the effectiveness of the liner and/or cutoff wall in containing the polluted materials. The wells should be installed and sampled prior to placement of the dredged material in order to obtain background information about existing groundwater quality.

Detailed Design Analysis

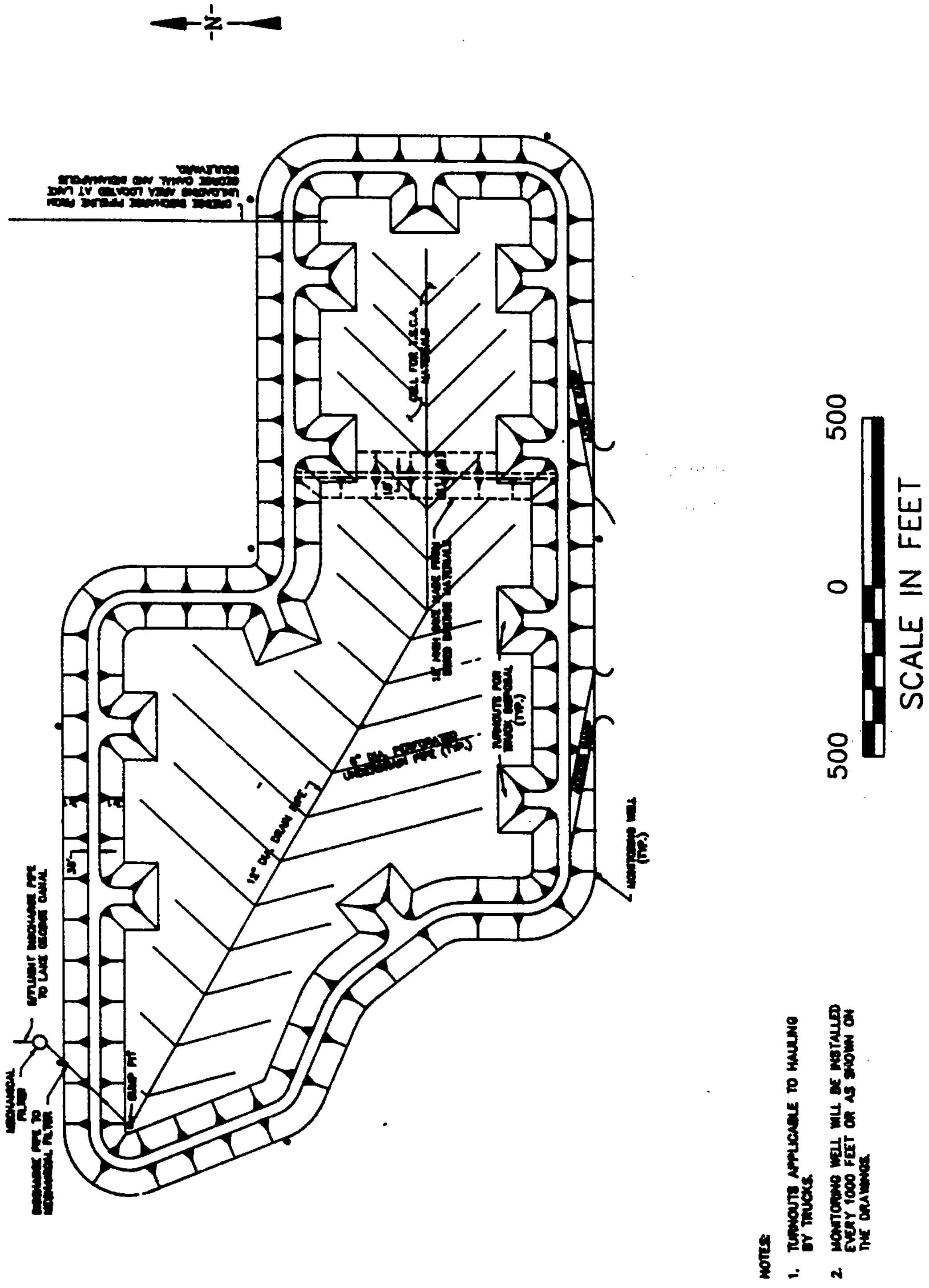
3.17. To analyze the 141st Street Site in order to develop a detailed design, the following items need to be accomplished:

1) An extensive soils investigation including sampling of the sand and clay materials down to bedrock. Undisturbed samples of the clay layer are required along with permeability tests of the sand and clay.

2) Stability analysis of the dike would be performed using the soil parameters established by the soil borings and lab testing. End-of-Construction and steady seepage conditions would be studied. Sudden drawdown conditions do not apply to this site.

3) Bearing capacity of the foundation soils would be checked to determine if they possess adequate strength for dike support.

3.18. Installation of groundwater monitoring wells should be performed during the soils investigation. The reason for this is that the equipment to install them would be on site and it is necessary to establish existing groundwater quality prior to confinement of the dredged materials.



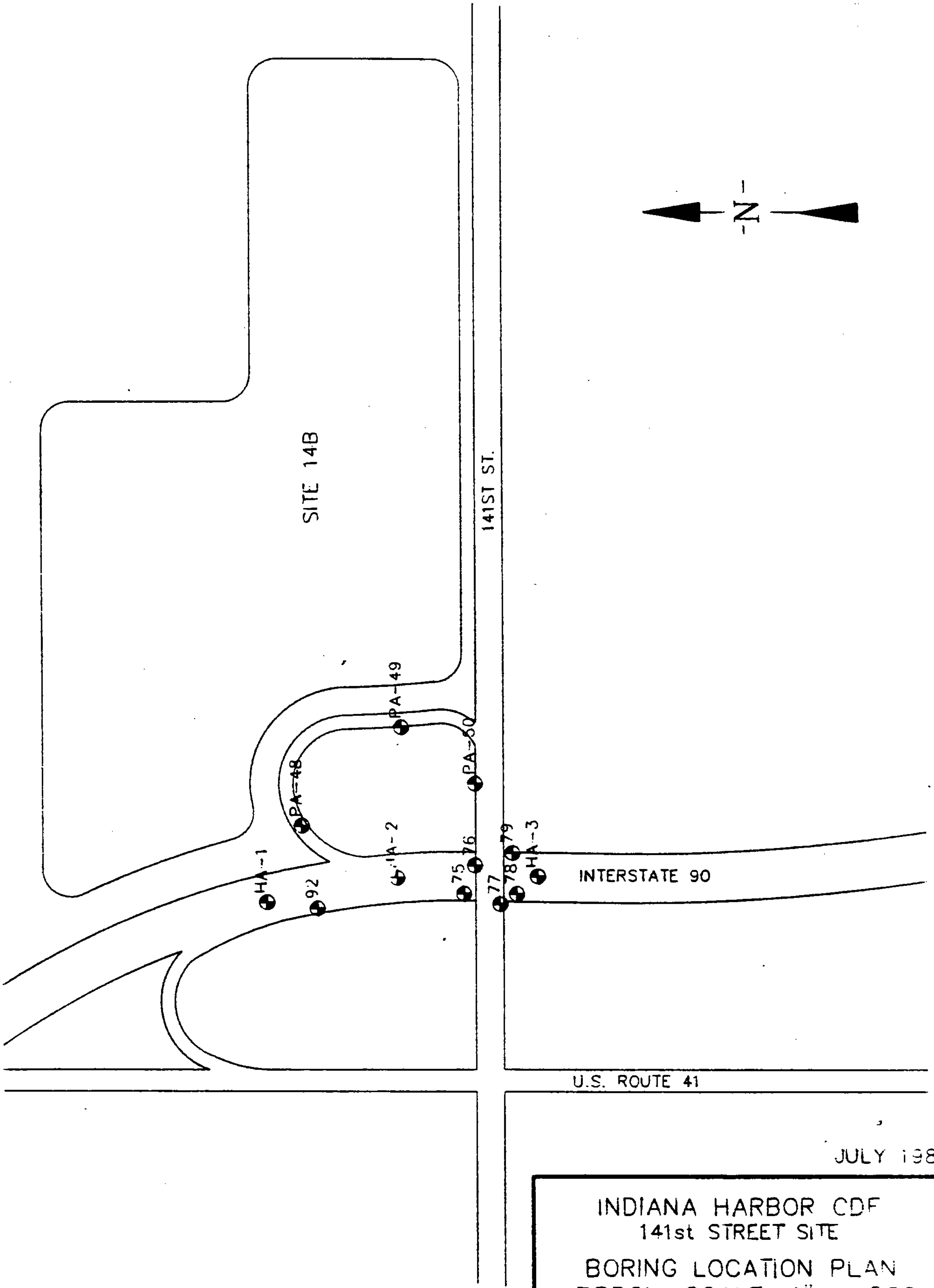
NOTES:

1. TURNOUTS APPLICABLE TO HAULING BY TRUCKS.
2. MONITORING WELL WILL BE INSTALLED EVERY 1000 FEET OR AS SHOWN ON THE DRAWINGS.

INDIANA HARBOR
CONFINED DISPOSAL FACILITY
CDF PLAN #2
141st STREET SITE

FIGURE L-7

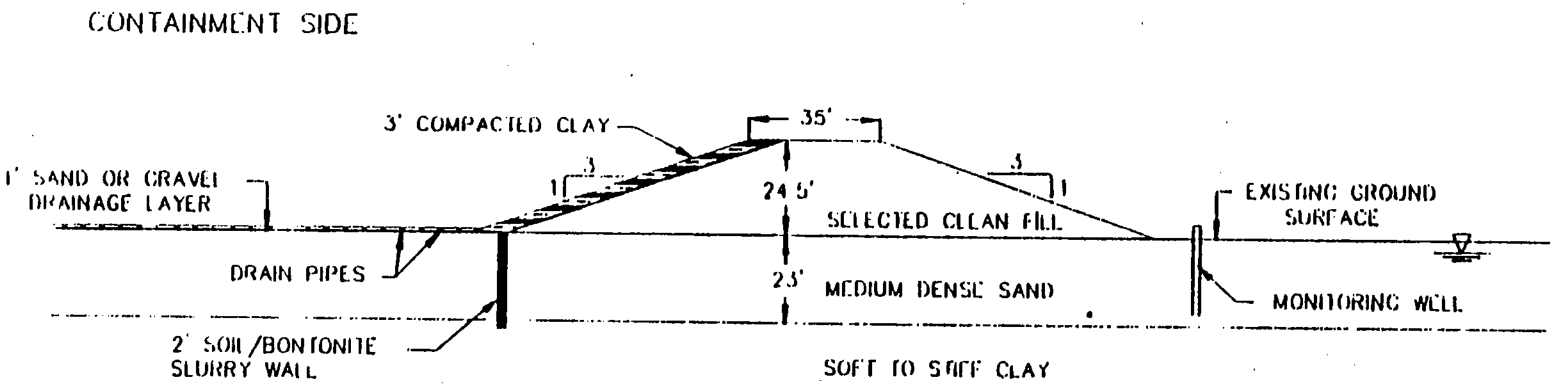
1023-24



JULY 1989

INDIANA HARBOR CDF
141st STREET SITE

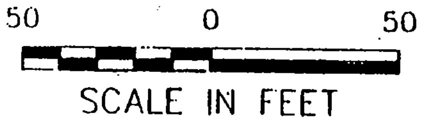
BORING LOCATION PLAN
APPROX. SCALE: 1" = 500
FIGURE L-8



NOTES.

1. Drainage layer and drain pipe will be sloped to drain towards the dewatering cell.

2. Groundwater at approximotely 3' Below Ground Surface.



JULY 1989

INDIANA HARBOR CDF
141st STREET SITE

CONCEPTUAL CROSS-SECTION.
(TYP)

FIGURE L-9

CDF PLAN #3 - "J"-PIT SITE

INTRODUCTION

Site Description

4.1. The proposed confined disposal facility, known as the "J"-Pit, is located in the South 3/4 of the S.E. 1/4 of Section 11 of Calumet Township, T36N, R9W, Lake County Indiana. The site is approximately 4.5 miles southeast of Indiana Harbor and Canal at the southwest corner of Colfax Street and 15th Avenue in Gary, (refer to figure L-10). The "J"-Pit is approximately 120 acres in extent, 100 acres of which is open excavation approximately 35 feet deep, and the remaining 20 acres are undeveloped open and wooded land. The site is bounded on the west and south by open field, on the east by the City of Gary Landfill, and on the north by wooded acreage. No existing dwellings are within 600 feet.

4.2. The site was previously used as a borrow pit for the excavation of sand found on the site, approximately 35 feet to 40 feet in thickness. The site was then approved by the State of Indiana as a potential site for a sanitary landfill. However the permit for designing the site as a landfill expired in 1979.

Plan #3 Description

4.3. The plan for the design of the confined disposal facility at the "J"-Pit site would be to construct a containment structure with the capacity to confine approximately 3,000,000 cubic yards of dredged material, having an estimated design life of 30 years. The plan would require regrading of the side slopes of the open excavation and construct a dike across one side of the excavation. A slurry wall would be constructed to provide a barrier along the side of the containment area that would be adjacent to the existing slopes. The barrier system would be keyed into the clay formation that underlies the site. A drainage layer would then be installed on the bottom of the site to permit dewatering of the dredged material. The dredged material would then be trucked in or conveyed by rail and unloaded. Effluent water from the dredgings would be discharged to the Gary sewage treatment plant via local sanitary sewers.

Investigations Performed

4.4. Several geotechnical investigations have been performed within the "J"-Pit. The first was performed by Salisbury Engineering, Inc. for Red Top Trucking Company, Inc. in May, 1972. This investigation consisted of three (3) soil borings within the pit. Only visual soil descriptions and classifications of the underlying soils were reported. No laboratory tests were performed on the samples collected and no analysis of the conditions encountered was made. Refer to attachment L-3, for the boring location map and the log of test borings. This investigation was supplemented in June, 1976 by Salisbury Engineering for Red Top Trucking and consisted of two (2) additional borings and laboratory testing of the samples collected. These results are also included in attachment L-3.

4.5. Red Top Trucking employed Salisbury Engineering again in April, 1983 to drill five (5) soil borings, of which three (3) were completed. No laboratory tests were performed on the samples collected. The boring location map and the boring logs from this exploration are included in attachment L-3.

4.6. Waste Management, Inc. (WMI) contracted Canonie Environmental in September, 1987 to perform a preliminary site investigation of the "J"-Pit prior to purchasing the site. During this investigation, six (6) soil borings and four (4) monitoring wells were installed. The data acquired was included in a second investigation by Canonie Environmental during the summer of 1988. The draft report, dated October 1988, defined the hydrogeology at the site, and recommended a groundwater monitoring system to be used during and after the life of a landfill proposed at the site. The information obtained from the draft report forms the basis for this section.

SUBSURFACE INVESTIGATIONS

General Remarks

4.7. The first investigation accomplished by Salisbury Engineering consisted of two parts. The first part involved drilling three (3) borings to a depth of 51.5 feet each, and the second consisted of drilling two borings to a depth of 50 feet each. The second investigation was completed by Salisbury Engineering, Inc. in 1983 and consisted of two (2) borings drilled to depths of 15 feet, and one drilled to 75 feet. These two investigations used conventional drilling and sampling techniques, however no soil samples were collected for laboratory testing. The boring logs of these two investigations are included in attachment L-3.

4.8. The third investigation was performed by Canonie Environmental for Waste Management, Inc. This study was accomplished in two phases, the first in 1987 and the second in 1988. The investigation consisted of drilling a total of 21 borings. Refer to the boring location plan shown on figure L-11. Four (4) borings, B-1 through B-4, penetrated into the bedrock to a maximum depth of 24 feet and were subsequently converted into groundwater monitoring wells. Additionally, nine (9) of the borings completed in the overburden soils were converted into monitoring wells. The drilling and sampling techniques employed by Canonie are discussed in the following sections. The boring logs from this investigation are contained in attachment L-4.

Soil Sampling Methods

4.9. The sampling procedures of Canonie consisted of split-spoon sampling and thin-walled Shelby tubes at 2.5 foot intervals. Disturbed samples were obtained using the split-spoon sampler and driving it 18 to 24 inches in accordance with the standard penetration test (SPT) ASTM D 1586. A representative sample of the material recovered was used to visually classify the soils according to the Unified Soil Classification System (USCS), ASTM D 2487, and saved for subsequent lab testing.

4.10. An undisturbed sample was taken for each layer of cohesive material encountered. The samples were obtained using a three inch diameter thin-walled Shelby tube sampler and hydraulically pushed into the soil a minimum of 24 inches, in compliance with ASTM D 1587. The undisturbed samples were immediately sealed with wax and capped prior to transporting to the laboratory for further testing.

Rock Coring Methods

4.11. Borings B-1, B-2, B-3, and B-4 were advanced 24 feet, 11.5 feet, 10 feet, and 15.5 feet respectively into the bedrock. The bedrock was cored using a diamond tipped NX core barrel. The rock cores were classified in the field. The core run length, percent recovery, rock quality designation (RQD), and bedrock descriptions are contained on the rock borehole logs in attachment L-4.

LABORATORY TESTING PROGRAM

4.12. Selected soil samples from the investigation by Canonie were subjected to the following physical parameter tests:

1) Sieve analysis
2) Hydrometer analysis
3) Atterberg limits analysis
4) Laboratory permeability testing
5) Moisture content

4.13. The results of the laboratory permeability testing are summarized on table L-3. The results of the other laboratory physical soil tests are summarized on table L-4. The specific tests completed and the referenced method is as follows:

TEST	NUMBER OF TESTS	METHOD
Sieve Analysis	30	ASTM D 442
Hydrometer Analysis	25	ASTM D 442
Atterberg Limits	33	ASTM D 4318
Permeability Tests	8	EPA SW-925
Moisture Content	27	ASTM D 2216

SUBSURFACE CONDITIONS

Soil Characteristics

4.14. Five separate stratigraphic units have been defined based on their distinguishing physical characteristics. These units are as follows:

> ZONE A - Upper sand layer, which typically occurs from ground surface to elevation 580 MSL. This unit is defined as a "locally useful" aquifer.
>
> A-B AQUITARD - Silty clay layer hydraulically separating ZONE A and ZONE B.
>
> ZONE B - A discontinuous silt zone, typically occurring between elevation 540 MSL and elevation 530 MSL. This unit is saturated, but is not a "locally useful" aquifer.
>
> B-C AQUITARD - Silty clay strata hydraulically separating ZONE B and ZONE C.
>
> ZONE C - Dolomite bedrock underlying the unconsolidated overburden. This unit occurs at an elevation of 488 MSL at the eastern edge of the site and at an elevation of 456 MSL at the western edge of the site. The dolomite bedrock is defined as a "locally useful" aquifer.

4.15. As presented on the boring logs, refer to attachment L-4, Zone A is found at this site only along the perimeter of the property where the sand has not been removed. Over the majority of the site, the sand has been excavated down to the top of the underlying silty clay unit, referred to as the A-B Aquitard. Zone A varies in thickness from 7 to 41 feet in the borings in which it was encountered.

4.16. Four (4) sieve analyses were performed on representative samples collected from Zone A. The results are shown in table L-4. Three of the four sieve tests yielded Unified Soils Classification System (USCS) designations of SP (poorly-graded sand) and one test yielded SW (well-graded sand). Generally, Zone A sands contain less than 10 percent fines. The density of the sands ranges from very loose to very dense, based on standard penetration test values.

4.17. The contact between Zone A and the A-B aquitard generally occurs between elevation 577 and 580 MSL. The A-B aquitard is typically 40 feet thick, with a USCS classification of CL based on hydrometer and Atterberg limits testing, refer to table L-4.

Hydrometer analyses of 16 samples indicate the majority of fines comprising the A-B aquitard are clay sized. Generally, the A-B aquitard contains less than 13 percent of sand size particles. The natural water content of this unit ranges from 20 to 30 percent. Hand penetrometer test results (Q_u) are recorded on the soil boring logs and indicate that the soil strength varies from 0.0 to 4.5 tons per square foot.

4.18. The Zone B saturated zone is comprised of a thin layer of clayey silt with up to 17 percent sand, as determined by the laboratory grain size analyses. Eight (8) representative Zone B soil samples were subjected to laboratory physical analyses with resultant USCS classification of ML (4 samples) and CL-ML (4 samples). The results are summarized in table L-4. Zone B is typically 5 to 10 feet thick and is not continuous beneath the site. The lateral extent of this zone beyond the investigated area is not known.

4.19. Underlying Zone B is a silty clay unit separating Zones B and C, referred to as the B-C aquitard. This aquitard is generally encountered between elevation 530 MSL and the top of bedrock and ranges from 42 feet to 75 feet in thickness. Six (6) representative soil samples of the aquitard were analyzed, with resulting USCS classification for all samples tested as CL (table L-4). The B-C aquitard is a silty clay with up to 12 percent sand. The natural water content of this unit ranges from 16 to 20 percent. Hand penetrometer results are indicated on the soil boring logs and indicate that the soil strength varies from 0.5 to 4.5 tons per square foot.

4.20. In the deeper soil borings, a significant increase in blow counts occurred within the B-C aquitard. This indicates a contact zone between the soft glacial lake clays and the stiffer glacial clayey tills. Based on data obtained from a limited amount of borings during this investigation, the contact between the lake clays and clay till occurs between elevation 515 MSL and elevation 505 MSL.

Bedrock Characteristics

4.21. Based upon the exploratory borings, the top of bedrock at this site occurs between elevation 456 and 488 MSL. The bedrock consists of a light gray, very fine-grained dolomite. The dolomite is medium-to-thick bedded with close to moderately close fractured horizontal joints. The upper 3 to 5 feet of the rock cores contained solution cavities known as vugs. The vugs were filled with calcite and pyrite crystals. In Boring B-3, the vugs were filled with a black, viscous liquid which exuded a petroleum odor. This liquid is probably naturally occurring crude oil generated from the decomposition of the biological fauna that inhabited the shallow seas of the Silurian Age.

Hydrogeology

4.22. During the geotechnical investigation by Canonie, thirteen (13) groundwater monitoring wells were installed within the various water bearing zones encountered. The hydrogeologic information obtained from these wells is somewhat preliminary, due to pumping from within the pit and the fact that water levels are still stabilizing in several of the wells on the site. However, some conclusions can be drawn regarding hydrogeologic units, potentiometric surfaces, and horizontal gradients.

4.23. Currently, water levels are being monitored in the three saturated zones identified at the site:

> ZONE A - An upper sand layer, which typically occurs between elevation 620 and 580 MSL. The sand is a "locally useful" aquifer.
>
> ZONE B - A discontinuous, silt seam which typically occurs between elevation 540 and 530 MSL. The silt is saturated, but is not a "locally useful" aquifer.
>
> ZONE C - Dolomite bedrock, which underlies the unconsolidated overburden, occurs at an elevation of 488 feet MSL at the eastern edge of the site and at an elevation of 456 feet MSL at the western edge of the site. It is defined as a "locally useful" aquifer.

4.24. Due to the influence of the pit, local water levels in Zone A have been altered from their natural state. Pumping within the pit has established an inward gradient from the surrounding Zone A layer. The three (3) Zone A monitoring wells are within the zone of influence established by the pit and therefore, water levels in these wells are not representative of static conditions and regional flow patterns. The water level elevation in Zone A for October, 1988 varies from an approximate elevation of 590 MSL (MW-7A) at the west end of the site to approximately 589 MSL (MW-6A) at the south edge to an approximate elevation of 582 MSL (MW-5A) at the eastern edge of the site. Zone A is an unconfined aquifer with a saturated thickness of approximately 10 feet. Groundwater elevations for October, 1988 for Zone A are shown on table L-5.

4.25. The water levels in at least three (3) of the six Zone B wells apparently have not stabilized as evidenced by a comparison of September, 1988 and October, 1988 water level measurements. This zone consists mainly of silt and does not yield significant amounts of water. During development, all the Zone B wells were pumped or bailed dry and recovered very slowly. It may take several months before the water levels stabilize in all of the Zone B wells. However, utilizing October, 1988 data from the three remaining Zone B wells (MW-6B, MW-8B, and MW-9B), the groundwater flow direction appears to be to the northwest. This is considered to be preliminary and could change as more data becomes available. The water level elevation in Zone B varies from an approximate elevation of 587 MSL (MW-6B) at the south edge of the site, to an approximate elevation of 568 MSL (MW-8B) in the northwest corner of the pit, to approximately elevation 582 MSL (MW-7B) in the northeast corner of the pit. Groundwater elevations for Zone B wells for October, 1988 are shown on table L-5.

4.26. October, 1988 water levels in the four (4) bedrock monitoring wells (MW-1C through MW-4C) indicate that the groundwater flow direction in Zone C is generally to the north-northwest. The water level elevation in Zone C varies from elevation 586 MSL (MW-2C and MW-4C) along the southern edge of the site, to an approximate elevation of 583 MSL (MW-3C) at the northeast corner of the site, to approximately 579 MSL (MW-1C) at the northwest corner of the site. These water levels indicate that the aquifer is confined. Based on the October data, the horizontal gradient in Zone C is approximately 1 foot per 300 feet. Groundwater elevations from October, 1988 for Zone C are shown on table L-5.

4.27. Because of the altered flow regime in Zone A, conclusions regarding the vertical gradient between Zones A and C cannot be made at this time. However, Zone A and Zone C are hydraulically separated by approximately 120 feet of relatively impermeable silty clay soils, with an intermediate discontinuous 10-foot thick silt layer (Zone B).

CONCLUSIONS AND RECOMMENDATIONS

Recommended CDF Design

4.28. The results of the hydrogeologic investigation by Canonie reveal that the site is suitable for CDF development. Two locally useful aquifers are present at the site, Zone A and Zone C and need to be protected. The groundwater in Zone A is proposed to be cut off by the installation of a slurry wall. This is necessary to prevent groundwater from seeping into the site, which would cause deterioration of the side slopes, and also to prevent contamination of the groundwater resulting from contact with the dredged material. The slurry wall should be keyed into the thick, relatively impermeable silty clay layer, referred to as the A-B aquitard. Zone A and Zone C are hydraulically separated by approximately 120 feet of relatively impermeable silty clays, with an intermediate discontinuous 10-foot thick silty layer, referred to as Zone B.

4.29. The side slopes in the excavation are controlled by the natural angle of repose of the granular soils of Zone A and the strength of the cohesive soils of the A-B Aquitard. The Zone A soils should provide a maximum slope of 3 horizontal to 1 vertical. The aquitard soils should provide a maximum cut slope of 2 horizontal to 1 vertical and an embankment slope of about 3 horizontal to 1 vertical.

4.30. Control of infiltration of groundwater from aquifers and aquitards can be accomplished by the construction of clay side seals or a perimeter slurry wall. However, with a hydrostatic head of approximately 10 feet or more acting on the barrier, the use of a slurry wall will have a lower risk of being breached from excessive pressure because of the greater weight of soil that would have to be displaced to cause loss of the integrity of the barrier. The aquitards will not generate enough infiltrating groundwater to pose a problem to the development of the CDF. Control of surface run-off and accumulation of storm water will be necessary to allow the CDF to dry out and consolidate.

4.31. An underdrain system is necessary to allow dewatering of the CDF and allow consolidation of the dredged material to occur. This system will consist of drain pipes within a one-foot-thick granular drainage blanket. The drain pipes will be sloped to drain towards a sump and the water pumped out and treated as necessary. The proposed slurry wall will prevent infiltration of groundwater from the upper Zone A sand layer so the design for the drainage system will only be for the dewatering of the site from dredging effluent and storm water run-on.

4.32. Results of soil testing in the A-B aquitard, at the bottom of the proposed CDF, indicates that the clay soil has a permeability of less than $1x10^{-7}$ cm/s, (refer to table L-3 for the permeability test results). The material has a USCS classification of CL. The top of bedrock (Zone C) is at elevation 488 MSL at its highest point on the site. This leaves at least 85 feet of CL material from the proposed invert of the CDF, at elevation 575 MSL, to the top of the uppermost aquifer underlying the invert. Permeability tests were incomplete for samples from the B-C aquitard at the time of this report.

4.33. The soils at the site are classified as CL by the USCS soil classification system and will provide suitable material for the side seals of the containment dikes and for a final cap to help minimize the infiltration of water. The bottom depth of the CDF will be designed in such a manner to create a mass balance between the excavation for the CDF with the final soil requirements so that additional soil from off-site sources should not be required at this facility.

4.34. Final surface contours should be established so that equipment can be easily maneuvered across the top of the cap to help maintain the vegetative cover and soil cover required to minimize infiltration into the disposal site. The cap should be constructed of compacted clay having a permeability of less than

$1x10^{-7}$ cm/sec and placed at a minimum slope of 4 percent to ensure surface run-off and minimize infiltration.

Groundwater Monitoring Program

4.35. It is recommended that the groundwater be monitored, both up-gradient and down-gradient of the CDF, to verify that the slurry wall and the underlying clay soils are providing containment of the pollutants. The monitoring plan is described in Appendix N.

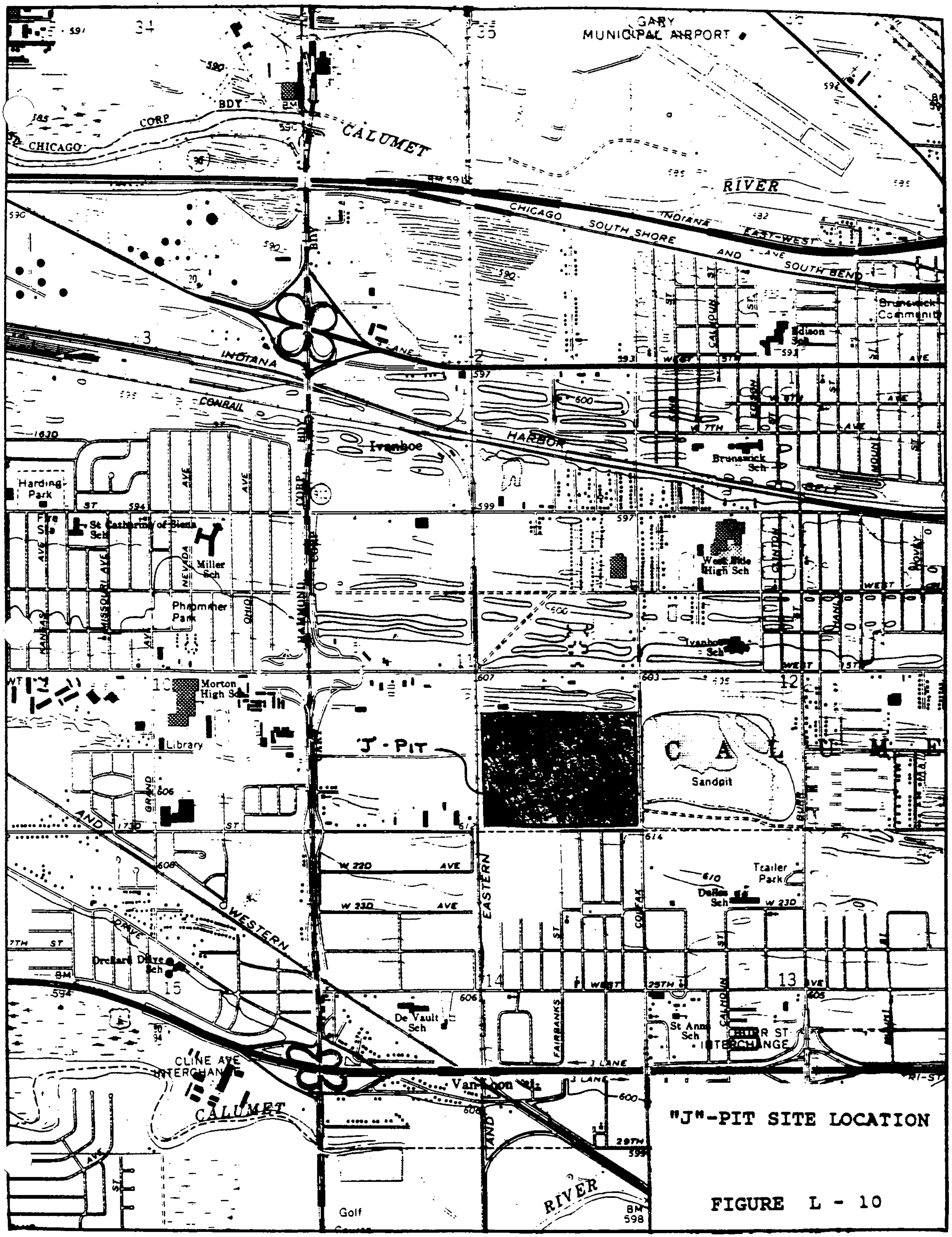
Recommendations for Additional Work

4.36. Additional work necessary for the preparation of a detailed design analysis is as follows:

1) A drilling program is necessary to confirm the results of the investigation performed by Canonie and to provide additional soils data for seepage and stability analyses.

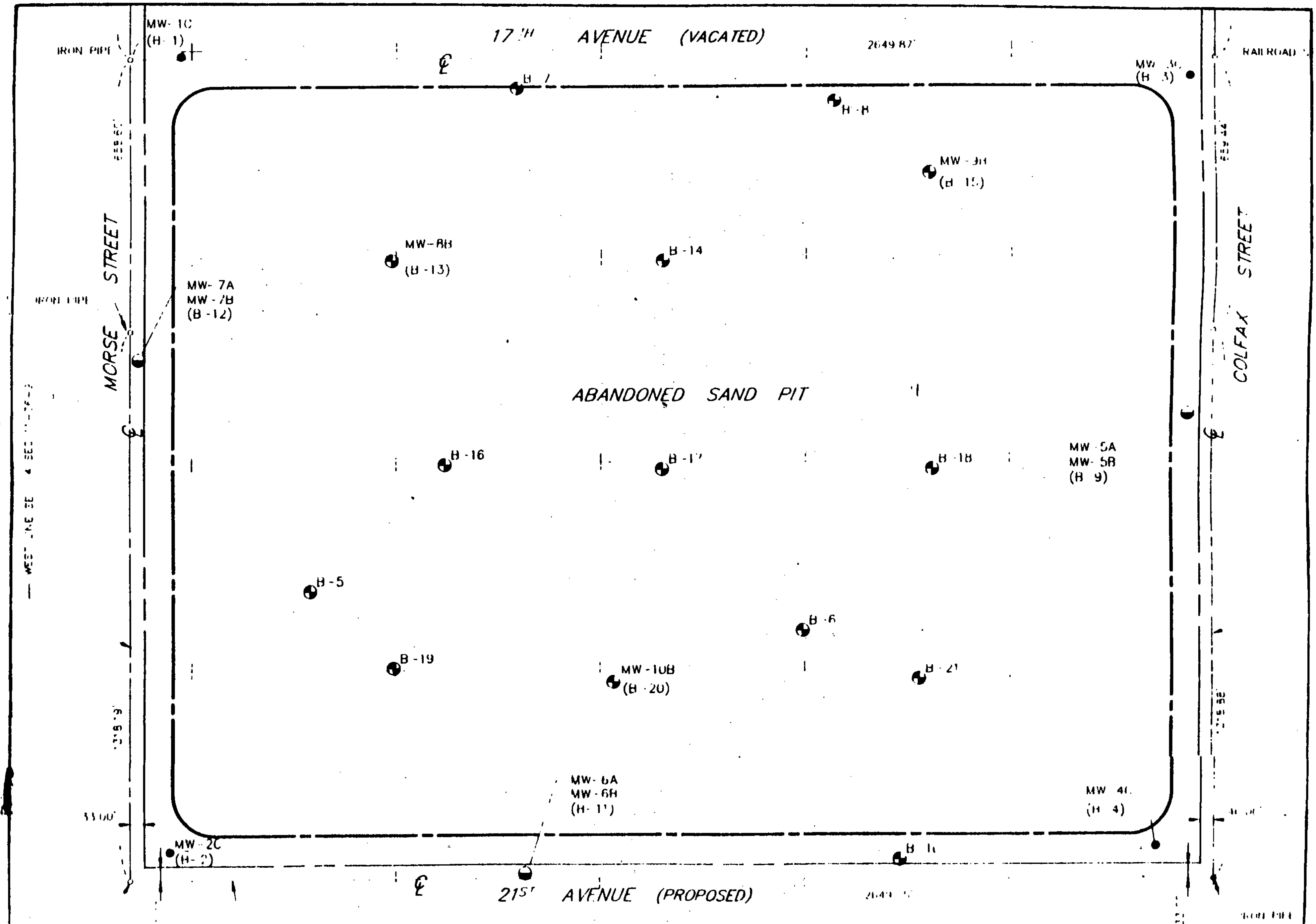
2) Stability analysis of the side slopes needs to be performed. End-of-Construction and steady seepage conditions need to be studied. Sudden drawdown conditions do not apply to this site.

3) Seepage analysis of Zone A needs to be performed in order to effectively design the perimeter slurry wall.



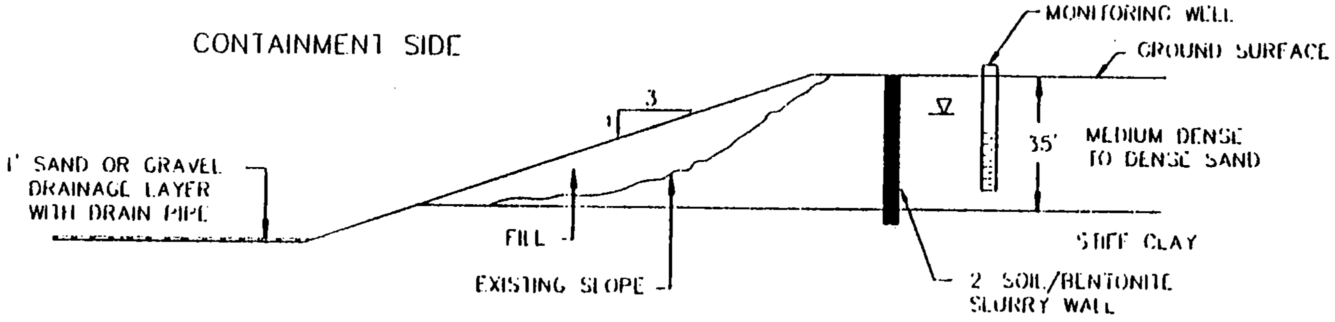
"J"-PIT SITE LOCATION

FIGURE L - 10

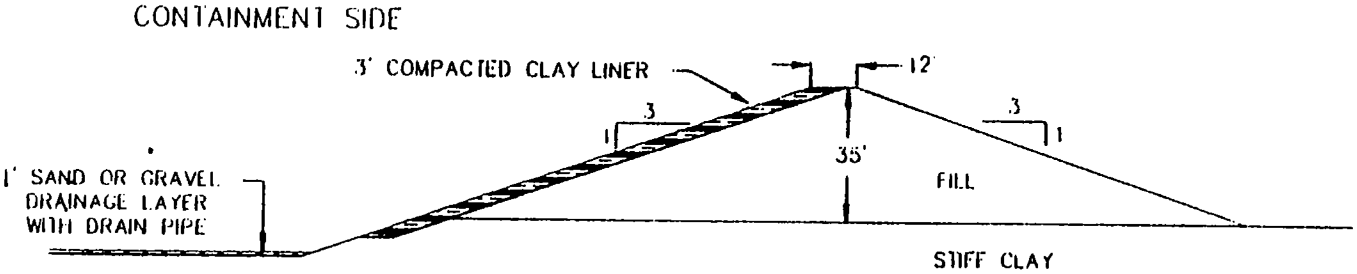


"J"-PIT SITE
BORING LOCATION PLAN

FIGURE - 11



EXISTING SLOPE



DIKE

NOTES:

1. Drainage Layer and Drain Pipe will be sloped to Drain towards a dewatering sump.

2. Groundwater approximately 10' below ground surface

3. Fill and compacted clay to come from excavating the bottom to the containment area.

50 0 50

SCALE IN FEET

INDIANA HARBOR CDF
"J" PIT SITE
CONCEPTUAL CROSS-SECTION
(TYP)

JULY 1989

FIGURE L-12

Table L-3. Summary of Lab Perm Test Results - "J"-Pit

BORING NUMBER	SAMPLE NUMBER	FLOW RATE $Q(cm^3/hr)$	DIFF. HEAD H(cm)	X-SEC AREA $A(cm^2)$	SAMPLE LENGTH L(cm)	K (cm/sec)	OVERBURDEN PRESSURE P(psi)
B-09	S-35	0.335	1477.1	40.5	8.11	$1.3x10^{-8}$	39.5
B-12	S-30	0.286	1125.4	41.7	7.25	$9.3x10^{-9}$	35.0
B-13	S-08	0.309	914.4	41.4	7.52	$1.5x10^{-10}$	13.5
B-15	S-07	0.324	914.4	41.6	7.03	$1.7x10^{-8}$	13.5
B-19	S-07	0.364	914.4	41.3	7.84	$2.1x10^{-8}$	13.5
B-21	S-07	0.323	914.4	39.6	7.25	$1.8x10^{-8}$	13.5

Note: From Canonie Environmental, Draft Report, Hydrogeologic Investigation, Glenwood Ridge Site, October, 1988, Table 5.

Table L-4. Summary of Laboratory Test Results - "J"-Pit

BORING	SAMPLE	ELEV. (MSL)		USCS	PERCENT PASSING			%	%	%	%	%	LIQUID	PLASTIC	PI	WATER
NUMBER	NUMBER	FROM	TO		#10	#40	#200	GRAVEL	SAND	SILT	CLAY	FINES	LIMIT	LIMIT		CONTENT
1	16	530.0	528.5	CL	---	---	---	---	---	---	---	---	46	20	26	---
1	17	525.0	523.5	CL	98	94	88	0	12	---	---	88	27	16	11	20
2	8	569.2	567.7	CL	---	---	---	---	---	---	---	---	32	16	16	---
2	9	564.2	562.7	CL	98	96	93	0	7	---	---	93	31	15	16	24
3	19	512.9	511.4	CL	---	---	---	---	---	---	---	---	28	16	12	---
3	20	507.9	506.4	ML	100	98	91	0	9	---	---	91	---	NP	---	17
4	13	540.5	539.0	ML	100	100	98	0	2	---	---	98	---	NP	---	18
5	4	562.0	560.0	CL	99	97	87	0	13	54	33	87	29	16	13	22
6	6	553.6	551.6	CL	98	95	91	1	8	48	43	91	28	15	13	22
7	2	581.5	580.0	SW	82	51	9	5	86	---	---	9	---	NP	---	14
8	12	530.3	528.8	ML	96	94	90	2	8	83	7	90	---	NP	---	16
9	5	610.5	608.5	SP	100	100	0	0	100	0	0	0	---	NP	---	5
9	35	550.5	548.5	CL	97	93	88	2	10	55	33	88	29	17	12	22
10	11	561.3	559.8	CL	99	96	88	1	11	60	28	88	30	19	11	30
11	6	584.8	583.3	SP	100	99	12	0	88	---	---	12	---	NP	---	36
12	8	597.1	595.1	SP	97	92	7	3	90	---	---	7	---	NP	---	22
12	30	553.1	551.1	CL	93	90	87	5	8	54	33	87	32	17	16	23
13	8	551.0	549.0	CL	98	96	93	1	6	53	40	93	31	18	14	24
13	12	531.0	529.5	CL	96	92	86	2	12	59	27	86	29	19	11	---
14	10	535.9	534.4	CL-ML	97	91	82	1	17	62	20	82	24	18	6	18
15	3	570.3	568.8	CL	97	96	90	3	7	51	39	90	32	16	15	24
15	5	560.3	558.3	CL	98	96	92	1	7	62	30	92	31	19	11	25
15	7	550.3	548.8	CL	97	92	87	0	13	57	30	87	31	17	14	30

1039-70

Table L-4. Summary of Laboratory Test Results - "J"-Pit (cont'd)

BORING	SAMPLE	ELEV.	(MSL)	USCS	PERCENT	PASSING		%	%	%	%	%	LIQUID	PLASTIC	PI	WATER
NUMBER	NUMBER	FROM	TO		#10	#40	#200	GRAVEL	SAND	SILT	CLAY	FINES	LIMIT	LIMIT		CONTENT
16	4	573.0	571.0	CL	97	94	87	1	12	50	37	87	35	18	17	25
16	23	535.0	533.0	CL-ML	100	100	99	0	1	81	18	99	22	17	5	21
17	24	533.7	531.7	CL	99	98	95	0	5	62	33	95	32	17	15	21
18	7	566.8	564.8	CL	98	95	90	1	9	53	37	90	33	19	15	26
19	7	552.1	550.1	CL	99	94	89	0	11	58	31	89	31	19	12	20
19	10	537.1	535.6	CL-ML	100	100	99	0	1	86	13	99	23	17	6	---
20	10.1	536.6	535.6	CL-ML	100	100	100	0	0	86	13	100	22	18	4	18
20	10.2	535.6	535.1	CL	100	99	97	0	3	64	33	97	32	18	14	---
21	7	551.2	549.2	CL	98	93	86	0	14	56	39	86	30	18	12	20
21	9	541.2	539.7	ML	100	100	100	0	0	93	7	100	---	NP	---	15

Table L-5. Summary of Groundwater Elevations - "J"-Pit 1/

WELL NO.	TOP PVC ELEV.	1 SEPTEMBER 1988 DEPTH TO WATER	1 SEPTEMBER 1988 WATER LEVEL ELEVATION	1 OCTOBER 1988 DEPTH TO WATER	1 OCTOBER 1988 WATER LEVEL ELEVATION
MW-5A	618.62	37.0	581.62	36.9	581.72
MW-6A	608.41	19.0	589.41	19.7	588.71
MW-7A	610.78	20.2	590.58	20.4	590.38
MW-5B	619.21	29.3	589.91	38.7	580.51
MW-6B	608.66	20.9	587.76	21.5	587.16
MW-7B	611.00	7.7	603.30	28.9	582.10
MW-8B	581.78	12.8	568.98	13.8	567.98
MW-9B	581.97	3.0	578.97	3.6	578.37
MW-10B	582.36	23.2	559.16	19.0	563.36
MW-1C	610.54	---- 2/	------	31.5	579.04
MW-2C	609.95	----	------	23.6	586.35
MW-3C	608.98	----	------	26.0	582.98
MW-4C	607.04	----	------	20.4	586.64

1/ Water levels are preliminary, particularly in Zone B wells. From Canonie Environmental, Draft Report, Hydrogeologic Investigation, Glenwood Ridge Site, October, 1988, Table 4.

2/ Wells MW-1C, MW-2C, MW-3C, and MW-4C were not completed before 1 September 1988.

CDF PLAN #4 - ECI SITE

INTRODUCTION

Site Description

5.1. The ECI site is located in East Chicago, Indiana in the SW quadrant of Section 17 and the NW quadrant of Section 20 of North Township, T37N, R10W, Lake County, Indiana. The site is of approximately 130 acres bordered on the north by the Cline Avenue Extension and on the east by Indianapolis Boulevard. The southern boundary is the Lake George Canal and the west side is bordered by a railroad corridor. Refer to figure L-13 for the site plan.

5.2. The site was formerly an oil refinery owned and operated by Sinclair, which was bought by the Atlantic Richfield Company (ARCO). Afterward, the property was purchased by the Energy Cooperative Industries (ECI). The site has been abandoned since 1981 after ECI filed for bankruptcy and is currently barren, with all above ground buildings and storage tanks demolished.

Plan #4 Description

5.3. Plan #4 involves the construction of an upland confined disposal facility on the ECI Site with a capacity of 3,000,000 cubic yards. The design calls for the use of off-site materials to construct earthen dikes around the perimeter of the facility. The dikes would have a 3 horizontal to 1 vertical slope to a height of approximately 25 feet above the existing grade and a crest width of approximately 35 feet.

5.4. The operating plan for the CDF is to transfer the dredged material from scows on the Lake George Canal and either mechanically rehandle it or hydraulically pump it to the facility. The CDF containment area will be located on the northern half of the site with the area to the south, along the Lake George Canal, to be developed by the City of East Chicago for recreational purposes. The CDF will take up about 120 acres of the total area.

SUBSURFACE INVESTIGATIONS

5.5. Limited information is available about the soil conditions near the ECI Site. One investigation was performed by Pittsburgh Testing Laboratory for Butler, Fairman, and Seufert, Inc. This investigation was conducted to obtain data for the design of the Cline Avenue Extension. Twenty-one (21) borings were drilled during the summer of 1975 and were made along the alignment of the new roadway, for retaining walls, and for bridges. Refer to figure L-13 for the locations of these borings. Copies of the borings logs are included in attachment L-5.

5.6. The borings were sampled using a split-spoon sampler at 2.5 foot intervals. Standard penetration test (SPT) results are included on the boring logs. The depth of the borings varied from 10.0 feet to 96.5 feet below grade.

SUBSURFACE CONDITIONS

5.7. The soils encountered during the investigation for the roadway consist of two (2) types. The upper soil layer is a gray, medium to fine grained sand, approximately 33 feet thick. This layer is in a loose condition near the surface and becomes medium dense to dense with depth. Occasional pockets of coarse sand and gravel were encountered during the investigation. In most of the borings, the upper 3 to 6 feet of sand was black and contained oil and chemical residues. The zone is saturated below 3 to 5 feet.

5.8. The second layer of soil encountered is a gray silty clay of stiff to very stiff consistency. This layer appears to be consistent between the borings that penetrated into it. Very hard silty clay was encountered below a depth of 79 feet in the two borings extending to that depth. No strength tests or moisture contents were performed on the soils, the relative consistency being estimated from the blow counts taken from SPT results.

CONCLUSIONS AND RECOMMENDATIONS

5.9. The general conditions of the ECI Site can be approximated from the borings taken along the Cline Avenue Extension. The conditions encountered there indicated that the site consists of about 33 feet of loose dense, medium to fine sand. The sand overlays gray silty clay of stiff to very stiff consistency which is assumed to extend down to bedrock, approximately 100 feet below the surface. Groundwater was found to be about 3 to 5 feet below grade.

Recommended Design

5.10. The recommended design for a confined disposal facility at the ECI Site is to construct earthen dikes up to about 25 feet above grade. The dikes should be built with 3:1 side slopes using off-site materials. Refer to figure L-14 for a conceptual cross-section. The use of off-site materials is suggested due to the high groundwater beneath the site, which would interfere with excavation below the water table and create problems in maintaining the integrity of the bottom and sides of the excavation because of excessive seepage. In addition, contaminated materials are known to underlay the site. As such, excavation of this material is not recommended due to the environmental concerns that would be raised.

5.11. A containment system is necessary for the CDF in order to prevent migration of pollutants contained within the dredged materials into the local groundwater. Two (2) alternatives are under consideration as barrier systems. The first would be to construct a 3 foot layer of compacted clay across the entire bottom of the containment facility. The recommended alternative would be to construct a slurry wall at the inside toe of the containment dikes and to have the dike slopes lined with a 3 foot layer of compacted clay. This system would trap the upper groundwater within the diked area and eliminate the need for the clay liner across the bottom of the CDF.

5.12. An underdrain system should be installed to assist in dewatering the dredged material, allowing the dredged material to consolidate at a faster rate. The underdrain system would consist of perforated drain pipe surrounded by a free draining gravel, trenched into the existing sand underlying the site. The pipes would be sloped towards a dewatering sump.

5.13. Groundwater monitoring wells need to be installed around the perimeter of the dikes in order to monitor the containment system. The wells should be installed up-gradient and down-gradient of the CDF, prior to the placement of the dredged material, and sampled to provide background information about existing groundwater quality. Refer to Appendix N for further details regarding monitoring.

Detailed Design Analysis

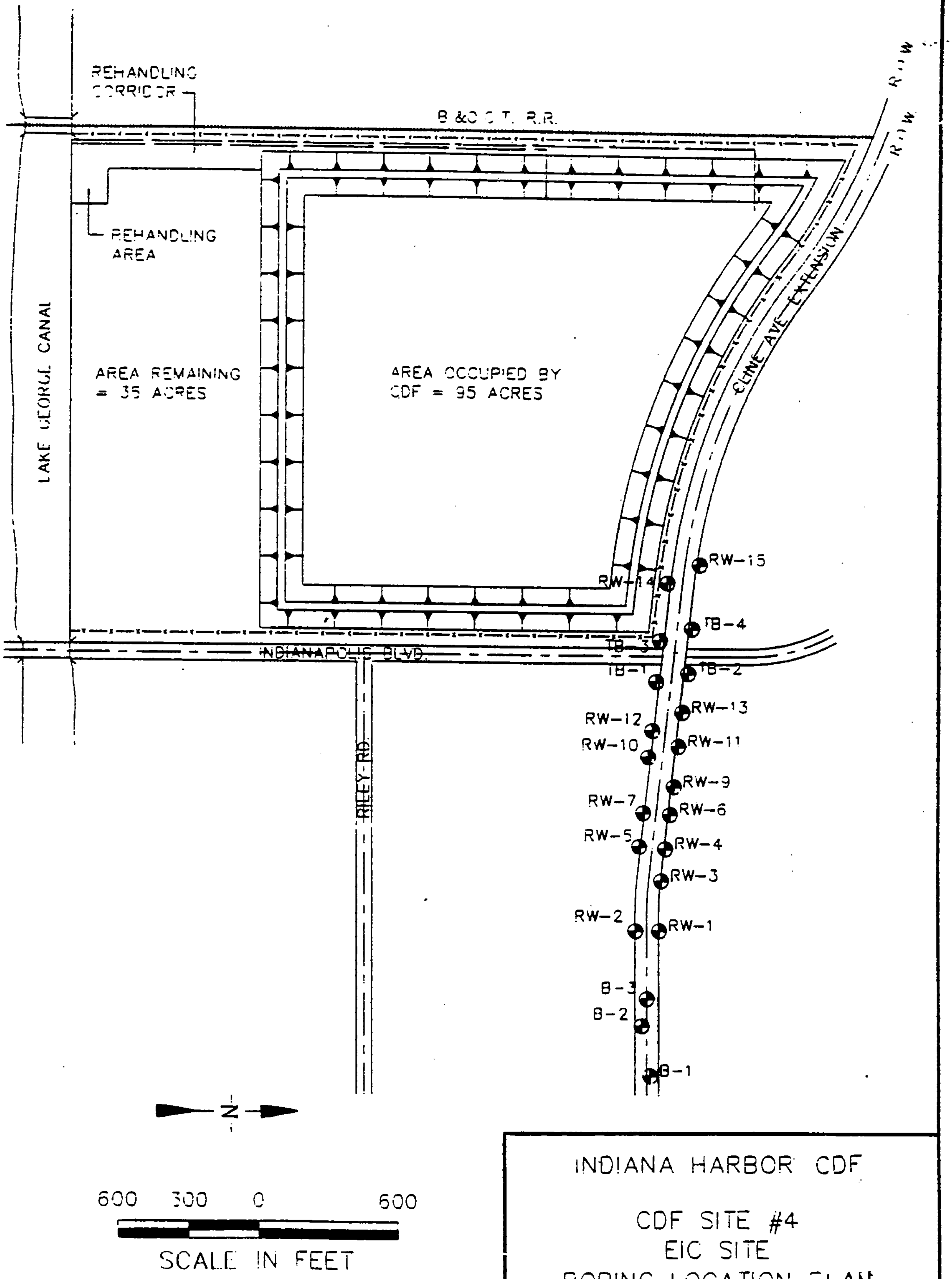
5.14. To develop a detailed design for the ECI Site, the following items need to be investigated:

1) An extensive soils investigation including sampling of the sand and clay materials down to bedrock. Undisturbed samples of the clay are required, along with permeability tests of the sand and clay layers.

2) Stability analysis of the dike would be performed using the soil parameters established by the soil borings and lab testing. End-of-Construction and steady seepage conditions would be studied. Sudden drawdown conditions do not apply to this site.

3) Bearing capacity of the foundation soils would be checked to determine if adequate strength for dike support is available.

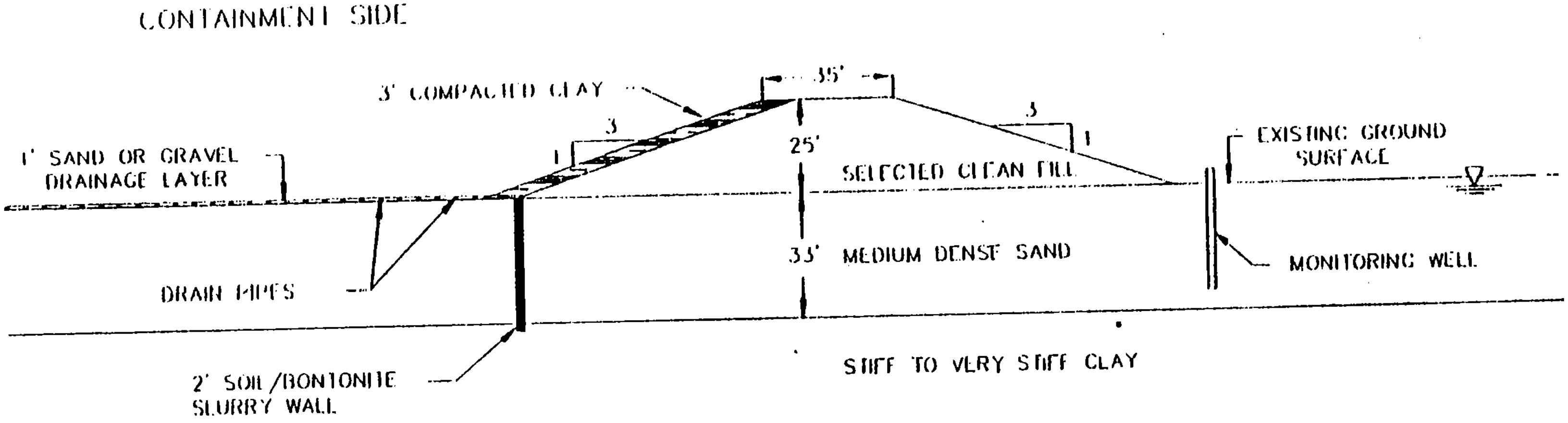
5.15. Installation of groundwater monitoring wells should be performed during the soils investigation phase. The reason for this is that the equipment to install them would be available and it is necessary to establish existing groundwater quality prior to confinement of the dredged materials.



INDIANA HARBOR CDF

CDF SITE #4
EIC SITE
BORING LOCATION PLAN

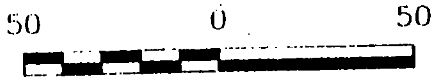
FIGURE L - 13



NOTES.

1. Drainage Layer and Drain Pipe will be sloped to Drain toward the dewatering cell.

2. Groundwater at approximately 3' Below Ground Surface.



SCALE IN FEET

INDIANA HARBOR CDF
ECI SITE
CONCEPTUAL CROSS-SECTION
(TYP)

JULY 1989

FIGURE L-14

PROPOSED PLAN - ECI SITE MODIFIED

INTRODUCTION

6.1. An evaluation of the preceding CDF Plans was performed, taking into account the various factors regarding the suitability of the sites for the construction of a CDF. Refer to the main report for a detailed account of the selection. The ECI Site was the site recommended for continued study.

6.2. Following the initial evaluation of the ECI Site, it was learned that the site is contaminated and that corrective action to clean up the site was underway. The Indiana Department of Environmental Management (IDEM), the City of East Chicago, and the ARCO had entered into an agreement to remediate the site. The remediation began with the taking of soil borings and the installation of monitoring wells and piezometers around the site, for the purpose of characterizing the site and to determine the extent of the pollution to be dealt with.

6.3. To incorporate the proposed CDF onto the ECI Site, the final plan for the remediation of the ECI Site must take into account the construction of the CDF. This will require close coordination between the non-federal interests and the Government, to ensure that the designs are compatible.

6.4. Several alternatives were examined which dealt with the coordination of the project for the separate issues of site remediation and the CDF. Originally, it was determined to separate the contaminates of the existing site and the dredged material. The concept being that the contamination below the existing ground surface would be the responsibility of the non-federal interests. Contamination within the dredged material would be the responsibility of the Government.

6.5. This concept is essentially the same, for the Government, as would be required for a generic clean upland CDF site. This alternative was shown to be costly and involves a complex design. Cost data of the alternatives is included in Appendix K. The conceptual plan was re-examined with separation of contaminates not required, and to use the CDF as a part of the engineered cap for the site. This alternative was determined to be the most cost efficient and is being recommended as the Proposed Plan - ECI Site Modified. The containment of the contaminates will be similar to the original concept for the site under Plan #4, which incorporates a cutoff wall around the perimeter of the site.

6.6. Another modification to the proposed plan, apart from the cross-contamination issue, is that the dikes will be built in stages or lifts. The reason for this is to provide a more economical arrangement by reducing the amount of dike material required and to increase the storage capacity of the facility.

SUBSURFACE CONDITIONS

6.7. Prior to remediating the ECI Site, ARCO and the City of East Chicago, in agreement with the IDEM, began a subsurface investigation to determine the soil characteristics and the depth and extent of the contamination on the site. The work was performed by Environmental Resources Management (ERM) - North Central, Inc., and later taken over by Geraghty and Miller, Inc. The investigation was started during the fall of 1991 and was underway at the time of this report. Four borings, 14 monitoring wells, and 29 piezometers were performed for this investigation. Refer to figure L-15 for their locations. The preliminary information received was that the characteristics of the site are similar to the conditions stated in paragraphs 5.7 and 5.8. Boring logs and laboratory test data from the investigation available for this report are included in attachment L-6.

6.8. The subsurface investigation performed indicates that the site is covered with 0 to 12 feet of fill, consisting of sand, cinders, and slag. Below the fill is 20 to 25 feet of sand. On-site pumping tests performed by Geraghty & Miller indicated an average hydraulic conductivity of $8.8\text{x}10^{-3}$ cm/sec for this layer. Below the sand is a layer of sandy silt to silt approximately 5 feet thick. Underlying this layer, below elevation 555 feet MSL is silty clay reported to be 60 to 65 feet thick, with a permeability of less than $1\text{x}10^{-7}$ cm/sec in laboratory tests on undisturbed samples performed by ERM. A cross-section of the subsurface profile in shown in figure L-16.

DESIGN RECOMMENDATIONS

Staged Dike Construction

6.9. Staged dike construction was considered as an alternate method of construction and is to be implemented in the modified ECI Site design. The primary advantages with using a staged dike construction procedure are: 1) the reduction in the initial cost of construction; 2) a shortened initial construction period; 3) reduced overall quantity of dike material required; and 4) increased storage capacity of the facility.

6.10. The configuration of the cross-section for the dikes involved looking into three different alternatives. These alternatives are shown in figure L-17 and the advantages and disadvantages of each are described below.

a. Alternative #1 - The dikes are to be constructed from the inside edge and expanded outward for this alternative. The advantages of this method are: 1) construction for all the stages will be on competent material, i.e. on previously constructed dike material and on prepared original ground; 2) requires the least amount of fill for dike construction in the first stage; 3) easiest to design and build; and 4) allows for simple barrier system design, permitting many options to be feasible. The disadvantages of this alternative are: 1) requires the greatest amount of material for dike construction over the life of the project; and 2) provides the smallest amount of storage capacity.

b. Alternative #2 - The dikes are to be constructed along the same centerline for all of the construction stages. The advantages are indicated as follows: 1) requires less dike material than alternative #1 over the life of the project; 2) provides more storage of dredged material than alternative #1; 3) allows for a relatively simple barrier system to be constructed; and 4) construction of dikes on dredged material will be minimal. The disadvantages are described as follows: 1) requires more material for dike construction than alternative #3; 2) provides less storage for dredged material than alternative #3; 3) fewer options for the barrier system design are available; 4) requires some construction of the dikes on dredged material; 5) requires a thorough dredged material management program to allow punctual dike raising; and 6) more difficult to design and build than alternative #1.

c. Alternative #3 - The dikes are to be constructed from the outside edge and expanded inward. The advantages are: 1) it requires the smallest amount of material for dike construction over the project life; and 2) provides the greatest amount of storage capacity. The disadvantages are: 1) it requires the greatest quantity of Stage 1 dike fill; 2) requires a significant amount of dike construction on the dredged material; 3) the barrier system will be difficult to design and build; and 4) requires an extensive dredged material management program.

6.11. After studying the different alternatives, Alternative #3 was selected as the preferred option. The size of the site is limited and the governing criteria is to maximize the storage capacity of the facility. Dike stability of the selected alternative will need to be studied; however, the foundation conditions of the site appear to be sufficient to allow construction of the proposed facility at an approximate 3 horizontal to 1 vertical slope. To allow the staged construction of the CDF to proceed in a timely manner, the dredged material will need to be managed rigorously.

6.12. Interior dikes are also to be constructed for the ECI Site - Modified Plan. One interior dike is to be built during the initial construction of the facility to allow operation of the CDF before the entire facility is constructed. This initial center dike will only be constructed to a partial height of the first stage. After the initial construction, all interior dikes will be constructed by using harvested dredged material.

6.13. Dike stability will need to be enhanced by proper managing of the dredged material. The dredged material management plan is described in more detail in Appendix O. The proposed plan is to harvest the crust that develops and bring that drier surface material near the dikes. This will provide a more stable foundation when the dikes are to be raised. The strength of the foundation may need to be verified and stability calculations performed prior to any raising of the perimeter dikes. If problems with the stability are indicated, remedial measures could include: delaying dike construction; or making a shallower, and thereby wider, slope on the interior side of the dike.

Containment System

6.14. A containment system is required to prevent the migration of polluted material beyond the limits of the CDF. There is a significant difference in the containment system requirements between the generic clean upland CDF site and the proposed ECI Site plan.

Generic Clean Upland CDF Site

6.15. The generic clean upland CDF site is required to meet stringent containment requirements. The USEPA and the IDEM have indicated that the facility would be classified as a solid waste landfill, based on the contamination expected from the dredged materials. Based upon this design assumption, the containment system for the generic clean upland CDF site will consist of two liners, a primary and a secondary, with a monitoring layer in between to detect leaks which may develop in the primary liner. This liner system will provide containment along the bottom and the sides of the CDF. When the CDF is full, the site will be capped with a single liner and covered with vegetation. A plan view of the clean site is shown in figure L-18.

6.16. First Stage. The bottom of the CDF and the first stage of dike construction will have a liner system consisting of 2 layers of High Density Polyethylene (HDPE) with a monitoring layer consisting of a synthetic drainage net in between. A schematic of the liner system for the clean site is shown in figure L-19. Initially, the site would be cleared and graded to provide a smooth surface. The secondary liner would then be placed and would consist of a 40 mil HDPE geomembrane. This would be followed by placement of a drainage net, for the monitoring layer. The primary layer, consisting of a 60 mil HDPE, would then be placed. This layer would provide the principal protection against leaking of polluted material.

6.17. Underdrainage System. A drainage layer would be installed above the primary liner on the bottom of the CDF. This layer would assist in dewatering the dredged material by providing a drainage layer beneath the material which would allow upward and downward drainage thereby reducing the overall seepage path. This results in a faster rate of consolidation of the dredged material allowing a shorter turnaround time. The drainage layer would consist of 24 inches of sand with perforated pipe embedded within. The drainage system would be sloped to a collection point consisting of a decanting/dewatering structure located in each cell. The structure would collect surface runoff as well as being connected to the underdrain system. The water within the structure would then be pumped out to the pre-treatment facility prior to discharge to the local sewer system.

6.18. <u>Second and Third Stages</u>. The second and the third stages of perimeter dikes shall be constructed on the dredged material contained within the CDF, as explained above in Stage Dike Construction. As a result, the design of the liner system will need to take into account the settling of the dredged material that is expected to occur. The settling may cause problems with the integrity of the liner.

6.19. The liner system must be able to withstand continued settling of the dredged material over the lifetime of the project and for many years thereafter. The primary concern is with the integrity of the liner over this period of time. The forces that would need to be resisted include differential settlement and stretching. The configuration of the proposed system is shown in figure L-19. The liner for these stages consists of a 60 mil HDPE primary liner placed directly upon the dredged material and welded to the primary liner from the stage 1 construction. A 12 inch layer of sand would be placed upon the primary liner to provide protection during construction of the remainder of the dike and to provide a monitoring layer for any leaks. This layer would slope towards the interior toe of the dike to a collection pipe. Above the sand layer, a 24 inch layer of compacted clay would act as the secondary liner. The remainder of the dike would be constructed of clean fill. On the interior face of the dike, a 24 inch thick clay layer would be formed during dike construction, upon which a synthetic drainage net would be placed and connected to the sand layer and collection pipe at the base of the dike. Finally, a 60 mil HDPE would be placed on the drainage net and welded to the primary liner under the raised portion of the dike. This system would be used for each of the stages after the initial construction.

6.20. <u>Final Cover</u>. Closure of the CDF consists of constructing an engineered cap over the dredged materials. This cap would be designed to limit rainfall from percolating through the dredged material and preventing animals and/or vegetation from being exposed to the polluted material. The proposed cap for the CDF would consist of a layer of clean fill or dredged material properly graded to allow surface runoff to occur without ponding on the facility. Next, a layer of clay, 24 inches thick, would be placed as the barrier system. The clay would be followed by a 6 inch layer of sand, then 24 inches of clean fill and finally 6 inches of topsoil. The top 36 inches of material would be the zone in which vegetation would be allowed to grow.

Proposed ECI Site

6.21. The plan for the proposed ECI Site was developed in coordination with the USEPA, the City of East Chicago, the ARCO, and the IDEM. The plan is essentially to use the CDF as part of the engineered cap to the closure of the ECI Site. As such, there would be no provision for the separation of the contaminates of the dredged material and the contamination that currently exists on the site. The requirements of this plan are described in the following paragraphs. The proposed site plan is shown in figure L-20.

6.22. Perimeter Cutoff Wall. The containment of the contaminates on the site would be through the use of a perimeter cutoff wall, (refer to figure L-20). It is proposed that the cutoff wall consist of a soil-bentonite slurry with a permeability of less than $1x10^{-7}$ cm/sec. The construction of the slurry wall would likely use the vibratory beam method. The durability of the wall is considered satisfactory in regards to being resistant to the contaminates which exist on the site, assumed to be primarily petroleum products, i.e. benzene constituents.

6.23. If on-going studies indicate that the soil-bentonite slurry wall is inadequate, an alternative would be the use of a vertical HDPE cutoff wall. This wall would be installed with methods similar to installing steel sheet piling, through the use a vibratory hammer. The joints of the panels would have an expanding sealant to prevent leakage through the wall.

6.24. The design and construction of this cutoff wall would be the responsibility of the non-federal interests. However, the Government would need to agree with the design and construction as being adequate for the containment of the pollutants expected within the dredged materials.

6.25. Dewatering Wells. A system of dewatering wells is required to establish an inward gradient onto the site. Essentially, this means that the groundwater underlying the site shall be drawn down, inducing the local groundwater to flow towards the site. The concept is that with an inward gradient maintained, contamination from the site would not be able to move away from the site. To induce this inward gradient, a series of dewatering wells would be installed around the perimeter of the site inside of the cutoff wall. A drawdown of 2 feet is determined to be sufficient to maintain an inward gradient.

6.26. It is estimated that approximately 21,000,000 gallons of water will be required to be removed in order to establish an inward gradient of 2 feet for the site. This initial drawdown would be the responsibility of the non-federal interests as part of the site remediation. In order to maintain the inward gradient, an estimated seepage through the slurry wall of 700 gallons per day will need to be removed. Seepage through the CDF and the remaining capped portions of the site were determined by use of the HELP model, described in Appendix F. The responsibility for maintaining the inward gradient would be shared between the Government and the non-federal interests.

6.27. Dike Construction. The dikes would be constructed in stages as explained above, in Stage Dike Construction. The first stage construction would be approximately 15 feet in height. The remaining stages would be 10 feet high. There would be no separation layer between the dredged material and the existing soils of the ECI Site for the proposed plan. The dike, however, would be constructed upon a 3 foot thick layer of compacted clay. This clay layer would be tied into the cap layer outside of the dikes, explained below. A section view of the plan is shown in figure L-21.

6.28. The dike would be constructed of readily available clean fill with slopes of 3 horizontal to 1 vertical. On the interior face of the dike slopes, would be a 3 foot thick layer of compacted clay. The clay layer would have a permeability of less than $1x10^{-7}$ cm/sec and shall serve as the containment layer to prevent migration of contaminates through the dikes. The bottom of each additional stage shall have a 3 foot thick layer of compacted clay, which shall tie into the clay layers from the stage below and into the stage above, (refer to figure L-21).

6.29. Final Cap. The final cap for the proposed ECI Site CDF shall be the same as described above for the generic upland CDF site. The cap for the ECI Site would also cover the property areas beyond the limits of the CDF and tie into the perimeter cutoff wall in order to fully encapsulate the site. This part of the cap would be the responsibility of the non-federal interests.

6.30. The capping of a portion of the site will require special consideration due to the presence of a railroad bisecting the site. For this section, it is considered that grouting of the railroad ballast and underlying materials would be appropriate to seal this section. The grout required would be a chemical grout due to the grain size of the materials. The responsibility of this portion of the cap would also be with the non-federal interests.

FUTURE INVESTIGATIONS

6.31. The design presented above is conceptual and will require additional investigations to analyze the features presented. To complete the design of the CDF the following information will need to be acquired.

a. The areas under the containment dikes and in locations where the cutoff wall is to go will need to be investigated in some manner, such as with ground penetrating radar and/or a magnetometer, to determine if there are any pipes, structures, or cavities which may exist under the ground surface resulting from previous uses of the site. These cavities could be abandoned storage tanks, pipelines, foundations, etc. Their presence could result in instability of the dikes due to piping of material or collapse of a cavity, and create problems during construction of the slurry wall.

b. Information from the subsurface investigation mentioned in paragraph 6.7 should be available by the time the detailed design phase begins. This information will be evaluated and a determination made of what additional data is required. The information required for design will include a general description of the subsurface conditions regarding the thickness of the geologic layers and the depth to groundwater, grain size determination of the granular materials underlying the site, the angle of internal friction of the granular materials, permeability of the various layers, and the strength characteristics of the clay materials. Boring information is recommended for about every 500 feet of dike to be constructed.

c. The physical and engineering characteristics of the dredged material need to be determined. The first stage stability design for the perimeter dikes will describe the dredged material as a fluid mass to be retained. However, material characteristics become very important for development of a dredged material management program and for implementing stage 2 and stage 3 dike construction. The information required includes determining the water content of the material expected when it is placed in the CDF, the time required to dry before management can begin, the strength of the material and volume at certain water contents, and the consolidation characteristics.

d. The minimum strength characteristics of the dike fill will need to be determined. An evaluation of potential borrow sites available for the construction of the dikes will be needed and their strength parameters used in the dike stability analyzes.

6.32. Following the gathering of the data indicated above, the design of the facility can proceed. The analyzes that need to be conducted are as follows:

a. Stability analyzes of the dike must be performed. These analyses should include:

- End-of-Construction condition, with the CDF empty for Stage 2 and Stage 3, taking into account the strength characteristics of the contained dredged material in previous stages and vehicle loading on top of the dikes;

- End-of-Construction condition, with the CDF full for each of the stages, taking into account the different characteristics of dry and fresh dredged material and vehicle loading on top of the dikes;

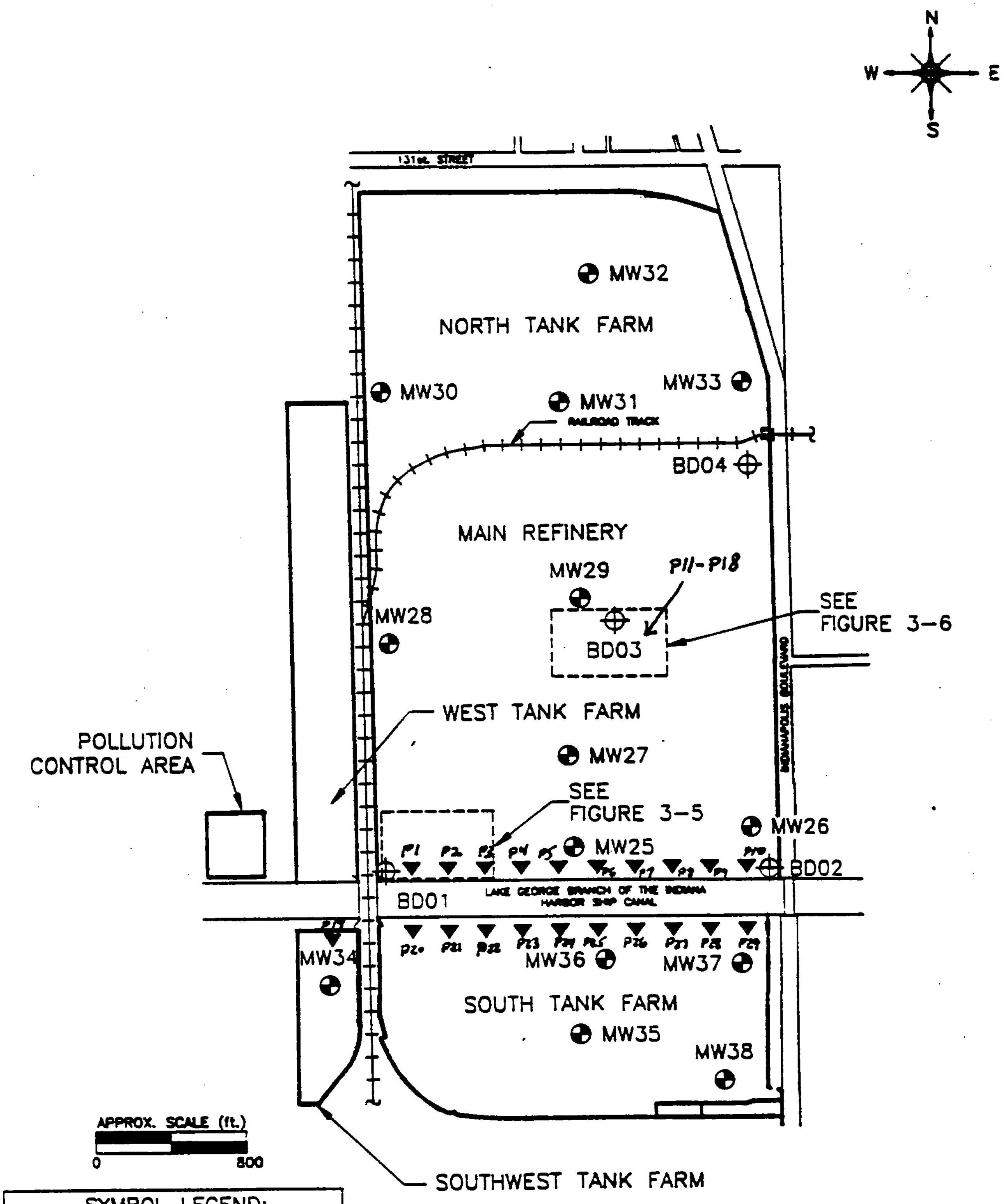
- Long term condition or steady seepage condition, with the CDF full for each of the stages taking into account the affect of saturated dredged material.

b. The bearing capacity of the dredged material with time will need to be determined. This information is necessary for the dredged management plan, to know when equipment will be able to proceed onto the material. In addition, the bearing capacity must be analyzed for the condition of constructing Stage 2 and Stage 3 dikes and the time at which those dikes may be built. The bearing capacity of the dike foundation will also be checked.

c. Settlement analyses must be performed for the dikes and the dredged material on the foundation soils. In addition, settlement calculations must also be performed for the dredged material under the conditions when Stage 2 and 3 dikes are constructed.

d. Seepage does not appear to be a concern with the CDF due to the barrier system that is to be built. However, the condition of a break in the containment system should be considered so that the dikes will remain stable in this event.

e. The design of the dewatering system, which includes the slurry wall and the dewatering wells, will need to be performed. This design will determine the spacing required for the dewatering wells in order to maintain the inward gradient and to adequately size the pumping and pre-treatment facilities and the appropriate thickness and depth of the wall. Also, the extent of the costs for the system to be allocated to the CDF and the amount to be allocated for the site remediation will need to be determined .



SYMBOL LEGEND:

◕	MONITORING WELL LOCATION
⊕	DEEP SOIL BORING LOCATION
▼	PIEZOMETER LOCATION
─┼─┼─┼─	RAILROAD
━━━	PROPERTY BOUNDARIES

NOTE:
SITE PROPERTY BOUNDARIES NOT EXACT. PENDING PROPERTY SURVEY.

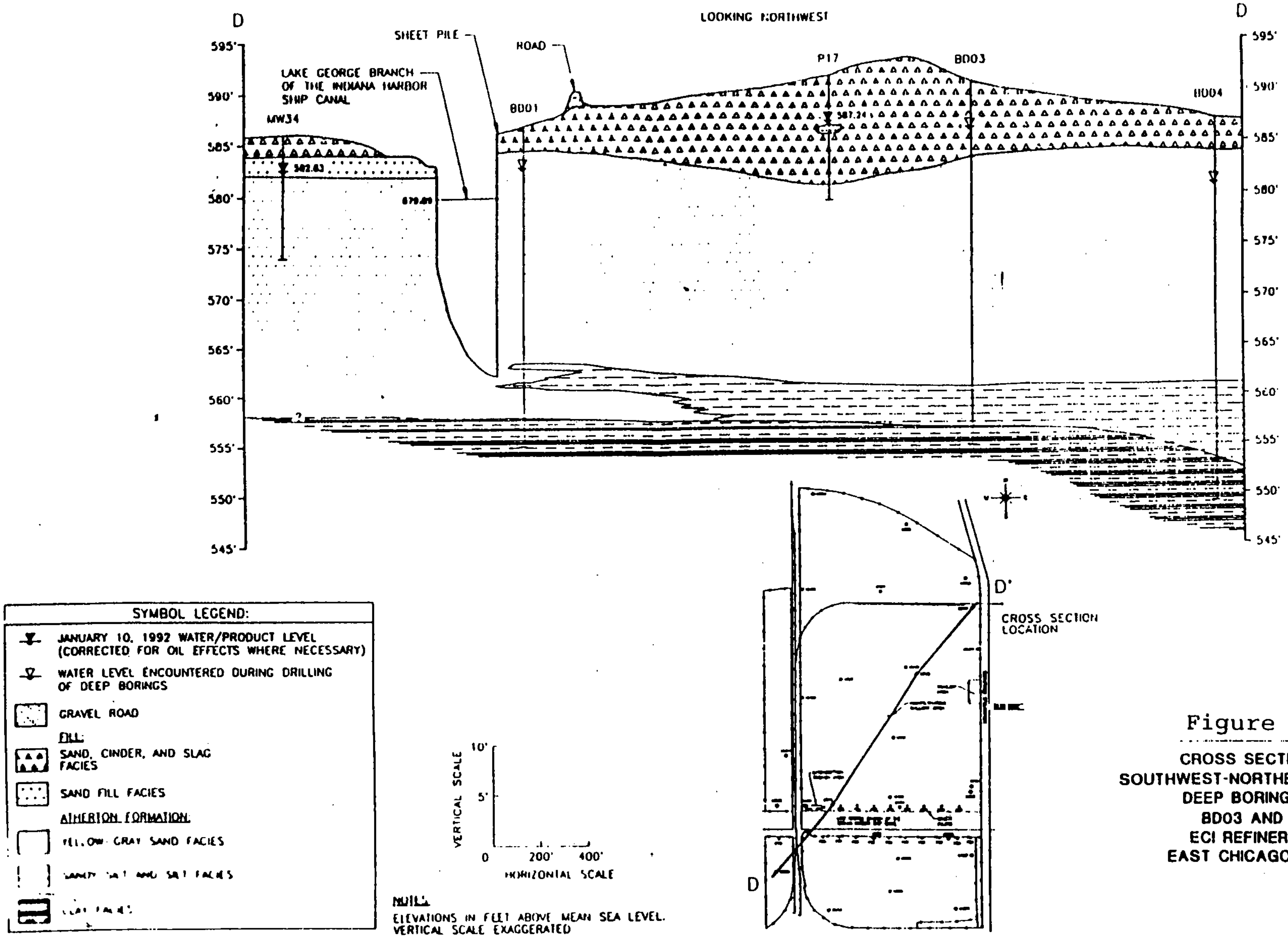
DIGITIZED FROM:
ENERGY COOPERATIVE, INC.
EAST CHICAGO REFINERY
EAST CHICAGO, INDIANA
SEPTEMBER, 1979
M&M PROTECTION CONSULTANTS
A SERVICE OF MARSH & McLENNAN
CHICAGO

Figure L-15

MONITORING WELL AND PIEZOMETER LOCATIONS
ECI REFINERY SITE
EAST CHICAGO, INDIANA

ERM

PROJECT	REPORT	DRAWN	CHECKED	DATE	APPROVED	CLIENT NAME
91110	FSP	CMM-		9/26/91		ARCO

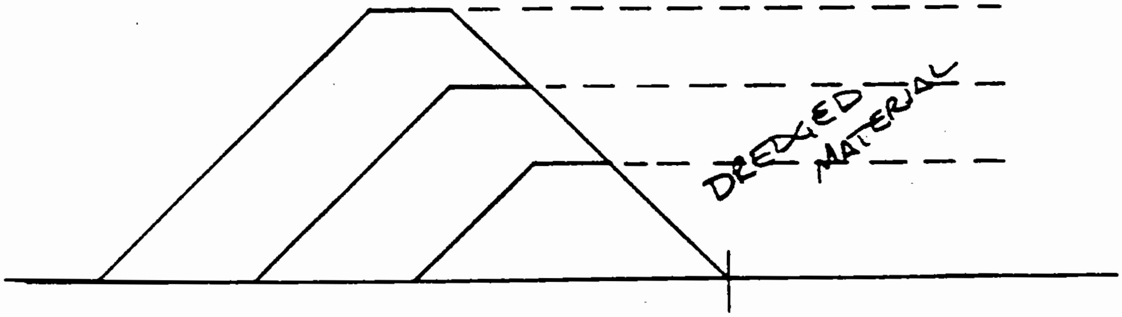


NOTES:
ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL.
VERTICAL SCALE EXAGGERATED

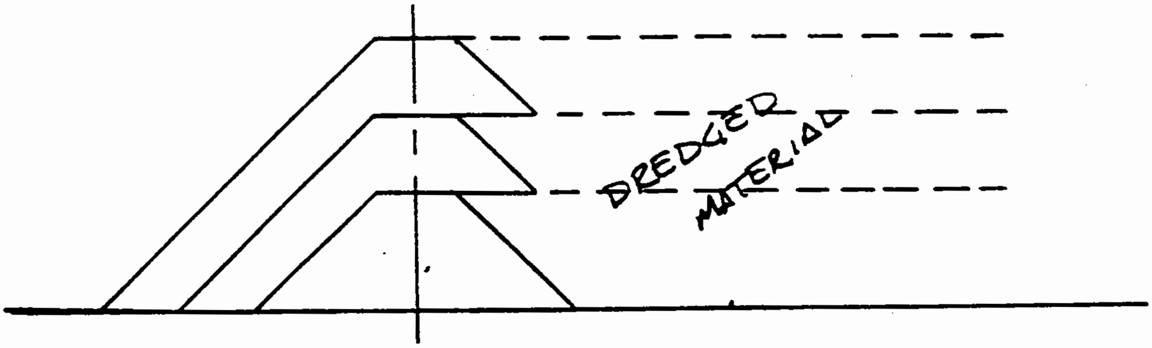
Figure L-16

CROSS SECTION D-D'
SOUTHWEST-NORTHEAST THROUGH
DEEP BORINGS BD01,
BD03 AND BD04
ECI REFINERY SITE
EAST CHICAGO, INDIANA

ERM



ALTERNATIVE #1



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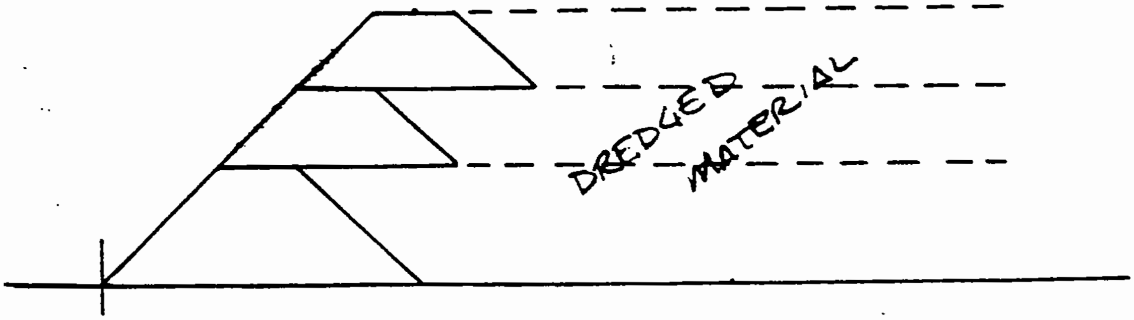


ALTERNATIVE #3

Figure L-17

Proposed Plan - ECI Site Modified Staged Construction Alternatives

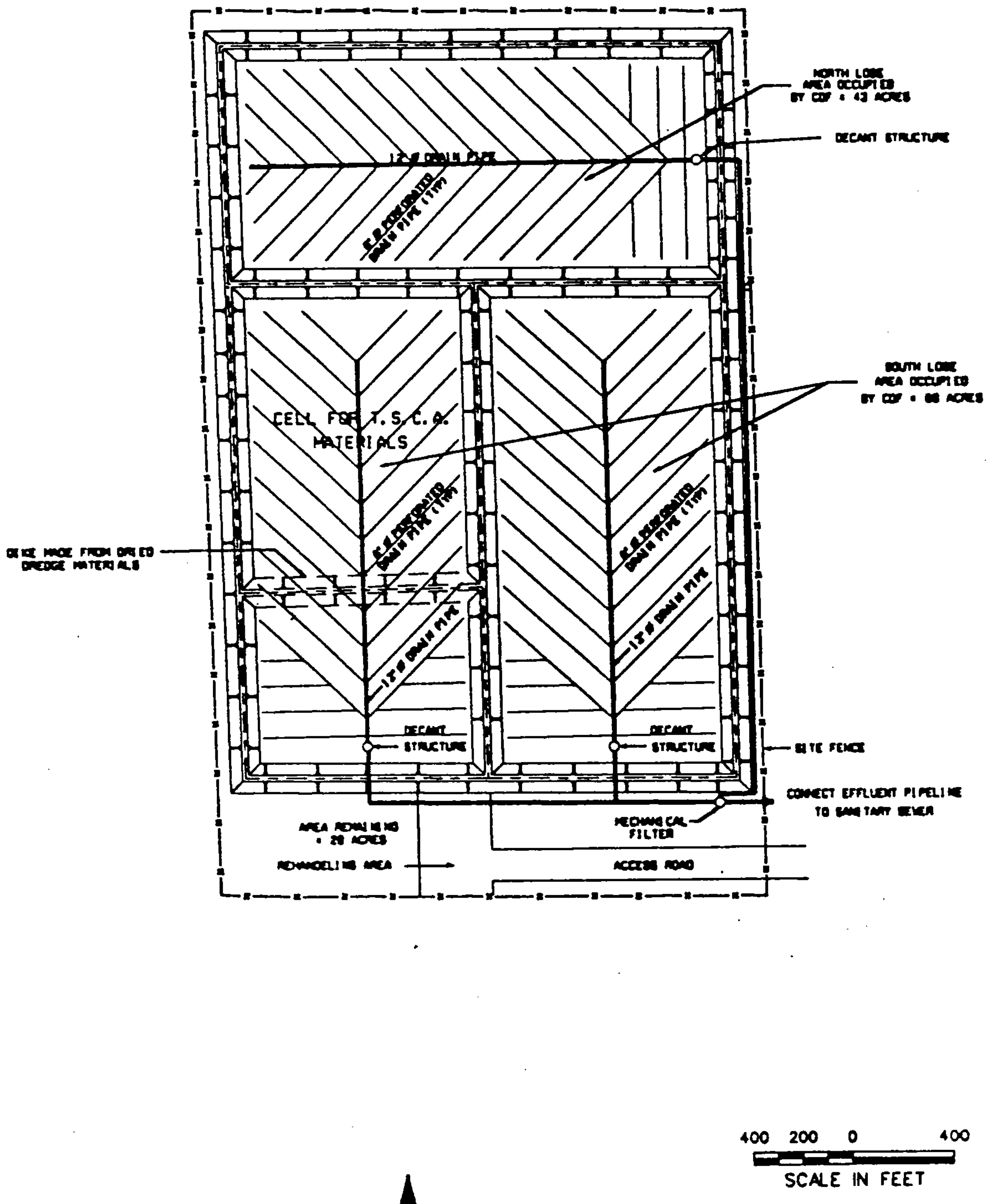
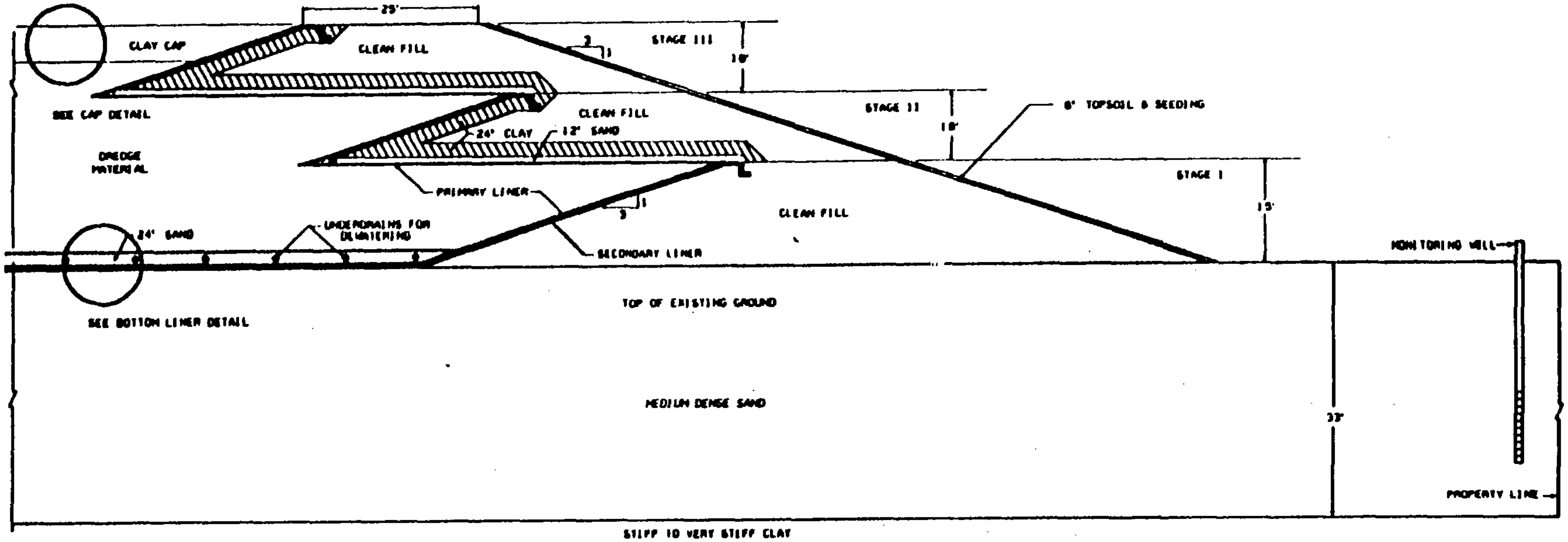


Figure L-18

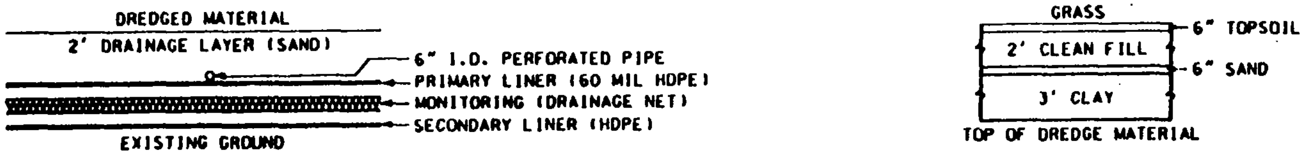
INDIANA HARBOR
CONFINED DISPOSAL FACILITY
GENERIC CLEAN UPLAND CDF SITE
PLAN VIEW
CHICAGO DISTRICT CORPS OF ENGINEERS
JUNE 1993

1059-1060



SECTION

N.T.S.



BOTTOM LINER DETAIL

N.T.S.

CAP DETAIL

N.T.S.

Figure L-19

INDIANA HARBOR
CONFINED DISPOSAL FACILITY

GENERIC CLEAN UPLAND CDF SITE
SECTION VIEW

CHICAGO DISTRICT CORPS OF ENGINEERS
JUNE 1993

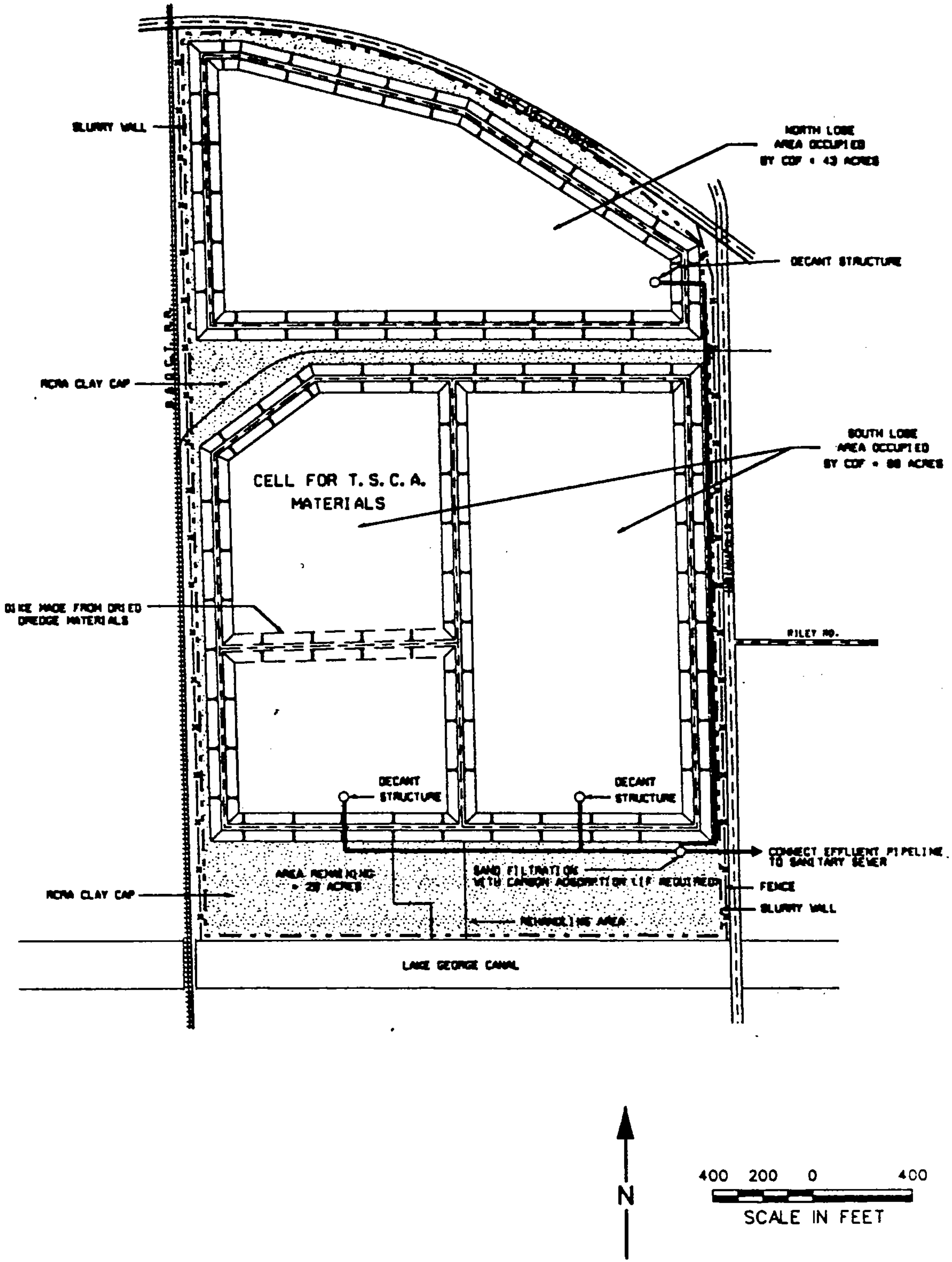
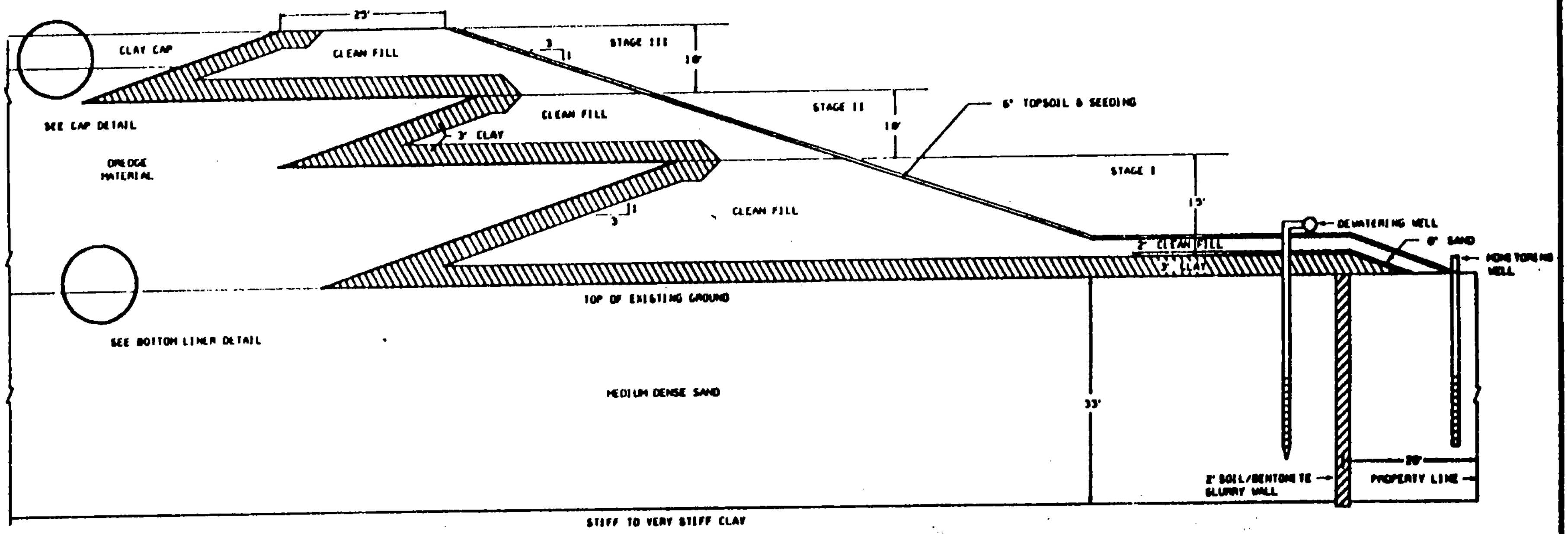


Figure L-20

INDIANA HARBOR
CONFINED DISPOSAL FACILITY
ECI SITE
RCRA CLOSURE/CORRECTIVE ACTION
WITH CDF PROJECT
PLAN VIEW
CHICAGO DISTRICT CORPS OF ENGINEERS
JUNE 1993

1041-62

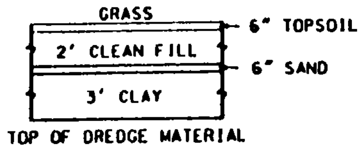


SECTION

N.T.S.

BOTTOM LINER DETAIL

N.T.S.



CAP DETAIL

N.T.S.

Figure L-21

INDIANA HARBOR
CONFINED DISPOSAL FACILITY
ECI SITE
RCRA CLOSURE/CORRECTIVE ACTION
WITH CDF PROJECT
SECTION VIEW
CHICAGO DISTRICT CORPS OF ENGINEERS
JUNE 1993

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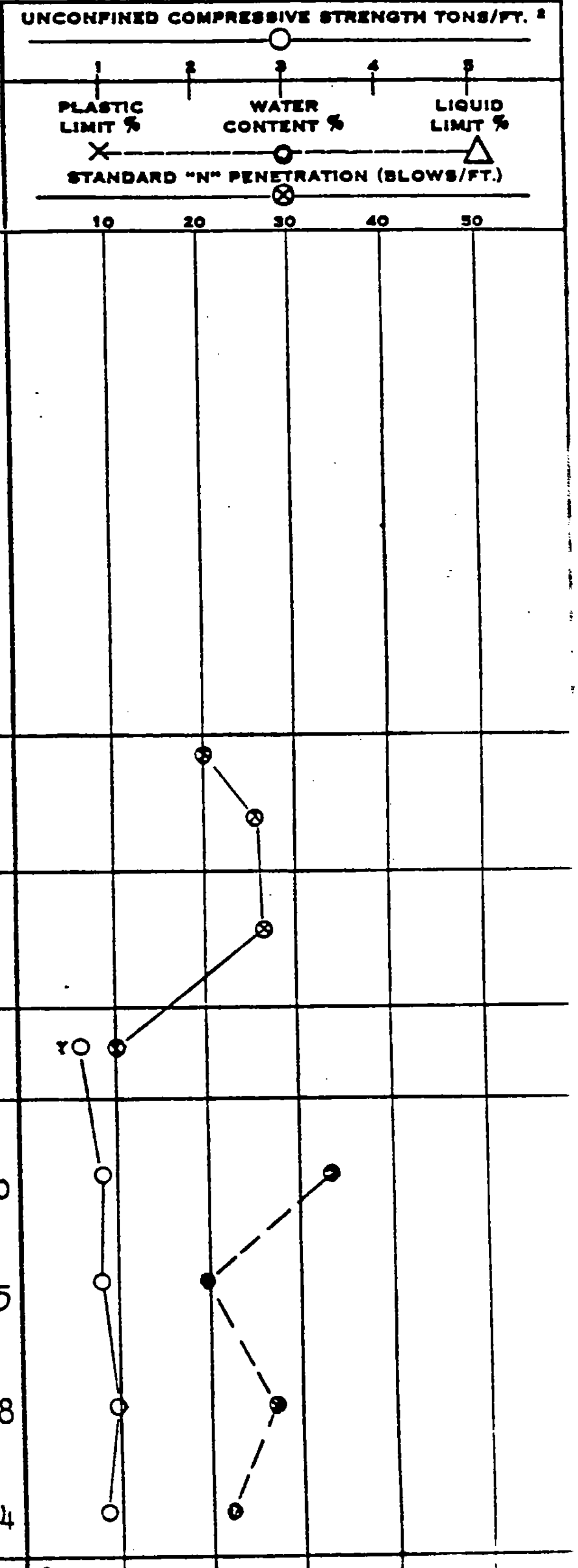
ATTACHMENT L - 1

INLAND STEEL SITE
- Boring Logs
- Laboratory Test Data

LOG OF BORING NO. [redacted]200

OWNER Inland Steel Co.	**ARCHITECT-ENGINEER**
SITE 4000' North of Indiana Harbor in Lake Michigan	**PROJECT NAME**

DEPTH / ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³
☒					Water	
10.0						
20.0						
	1	SS		—	Fine to medium sand, trace silt and gravel - brown and slightly gray - saturated - medium dense (SP)	
	2	SS		—		
).0						
	3	SS			Silty fine to medium sand, trace gravel - gray - medium dense (SP-SM)	
	4	SS			Silty clay, trace sand - gray - stiff (CL-CH)	
).0						
	5	3" ST			Silty clay, trace sand and gravel with irregular silt seams from 45' to 48' - gray - stiff (CL)	90
	6	3" ST		—		105
).0						
	7	3 ST		—		98
	8	ST				104
8.0						



Continued on page 2

1047 GY

LOG OF BORING NO. 200 [redacted] (CONTINUED)

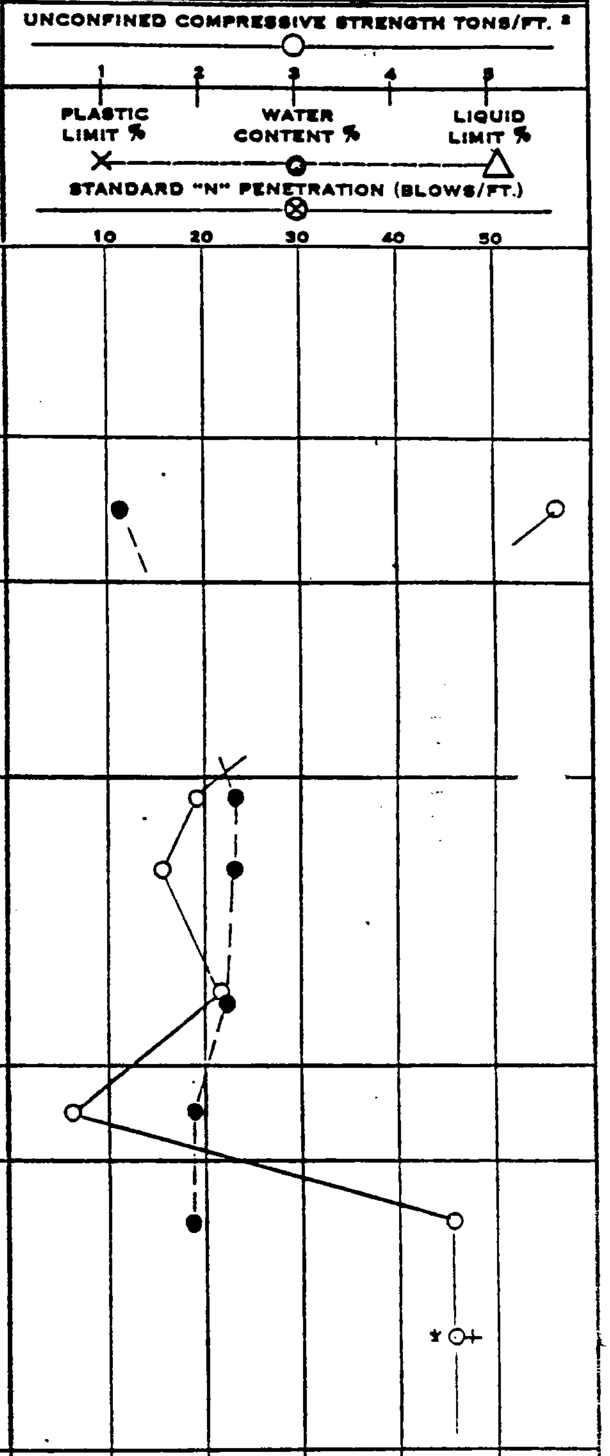
OWNER
INLAND STEEL CO.

ARCHITECT-ENGINEER

SITE 4000' NORTH OF INDIANA HARBOR IN LAKE MICHIGAN

PROJECT NAME

DEPTH / ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³
☒						
					CONTINUED FROM PAGE 1	
58.0						
60.0					SANDY AND SILTY CLAY - GRAYISH BROWN - HARD (CL-SC)	
	9	ST				124
	—	3" ST			SILTY CLAY, TRACE SAND AND GRAVEL - GRAY - STIFF TO TOUGH (CL)	
	—	3" ST				
70.0						
	—	3" ST				
	10	ST			SILTY CLAY, TRACE SAND AND GRAVEL - GRAY - TOUGH TO VERY TOUGH (CL)	104
	11	ST				102
80.0						
	12	3" ST				103
	13	ST			SILT, TRACE CLAY - GRAY - DENSE (ML)	109
90.0	14	ST			SILTY CLAY, TRACE TO SOME SAND, TRACE GRAVEL - GRAY - HARD TO HARDPAN (CL)	115
	15	SS				
100						
					CONTINUED ON PAGE 3	



2 OF 3

LOG OF BORING NO. [redacted] (CONTINUED)

OWNER INLAND STEEL CO.	ARCHITECT-ENGINEER
SITE 4000' NORTH OF INDIANA HARBOR IN LAKE MICHIGAN	PROJECT NAME

UNCONFINED COMPRESSIVE STRENGTH TONS/FT.² ○ — 1, 2, 3, 4, 5

PLASTIC LIMIT % × — WATER CONTENT % ⊖ — LIQUID LIMIT % △

STANDARD "N" PENETRATION (BLOWS/FT.) ⊗ — 10, 20, 30, 40, 50

DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³	
					CONTINUED FROM PAGE 2		
100	16	ST		—	SILTY CLAY, TRACE TO SOME SAND, AND GRAVEL - GRAY - HARDPAN (CL)	126	● ×○+
	17	SS					
110	18	SS					
					HARDPAN & LIMESTONE GRAVEL		
114.5	19	BB			LIMESTONE		
					END OF BORING		
					REFUSAL TO ST AT 91', 101'		
					40' OF 4" CASING		

WATER LEVEL OBSERVATIONS	
W.L.	W.S. OR W.D.
W.L.	B.C.R. A.C.R.
W.L.	

SOIL TESTING SERVICES
INC.
111 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS

BORING STARTED 3/26/68	
BORING COMPLETED 3/27/68	
RIG 82	FOREMAN [illegible]
DRAWN MP	APPROVED JBA
JOB # 11757	SHEET 3 OF 3

1969-70

LOG OF BORING NO. [redacted] 201

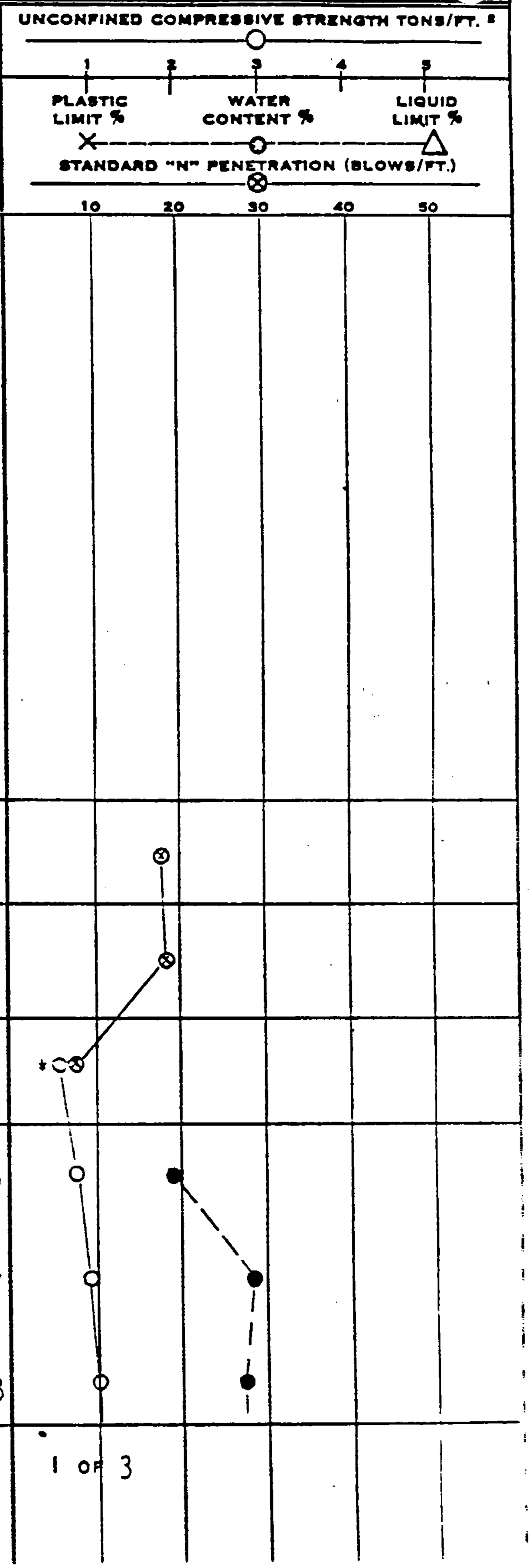
OWNER
Inland Steel Co.

ARCHITECT - ENGINEER

SITE 4000' North of Indiana Harbor
in Lake Michigan

PROJECT NAME

DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
☒					SURFACE ELEVATION	
					Water	
10.0						
20.0						
30.0	1	SS			Fine to medium sand, trace sand - grayish brown - med. dense - saturated (SP)	
	2	SS			Silty fine sand, trace coarse sand and gravel - gray - saturated - medium dense (SM)	
40.0	3	SS			Silty clay, trace sand and gravel - gray - soft (CL-CH)	
	4	ST			Silty clay, trace sand and gravel - gray - stiff (CL)	108
50.0	5	ST				97
	6	ST				98
58.0						



Continued on page 2

1 of 3

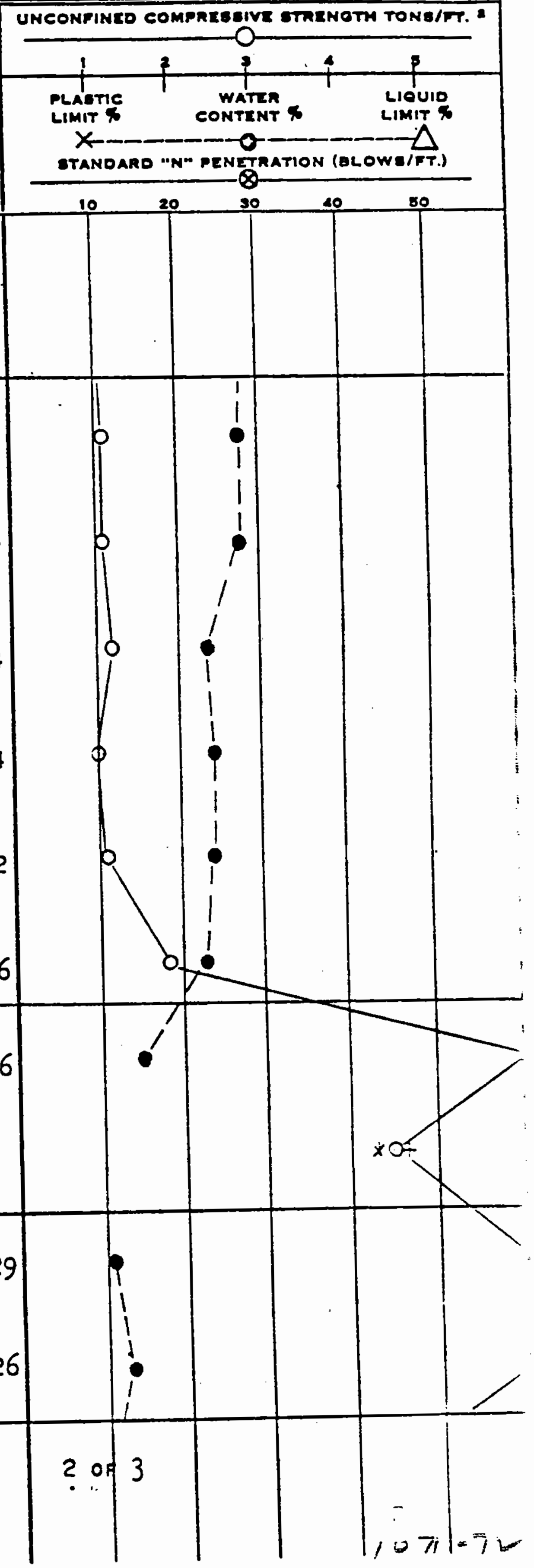
1

4

LOG OF BORING NO. [redacted] (CONTINUED)

OWNER Inland Steel Co.	ARCHITECT-ENGINEER
SITE 4000' North of Indiana Harbor in Lake Michigan	PROJECT NAME

DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³
☒						
					Continued from page 1	
58.0					Silty clay, trace sand and gravel - gray - tough	
60.0						
	7	ST				97
	8	ST				97
70.0						
	9	ST				104
	10	ST				104
80.0						
	11	ST				102
	12	ST				106
90.0					Silty clay, trace to some sand, trace gravel - gray - hard to hardpan (CL)	
	13	ST				126
	14	SS				
100					Silty clay, trace to some sand, trace gravel - gray - hardpan (CL)	
	15	ST				129
	15	ST				126
103						
					Continued on page 3	



2 of 3

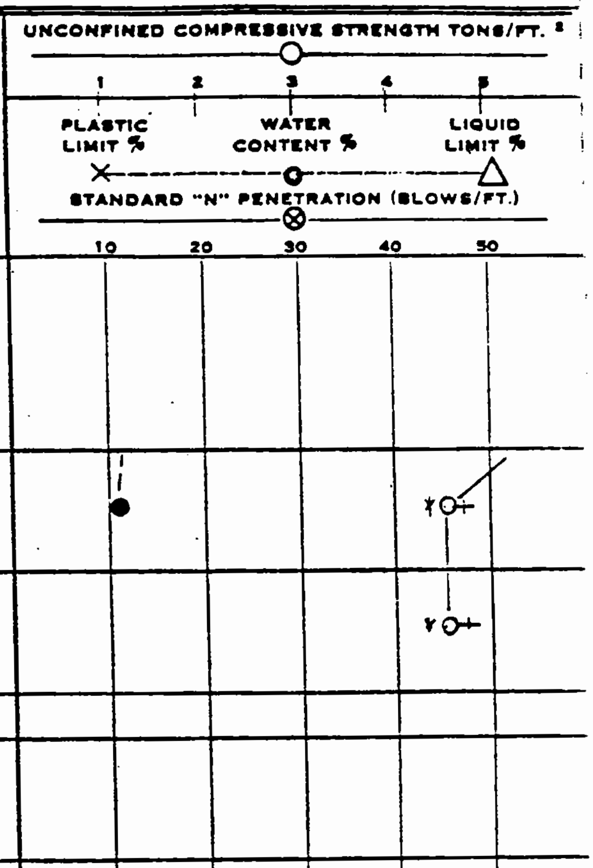
1071-72

20'

LOG OF BORING NO. 2

OWNER Inland Steel Co.	**ARCHITECT-ENGINEER**
SITE 4000' North of Indiana Harbor in Lake Michigan	**PROJECT NAME**

DEPTH	ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³
☒						Continued from page 2	
105							
110		17	ST			Silt, some very fine sand, trace clay - light gray and light brown = moist - very dense (ML)	
		18	SS			Clayey silt, some sand and gravel - gray - very dense (ML-CL)	
120						Boulder, clay and silt	
		19	DB			Limestone	
125						End of Boring 45'. of 4" casing	



*Calibrated Penetrometer

WATER LEVEL OBSERVATIONS		
W.L.		W.S. OR W.D.
W.L.	B.C.R.	A.C.R.
W.L.	+2.25' I.E. above water surface BCR	

SOIL TESTING SERVICES
INC.
111 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS

BORING STARTED	3/25/[illegible]		
BORING COMPLETED	3/25[illegible]		
RIG	82	FOREMAN	[illegible]
DRAWN	MP	APPROVED	JBA
JOB #	11757	SHEET	3 of 3

LOG OF BORING NO. 202

OWNER
Inland Steel Co.

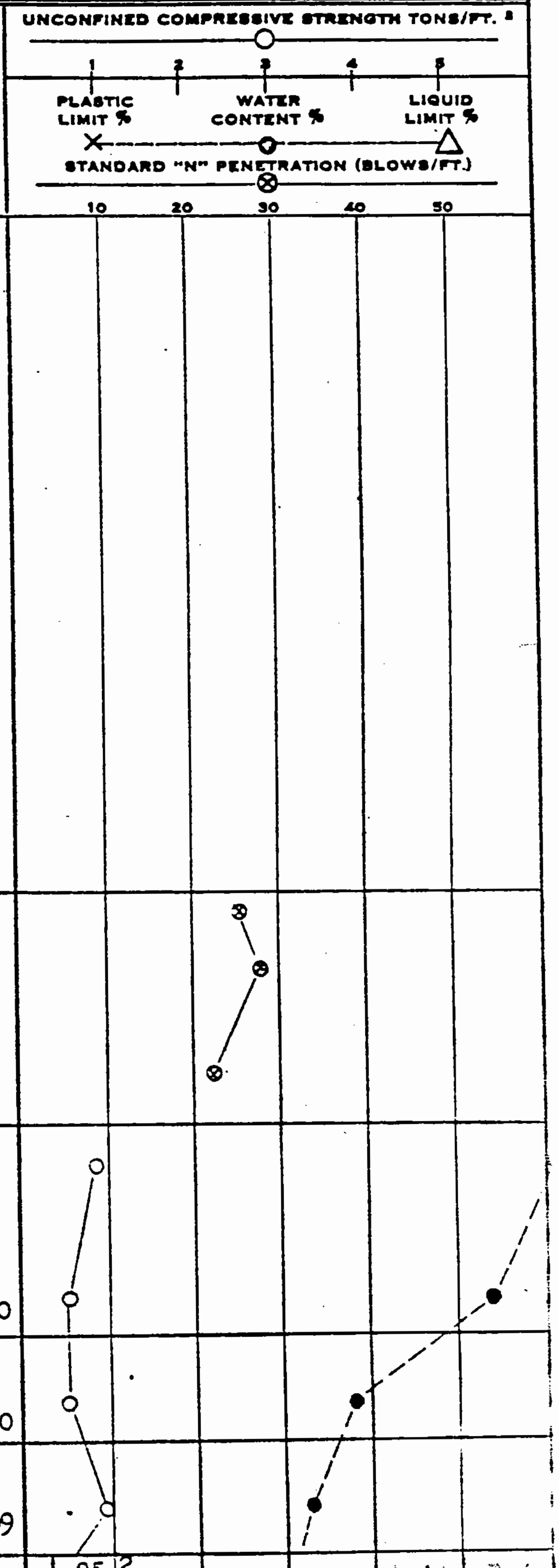
ARCHITECT - ENGINEER

SITE 4000' North of Indiana Harbor
in Lake Michigan

PROJECT NAME

DEPTH / ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³
☒					Water	
10.0						
20.0						
30.0						
	1	SS			Fine to coarse sand, trace silt and gravel - gray - medium dense - saturated (SP-SW)	
	2	SS				
40.0	—					
	3	3" ST			Organic clay - dark gray and dark brown - soft (OH)	53
50.0	4	3" ST				70
	5	3" ST			Silty clay, trace shells and decayed matter - gray and slightly dark gray - soft (CL-OL)	80
60.0	6	3" ST			Silty clay, with fat clay seams - dark gray - stiff (CL)	89
63.5						

Continued on page 2

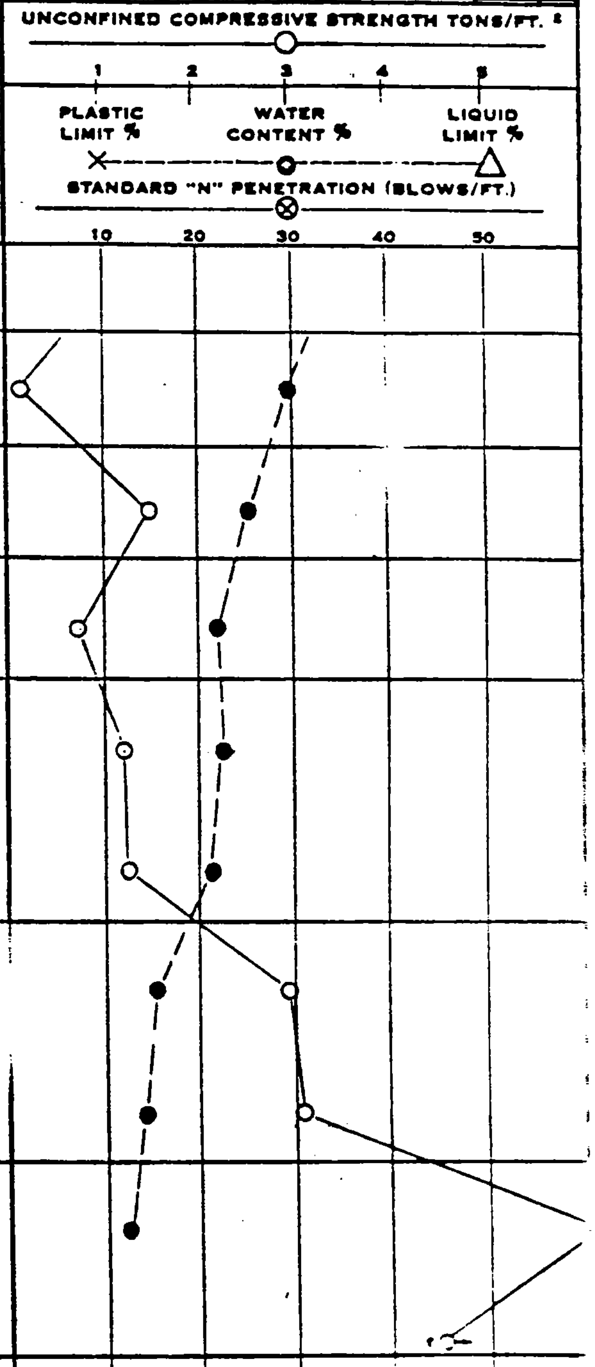


20

LOG OF BORING NO. [redacted] (CONTINUED)

OWNER INLAND STEEL CO.	**ARCHITECT-ENGINEER**
SITE 4000' NORTH OF INDIANA HARBOR IN LAKE MICHIGAN	**PROJECT NAME**

DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
☒					SURFACE ELEVATION	
					CONTINUED FROM PAGE 1	
63.5	7	3" ST			SILTY CLAY - GRAY - SOFT (CL-CH)	87
70.0	8	3 ST			SILTY CLAY, TRACE SAND AND GRAVEL - GRAY - TOUGH (CL-CH)	101
	9	3" ST			SILTY CLAY, TRACE SAND AND GRAVEL - GRAY - STIFF (CL)	103
80.0	10	ST			SILTY CLAY, TRACE SAND AND GRAVEL - GRAY - TOUGH (CL)	106
	11	3" ST				106
90.0	12	3 ST			SILTY CLAY, TRACE TO SOME SAND, TRACE GRAVEL - GRAY - VERY TOUGH TO HARD (CL)	125 116
	13	ST				121
100	14	ST			SILTY CLAY, SOME SAND, TRACE GRAVEL - GRAY - HARD PAN (CL)	128
106	15	SS				
					END OF BORING 45' OF 4" CASING USED	



CALIBRATED PENETROMETER

WATER LEVEL OBSERVATIONS		
W.L.	W.S. OR W.D.	
W.L.	B.C.R.	A.C.R.
W.L.		

SOIL TESTING SERVICES
INC.
111 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS

BORING STARTED 3/27	
BORING COMPLETED 3/27	
RIG 82	FOREMAN [illegible]
DRAWN MP	APPROVED JBA
JOB # 11757	SHEET OF 2

LOG OF BORING NO. [redacted] 203

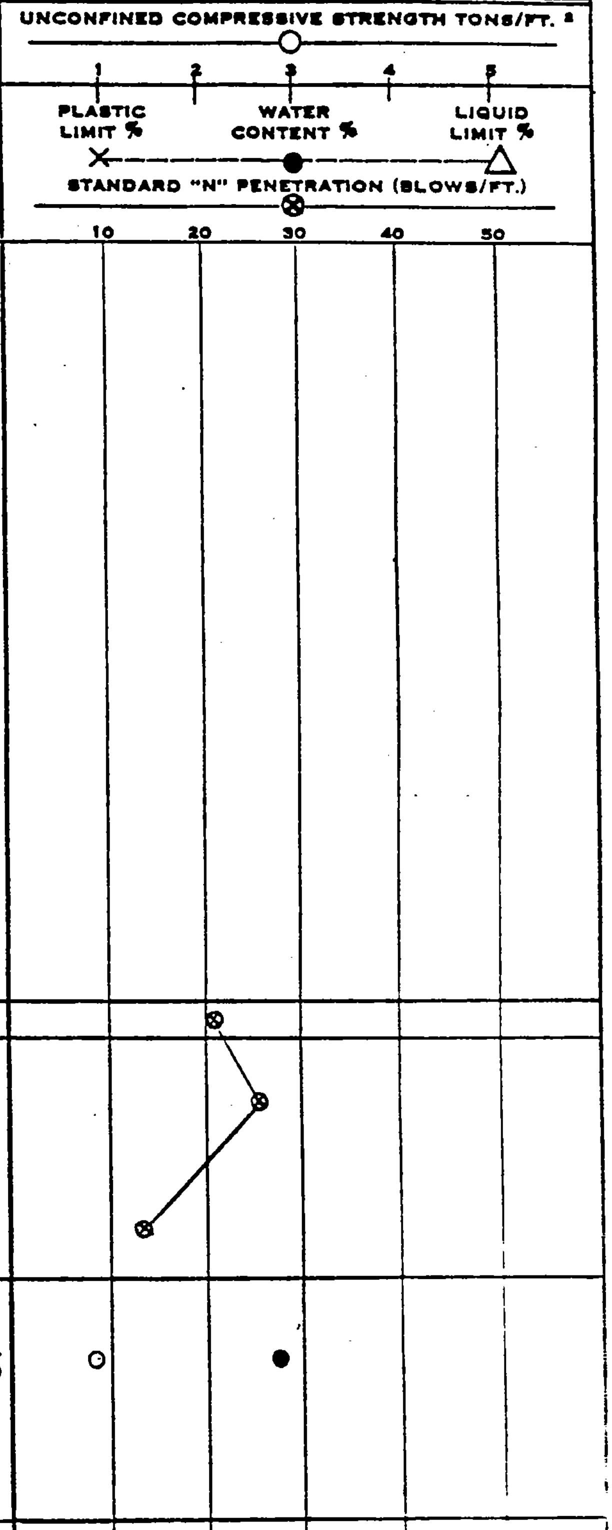
OWNER
Inland Steel Co.

ARCHITECT-ENGINEER

SITE 4000' North of Indiana Harbor
in Lake Michigan

PROJECT NAME

DEPTH / ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³
☒						
					WATER	
10.0						
20.0						
30.0						
	1	SS			"A"	
	2	SS			SILTY FINE SAND - GRAY - MEDIUM DENSE - SATURATED (SM)	
40.0						
	3	SS		—		
					SILTY CLAY, TRACE SAND AND GRAVEL - GRAY - STIFF (CL)	
	4	3" ST		—		96
50.0						
53.0	5	3" ST				



CONTINUED ON PAGE 2

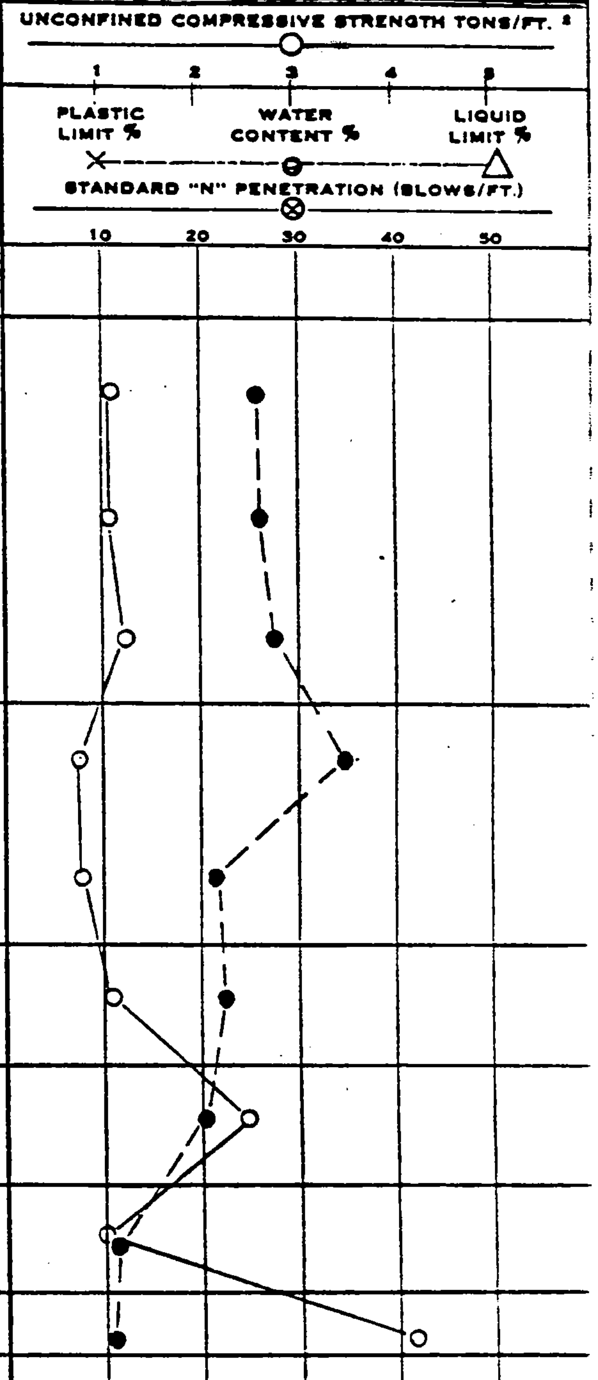
1 OF 2

203

LOG OF BORING NO. [redacted] (CONTINUED)

OWNER Inland Steel Co.	ARCHITECT-ENGINEER
SITE 4000' North of Indiana Harbor in Lake Michigan	PROJECT NAME

DEPTH / ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
☒					SURFACE ELEVATION	
					Continued from page 1	
53.0					Silty clay, trace sand and gravel - gray - tough (CL)	
	6	3" ST				99
60.0	7	3" ST				97
	8	3" ST				100
70.0	9	3" ST			Silty clay, trace sand and gravel - gray - stiff (CL-CH)	
	10	3" ST				108
80.0	1	3" ST			Silty clay, trace sand and gravel - gray - tough (CL)	105
	12	3" ST			Silty clay, trace sand and gravel - gray - very tough (CL)	110
-0.0	13	3 ST			Silty clay, trace to some sand, trace gravel with sand seams - reddish brown and light gray - tough (CL)	
96.0	14	ST			Silty clay, trace to some sand, trace gravel - gray - hard (CL)	



End of Boring
50' of 4" Casing

*Calibrated Penetrometer

"A": Fine to medium sand, trace tosome silt - grayish brown - medium dense - saturated (SP)

WATER LEVEL OBSERVATIONS		
W.L.	W.S. OR W.D.	
W.L.	B.C.R.	A.C.R.
W.L.		

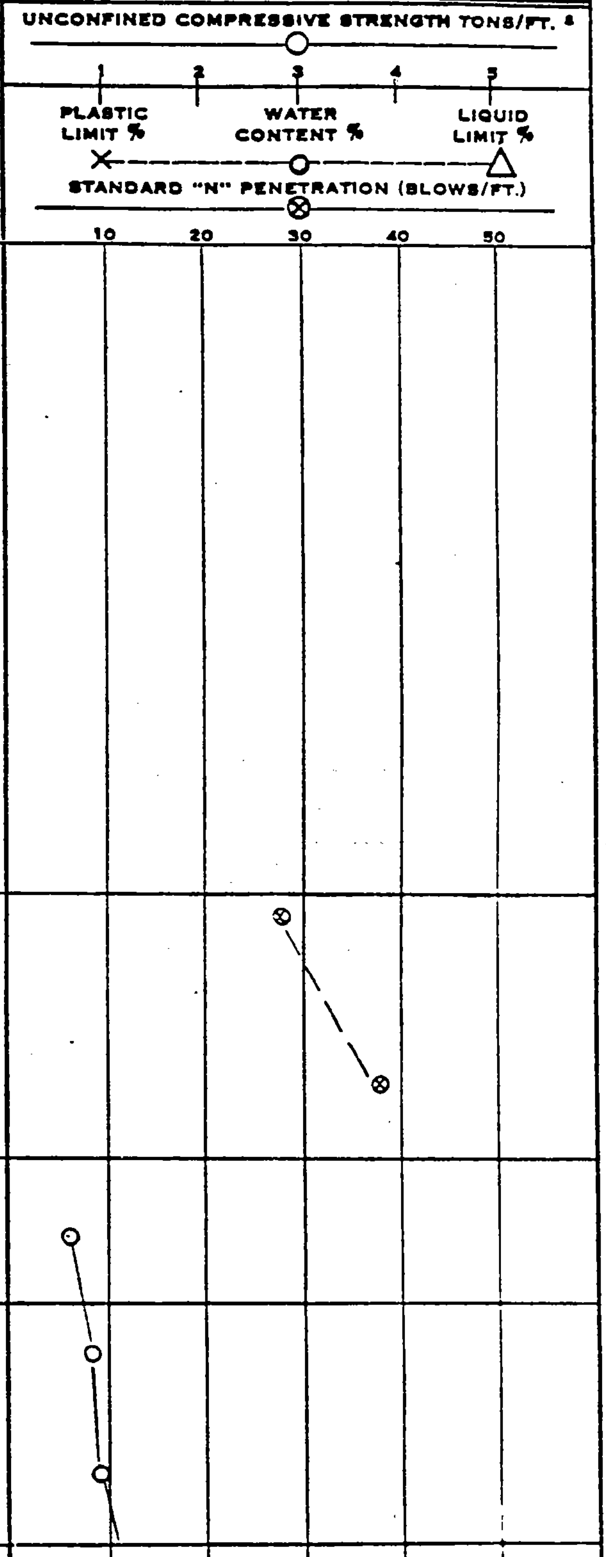
SOIL TESTING SERVICES
INC.
111 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS

BORING STARTED 4/6/6	
BORING COMPLETED	
RIG 82	FOREMAN MOULDS
DRAWN MP	APPROVED BA
JOB # 11757	SHEET 2 OF 2

LOG OF BORING NO. [redacted] 204

OWNER Inland Steel Company	**ARCHITECT-ENGINEER**
SITE 4000' North of Indiana Harbor in Lake Michigan	**PROJECT NAME**

DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
☒					SURFACE ELEVATION	
					Water	
10.0						
20.0						
	1	SS			Fine to medium sand, trace silt and gravel - brown and gray - dense - saturated (SP)	
30.0						
	2	SS				
40.0	3	3" ST			Silty clay, trace sand and gravel - gray - soft (CL)	
	4	3" ST			Silty clay, trace sand and gravel - gray - stiff (CL)	
50.0	5	3" ST				
54.0					Continued on following page.	



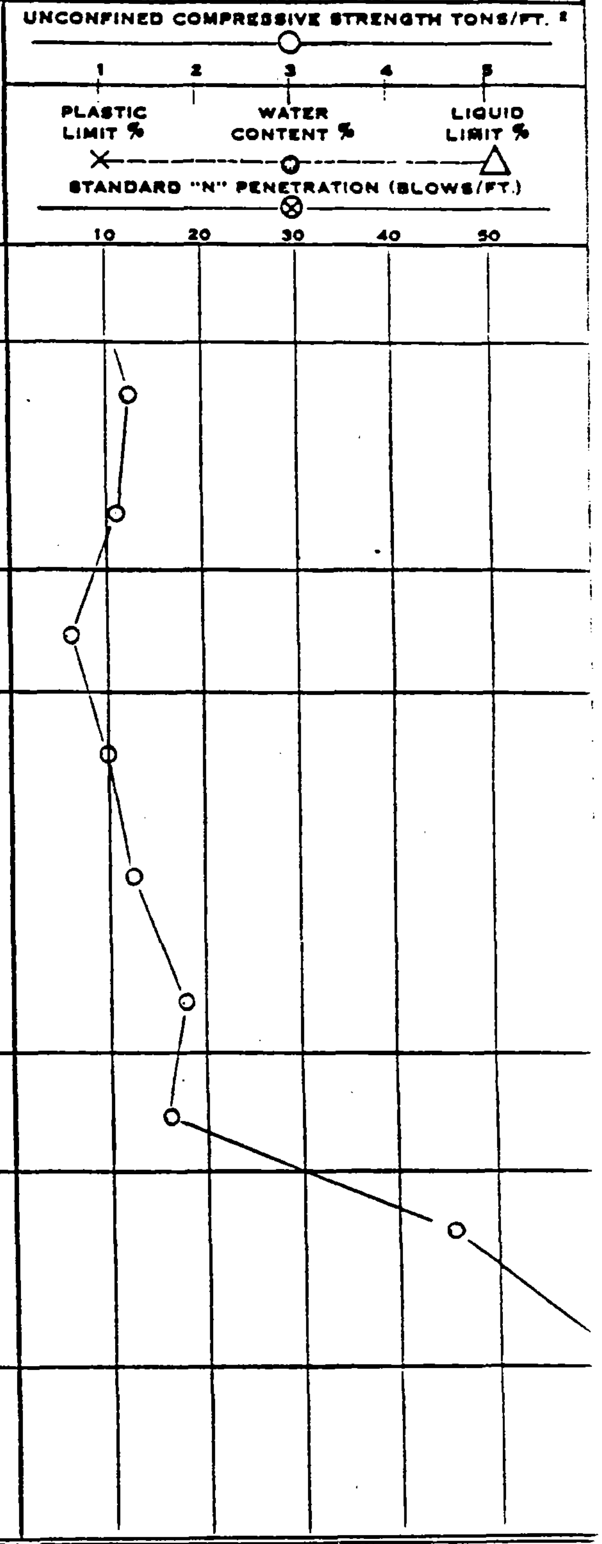
Sheet 1 of 2

1071 78

LOG OF BORING NO. [redacted] (CONTINUED)

OWNER Inland Steel Company	**ARCHITECT - ENGINEER**
SITE 4000' North of Indiana Harbor in Lake Michigan	**PROJECT NAME**

DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³
☒					Continued from previous page.	
54.0	6	3" ST			Silty clay, trace sand and gravel - gray - tough (CL)	
60.0	7	3" ST				
	8	3" ST			Silty clay, trace sand and gravel - gray - soft (CL)	
70.0	9	3" ST			Silty clay, trace sand and gravel - gray - tough (CL)	
	10	3" ST				
80.0	11	3" ST				
	12	3" ST			Silty clay, trace sand and gravel - gray - very tough (CL)	
90.0	13	2" ST			Silty clay, trace to some sand, trace gravel - gray - hard to hardpan (CL)	123
96.5	14	2" ST			End of Boring. 40' of 4" Casing Used.	



WATER LEVEL OBSERVATIONS		
W.L.		W.S. OR W.D.
W.L.	B.C.R.	A.C.R.
W.L.		

SOIL TESTING SERVICES
INC.
111 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS

BORING STARTED 4-9-[illegible]	
BORING COMPLETED 4-9-[illegible]	
RIG 82	FOREMAN MOULD
DRAWN MP	APPROVED CNB
JOB # 11757	SHEET 2 OF 2

LOG OF BORING NO. (Ceil 203)

OWNER Inland Steel Co.

ARCHITECT-ENGINEER

SITE Indiana Harbor Works

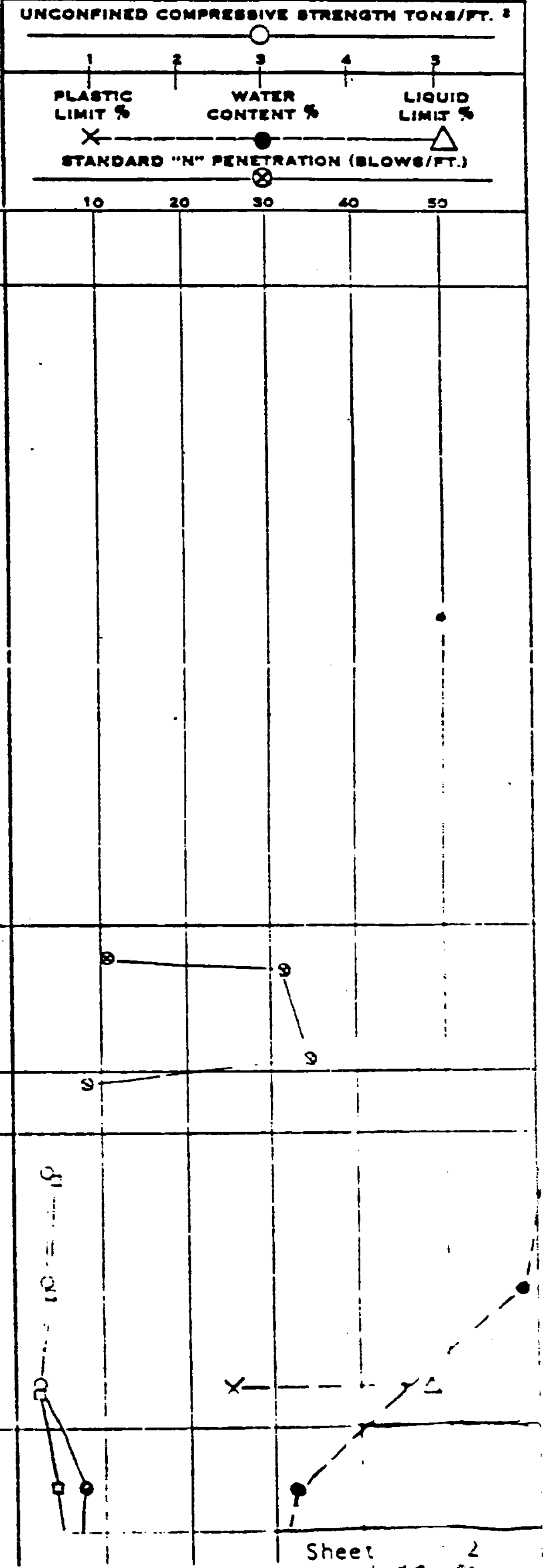
PROJECT NAME Cofferdam Extension - Plant 2.

Water Elevation: 579.6

SURFACE ELEVATION 581.91 USGS

ELEV. USGS	DEPTH	SAMPLE NO.	TYPE SAMPLE	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
		1	RB WO	Three inch asphalt surface over slag with some sand and gravel	
	10.0		RB	Limestone Fill 3/4" to 12" size.	
	20.0				
			RB		
	30.0				
47.9		2	SS WS	Fine sand, trace gravel - brown and gray - wet - medium dense to dense (SP)	
	40.0				
540.9		3 3A	SS	Sand and limestone gravel, trace silt-lt.gray-wet (GP)	
37.9		4	3" ST	Organic clay, trace shells - dark gray - soft (OH)	63
	50.0				
		5	3" ST		66
		6	3" ST	Organic content = 8.8%	73
3.9	60.0			Clayey, organic silt, trace shale - gray to dark gray - stiff (CL-OH)	
		7	3" ST		84
18.9	63.0				

(Cont. on Sheet 2)



Sheet 2

LOG OF BORING NO. ~~2-1~~ 324 (Cont.)

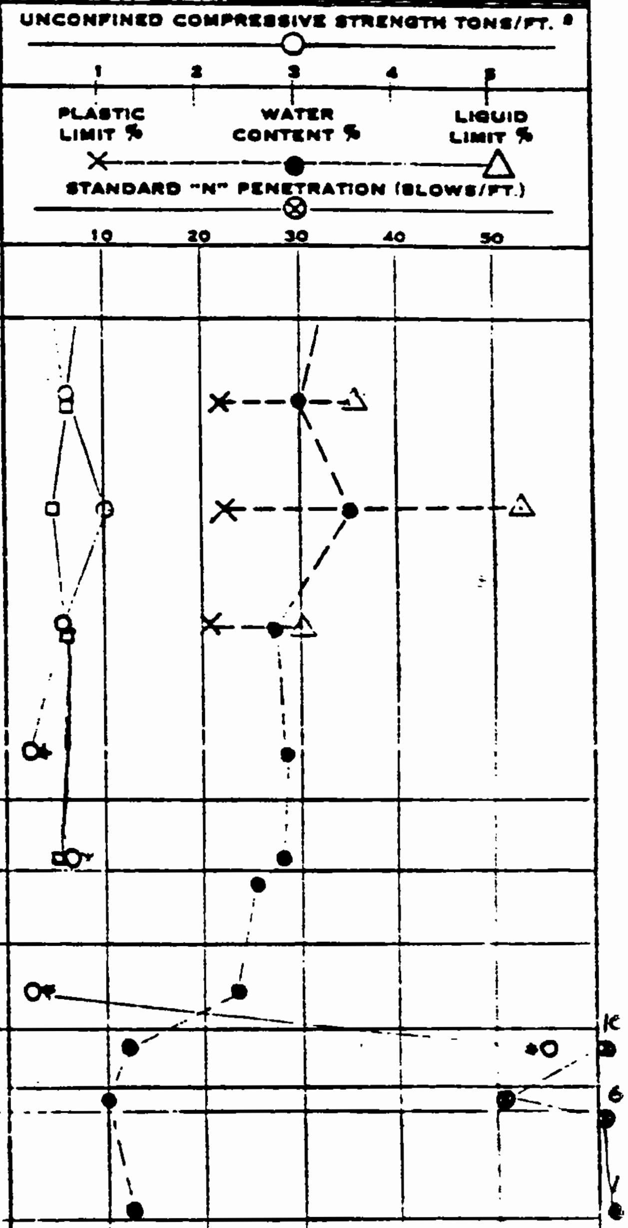
OWNER Inland Steel Co.

ARCHITECT-ENGINEER

SITE Indiana Harbor Works

PROJECT NAME Cofferdam Extension - Plant 2.

	DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL *	UNIT DRY WT. LBS./FT.³
	☒					SURFACE ELEVATION	
						(Cont. from Sheet 1)	
18.9	63.0						
		8	3" ST			Organic silty clay - gray to gray-brown - stiff (CL to CL-ML) Organic content = 8.4 to 10.6%	92
	70.0						
		9	3" ST				89
		10	3" ST				96
	80.0						
		11	3" ST				
498.9						Silty and clayey fine sand - medium dark gray (SC)	
95.9		12	3"				98
		12A	ST			Fine sand, tr. silt - med. dk. gray - moist to wet (SP)	98
92.9	90.0					Slightly organic silty clay - medium dark gray - soft (CL-ML)	
		13	ST				
489.4		14	SS			Silty sandy clay, trace gravel - gray - hard (CL-SC)	
86.9 485.9		15	SS			"A"	
						Clayey silt, trace fine sand and gravel - gray - hard - moist (ML-CL)	
481.4	100. 100.5	16	SS				
						End of Boring	



*Calibrated Penetrometer

⊐ = Torvane

"A": Fine to medium sand, trace gravel and shells, clay seams - dense - gray (SP)

45' of 4" casing used.

Note: Consolidation tests performed on Samples 6, 8 and 10.
Triaxial Compression tests performed on Samples 8 and 9.

WATER LEVEL OBSERVATIONS		
W.L.	W.S. OR W.D.	
W.L.	B.C.R.	A.C.R.
W.L.		

SOIL TESTING SERVICES
INC.
111 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS

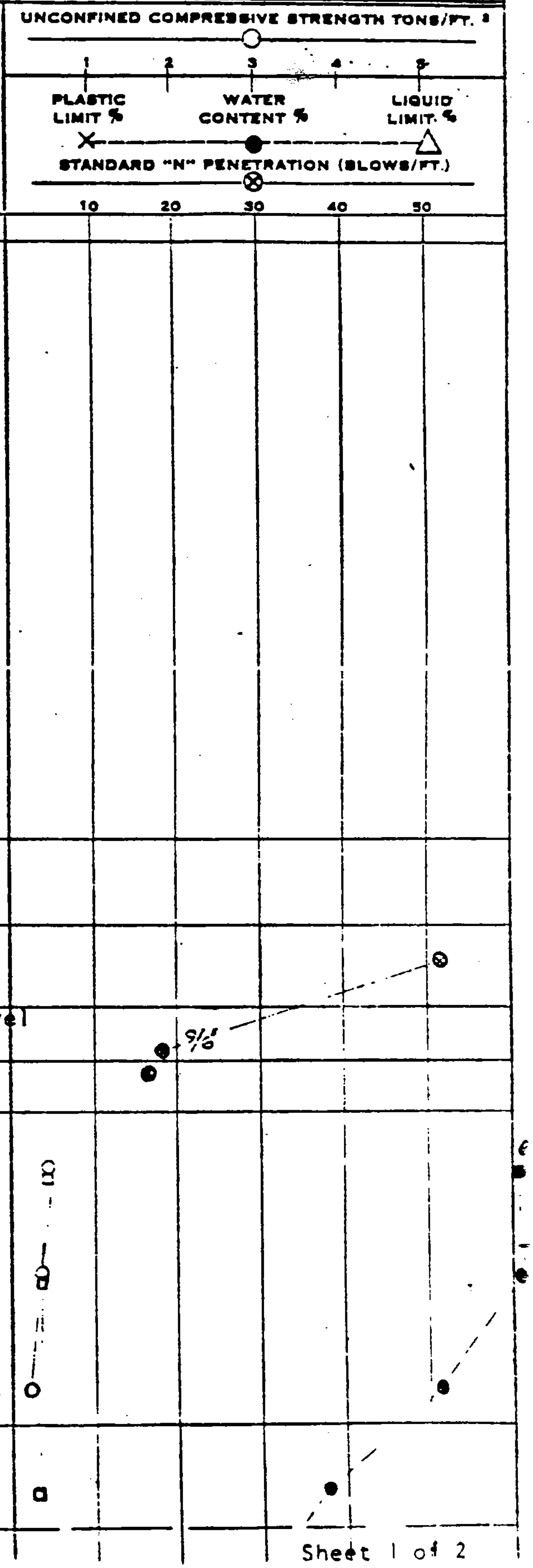
BORING STARTED	
BORING COMPLETED	
RIG 3	FOREMAN
DRAWN [illegible]	APP'D
JOB # 14[illegible]	SHEET

LOG OF BORING NO. 322 (Cell 198)

OWNER Inland Steel Co.	**ARCHITECT-ENGINEER**
SITE Indiana Harbor Works	**PROJECT NAME** Cofferdam Extension - Plant 2.

ELEV.
GS
53
49
545
2.5
540
25

DEPTH	ELEVATION	SAMPLE NO.	TYPE SAMPLE	SAMPLE DIST.	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
☒						SURFACE ELEVATION 583.0' USGS	
			RB			2" asphalt surface over slag Fill	
10.0 20.0 30.0			RB			Crushed limestone Fill	
			RB			Sand and limestone gravel	
		1	SS			Fine to medium sand - brown - dense - wet (SP)	
40.0		2	SS			Fine to med.sand & limestone gravel brown & lt.gray - med.dense wet (GP)	
		2A				Fine sand, tr.to some silt - gray - med.dense - wet (SP)	
		3	3" ST			Organic clay, trace shells - dark gray - soft (OH)	63
50.0		4	3" ST				56
		5	3" ST				71
60.0						Silty clay, moderately organic, trace shells & decayed roots - gray - soft to stiff (CL-ML)	
		6	3" ST				83
63.0							
						(Cont. on Sheet 2)	



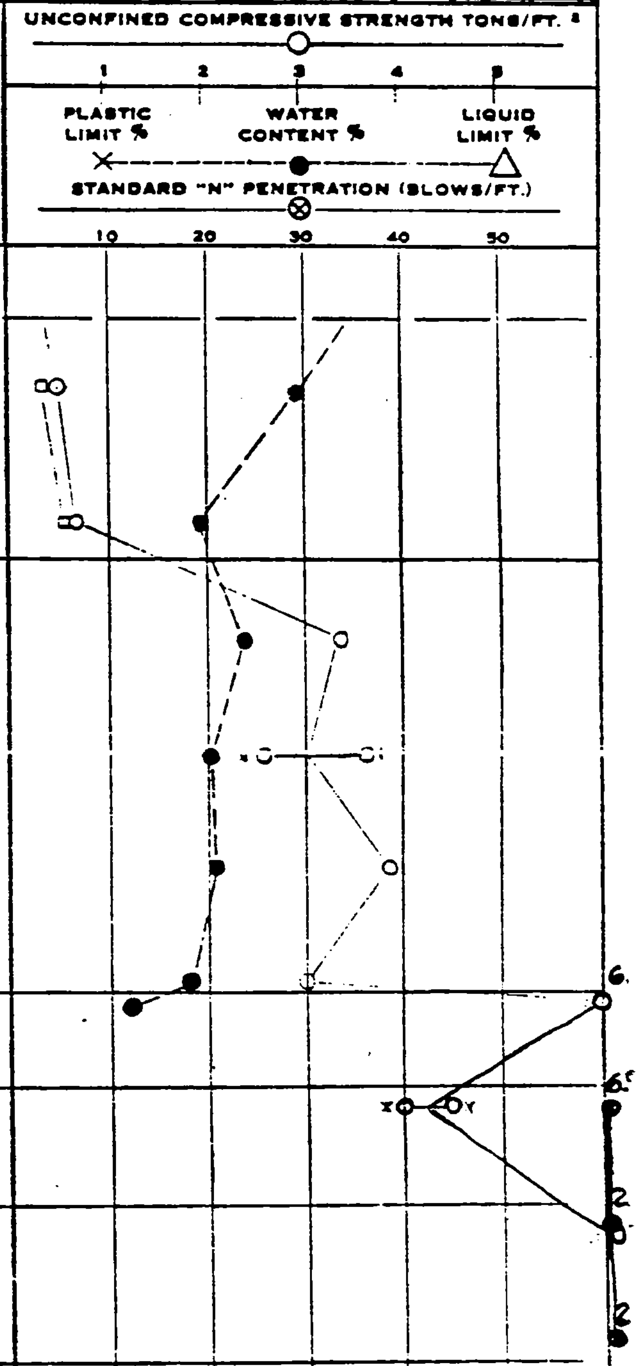
Sheet 1 of 2

325

LOG OF BORING NO. ~~B-2~~ (Cell 198) (Cont.)

OWNER Inland Steel Co.	**ARCHITECT-ENGINEER**
SITE Indiana Harbor Works	**PROJECT NAME** Cofferdam Extension - Plant 2.

	DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	DESCRIPTION OF MATERIAL * SURFACE ELEVATION	UNIT DRY WT. LBS./FT.³
				(Cont. from Sheet 1)	
	63.0				
		7	3" ST	Silty clay, moderately organic, trace shells and decayed roots - gray - soft to stiff (CL-ML)	94
	70.0				
10		8	3" ST		105
		9	3" ST	Silty clay, trace sand and gravel - brown and gray - very tough and hard (CL)	104
	80.0				
		10	3" P ST		106
		11	2" ST		109
	90.0				
92		12	3" ST		115
		12A		Silty clay, trace to some sand, trace gravel - gray - hard (CL)	
88		13	SS	Silty clay, trace sand - hard (CL)	
83	100.0				
		14	SS	Silty clay, trace to some sand, trace gravel - gray - very hard (CL)	
476.5	106.5	15	SS		
				End of Boring 45' of 4" casing used.	



*Calibrated Penetrometer
☐= Torvane

WATER LEVEL OBSERVATIONS			
W.L.	W.S. OR W.D.		
W.L.	B.C.R.		A.C.R.
W.L.			

SOIL TESTING SERVICES INC.
111 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS

BORING STARTED 6-17-71	
BORING COMPLETED 6-18-71	
RIG 3	FOREMAN
DRAWN MD	APPROVED
JOB # 14647	SHEET 2 2

LOG OF BORING NO. [redacted] [illegible] 203/

OWNER Inland Steel Co.

ARCHITECT-ENGINEER

SITE Indiana Harbor Works

PROJECT NAME Cofferdam Extension - Plant 2.

UNCONFINED COMPRESSIVE STRENGTH TONS/FT.² ○ 1 2 3 4 5

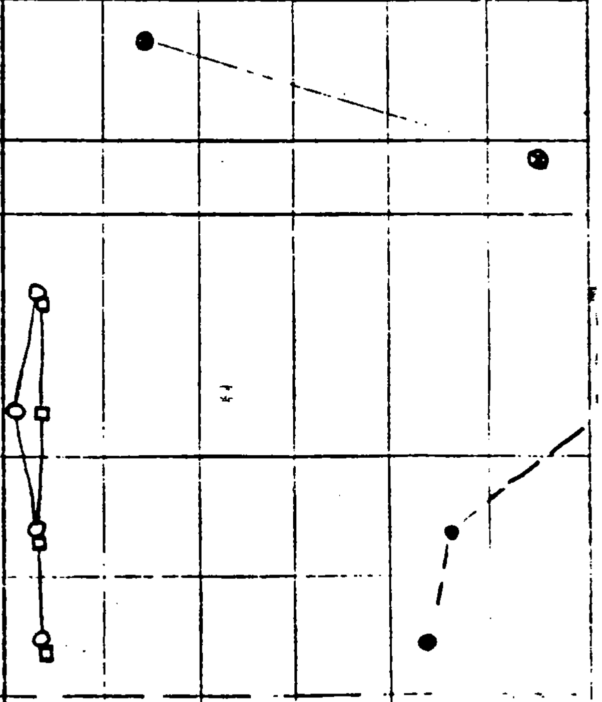
PLASTIC LIMIT % ✕ — **WATER CONTENT %** ● — **LIQUID LIMIT %** △

STANDARD "N" PENETRATION (BLOWS/FT.) ⊗ 10 20 30 40 50

SURFACE ELEVATION 583.6' USGS

ELEV. USGS	DEPTH ELEVATION	SAMPLE NO.	TYPE SAMPLE	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
			RB	2" asphalt surface over slag Fill	
	10.0		RB	Limestone Fill	
	20.0				
	30.0				
549.6		1	SS	Fine to coarse sand, trace gravel - brown - medium dense - wet (SP)	
43.6	40.0	2	SS	Fine to med.sand - brown - dense - wet (SP)	
540.6		3	3" ST	Organic clay, trace shells - dark gray - soft (OH)	55
	50.0	4	3" ST		55
30.6		5	3" ST	Moderately organic clay, trace shells - gray to dark gray - soft to stiff (CL-OH)	73
6	60.0	6	3" ST	Slightly organic silty clay. trace shells - gray & gray-brown - soft (CL-ML)	76
	63.0				

(Cont. on Sheet 2)

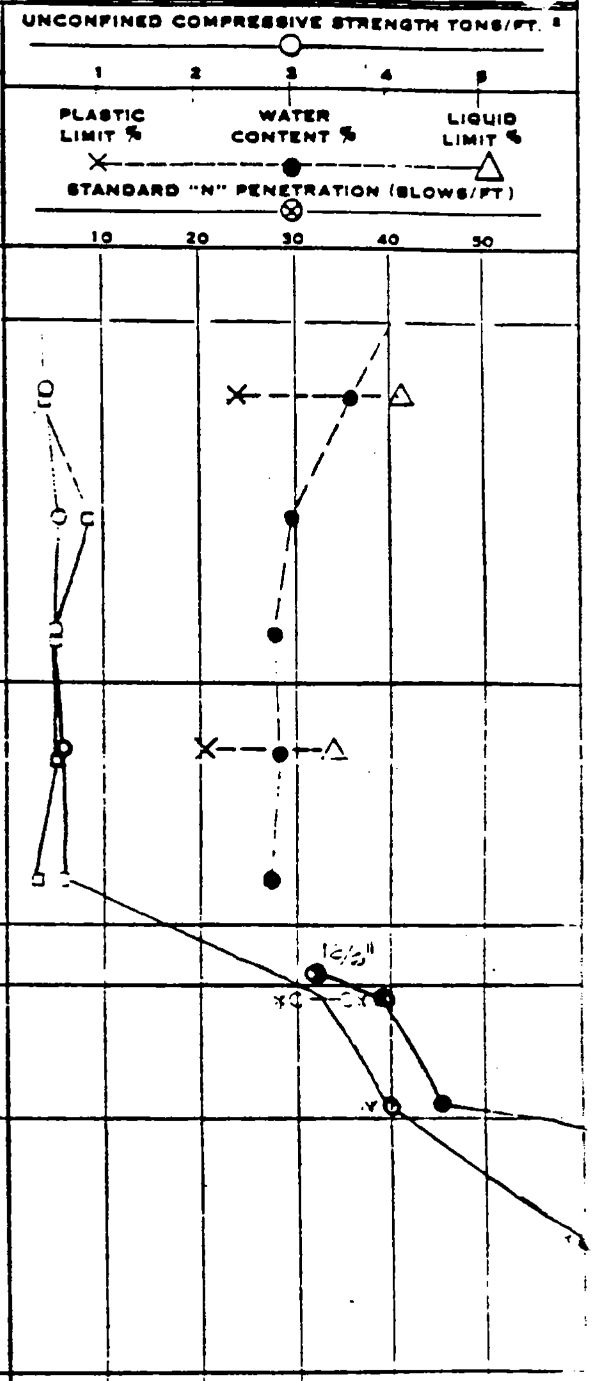


Sheet 1 of 2

LOG OF BORING NO. [redacted] (Cell 208) (Cont.)

OWNER Inland Steel Co.	**ARCHITECT-ENGINEER**
SITE Indiana Harbor Works	**PROJECT NAME** Cofferdam Extension - Plant 2.

Elevation	Depth	Sample No.	Type Sample	Description of Material	Unit Dry Wt. Lbs./Ft.³
				SURFACE ELEVATION	
				(Cont. from Sheet 1)	
20.6	63.0				
		7	3" ST	Slightly organic silty clay, trace shells - gray and gray-brown - soft (CL-ML)	83
	70.0	8	3" ST		91
		9	3" ST	Organic content = 5.6 to 7.0%	94
505.6	80.0				
		10	3" ST	Silty clay, thin horizontal seams of dark gray organic matter @ 80', trace very fine sand @ 85' - gray and gray-brown - stiff (CL-ML)	95
		11	3" ST		98
495.6	90.0		SS	Silty clayey sand & gravel - brown - dense - wet (SC)	
93.1		12A		Silty clay, trace sand - gray - very tough to hard (CL)	
89.6		13	SS		
	100.0	14	SS	Silty clay, trace to some sand, trace gravel - gray - hard (CL)	
479.1	106.5	15	SS		
				End of Boring	



45' of 4" casing used.

Note: Triaxial Compression tests performed on Samples 7 and 10.

*Calibrated Penetrometer

☐ = Torvane

WATER LEVEL OBSERVATIONS	
W.L.	W.S. OR W.D.
W.L.	B.C.R. A.C.R.
W.L.	

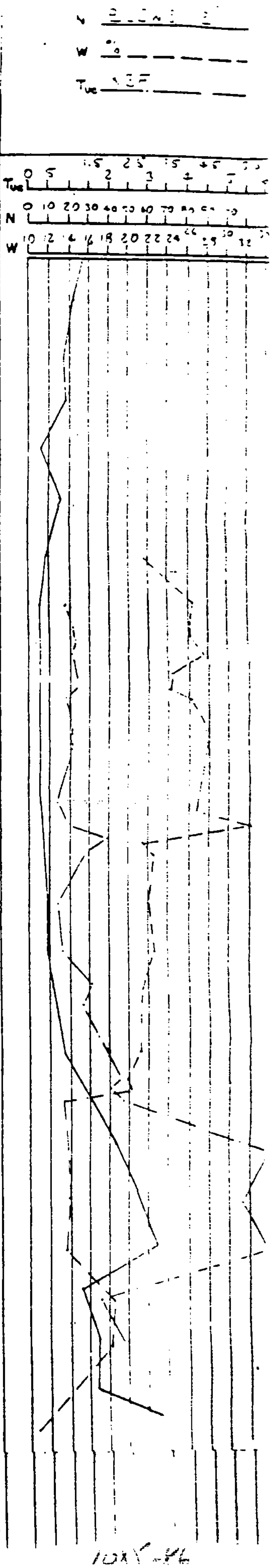
SOIL TESTING SERVICES
INC.
111 PFINGSTEN ROAD
NORTHBROOK, ILLINOIS

BORING STARTED	6-16-71		
BORING COMPLETED	6-19-71		
RIG	3	FOREMAN	
DRAWN	MD	APPROVED	
JOB #	14647	SHEET	

DEPTH IN FEET	BLOWS ON SPOON FOR 12 INCHES N	SYMBOL	DESCRIPTION	SAMPLE NO.	NATURAL MOISTURE % W	LIQUID LIMIT LL	PLASTICITY INDEX I_P	UNCONFINED SHEAR STRESS #/SF T_{uc}	STRAIN % ε	UNIT DRY WEIGHT #/CF γ_d
	12		Fill: slag	1						
10	27			2						
	21			3						
20	17			4						
	18			5						
30	6			6						
	15			7						
40	9		Sand, gray, silty, w/trace of gravel & organic material	8	21.6					
			Clay, gray, silty, w/trace of sand							
	6			9	26.3			840	20.0	101
50				S-1	26.1 26.1 27.5			1110 1180 1060	13.8 18.6 18.4	98 98 97
				S-2	24.3 24.1 26.1			1230 850	16.5 20.0	102 98
60				S-3	27.7 27.9 27.8			1100 1040 1060	9.8 9.5 9.7	98 97 96
	7			10	26.8			700	20.0	98
70			gray, silty, w/trace of sand & some gravel	S-4	32.0 21.6 22.5			970 1870 1440	4.0 14.9 15.0	91 113 114
	9		seam of gray sandy clay w/gravel - 69'-70'	11	22.1			730	18.3	109
80	9			12	22.4			790	20.0	109
				S-5	21.9 21.6 21.6			1560 1310	12.5 15.6	109 105
90	16			13	21.3					
			gray, silty, w/some sand & gravel	S-6	19.8 20.1 13.2			2310 2020 2320	13.5 10.8 10.5	109 107 120
100	43			14	13.8			5900	13.2	120
	54			15	13.9			5300	13.3	123
110	64			16	13.7			5900	20.0	126
	25			17	18.5			1790	20.0	118
120	35			18	18.3			2460	20.0	118
	35			19	*					
	67		Silt, gray, clayey, w/some sand	20	10.9					
130			Boulder or rock							
			End of boring @ 130.5'							
140										

REMARKS:
Encountered water at 3.5'
* No recovery

Boring Completed: 9/25/78
Location: East Chicago, Indiana
Soil No.: C. 3071



10XX-PL

STS JOB NO. [illegible]
DATE 10/71
Page 1 of 1

a

PERMEABILITY DATA

	BORING	SAMPLE	APPLIED PRESSURE tsf	TIME AT 50 % CONSOLIDATION	COEFICIENT OF CONSOLIDATION Cv in^2/min.	COEFFICIENT OF PERMEABILITY K, cm/sec		
1	324 (1971)	6	0.32	1.8 min.	.0271	2.0×10^{-7}		
2	324 "	6	.64	3.0	.0163	1.1×10^{-7}		
3	324 "	6	1.26	10.1	.000485	3.2×10^{-8}		
4	324 "	6	2.53	4.2	.0117	5.1×10^{-8}		
5								
6	324 "	8	.32	1.0	.049	2.0×10^{-7}		
7	324 "	8	.64	2.0	.0245	7.4×10^{-8}		
8	324 "	8	1.26	2.8	.0175	4.6×10^{-8}		
9	324 "	8	2.53	1.2	.0409	7.3×10^{-8}		
10								
11	324 "	10	.32	3.2	.0153	7.5×10^{-8}		
12	324 "	10	.64	3.0	.0164	5.8×10^{-8}		
13	324 "	10	1.26	1.9	.0258	7.7×10^{-8}		
14	324 "	10	2.53	1.3	.0377	6.4×10^{-8}		
15								
16	200 (1968)	8	.576	7.0	.00702	2.5×10^{-8}		
17	200 "	8	.976	8.0	.00614	1.8×10^{-8}		
18	200 "	8	1.973	6.3	.00779	2.5×10^{-8}		
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								

DATE 10/71

Page 1 of 1

BORING	SAMPLE	DEPTH	ELEV.	WATER CONTENT %	UNCONFINED COMPRESSIVE STRENGTH TSF	TORVANE SHEAR STRENGTH TSF	ORGANIC CONTENT %	LIQUIDITY INDEX
324 (1971)	4	45	536.9	61.5	0.30	0.20		
	5	50	531.9	57.4	0.30	0.18		
	6	55	526.9	44.3	0.20	0.13	8.8	0.85
	7	60	521.9	32.5	0.70	0.19		
	8	65	516.9	29.7	0.60	0.30	8.4	0.60
	9	70	511.9	34.6	1.0	0.22	9.4	0.38
	10	75	506.9	26.6	0.50	0.29	10.6	0.62
	11	80	501.9	27.9	0.25*	--		
	12	85	496.9	26.8	0.6-0.8*	0.20		
	13	90	491.9	23.8	0.25*	--		
	14	95	486.9	12.1	5.5*	--		
325"	3	45	538.0	61.4	0.36	0.17		
	4	50	533.0	73.0	0.27	0.15		
	5	55	528.0	51.4	0.20	--		
	6	60	523.0	37.0	0.20	0.12		
	7	65	518.0	28.8	0.41	0.16		
	8	70	513.0	19.0	0.66	0.29		
	9	75	508.0	23.8	3.3	--		
	10	80	503.0	20.4	2.6-3.6*	--		
	11	85	498.0	21.1	3.8	--		
	12	90	493.0	17.4	3.0	--		
	12A	91	492.0	13.2	6.0	--		
	13	95	488.0	15.2	4-4.5*	--		
	14	100	483.0	11.9	7.0+*	--		
326"	3	45	538.6	75.0	0.27	0.18		
	4	50	533.6	75.3	0.11	0.15		
	5	55	528.6	73.3	0.27	0.16		
	6	60	523.6	43.6	0.34	0.19		
	7	65	518.6	35.9	0.34	0.14	7.0	0.62
	8	70	513.6	29.2	0.54	0.40		
	9	75	508.6	27.3	0.48	0.22		
	10	80	503.6	28.3	0.56	0.21	5.6	0.49
	11	85	498.6	27.0	0.51	0.12		
	12A	90.6	493.0	19.2	3-3.5*	--		
	13	95	488.6	15.4	3.8-4.5*	--		
	14	100	483.6	12.1	6.0*	(*Calibrated Penetrometer)		

1087-88

SHEAR STRENGTH DATA

STS JOB NO 4647
DATE 10/71
Page 1 of 2

BORING	SAMPLE	DEPTH	ELEV. ESTIMATED USGS	WATER CONTENT	UNCONFINED COMPRESSIVE STRNGTH	LIQUIDITY INDEX
200 (1968)	5	40	538	33.0	0.88	
	6	45	533	19.6	0.77	
	7	50	528	26.6	0.94	
	8	55	523	22.8	0.86	0.33
	9	60	518	11.7	5.6	
	10	72	506	23.0	1.9	
	11	75	503	23.0	1.5	
	12	80	498	22.4	2.1	
	13	85	493	18.6	0.6	
	14	90	488	18.3	4.5	
201	4	45	533	18.7	0.7	
	5	50	528	27.7	0.9	
	6	55	523	26.9	1.0	
	7	60	518	26.9	1.1	
	8	65	513	27.3	1.1	
	9	70	508	23.1	1.2	
	10	75	503	23.7	1.0	
	11	80	498	23.8	1.1	
	12	85	493	22.7	1.8	
	13	90	488	14.6	7.1	
202	3	44	534	79.6	0.80	
	4	50	528	53.7	0.51	0.89
	5	55	523	37.9	0.43	
	6	60	518	33.1	0.90	
	7	65	513	29.3	0.17	
	8	70	508	24.8	1.45	
	9	75	503	22.0	0.66	
	10	80	498	22.5	1.2	
	11	85	493	21.7	1.26	
	12	90	488	14.6	2.9	
	13	95	483	13.8	3.1	
	14	100	478	12.0	10.1	

SHEAR STRENGTH DATA

STS JOB NO [illegible]
DATE 10/71
Page 2 of 2

	BORING	SAMPLE	DEPTH	ELEV. ESTIMATED USGS	WATER CONTENT	UNCONFINED COMPRESSIVE STRNGTH	LIQUIDITY INDEX	
1	203 (1968)	4	45	533	26.5	0.80		
2		6	55	523	25.4	1.1		
3		7	60	518	26.2	1.1		
4		8	65	513	26.6	1.2		
5		9	70	508	34.5	0.7		
6		10	75	503	21.9	0.7		
7		11	80	498	22.5	1.1		
8		12	85	493	20.5	2.4		
9		13	90	488	11.6	1.0		
10		14	95	483	10.9	4.2		
11								
12	204	3	40	538		0.58		
13		4	45	533		0.76		
14		5	50	528		0.89		
15		6	55	523		1.26		
16		7	60	518		1.12		
17		8	65	513		0.57		
18		9	70	508		1.04		
19		10	75	503		1.28		
20		11	80	498		1.72		
21		12	85	493		2.55		
22		13	90	488		4.5		
23		14	95	483		8.0		
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								

ATTACHMENT L - 2

SITE 14B
Boring Logs

CASE COMPANY

Lake Street (Hwy 20) & Barrington Road
ROSELLE, ILLINOIS

CONSTR. SECT. C-1
DESIGN SECT. D-1A
COUNTY Lake

FOR Deleuw Cather & Co.

TEST BORING LOG

BORING NO. # 75
LOCATION 141st & ℄ of Toll Road
SHEET 1 OF 1
GROUND ELEV. 583.00
STATION 477 & 96.83
OFFSET 55' R of ℄
DATE STARTED 7-30-54 2:00PM
DATE COMPLETED 7-31-54 11:00AM
TYPE & SIZE OF BIT 16" & 20" Bucket
TYPE OF SAMPLER Spl. Spoon
DIA. OF AUGER
SAMPLER SIZE 1 3/8"
I. D. WTG. OF HAMMER 140#
FALL 30"
CASING SIZE 18"
I. D. WTG. OF HAMMER
FALL -
CASING LEFT IN PLACE ------
LINEAR FT.
ELEV. OF TOP OF ROCK

GROUND WA		
ELEV.	TIME	
3'	2:45PM	7-30-
3'	8:00AM	7-31-

BLOWS ON CASING PER FOOT	SAMPLE NO.	TYPE OF SAMPLE	SAMPLE DEPTH FROM-TO	SAMPLER BLOWS PER 6"	DEPTH FROM-TO	DESCRIPTION OF MATERIAL AND REMARKS	ROCK COR
	1	Bucket	5'		0-6"	Top soil & weeds	
	2	SS	9-11'	1,3,2,3	6"-5'	Coarse Brown Sand	10
	3	SS	14-16'	2,4,4,6			10
	4	SS	19-21'	3,3,4,8	5-10'	Fine Brownish grey sand	10
	5	SS	24-26'	3,4,6,8	10-23'	Fine grey sand	10
	6	SS	29-31'	4,5,7,9			10
	7	SS	34-36'	3,4,7,9	23-44'	Soft grey clay	10
	8	SS	39-41'	3,5,8,10			1
	9	SS	44-46'	4,7,11, 17	44-59'	Tough to very hard dry grey clay small black gravel & shale	9
	10	SS	49-51'	14,21,32,37			
	11	SS	54-56'	20,40,50,55			50
		DB	56-59'		59'	Hit boulder or rock shelf	
		Bottom of hole 59'					

DRILLER Pat Wells
HELPER Don Meyer
INSPECTOR J. Artwahl
ENGINEER E. F. Dawson Jr.

CASE COMPANY

Lake Street (Hwy 20) & Barrington Road
ROSELLE, ILLINOIS

CONSTR. SECT. C-1
DESIGN SECT. D-1A
COUNTY Lake

FOR DeLeuw Cather & Co.

TEST BORING LOG

BORING NO. #76 LOCATION Rt.#41 & Interchange SHEET 1 OF 1
GROUND ELEV. 582.9 STATION 478 & 30.83 OFFSET 25' L of ℄
DATE STARTED 7-23-54 3:00PM DATE COMPLETED 7-30-54 12:45PM
TYPE & SIZE OF BIT 16" & 20" Bucket
TYPE OF SAMPLE Spl.Spoon & 3"Undist.
SAMPLER SIZE 1 3/8" I. D. WTG. OF HAMMER 140# FALL 30"
CASING SIZE 18" I. D. WTG. OF HAMMER FALL
CASING LEFT IN PLACE ELEV. OF TOP OF ROCK

GROUND WATER ELEV.	TIME	DATE
3'	4:00PM	7-2
3'	8:00AM	7-2
3'	8:00AM	7-3

BLOWS ON CASING PER FOOT	SAMPLE NO.	TYPE OF SAMPLE	SAMPLE DEPTH FROM-TO	SAMPLER BLOWS PER 6"	DESCRIPTION OF MATERIAL AND REMARKS
	1	Bucket	4-6'		0-6" Top soil & weeds
	2	Bucket	9-11'		6"-5' Coarse brown sand
Added 5 bags of drilling clay					
	3	SS	14-16'	3,4,6,8	5-10' Fine brownish grey sand
Set 16' of casing					
	4	SS	19-21'	3,7,10, 18	10-23' Med. Dense fine grey sand
Added 4' of casing					
	5	3"Undist	24-26'		23-49' Soft grey clay
	6	SS	29-31'	3,4,7,10	
	7	3"Undist	34-36'		
	8	SS	44-46'	4,7,9,12	
	9	3"Undist	44-46'		
	10	SS	49-51'	5,9,15, 20	49-61' Tough to very hard clay small gravel & shale
	11	SS	54-56'	20-45-50-51	
	12	SS	59-61'	40,65,60, 62	61' Hit boulder or rock shelf
		Bottom of hole 61'			

DRILLER Pat Wells J. Artwahl
HELPER Bob Erwin ENGINEER E. F. Dawson Jr.

CASE COMPANY
Lake Street (Hwy 20) & Barrington Road
ROSELLE, ILLINOIS

CONSTR. SECT. C-1
DESIGN SECT. "D-1A
COUNTY Lake

FOR DeLeuw Cather & Co.

TEST BORING LOG

BORING NO. # 77
LOCATION 141st & ℄ of Toll Road
SHEET 1 OF 1
GROUND ELEV 584.4
STATION 478 & 85.83
OFFSET 55' R of ℄
DATE STARTED 7-30-54 1:00PM
DATE COMPLETED 7-30-54 5:00PM
TYPE & SIZE OF BIT 16" & 20" Bucket
TYPE OF SAMPLER Spl. spoon & 3"Undist.
OF AUGER
SAMPLER SIZE 1 3/8"
I. D. WTG. OF HAMMER 140# FALL 30"
CASING SIZE 18"
I. D. WTG. OF HAMMER FALL
CASING LEFT IN PLACE ----- LINEAR FT.
ELEV. OF TOP OF ROCK

GROUND WATER DATA		
ELEV.	TIME	DATE
3'	1:30PM	7-30-5

BLOWS ON CASING PER FOOT	SAMPLE NO.	TYPE OF SAMPLE	SAMPLE DEPTH FROM-TO	SAMPLER BLOWS PER 6"	DEPTH FROM-TO	DESCRIPTION OF MATERIAL AND REMARKS	ROCK CORE
	1	Bucket 5'			0-6"	Top soil & weeds	
	2	SS	9-11'	1,1,3,4	6"-5'	Coarse brown sand (Loose)	100
Added 5 Bags of drilling clay							
	3	SS	14-16'	3,3,7,9			100
Set 16' of casing					5-10'	Fine brownish grey sand	
	4	SS	19-21'	3,5,6,6,			100
Added 4' of casing							
	5	SS	24-26'	3,3,3,4	10-23'	Fine grey sand	100
	6	3"Undist	29-31'				
					23-49'	Soft grey clay	
	7	SS	34-36'	4,5,7,7			100
	8	3"Undist	39-41'	4,5,5,6			
					49-61'	Tough to very hard dry grey clay small gravel & shale	
	9	SS	44-46'	5,7,7,8			100
	10	3"Undist	49-51'	9,10,15,20			
	11	SS	54-56'	20,29,30,37			70
	12	SS	59-61'	41,49,55, 60	61'	Hit boulder or rock shelf	5
		Bottom of hole 61'					

DRILLER Pat Wells
INSPECTOR J. Artwahl
HELPER Bob Erwin
ENGINEER E. F. Dawson Jr.

CASE COMPANY
Lake Street (Hwy 20) & Barrington Road
ROSELLE, ILLINOIS

CONSTR. SECT. C-1
DESIGN SECT. D-1
COUNTY Lake

FOR DeLeuw Cather & Co.

TEST BORING LOG

BORING NO. #78
LOCATION Rt. 41 Interchange
SHEET 1 OF 1
GROUND ELEV. 583.9
STATION 479 & 19.83
OFFSET 25' R of ℄
DATE STARTED 7-29-54 11:45AM
COMPLETED 7-29-54 5:20PM
TYPE & SIZE OF BIT 16" Bucket
TYPE OF SAMPLE Spl.Spoon-3"Undist
DIA. OF AUGER
SAMPLER SIZE 1 3/8"
I. D. WTG. OF HAMMER 140#
FALL 30"
CASING SIZE ----
I. D. WTG. OF HAMMER
FALL
CASING LEFT IN PLACE ----- LINEAR FT.
ELEV. OF TOP OF ROCK

GROUND WATER

ELEV.	TIME	DATE
2'	1:00PM	7-29-

BLOWS ON CASING PER FOOT	SAMPLE NO.	TYPE OF SAMPLE	SAMPLE DEPTH FROM-TO	SAMPLER BLOWS PER 6"	DEPTH FROM-TO	DESCRIPTION OF MATERIAL AND REMARKS	ROCK CORE
	1	Bucket	5'		0-6"	Top soil & weeds	
	2	SS	10-12'	2,6,12, 21	6"-5'	Brownish grey (med.fine) sand	100
	3	SS	15-17'	5,9,8,19	5-21'	Fine grey sand-Med dense	100
	4	SS	20-22'	1,7,9,2,8			100
					21-25'	Soft grey clay	
	5	3"Undist	23-25'				
		Bottom of Hole 25'					

DRILLER Joe Carl
INSPECTOR J. Artwahl

CASE COMPANY
Lake Street (Hwy 20) & Barrington Road
ROSELLE, ILLINOIS

CONSTR. SECT. C-1
DESIGN SECT. D-1A
COUNTY Lake

FOR DeLeuw Cather & Co.

TEST BORING LOG

BORING NO. #79 LOCATION 141st. & ℄ of Toll Road SHEET 1 OF 1
GROUND ELEV. 583.4 STATION 479 & 19.83 OFFSET 55' L of ℄
DATE STARTED 7-30-54 8:00PM DATE COMPLETED 7-31-54 11:30AM
TYPE & SIZE OF BIT 16" & 20" Bucket
TYPE OF SAMPLER Spl. Spoon DIA. OF AUGER
SAMPLER SIZE 1 3/8" I. D. WTG. OF HAMMER 140# FALL 30"
CASING SIZE 18" I. D. WTG. OF HAMMER FALL
CASING LEFT IN PLACE -------- LINEAR FT. ELEV. OF TOP OF ROCK

GROUND WATER DATA		
ELEV.	TIME	DAT
3'	8:00PM	7-30-
3'	8:00AM	7-31-

BLOWS ON CASING PER FOOT	SAMPLE NO.	TYPE OF SAMPLE	SAMPLE DEPTH FROM-TO	SAMPLER BLOWS PER 6"	DEPTH FROM-TO	DESCRIPTION OF MATERIAL AND REMARKS	ROC COR & REC
	1	Bucket	5'		0-6"	Top soil & weeds	
	2	SS	9-11'	2,4,2,1	6"-5'	Coarse brown sand	7
	3	SS	14-16'	2,5,10,13			7
					5-10'	Fine brownish grey sand	
	4	SS	19-21'	2,5,7,9			10
	5	SS	24-26'	3,4,5,8	10-23'	Fine grey sand-med. dense	10
	6	SS	29-31'	3,4,2,9			10
					23-44'	Soft grey clay-traces of small	
	7	SS	34-36'	3,4,8,9		black gravel	10
	8	SS	39-41'	3,4,7,9			10
					44-60'	Very hard dry grey clay-small	
	9	SS	44-46'	3,5,8,11		black gravel & shale	10
	10	SS	49-51'	13,26,29,34			10
	11	SS	54-56'	14,21,38,40			5
		DB	56-60'		60'--	Hit rock shelf or boulders	
		Bottom of hole 60'					

DRILLER R. Face INSPECTOR J. Artwahl
HELPER Bob Biddle ENGINEER E. F. Dawson Jr.

CASE COMPANY

Lake Street (Hwy 20) & Barrington Road
ROSELLE, ILLINOIS

CONSTR. SECT. C-1
DESIGN SECT. D-1
COUNTY Lake

FOR DeLeuw Cather & Co.

TEST BORING LOG

BORING NO. #92
LOCATION Rt. 41 Interchange
SHEET 1 OF 1
GROUND ELEV 582.2
STATION 472+07 Station on Forward Tan. P.I.4
OFFSET 104' R of ℄
DATE STARTED 7-28-54 11:30AM
DATE COMPLETED 7-28-54
TYPE & SIZE OF BIT 16" Bucket
TYPE OF SAMPLE Spl. Spoon-3"Undist.
DIA. OF AUGER
SAMPLER SIZE 1 3/8"
O. D. WTG. OF HAMMER 140# FALL 30"
CASING SIZE [illegible]
I. D. WTG. OF HAMMER FALL -
CASING LEFT IN PLACE —— LINEAR FT.
ELEV. OF TOP OF ROCK

GROUND WATER DATA		
ELEV.	TIME	DA
3'	12:50PM	7-28-5

BLOWS ON CASING PER FOOT	SAMPLE NO.	TYPE OF SAMPLE	SAMPLE DEPTH FROM-TO	SAMPLER BLOWS PER 6"	DEPTH FROM - TO	DESCRIPTION OF MATERIAL AND REMARKS	ROCK COR
	1	Bucket	3'		0-3'	Top soil (6") brown sand	
	2	Bucket	5'		3-5'	Loose brownish grey sand	
	3	SS	10-12'	2,6,7,8	5-23'	Fine grey sand-med dense	10
	4	SS	15-17'	4,7,7,7			10
	5	3"Undist	23-25'	3,2,3,4	23-25'	Soft grey clay	

Bottom of hole 25'

DRILLER Joe Carl
INSPECTOR J. Artwahl

DE LEUW, CATHER & COMPANY

Engineers

Chicago, Illinois

Constr Sect. 2

Design Sect. D - 1A

County Lake

TEST BORING LOG

Boring No. PA - 48 Location "Off" Ramp at 141st St Sheet ____ of ____

Ground Elev. 581.8 Station 13 + 50 Offset 15' L

Date Started 11/10/54 Date Completed 11/10/54

Type & Size of Bit Power Auger

Type of Sampler ____ Diameter of Auger 6"

Sampler Size ____ I.D. Wgt. of Hammer ____ Fall ____

Casing Size ____ I.D. Wgt. of Hammer ____ Fall ____

Ground Water Data

Elev.	Time	Date
580.8		11/10/54

Casing Left in Place ____ Linear Feet ____ Elev. of Top of Rock ____

Blows on Casing Per Foot	Sample No	Type of Sample	Sample Depth From-To	Sampler Blows Per Foot	Depth From-To	Description of Material and Remarks	Rock Core Rec.
					0-.75	Topsoil with root growth	
					0.75-5.0	Very uniform fine grey and yellow sand	
						There was oil in surface water - obviously came from nearby swamp.	
						Could not penetrate further because of flowing sand below water table.	

Driller R. Faron ____ Inspector ____

[illegible] P. Jorgesen ____ [illegible] J. A. Jacobson

DE LEUW, CATHER & COMPANY
Engineers
Chicago, Illinois

Constr Sect. 2
Design Sect. D-1A
County Lake

TEST BORING LOG

Boring No. PA-49 [illegible] "Off" Ramp at 141st St. Sheet ___ of ___

Ground Elev. 580.4 Station 6 + 00 Offset 35' L

Date Started 1/10/54 Date Completed 11/10/54

Type & Size of Bit Power Auger

Type of Sampler ___ Diameter of Auger 6"
Sampler Size ___ I.D. Wt. of Hammer ___ Fall ___
Casing Size ___ I.D. Wt. of Hammer ___ Fall ___

Ground Water Data		
Elev.	Time	Date
581.2		11/1954

Casing Left in Place ___ Linear Feet ___ Elev. of Top of Rock ___

Blows on Casing Per Foot	Sample No.	Type of Sample	Sample Depth From-To	Number Blows Per Foot	Depth From-To	Description of Material and Remarks	Rock Core % Rec.
					0-0.8	Water with oil on surface	
					0.8-1.5	Organic Material with very heavy root growth	
			Can 2-3'		1.5-4.5	Very uniform and fine grey to yellow brown sand	
						Could not prevent hole from caving in because of flowing sand.	

Driller R. Faron [illegible]
Helper R. Jorgensen [illegible] J. A. Jacobsen

De Leuw, Cather & Company

Engineers

Chicago, Illinois

Constr Sect. 2
Design Sect. D - 1A
County Lake

TEST BORING LOG

Boring No. PA - 50
"Off" Ramp at 141st St.
Sheet ______ of ______

Ground Elev. 582.5
Station 2 + 25
Offset On Centerline

Date Started 11/10/54
Date Completed 11/10/54

Type & Size of Bit Power Auger

Type of Sampler ______ Diameter of Auger 6"
Sampler Size ______ [illegible]
Casing Size ______ [illegible]

Ground Water Data		
Elev.	Time	Date
581.0		11/10/54

Casing Left in Place ______ Linear Feet ______ Elev. of Top of Rock ______

Blows on Casing Per Foot	[illegible]	Type of Sample	[illegible] From-To	[illegible] Blows per Foot	Depth From-To	Description of Material and Remarks	Rock Core % Rec.
					0-.5	Topsoil with root growth	
					0.5-4.5	Very uniform fine grey and yellow sand	
						Could not penetrate further because of flowing sand below water table.	

[illegible] R. Faron

P. Jorgensen

J. A. Jacobson

DE LEUW, CATHER & COMPANY
Engineers
Chicago, Illinois

Constr Sect. 2
Design Sect. D - IA
County Lake

TEST BORING LOG

Boring No. H.A. -1 Location Swamp East of Calumet Sheet 1 of 1

Ground Elev. ______ Station 470 & 00 Offset On Centerline

Date Started 6/7/54 Date Completed 6/7/54

Type & Size of Bit Hand Auger

Type of Sampler ______ Diameter of Auger 2"
Sampler Size ______ I.D. Wgt. of Hammer ___ Fall ___
Casing Size ______ I.D. Wgt. of Hammer ___ Fall ___

Ground Water Date		
Elev.	Time	Date
Not located		

Casing Left in Place ______ Linear Feet ______ Elev. of Top of Rock ______

Blows on Casing Per Foot		Sample No.	Type of Sample	Sample Depth From-To	Sampler Blows Per Foot	Depth From-To	Description of Material and Remarks	R Core % R.
						0 - 1	Black sandy topsoil	
						1 - 4	Clean very fine uniform	
							brown sand	

Driller P.L. Jorgensen Inspector R. Fadum
Helper J. Artwohl Engineer J.C. Steinsberger

DE LEUW, CATHER & COMPANY
Engineers
Chicago, Illinois

Constr Sect. 2
Design Sect. D -1 A
County Lake

TEST BORING LOG

Boring No. H. A. - 2
Location East of Calumet
Sheet 1 of 1
Ground Elev. ____
Station 475 + 00
Offset On Centerline
Date Started 6 / 7 / 54
Date Completed 6 / 7/ 54
Type & Size of Bit Hand Auger
Type of Sampler ____
Diameter of Auger 2 "
Sampler Size ____
I.D. Wgt. of Hammer ____ Fall ____
Casing Size ____
I.D. Wgt. of Hammer ____ Fall ____

Ground Water Date		
Elev.	Time	Date
Depth 1.5'		6/7/54

Casing Left in Place ____ Linear Feet ____ Elev. of Top of Rock ____

Blows on Casing Per Foot		Sample No	Type of Sample	Sample Depth From-To	Sampler Blows Per Foot	Depth From-To	Description of Material and Remarks	R C & Re
						0-0.3	Black sandy topsoil	
						.3-1.5	Clean very fine uniform brown	
						1.5-4	sand. Same but saturated	
							Material flowed into hole	
							so that the hole could not	
							be advanced.	

Driller R. Fadum
Helper J. Artwohl
Inspector P.L. Jorgensen
Engineer J.C. Steinsberger

DE LEUW, CATHER & COMPANY
Engineers
Chicago, Illinois

Constr Sect. 2
Design Sect. D-1 A
County Lake

TEST BORING LOG

Boring No. H.A. - 3 Location East of Calumet Sheet 1 of 1

Ground Elev. ______ Station 480 & 00 Offset On Centerline

Date Started 6/7/54 Date Completed 6/7/54

Type & Size of Bit Hand Auger

Type of Sampler ______ Diameter of Auger 2"
Sampler Size ______ I.D. Wgt. of Hammer ___ Fall ___
Casing Size ______ I.D. Wgt. of Hammer ___ Fall ___

Ground Water Data		
Elev.	Time	Date
Depth	5'	6/7/54

Casing Left in Place ______ Linear Feet ______ Elev. of Top of Rock —

Blows on Casing Per Foot		Sample No	Type of Sample	Sample Depth From-To	Sampler Blows Per Foot	Depth From-To	Description of Material and Remarks	Rock Core % Re
						0 - 0.5	Black sandy topsoil	
						0.5 - 5.0	Clean very fine uniform	
	—						brown sand	

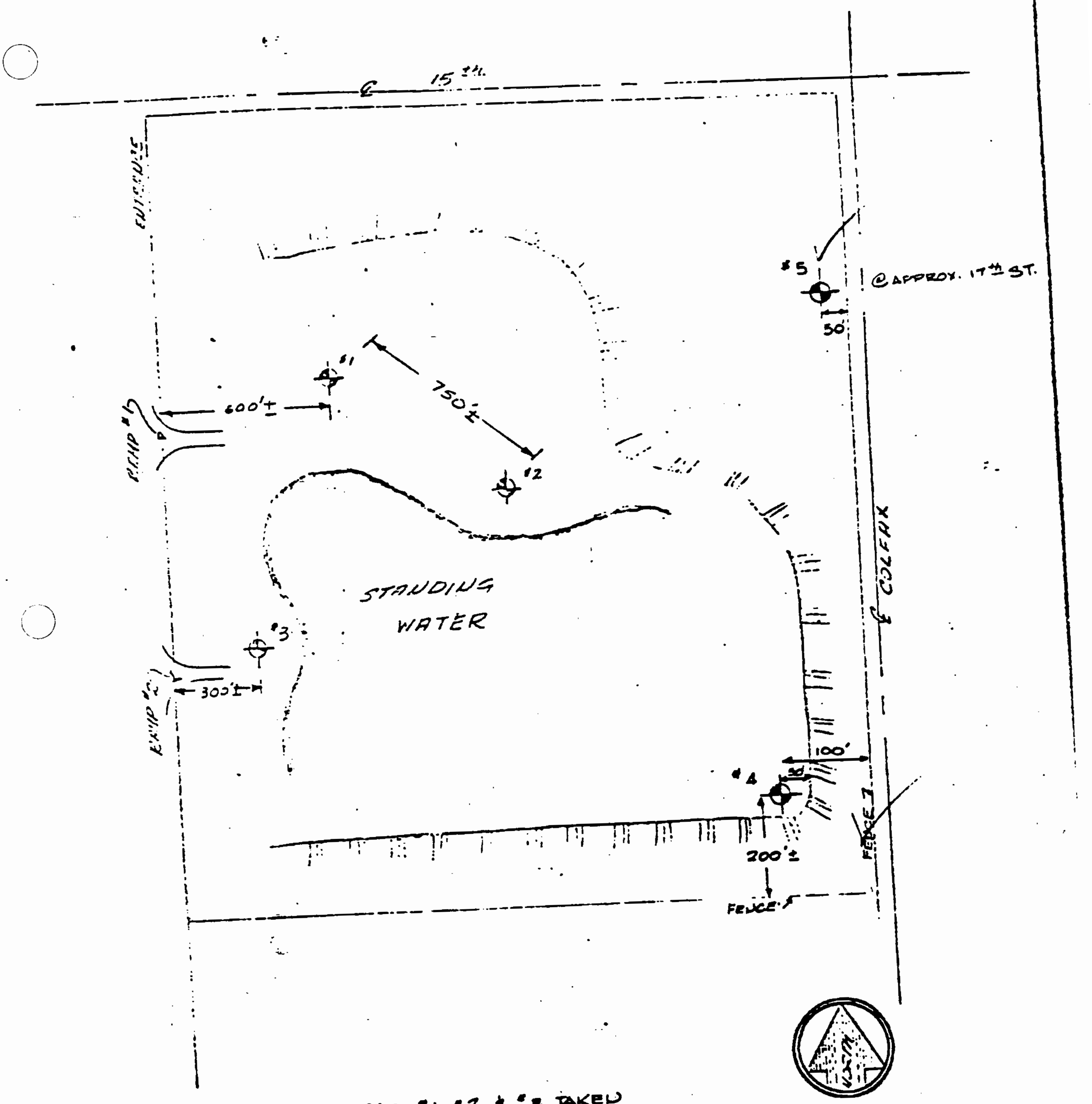
Driller R. Fadum Inspector P.L. Jorgensen
Helper J. Artwohl Engineers J.C. Steinsberger

ATTACHMENT L - 3

"J" - PIT SITE
Red Top Trucking / Salisbury Engineering
- Boring Logs: May 1972
- Boring Logs: June 1976
- Boring Logs: April 1983

[illegible]
E. MAIN STREET, GRIFFITH, IND.

BORING LOCATIONS



NOTE: TEST BORINGS #1, #2 & #3 TAKEN IN MAY, 1972. TEST BORINGS #4 & #5 TAKEN IN JUNE, 1976.

SCALE NONE
(DRILLER'S SKETCH)

TEST BORINGS
15th & COLFAX
SAND PIT

1107-08

LISBURY ENGINEERING INC.
E. MAIN ST., GRIFFITH, IND.

LOG OF TEST BORING NO.__

R LEVEL DATA	STARTED 5-5-72	LOCATION Test Borings 15th & Colfax Sand Pit
T – IN 0 URF.	COMPLETED Same	
SURFACE 1/HURS	DRILLER M. Cook	CLIENT Red Top Trucking Co., Inc. Hammond, Indiana
T.___IN ___HR.	INSPECTOR	
T IN HR.	FILE NO. 2063	

DESCRIPTION OF MATERIAL

CONSISTENCY
COLOR
TEXTURE

FACE ELEVATION:

BROWN FINE SAND

GRAY SAND AND COARSE GRAVEL

GRAY FINE SAND

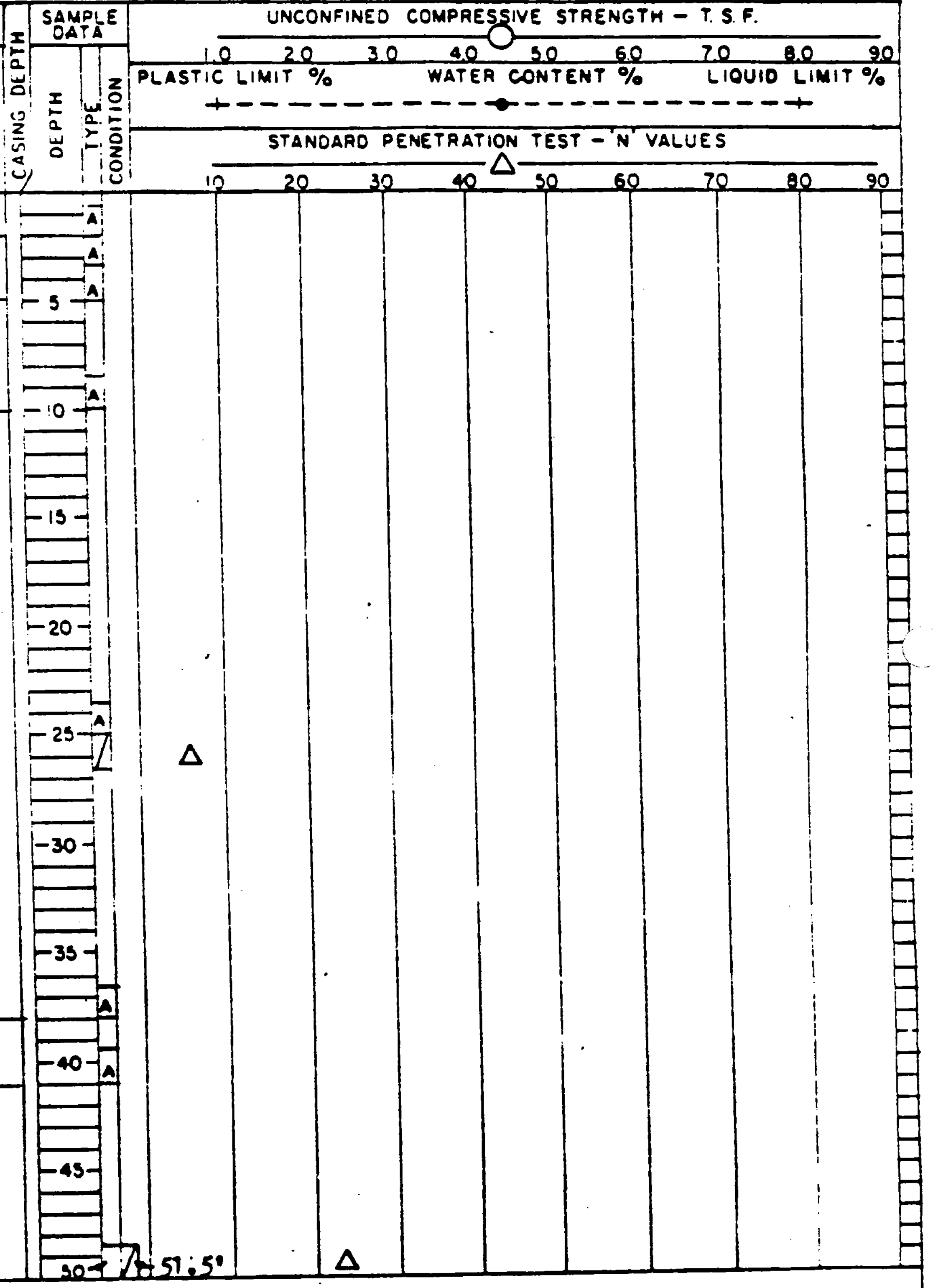
GRAY SILTY, SANDY CLAY WITH GRAY SAND SEAMS

SPLIT-SPOON SAMPLE MEDIUM-STIFF @ 26.5'

GRAY CLAY AND GRAVEL (HARD DRILLING)

GRAY CLAY

SPLIT-SPOON SAMPLE VERY STIFF @ 51.5'
BORING STOPPED @ 51.5'



NOTES.
Δ – SPLIT SPOON, ■ – SHELBY TUBE, ◫ – PISTON, ■ – AUGER, ⊕ – CALIBRATED PENETROMETER
D – DISTURBED, COHESIONLESS SOIL OR AUGER SAMPLE I – SUFFICIENTLY COHESIVE TO HOLD SAMPLE INTACT
U – UNDISTURBED SHELBY TUBE OR PISTON SAMPLE L – LOST, NO SAMPLE RECOVERY
THE 'N' VALUES IN THE STANDARD PENETRATION TEST ARE BLOWS PER FOOT REQUIRED TO DRIVE A 2" O.D. SPLIT SPOON SAMPLER USING A 140 POUND PIN WEIGHT FALLING FREE FOR A DISTANCE OF 30"

SALISBURY ENGINEERING INC.
511 E. MAIN ST., GRIFFITH, IND.

LOG OF TEST BORING NO. __

ATER LEVEL DATA	STARTED 5-5-72	LOCATION Test Borings 15th & Colfar Sand Pit
_ FT. _ IN 0 HR.	COMPLETED Same	
I SURFACE 1/4 HRS	DRILLER M. Cook	
___ IN ___ HR.	INSPECTOR	CLIENT Red Top Trucking Co., Inc. Hammond, Indiana
FT IN HR.	FILE NO. 2063	

DESCRIPTION OF MATERIAL

CONSISTENCY
COLOR
TEXTURE

SURFACE ELEVATION:

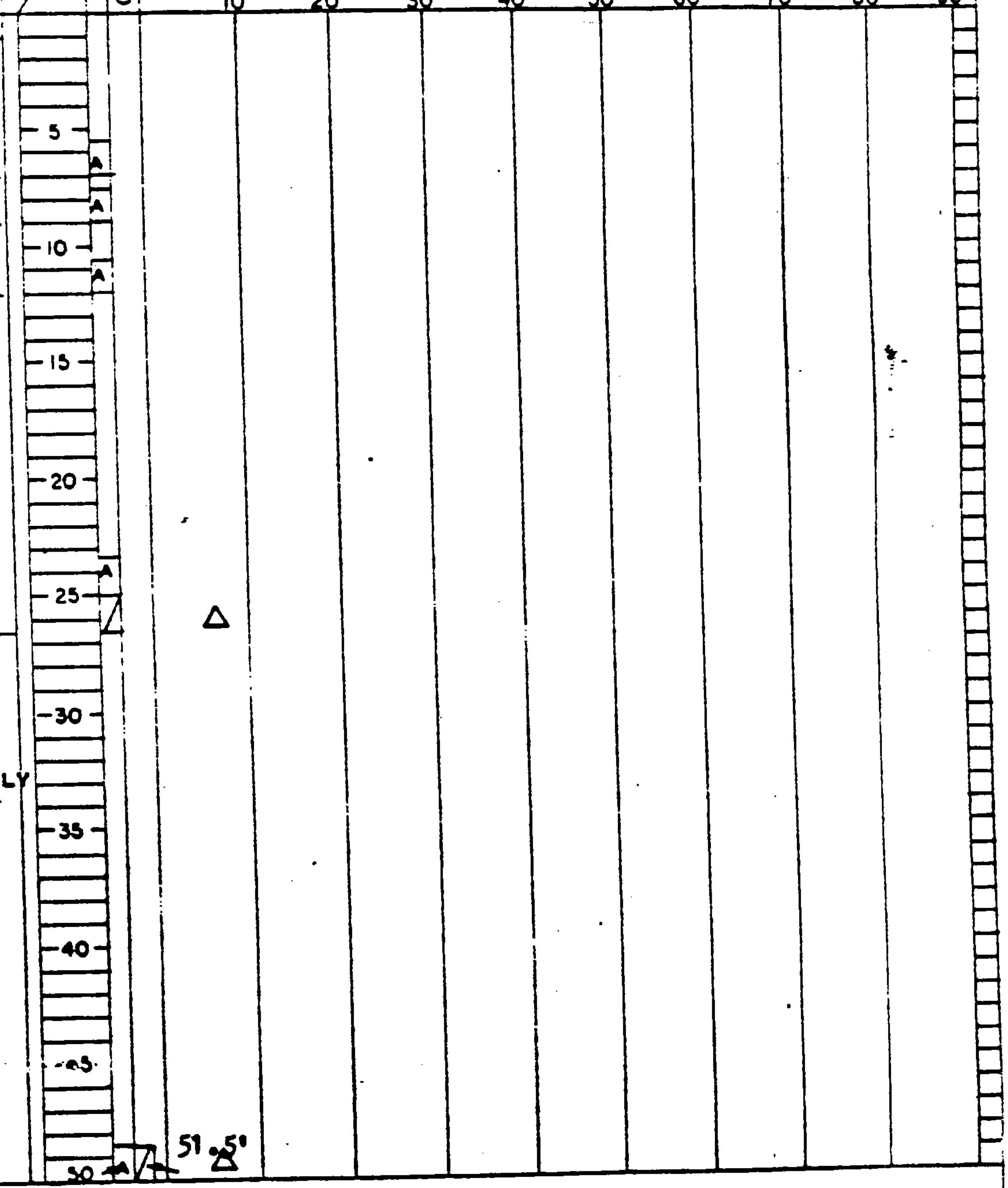
CASING DEPTH | SAMPLE DATA: DEPTH | TYPE | CONDITION

UNCONFINED COMPRESSIVE STRENGTH – T.S.F.: 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0

PLASTIC LIMIT % — WATER CONTENT % — LIQUID LIMIT %

STANDARD PENETRATION TEST – 'N' VALUES: 10 20 30 40 50 60 70 80 90

Description of material	Depth	Type
Brown fine sand		
Gray medium sand	5	A
Brown-gray silty, sandy clay		A
Medium to coarse gray sand	10	A
Gray clay and medium gravel	15, 20	A
Split-spoon sample medium-stiff @ 26.5'	25	
Gray clay and gravel mixed with sand seams occuring at approximately 3' to 5' intervals	30, 35, 40, 45	
Split-spoon sample medium-stiff @ 51.5' Boring stopped @ 51.5'	50	A



NOTES
– SPLIT SPOON, ■ – SHELBY TUBE, ◫ – PISTON, ■ – AUGER, ⊕ – CALIBRATED PENETROMETER
– DISTURBED, COHESIONLESS SOIL OR AUGER SAMPLE   I – SUFFICIENTLY COHESIVE TO HOLD SAMPLE INTACT
U – UNDISTURBED SHELBY TUBE OR PISTON SAMPLE   L – LOST, NO SAMPLE RECOVERY
THE 'N' VALUES IN THE STANDARD PENETRATION TEST ARE BLOWS PER FOOT REQUIRED TO DRIVE A 2" O.D. SPLIT SPOON SAMPLER USING A 140 POUND PIN WEIGHT FALLING FREE FOR A DISTANCE OF 30"

1109-10

LISBURY ENGINEERING INC.
11 E. MAIN ST., GRIFFITH, IND.

LOG OF TEST BORING NO. 3

TER LEVEL DATA
FT. – IN 0 HR
SURFACE 1½ HR
FT. ___ IN. ___ HR.
FT ___ IN ___ HR.

STARTED 5-[illegible]-72
COMPLETED SAME
DRILLER M. COOK
INSPECTOR
FILE NO. 2068

LOCATION TEST BORINGS
15TH & COLFAX
SAND PIT
CLIENT RED TOP TRUCKING CO., INC.
HAMMOND, INDIANA

DESCRIPTION OF MATERIAL
CONSISTENCY
COLOR
TEXTURE
SURFACE ELEVATION:

BROWN FINE SAND

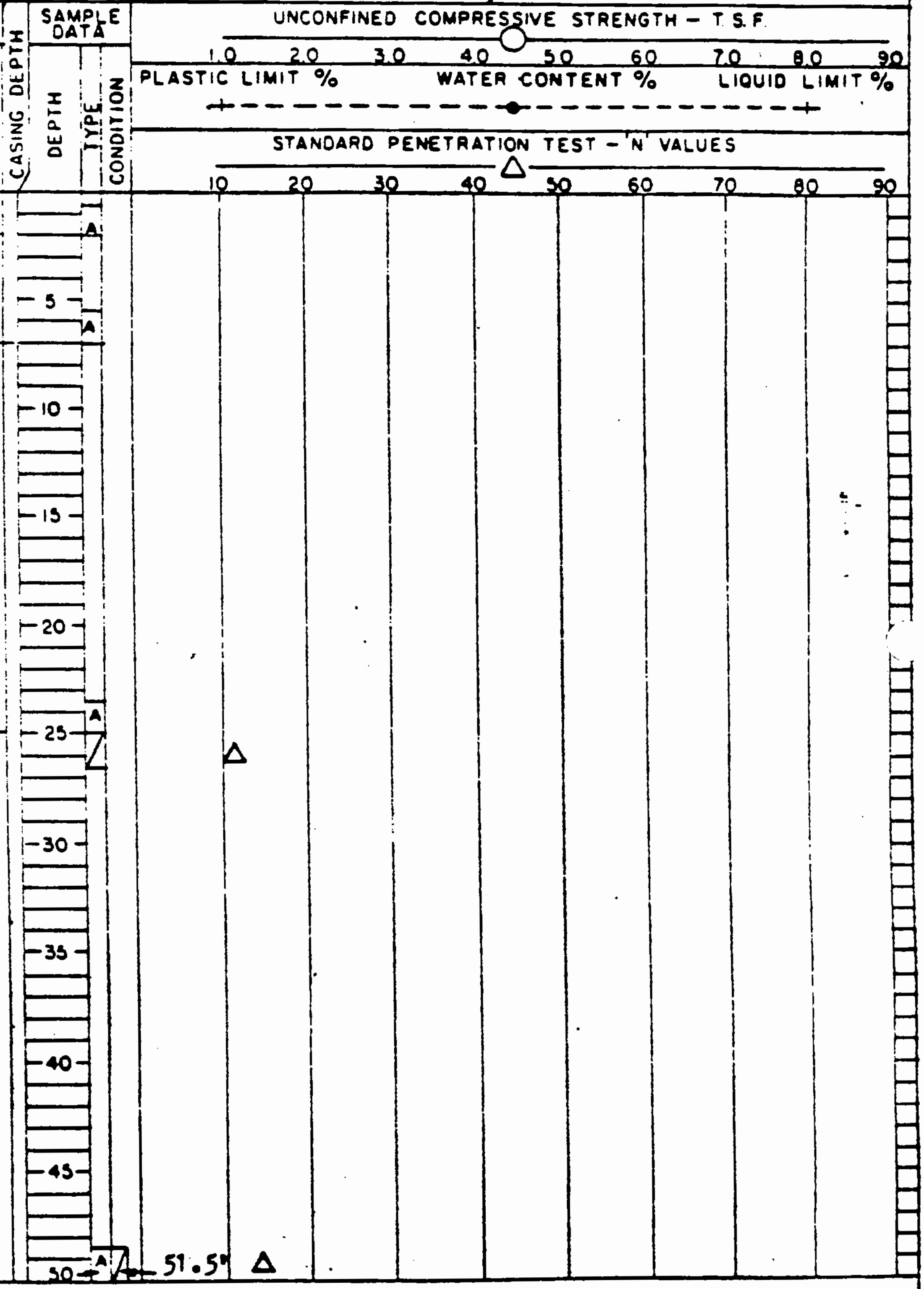
GRAY MEDIUM SAND

GRAY SANDY CLAY WITH SOME MEDIUM GRAVEL

SPLIT-SPOON SAMPLE
STIFF @ 20.5'

GRAY CLAY WITH SOME SAND SEAMS

SPLIT-SPOON SAMPLE
STIFF @ 51.5'
BORING STOPPED @ 51.5'



NOTES.
Δ – SPLIT SPOON, ■ – SHELBY TUBE, ◫ – PISTON, ■ – AUGER, ⊕ – CALIBRATED PENETROMETER
D – DISTURBED, COHESIONLESS SOIL OR AUGER SAMPLE   I – SUFFICIENTLY COHESIVE TO HOLD SAMPLE INTACT
U – UNDISTURBED SHELBY TUBE OR PISTON SAMPLE   L – LOST, NO SAMPLE RECOVERY
THE 'N' VALUES IN THE STANDARD PENETRATION TEST ARE BLOWS PER FOOT REQUIRED TO DRIVE A 2" O.D. SPLIT SPOON SAMPLER USING A 140 POUND PIN WEIGHT FALLING FREE FOR A DISTANCE OF 30"

ALISBURY ENGINEERING INC.
501 E. MAIN STREET, GRIFFITH, IND.

LOG OF TEST BORING NO. 4

WATER LEVEL DATA
Y FT. ___ IN. 0 HR.
Y FT. ___ IN. 1/4 HR.
___ IN. ___ HR.
___ FT. ___ IN. ___ HR.

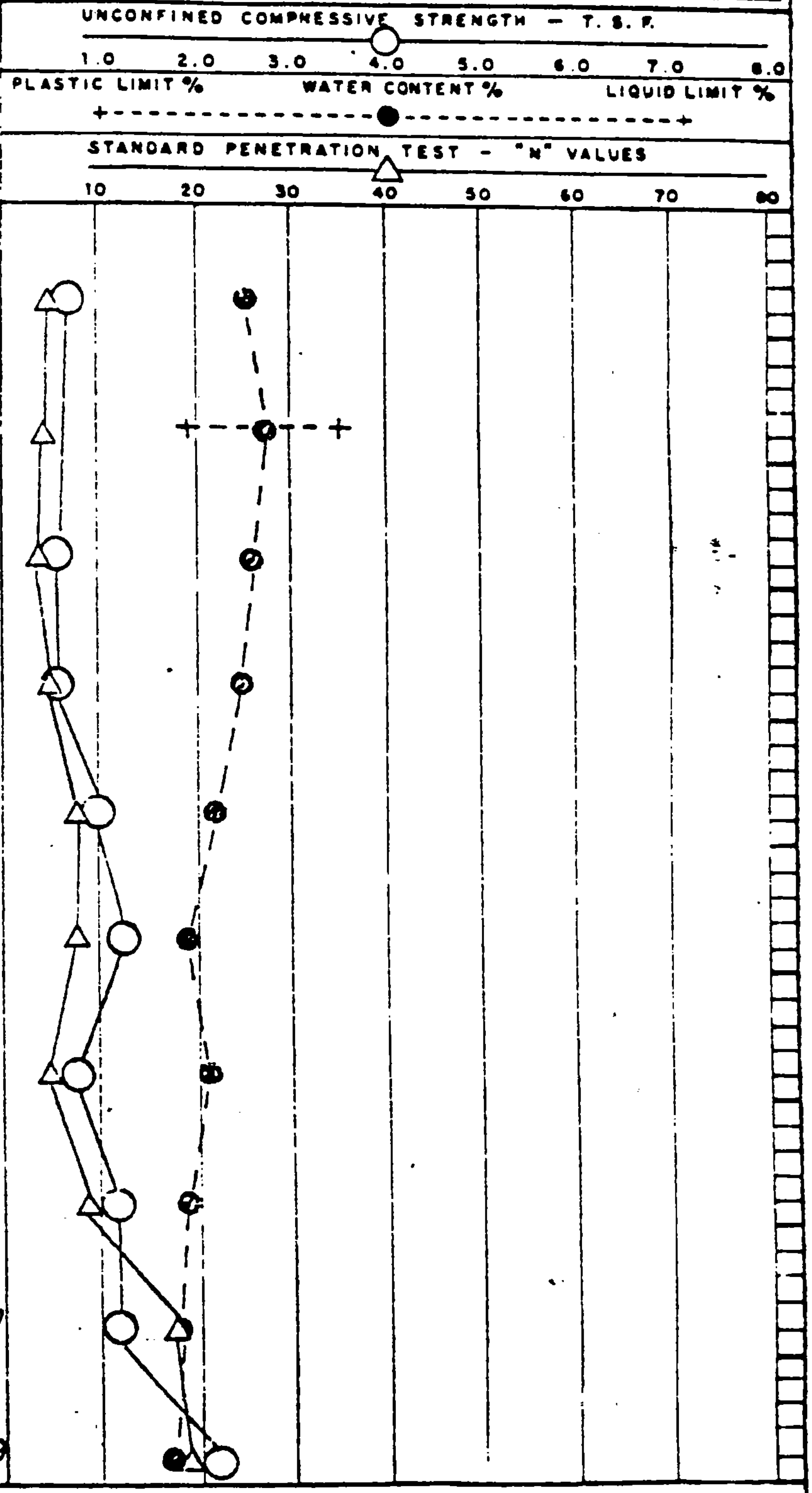
STARTED 5-22-76
COMPLETED SAME
DRILLER WANDERSEE
LOGGER KOLLASCH
FILE NO. 2063

LOCATION 15TH AND COLFAX
GARY, INDIANA

CLIENT RED TOP TRUCKING CO., INC.
HAMMOND, INDIANA

OUND ELEVATION:

STRATA DEPTH	SOIL DESCRIPTION	SAMPLE DATA DEPTH	TYPE	CONDITION	"N" VALUE
	MEDIUM GRAY AND BROWN MOTTLED CLAY WITH TRACES OF SHALE AND FINE GRAVEL	5.0	/	I	5
.0	SOFT GRAY MOTTLED CLAY WITH TRACES OF REDDISH CLAY	10.0	/	D	4
2.5	SOFT GRAY MOTTLED CLAY WITH TRACES OF REDDISH CLAY	15.0	/	D	3
7.5	MEDIUM GRAY MOTTLED CLAY WITH TRACES OF FINE GRAVEL	20.0	/	D	5
.5	MEDIUM TO STIFF GRAY MOTTLED CLAY WITH TRACES OF FINE GRAVEL	25.0	/	I	8
		30.0	/	I	8
.5	MEDIUM GRAY MOTTLED CLAY WITH TRACES OF FINE GRAVEL	35.0	/	D	5
.5	MEDIUM TO STIFF GRAY MOTTLED CLAY WITH TRACES OF FINE GRAVEL	40.0	/	I	9
.5	STIFF TO VERY STIFF GRAY SILTY CLAY WITH TRACES OF SHALE AND FINE GRAVEL	45.0	/	I	17
0.0		50.0	/	I	19



OTES: TEST BORING ENDED AT 50.0'

EGEND:
▱ SPLIT SPOON, ■ SHELBY TUBE, ▯ PISTON, A AUGER, ▨ ROCK CORE, ⊕ CALIBRATED PENTROMETER
D - DISTURBED, COHESIONLESS SOIL OR AUGER SAMPLE
I - SUFFICIENTLY COHESIVE TO HOLD SAMPLE INTACT
U - UNDISTURBED, SHELBY TUBE OR PISTON SAMPLE
L - LOST, NO SAMPLE RECOVERY

Ex-3

ALISBURY ENGINEERING INC.
501 E. MAIN STREET, GRIFFITH, IND.

LOG OF TEST BORING NO. 5

ATER LEVEL DATA
Y FT. ___ IN. 0 HR.
Y FT. ___ IN. 1/4 HR.
__ FT. ___ IN. ___ HR.
__ FT. ___ IN. ___ HR.

STARTED 5-22-76
COMPLETED Same
DRILLER Kollasch
LOGGER Wandersee
FILE NO. 2063

LOCATION 15th and Colfax
Gary, Indiana

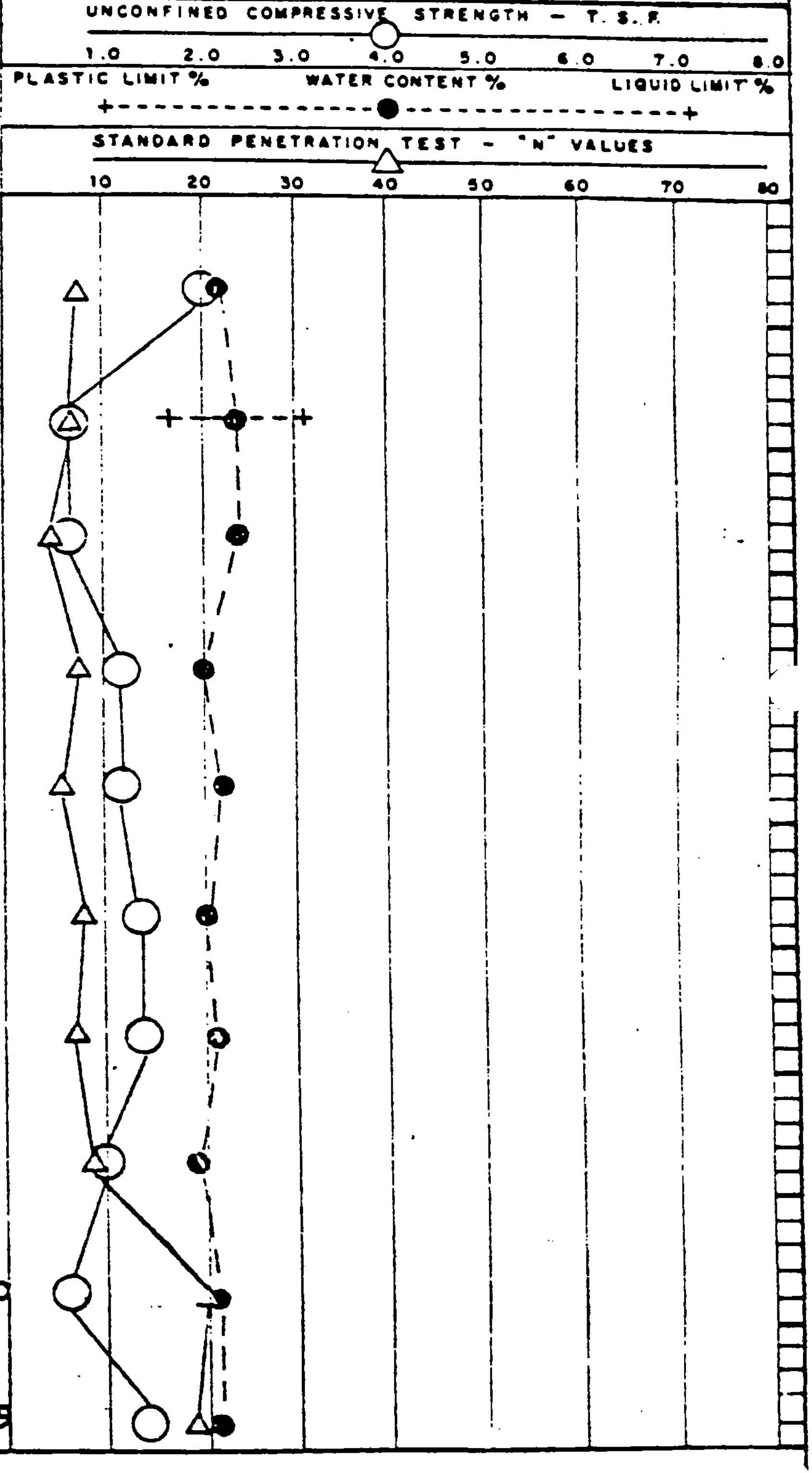
CLIENT Red Top Trucking Co., Inc.
Hammond, Indiana

OUND ELEVATION:

	SOIL DESCRIPTION
.0	Medium gray clay streaked with brown clay, traces of fine gravel and shale
.5	Medium gray clay streaked with brown clay, trace of fine gravel and shale
.0	Medium-stiff gray clay with traces of fine shale
.0	Very stiff gray clay with with 1/8" lenses of gray silt

SAMPLE DATA

DEPTH	TYPE	CONDITION	"N" VALUE
	☐	I	8
5.0			
	☐	I	7
10.0			
	☐	I	5
15.0			
	☐	I	7
20.0			
	☐	I	6
25.0			
	☐	I	8
30.0			
	☐	I	9
35.0			
	☐	I	9
40.0			
	☐	I	20
45.0			
	☐	I	19
50.0			

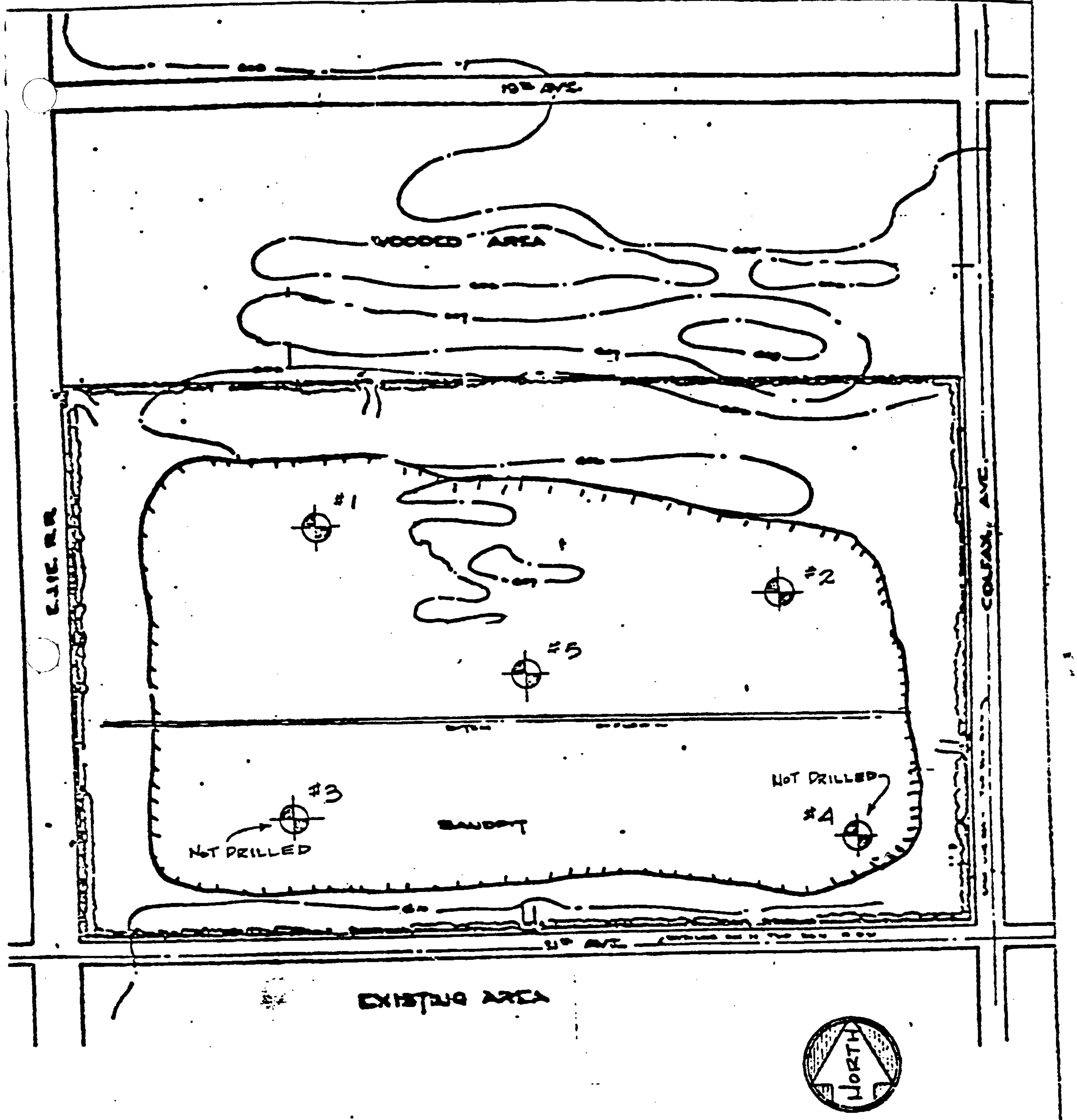


OTES: Test Boring ended at 50.0'

EGEND:
☐ SPLIT SPOON, ■ SHELBY TUBE, ▯ PISTON, A AUGER, ▨ ROCK CORE, ⊕ CALIBRATED PENTROMETER
D - DISTURBED, COHESIONLESS SOIL OR AUGER SAMPLE   I - SUFFICIENTLY COHESIVE TO HOLD SAMPLE INTACT

ALISBURY ENGINEERING
1 EAST MAIN STREET, GRIFFITH, IND.

BORING LOCATIONS



SCALE: NONE

(REPRODUCED FROM CLIENT'S PLAN)

"J" PIT
15TH & COLFAX
GARY, INDIANA

FILE # 6226 DATE 4/20/83

SALISBURY ENGINEERING
501 E. MAIN STREET, GRIFFITH, IND.

BORING NO. 1

WATER LEVEL DATA
DRY FT. W.D.
DRY FT. 1/4 HR. A.D.
____FT. ____HR. A.D.
____FT. ____HR. A.D.

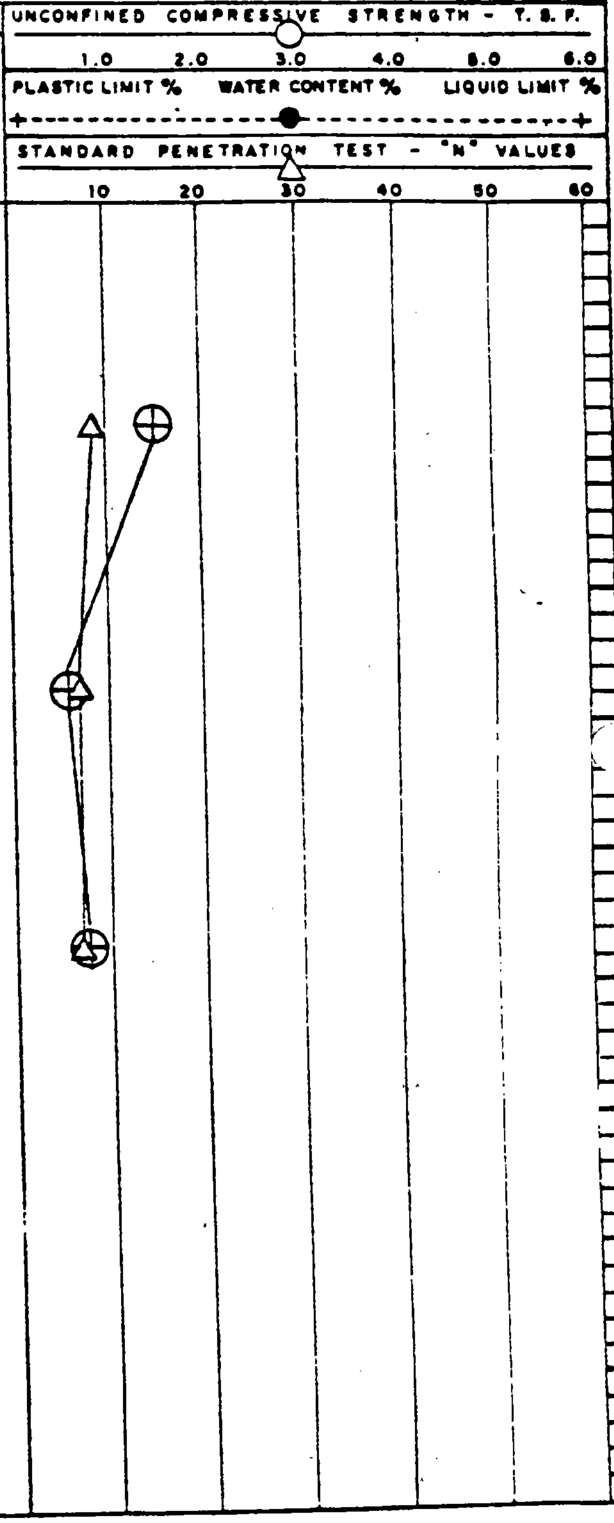
STARTED 4/19/83
COMPLETED SAME
DRILLER WANDERSEE
HELPER JANKE
FILE NO. 6226

LOCATION "J" PIT
15TH & COLFAX
GARY, INDIANA

CLIENT RED TOP TRUCKING CO., INC.
HAMMOND, INDIANA

GROUND ELEVATION:

STRATA DEPTH	SOIL DESCRIPTION	DEPTH	SAMPLE DATA: TYPE	RECOVERY	NUMBER	UNIT DRY WT. LBS./FT.³
.7	MEDIUM DENSE COARSE BROWN SAND (SP) MOIST					
8.0	STIFF GRAY, STREAKED WITH BROWN, SILTY CLAY, TRACES OF FINE GRAVEL (CL), DAMP	2.5				
		5.0	▨		1	
		7.5				
15.0	MEDIUM STIFF GRAY CLAY (CL), MOIST	10.0	▨		2	
		12.5				
		15.0	▨		3	
	SOIL BORING ENDED AT 15.0'	17.5				
		20.0				
		22.5				
		25.0				



NOTES: 1) ALL DESCRIPTIONS OF SOIL SAMPLES WERE MADE BY VISUAL EXAMINATION.
2) BORING SEALED WITH CEMENT-BENTONITE GROUT.

LEGEND: ▨ - SPLIT SPOON, ■ - SHELBY TUBE, ▯ - PISTON, A - AUGER, ▨ - ROCK CORE, ⊕ - CALIBRATED PENETROMETER

W.D. - WHILE DRILLING, A.D. - AFTER DRILLING

THE "N" VALUES IN THE STANDARD PENETRATION TEST ARE BLOWS PER FOOT REQUIRED TO DRIVE A 2" O.D. SPLIT SPOON SAMPLER USING A 140 POUND WEIGHT FALLING FREE FOR A DISTANCE OF 30"

SALISBURY ENGINEERING
501 E. MAIN STREET, GRIFFITH, IND.

BORING NO. 2

WATER LEVEL DATA	
1.0 FT. W.D.	
3.5 FT. 1/4 HR. A.D.	
___ FT. ___ HR. A.D.	
___ FT. ___ HR. A.D.	

STARTED 4/19/83
COMPLETED Same
DRILLER Wandersee
[illegible] Janke
FILE NO. 6226

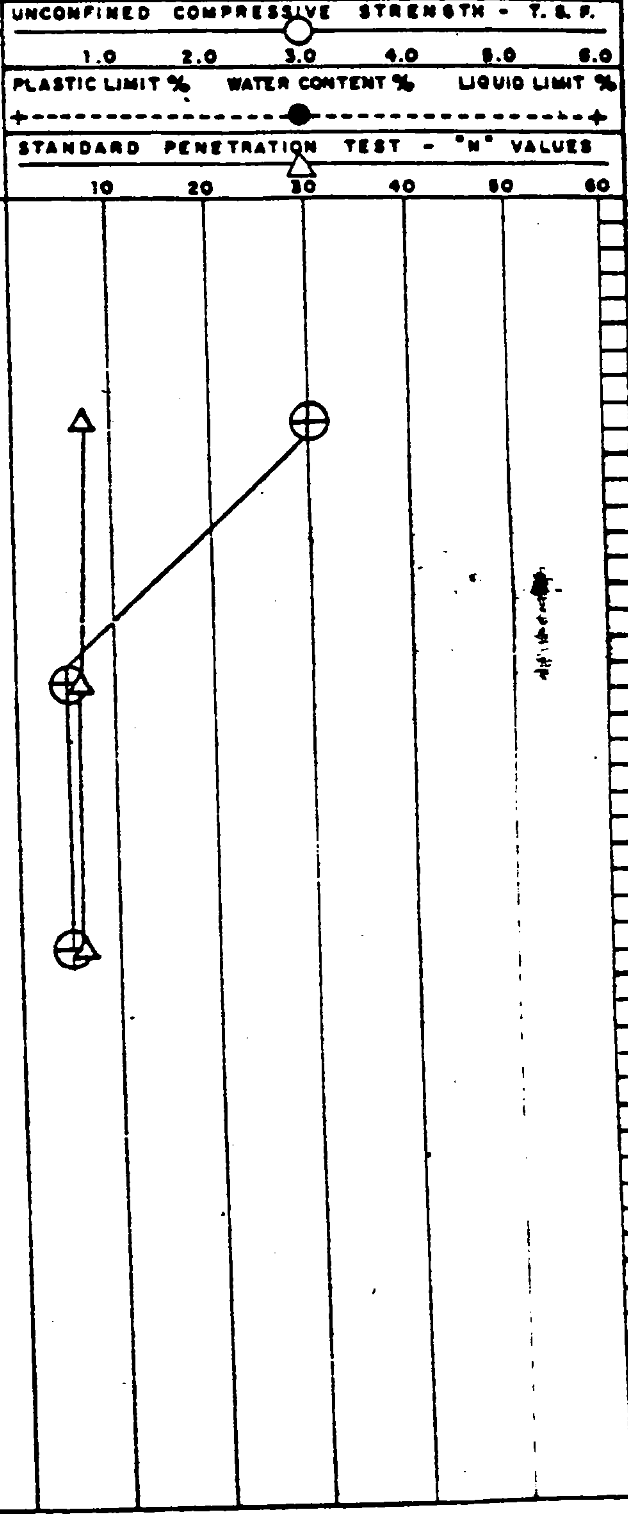
LOCATION "J" Pit
15th & Colfax
Gary, Indiana

CLIENT Red Top Trucking Co., Inc.
Hammond, Indiana

GROUND ELEVATION:

STRATA DEPTH	SOIL DESCRIPTION
0.5	Brown fine to medium sand (SP) moist to wet
4.0	Gray medium to coarse sand (SP), wet
8.5	Very stiff brown and gray silty clay, traces of fine gravel (CL), damp
13.0	Medium stiff gray, streaked with brown, clay (CL), moist
15.0	Medium stiff gray clay (CL), moist
	Soil Boring ended at 15.0'

DEPTH	SAMPLE DATA TYPE	RECOVERY	NUMBER	UNIT DRY WT. LBS./FT.³
4.0–5.0	◸		1	
8.5–10.0	◸		2	
13.5–15.0	◸		3	



NOTES: 1) All descriptions of soil samples were made by visual examination.
2) Boring sealed with cement-bentonite grout.

LEGEND:
◸ - SPLIT SPOON, ■ - SHELBY TUBE, ▯ - PISTON, A - AUGER, ▨ - ROCK CORE, ⊕ - CALIBRATED PENETROMETER
W.D. - WHILE DRILLING, A.D. - AFTER DRILLING

THE "N" VALUES IN THE STANDARD PENETRATION TEST ARE BLOWS PER FOOT REQUIRED TO DRIVE A 2" O.D. SPLIT SPOON SAMPLER USING A 140 POUND WEIGHT FALLING FREE FOR A DISTANCE OF 30".

SALISBURY ENGINEERING
1501 E. MAIN STREET, GRIFFITH, IND.

BORING NO. 5

WATER LEVEL DATA	STARTED 4/18/83	LOCATION "J" PIT
0.5 FT. W.D.	COMPLETED SAME	15TH & COLFAX
8.5 FT. 1/4 HR. A.D.	DRILLER WANDERSEE	GARY, INDIANA
FT. HR. A.D.	HELPER JANKE	CLIENT RED TOP TRUCKING CO., INC.
FT. HR. A.D.	FILE NO. 6226	HAMMOND, IN

GROUND ELEVATION:

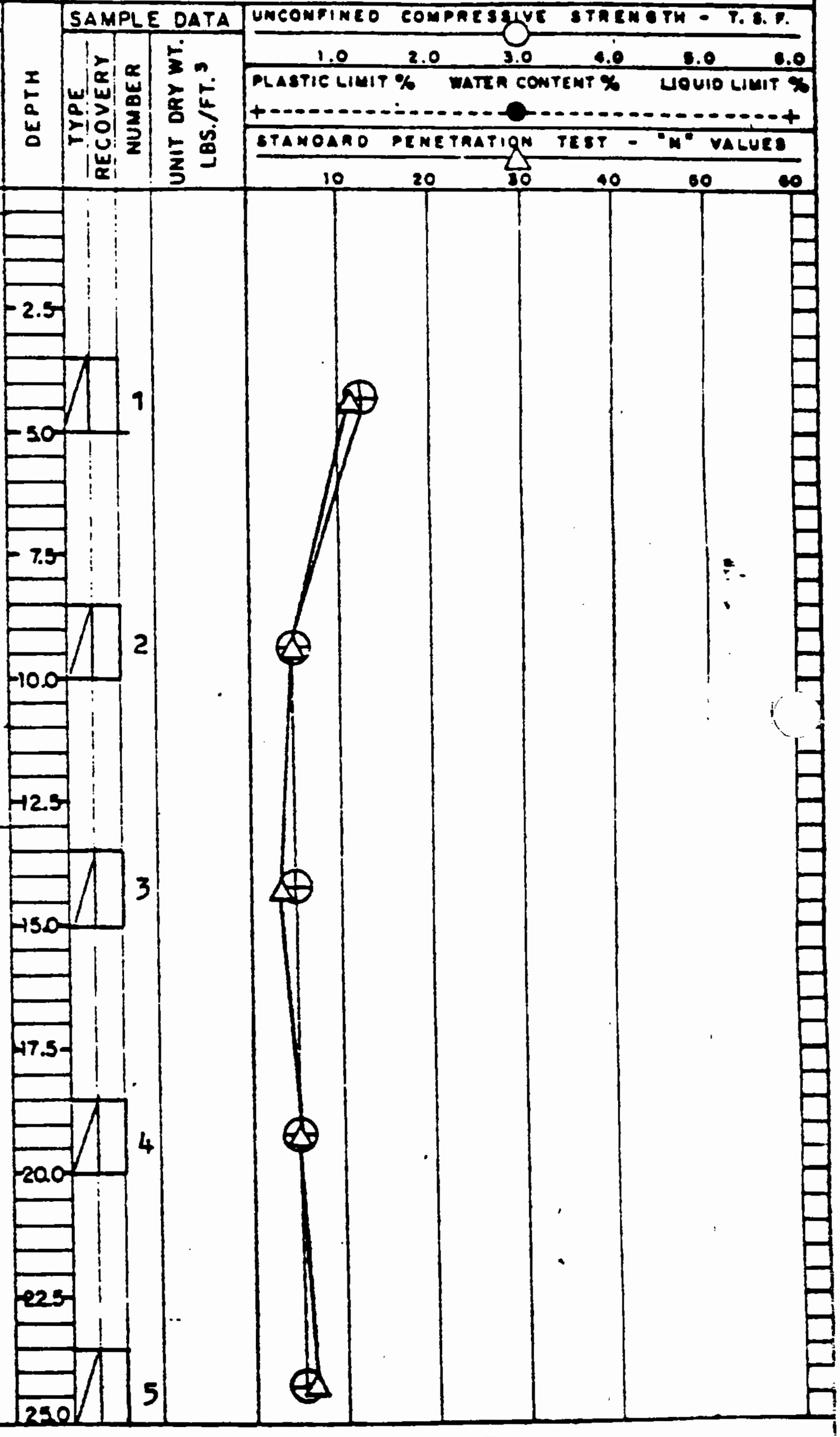
STRATA DEPTH — SOIL DESCRIPTION

0.5 BROWN SAND, (SP), MOIST TO WET

STIFF TO MEDIUM STIFF GRAY, STREAKED WITH BROWN, SILTY CLAY, TRACES OF FINE GRAVEL (CL), DAMP TO MOIST

13.0 SOFT TO MEDIUM STIFF GRAY CLAY (CL), MOIST TO WET

(CONTINUED)



NOTES: 1) ALL DESCRIPTIONS OF SOIL SAMPLES WERE MADE BY VISUAL EXAMINATION.
2) BORING SEALED WITH CEMENT-BENTONITE GROUT.

LEGEND:
▨ - SPLIT SPOON, ■ - SHELBY TUBE, ▯ - PISTON, Ⓐ - AUGER, ▩ - ROCK CORE, ⊕ - CALIBRATED PENETROMETER
W.D. - WHILE DRILLING, A.D. - AFTER DRILLING

THE "N" VALUES IN THE STANDARD PENETRATION TEST ARE BLOWS PER FOOT REQUIRED TO DRIVE A 2" O.D. SPLIT SPOON SAMPLER USING A 140 POUND WEIGHT FALLING FREE FOR A DISTANCE OF 30".

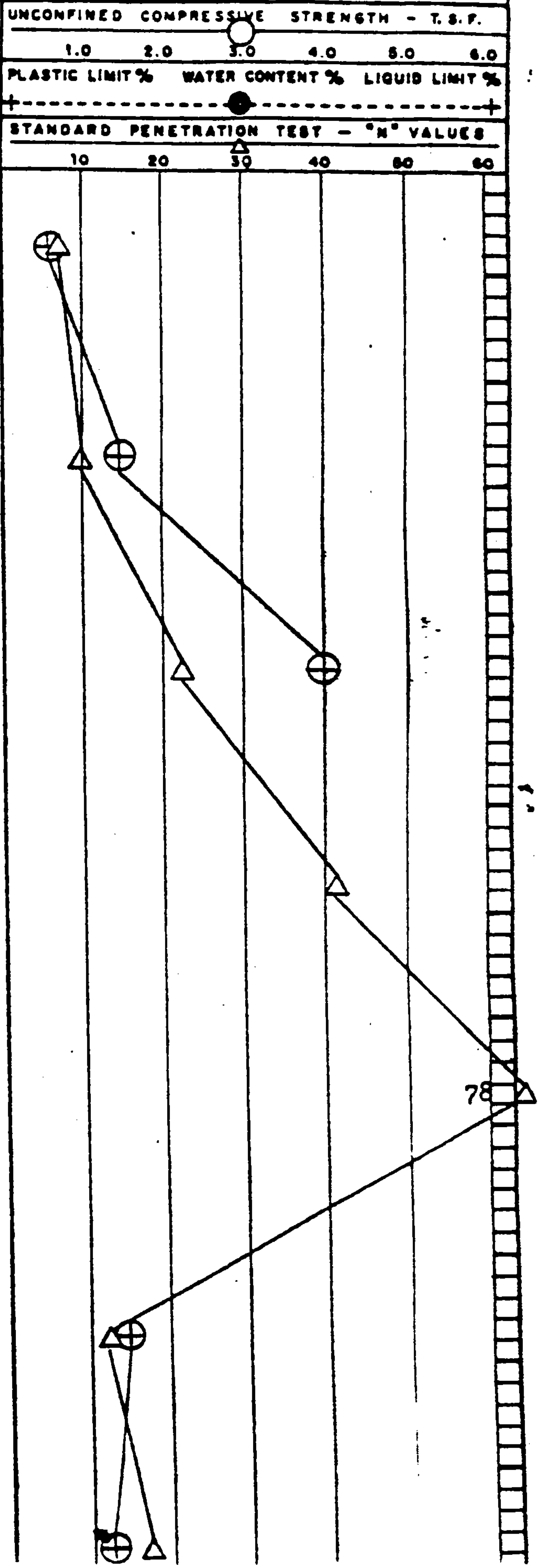
SALISBURY ENGINEERING
1501 E. MAIN STREET, GRIFFITH, IND.

BORING NO. 5

FILE NO. 6226

STRATA DEPTH	SOIL DESCRIPTION (CONTINUED FROM 22.5')	DEPTH	SAMPLE DATA: TYPE	RECOVERY	NUMBER	UNIT DRY WT. LBS./FT.³
		22.5				
	SOFT TO MEDIUM STIFF GRAY CLAY (CL), MOIST TO WET	25.0			5	
28.0		27.5				
	STIFF GRAY CLAY (CL), MOIST TO DAMP	30.0			6	
33.0		32.5				
	VERY STIFF TO HARD GRAY SILTY CLAY (CL), DAMP	35.0			7	
39.0		37.5				
	DENSE GRAY SILT (1 TO 2 INCHES THICK) LAYERED WITH CLAY (UP TO 1/8" THICK) (MH WITH THIN LAYERS OF CL), MOIST	40.0			8	
43.0		42.5				
	DENSE GRAY SILT (MH), MOIST TO WET	45.0			9	
49.0		47.5				
	STIFF GRAY SILTY CLAY, LITTLE FINE SHALE (CL), DAMP TO MOIST	50.0			10	
		52.5				
					11	

(CONTINUED)



SALISBURY ENGINEERING
1501 E. MAIN STREET, GRIFFITH, IND.

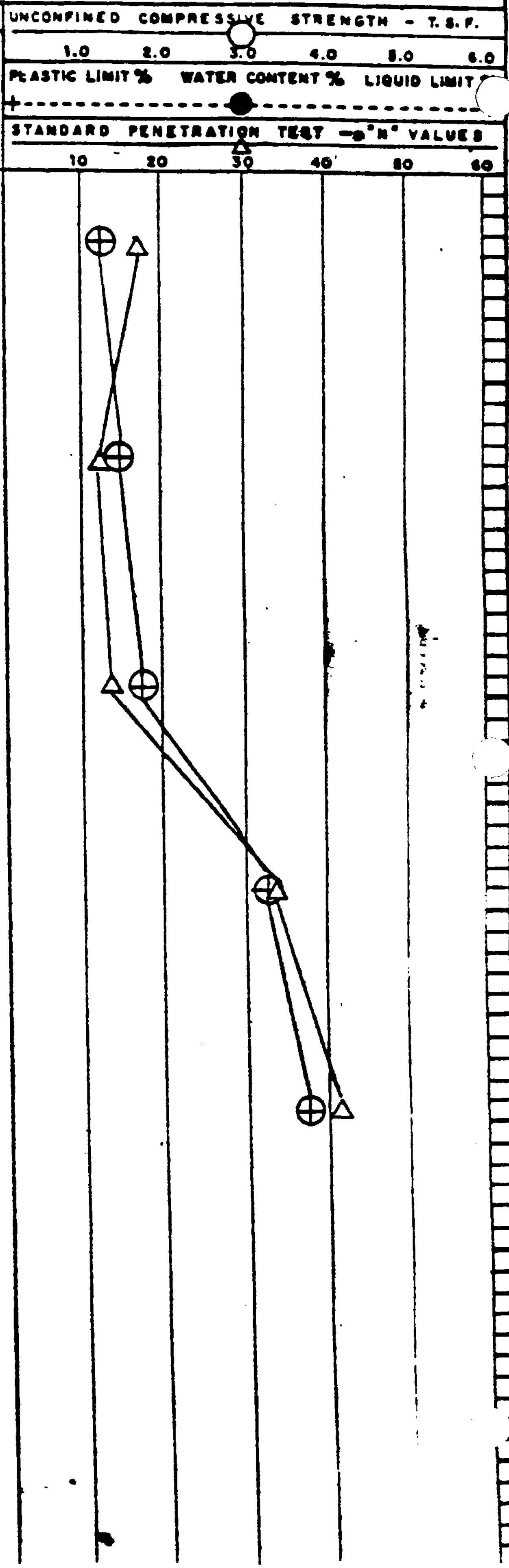
BORING NO. 5

FILE NO. 6226

SOIL D[illegible]TION

(CONTINUED FROM 52.5

STRATA DEPTH	SOIL D[illegible]TION	DEPTH	SAMPLE DATA TYPE	RECOVERY	NUMBER	UNIT DRY WT. LBS./FT.³
	STIFF GRAY SILTY CLAY, LITTLE FINE SHALE (CL), DAMP TO MOIST	52.5				
		55.0			11	
		57.5				
		60.0			12	
		62.5				
		65.0			13	
68.0		67.5				
	VERY STIFF GRAY SILTY CLAY, LITTLE FINE SHALE (CL), DAMP	70.0			14	
		72.5				
75.0		75.0			15	
	SOIL BORING E[illegible] 75.0'	77.5				
		80.0				
		82.5				



ATTACHMENT L - 4

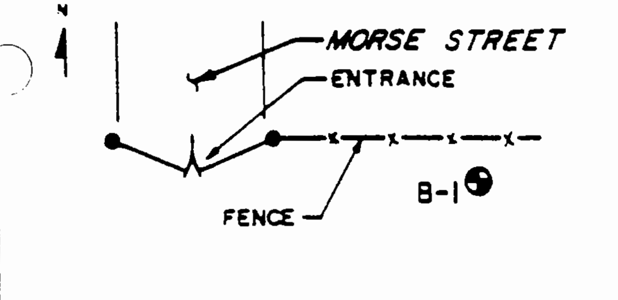
"J" - PIT SITE
Waste Management / Canonie Environmental
- Soil Boring Logs
- Rock Boring Logs

1119

SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DRILLING METHOD: Rotary Wash Method with 3-7/8" dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer.

BORING NO 3-1

SHEET 1 OF 3

WATER LEVEL		19.5'	19.5'	
TIME		1005	0930	
DATE		10/19	10/29	
CASING DEPTH				

DRILLING	
START	FINISH
TIME 0930	TIME 1600
DATE 10/8	DATE 10/8

DATUM MSL

ELEVATION 608.50

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was northwest corner of property; flat and scarcely vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
			White Fine Gravel And Fine To Coarse Sand Fill With A Trace Of Vegetation.								
	5,10,12 (67%)	1	Light To Dark Brown Fine Sand, Trace Of Fine Gravel; Dry To Moist (SP).								
10	9,9,12 (78%)	2									
	9,10,12 (78%)	3	6-In. Layer Of Brown-Gray Medium To Coarse Sand, Trace Of Fine Gravel, Moist (SP) At 9.0 Ft.								
20	12,30,33 (59%)		Gray Fine Sand; Moist (SP).								
	14,32,34 (39%)		Gray Fine To Coarse Gravel And Sand, Moist To Wet (GW).								
30	5,11,18 (22%)		Gray Fine Sand; Moist (SP).								
	4,4,5 (78%)	7									
40	0,0,1 (100%)	8									
	0,0,1 (8%)	9	Gray Silty Clay, Trace Of Fine Sand; Moist To Wet; Lean (CL).								
50	0,0,1 (39%)	10									
	0,0,1 (33%)	11									
60	1,3,3 (8%)	12									
	1,2,3 (89%)	13									
70	1,5,5 (56%)	14									

Note: All dates are 1987.

Continued SL 01188

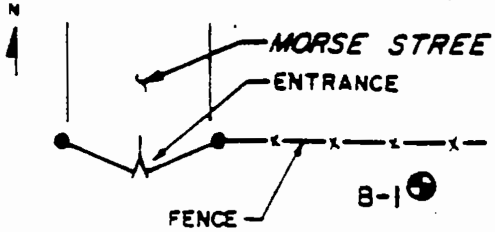
DRILLING CONTR. D & G Drilling, Inc.

LOGGED BY Canonie Environmental (F.A. Halterman)

SOIL BOREHOLE LOG

37-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 608.50

DRILLING METHOD Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD Split-spoon (SS) with pneumatic drive hammer

BORING NO B-1

SHEET 2 OF 3

WATER LEVEL	19.5'	19.5'
TIME	1005	0930
DATE	10/19	10/19
CASING DEPTH		

DRILLING	
START	FINISH
TIME 0700	TIME 1530
DATE 10/9	DATE 10/9

DRILL RIG CME 55

SURFACE CONDITIONS Area was northwest corner of property; flat and scarcely vegetated.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS				
							WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	14,12,6 (67%)		15 Gray Clayey Silt, Some Fine Sand; Wet; Slightly Plastic (ML).								
80	0,0,1 (78%)		16					46	20		*
	0,0,1 (84%)		*Cation Exchange Capacity = 13.4 mEq/100g				20	27	16		
90	1,3,8 (83%)		18								
	15,25,29 (22%)		19								
100	15,19,27 (67%)		20 Gray Silty Clay, Trace Of Fine To Coarse Sand, Fine Gravel, Shell Fragments; Wet To Moist; Lean (CL).								
	[illegible] (35%)		21								
110	10,18,22 (23%)		22								
	11,20,21 (67%)		23								
120	11,20,19 (78%)		24								
	9,12,9 (33%)		25								
130	12,22,18 (67%)		26 Gray Clayey Silt, Trace Of Fine To Coarse Sand, Fine Gravel; Moist; Slightly Plastic (ML).								
	9,12,15 (33%)		27								
140	[illegible],11,14 ([illegible]%)		28								

Note: All dates are 1987.

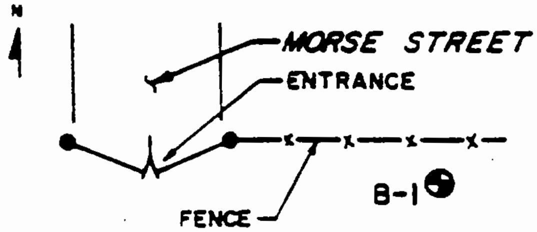
DRILLING CONTR. D & G Drilling, Inc.

LOGGED BY Canonie Environmental (F.A. Halterman)

SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL
ELEVATION 608.50

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer.

BORING NO. B-1

SHEET 3 OF 3

WATER LEVEL		19.5	19.5	
TIME		1005	0930	
DATE		10/19	10/19	
CASING DEPTH				

DRILLING	
START	FINISH
TIME 0700	TIME 1530
DATE 10/9	DATE 10/9

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT-LBS

SURFACE CONDITIONS Area was northwest corner of property; flat and scarcely vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	10,11,18 (72%)		29								
150	12,16,17 (67%)	▨	30 Gray Silty Clay, Trace Of Fine To Coarse Sand; Moist; Lean (CL).								
			Top Of Bedrock At 153.0 Ft.								
160											
170			From 153.0 Ft. To 177.0 Ft., See Rock Borehole Log RL-3715, Page 4 of 4.								
180			Bottom Of Boring At 177.0 Ft.								

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

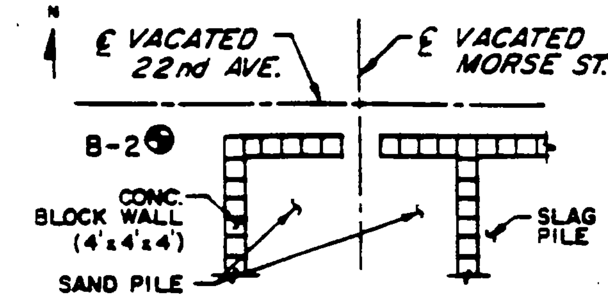
Canonie Environmental (F.A. Halterman)

1123-24

SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 607.67

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer.

WATER LEVEL	22.2'	22.9'	
TIME	1030	0930	
DATE	10/19	10/30	
CASING DEPTH			

BORING NO. B-2

SHEET 1 OF 3

DRILLING	
START	FINISH
TIME 0700	TIME 1500
DATE 9/13	DATE 9/13

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was southwest corner of property; flat and moderately vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	5,9,12 (50%)	1 Dark Brown Organic Fine Sandy Soil With Some Vegetation, Roots.								
		Dark Brown To Black Fine Sand; Dry (SP).								
10	2,6,12 (61%)	2 Brown Fine Sand; Damp To Moist (SP).								
	5,8,13 (56%)	3								
20	6,10,13 (0%)	4 Gray Fine Sand; Moist (SP).								
	3,4,5 (44%)	5								
30	1,1,2 (33%)	6								
	1,3,1 (67%)	7								
	0,0,1 (78%)	8					32	16		*
40	0,1,1 (83%)	9 Gray Silty Clay, Trace Of Fine To Coarse Sand; Moist To Wet; Lean (CL).				24	31	15		
50	0,0,1 (78%)	10 *Cation Exchange Capacity = 13.2 mEq/100g								
	0,1,1 (67%)	11								
60	0,0,1 (78%)	12								
	13,14,16 (28%)	13 Gray Clayey Silt; Wet; Slightly Plastic (ML).								
70	4,6,9 (33%)	14 Gray Silty Clay; Wet; Lean (CL).								

Note: All dates are 1987.

DRILLING CONTR. D & G Drilling, Inc

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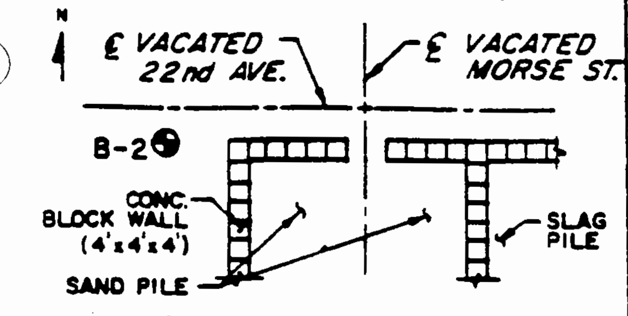
SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 607.67

DRILLING METHOD:	Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.
SAMPLING METHOD:	Split-spoon (SS) with pneumatic drive hammer.
BORING NO.	B-2
SHEET	2 OF 3

WATER LEVEL	22.2'	22.9'		
TIME	1030	0930		
DATE	10/19	10/30		
CASING DEPTH				

DRILLING	START	FINISH
TIME	0700	1500
DATE	10/14	10/14

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was southwest corner of property; flat and moderately vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	12,14,8 (83%)		15 Gray Clayey Silt; Moist To Wet; Slightly Plastic, (ML).								
80	0,2,6 (78%)		16								
	0,1,1 (67%)		17								
90	0,2,1 (0%)		18								
	4,7,9 (67%)		19								
100	14,16,20 (78%)		20								
	16,20,28 (67%)		21 Gray Silty Clay, Trace Of Fine To Coarse Sand, Fine Gravel, Shell Fragments; Moist; Lean (CL).								
110	40,45,100/2 (72%)		22								
	20,22,31 (89%)		23								
	21,18,22 (33%)		24								
120	18,23,25 (83%)		25								
130	15,21,20 (89%)		26								
	7,9,13 (0%)		27								
140	8,12,15 (89%)		28								

Note: All dates are 1987.

DRILLING CONTR. D & G Drilling, Inc.

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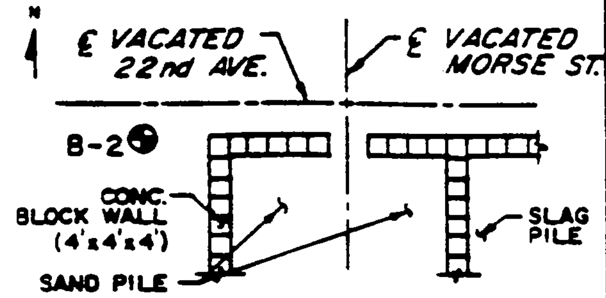
SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 607.67

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer.

WATER LEVEL	22.2'	22.9'			
TIME	1030	0930			
DATE	10/19	10/30			
CASING DEPTH					

BORING NO B-2

SHEET 3 OF 3

DRILLING	
START	FINISH
TIME	TIME
0700	1500
DATE	DATE
10/14	10/14

SURFACE CONDITIONS Area was southwest corner of property; flat and moderately vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	17,28,39 (96%)	▨	29 Gray Silty Clay, Trace Of Fine To Coarse Sand, Fine Gravel; Moist; Lean (CL).								
150	14,17,29 (56%)	▨	30								
			Top Of Bedrock At 152.0 Ft.								
160			From 152.0 Ft. To 163.5 Ft. See Rock Borehole Log RL3716, Page 4 of 4								
			Bottom Of Boring At 163.5 Ft.								
170											

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

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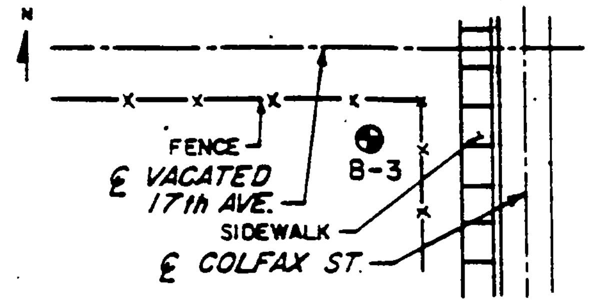
SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 606.36

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer.

BORING NO. B-3

SHEET 1 OF 2

WATER LEVEL	27.1'				
TIME	1000				
DATE	11/4				
CASING DEPTH					

DRILLING	
START	FINISH
TIME 0700	TIME 1500
DATE 10/15	DATE 10/15

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was northeast corner of property; flat and moderately vegetated.

									TEST RESULTS				
DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING		WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
				Vegetation, Roots.									
	3,4,5 (83%)		1										
10	5,7,7 (78%)		2										
	11,17,23 (33%)		3	Brown Fine Sand; Damp To Moist (SP).									
20	12,13,13 (28%)		4										
	12,10,11 (33%)		5										
30	3,4,5 (58%)		6										
	2,3,3 (67%)		7										
40	1,1,1 (78%)		8										
	3,0,1 (58%)		9										
50	0,0,1 (33%)		10	Gray Silty Clay, Trace Of Fine To Coarse Sand, Fine Gravel; Moist To Wet; Lean (CL).									
	0,0,1 (58%)		11										
60	3,3,4 (83%)		12										
	3,2,2 (67%)		13										
70	15,14,11 (83%)		14										

Note: All dates are 1987.

D & G Drilling, Inc.

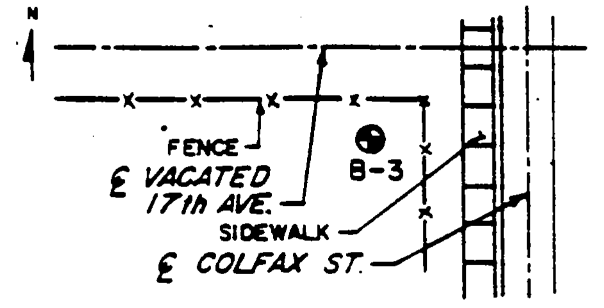
DRILLING CONTR

Canonie Environmental (F.A. Halterman)

SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 606.36

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer.

BORING NO. B-3

SHEET 2 OF 2

WATER LEVEL	27.1'			
TIME	1000			
DATE	11/4			
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
0700	1530
DATE	DATE
10/19	10/19

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT-LBS

SURFACE CONDITIONS Area was northeast corner of property; flat and moderately vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	15,21,20 (67%)		15 Gray Clayey Silt; Wet; Slightly Plastic (ML).								
80	2,3,3 ([illegible])		16								
	0,0,1 ([illegible])		17 Gray Silty Clay, Trace Of Fine To Coarse Sand, Gravel, Wet, Lean (CL).								
90	1,0,1 (94%)		18								
	1,1,1 ([illegible])		19					28	16		
100	11,12,26 (44%)		20 Gray Clayey Silt; Wet; Non-Plastic (ML).				17		NP		
	15,15,14 (56%)		21								
110	14,18,21 (61%)		22								
	10,12,16 (67%)		23 Gray Silty Clay, Trace Of Fine To Coarse Sand, Fine Gravel; Moist; Lean (CL).								
120			Top Of Bedrock At 118.5 Ft. From 118.5 Ft. To 128.5 Ft., See Rock Borehole Log RL-3717, Page 3 of 3.								
130			Bottom Of Boring At 128.5 Ft.								

Note: All dates are 1987.

DRILLING CONTR. D & G Drilling, Inc

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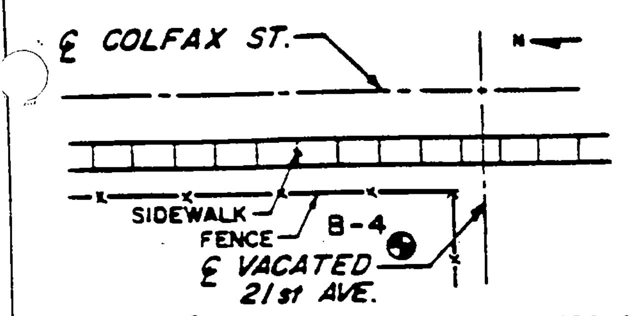
SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DRILLING METHOD:	Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.
SAMPLING METHOD:	Split-spoon (SS) with pneumatic drive hammer.
BORING NO	B-4
SHEET	1 OF 2

WATER LEVEL	17.7			
TIME	1125			
DATE	11/2			
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
0700	1805
DATE	DATE
10/20	10/20

DATUM MSL ELEVATION 604.00

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was southeast corner of property; inclined and vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	6.10.11 ([illegible])		1 Brown Fine Sand; Damp To Moist (SP).								
10	10.13.17 ([illegible])		2								
	10.13.19 ([illegible])		3								
	12.14.21 ([illegible])		4 Gray Fine Sand; Moist (SP).								
20	11.13.19 ([illegible])		5 Gray Silty Clay, Trace Of Fine To Coarse Sand; Fine Gravel; Moist To Wet; Lean (CL).								
	1.1.2 (75%)		6								
30	0.0.1 (75%)		7								
	0.0.1 (83%)		8								
40	0.0.1 ([illegible])		9								
	0.1.1 (83%)		10								
50	1.1.2 (67%)		11								
	1.2.2 (33%)		12								
60	16.21.20 ([illegible])		13 Gray Clayey Silt, Some Fine Sand; Wet; Non-Plastic (ML).								
70	11.9.12 ([illegible])		14								

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

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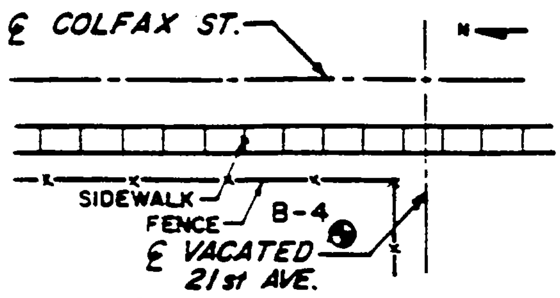
SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 604.00

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer.

BORING NO. B-4

SHEET 2 OF 2

WATER LEVEL	17.7'			
TIME	1125			
DATE	11/2			
CASING DEPTH				

DRILLING	
START	FINISH
TIME 0700	TIME 1805
DATE 10/20	DATE 10/20

DRILL RIG CME 55

SURFACE CONDITIONS Area was southeast corner of property; inclined and vegetated.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	2,2,2 ([illegible])		15								
80	2,4,5 (7[illegible])		16								
	2,3,3 ([illegible])		17								
90	3,4,6 (78%)		18 Gray Silty Clay, Trace Of Fine To Coarse Sand; Wet; Lean (CL).								
	3,6,5 (67%)		19								
100	10,12,14 (89%)		20								
	18,21,24 (89%)		21								
110	21,23,29 (61%)		22								
	20,21,50 (56%)		23								
120			Top of Bedrock At 116.5 Ft. From 116.5 Ft. To 132.0 Ft., See Rock Borehole RL3178, Page 3 of 3.								
130			Bottom Of Boring At 132.0 Ft.								
140											

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

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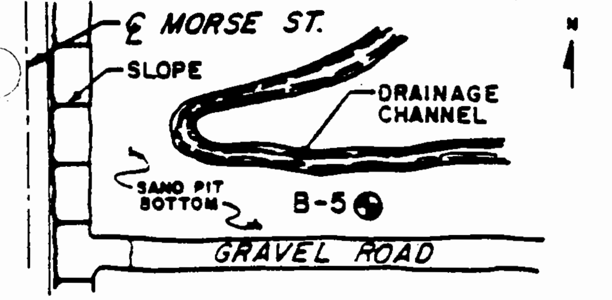
SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 579.97

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer, Shelby-Tube (ST).

BORING NO. B-5

SHEET 1 OF 2

DRILLING	
START	FINISH
TIME	TIME
0700	1500
DATE	DATE
10/21	10/21

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILL RIG CME 55

SURFACE CONDITIONS Area was at bottom of sand pit; open, flat, and marshy.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
			Vegetation, Roots.								
	5.6.6 (100%)		1								
10	3.3.4 (100%)		2								
	2.3.4 (100%)		3								
20	Pushed (83%)		4				22	29	16		*
	2.3.4 (100%)		5								
30	3.5.5 (39%)		6								
	5.7.9 (83%)		7								
40	4.5.7 (100%)		8 Gray Silty Clay, Trace Of Fine To Coarse Sand, Shell Fragments; Moist To Wet; Lean (CL).								
	5.6.6 (94%)		9								
50	4.5.7 (89%)		10								
	6.6.8 (100%)		11 *Coeff. of Permeability = 2×10^{-8} cm/sec Cation Exchange Capacity = 12.7 mEq/100g								
60	4.5.7 (100%)		12								
	4.5.7 (83%)		13								
70	4.4.6 (100%)		14								

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

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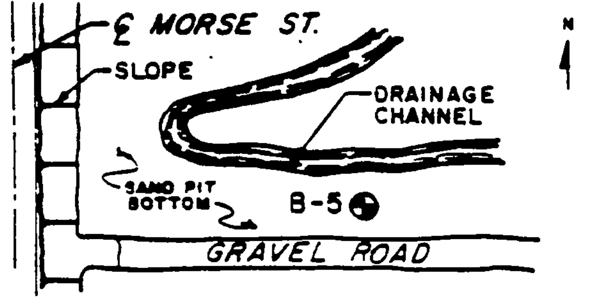
1121-87

SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 579.97

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer, Shelby-Tube (ST).

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

BORING NO B-5

SHEET 2 OF 2

DRILLING	
START	FINISH
TIME 0700	TIME 1500
DATE 10/21	DATE 10/21

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was at bottom of sand pit; open, flat, and marshy.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT	PLASTIC LIMIT	SPECIFIC GRAVITY	OTHER TESTS
	9,14,17 (100%)		15 Gray Silty Clay, Trace Of Fine To Coarse Sand, Shell Fragments; Moist To Wet, Lean (CL).								
80	10,15,20 (80%)		16								
	13,15,25 (90%)		17								
	20,47,50 (100%)		18 Gray Clayey Silt, Trace Of Fine To Coarse Sand, Fine Gravel; Moist; Slightly Plastic (ML).								
90	20,62,50 (70%)		19								
100	15,27,23 (100%)		20 Gray Silty Clay, Trace Of Fine To Coarse Sand, Fine Gravel; Moist; Lean (CL).								
	17,30,30 (95%)		21								
110	16,27,42 (33%)		22								
	15,16,22 (100%)		23								
120	65/2 (3%)		24								
130			Bottom Of Boring (Top Of Bedrock) At 121.0 Ft.								

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, In

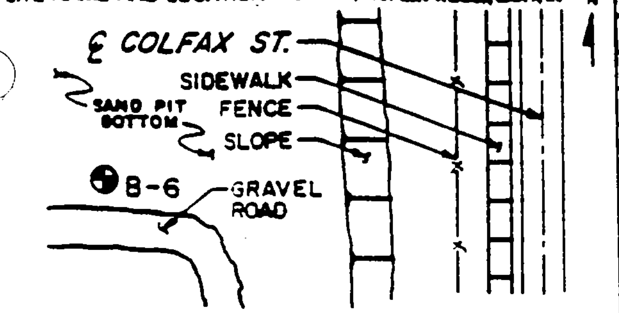
LOGGED BY Canonie Environmental (F.A. Halterman)

Printed on recycled paper.

SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS[illegible], GARY, IN



DATUM MSL ELEVATION 581.57

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.

SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer, Shelby-Tube (ST).

BORING NO. B-6

SHEET 1 OF 2

DRILLING	START	FINISH
TIME	0700	1500
DATE	10/22	10/22

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was at bottom of sand pit; open, flat, and marshy.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SAMPLE NUMBER	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	5,3,6 (100%)	1								
10	2,3,3 (100%)	2								
	2,2,2 (88%)	3								
20	1,2,2 (89%)	4								
	1,1,2 (78%)	5								
30	Pushed (30%)	6				22	28	15		*
	3,4,5 (100%)	7								
40	4,5,8 (100%)	8								
	17,15,15 (100%)	9								
50	8,8,10 (94%)	10								
	5,6,7 (100%)	11								
60	6,6,7 (100%)	12								
	4,6,7 (100%)	13								
70	5,5,7 (100%)	14								
	7,10,15 (100%)	15								

DESCRIPTION OF MATERIAL

Vegetation, Roots.

Gray Silty Clay, Trace Of Fine To Coarse Sand, Shell Fragments; Moist To Wet; Lean (CL).

* Coeff. of Permeability = 1.7 x 10^{-8} cm/sec, Cation Exchange Capacity = 12.7 mEq/100g

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

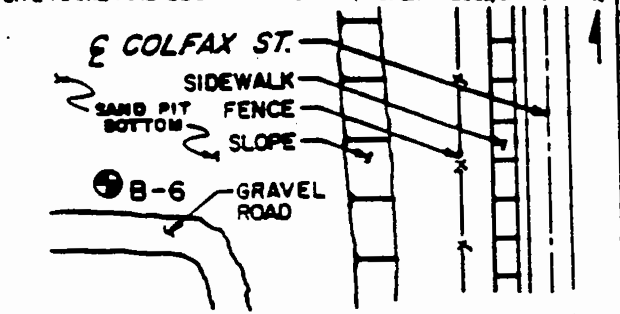
LOGGED BY Canonie Environmental (F.A. Halterman)

Printed on recycled paper.

SOIL BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS, GARY, IN



DATUM MSL
ELEVATION 581.57

DRILLING METHOD: Rotary wash method with 3-7/8 in. dia. tricone bit and Series AWML drill rods.
SAMPLING METHOD: Split-spoon (SS) with pneumatic drive hammer, Shelby-Tube (ST).

BORING NO. B-6
SHEET 2 OF 2

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
0700	1500
DATE	DATE
10/22	10/22

DRILL RIG CME 55
SURFACE CONDITIONS Area was at bottom of sand pit; open, flat, and marshy.
ANGLE Vertical BEARING None
SAMPLE HAMMER TORQUE -- FT.-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
80	28,29,35 (89%)		16 Gray Clayey Silt, Trace Of Fine To Coarse Sand; Moist; Slightly Plastic (ML).								
	10,27,42 (100%)		17 Gray Silty Clay, Trace Of Fine To Coarse Sand; Moist; Lean (CL).								
90	47,50/2 (28%)		18 Gray Clayey Fine To Coarse Sand, Trace Of Fine Gravel; Moist (SC).								
100	50/6 (17%)		19 Gray Clayey Silt, Some Fine Sand, With Some Fine To Coarse Gravel Sized Fragments Of Very Weathered Dolomite Bedrock; Moist; Slightly Plastic (ML).								

Bottom Of Boring At 97.0 Ft.

Note: All dates are 1987.

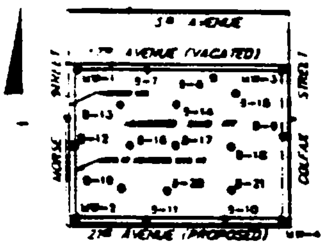
DRILLING CONTR. D & G Drilling, Inc.

LOGGED BY Canonie Environmental (F.A. Halterman)

SOIL BOREHOLE LOG

PROJECT NO [illegible]-141

SITE NAME AND LOCATION Glenwood Ridge Landfill
Gary, IN



DATUM MSL **ELEVATION** 585.00

DRILLING METHOD: [illegible]-in. auger, rotary wash, 4-in. tricone.

SAMPLING METHOD: 2-in. O.D. split spoon.

BORING NO. B-7

SHEET 1 OF [illegible]

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
1200	0830
DATE	DATE
8-1-88	8-2-88

DRILL RIG CME

SURFACE CONDITIONS Gravel road in pit, dry, north end.

ANGLE Vertical **BEARING** None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER QU TESTS
	9,10,17 (70%)		1 Medium Dense Brown Fine To Coarse Sand And Fine Gravel, Moist (SW).	2" O.D. SPLIT SPOON			11.7				
5 (580.0)	17,22,16 (75%)		2 Dense Brown Fine To Coarse Sand, Trace Fine Gravel, Wet (SW). 2-inch Fine Sand Layer At 5.0 Ft.				13.9				
10 (575.0)	3,2,5 (40%)		3 Soft To Medium Stiff Gray Clay, Trace of Silt, Wet (CL).				25.2				[illegible]
15 (570.0)	1,1,3 (100%)		4				25.2				[illegible]
20 (565.0)	1,1,2 (100%)		5				26.1				[illegible]
25 (560.0)	3,5,7 (60%)		6 Stiff Gray Clay, Some Silt, Moist (CL). Reddish-Brown Clay Pockets.				19.3				[illegible]
30 (555.0)	3,4,5 (90%)		7 Soft To Stiff Gray Clay, Trace of Silt, Moist (CL).				21.7				[illegible]
35 (550.0)	2,3,4 (90%)		8				24.6				[illegible]

DRILLING CONTR FOX DRILLING, INC.

LOGGED BY PS CANONIE

DATE 8-1-88 CHK'D BY

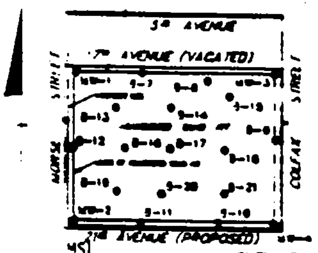
SL 05096

113

SOIL BOREHOLE LOG

PROJECT NO ..-[41]

SITE NAME AND LOCATION: GLENWOOD RIDGE LANDFILL GARY, IN	DRILLING METHOD: 4-in. auger, rotary wash, 4-in. tricone.		BORING NO B-7
	SAMPLING METHOD: 2-in. O.D. split-spoon.		SHEET 2 OF
			DRILLING
	WATER LEVEL		START / FINISH
	TIME		TIME 1000 / TIME 0830
	DATE		DATE 8-1-88 / DATE 8-2-88
DATUM MSL ELEVATION 585.00	CASING DEPTH		
DRILL RIG CME	SURFACE CONDITIONS Gravel road in pit, dry, north end.		
ANGLE Vertical BEARING None			
SAMPLE HAMMER TORQUE FT-LBS			



DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLER TYPE	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
40 (545.0)	2,4,5 (100%)	9	Soft To Stiff Gray Clay, Trace Of Silt, Moist (CL).	2" O.D. SPLIT SPOON			19.9				0.50
45 (540.0)	2,3,4 (100%)	10					21.8				0.50
50 (535.0)	4,6,10 (100%)	11	Gray Clayey Silt, Moist (ML).				30.0				
55 (530.0)	2,3,5 (100%)	12	Medium Stiff To Stiff Gray Clay, Trace Of Silt, Moist (CL).				24.2				
60 (525.0)	2,3,4 (100%)	13					23.2				
65 (520.0)	2,5,7 (60%)	14					23.1				
70 (515.0)	2,5,6 (100%)	15					23.2				
	4,8,9 (90%)	16					14.6				

DRILLING CONTR FOX DRILLING, INC

SL v5097

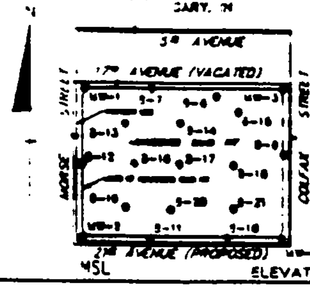
LOGGED BY PS : CANONIE

DATE 8-1-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO. [illegible]

SITE NAME AND LOCATION Glenwood Ridge Landfill Gary, IN



DATUM MSL ELEVATION 585.00

DRILLING METHOD 3-in. auger, rotary wash, 4-in. tricone.

BORING NO B-7

SHEET 3 OF [illegible]

SAMPLING METHOD 2-in. O.D. split-spoon.

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING START	DRILLING FINISH
TIME 1200	TIME 0830
DATE 8-1-88	DATE 8-2-88

DRILL RIG CME

SURFACE CONDITIONS Gravel road in pit, dry, north end.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE - FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6-IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
			Medium Stiff To Stiff Gray Clay, Trace Of Silt, Moist (CL).	2" O.D. SS							
80 (505.0)	7,11,16 (60%)	17	Very Stiff Gray Clay, Some Silt And Fine Sand, Dry (CL).				16.1				3.25
			Bottom Of Boring At 80.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

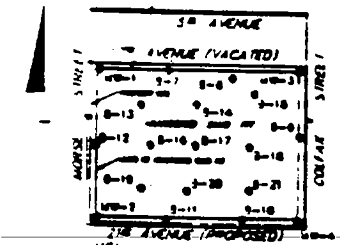
LOGGED BY PS-CANONIE

1137-38

SOIL BOREHOLE LOG

PROJECT NO. [illegible]-141

SITE NAME AND LOCATION: Glenwood Ridge Landfill, Gary, IN



DATUM	MSL
ELEVATION	583.81
DRILL RIG	CME 75
ANGLE	vertical
BEARING	None
SAMPLE HAMMER TORQUE	FT-LBS
DRILLING METHOD	4-in. auger, 4-in. dia. tricone (rotary wash).
SAMPLING METHOD	2-in. O.D. split-spoon.
SURFACE CONDITIONS	North gravel road in sand pit, dry.
BORING NO	B-8
SHEET	1 of 1

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	START	FINISH
TIME	1100	1430
DATE	8-2-88	8-2-88

DEPTH (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS Qu
	10,16,15 (80%)		1 Medium Dense Brown Fine Sand, Moist (SP).	2" O D SPLIT SPOON			19.3				
5 (578.81)	7,19,16 (75%)		2 Dense Brown Fine To Medium Sand, Wet (SP). Water Level At Approximately 5 Ft.				20.7				
10 (573.81)	4,7,3 (70%)		3 Stiff Gray/Brown Clay, Trace Of Silt, Dry (CL).				21.9				2.00
15 (568.81)	[illegible] (100%)		4 Very Soft To Medium Stiff Gray Clay, Trace Of Silt, Wet (CL).				27.3				0.25
20 (563.81)	1,1,2 (100%)		5				27.7				0.50
25 (558.81)	1,3,3 (80%)		6				25.9				0.25
30 (553.81)	1,3,3 (70%)		7				23.2				0.25
35 (548.81)	2,3,4 (60%)		8 Medium Stiff Gray Clay, Some Silt, Moist (CL).				21.2				

DRILLING CONTR. FOX DRILLING, INC.

SL 100

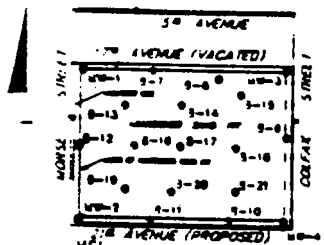
LOGGED BY CANONIE

DATE 8-2-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO. [illegible]-141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL
GARY, IN



DATUM MSL
ELEVATION 583.81

DRILLING METHOD 4-in. Tricone rotary wash.

SAMPLING METHOD 2-in. O.D. split-spoon.

BORING NO. B-3

SHEET 3 OF

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
1100	1430
DATE	DATE
8-2-88	8-2-88

DRILL RIG CME 75

SURFACE CONDITIONS North gravel road in sand pit, dry.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
			Very Stiff Gray Silty Clay, Dry (CL).	2" O D SS							
			Hard Gray Silty Clay, Some Fine To Coarse Sand, Dry (CL).								
80 (503.81)	14,22,27 (60%)	17	Gray Silty Clay And Fine To Coarse Sand, Dry (SW&CL).				22.2				34.5
			Bottom Of Boring At 80.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

SL 05099

LOGGED BY PS-CANONIE

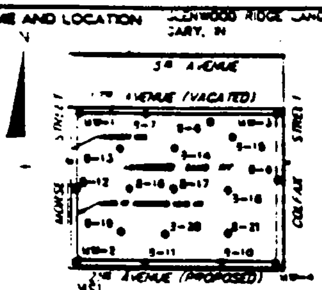
DATE 8-2-88 CHK'D BY

1139-40

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION Glenwood Ridge Landfill
Gary, IN



DATUM MSL **ELEVATION** 583.81

DRILLING METHOD 4-in. auger, [illegible]
[illegible] tricone (rotary wash).

SAMPLING METHOD 2-in. O.D. split-
spoon.

BORING NO [illegible]-8

SHEET [illegible] OF [illegible]

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
1100	1430
DATE	DATE
8-2-88	8-2-88

DRILL RIG CME 75

SURFACE CONDITIONS North gravel road in sand pit, dry.

ANGLE Vertical **BEARING** None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS Qu
40 (543.81)	2,4,5 (50%)		9 Medium Stiff Gray Clay, Some Silt, Moist (CL).	2" O D SPLIT SPOON			23.3				0.75
45 (538.81)	1,3,4 (60%)		10 Soft To Medium Stiff Gray Clay, Trace Of Silty Moist (CL).				21.3				0.25
50 (533.81)	1,3,5 (60%)		11				20.8				0.75
55 (528.81)	14,20,23 (60%)		12 Dense Gray [illegible], Trace Of Clay, Trace Of Fine Sand, Moist [illegible].				16.3				
60 (523.81)	1,3,5 (60%)		13 Medium Stiff Gray Clay, Trace Of Silt, Moist (CL).				23.4				1.00
65 (518.81)	2,4,5 (60%)		14				22.0				0.50
[illegible] (513.81)	4,6,9 (60%)		15				23.2				1.75
	9,15,18 (60%)		16 Very Stiff Gray Silty Clay, Dry (CL).				25.4				[illegible]

DRILLING CONTR FOX DRILLING, INC

SL 05101

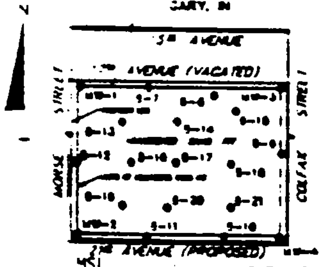
LOGGED BY PS-CANONIE CHK'D BY

DATE 8-2-88

SOIL BOREHOLE LOG

PROJECT NO [illegible]141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 618.83

DRILLING METHOD [illegible] in. Auger, [illegible] in. [illegible] a. Rotary Wash.

SAMPLING METHOD [illegible] in. O.D. Split Spoon.

BORING NO. B-9

SHEET 1 OF [illegible]

WATER LEVEL					
TIME					
DATE					
CASING DEPTH					

DRILLING	
START	FINISH
TIME	TIME
1000	1515
DATE	DATE
3-4-88	3-[illegible]-88

DRILL RIG CME 75

SURFACE CONDITIONS East perimeter of sand pit, dry.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL		SAMPLER AND INT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS QU
	2,4,5 (30%)		1	Loose To Dense Brown Fine Sand, Moist To Wet (SP).	2" O D SPLIT SPOON			3.9				
	4,5,7,7 (75%)		2	Grayish Brown From 3.5 Ft. To 4.0 Ft.				6.4				
5 (618.83)	5,6,7,6 (80%)		3	Medium Dense To Very Dense Brown Fine Sand, Moist To Wet (SP).				5.6				
	5,5,6,6 (70%)		4					4.2				
	3,4,5,7 (60%)		5					4.8				
10 (608.83)	6,9,13,15 (30%)		6					20.8				
	8,13,16,17 (40%)		7					21.2				
15 (608.83)	8,11,13,15 (40%)		8					21.6				
	3,13,19,29 (40%)		9					18.2				
	17,32,44,4 (50%)		10	Very Dense Brown Fine To Medium Sand, Wet (SP).				16.7				
20 (598.83)	16,33,51,69 (50%)		11	Medium Dense To Very Dense Brown Fine Sand, Moist To Wet (SP).				16.0				
	22,42,60, 100 (60%)		12					10.4				
25 (593.83)	27,39,66, 125 (65%)		13					6.5				
	35,57,73, 108 (65%)		14					6.0				
	24,39,30, 148 (75%)		15	Rust Colored Layers At 29.0 Ft.				[illegible].0				
30 (588.83)	50,87,170, 200 (70%)		16					9.7				
	46,96,180, 200 (100%)		17					16.2				
35 (583.83)	42,95,125, 200 (90%)		18					19.3				
	42,56,66,94 (75%)		19					16.9				

DRILLING CONTR FOX DRILLING, INC

SL 05133

LOGGED BY PS-CANONIE

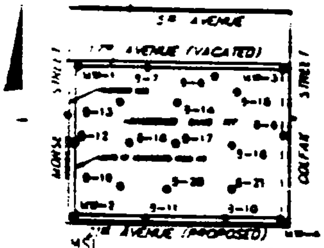
DATE 8-8-88 CHK'D BY

1141-42

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION [illegible]wood Ridge Landfill, Gary, IN



DRILLING METHOD	[illegible] auger, [illegible]				**BORING NO** [illegible]9
[illegible] rotary wash.					**SHEET** [illegible] OF [illegible]
SAMPLING METHOD	[illegible] split-				**DRILLING**
spoon.					**START** / **FINISH**
WATER LEVEL					**TIME** / **TIME**
TIME					1000 / 1515
DATE					**DATE** / **DATE**
CASING DEPTH					8-4-88 / 8-8-88

DATUM MSL **ELEVATION** 618.83

DRILL RIG CME 75 **SURFACE CONDITIONS** East perimeter of sand [illegible]

ANGLE Vertical **BEARING** None

SAMPLE HAMMER TORQUE [illegible] LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLER TYPE	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS Qu
	10,32,57,65 (50%)	20	Medium Dense To Very Dense Brown Fine Sand, Moist To Wet (SP).	2" O D SPLIT SPOON			20.4				
40 (578.83)	22,30,17,13 (40%)	21					19.3				
	4,7,10,11 (75%)	22	Soft To Very Stiff Gray-Brown Clay, Trace Silt, Dry To Wet (CL).				23.4				3.00
45 (573.83)	4,6,8,10 (90%)	23					25.5				1.50
	2,3,4,6 (80%)	24					27.1				1.00
	1,2,3,3 (90%)	25					26.7				0.25
50 (568.83)	1,2,2,3 (65%)	26	Very Soft To Stiff Gray Silty Clay, Trace Fine To Medium Sand, Moist To Wet (CL).				27.0				0.25
	3,3,5,6 (0%)	27									
	1,3,3,4 ([illegible]0%)	28					26.8				0.00
55 (563.83)	1,2,3,4 ([illegible]0%)	29					26.3				0.00
	1,3,2,4 (70%)	30					24.7				0.25
60 (558.83)	1,2,4,4 (90%)	31					22.7				0.50
	1,3,3,5 (65%)	32					22.6				0.75
65 (553.83)	4,5,6,8 ([illegible]5%)	33					24.7				0.50
	2,5,6,8 ([illegible]0%)	34					23.7				0.25
	ST	35		ST			22.0	28.7	16.3		0.75
70 (548.83)	[illegible],4,6,8 (100%)	36		2" OD SS			21.0				
	2,4,5,7 (90%)	37					20.2				0.75
	2,5,7,9 (100%)	38									[illegible]

DRILLING CONTR FOX DRILLING, INC

SL05134

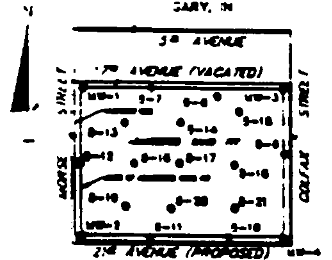
LOGGED BY PS-CANONIE CHK'D BY

DATE 8-8-88

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION Glenwood Ridge Landfill Gary, IN



DATUM MSL ELEVATION 618.83

DRILLING METHOD	[illegible]-in. dia. rotary wash.	BORING NO	[illegible]-9
SAMPLING METHOD	2-in. O.D. split spoon.	SHEET	1 OF [illegible]
		DRILLING	
		START	FINISH
WATER LEVEL		TIME	TIME
TIME		1000	1515
DATE		DATE	DATE
CASING DEPTH		8-4-88	8-8-88

DRILL RIG CME 75

SURFACE CONDITIONS East perimeter of sand pit, dry.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER TYPE AND SIZE	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
		▨	38 Very Soft To Stiff Gray Clay, Trace Of Silt,	2" O D SPLIT SPOON			22.1				1.00
	4,7,10,13 (90%)	▨	39 Moist To Wet (CL).				18.9				1.50
		▨	1-In. Clayey Fine Sand Layer At 77.0 Ft.								
	4,6,8,10 (95%)	▨	40				22.1				1.00
80 (538.83)	2,4,6,12 (100%)	▨	41 1-In. Clayey Silt Layer At 81.0 Ft.				20.6				1.25
	12,30,15,27 (100%)	▥	42 Dense Gray Silt, Trace Of Clay, Trace Fine Sand, Dry (ML).				17.3				2.00
		▨	Stiff Gray Clay, Trace Of Silt, Dry (CL).				18.0				
85 (533.83)	20,25,20,21 (100%)	▥	● Medium Stiff Gray Silt, Trace Of Clay, Trace Of Fine Sand, Dry (ML).				16.9				
	10,15,14,16 (100%)	▥	44				17.6				
	15,12,8,7 ([illegible]0%)	▥	45				19.3				0.50
		▨					32.2				
90 (528.83)	1,5,4,7 (100%)	▨	46 Medium Stiff To Stiff Gray Clay, Trace Of Silt, Moist (CL).				25.0				0.50
	2,5,6,9 (95%)	▨	47				21.2				1.25
95 (523.83)	3,5,6,8 (100%)	▨	48				20.0				0.75
	3,5,7,9 (100%)	▨	49				20.9				0.75
	2,5,6,8 (95%)	▨	50				21.8				1.00
100 (518.83)			Bottom Of Boring At 100.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

SL 05136

LOGGED BY PS-CANONIE

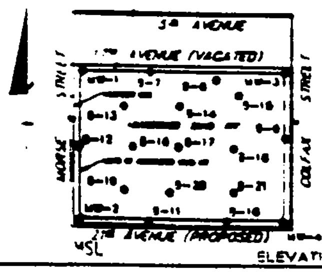
DATE 8-8-88 CHK'D BY

1143-44

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 609.75

DRILLING METHOD [illegible] dia. auger and rotary wash.

SAMPLING METHOD split-spoon.

BORING NO [illegible]

SHEET [illegible]

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING

	START	FINISH
TIME	0845	1445
DATE	7-22-88	7-22-88

DRILL RIG

SURFACE CONDITIONS South perimeter of sand pit. Scattered [illegible] and broken concrete on surface.

ANGLE Vertical BEARING

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NO.	SAMPLE DESCRIPTION MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	1,2,2 (10%)		1	Very Loose Brown Silty Sand, Trace Of Roots, Moist (SW-SM).	2" O.D. SPLIT SPOON			11.2				
5 (604.75)	6,11,10 (30%)		2	Medium Dense Brown Silty Fine To Coarse Sand, Fine To Coarse Gravel, Moist (SW-SM).				3.6				
10 (599.75)	2,3,3 (60%)		3	Loose Brown Fine To Coarse Sand, Trace Fine To Coarse Gravel, Moist (SW).				3.2				
15 (594.75)	16,21,17 (60%)		4	Medium Dense To Very Dense Brown Fine To Medium Sand, Wet (SP).				24.9				
20 (589.75)	15,20,37 (70%)		5					22.4				
25 (584.75)	10,12,26 (65%)		6					24.4				
30 (579.75)	15,8,6 (30%)		7					22.3				
35 (574.75)	4,6,9 (50%)	▨	8	Stiff Brown/Gray Clay, Trace Of Fine To Medium Sand, Wet (CL).				25.1				

DRILLING CONTR FOX DRILLING, INC

SL 05147

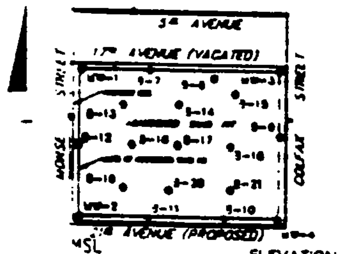
LOGGED BY JD - CANONIE

DATE 7-22-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 609.75

DRILLING METHOD: 4-in. dia. auger and rotary wash.

SAMPLING METHOD Split-spoon.

BORING NO S-10

SHEET OF

WATER LEVEL					
TIME					
DATE					
CASING DEPTH					

DRILLING	
START	FINISH
TIME	TIME
0845	1445
DATE	DATE
7-22-88	7-22-88

DRILL RIG

SURFACE CONDITIONS South perimeter of sand pit. Scattered garbage and broken concrete on surface.

ANGLE Vertical BEARING

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
40 (569.75)	2,2,3 (75%)		9 Medium Stiff Gray Clay, Trace Of Silt, Trace Of Fine To Medium Sand, wet (CL).	2" O D SPLIT SPOON			27.2				0.50
45 (564.75)	2,2,3 (90%)		10 Soft To Medium Stiff Gray Silty Clay, Trace Of Fine Sand, wet (CL).				27.6				0.25
50 (559.75)	1,2,2 (100%)		11				29.8	29.9	19.[illegible]		.25
55 (554.75)	2,2,3 (75%)		12				24.0				.1
60 (549.75)	2,2,3 (70%)		13				23.6				.5
65 (544.75)	2,2,3 (100%)		14				22.8				.4
70 (539.75)	7,10,13 (70%)		15 Stiff Gray Clayey Silt, Trace Of Fine To Coarse Sand, wet (ML).				15.4				3
	6,20,21 (60%)		16 Very Stiff Gray Clayey Silt, Trace Of Fine Sand, wet (ML).				17.3				

DRILLING CONTR FOX DRILLING, INC.

SL 05148

LOGGED BY TD-CANONIE CHK'D BY

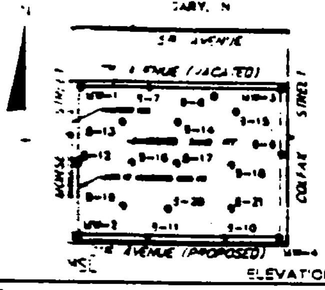
DATE 7-22-88

1145-46

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION	Glenwood Ridge Landfill Gary, IN
DRILLING METHOD	[illegible] and rotary wash.
SAMPLING METHOD	[illegible] O.D. Split-Spoon.
BORING NO	[illegible]
SHEET	[illegible]
DATUM	MSL
ELEVATION	609.75



	DRILLING START	DRILLING FINISH
TIME	0845	1445
DATE	7-22-88	7-22-88

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILL RIG

ANGLE Vertical BEARING

SAMPLE HAMMER TORQUE FT-LBS

SURFACE CONDITIONS South perimeter of sand pit. Scattered garbage and broken concrete on surface.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %				OTHER TESTS
80 (529.75)	6,14,27 (70%)		17 Very Stiff Gray Clay, Trace of Silt, wet (CL).	2" O.D. SPLIT SPOON			17.4				2.75
85 (524.75)	6,11,16 (30%)		18 Medium Stiff Gray Clay, Trace Of Silt, Trace of Fine To Medium Sand, wet (CL).				19.8				[illegible]
90 (519.75)	4,8,12 (90%)		19 Stiff Gray Clay, Trace of Silt, Trace of Fine Sand, wet (CL).				20.2				
95 (514.75)	4,8,[illegible] (100%)		20				22.[illegible]				
100 (509.75)	5,11,13 (30%)		21				16.2				
			Bottom of Boring At [illegible] Ft.								

FOX DRILLING, INC

DRILLING CONTR.

SL [illegible] 49

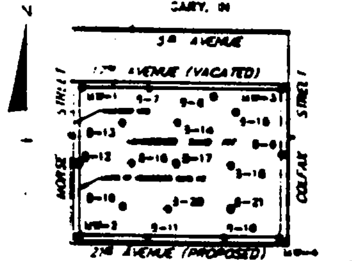
LOGGED BY J.D. CANONIE

DATE 7-22-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION Glenwood Ridge Landfill
Gary, IN



DRILLING METHOD	[illegible] rotary	BORING NO	-11
	wash.	SHEET	of
SAMPLING METHOD	[illegible]	DRILLING	
		START	FINISH

WATER LEVEL					TIME	TIME
TIME					0940	[illegible]
DATE					DATE	DATE
CASING DEPTH					7-25-88	7-25-88

DATUM MSL ELEVATION 608.39

DRILL RIG CME 75

SURFACE CONDITIONS South perimeter of [illegible], wet sand, muddy.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE – FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER TYPE	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS	QU
	1.5.7 (40%)		1 Medium Dense Brown Fine To Medium Sand. Dry (SP). Trace Of Roots From 0.0 To 5.0 Ft.	2" O.D. SPLIT SPOON			6.8					
5 (603.39)	1.1.2 (20%)		2				9.3					
10 (598.39)	8.14.16 (40%)		3				23.9					
15 (593.39)	17.21.29 (40%)		4				19.9					
20 (588.39)	21.30.38 (0%)		5 Very Dense Brown/Gray Fine To Medium Sand. Trace of Silt, Moist (SP). Pushed Spoon From 20.0 Ft. To 21.5 Ft. For Sample.				25.6					
25 (583.39)	8.12.17 (30%)		6 Medium Dense Gray Fine To Medium Sand. Moist (SP).				35.5					
30 (578.39)	4.6.9 (60%)		7 Very Stiff Gray/Brown Clay, Trace of Silt, Some Fine To Coarse Sand, Some Fine To Medium Gravel, Moist (CL).				24.4				[illegible]	
35 (573.39)	4.5.6 (35%)		8 Stiff Gray Clay, Trace Of Silt, Trace Fine To Coarse Sand, Moist (CL).				23.7				[illegible]	

DRILLING CONTR FOX DRILLING, INC

SI 05117

LOGGED BY PS CANONIE CHK'D BY

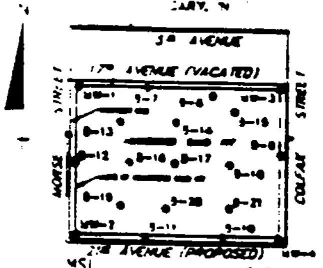
DATE 7-25-88

1147-46

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION [illegible]WOOD RIDGE LANDFILL GARY, IN



DATUM MSL
ELEVATION 608.39

DRILLING METHOD [illegible] Wash.

SAMPLING METHOD 2" O.D. Split-Spoon.

BORING NO [illegible]-11

SHEET [illegible] OF [illegible]

	DRILLING	
	START	FINISH
TIME	0940	1500
DATE	7-25-88	7-25-88

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILL RIG CME 75

SURFACE CONDITIONS South perimeter of sand pit. Wet sand. Muddy.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6" ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER TYPE AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS QU
			Medium Stiff Gray Clay, Trace of Silt, Moist (CL).	2" O D SPLIT SPOON							
40 (568.39)	[illegible],3 (100%)		9				26.7				0.50
45 (563.39)	1,3,4 (90%)		10				22.9				0.50
[illegible] (558.39)	1,2,4 ([illegible]%)		11				23.7				[illegible]
[illegible] (553.39)	[illegible] ([illegible]%)		12				[illegible].5				[illegible]
50 (548.39)	[illegible],3,6 ([illegible]%)		13				21.4				[illegible]
			Gray Clayey [illegible]								
55 (543.39)	[illegible],3 ([illegible]%)		14				24.4				[illegible]
			Medium Stiff Gray Clay, Trace of Silt, Moist (CL).								
[illegible] (538.39)	2,3,5 (100%)		15				20.2				
			Stiff Gray Clayey Silt, Moist (ML).								
	3,6,9 (90%)		16				17.8				[illegible]

DRILLING CONTR FOX DRILLING, INC

SL05118

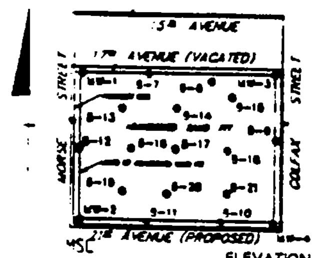
LOGGED BY PS-- CANONIE CHK'D BY

DATE 7-25-88

SOIL BOREHOLE LOG

PROJECT NO. [illegible]-141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL
GARY, IN



DATUM MSL ELEVATION 611.11

DRILLING METHOD: [illegible] (rotary wash).

SAMPLING METHOD: 2-in. O.D. split-spoon, Shelby tube.

BORING NO. B-12

SHEET 2 OF 3

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
1000	0930
DATE	DATE
8-17-88	8-19-88

DRILL RIG CME 75

ANGLE vertical BEARING none

SAMPLE HAMMER TORQUE FT-LBS

SURFACE CONDITIONS west gravel road, perimeter of sand pit.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
		19	Same As Above.	2" O D SPLIT SPOON							
	2,3,5,5 (80%)	20	2-In. Brown Clay Seam At 41.0 Ft.				24.8				0.50
40 (571.11)	1,3,3,4 (90%)	21					23.8				0.50
	1,3,3,3 (90%)	22					25.8				0.25
45 (566.11)	1,1,2,2 (90%)	23					25.1				0.25
	2,2,3,3 (90%)	24					24.5				0.25
	2,5,8,11 (80%)	25					19.8				1.25
50 (561.11)	3,4,5,5 (0%)	26	Stiff Gray Clayey Silt, Trace Of Fine Sand Wet (ML).								
	2,3,5,5 (80%)	27	Soft To Stiff Gray Silty Clay, Trace Fine To Coarse Sand, Trace Fine Gravel, Wet (CL).				16.3				0.50
55 (556.11)	2,4,8,3 (70%)	28					19.3				0.75
	1,4,6,9 (60%)	29					19.5				
		30	Clayey Silt Seams From 55.0 Ft. To 56.5 Ft.	ST			23.0	32.2	16.5		
60 (551.11)	2,4,5,6 ([illegible]%)	31		2" O D SPLIT SPOON			24.7				[illegible]25
	1,4,4,5 (70%)	32	Medium Stiff To Very Stiff Gray Clay, Trace Of Silt, Trace Of Fine Sand, Wet (CL).				24.0				[illegible]
65 (546.11)	1,2,5,7 (90%)	33					21.[illegible]				[illegible]
	5,7,8,14 (80%)	34					16.5				[illegible].50
	3,6,9,15 (90%)	35					24.7				[illegible]
70 (541.11)	5,17,47,56 (90%)	36	Very Dense Gray Silt, Some Clay, Wet (ML).				19.2				
	12,8,10,11 (90%)	37	Stiff To Very Stiff Gray Clay, Trace Of Silt, Trace Of Fine Sand, Wet (CL).				25.3				[illegible]
	4,8,11,14	38									

DRILLING CONTR FOX DRILLING, INC

SL 05103

LOGGED BY TD-CANONIE CHK'D BY

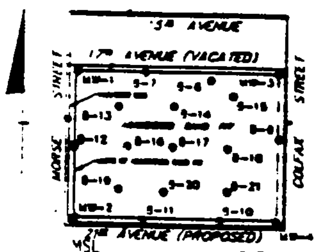
DATE 8-19-88

1149-53

SOIL BOREHOLE LOG

PROJECT NO 7-141

SITE NAME AND LOCATION Glenwood Ridge Landfill Gary, IN



DATUM MSL

ELEVATION 611.11

DRILLING METHOD -in. [illegible] rotary wash.

SAMPLING METHOD 2-in. O.D. Split-Spoon.

BORING NO -12

SHEET 3 OF

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
1000	1330
DATE	DATE
8-17-88	8-19-88

DRILL RIG CME 75

SURFACE CONDITIONS West gravel road, perimeter of sand pit.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT.-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER TYPE AND SIZE	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	qu OTHER TESTS
	70%)		38	2" O D SPLIT SPOON			14.1				2.50
	4,7,10,16 (80%)		39 Very Stiff Gray Silty Clay, Trace Of Fine Sand, wet (CL).				16.6				2.00
	3,6,9,12 (90%)		40				19.2				1.00
80 (531.11)	6,7,10,13 (80%)		41 Medium Stiff To Stiff Gray Clay, Trace Fine Sand, wet (CL).				22.0				0.75
	4,5,9,11 (90%)		42				21.7				1.00
85 (526.11)	3,6,7,10 (90%)		43				21.8				0.75
	3,4,7,10 (100%)		44				22.5				0.75
	3,6,9,12 (100%)		45				22.5				0.75
90 (521.11)	3,5,8,10 (100%)		46				24.1				0.75
	4,7,8,12 (100%)		47				23.8				0.50
95 (516.11)	3,6,7,11 (100%)		48				23.4				0.50
	4,6,9,15 (100%)		49				22.9				0.75
100 (511.11)	4,6,11,14 (80%)		50				22.2				1.25

Bottom Of Boring At 100.0 Ft.

DRILLING CONTR FOX DRILLING, INC

SL 05104

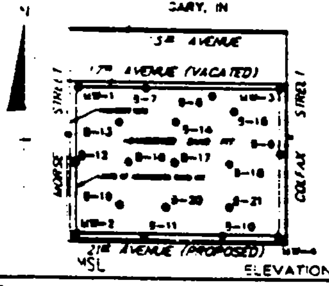
LOGGED BY TD - CANONIE

DATE 8-19-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION Glenwood Ridge Landfill Gary, IN



DATUM MSL ELEVATION 579.52

DRILLING METHOD 3-in. [illegible] stem auger.

SAMPLING METHOD 2-in. O.D. split-spoon, Shelby tube (S-8).

BORING NO B-13

SHEET [illegible] OF [illegible]

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
700	1030
DATE	DATE
7-20-88	7-20-88

DRILL RIG Diedrich D-50

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

SURFACE CONDITIONS Open field, bottom of sand pit. Muddy with water channels.

N14+91, W20+11

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
	10,13,17 (60%)	▨	1 Hard Brown Clay, Trace Of Silt, Trace Of Fine To Coarse Sand And Fine To Coarse Gravel, Dry (CL).	2" OD SPLIT SPOON			14.3				>4.5
5 (574.52)	5,6,6 (60%)	▨	2 Very Stiff Brown/Gray Clay, Trace Of Silt, Moist (CL).				21.4				2.25
10 (569.52)	3,4,6 (70%)	▨	3 Medium Stiff To Stiff Gray Clay, Trace Of Silt, Moist (CL).				24.0				0.75
15 (564.52)	4,6,7 (100%)	▨	4				22.0				0.75
			5 Gray Clayey Sand And Gravel, Wet (SC&GC).				22.7				
20 (559.52)	3,4,5 (80%)	▨	6 Medium Stiff Gray Clay, Trace Of Silt, Moist (CL).				21.8				0.75
25 (554.52)	3,4,6 (80%)	▨	7 Gray Clay, Trace Of Silt, Trace Of Fine To Coarse Sand, Wet (CL).				24.5				0.50
30 (549.52)	-- (100%)	▨	8 Medium Stiff Gray Silty Clay, Trace Fine To Coarse Sand, Moist (CL).	3" ST			24.3	31.2	17.3		
35 (544.52)	5,6,9 (100%)	▨	9	2" OD SS			23.3				0.75

DRILLING CONTR FOX DRILLING, INC.

SL 05060

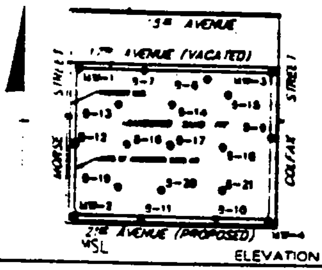
LOGGED BY PS - CANONIE CHK'D BY

DATE 7-20-88

SOIL BOREHOLE LOG

PROJECT NO [illegible]-141

SITE NAME AND LOCATION [illegible]NWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 579.52

DRILLING METHOD 3-in. [illegible] [illegible]ow- stem auger.

SAMPLING METHOD 2-in. O.D. split- spoon. Shelby tube (S-8).

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

BORING NO. B-13

SHEET [illegible] OF [illegible]

DRILLING	
START	FINISH
TIME	TIME
700	1030
DATE	DATE
7-20-88	7-20-88

DRILL RIG Diedrich D-50

SURFACE CONDITIONS Open field, bottom of sand pit. Muddy with water channels.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT -LBS

N14+91, W20+11

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
40 (539.52)	5,3,11 (100%)	▨	10 Medium Stiff Gray Clay, Trace of Silt, Wet(CL).	2" O.D. SPLIT SPOON			18.5				0.75
45 (534.52)	6,9,11 (100%)	▨	11				19.9				1.00
		▨	Stiff Gray Clay, Silty Clay, Trace Fine To Medium Sand, Wet (CL).								
50 (529.52)	6,7,8 (100%)	▨	12					29.1	18.5		1.25
			Bottom Of Boring At 50.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

SL [illegible]5116

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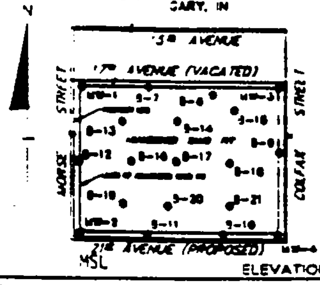
DATE 7-20-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO -141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL
ELEVATION 579.35

DRILLING METHOD: 6-in. O.D. hollow-stem auger.

SAMPLING METHOD 2-in. O.D. split-spoon.

BORING NO. -14

SHEET OF

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
1030	1215
DATE	DATE
7-15-88	7-15-88

DRILL RIG Diedrich D-50

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT -LBS

SURFACE CONDITIONS Open field, bottom of sand pit. Dry with water channels.

N14+90, W13+48

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
	5,7,8 (25%)	▨	1 Hard Brown Clay, Trace Of Sand, Trace of Silt, Moist (CL).	2" O.D. SPLIT SPOON			15.8				>4.5
5 (574.35)	3,3,4 (60%)	▨	2 Very Stiff Brownish Gray Clay, Trace of Silt, Wet (CL).				22.3				2.25
10 (569.35)	2,2,2 (60%)	▨	3 Very Soft To Stiff Gray Clay, Trace of Silt, Wet (CL).				25.8				0.25
15 (564.35)	2,3,3 50%)	▨	4				25.0				0.00
20 (559.35)	2,2,3 (70%)	▨	5				22.1				0.25
25 (554.35)	3,4,8 (60%)	▨	6				21.5				0.75
30 (549.35)	6,7,9 (60%)	▨	Some Fine To Coarse Sand From 28.5 Ft. To 29.0 Ft. 7				12.8				1.25
35 (544.35)	6,8,10 60%)	▨	Stiff Gray Clay, Trace of Fine To Coarse Sand, Trace of Silt (CL). 8 Stiff To Very Stiff Gray Clay, Trace Of Silt, Wet (CL).				19.4				1.25

DRILLING CONTR. FOX DRILLING, INC

SL 05087

LOGGED BY TD - CANONIE

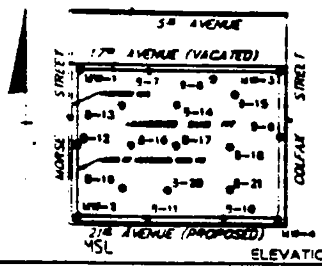
DATE 7-15-88 CHK'D BY

[illegible]

SOIL BOREHOLE LOG

PROJECT NO -141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL
GARY, IN



DATUM MSL ELEVATION 579.35

DRILLING METHOD 6-in. O.D. hollow-stem auger.

SAMPLING METHOD 2-in. O.D. split-spoon.

BORING NO B-14

SHEET 3 OF

DRILLING	
START	FINISH
TIME	TIME
1030	1215
DATE	DATE
7-15-88	7-15-88

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILL RIG Diedrich D-50

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

SURFACE CONDITIONS Open field, bottom of sand pit. Dry with water channels.
N14+90, W13+48

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
40 (539.35)	5,10,12 (70%)	▨	9 Stiff To Very Stiff Gray Clayey Silt, Some Fine To Medium Sand, Wet (CL-ML).	2" O.D SPLIT SPOON			16.2				2.25
45 (534.35)	8,9,11 (70%)	▨	10				17.7	24.1	17.8		2.00
50 (529.35)	3,6,10 (80%)	▨	11				21.3				1.00
			Bottom Of Boring At 50.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

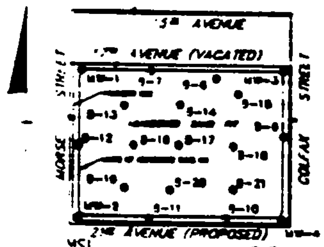
LOGGED BY TD - CANONIE

DATE 7-15-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO. [illegible]-141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 578.76

DRILLING METHOD	[illegible]-in. dia. auger and rotary wash.	BORING NO	B-15
SAMPLING METHOD.	2" O.D. split-spoon. Shelby tubes at 18.5 ft. and 28.5 ft.	SHEET	1 of 1

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
1240	1530
DATE	DATE
8-3-88	8-3-88

DRILL RIG CME 75

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

SURFACE CONDITIONS Northeast corner in bottom of sand pit, muddy with water channel.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
	2,2,3 (20%)	▨	1 Stiff Gray/Brown Clay, Trace Of Silt, Trace of Fine Sand, Dry (CL).	2" O. D. SPLIT SPOON			22.3				1.75
5 (573.76)	3,6,7 (90%)	▨	2 Very Stiff Gray/Brwn Clay, Trace Of Silt, Dry (CL).				24.3				2.50
10 (568.76)	3,3,3 (100%)	▨	3 Very Soft To Medium Stiff Gray Clay, Trace Of Silt, Moist (CL).				23.8				0.50
15 (563.76)	1,2,2 (75%)	▨	4				26.4				[illegible]
20 (558.76)	ST	▨	5	ST			25.0	31.0	19.1		
25 (553.76)	3,4,6 (25%)	▨	6	2" O D SS			24.3				
30 (548.76)	ST	▨	7	ST			30.0	31.0	17.[illegible]		
35 (543.76)	3,4,7 ([illegible]%)	▨	8	2" O D SS			23.3				

DRILLING CONTR. FOX DRILLING, INC.

SL 05094

LOGGED BY [illegible] CANONIE

DATE 8-3-88 CHK'D BY

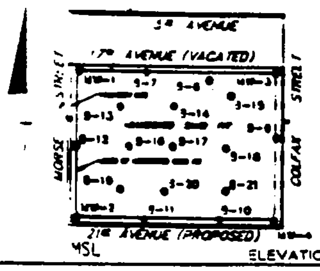
35

1151-46

SOIL BOREHOLE LOG

PROJECT NO -141

SITE NAME AND LOCATION ENWOOD RIDGE LANDFILL
GARY, IN



DATUM MSL	**ELEVATION** 578.76					
DRILLING METHOD: in. I.D. auger and rotary wash.					**BORING NO.**	3-15
SAMPLING METHOD " O.D. split-spoon.					**SHEET**	2 OF
					DRILLING	
					START	**FINISH**
WATER LEVEL					**TIME**	**TIME**
TIME					1240	1530
DATE					**DATE**	**DATE**
CASING DEPTH					8-3-88	8-3-88

DRILL RIG CME 75

SURFACE CONDITIONS Northeast corner in bottom of sand pit. muddy with water channel.

ANGLE vertical **BEARING** None

SAMPLE HAMMER TORQUE FT -LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS Qu
40 (538.76)	2,4,5 (90%)	▨	9 Very Soft To Medium Stiff Gray Clay, Trace Of Silt, Moist (CL).	2" O D SS			22.3				0.75
45 (533.76)	3,6,12 (100%)	▨	10 Gray Clayey Silt, Dry (ML).				16.4				
50 (528.76)	13,14,16 (30%)	▨	11				18.3				1.25
			Bottom Of Boring At 50.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

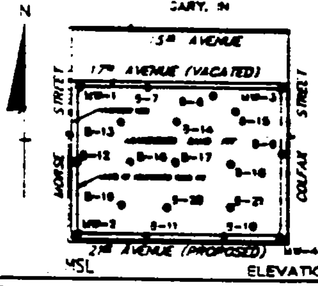
05095

DATE 8-3-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO. -141

SITE NAME AND LOCATION	GLENWOOD RIDGE LANDFILL GARY, IN
DATUM	MSL
ELEVATION	578.95



DRILLING METHOD:	3-in. hollow-stem auger.
SAMPLING METHOD:	2-in. O.D. split-spoon.

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

BORING NO.	B-16
SHEET	1 OF [illegible]

DRILLING	
START	FINISH
TIME	TIME
1215	0915
DATE	DATE
7-12-88	7-13-88

DRILL RIG	Diedrich D-50
ANGLE	Vertical
BEARING	None
SAMPLE HAMMER TORQUE	FT -LBS
SURFACE CONDITIONS	Open field. Bottom of sand pit. Dry with water channels.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS QU
	6,6,6,6 (15%)		1 Hard Brown Clay, Trace Of Silt, Trace Of Fine Sand, Dry (CL).	2" O D SPLIT SPOON			15.6				4.50
	5,5,4,4 (30%)		2 Stiff Brown Clay, Trace Of Silt, Trace Of Fine Sand, Moist (CL).				14.7				1.00
	3,3,3,5 (0%)		3 Soft To Stiff Gray Silty Clay, Trace Fine Sand, Wet (CL).								1.00
5 (573.95)	2,2,3,5 (60%)		4				24.7	35.0	18.0		0.50
	2,2,4,5 (100%)		5				23.4				0.50
10 (568.95)	1,3,3,4 (70%)		6				24.0				0.50
	3,3,4,6 (70%)		7				23.0				0.25
15 (563.95)	2,3,3,5 (60%)		8				23.1				0.25
	2,3,4,6 (50%)		9				21.3				[illegible]
	2,3,4,5 (50%)		10				21.6				[illegible]
20 (558.95)	2,3,5,6 (70%)		11				22.1				[illegible]
	2,3,3,5 (50%)		12				22.1				[illegible]
25 (553.95)	3,5,6,9 (70%)		13				19.5				[illegible]
	2,3,5,7 (70%)		14				21.9				[illegible]
	2,4,5,7 (70%)		15				19.8				[illegible]
30 (548.95)	3,4,6,8 (60%)		16				20.0				[illegible]
	3,5,7,9 (80%)		17				22.0				[illegible]
35 (543.95)	10,13,13,15 (60%)		18				21.0				[illegible]
	3,7,10,13 (75%)		19				15.4				[illegible]

DRILLING CONTR FOX DRILLING, INC

SL 05091

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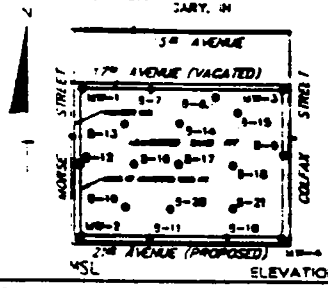
DATE 7-12-88 CHK'D BY

1157-18

SOIL BOREHOLE LOG

PROJECT NO. -141

SITE NAME AND LOCATION Glenwood Ridge Landfill, Gary, IN



DATUM MSL
ELEVATION 578.95

DRILLING METHOD: 6-in. hollow-stem auger.

SAMPLING METHOD: 2-in. O.D. split-spoon.

BORING NO. B-16

SHEET 2 OF 2

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
1215	0915
DATE	DATE
7-12-88	7-13-88

DRILL RIG Diedrich D-50

SURFACE CONDITIONS Open field. Bottom of sand pit. Dry with water channels.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS Qu
	3,7,10,13 (50%)		20 Soft To Stiff Gray Silty Clay, Trace Of Fine Sand, Wet (CL).	2" O.D. SS			19.5				1.00
40 (538.95)	4,8,11,13 (80%)		21				20.0				0.50
	4,5,15,16 (75%)		22				20.4				0.75
45 (533.95)	4,8,12,10 (70%)		23 Medium Stiff To Stiff Gray Clayey Silt, Wet (CL-ML).				20.6	21.6	16.8		2.00
	4,7,5,15 (70%)		24				30.6				0.50
			Soft Gray Fine Sandy Silt, Wet (ML).								
	14,8,9,9 (70%)		25				16.2				0.00
50 (528.95)			Bottom Of Boring At 50.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

S 05092

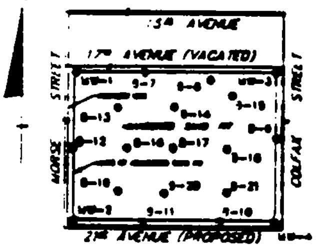
LOGGED BY ID CANONIE

DATE 7-12-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO. 87-141

SITE NAME AND LOCATION: GLENWOOD RIDGE LANDFILL, GARY, IN



DATUM: MSL
ELEVATION: 579.66

DRILLING METHOD: 8-in. hollow-stem auger.

SAMPLING METHOD: 2-in. O.D. split-spoon.

BORING NO: B-17

SHEET: 1 OF

	WATER LEVEL			
TIME				
DATE				
CASING DEPTH				

DRILLING	START	FINISH
TIME	1045	900
DATE	7-13-88	7-14-88

DRILL RIG: Diedrich D-50

ANGLE: Vertical   BEARING: None

SAMPLE HAMMER TORQUE: FT.-LBS

SURFACE CONDITIONS: Open field, bottom of sand pit. Dry with water channels.

N9+83, W13+55

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
	11,11,12,14 (40%)		1 Hard Brown Clay, Trace Of Silt, Trace Of Fine Sand, Moist (CL).	2" O.D. SPLIT SPOON			16.3				4.50
	5,7,7,8 (60%)		2 Stiff Gray-Brown Clay, Trace Of Silt, Trace Of Fine Sand and Roots, Moist (CL).				20.9				2.00
5 (574.66)	3,4,6,7 (70%)		3 Very Stiff Gray-Brown Clay, Trace Of Silt, Moist (CL).				23.2				2.50
	2,3,4,6 (60%)		4 Medium Stiff Gray-Brown Clay, Trace Of Silt, Wet (CL).				24.7				1.00
	1,2,4,4 (50%)		5 Medium Stiff Gray Clay, Trace Of Silt, Wet (CL).				26.0				0.50
10 (569.66)	1,2,2,4 (50%)		Soft Gray Clay, Trace Of Silt, Wet (CL). 6				25.9				0.25
	2,2,3,3 (50%)		7				26.4				0.25
	2,3,3,4 (50%)		8				25.9				0.25
15 (564.66)	2,3,3,5 (50%)		9				24.4				0.25
	3,2,2,4 (40%)		10 Soft Gray Silty Sand, Some Clay, Wet (SM).				19.1				0.25
20 (559.66)	1,2,3,4 (100%)		11 Very Soft To Soft Gray Clay, Trace Of Fine To Coarse Sand, Wet (CL).				21.8				0.00
	1,4,4,5 (100%)		12				23.6				0.25
25 (554.66)	1,2,4,5 (100%)		13 Soft To Stiff Gray Silty Clay, Wet (CL).				21.0				0.50
	1,4,5,6 (30%)		14				20.6				0.75
30	2,3,6,8 (70%)		15				21.3				0.25
(549.66)	6,9,9,12 (70%)		16				19.1				0.75
	2,4,6,9 (90%)		17				20.0				1.00
35	1,4,6,7 (70%)		18				20.9				0.75
(544.66)	3,5,8,11 (60%)		19				20.9				

DRILLING CONTR. FOX DRILLING, INC

SL 05141

LOGGED BY TD - CANONIE

CHK'D BY

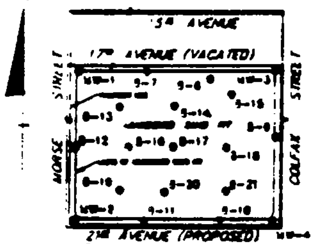
DATE 7-13-88

1159-1160

SOIL BOREHOLE LOG

PROJECT NO. [illegible]-141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN	**DRILLING METHOD** [illegible]-in. ID Hollow-stem auger		**BORING NO** S-17
	SAMPLING METHOD 2-in. O.D. Split- Spoon.		**SHEET** OF
			DRILLING
	WATER LEVEL		**START** TIME 1045 / **FINISH** TIME 900
	TIME		
	DATE		**DATE** 7-13-88 / **DATE** 7-14-88
DATUM MSL **ELEVATION** 579.66	**CASING DEPTH**		
DRILL RIG Diedrich D-50	**SURFACE CONDITIONS** Open field, bottom of sand pit. Dry with water channels.		
ANGLE Vertical **BEARING** None			
SAMPLE HAMMER TORQUE FT-LBS	N9+83, W13+55		



DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER TYPE	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
	3,6,9,11 (90%)	▨	19 Soft To Stiff Gray Silty Clay, Wet (CL). 20	2" O.D. SPLIT SPOON			18.5				1.25
40 (539.66)	3,7,9,11 (80%)	▨	21				18.6				1.00
	4,7,8,11 (90%)	▨	22				18.7				1.00
45 (534.66)	3,6,8,11 (60%)	▨	23				18.8				1.00
	5,6,8,11 (80%)	▨	24				20.9	32.0	17.2		0.50
50 (529.66)	5,7,9,9 (100%)	▨	25				18.4				0.75
			Bottom Of Boring At 50.0 Ft.								

DRILLING CONTR. FOX DRILLING, INC.

SL 05120

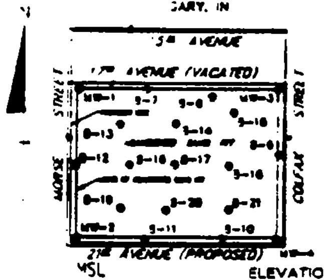
LOGGED BY T.D. - CANONIE CHK'D BY

DATE 7-13-88

SOIL BOREHOLE LOG

PROJECT NO. [illegible]-141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN	DRILLING METHOD: 3-in. ID [illegible]w-stem auger.	BORING NO. S-18
	SAMPLING METHOD: 2-in. O.D. Split-spoon.	SHEET 1 OF 2



WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME 1100	TIME 0900
DATE 7-14-88	DATE 7-15-88

DATUM MSL ELEVATION 578.84

DRILL RIG Diedrich D-50

SURFACE CONDITIONS Open field. Bottom of sand pit. Dry with water channels.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS 49+82, 46+88

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLER TYPE AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
	4,6,7,9 (10%)	▨	1	Hard Brown Clay, Trace Of Sand, Moist (CL).	2" O D SPLIT SPOON			13.1				4.50
	9,7,8,9 (15%)	▨	2					14.8				4.50
5	3,3,3,4 (30%)	▨	3	Medium Stiff Brownish Gray Clay, Trace Of Silt, Wet (CL).				25.7				1.00
(573.84)	2,3,3,4 (50%)	▨	4					26.3				0.50
	2,2,2,3 (50%)	▨	5	Very Soft To Stiff Gray Silty Clay, Trace Fine Sand, Wet (CL).				24.9				0.25
10 (568.84)	1,1,2,2 (60%)	▨	6					26.6				0.25
	1,2,3,3 (60%)	▨	7					25.5	33.3	18.6		0.25
15 (563.84)	2,2,2,3 (50%)	▨	8					26.5				0.00
	1,1,2,3 (60%)	▨	9					25.2				0.25
	2,2,3,3 (50%)	▨	10					23.6				0.25
20 (558.84)	2,4,3,4 (50%)	▨	11					22.6				0.50
	2,2,3,4 (50%)	▨	12					21.5				0.25
25 (553.84)	1,3,4,4 (50%)	▨	13					21.6				0.50
	2,3,4,6 (60%)	▨	14					22.6				0.50
30 (548.84)	2,3,5,5 (60%)	▨	15					20.7				0.50
	3,4,5,5 (60%)	▨	16					20.9				0.50
	3,5,7,10 (70%)	▨	17					20.9				[illegible]
35 (543.84)	4,7,7,10 (70%)	▨	18					19.3				1.00
	4,5,8,10 ([illegible]0%)	▨	19					19.2				[illegible]

DRILLING CONTR FOX DRILLING, INC.

SL 05085

LOGGED BY TD-CANONIE

CHK'D BY

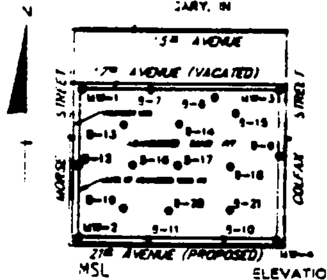
DATE 7-15-88

1161-62

SOIL BOREHOLE LOG

PROJECT NO -141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 578.84

DRILLING METHOD: 3-in. ID Hollow-Stem Auger.

SAMPLING METHOD: 2-in. O.D. Split-Spoon.

BORING NO. B-18

SHEET 2 OF

WATER LEVEL					
TIME					
DATE					
CASING DEPTH					

DRILLING	
START	FINISH
TIME	TIME
1100	0900
DATE	DATE
7-14-88	7-15-88

DRILL RIG Diedrich D-50

SURFACE CONDITIONS Open field. Bottom of sand pit. Dry with water channels.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS 49+82, 46+88

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
	4,8,11,12 (30%)		20 Very Soft To Stiff Gray Silty Clay, Trace Fine Sand, Wet (CL).	2" O.D. SS			18.4				1.00
40 (538.84)	4,8,11,16 (70%)		21 Very Stiff Gray Clay, Some Silt, Wet (CL).				15.4				3.50
	3,4,7,11 (70%)		22 Soft To Very Stiff Gray Clay, Trace of Silt, Wet (CL).				20.0				2.00
45 (533.84)	4,7,11,12 (70%)		23				16.6				3.50
	6,9,10,11 (70%)		24				20.3				0.50
50 (528.84)	6,12,13,17 (70%)		25 Stiff Gray Clay, Some Fine To Coarse Sand And Fine Gravel (CL).				12.8				1.50
			Bottom of Boring At 50.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

05086

LOGGED BY TD-CANONIE

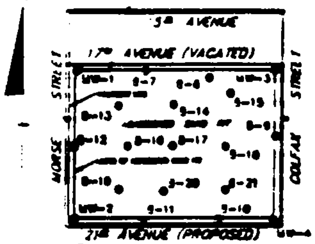
DATE 7-15-88 CHK'D BY

42

SOIL BOREHOLE LOG

PROJECT NO -141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 580.63

DRILLING METHOD 8-in. hollow-stem auger.

SAMPLING METHOD: 2-in. O.D. split-spoon. Shelby Tube at 29.0 Ft.

BORING NO. S-19

SHEET 1 OF 2

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
0815	1045
DATE	DATE
7-12-88	7-12-88

DRILL RIG Diedrich D-50

SURFACE CONDITIONS Open field. Bottom of sand pit. Dry with water channels.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT.-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
	5,7,6 (20%)		1 Hard Brown Clay, Trace Of Silt, Trace Of Fine Sand, Dry (CL).	2" O D SPLIT SPOON			15.1				4.50
5 (575.63)	4,4,4 (10%)		2				17.7				4.50
10 (570.63)	3,3,4 (15%)		3 Stiff Brown Clay, Trace Of Silt, Trace Of Fine Sand, Moist (CL).				18.3				1.75
15 (565.53)	2,3,4 (90%)		4 Soft Gray Silty Clay, Trace Fine To Coarse Sand, Wet (CL).				24.8				0.50
20 (560.63)	2,3,3 (90%)		5				24.4				0.25
25 (555.63)	3,4,6 (75%)		6				21.8				0.50
30 (550.63)	24" Recovery		7	ST			20.0	30.8	18.3		
35 (545.63)	4,5,3 (100%)		8	2" O D SS			22.3				0.25

DRILLING CONTR FOX DRILLING, INC.

LOGGED BY TD - CANONIE

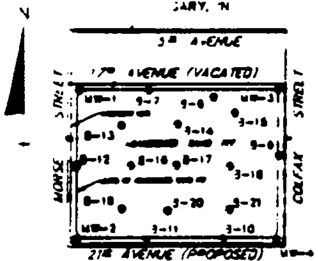
DATE 7-12-88 CHK'D BY

1163-64

SOIL BOREHOLE LOG

PROJECT NO [illegible]

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL
GARY, IN



DATUM MSL ELEVATION 580.63

DRILLING METHOD 3-in. hollow-stem auger.

SAMPLING METHOD 2-in. O.D. split-spoon.

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

BORING NO B-19

SHEET 1 OF

DRILLING	
START	FINISH
TIME	TIME
0815	1045
DATE	DATE
7-12-88	7-12-88

DRILL RIG Diedrich D-50

SURFACE CONDITIONS Open field. Bottom of sand pit. Dry with water channels.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING	BLOWS/FT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
40 (540.63)	4,5,3 (100%)		9 Medium Stiff Silty Gray Clay, Wet (CL).	2" O.D. SPLIT SPOON			20.0				0.75
45 (535.63)	6,11,17 (70%)		10 Hard Gray Clayey Silt, Moist (CL-ML).				16.3	22.8	17.0		4.50
			Fine Silty Sand, Wet (SM).				16.5				
50 (530.63)	13,15,27 (50%)		11								
			Bottom of Boring At 50.0 Ft.								

DRILLING CONTR FOX DRILLING, INC.

05144

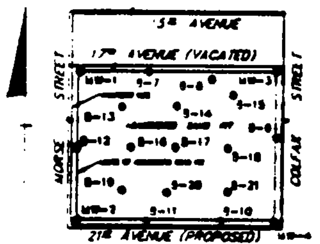
LOGGED BY TD - CANONIE

DATE 7-12-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO. [illegible]141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL
GARY, IN



DATUM MSL **ELEVATION** 580.05

DRILLING METHOD: [illegible]-in. [illegible]-stem auger.

SAMPLING METHOD 2-in. O.D. Split-spoon.

BORING NO. B-20

SHEET 1 OF 2

						DRILLING	
						START	FINISH
WATER LEVEL						TIME	TIME
TIME						1200	0930
DATE						DATE	DATE
CASING DEPTH						7-8-88	7-11-88

DRILL RIG Diedrich D-50

ANGLE Vertical **BEARING** None

SAMPLE HAMMER TORQUE FT-LBS

SURFACE CONDITIONS Open field. Bottom of sand pit. Dry with water channels.

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS QU
	7,9,9 (30%)	▨	1 Hard Gray Clay, Some Silt, Trace Of Fine Sand And Roots, Dry (CL).	2" O.D. SPLIT SPOON			16.4				4.50
5 (575.05)	4,4,5 (95%)	▨	2 Soft Gray/Brown Clay, Trace Of Silt, Trace Of Fine Sand, Trace of Roots, Moist (CL).				23.5				0.25
10 (570.05)	2,2,3 (70%)	▨	3 Very Soft To Medium Stiff Gray Clay, Trace Of Silt, Moist (CL).				25.0				0.00
15 (565.05)	1,2,2 (30%)	▨	4				25.9				0.00
20 (560.05)	2,3,3 (90%)	▨	5				24.6				0.00
25 (555.05)	3,4,4 (95%)	▨	6				22.9				[illegible]
30 (550.05)	2,4,6 (100%)	▨	7				21.6				0.50
35 (545.05)	3,5,6 (90%)	▨	8				21.1				

DRILLING CONTR FOX DRILLING, INC

SL 05089

LOGGED BY LA-CANONIE

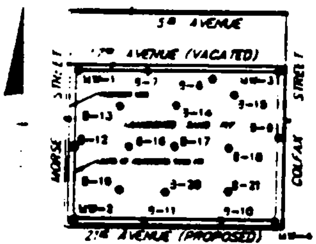
DATE 7-11-88 CHK'D BY

1104-66

SOIL BOREHOLE LOG

PROJECT NO -141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 580.05

DRILLING METHOD 3-In. ID Hollow-Stem Auger.

SAMPLING METHOD 2-In. O.D. Split-Spoon.

BORING NO B-20

SHEET OF

DRILLING	
START	FINISH
TIME	TIME
1200	0930
DATE	DATE
7-8-88	7-11-88

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILL RIG Diedrich D-50

SURFACE CONDITIONS Open Field. Bottom of Sand Pit. Dry With Water Channels.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS qu
40 (540.05)	12,16,32 (90%)	▨	9 Fine Sandy Silt, Moist (SM).	2" O.D. SS			14.7				4.50
45 (535.05)	6,7,11 (80%)	▨	10 Stiff Gray Silt, Some Clay, Moist (CL-ML). 6-In. Clay Layer At 44.5 Ft.				17.8	21.7 32.1	12.6 17.9		[illegible]
50 (530.05)	3,4,5 (100%)	▨	11 Stiff Gray Silty Clay, Moist (CL).				20.9				
			Bottom of Boring At 50.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

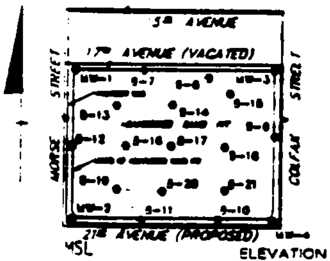
S-05090

LOGGED BY L.A. CANONIE DATE 7-11-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO. -141

SITE NAME AND LOCATION	GLENWOOD RIDGE LANDFILL GARY, IN
DRILLING METHOD:	5-in. hollow-stem auger.
BORING NO	-21
SAMPLING METHOD:	2-in. O.D. split-spoon. 3-in. Shelby Tube (S-7).
SHEET	1 of 2



					DRILLING	
					START	FINISH
WATER LEVEL					TIME	TIME
TIME					1030	1330
DATE					DATE	DATE
CASING DEPTH					7-11-88	7-11-88

DATUM MSL ELEVATION 579.69

DRILL RIG	SURFACE CONDITIONS Open field. Bottom of sand pit. Dry with water channels.
ANGLE Vertical BEARING None	
SAMPLE HAMMER TORQUE FT-LBS	

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS Qu
	5,7,6 (40%)		1 Very Stiff To Hard Brown Silty Clay, Trace Fine To Coarse Sand And Roots, Moist (CL).	2" O D SPLIT SPOON			16.6				4.50
5 (574.69)	4,6,8 (80%)		2				21.3				3.50
10 (569.69)	2,2,3 (50%)		3 Soft To Medium Stiff Gray Silty Clay, Some Fine To Medium Sand, Wet (CL).				24.8				[illegible]
15 (564.69)	2,2,3 (100%)		4				26.6				[illegible]
20 (559.69)	3,3,4 (75%)		5				23.6				[illegible]
25 (554.69)	2,3,3 (70%)		6				22.0				
30 (549.69)	ST 22" Recovery		7	ST			20.0	29.6	17		
35 (544.69)	3,4,5 (100%)		8	2" O D SS			19.3				

DRILLING CONTR FOX DRILLING, INC

SL 05145

LOGGED BY T.D. - CANONIE

DATE 7-11-88 CHK'D BY

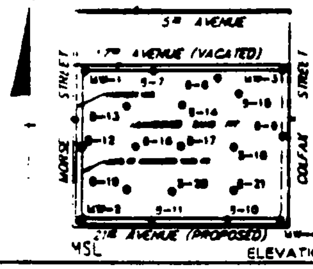
47

1167-68

SOIL BOREHOLE LOG

PROJECT NO [illegible]-141

SITE NAME AND LOCATION GLENWOOD RIDGE LANDFILL GARY, IN



DATUM MSL ELEVATION 579.69

DRILLING METHOD	3-in. I.D. hollow-stem auger.	BORING NO	B-21
SAMPLING METHOD	2-in. O.D. split-spoon.	SHEET	2 OF 2
		DRILLING	
		START	FINISH
WATER LEVEL		TIME	TIME
TIME		1030	1330
DATE		DATE	DATE
CASING DEPTH		7-11-88	7-11-88

DRILL RIG

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

SURFACE CONDITIONS Open field. Bottom of sand pit. Dry with water channels.

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS QU
40 (539.69)	15,24,50 (100%)	▦	9 Hard Gray Silt, Trace Of Clay, Moist (ML).	2" O.D. SS			14.9				4.50
45 (534.69)	4,6,10 (100%)	▨	10 Stiff Gray Clay, Trace Of Silt, Moist (CL).				18.9				2.00
50 (529.69)	3,5,7 (90%)	▨	11				19.3				1.50
			Bottom Of Boring At 50.0 Ft.								

DRILLING CONTR FOX DRILLING, INC

05146

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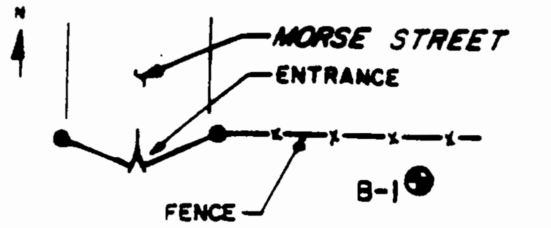
DATE 7-11-88

4

ROCK BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL ELEVATION 608.50

DRILLING METHOD: Diamond tip NX core and 3-7/8 in. dia. tricone bit ream.

SAMPLING METHOD: NX-type core barrel.

BORING NO. B-1

SHEET 1 OF 1

WATER LEVEL	19.5'	19.5'
TIME	1005	0930
DATE	10/19	10/29
CASING DEPTH		

DRILLING	
START	FINISH
TIME 0700	TIME 1600
DATE 10/12	DATE 10/12

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was northwest corner of property; flat and scarcely vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	CORES RUN NO.	CORES NO. AND SIZE OF CORE PIECES	CORES % RECOVERY	CORES RQD	SOIL DESCRIPTION OR ROCK LITHOLOGY	SYMBOL	ROCK STRUCTURE	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS DEPTH IN FEET FROM	TEST RESULTS DEPTH IN FEET TO	PERMEABILITY CM./SEC.
						Top Of Bedrock At 153.0 Ft.								
155						Dolomite; Light Gray, Medium To Thickly Bedded, Slightly Weathered, Very Fine Grained.				None				
160 165		1	1-24" 2-16" 1-9" 4-6" 3-4" 2-2"	88	84			Close To Moderately Close Fractured Horizontal Joints.	NX Core Barrel					
170 175		2	1-37" 1-16" 1-10" 3-7" 1-5" 1-4" 1-3"	80	78			Close To Wide Fractured Horizontal Joints.						
180						Bottom Of Boring At 177.0 Ft.								

Note: All dates are 1987.

D & G Drilling, Inc. DRILLING CONTR

LOGGED BY Canonie Environmental (F.A. Halterman) CHK'D BY

DATE 12/23/87

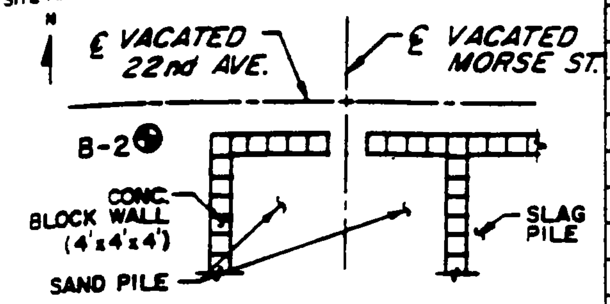
RI 03715

1169-70

ROCK BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DRILLING METHOD:	Diamond tip NX core and 3-7/8 in. dia. tricone bit ream.
SAMPLING METHOD:	NX-type core barrel.
BORING NO.	B-2
SHEET	1 OF 1

WATER LEVEL	22.2'	22.9'		
TIME	1030	0930		
DATE	10/19	10/30		
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
0700	1500
DATE	DATE
10/14	10/14

DATUM MSL

ELEVATION 607.67

DRILL RIG CME 55

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

SURFACE CONDITIONS Area was southwest corner of property; flat and moderately vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	CORES RUN NO.	CORES NO. AND SIZE OF CORE PIECES	CORES % RECOVERY	CORES RQD	SOIL DESCRIPTION OR ROCK LITHOLOGY	SYMBOL	ROCK STRUCTURE	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS DEPTH IN FEET FROM	TEST RESULTS DEPTH IN FEET TO	TEST RESULTS PERMEABILITY CM./SEC.
						Top Of Bedrock At 152.0 Ft.								
155 160		1	1-24" 1-10" 1-6" 5-5" 2-3" 3-2"	64	59	Dolomite; Light Gray, Medium To Thickly Bedded, Slightly Weathered, Very Fine Grained. From 153.5 Ft. To 154.5 Ft., Interbedded Silty Clay Seams With Some Dolomite Medium To Coarse Sand, Fine Gravel Sized Fragments.		Close To Moderately Close Fractured Horizontal Joints.	NX Core Barrel	None				
165 170						Bottom Of Boring At 163.5 Ft.								

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

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DATE 12/23/87

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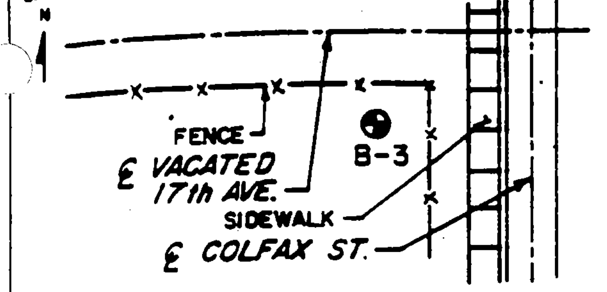
ROCK BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL
ELEVATION 606.36
DRILL RIG CME 55
ANGLE Vertical
BEARING None
SAMPLE HAMMER TORQUE -- FT.-LBS

DRILLING METHOD: Diamond tip NX core and 3-7/8 in. dia. tricone bit ream.
SAMPLING METHOD: NX-type core barrel.

WATER LEVEL	27.1'			
TIME	1000			
DATE	11/4			
CASING DEPTH				

BORING NO. B-3
SHEET 1 OF 1

DRILLING	
START	FINISH
TIME 0700	TIME 1500
DATE 10/19	DATE 10/19

SURFACE CONDITIONS Area was northeast corner of property; flat and moderately vegetated.

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	CORES RUN NO.	NO. AND SIZE OF CORE PIECES	% RECOVERY	RQD	SOIL DESCRIPTION OR ROCK LITHOLOGY	SYMBOL	ROCK STRUCTURE	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS DEPTH IN FEET FROM	TO	PERMEABILITY CM./SEC.
						Top Of Bedrock At 118.5 Ft.								
120 125		1	2-13" 3-9" 1-8" 1-6" 1-5" 5-4" 1-3" 5-2"	88	97	Petrolyphic Dolomitic Breccia; Light Gray, Thickly-Grade Bedded, Slightly Weathered.		Close To Moderately Close Fractured Horizontal Joints.	NX Core Barrel	None				
						Dolomite; Light Gray, Thick Bedded Slightly Weathered, Fine Grained.								
130						Bottom Of Boring At 128.5 Ft.								

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

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DATE 12/23/87 CHK'D BY

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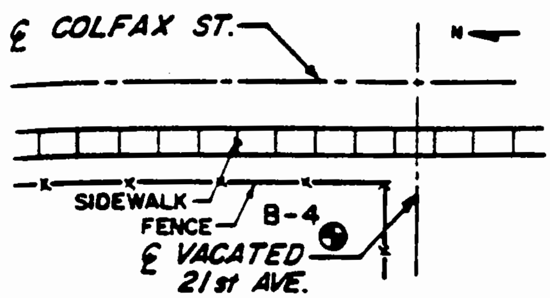
1171-72

ROCK BOREHOLE LOG

87-141

SITE NAME AND LOCATION J-PIT (A.J. EXPRESS), GARY, IN



DATUM MSL
ELEVATION 604.00

DRILLING METHOD: Diamond tip NX core and 3-7/8 in. dia. tricone bit ream.

SAMPLING METHOD: NX-type core barrel.

BORING NO. B-4

SHEET 1 OF 1

WATER LEVEL	17.7			
TIME	1125			
DATE	11/2			
CASING DEPTH				

DRILLING	
START	FINISH
TIME 0700	TIME 1805
DATE 10/20	DATE 10/20

DRILL RIG CME 55

SURFACE CONDITIONS Area was southeast corner of property; inclined and vegetated.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE -- FT.-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/6 IN. ON SAMPLER (RECOVERY)	CORES: RUN NO.	CORES: NO. AND SIZE OF CORE PIECES	CORES: % RECOVERY	CORES: RQD	SOIL DESCRIPTION OR ROCK LITHOLOGY	SYMBOL	ROCK STRUCTURE	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS: DEPTH IN FEET FROM	TEST RESULTS: DEPTH IN FEET TO	TEST RESULTS: PERMEABILITY CM./SEC.
						Top Of Bedrock At 116.5 Ft.								
120		1	1-26" 1-23" 1-18" 2-9" 1-7" 1-5" 1-4" 3-3"	93	84	Dolomite; Light Gray, Medium To Thickly Bedded, Slightly Weathered, Very Fine Grained.		Close To Moderately Close Fractured Horizontal Joints.	NX Core Barrel	None				
125														
130														
						Bottom Of Boring At 132.0 Ft.								
135														

Note: All dates are 1987.

DRILLING CONTR D & G Drilling, Inc.

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DATE 12/23/87

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ATTACHMENT L - 5

ECI SITE
Soil Boring Logs

PITTSBURGH TESTING LABORATORY

3828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

Contractor r Client: Butler, Fairman & Seufert
Lake County

TEST BORING LOG

RIG NUMBER ____

Job No. IND-2872

Project: MM-850(23)PE

Weather: Hot

Str. No. 912-45-2551

Boring Number: 1

Location: Ind. Harbor Belt Rte.

Sheet 1 of 2

Ground Elevation: 587.0

Station: 169+90

Offset: 30' Rt. PR-1-E

ate Started: 8-19-75

Date of Completion: 8-19-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
6'	While Drilling	8-19-75
6'	At End of Boring	8-19-75
6'	At 24 hours	8-20-75

Elevation of Top of Rock: None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
						0' - 2½'	Black silty sand with trace medium gravel (chemical mixed)
	1.	S.S.	2½ - 4	2-3-5	H.S.	2½' -	Brown wet loose silty clay with
						- 5'	sand and medium gravel
18"	2.	S.S.	5 - 6½	5-9-8	H.S.	5' -	Brown very stiff silty clay
						- 7½'	with sand & medium gravel
18"	3.	S.S.	7½ - 9	6-7-10	H.S.	7½' -	Gray wet medium dense fine to
						- 10'	medium sand
18"	4.	S.S.	10 - 11½	4-10-14	H.S.	10' -	Gray wet medium dense to dense
18"	5.	S.S.	12½ - 14	11-20-22	H.S.		fine to coarse sand with trace
18"	6.	S.S.	15 - 16½	12-21-26	H.S.	- 17½'	of fine gravel
18"	7.	S.S.	17½ - 19	16-19-23	H.S.	17½' -	Gray wet dense fine sand
18"	8.	S.S.	20 - 21½	16-20-23	H.S.		
18"	9.	S.S.	25 - 26½	17-18-19	H.S.		
18"	10.	S.S.	30 - 31½	11-17-19	H.S.	- 35'	
18"	11	S.S.	35 - 36½	4-6-7	H.S.	35' -	Gray moist medium dense silty cl

* — Measure to ... ch

riller: Fred Maxwell

Inspector: N. Ray Neel

elper: Donald Black

Engineer: ____

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PITTSBURGH TESTING LABORATORY

2121 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert
Lake County

RIG NUMBER ______

Job No. IND-2372

Project MM-850(23)PE

Weather Hot

Str. No. 912-45-2551

Boring Number 1

Location Ind. Harbor Belt Rte.

Sheet 2 of 2

Ground Elevation 587.0

Station 169+90

Offset 30' Rt. PR-1-E

Date Started 8-19-75

Date of Completion 8-19-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
6'	While Drilling	8-19-75
6'	At End of Boring	8-19-75
6'	At 24 hours	8-20-75

Elevation of Top of Rock None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
	12.	S.S.	40 - 41½	8-10-14	H.S.	- 41.5	
							B.T.H. - 41.5'

* – Measure to nearest inch

Driller Fred Maxwell

Inspector N. Ray Neel

Helper Ronald Black

Engineer ______

PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor/Client: Butler, Fairman & Seufert, Inc.

Job No. HID-2872

RIG NUMBER ____

Project: Lake County [illegible]-550(23) [illegible]

Str. No. 912-45-2551

Weather ____

Boring Number: 2

Location: Ind. Harbor Belt Rte.

Sheet 1 of 1

Ground Elevation: 585.9

Station: Sta. 171 + 90

Offset: 30' LT. PR-1-E

Date Started: 8-19-75

Date of Completion: 8-19-75

ST = SHELBY TUBE HS = HOLLOW STEM

PA = POWER AUGER HA = HAND AUGER

RC = ROCK CORE SS = SPLIT SPOON

W = WASH

GROUND WATER DATA		
Elevation	Time	Date
6'	While Drilling	8-19-75
6'	At End of Boring	8-19-75
6'	At 24 hours	8-19-75

Elevation of Top of Rock ____

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
Hand Sample						0'-2½	Black moist loose oily sand w/ traces of cinders.
18	1	SS	2½-4	3-5-7	H.S.	2½'-	Gray moist medium dense coarse sand.
18"	2	SS	5-6½	6-8-10	H.S.	-5'	
18"	3	SS	7½-9	7-7-9	H.S.	7½'-	Gray wet medium dense sand.
						-10'	
18"	4	SS	10-11½	7-11-15	H.S.	10'-	Gray wet medium dense fine to coarse sand w/ traces of grave
18"	5	SS	12½-14	14-18-23	H.S.		
18"	6	SS	15-16½	13-24-25	H.S.		
						-27½'	
18"	7	SS	17½-19	15-22-21	H.S.	27½'-	Gray wet dense fine sand.
18"	8	SS	25-26½	16-19-22	H.S.		
18"	9	SS	30-31½	11-18-18	H.S.	-33'	Gray moist stiff to very stiff
18"	10	SS	35-36½	5-7-7	H.S.	33'-	silty clay.
18	11	SS	40-41½	9-10-15	H.S.	-41½'	B.T.H. 41.5'

* – Measure to nearest Inch

Driller: Fred Maxwell

Inspector: N. Ray Neel

Helper: Donald R. Black

Engineer: ____

PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert, Inc.

Job No. IND-2872

RIG NUMBER ____

Project Lake County MM-[illegible](23)FE - Str. 912-45-2551

Weather ____

Boring Number 3 **Location** Ind. Harbor Belt Rt. **Sheet** 1 **of** 2

Ground Elevation 587.2 **Station** 173+20 **Offset** Centerline PR-1-E

Date Started 8-19-75 **Date of Completion** 8-20-75

ST = SHELBY TUBE **HS = HOLLOW STEM**

PA = POWER AUGER **HA = HAND AUGER**

RC = ROCK CORE **SS = SPLIT SPOON**

W = WASH

GROUND WATER DATA		
Elevation	Time	Date
4	While Drilling	8-19-75
7	At End of Boring	8-20-75
7	At 24 hours	8-21-75

Elevation of Top of Rock ____

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
18"	1	SS	2½-4	4-6-8	H.S.	0'-	Black moist medium dense sa with trace of oil&organic
						- 5'	
18"	2	SS	5-6½	6-7-9	H.S.	5'-	Brown wet medium dense coarse with trace medium gravel.
						- 7½'	
18	3	SS	7½-9	5-9-14	H.S.	7½'-	Gray wet medium dense to dens sand w/small trace of fine g
18"	4	SS	10-11½	7-12-15	H.S.		
18"	5	SS	12½-14	12-15-14	H.S.		
18"	6	SS	15-16½	22-18-19	H.S.		
18"	7	SS	17½-19	14-19-20	H.S.	-20'	
18"	8	SS	20-21½	13-17-21	H.S.	20'-25'	Gray wet dense fine to coarse sand.
18	9	SS	25-26½	13-18-22	H.S.	25'-	Gray wet dense sand with trac of silt.
18	10	SS	30-31½	16-19-21	H.S.	-35'	
18"	11	SS	35-36½	2-2-2	H.S.	35'-~~45'~~	Gray wet soft silt.
						43½'	

* – Measure to nearest inch

Driller Jerry W. Patterson **Inspector** N. Ray Neel

Helper Ricky L. Patterson **Engineer** ____

PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 48219

TEST BORING LOG

Contractor / Client: Butler, Fairman & Seufert, Inc

Job No. IND-2372

RIG NUMBER

Lake County -

Project IM-850(23)PE

Str. 912-45-2551

Weather

Boring Number 3

Location Ind. Harbor Belt Ret.

Sheet 2 of 2

Ground Elevation 587.2

Station 173+20

Offset Centerline PR-1-E

Date Started 8-20-75

Date of Completion 8-20-75

ST = SHELBY TUBE

HS = HOLLOW STEM

PA = POWER AUGER

HA = HAND AUGER

RC = ROCK CORE

SS = SPLIT SPOON

W = WASH

GROUND WATER DATA

Elevation	Time	Date
5	While Drilling	8-20-75
5	At End of Boring	8-20-75
6	At 24 hours	8-21-75

Elevation of Top of Rock

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
18"	12	SS	43½-45	4-5-7	H.S.	43½'-	Gray moist stiff silty clay w traces of fine gravel.
						-50'	Gray moist very stiff silty cl
18"	13	SS	50-51½	18-13-14	H.S.	50'-55'	
18"	14	SS	55-56½	5-7-8	H.S.	55'-	Gray moist medium stiff to ver stiff silty clay w/trace fine
18	15	SS	65-66½	8-7-8	HSS.		
18"	16	SS	70-71½	8-9-9	H.S.		
18"	17	SS	75-76½	9-10-10	H.S.	-78½'	
18"	18	SS	80-81½	10-11-10	H.S.	78½'-	Gray moist very stiff gray cla mixed with gravel.
18"	19	SS	85-86½	10-11-13	H.S.		
18	20	SS	90-91½	11-12-12	H.S.		
18"	21	SS	95-96½	11-14-14	H.S.	-96½'	B.T.H. - 96.5'

* – Measure to nearest inch

Driller Jerry M. Patterson

Helper Ricky L. Patterson

Inspector M. Ray Neel

Engineer

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PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert, Inc.

Job No. IND-2872

RIG NUMBER ____

Project Lake County - M-650(23)IL

Weather Hot

Boring Number RW-1 Location Retaining wall boring Sheet 1 of 1

Ground Elevation 589.3 Station 175+92 Offset 55' Rt. PR-1-E line

Date Started 8-15-75 Date of Completion 8-15-75

ST = SHELBY TUBE HS = HOLLOW STEM

PA = POWER AUGER HA = HAND AUGER

RC = ROCK CORE SS = SPLIT SPOON

W = WASH

GROUND WATER DATA		
Elevation	Time	Date
3'	While Drilling	8-15-75
3'	At End of Boring	8-15-75
3'	At 24 hours	8-16-75

Elevation of Top of Rock None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]	1	S.S.	1-2½	4-5-6	H.S.	0-3'	Black wet oily sand and roc[illegible]ll (visual)
12"	2	S.S.	3½-5	10-10-9	H.S.	3'-5'	Gray wet medium dense gravelly
							sand (Lab. #2) A-1-b
14"	3	S.S.	6-7½	10-11-11	H.S.	5'-	Gray wet medium dense sand
18"	4	S.S.	8½-10	11-8-9	H.S.	-10'	(Lab#3) A-3
							BTH 10.0'

* – Measure to nearest Inch

Driller C. Jones

Inspector N. Ray Neel

Helper R. Buchanan

Engineer ____

[illegible] LABORATORY
[illegible]

TEST BORING LOG

Contractor or Client: Butl[illegible] Fairman Seufert, Inc.

Job No.: [illegible]

RIG NUMBER:

Project: Lake County - [illegible]

Weather: Hot

Boring Number: R[illegible]-2

Location: Retaining wall boring

Sheet 1 of 1

Ground Elevation: 587.3

Station: 175+93

Offset: 55' Lt. PR-I-E line

Date Started: 8-14-75

Date of Completion: 8-14-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA

Elevation	Time	Date
6.5'	While Drilling	8-14-75
4'	At End of Boring	8-14-75
4'	At 24 hours	8-15-75

Elevation of Top of Rock: None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]"	1	SS	1-2½	Cave-in, at 2'	H.S	0-3'	Black oily gravel fill (visual)
8"	2	SS	3½-5	4-5-7	H.S.	3'-	Gray wet medium dense to dense
11"	3	SS	6-7½	11-14-21	H.S.		Sand (lab#3) A-3
14"	4	SS	8½-10	32-27-21	H.S.		
16"	5	SS	11-12½	9-11-12	H.S.		
17"	6	SS	13½-15	17-16-20	H.S.		
13"	7	SS	16-17½	17-16-15	H.S.		
15"	8	SS	18½-20	18-15-10	H.S.		
14"	9	SS	23½-25	15-17-21	H.S.		
13"	10	SS	28½-30	12-14-14	H.S.	33½	
12"	11	SS	33½-35	16-17-13	H.S.	33½	Gray moist stiff clay
15"	12	SS	38½-40	3-4-4	H.S.		(Lab#5) A-6
16"	13	SS	43½-45	4-5-3	H.S.	-45	
							BTH 45.0'

* – Measure to nearest inch

Driller: C. Jones

Inspector: M. Ray Neel

Helper: [illegible]. Buchanan

Engineer:

PITTSBURGH TESTING LABORATORY

[illegible] AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert, Inc.
Job No. IND-2872

Lake County -
RIG NUMBER ____

Project M-850(23)Pe
Weather Hot

Boring Number RW3 Location Retaining Wall Boring Sheet 1 of 1
Ground Elevation 588.7 Station 178+20 Offset 55' Rt. PR-1-E Line
Date Started 8-12-75 Date of Completion 8-12-75

ST = SHELBY TUBE HS = HOLLOW STEM
PA = POWER AUGER HA = HAND AUGER
RC = ROCK CORE SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
5'	While Drilling	8-12-75
4'	At End of Boring	8-12-75
4'	At 24 hours	8-13-75

Elevation of Top of Rock None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From - To	Sampler Blows per 6 Inches	Drilling Method	Depth From - To	Description of material and Remarks
							Color Type TOPSOIL*
10"	1	S.S.	1 - 2½	4-5-6	H.S.	0' -	Black oily medium dense sand
8"	2	S.S.	3½ - 5	5-5-7	H.S.	- 4½'	and gravel (Visual)
9"	3	S.S.	6 - 7½	8-8-9	H.S.	4½' -	Gray wet medium dense sand
16"	4	S.S.	8½ - 10	9-9-9	H.S.		(Lab. No. 3) A-3
16"	5	S.S.	11 - 12½	10-12-12	H.S.	- 14'	
18"	6	S.S.	13½ - 15	11-15-18	H.S.	14' -	Gray wet dense sand (Lab. #3)
13"	7	S.S.	16 - 17½	10-12-19	H.S.		A-3
11"	8	S.S.	18½ - 20	7-15-20	H.S.		
13"	9	S.S.	23½ - 25	10-12-16	H.S.		
13"	10	S.S.	28½ - 30	13-15-17	H.S.	- 33'	
8"	11	S.S.	33½ - 35	6-4-5	H.S.	33' -	Gray moist medium stiff to
16"	12	S.S.	38½ - 40	4-6-7	H.S.		stiff clay (Lab. #5) A-6
8"	13	S.S.	43½ - 45	5-8-7	H.S.	- 45'	
							B.T.H. - 45.0'

*- Measure to nearest inch

Driller Charles Jones
Inspector N. Ray Neal
Helper Francis Buchanan
Engineer ____

PITTSBURGH TESTING LABORATORY

2026 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client: Butler, Fairman & Seufert, Inc.
Lake County

Job No. IND-[illegible]2

RIG NUMBER ____

Project: [illegible]-350(23)PE

Weather: Hot

Boring Number: RW 4

Location: Retaining Wall Boring

Sheet 1 of 1

Ground Elevation: 588.4

Station: 179+60

Offset: 55' Rt. PR-1-E Line

Date Started: 8-20-75

Date of Completion: 8-20-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA

Elevation	Time	Date
5'	While Drilling	8-20-75
2.5'	At End of Boring	8-20-75
4'	At 24 hours	8-21-75

Elevation of Top of Rock: None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
14"	1	S.S.	1 - 2½	4-5-6	H.S.	0 - 3'	Black moist med. dense oily sandy gravel (Lab. #1) A-1-a
14"	2	S.S.	3½ - 5	5-6-5	H.S.	3' - 6'	Gray wet medium dense sand
							(Lab. #3) A-3
15"	3	S.S.	6 - 7½	9-13-20	H.S.	6' -	Gray wet dense fine sand with
18"	4	S.S.	8½ - 10	15-20-21	H.S.	- 10'	medium to large gravel.
							B.T.H. - 10.0'

* – Measure to nearest Inch

Driller: Charles Jones

Inspector: N. Ray Neel

Helper: Francis Buchanan

Engineer: ____

632

PITTSBURGH TESTING LABORATORY

2823 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46213

TEST BORING LOG

Contractor or Client: Butler, Fairman & Seufert
Lake County

Project: MM-850(23)PE

Job No.: IND-20[illegible]

RIG NUMBER:

Weather: Hot

Boring Number: RW5

Location: Retaining Wall Boring

Sheet 1 of 1

Ground Elevation: 589.4

Station: 179+40

Offset: 45' Lt. PR-1-E Line

Date Started: 8-20-75

Date of Completion: 8-20-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
4'	While Drilling	8-20-75
2.5'	At End of Boring	8-20-75
3'	At 24 hours	8-21-75

Elevation of Top of Rock: None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color / Type / TOPSOIL*
10"	1	S.S.	1 - 2½	4-4-5	H.S.	0' -	Black oily moist loose sandy
						- 3'	gravel. A-1-a (Lab. No. 1)
12"	2	S.S.	3½ - 5	7-6-5	H.S.	3' -	Black oily medium dense fine
						- 6'	sand with small to medium gravel
14"	3	S.S.	6 - 7½	15-12-11	H.S.	6' -	Black wet medium dense fine
						- 8½'	sand with small to medium gravel
14"	4	S.S.	8½ - 10	20-10-13	H.S.	8½' -	Brown wet medium dense sandy
						- 10'	gravel. A-1-a(o) Lab. #1
							B.T.H. - 10.0'

* – Measure to nearest Inch

Driller: Charles Jones

Inspector: N. Ray Neel

Helper: Francis Buchanan

Engineer:

PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor
lient Butler, Fairman & Seufert, Inc.

Job No. IND-2872

Lake County -

RIG NUMBER ____

roject MM-850(23)PE

Weather Hot

Boring Number RW 6

Location Retaining Wall Boring

Sheet 1 of 1

Ground Elevation 589.2

Station 180+90

Offset 55' Rt. PR-1-E Line

ate Started 8-19-75

Date of Completion 8-19-75

ST = SHELBY TUBE

HS = HOLLOW STEM

PA = POWER AUGER

HA = HAND AUGER

RC = ROCK CORE

SS = SPLIT SPOON

W = WASH

GROUND WATER DATA		
Elevation	Time	Date
3.5'	While Drilling	8-19-75
3.5'	At End of Boring	8-19-75
4'	At 24 hours	8-20-75

Elevation of Top of Rock None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]"	1	S.S.	1 - 2½	1-2-2	H.S.	0' -	Black moist to wet loose to
14"	2	S.S.	3½ - 5	2-3-3	H.S.		medium dense sandy gravel
16"	3	S.S.	6 - 7½	5-4-7	H.S.	- 8'	(Lab. #1) . A-1-a
15"	4	S.S.	8½ - 10	6-9-13	H.S.	8' -	Gray wet medium dense fine
						- 10'	sand. (Lab. #3) A-3
							B.T.H. - 10.0'

* – Measure to nearest Inch

riller Charles Jones

Inspector N. Ray Neel

elper Francis Buchanan

Engineer ____

PITTSBURGH TESTING LABORATORY
2925 N WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert, Inc.

Lake County

Project [illegible]-650(23)PE

RIG NUMBER ____

Job No. IND-[illegible]72

Weather Hot

Boring Number RW 7

Location Retaining Wall Boring

Sheet 1 of 1

Ground Elevation 588.7

Station 180+95

Offset 55' Lt. PR-1-E Line

Date Started 8-19-75

Date of Completion 8-19-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
3'	While Drilling	8-19-75
3'	At End of Boring	8-19-75
3'	At 24 hours	8-20-75

Elevation of Top of Rock None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]	1	S.S.	2½ - 4	3-5-4	H.S.	0' -	Gray wet loose sand
13"	2	S.S.	5 - 6½	5-5-4	H.S.	- 7½'	(Lab. No. 3) A-3
15"	3	S.S.	7½ - 9	9-8-8	H.S.	7½' -	Gray wet medium dense sand
15"	4	S.S.	10 - 11½	8-8-8	H.S.		
15"	5	S.S.	12½ - 14	8-9-9	H.S.		
16"	6	S.S.	15 - 16½	10-11-14	H.S.		
16"	7	S.S.	17½ - 19	10-11-12	H.S.	- 19'	
16"	8	S.S.	20 - 21½	11-12-12	H.S.	19'	Gray wet medium dense fine
16"	9	S.S.	25 - 26½	10-11-11	H.S.		sand
16"	10	S.S.	30 - 31½	11-12-14	H.S.	- 30'	
17"	11	S.S.	35 - 36½	4-5-6	H.S.	30' -	Gray moist stiff clay
18"	12	S.S.	40 - 41½	5-5-6	H.S.		A-6 (Lab. No. 4)
18"	13	S.S.	45 - 46½	4-6-5	H.S.	- 46½	
							B.T.H. - 46.5'

* – Measure to nearest inch

Driller Jerry Patterson

Helper Donald Black

Inspector N. Ray Neel

Engineer ____

PITTSBURGH TESTING LABORATORY
2313 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor Client Butler, Fairman & Seufert, Inc.
Lake County
roject MM-350(23)PE -

Job No. IND-2872

RIG NUMBER ____

Weather Hot

Boring Number RW 9
Location Retaining Wall Boring
Sheet 1 of 1
ound Elevation 588.5
Station 182+15
Offset 55' Rt. PR-1-E Line
ate Started 8-19-75
Date of Completion 8-19-75

ST = SHELBY TUBE
HS = HOLLOW STEM
A= POWER AUGER
HA = HAND AUGER
RC= ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA

Elevation	Time	Date
3'	While Drilling	8-19-75
3'	At End of Boring	8-19-75
3'	At 24 hours	8-20-75

Elevation of Top of Rock None

ample ecovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]'	1	S.S.	1 - 2½	2-1-3	H.S.	0' -	Black moist oily very loose
15"	2	S.S.	3½ - 5	2-2-3	H.S.		to medium dense sandy gravel
16"	3	S.S.	6 - 7½	4-5-8	H.S.	- 8'	A-1-a (Lab. No. 1)
17"	4	S.S.	8½ - 10	5-4-7	H.S.	8' -	Gray wet fine medium dense
						- 10'	sand. A-3 (Lab. No. 3)
							B.T.H. - 10.0'

* - Measure to nearest inch

iller Charles Jones
elper Francis Buchanan
Inspector N. Ray Neel
Engineer ____

532 .

[illegible]

PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

ontractor
Client Butler, Fairman & Seufert

Lake County

roject MM-850(23)PE

Job No. IND-2872

RIG NUMBER

Weather Hot

oring Number RW 10

Location Retaining Wall Boring

Sheet 1 of 1

round Elevation 587.7

Station 183+35

Offset 55' Lt. PR-1-E Line

ate Started 8-19-75

Date of Completion 8-19-75

GROUND WATER DATA

Elevation	Time	Date
4.0	While Drilling	8-19-75
4.0	At End of Boring	8-19-75
4.0	At 24 hours	8-20-75

Elevation of Top of Rock None

T = SHELBY TUBE

HS = HOLLOW STEM

PA = POWER AUGER

HA = HAND AUGER

RC = ROCK CORE

SS = SPLIT SPOON

W = WASH

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]3"	1	S.S.	1 - 2½	1-2-2	H.S.	0' -	Black oily moist very loose s[illegible]d
						- 3½'	gravel. A-1-a Lab. No. 1
13"	2	S.S.	3½ - 5	2-1-1	H.S.	3½' -	Peat Layer change to sand
						- 4½'	(Visual)
14"	3	S.S.	6 - 7½'	4-5-7	H.S.	4½' -	Gray wet medium dense sand
15"	4	S.S.	8½ - 10	6-8-11	H.S.	- 10'	A-3 Lab. No. 3
							B.T.H. - 10.0'

* - Measure to nearest inch

riller Charles Jones

Inspector N. Ray Neel

elper Francis Buchanan

Engineer

PITTSBURGH TESTING LABORATOR

2323 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert, Inc.

Job No. IND-2872

Lake County

RIG NUMBER ____

Project MM-330(23)FE -

Weather Hot

Boring Number RW 11 Location Retaining Wall Boring Sheet 1 of 1

Ground Elevation 537.8 Station 184+10 Offset 55' Rt. PR-1-E Line

Date Started 8-25-75 Date of Completion 8-25-75

GROUND WATER DATA		
Elevation	Time	Date
4.5'	While Drilling	8-25-75
4.5'	At End of Boring	8-25-75
4'	At 24 hours	8-26-75

Elevation of Top of Rock None

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type *TOPSOIL*
[illegible]"	1	S.S	2½ - 4	5-4-4	H.S.	0' -	Gray wet loose to medium dense
16"	2	S.S.	5 - 6½	5-6-5	H.S.		sand. A-3 (Lab. No. 3)
15"	3	S.S.	7½ - 9	4-3-4	H.S.		
16"	4	S.S.	10 - 11½	6-5-5	H.S.		
17"	5	S.S.	12½ - 14	5-6-6	H.S.		
18"	6	S.S.	15 - 16½	4-10-11	H.S.		
13"	7	S.S.	17½ - 19	5-11-11	H.S.		
15"	8	S.S.	20 - 21½	14-9-20	H.S.	- 25'	
18"	9	S.S.	25 - 26½	9-11-10	H.S.	25' -	Gray wet medium dense sand
18"	10	S.S.	30 - 31½	9-10-10	H.S.	- 35'	
17"	11	S.S.	35 - 36½	5-5-4	H.S.	35' -	Gray moist medium stiff to
15"	12	S.S.	40 - 41½	4-6-11	H.S.		very stiff clay with some sand
17"	13	S.S.	45 - 46½	4-8-5	H.S.	- 46½'	A-6 (Lab. No. 4)
							B.T.H. - 46.5'

* – Measure to nearest Inch

Driller Charles Jones

Inspector N. Ray Neel

Helper Francis Buchanan

Engineer ____

1189-90

PITTSBURGH TESTING LABORATORY

[illegible] WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert
Lake County

Job No. IND-[illegible]72

RIG NUMBER

Project MM-850(23)PE -

Weather Hot

Boring Number RW 12
Location Retaining Wall Boring
Sheet 1 of 1

Ground Elevation 588.5
Station 184+60
Offset 55' Lt. PR-1-[illegible] Line

Date Started 8-19-75
Date of Completion 8-19-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
4.0'	While Drilling	8-19-75
4.0'	At End of Boring	8-19-75
3.5'	At 24 hours	8-20-75

Elevation of Top of Rock None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]"	1	S.S.	1 - 2½	2-4-5	H.S.	0' -	Black moist loose sandy grav
						- 2½'	A-1-a (Lab. No. 1)
16"	2	S.S.	3½ - 5	4-8-13	H.S.	2½' -	Gray moist medium dense fine
						5½'	sand
16"	3	S.S.	6 - 7½	5-8-9	H.S.	5½' -	Gray wet medium dense sand
18"	4	S.S.	8½ - 10	5-7-11	H.S.	- 10'	A-3 (Lab. No. 3)
							B.T.H. - 10.0'

* – Measure to nearest inch

Driller Charles Jones
Inspector N. Ray Neel

Helper Francis Buchanan
Engineer

TS-[illegible]

PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS INDIANA 46213

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert, Inc.

Job No. IND-2872

Lake County

RIG NUMBER

Project IM-350(23)FE

Weather Hot

Boring Number RW 13

Location Retaining Wall Boring

Sheet 1 of 1

Ground Elevation 588.8

Station 186+00

Offset 55' Rt. PR-1-E Line

Date Started 8-19-75

Date of Completion 8-19-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
4'	While Drilling	8-19-75
4'	At End of Boring	8-19-75
4'	At 24 hours	8-20-75

Elevation of Top of Rock None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks Color Type TOPSOIL*
24"	1	S.S.	1 - 2½	2-3-3	H.S.	0' -	Black moist loose sandy gravel
						- 3½'	A-1-a Lab. No. 1
13"	2	S.S.	3½ - 5	3-2-1	H.S.	3½' -	dark oily peat
						- 5'	(Visual)
16"	3	S.S.	6 - 7½	7-9-10	H.S.	5' -	Gray damp medium dense sand
						- 8½'	A-3 Lab. No. 3
18"	4	S.S.	8½ - 10	9-22-29	H.S.	8½' -	Gray damp very dense sandy
						- 10'	gravel
							B.T.H. - 10.0'

* – Measure to nearest inch

Driller Charles Jones

Inspector N. Ray Neel

Helper Francis Buchanan

Engineer

:TS32

1191-9

PITTSBURGH TESTING LABORATORY

3923 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

ontractor
r Agent Butler, Fairman & Seufert

Job No. IND-2872

Lake County
MM-850(23)FE

RIG NUMBER ____

roject Str. No. 912-45-6604

Weather Hot

oring Number B-1

Location Indianapolis Blvd.

Sheet 1 of 2

round Elevation 589.8

Station 186+20

Offset 35' Lt. PR-I-E line

ate Started 7-8-75

Date of Completion 7-9-75

T = SHELBY TUBE　HS = HOLLOW STEM

A = POWER AUGER　HA = HAND AUGER

C = ROCK CORE　SS = SPLIT SPOON

W = WASH

GROUND WATER DATA		
Elevation	Time	Date
5'	While Drilling	7-8-75
5'	At End of Boring	7-9-75
5'	At 24 hours	7-10-75

Elevation of Top of Rock None

ample ecovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color　Type　TOPSOIL*
15"	1	SS	2½-4	3-3-3	H.S.	0-5'	Dark oily loose sand
14"	2	SS	5-6½	5-4-4	H.S.	5'-9'	Gray wet loose medium sand.
15"	3	SS	7½-9	5-6-5	H.S.	9'	Gray wet medium dense sand.
17"	4	SS	10-11½	8-8-8	H.S.		
15"	5	SS	12½-14	7-8-9	H.S.		
12"	6	SS	15-16½	9-8-11	H.S.		
13"	7	SS	17½-19	9-10-11	H.S.		
14"	8	SS	20-21½	9-11-14	H.S.	-25	
14"	9	SS	25-26½	8-7-8	H.S.	25'-28½	Gray, wet medium dense gravely sand.
15"	10	SS	30-31½	8-10-10	H.S.	28½-	Gray damp stiff to very stiff silty clay.
17"	11	SS	35-36½	5-4-7	H.S.		
17"	12	SS	40-41½	6-5-8	H.S.		
16"	13	SS	45-46½	7-8-7	H.S.		
[illegible]	14	SS	50-51½	15-13-13	H.S.		

* – Measure to nearest Inch

iller Jerry W. Patterson

Inspector N. Ray Noel

iper Ricky L. Patterson

Engineer ____

PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client: Butler, Fairman & Seufert

Job No.: IND-2872

RIG NUMBER:

Project: Lake County - MM-850(23)FE Str. No. 912-45-6604

Weather: Hot

Boring Number: B-1 Location: Indianapolis Blvd. Sheet 2 of 2

Ground Elevation: 589.8 Station: 186+20 Offset: 35' Lt. PR-1-E Line

Date Started: 7-8-75 Date of Completion: 7-9-75

ST = SHELBY TUBE HS = HOLLOW STEM

PA = POWER AUGER HA = HAND AUGER

RC = ROCK CORE SS = SPLIT SPOON

W = WASH

GROUND WATER DATA

Elevation	Time	Date
5'	While Drilling	7-8-75
5'	At End of Boring	7-9-75
5'	At 24 hours	7-10-75

Elevation of Top of Rock: None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]	15	SS	55-56½	6-7-7	H.S.		Gray damp stiff to very stiff
12"	16	SS	60-61½	8-7-7	H.S.		Silty clay
12"	17	SS	65-66½	8-7-7	H.S.		
14"	18	SS	70-71½	7-8-7	H.S.	- 79.0'	
14"	19	SS	75-76½	10-8-9	H.S.	79'	
15"	20	SS	80-81½	10-11-11	H.S.		Gray moist very stiff to hard
15"	21	SS	85-86½	11-16-19	H.S.		Silty clay (hardpan)
18"	22	SS	90-91½	15-17-19	H.S.	-91.5'	
							BTH-91.5'

* – Measure to nearest inch

Driller: Jerry W. Patterson Inspector: N. Ray Neel

Helper: Ricky L. Patterson Engineer:

1153-9 ✓

PITTSBURGH TESTING LABORATORY

[illegible] AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

ontractor
Client Butler, Fairman & Seufert

Job No. IND-2872

Lake County
MM-850(23)PE -
oject

RIG NUMBER ____

Str. No. 912-45-6604

Weather Hot

ring Number B-2 Location Indianapolis Blvd. Sheet 1 of 1

ound Elevation 588.0 Station 187+70 Offset 55' Rt PR-1-E-line

te Started 7-10-75 Date of Completion 7-10-75

GROUND WATER DATA		
Elevation	Time	Date
5'	While Drilling	7-10-75
5'	At End of Boring	7-10-75
5'	At 24 hours	7-11-75

Elevation of Top of Rock ____

T = SHELBY TUBE HS = HOLLOW STEM

A= POWER AUGER HA = HAND AUGER

C= ROCK CORE SS = SPLIT SPOON

W = WASH

mple covery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
2"	1	SS	2½-4	4-3-3	H.S.	0' - 5'	Dark wet loose oily sand
10"	2	SS	5-6½	8-7-6	H.S.	5' -	Gray wet loose to medium
14"	3	SS	7½-9	3-4-6	H.S.		dense sand and gravel.
15"	4	SS	10-11½	4-5-5	H.S.		
14"	5	SS	12½-14	5-4-5	H.S.	-15'	
16"	6	SS	15-16½	5-6-6	H.S.	15' -	Gray wet loose to medium dense sand.
16"	7	SS	17½-19	5-6-5	H.S.		
15"	8	SS	20-21½	5-4-5	H.S.		
15"	9	SS	25-26½	8-9-8	H.S.		
14"	10	SS	30-31½	6-10-14	H.S.	-33'	
14"	11	SS	35-36½	7-9-11	H.S.	33' -	Gray moist very stiff silty
14"	12	SS	40-41½	8-11-10	H.S.	41½	clay
							BTH 41.5'

* – Measure to nearest inch

ller Jerry W. Patterson Inspector N. Ray Neel

per Ricky L. Patterson Engineer ____

2.

PITTSBURGH TESTING LABORATORY

[illegible] N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client: Butler, Fairman & Seufert

Job No. IND-2672

RIG NUMBER ____

Project: Lake County TM-850(23)II

STr. No. 912-45-6604

Weather: Hot

Boring Number: B-3

Location: Indianapolis Blvd.

Sheet 1 of 1

Ground Elevation: 587.5

Station: 188+00

Offset: 55' Lt. PR-I-E-Line

Date Started: 7-21-75

Date of Completion: 7-21-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
5'	While Drilling	7-21-75
4'	At End of Boring	7-21-75
5'	At 24 hours	7-22-75

Elevation of Top of Rock: None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color / Type / TOPSOIL*
[illegible]0"	1	SS	2½-4	3-4-3	H.S	0-4'	Slag and cinder fill.
12"	2	SS	5-6½	3-4-4	H.S.	4'-7'	Gray wet loose sand.
16"	3	SS	7½-9	9-10-10	H.S.	7-10'	Gray wet medium dense sand & Gr
17"	4	SS	10-11½	11-14-15	H.S.	10'-	Gray wet medium dense sand.
12"	5	SS	12½-14	11-13-11	H.S.		
13"	6	SS	15-16½	10-10-11	H.S.		
15"	7	SS	17½-19	10-11-11	H.S.		
14"	8	SS	20-21½	9-9-10	H.S.		
15"	9	SS	25-26½	10-10-12	H.S.		
16"	10	SS	30-31½	10-13-16	H.S.	-33'	
17"	11	SS	35-36½	9-8-7	H.S.	33'	Gray damp stiff silty clay.
17"	12	SS	40-41½	7-8-7	H.S.	-41½	
							BTH 41.5'

* – Measure to nearest inch

Driller: Jerry W. Patterson

Inspector: M. Ray Neel

Helper: Ricky L. Patterson

Engineer: ____

7532

PITTSBURGH TESTING LABORATORY

2828 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor
r Client Butler Fairman & Seufort

Job No. IND-2872

Lake County
[illegible]-850(23)FE

roject

RIG NUMBER

STr. No. 912-45-6604

Weather Hot

Boring Number B-4

Location Indianapolis Blvd.

Sheet 1 of 1

round Elevation 587.9

Station 189+25

Offset 25' rt. PR-I-E line

ate Started 7-22-75

Date of Completion 7-23-75

T = SHELBY TUBE
HS = HOLLOW STEM
A = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
5½	While Drilling	7-22-75
5	At End of Boring	7-23-75
5	At 24 hours	7-24-75

Elevation of Top of Rock None

ample ecovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]	1	SS	2½-4	3-5-5	H.S.	0' -	Black slag and cinder fill loose oily.
10"	2	SS	5-6½	4-6-5	H.S.	6'	
12'	3	SS	7½-9	5-6-4	H.S.	6'	Gray wet loose to medium dense fine to medium sand.
15'	4	SS	10-11½	5-6-6	H.S.		
14"	5	SS	12½-14	5-6-7	H.S.		
16"	6	SS	15-16½	10-9-7	H.S.		
12"	7	SS	17½-19	11-8-9	H.S.		
13"	8	SS	20-21½	10-10-8	H.S.		
15"	9	SS	25-26½	10-14-13	H.S.		
16"	10	SS	30-31½	11-9-16	H.S.	-33'	
18"	11	SS	35-36½	8-7-7	H.S.	33'-	Gray damp stiff clay with
18"	12	SS	40-41½	9-7-6	H.S.	41½	traces of silt.
							BTM. 41.5'

* – Measure to nearest Inch

iller Jerry W. Patterson

Inspector N. Ray Neel

Helper Ricky L. Patterson

Engineer

PITTSBURGH TESTING LABORATORY

2328 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46219

TEST BORING LOG

Contractor or Client: Butler, Fairman & Seufert, Inc.
Lake County

Job No.: IND-2872

RIG NUMBER: ____

Project: MM-850(23)PE

Weather: Hot

Boring Number: RW 14
Location: Retaining Wall Boring
Sheet 1 of 1

Ground Elevation: 586.2
Station: 191+10
Offset: 55' Lt. PR-1-E Line

Date Started: 8-14-75
Date of Completion: 8-14-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
4.0'	While Drilling	8-14-75
4.0'	At End of Boring	8-14-75
4.0'	At 24 hours	8-15-75

Elevation of Top of Rock: None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color Type TOPSOIL*
[illegible]	1	S.S.	1 - 2½	7-13-21	H.S.	0' -	Black moist to wet medium
17"	2	S.S.	3½ - 5	7-15-12	H.S.		dense to dense gravelly sand
15"	3	S.S.	6 - 7½	9-9-12	H.S.		A-1-b (Lab. No. 2)
15"	4	S.S.	8½ - 10	8-9-10	H.S.	- 10'	
							B.T.H. - 10.0'

* – Measure to nearest Inch

Driller: Charles Jones
Inspector: N. Ray Neel
Helper: Francis Buchanan
Engineer: ____

PITTSBURGH TESTING LABORATORY

2028 N. WEBSTER AVENUE
INDIANAPOLIS, INDIANA 46213

TEST BORING LOG

Contractor or Client Butler, Fairman & Seufert, Inc.

Job No. [illegible]

Lake County

RIG NUMBER

Project M-850(23)PE -

Weather Hot

Boring Number RW 15

Location Retaining Wall Boring

Sheet 1 of 1

Ground Elevation 586.0

Station 192+00

Offset 55' Rt. PR-1-E Line

Date Started 8-14-75

Date of Completion 8-14-75

ST = SHELBY TUBE
HS = HOLLOW STEM
PA = POWER AUGER
HA = HAND AUGER
RC = ROCK CORE
SS = SPLIT SPOON
W = WASH

GROUND WATER DATA		
Elevation	Time	Date
3.5'	While Drilling	8-14-75
3.5'	At End of Boring	8-14-75
3.5'	At 24 hours	8-15-74

Elevation of Top of Rock None

Sample Recovery	Sample Number	Type of Sample	Sample Depth From – To	Sampler Blows per 6 Inches	Drilling Method	Depth From – To	Description of material and Remarks
							Color . Type TOPSOIL*
[illegible]"	1	S.S.	1 - 2½	6-7-8	H.S.	0' -	Black moist to wet medium dense
15"	2	S.S.	3½ - 5	11-12-12	H.S.		gravelly sand. A-1-b
16"	3	S.S.	6 - 7½	7-9-12	H.S.		Lab. No. 2
17"	4	S.S.	8½ - 10	8-9-14	H.S.	- 11'	
16"	5	S.S.	11 - 12½	11-17-20	H.S.	11' -	Gray wet fine medium dense to
15"	6	S.S.	13½ - 15	12-14-15	H.S.		dense sand. A-3
15"	7	S.S.	16 - 17½	7-11-23	H.S.		Lab. No. 3
13"	8	S.S.	18½ - 20	10-13-19	H.S.		
17"	9	S.S.	23½ - 25	8-13-19	H.S.		
18"	10	S.S.	28½ - 30	7-9-13	H.S.	- 33'	
18"	11	S.S.	33½ - 35	4-6-7	H.S.	33' -	Gray moist stiff clay. A-6
						- 38½'	Lab. No. 5
17"	12	S.S.	38½ - 40	4-5-7	H.S.	38½' -	Gray wet stiff clay A-6
17"	13	S.S.	43½ - 45	4-4-6	H.S.	- 45'	Lab. No. 5

B.T.H. = 45.0'

* – Measure to nearest Inch

Driller Charles Jones

Inspector N. Ray Neel

Helper Francis Buchanan

Engineer

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ATTACHMENT L - 6

ECI SITE
ERM-North Central, Inc. / Geraghty & Miller, Inc.
- Soil Boring Logs
- Laboratory Test Data

ERM North Central, Inc.
Environmental Resources Management

GEOLOGIC DRILL LOG

PROJECT/TASK: ECI Refinery Site	PROJECT NUMBER: 91110EM	SHEET NO.: 1 of 2	HOLE NUMBER: BD01		
SITE: East Chicago	COORDINATES: N 8520.5; E843.0	CONTAMINANT SCREENING NOTES: *HNu w/10.2 eV Probe **Headspace Sample			
BEGUN: 10-31-91	COMPLETED: 11-1-91	DRILLER: Bill Bryant-EDAC	DRILLING EQUIPMENT: Gus Pech 1000R, 4-1/4" I.D. HSA	BORING DIA.: 7"	TOTAL DEPTH: 30
CORE RECOVERY (FT./%):	CORE BOXES: 0	SAMPLES:	ELEV. TOP CASING:	GROUND ELEV.: 586.8	DEPTH/ELEV. GROUND WATER: ▽ 4.0 / 582.80
DEPTH/ELEV. TOP OF ROCK: NOT ENCOUNTERED	SAMPLE DEVICE: 2"x2' Split Spoon/140 lb. hammer	CASING LEFT IN HOLE: DIA./LENGTH:	LOGGED BY: John Roberts		

Lab Sample # / Time	Recovery (feet)	Length (feet)	Blow Count / RQD (%)	Sample Scan VOC (ppm)	Headspace VOC (ppm)	Visual Observ.	LAYER DEPTH	DEPTH	DESCRIPTION AND CLASSIFICATION density, grain size/shape, color, structure composition, sorting, texture, moisture facies, odor	DRILLING NOTES water levels, water return, character of drilling, etc.
	1.0	2.0	3 10 9 10		4.6				0-2.5': FILL; Crushed slag up to 1" diameter with oil coating.	
	0.8	2.0	11 10 5 11		42		-2.5		2.5-4.0': SAND;	
00104 14:45	1.7	2.0	6 11 17 21		50		▽	5	4.0-6.0': SAND; Fine to medium grained sand, coarse at base saturated with oil and water.	Geotech sample
	1.5	2.0	3 8 11 12		88				6.0-10.0': SAND; Medium grained native sand, stained black at top of interval, grades to gray at base of spoon, no sharp contact.	
	1.2	2.0	1 2 9 12		74					
	1.7	2.0	2 2 6 10		56			10	10.0-12.0': SAND; Medium to fine grained sand with narrow pebble intervals at 11' and 11.5', light yellow gray.	
	2.0	2.0	2 6 8 22		73				12.0-15.5': SAND; Medium grained sand, light yellow gray with black bands of heavy minerals at 12.8' and 13.7, wood fiber at 15'.	
00106 15:30	1.8	2.0	2 2 6 14		23		-15.5 -15.7	15	15.5-15.75': SAND; Poorly sorted coarse and medium sand with shell hash. 15.75-16.0': SAND; Fine grained sand, light yellow gray.	Geotech sample
	2.0	2.0	0 3 11 18		20				16.0-17.5': SAND; Medium grained sand. 17.5-18.0': SAND; Fine grained laminated sand, medium light yellow gray.	
	2.0	2.0	2 2 8 12		9.8			20	18.0-23.5': SAND; Medium grained sand with shells and occasional pebbles, mottled light yellow gray and dark yellow gray at 20'.	

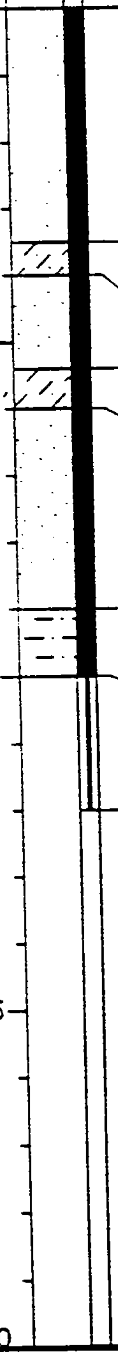
1201-02

ERM North Central, Inc.
Environmental Resources Management

GEOLOGIC DRILL LOG	PROJECT/TASK ECI Refinery Site	PROJECT NUMBER 91110EM	SHEET NO. 2 of 2	HOLE NUMBER BD01
SITE East Chicago	COORDINATES N 8520.5; E343.0	CONTAMINANT SCREENING NOTES *HNu w/10.2 eV Probe **Headspace Sample		
BEGUN 10-31-91	COMPLETED 11-1-91	DRILLER Bill Bryant-EDAC	DRILLING EQUIPMENT Gus Pech 1000R, 4-1/4" I.D. HSA	BORING DIA. 7" / TOTAL DEPTH 30

Continued

SAMPLES/R.CORE				CONTAMINANT SCREENING		
Lab Sample # / Time	Recovery (feet)	Length (feet)	Blow Count / RQD (%)	Sample Scan VOC (ppm)	Headspace VOC (ppm)	Visual Observ.
	2.0	2.0	2 3 8 9		1.3	
	2.0	2.0	4 7 10 10		0.2	
D0124 16:30	2.0	2.0	3 6 4 8		4.0	
	1.5	2.0	3 9 11 13		0.0	
	1.5		3 5 5 5		2.0	
D0130 07:45						

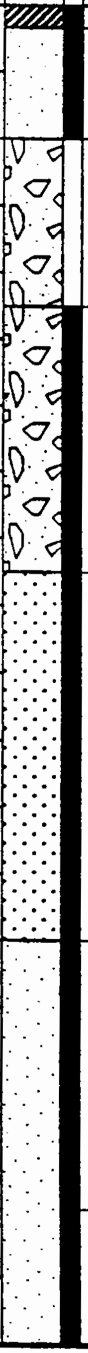


LAYER DEPTH	DEPTH	DESCRIPTION AND CLASSIFICATION density, grain size/shape, color, structure composition, sorting, texture, moisture facies, odor	DRILLING NOTES water levels, water return, character of drilling, etc.
	20		
-23.5 -24		23.5-24.0': SILTY SAND: Light yellow gray, weakly laminated.	Geotech sample
-24 -25.4	25	24.0-25.4': SAND: Fine grained, light yellow gray, weakly laminated.	
-25.4 -26		25.4-26.0': SILT and SAND: Silt and silty sand, light yellow gray.	
-26 -29		26.0-29.0': SAND: Well sorted fine grained sand, laminated 1-3mm thick, medium gray, saturated, poorly sorted at 28.5'.	
-29 -30	30	29.0-30.0': SILTY CLAY: Medium gray, stiff, 5-10% sand, 5% gravel and pebbles, moist.	Clay Contact
		Took shelby tube sample from 30-32 feet.	End of Boring
	35		
	40		

ERM North Central, Inc.
Environmental Resources Management

GEOLOGIC DRILL LOG

PROJECT/TASK ECI Refinery Site	PROJECT NUMBER 9111OEM	SHEET NO. 1 of 2	HOLE NUMBER BD02	
TE East Chicago	COORDINATES N 8645.0; E10056.0	CONTAMINANT SCREENING NOTES *HNu w/10.2 eV Probe **Headspace Sample		
BEGUN 10-29-91	COMPLETED 10-31-91	DRILLER Bill Bryant-EDAC	DRILLING EQUIPMENT Gus Pech 1000R, 4-1/4" I.D. HSA	BORING DIA. 7"
TOTAL DEPTH 34	CORE RECOVERY (FT./%) /	CORE BOXES -	SAMPLES	ELEV. TOP CASING
GROUND ELEV. 588.0	DEPTH/ELEV. GROUND WATER ▽ / 588.00	DEPTH/ELEV. TOP OF ROCK NOT ENCOUNTERED		
SAMPLE DEVICE 2"x2' Split Spoon/140 lb. hammer	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY John Roberts		



SAMPLES/R.CORE				CONTAMINANT SCREENING						
Lab Sample # / Time	Recovery (feet)	Length (feet)	Blow Count / RQD (%)	Sample Scan VOC (ppm)	Headspace VOC (ppm)	Visual Observ.	LAYER DEPTH	DEPTH	DESCRIPTION AND CLASSIFICATION density, grain size/shape, color, structure composition, sorting, texture, moisture facies, odor	DRILLING NOTES water levels, water return, character of drilling, etc.
	1.7	2.0	3 10 13 11		0.0				0-0.33': TOPSOIL 0.33-2.0': SAND: Yellow sand, dark brown sand with cinders and black staining at tip of spoon.	
	0.0	2.0							2.0-4.5': SPOON REFUSAL. Rocks and bricks, concrete from 3' to 4.5'.	
00204 16.05	1.2	2.0	6 6 8		0.0			5	4.5-8.5': FILL: Dark brown to orange brown sand with slag, cinders, rotted timber and top soil, trace of pebbles, oil stained.	Geotech sample
	1.6	2.0	7 3 14 23		0.0					
	1.2	2.0	5 9 17 30		0.0				8.5-14.0': SAND. Fine to medium sand, angular, yellow gray.	
	1.2	2.0	1/12" 4 6		0.0			10		
	1.3	2.0	3 3 5 14		0.0					
00214 07:09	2.0	2.0	4 5 23 30		0.0			15	14.0-18.0': SAND: Moderately sorted sand, medium gray, medium grained with 5-10% coarse grains, 1-5mm laminations of coarse grained material and heavy minerals.	Geotech sample
	1.3	2.0	2 2 5 10		0.0					
	1.3	2.0	2 5 8 17		0.0			20	18.0-20.0': SAND: Well sorted, medium to fine grained sand, medium gray, 1-5mm laminations of coarse grained material and heavy minerals.	

1203 rot

ERM North Central, Inc.
Environmental Resources Management

GEOLOGIC DRILL LOG

PROJECT/TASK ECI Refinery Site	**PROJECT NUMBER** 91110EM	**SHEET NO.** 2 of 2	**HOLE NUMBER** BD02	
SITE East Chicago	**COORDINATES** N 8645.0; E 0056.0	**CONTAMINANT SCREENING NOTES** *HNu w/10.2 eV Probe **-Headspace Sample		
BEGUN 10-29-91	**COMPLETED** 10-31-91	**DRILLER** Bill Bryant-EDAC	**DRILLING EQUIPMENT** Gus Pech 1000R, 4-1/4" I.D. HSA	**BORING DIA.** 7" / **TOTAL DEPTH** 34

Continued

SAMPLES/R.CORE				CONTAMINANT SCREENING							
Lab Sample # / Time	Recovery (feet)	Length (feet)	Blow Count / RQD (%)	Sample Scan VOC (ppm)	Headspace VOC (ppm)	Visual Observ.	LAYER DEPTH	DEPTH	SAMPLE	DESCRIPTION AND CLASSIFICATION density, grain size/shape, color, structure composition, sorting, texture, moisture facies, odor	DRILLING NOTES water levels, water return, character of drilling, etc.
	1.5	2.0	2 4 10 18		0.0			20		20.0-30.0': <u>SAND</u>; Fine to very fine sand, homogenous to well sorted, medium gray. 1-4mm laminations and some shell material at 22'. Very stringy plant fibers present at 26'.	
	1.5	2.0	2 4 8 11		0.0						
00224 08:07	1.6	2.0	0 3 11 14		0.0			25			
	1.7	2.0	2 9 10 18		0.0						
	1.5	2.0	6 12 18 19		0.0						
	1.7	2.0	3 8 10 12		0.0			30		30-32.0': <u>SAND</u>; Well sorted sand, medium gray, very fine gravel, trace of silt and clay, laminated.	
	1.7	2.0	6 2 1 1		0.0					32-33.5': <u>SAND</u>; Well sorted sand, medium to fine grained at top, coarse grained at base, laminated.	
							-33.5			33.5-34.0': <u>CLAY</u>; Medium gray clay, trace of silt, soft, moist.	Clay contact
00234 09:55							-34	35		Took shelby tube sample from 34-36 feet.	End Of Boring
								40			

ERM North Central, Inc.
Environmental Resources Management

GEOLOGIC DRILL LOG

PROJECT/TASK ECI Refinery Site	PROJECT NUMBER 9110EM	SHEET NO. 1 of 2	HOLE NUMBER BD03		
ITE East Chicago	COORDINATES N 10017.0; E9452.0	CONTAMINANT SCREENING NOTES *HNu w/10.2 eV Probe **Headspace Sample			
BEGUN 10-28-91	COMPLETED 10-28-91	DRILLER Bill Bryant-EDAC	DRILLING EQUIPMENT Gus Pech 1000R, 4-1/4" I.D. HSA	BORING DIA. 7"	TOTAL DEPTH 36
CORE RECOVERY (FT./%)	CORE BOXES 0	SAMPLES	ELEV.TOP CASING	GROUND ELEV. 590.8	DEPTH/ELEV. GROUND WATER ∇ - 530.80
DEPTH/ELEV. TOP OF ROCK NOT ENCOUNTERED	SAMPLE DEVICE 2"x2' Split Spoon/140 lb. hammer	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY John Roberts		

SAMPLES/R.CORE				CONTAMINANT SCREENING								
Lab Sample # / Time	Recovery (feet)	Length (feet)	Blow Count / RQD (%)	Sample Scan VOC (ppm)	Headspace VOC (ppm)	Visual Observ.	LAYER DEPTH	DEPTH	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION density, grain size/shape, color, structure composition, sorting, texture, moisture facies, odor	DRILLING NOTES water levels, water return, character of drilling, etc.
	1.5	2.0	12 24 26 22								0-1.5'. FILL, Dark brown sandy clay with cinders, moist, rocks and broken concrete to 2" diameter. 1.5-6.5'. GRAVEL, Yellow-brown to orange brown medium gravel (0.5" diameter) with clay and sand	HNu not working due to heavy rain.
	0.8	2.0	9 15								2.0-2.8'. No recovery: concrete. 2.8-3.8': ANGULAR CRUSHED LIMESTONE. Medium gray, with sand and clay, 4" seam of black stained medium sand, strong petroleum odor at 3.8'.	Water level at 3' Geotech sample
00304 11.20	1.0	2.0	7 8 7 9					5			4-6.5'. FILL; Cinders, gravel, broken rock, black to gray, 2" seam of fine to medium grained sand, stained black, strong petroleum odor, saturated.	
	1.3	2.0	7 15 18 21								6.5-16.0': SAND, Fine to medium sand, stained black, trace of coarse gravel to 1" diameter, strong petroleum odor.	
	1.0	2.0	3 10 12 11									
	1.0	2.0	3 12 28 28					10				
	1.3	2.0	2 5 14 28									
00314 12.05	1.8	2.0	4 5 6 23					15			1" medium gravel at 15.5'.	Geotech sample
	1.2	2.0	5 13 24 26								16-20.0': SAND; Medium to fine grained sand, light yellow gray, angular, well sorted.	
	1.25	2.0	4 11 21 32					20				

1203-06

ERM North Central, Inc.
Environmental Resources Management

GEOLOGIC DRILL LOG

PROJECT/TASK ECI Refinery Site	PROJECT NUMBER 9110EM	SHEET NO. 2 of 2	HOLE NUMBER BD03		
SITE East Chicago	COORDINATES N 10017.0, E9452.0	CONTAMINANT SCREENING NOTES *HNu w/10.2 eV Probe **Headspace Sample			
BEGUN 10-28-91	COMPLETED 10-28-91	DRILLER Bill Bryant-EDAC	DRILLING EQUIPMENT Gus Pech 1000R, 4-1/4" I.D. HSA	BORING DIA. 7"	TOTAL DEPTH 36

Continued

SAMPLES/R.CORE				CONTAMINANT SCREENING								
Lab Sample # / Time	Recovery (feet)	Length (feet)	Blow Count / RQD (%)	Sample Scan VOC (ppm)	Headspace VOC (ppm)	Visual Observ.	LAYER DEPTH	DEPTH	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION density, grain size/shape, color, structure composition, sorting, texture, moisture facies, odor	DRILLING NOTES water levels, water return, character of drilling, etc.
	1.5	2.0	[illegible]					20			20-30.0': <u>SAND</u>, Fine to medium grained sand, moderately well sorted, moderately well laminated.	
	1.6	2.0	[illegible] 24									
00324 15.00	1.25	2.0	6 12 15 22					25				Geotech sample
	1.8	2.0	4 10 18 20									
	1.3	2.0	[illegible]									
	0.5	2.0	[illegible] 10				30	30			30-34.0'. <u>SILT</u>, Light yellow gray silt with trace clay.	
	0.5	2.0	7 8 10 6									
	1.4	2.0	3 5 5 6				34	35			34-36.0'. <u>CLAY</u>: Light yellow gray clay, plastic, wet.	Clay Contact
00336 16.27							36				Took shelby tube sample from 36-38 feet at 16:27.	End Of Boring
								40				

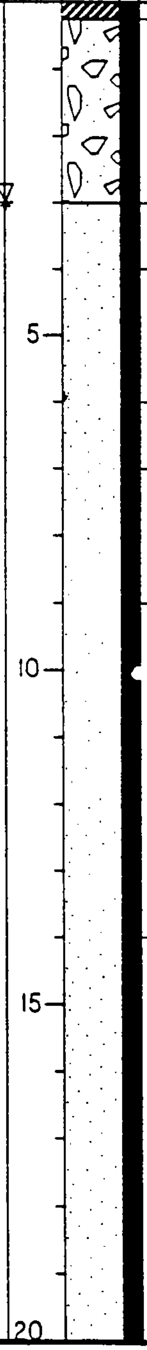
ERM North Central, Inc.
Environmental Resources Management

GEOLOGIC DRILL LOG

PROJECT/TASK ECI Refinery Site		PROJECT NUMBER 3110EM	SHEET NO. 1 of 2	HOLE NUMBER **BD04**
SITE East Chicago	COORDINATES N10790.9; E10090.9	CONTAMINANT SCREENING NOTES *HNu w/10.2 eV Probe **Headspace Sample		
BEGUN 10-29-91	COMPLETED 10-29-91	DRILLER Bill Bryant-EDAC	DRILLING EQUIPMENT Gus Pech 1000R, 4-1/4" I.D. HSA	BORING DIA. 7"
TOTAL DEPTH 36	CORE RECOVERY (FT./%)	CORE BOXES 0	SAMPLES	ELEV. TOP CASING
GROUND ELEV. 587.0	DEPTH/ELEV. GROUND WATER ∇ 3.0 / 584.00	DEPTH/ELEV. TOP OF ROCK NOT ENCOUNTERED	SAMPLE DEVICE 2"x2' Split Spoon/140 lb. hammer	CASING LEFT IN HOLE: DIA./LENGTH
LOGGED BY John Roberts				

SAMPLES/R.CORE				CONTAMINANT SCREENING		
Lab Sample # / Time	Recovery (feet)	Length (feet)	Blow Count / RQD (%)	Sample Scan VOC (ppm)	Headspace VOC (ppm)	Visual Observ.
	1.25	2.0	7 10 9 [illegible]		3.0	
	1.3	2.0	7 24 28 40		[illegible]	
00404 09:10	1.5	2.0	9 22 27 30		220	
	1.5	2.0	11 24 24 39		175	
	[illegible]	2.0	5 13 15 21		175	
	1.6	2.0	10 22 26 24		175	
	1.9	2.0	3 5 14 24		110	
00414 10:10	1.6	2.0	2 4 14 28		142	
	2.0	2.0	2 4 14 20		74	
	2.0	2.0	4 7 9 11		30	

LAYER DEPTH



DESCRIPTION AND CLASSIFICATION density, grain size/shape, color, structure composition, sorting, texture, moisture facies, odor	DRILLING NOTES water levels, water return, character of drilling, etc.
0-0.25': <u>TOPSOIL</u>	
0.25-3.0': <u>FILL</u>. Yellow and red bricks and brown to olive brown sand	
3-4.0': <u>SAND and PEBBLY SAND</u>. Black oil stained sand with twigs, and yellow brown pebbly sand, rounded pebbles 0.5-1" diameter.	Geotech sample
4-6.0': <u>SAND</u>: Yellow gray medium grained sand with 5% rounded pebbles.	
6-7.0': <u>SAND</u>: Fine yellow gray to tan sand.	
7-9.0': <u>SAND</u>: Yellow gray medium to coarse grained sand, angular, 5% pebbly material as poorly developed laminar zones up to 1" thick.	
9-14.0': <u>SAND</u>: Fine yellow gray massive sand with rare shell fragments and trace pebbles.	
14-20.0': <u>SAND</u>: Fine to medium grained massive sand, moderately to well sorted, shell material to 4mm.	Geotech sample

ERM North Central, Inc.
Environmental Resources Management

GEOLOGIC DRILL LOG

PROJECT/TASK ECI Refinery Site		PROJECT NUMBER 311OEM	SHEET NO. 2 of 2	HOLE NUMBER BD04
SITE East Chicago	COORDINATES N 10730.3, E10030.9	CONTAMINANT SCREENING NOTES *HNu w/10.2 eV Probe **Headspace Sample		
BEGUN 10-23-91	COMPLETED 10-23-91	DRILLER Bill Bryant-EDAC	DRILLING EQUIPMENT Gus Pech 1000R, 4-1/4" I.D. HSA	BORING DIA. -- TOTAL DEPTH 36

Continued

SAMPLES/R.CORE				CONTAMINANT SCREENING								
Lab Sample # / Time	Recovery (feet)	Length (feet)	Blow Count / RQD (%)	Sample Scan VOC (ppm)	Headspace VOC (ppm)	Visual Observ.	LAYER DEPTH	DEPTH	GRAPHIC LOG	SAMPLE	DESCRIPTION AND CLASSIFICATION density, grain size/shape, color, structure composition, sorting, texture, moisture facies, odor	DRILLING NOTES water levels, water return, character of drilling, etc.
	2.0	2.0	[illegible]		24			20			20-26.0': SAND: Fine to very fine angular sand, yellow gray, massive to weakly laminated, some shell material.	
	2.0	2.0	[illegible]		3.4							
00424 11:08	2.0	2.0	3 8 13 6		0.8			25				Geotech sample
	2.0	2.0	5 12 14 16		0.8		-26		╱╱		26-34.0': SILTY SAND: Well laminated silty sand, interbedded with trace shell fragments and hair or plant fibers, and wood fiber, light yellow gray, increasing in silt at 32'.	
	2.0	2.0	[illegible]		3.4				╱╱			
	2.0	2.0	[illegible]		6.0			30	╱╱			
	1.0	2.0	[illegible]		6.8				╱╱			
	0.7	2.0	[illegible]		0.1		-34	35	☰		34-36.0': CLAY: Gray clay, plastic.	Clay contact
00436 13.25							-36				Took shelby tube sample from 36-38 feet.	End of boring
								40				

PARTICLE SIZED ANALYSES SUMMARY FOR THE CALUMET SEDIMENTS

CORE LABORATORIES

Company :ERM-NORTH CENTRAL, INC.	Field :	File No.:57111-17052P
Well :ECI REFINERY SITE	Coring Fl.:	Date :15-OCT-91
Location:	Core Dia :	Analysts:GC
Co,State:	Coring Eq.:	Method :Sieve

PARTICLE SIZE ANALYSIS

Sample Number	Depth Top ft	Intvl Rep ft	Grain Size								Statistics					
			Sand					Silt & Clay								
			Very Coarse %	Coarse %	Medium %	Fine %	Very Fine %	ϕ = 4 to 6 %	ϕ = 6 to 8 %	ϕ = 8 & up %	Median Grain Size in	Mean Grain Size in	Std. Dev. ϕ	Skew-ness	Kur-tosis	Trask Coeff.
	4.0					Formation: W.O.# 91110										
DB 1	4.0	2.0	-	-	0.1	0.6	78.5	12.5	-	8.2	0.0030	0.0029	0.6161	0.3759	2.4339	1.1776
DB 1	14.0	2.0	1.0	0.2	0.8	41.1	53.8	1.5	-	1.5	0.0055	0.0056	0.4257	0.0423	1.1743	1.2063
DB 1	24.0	2.0	25.6	1.3	6.8	61.5	4.1	0.3	-	0.4	0.0099	0.0185	-	-	-	3.1378
DB 2	4.0	2.0	5.7	4.9	11.1	52.9	23.2	1.2	-	1.0	0.0078	0.0081	1.0550	-0.244	1.8785	1.3868
DB 2	14.0	2.0	3.3	1.6	4.3	62.6	26.2	0.8	-	1.2	0.0069	0.0069	0.5762	-0.197	1.9328	1.1928
DB 2	24.0	2.0	0.0	0.0	0.2	2.2	88.8	4.6	-	4.1	0.0042	0.0040	0.4585	0.4299	1.0920	1.2379
DB 3	4.0	2.0	54.7	4.9	8.6	14.5	6.5	2.7	-	8.0	0.0791	-	-	-	-	-
DB 4	4.0	2.0	28.7	23.0	30.8	15.4	0.9	0.2	-	1.1	0.0243	0.0282	-	-	-	2.0694
DB 4	14.0	2.0	6.8	5.2	11.7	47.6	27.0	0.5	-	1.0	0.0075	0.0086	1.0655	-0.448	1.6069	1.4335
DB 4	24.0	2.0	-	-	0.1	1.2	88.8	6.0	-	3.9	0.0032	0.0032	0.3241	0.2073	1.3050	1.1430
P 1	2.0	2.0	8.8	3.7	6.9	50.3	24.1	1.6	-	4.6	0.0070	0.0078	1.2719	-0.267	2.6084	1.3622
P 1	8.0	2.0	0.6	0.8	4.1	79.1	14.3	0.4	-	0.7	0.0075	0.0076	0.3914	-0.004	1.1324	1.1844
P 2	2.0	2.0	5.6	2.6	4.8	61.9	20.8	0.9	-	3.3	0.0069	0.0068	0.9255	-0.193	4.4374	1.1661
P 2	8.0	2.0	3.4	1.1	3.4	67.5	22.8	0.5	-	1.3	0.0070	0.0070	0.5109	-0.133	1.7943	1.1761
P 3	4.0	2.0	-	0.1	4.0	80.1	13.8	0.7	-	1.2	0.0075	0.0075	0.3759	0.0315	1.0950	1.1837
P 4	4.0	2.0	25.7	4.3	9.3	41.1	11.8	2.5	-	5.3	0.0095	0.0161	-	-	-	3.30[illegible]
P 5	4.0	2.0	2.0	0.5	0.9	16.4	77.8	1.4	-	1.1	0.0050	0.0048	0.4377	0.1279	1.5935	1.15[illegible]
P 6	4.0	2.0	14.4	3.1	6.0	31.8	40.0	1.9	-	2.7	0.0063	0.0091	1.5422	-0.512	1.7271	1.5374
P 7	4.0	2.0	24.7	6.4	14.3	29.1	12.7	4.3	-	8.4	0.0105	0.0140	-	-	-	2.7316
P 8	4.0	2.0	0.4	0.6	3.2	34.9	41.2	4.5	-	15.2	0.0049	0.0041	-	-	-	1.5427
P 9	6.0	1.0	-	-	0.6	22.0	48.8	6.2	-	22.3	0.0035	0.0021	-	-	-	1.6558
P 10	6.0	2.0	11.8	1.3	1.7	8.7	67.4	5.4	-	3.6	0.0039	0.0045	1.2855	-0.501	2.4756	1.3829
P 11	4.0	2.0	-	0.7	7.4	84.0	7.0	0.2	-	0.8	0.0084	0.0083	0.3740	0.0716	0.9913	1.1960
P 12	4.0	2.0	17.1	3.3	9.3	65.4	4.4	0.1	-	0.3	0.0093	0.0165	-	-	-	1.3536
P 13	4.0	2.0	8.3	1.3	3.9	65.3	19.2	0.4	-	1.7	0.0071	0.0074	0.8768	-0.409	3.5085	1.1902
P 14	4.0	2.0	51.5	6.0	6.1	29.7	3.3	2.0	-	1.4	0.0710	-	-	-	-	-
P 16	4.0	2.0	49.7	3.9	8.6	21.[illegible]	10.1	1.8	-	4.7	0.0422	-	-	-	-	-
P 17	4.0	2.0	41.4	6.5	10.0	18.8	12.7	3.3	-	7.3	0.0204	-	-	-	-	-
P 19	4.0	2.0	17.0	2.6	5.4	46.2	24.4	1.3	-	3.0	0.0069	0.0134	1.7351	-0.611	1.9247	1.4578
P 20	4.0	2.0	23.4	4.4	11.7	33.1	17.0	2.8	-	7.5	0.0078	0.0141	-	-	-	2.4597
P 21	4.0	2.0	37.6	6.0	8.5	22.9	16.6	4.4	-	3.9	0.0134	-	-	-	-	-
P 22	4.0	2.0	30.1	4.6	5.3	42.3	15.0	0.9	-	1.7	0.0076	-	-	-	-	3.6592
P 23	4.0	2.0	61.8	4.8	11.6	18.4	1.9	0.4	-	1.1	0.0841	-	-	-	-	-
P 24	4.0	2.0	14.2	1.5	6.8	62.8	13.2	0.4	-	1.2	0.0077	0.0098	1.1206	-0.623	2.4773	1.2837
P 25	4.0	2.0	10.6	7.2	10.6	63.4	7.4	0.3	-	0.7	0.0090	0.0117	1.1326	-0.580	2.0305	1.3323
P 26	4.0	1.0	24.8	4.2	14.3	52.9	3.2	0.2	-	0.4	0.0106	0.0189	-	-	-	2.2965
P 27	4.0	2.0	28.8	1.3	12.3	49.2	7.0	0.3	-	0.6	0.0102	-	-	-	-	3.3131
P 28	4.0	2.0	3.2	2.2	9.5	75.7	9.0	0.1	-	0.3	0.0084	0.0084	0.5591	-0.197	1.6022	1.2260
P 29	4.0	2.0	43.8	4.4	6.9	29.4	10.1	1.6	-	3.8	0.0177	-	-	-	-	-
MW 13	3.0	2.0	44.7	3.9	6.2	41.2	2.7	0.4	-	0.9	0.0171	-	-	-	-	-
MW 13	7.0	2.0	11.5	3.3	9.4	65.1	8.7	0.7	-	1.4	0.0083	0.0099	1.0314	-0.543	2.3642	1.2911
MW 14	2.0	2.0	34.5	4.3	12.2	29.5	7.7	2.8	-	9.1	0.0117	-	-	-		3.4972
MW 14	8.0	2.0	33.4	5.4	7.8	44.1	7.1	0.8	-	1.3	0.0106	-	-	-		3.4262
MW 17	2.0	2.0	32.0	4.6	5.4	21.8	23.2	3.7	-	9.3	0.0083	-	-	-		[illegible].5352
MW 17	8.0	2.0	18.9	2.1	6.2	43.4	26.6	1.3	-	1.5	0.0077	0.0143	-	-		[illegible]
MW 18	4.0	2.0	30.2	4.3	10.2	28.5	15.6	3.3	-	7.9	0.0095	-	-	-		3.9500
MW 18	8.0	2.0	4.3	2.5	7.4	71.4	11.9	0.7	-	1.6	0.0076	0.0079	0.6933	-0.341	2.332[illegible]	1.2180
MW 25	4.0	2.0	16.5	3.9	9.1	50.5	15.9	1.8	-	2.4	0.0078	0.0145	-	-		1.5604
MW 26	4.0	2.0	38.3	10.6	11.8	19.5	10.9	2.5	-	6.4	0.0218	-	-	-		3.5170

CORE LABORATORIES

Company :ERM-NORTH CENTRAL,INC.
Well :ECI REFINERY SITE
Location:
Co,State:

Field :
Coring Fl.:
Core Dia :
Coring Eq.:

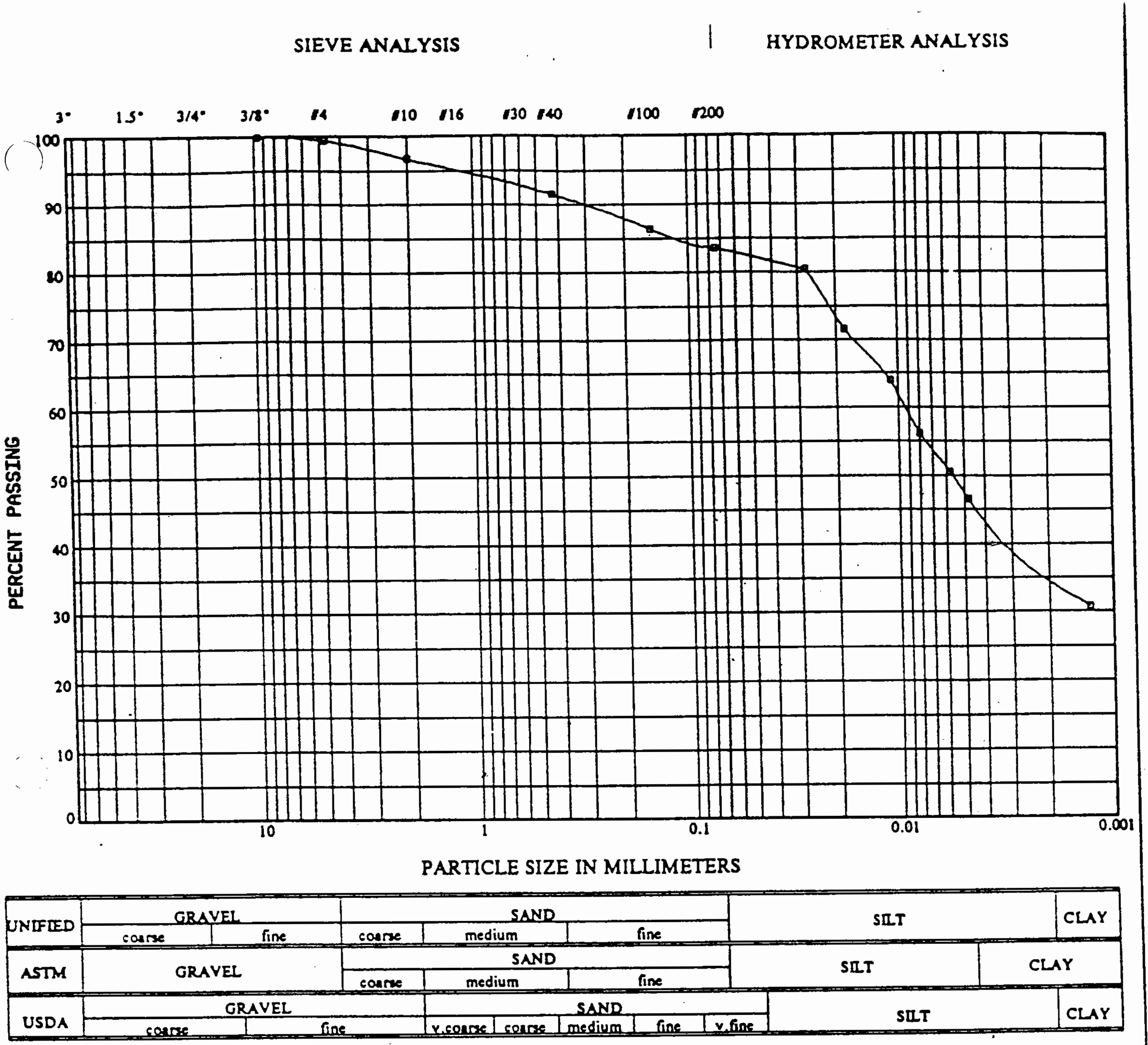
File No.:57111-17052P
Date :15-OCT-91
Analysts:GC
Method :Sieve

PARTICLE SIZE ANALYSIS

Sample Number	Depth Top ft	Intvl Rep ft	Grain Size								Statistics					
			Sand					Silt & Clay			Median Grain Size in	Mean Grain Size in	Std. Dev. ø	Skew-ness	Kur-tosis	Trask Coeff.
			Very Coarse %	Coarse %	Medium %	Fine %	Very Fine %	ø = 4 to 6 %	ø = 6 to 8 %	ø = 8 & up %						
MW 27	4.0	2.0	38.4	7.6	13.3	17.2	12.9	2.9	-	7.7	0.0184	-	-	-	-	-
MW 29	4.0	2.0	15.2	4.3	16.9	38.0	17.3	2.4	-	5.9	0.0086	0.0112	1.7625	-0.209	1.6929	1.7400
MW 33	4.0	2.0	16.9	7.2	19.7	45.9	6.6	1.1	-	2.5	0.0106	0.0160	1.4726	-0.471	1.2622	1.6790
MW 34	4.0	2.0	4.8	2.2	13.8	67.5	8.9	0.8	-	2.0	0.0089	0.0089	0.7578	-0.143	2.1099	1.2530
MW 35	6.0	2.0	1.3	0.5	4.3	80.3	12.6	0.3	-	0.6	0.0076	0.0076	0.3912	-0.030	1.0902	1.1921
MW 36	4.0	2.0	4.1	3.7	9.2	65.6	11.0	3.5	-	3.0	0.0089	0.0083	0.9158	0.1347	2.6283	1.2565
MW 37	4.0	2.0	37.6	5.5	15.5	36.4	4.0	0.4	-	0.7	0.0144	-	-	-	-	3.1159
MW 38	4.0	2.0	9.2	3.5	8.6	70.8	7.4	0.2	-	0.5	0.0086	0.0092	0.8882	-0.431	2.5478	1.2498

1211-17

PARTICLE SIZE ANALYSES FOR THE GLACIAL TILL UNIT



SIEVE ANALYSIS DATA

SIEVE	PERCENT PASSING
3/8"	100.0
4	99.4
10	96.7
40	91.5
100	86.3
200	83.5

DESIGN DATA

Percent of Gravel = 0.6

Percent of Sand = 15.9

Percent of Silt = 36.1

Percent of Clay = 47.4

Specific Gravity:

CLASSIFICATION SUMMARY

Liquid Limit = 28.6

Plastic Limit = 16.9

Plasticity Index = 11.7

NP = Non-Plastic

Natural Moisture = 19.7%

L.O.I. =

File No. 52-12147

PROJECT

Grain Size Analysis
3500 Indianapolis Blvd.
East Chicago, Indiana
REPORT No. 1

COMBINED PARTICLE SIZE DISTRIBUTION

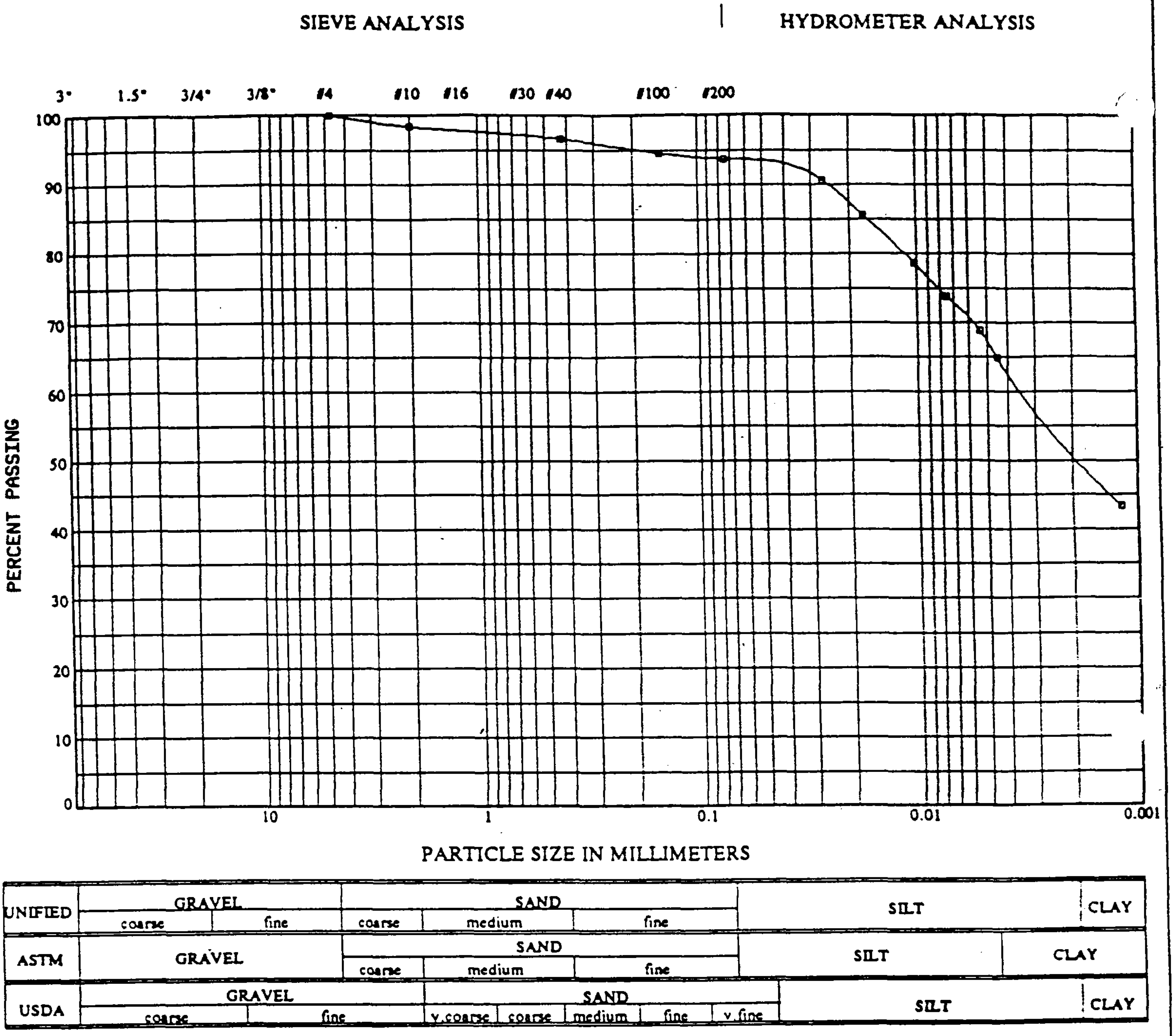
CLIENT:
ERM North Central

SAMPLE DESCRIPTION:
Brown and gray silty CLAY, little sand, trace gravel

BORING NO.: ECBD1030 SAMPLE NO.: 1 DEPTH:

ATEC Associates, Inc.
2646 Highway Avenue
Highland, Indiana 46322

Date Tested:
11/20/91



SIEVE ANALYSIS DATA

SIEVE	PERCENT PASSING
4	100.0
10	98.4
40	96.6
100	94.5
200	93.7

DESIGN DATA

Percent of Gravel = 0.0
Percent of Sand = 6.3
Percent of Silt = 26.5
Percent of Clay = 67.2

Specific Gravity:

CLASSIFICATION SUMMARY

Liquid Limit = 39.7
Plastic Limit = 19.0
Plasticity Index = 20.7
Natural Moisture = 25.8%
L.O.I. =

NP = Non-Plastic

File No. 52-12147

PROJECT
Grain Size Analysis
3500 Indianapolis Blvd.
East Chicago, Indiana
REPORT No. 2

COMBINED PARTICLE SIZE DISTRIBUTION

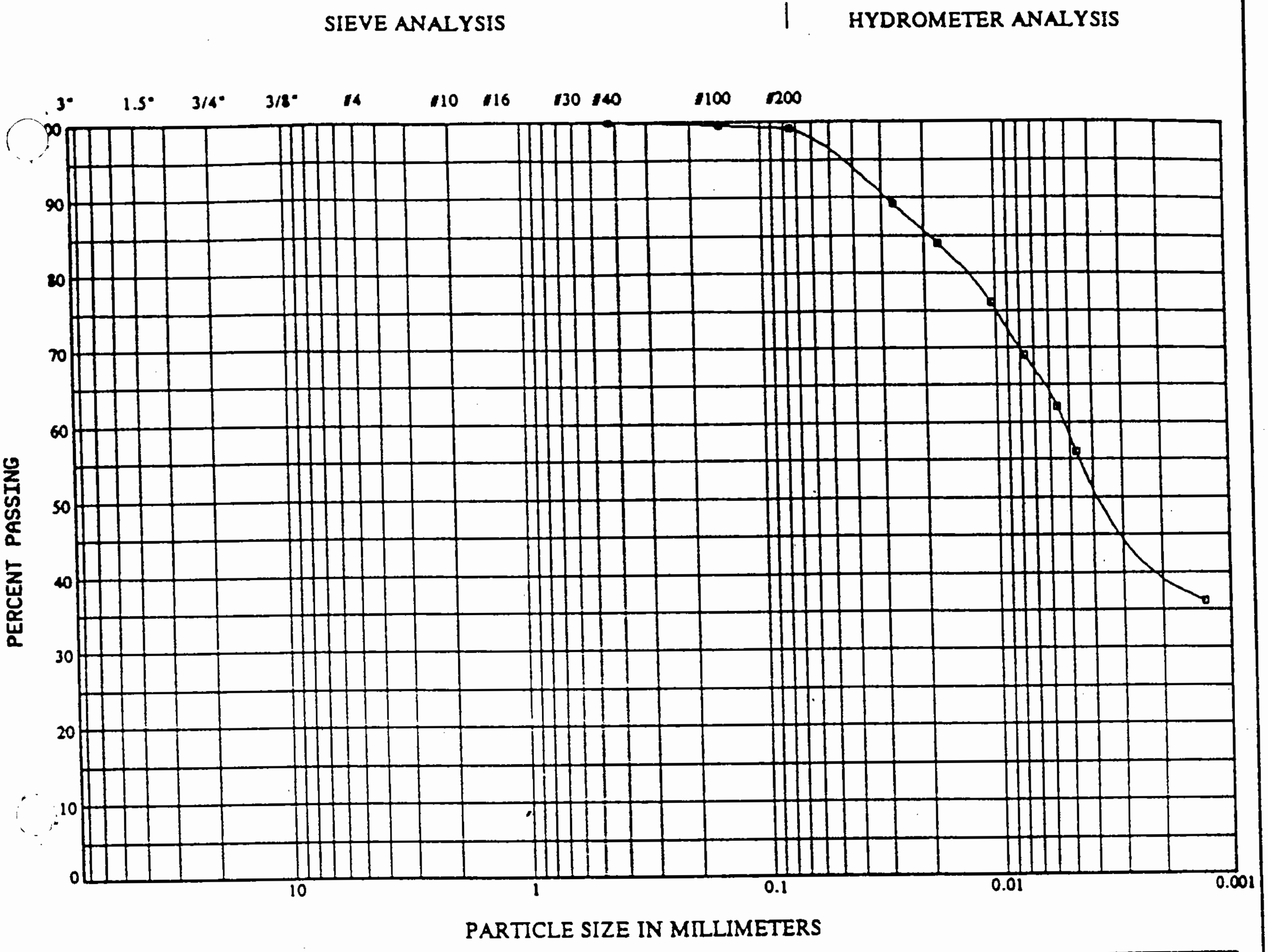
CLIENT:
ERM North Central

SAMPLE DESCRIPTION:
Gray silty CLAY, trace sand

BORING NO.: ECBD0336 **SAMPLE NO.:** 2 **DEPTH:**

ATEC Associates
2646 Highway Avenue
Highland, Indiana 46322

Date Tested
11/20/91



UNIFIED	GRAVEL		SAND			SILT	CLAY
	coarse	fine	coarse	medium	fine		

ASTM	GRAVEL	SAND			SILT	CLAY
		coarse	medium	fine		

USDA	GRAVEL		SAND					SILT	CLAY
	coarse	fine	v.coarse	coarse	medium	fine	v.fine		

SIEVE ANALYSIS DATA

SIEVE	PERCENT PASSING
10	100.0
40	100.0
100	99.6
200	99.2

DESIGN DATA

Percent of Gravel = 0.0
Percent of Sand = 0.8
Percent of Silt = 41.0
Percent of Clay = 58.2

Specific Gravity:

CLASSIFICATION SUMMARY

Liquid Limit = 51.5
Plastic Limit = 25.5
Plasticity Index = 26.0
Natural Moisture = 42.5%
L.O.I. =

NP = Non-Plastic

File No. 52-12147

PROJECT

Grain Size Analysis
3500 Indianapolis Blvd.
East Chicago, Indiana
REPORT No. 3

COMBINED PARTICLE SIZE DISTRIBUTION

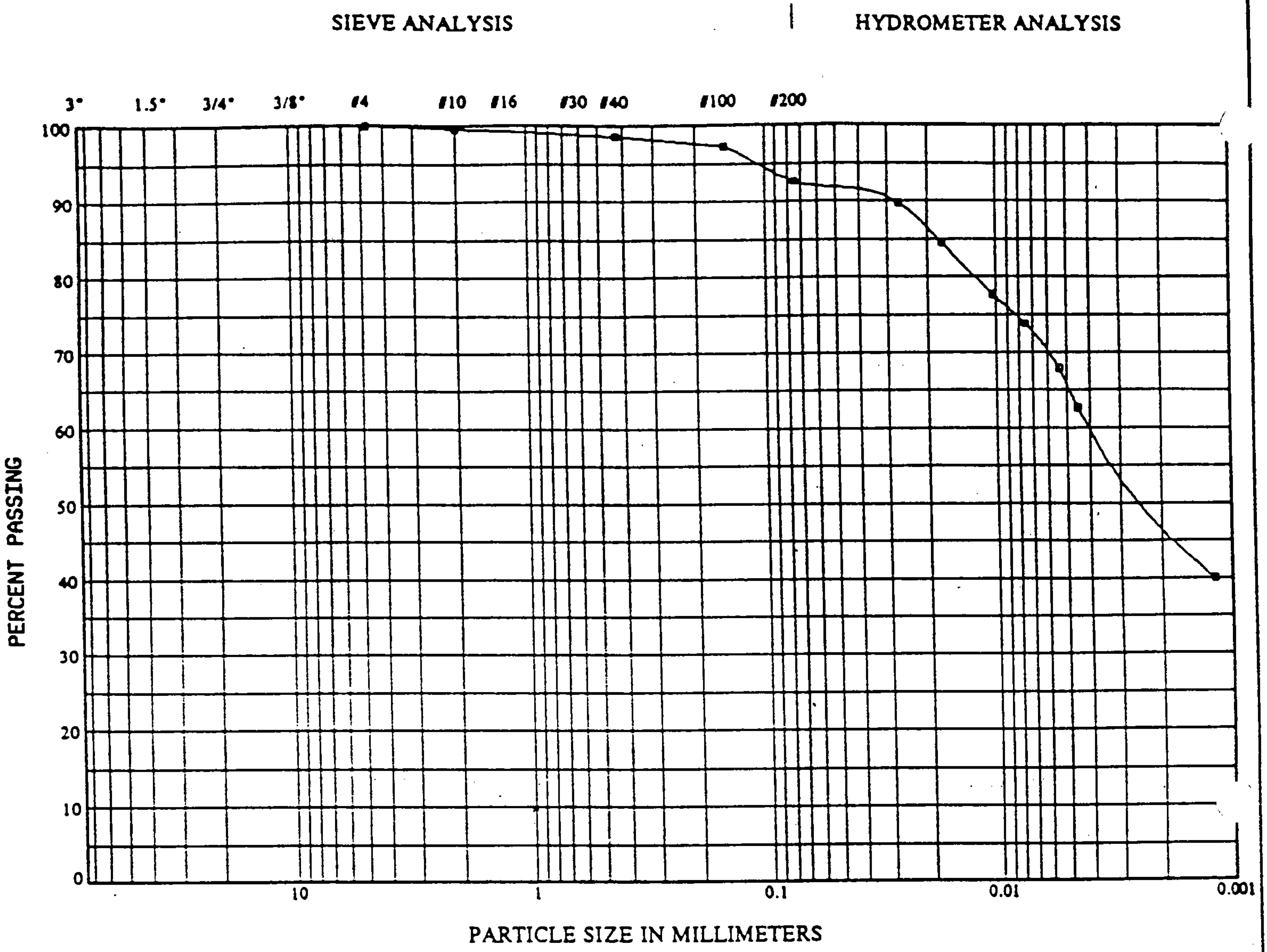
CLIENT:
ERM North Central

SAMPLE DESCRIPTION:
Brown and gray silty CLAY, trace sand

BORING NO.: ECBD0234 SAMPLE NO.: 3 DEPTH:

ATEC Associates Inc.
2646 Highway Avenue
Highland, Indiana 46322

Date Tested
11/20/91



UNIFIED	GRAVEL		SAND			SILT	CLAY
	coarse	fine	coarse	medium	fine		

ASTM	GRAVEL	SAND			SILT	CLAY
		coarse	medium	fine		

USDA	GRAVEL		SAND					SILT	CLAY
	coarse	fine	v.coarse	coarse	medium	fine	v.fine		

SIEVE ANALYSIS DATA

SIEVE	PERCENT PASSING
4	100.0
10	99.6
40	98.6
100	97.2
200	92.6

DESIGN DATA

Percent of Gravel = 0.0

Percent of Sand = 7.4

Percent of Silt = 27.0

Percent of Clay = 65.6

Specific Gravity:

CLASSIFICATION SUMMARY

Liquid Limit = 31.3

Plastic Limit = 17.9

Plasticity Index = 13.4

NP = Non-Plastic

Natural Moisture = 24.5%

L.O.I. =

File No. 52-12147

PROJECT

Grain Size Analysis
3500 Indianapolis Blvd.
East Chicago, Indiana
REPORT No. 4

COMBINED PARTICLE SIZE DISTRIBUTION

CLIENT:
ERM North Central

SAMPLE DESCRIPTION:
Gray silty CLAY, trace sand

BORING NO.: ECBD0436 SAMPLE NO.: 4 DEPTH:

ATEC Associates, Inc.
2646 Highway Avenue
Highland, Indiana 46322

Date Tested:
11/20/91

SUMMARY OF THE RESULTS OF FIELD PERMEABILITY TEST ANALYSES FOR THE CALUMET SEDIMENTS

12-17-18

HYDRAULIC CONDUCTIVITY TESTS SUMMARY
ECI REFINERY SITE
EAST CHICAGO, INDIANA

Well	Test	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)
MW14	Slug	1.70×10^{-2}	48.18
MW15	Slug	1.30×10^{-2}	36.85
MW16	Slug	1.60×10^{-3}	4.53
MW17	Slug	6.90×10^{-3}	19.56
MW18	Slug	1.20×10^{-2}	34.01
MW36	Slug	2.70×10^{-3}	7.65
ME36	Duplicate slug	2.80×10^{-3}	7.94
P02	Slug	1.60×10^{-2}	45.34
P03	Slug	2.20×10^{-3}	6.24
P12	Slug	9.70×10^{-3}	27.49
P14	Slug	8.40×10^{-3}	23.81
P16	Slug	9.00×10^{-3}	25.50
P18	Slug	1.30×10^{-2}	36.84
P24	Slug	8.20×10^{-3}	23.24
P25	Slug	2.50×10^{-2}	70.86
P26	Slug	8.40×10^{-2}	238.08
	Geometric average:	9.5×10^{-3}	26.90
	Geometric average w/o P26:	8.8×10^{-3}	24.94

LABORATORY PERMEABILITY TESTING FOR THE GLACIAL TILL UNIT

12-19-[illegible]

ATEC Associates, Inc.
☐ 1501 East Main Street • Griffith, Indiana 46319 (219) 924-8600/(312) 375-8082
☐ 22 W. Erie St. Chicago, IL 60610 (312) 266-1066

PERMEABILITY TEST

CLIENT: ERM North Central
Deerfield, IL

PROJECT: Lab Testing
East Chicago, IN

FILE NO. 1-2147
DATE 11-14-91
REPORT NO.
SHEET ____ OF ____
TECHNICIAN DG

LAB NO. 1 BORING NO. ECBD 0234 SAMPLE NO. ____ DEPTH ____

CLASSIFICATION ____

READING NUMBER	Q FLOW (ML)	h_o INITIAL HEAD (CM)	$h_o - h_i$ DROP IN HEAD (CM)	h_i FINAL HEAD (CM)	INITIAL TIME	FINAL TIME	t TIME (SECONDS)	K PERMEABILITY RATE (CM/SEC)
1	13	90	7.7	82.3	11/14 2:30pm	11/15 6:45am	58500	2.0×10^{-7}
2	20	90	12.2	77.8		11/15 5:00pm	95400	2.3×10^{-7}
3	55	90	33.0	57.0		11/18 6:45	317700	1.9×10^{-7}

AREA OF STANDPIPE (CM^2) $a = 1.667$

LENGTH OF SAMPLE (CM) $L = 2.54$

AREA OF SAMPLE (CM^2) $A = 31.65$

WET DENSITY PCF

$$K = \left(\frac{2.3\,a\,L}{At}\right) \text{LOG} \frac{Ho}{Hi} = 1.9 \times 10^{-7}$$

ATEC Associates, Inc.
☐ 1501 East Main Street • Griffith, Indiana 46319 (219) 924-8880/(312) 375-9092
☐ 22 W. Erie St. Chicago, IL 60610 (312) 266-1056

PERMEABILITY TEST

CLIENT
ERM North Central
Deerfield, IL

PROJECT
Lab Testing
East Chicago, IN

FILE NO. 1-2147
DATE 11-11-91
REPORT NO. ______
SHEET ______ OF ______
TECHNICIAN DG

LAB NO. 2 BORING NO. ______ SAMPLE NO. ECBD0336 DEPTH 36'-38'

CLASSIFICATION ______

READING NUMBER	Q FLOW (ML)	h_o INITIAL HEAD (CM)	$h_o - h_i$ DROP IN HEAD (CM)	h_i FINAL HEAD (CM)	INITIAL TIME	FINAL TIME	t TIME (SECONDS)	K PERMEABILITY RATE (CM/SEC)
1	4	90.0	2.5	87.5	11/11 3:08pm	11/12 7:28am	58800	6.3×10^{-8}
2	4	90.0	2.7	87.3		11/12 3:28	87600	4.5×10^{-8}
3	8	90.0	4.6	85.4		11/13 4:08pm	176400	3.9×10^{-8}

AREA OF STANDPIPE (CM^2) a = 1.647 cm

LENGTH OF SAMPLE (CM) L = 2.54 cm

AREA OF SAMPLE (CM^2) A = 31.65 cm

WET DENSITY PCF

$$K = \left(\frac{2.3\,a\,L}{At}\right) \text{LOG}\,\frac{Ho}{Hi} = 3.9 \times {}^{-8}$$

ATEC Associates, Inc.
☐ 1301 East Main Street • Griffith, Indiana 46319 (219) 924-6690/(312) 375-1092
☐ 22 W. Erie St. Chicago, IL 60610 (312) 266-1066

PERMEABILITY TEST

CLIENT: ERM North Central
Deerfield, IL

PROJECT: Lab Testing
East Chicago, IN

FILE NO. 1-2147
DATE 11-14-91
REPORT NO.
SHEET ____ OF ____
TECHNICIAN DG

LAB NO. 2 BORING NO. ECBD 0130 SAMPLE NO. ____ DEPTH ____

CLASSIFICATION ____

READING NUMBER	Q FLOW (ML)	h_o INITIAL HEAD (CM)	$h_o - h_i$ DROP IN HEAD (CM)	h_i FINAL HEAD (CM)	INITIAL TIME	FINAL TIME	$\pm$ TIME (SECONDS)	K PERMEABILITY RATE (CM/SEC)
1	3	90	1.6	88.4	11/14 2:30pm	11/15 6:45am	58500	4.0×10^{-8}
2	4	90	2.3	87,7		11/15 5:00pm	95400	3.5×10^{-8}
3	11	90	6.5	83.5		11/18 6:45am	317700	3.1×10^{-8}

AREA OF STANDPIPE (CM^2) a = 1.647

LENGTH OF SAMPLE (CM) L = 2.54

AREA OF SAMPLE (CM^2) A = 31.65

WET DENSITY PCF

$$K = \left(\frac{2.3\,a\,L}{At}\right) \text{ LOG } \frac{Ho}{Hi} = 3.1 \times 10^{-8}$$

ATEC Associates, Inc.
☐ 1501 East Main Street • Griffith, Indiana 46319 (219) 924-6680/(312) 375-8082
☐ 22 W. Erie St. Chicago, IL 60610 (312) 266-1066

PERMEABILITY TEST

CLIENT
ERM North Central
Deerfield, IL

PROJECT
Lab Testing
East Chicago, IN

FILE NO. L-2147
DATE 11-11-91
REPORT NO.
SHEET ____ OF ____
TECHNICIAN DG

LAB NO. 3 BORING NO. ____ SAMPLE NO. ECBD0436 DEPTH 36-381

CLASSIFICATION ____

READING NUMBER	Q FLOW (ML)	h_o INITIAL HEAD (CM)	$h_o - h_i$ DROP IN HEAD (CM)	h_i FINAL HEAD (CM)	INITIAL TIME	FINAL TIME	t TIME (SECONDS)	K PERMEABILITY RATE (CM/SEC)
1	11	90.0	6.8	83.2	11/11 3:08pm	11/12 7:28am	58800	1.7×10^{-7}
2	14	90.0	8.5	81.5		11/12 12:08	75600	1.7×10^{-7}
3	15	90.0	9.2	80.8		11/12 3:28	87600	1.6×10^{-7}
4	27	90.0	16.4	73.6		11/13 4:08pm	176400	1.5×10^{-7}

AREA OF STANDPIPE (CM^2) a = 1.667 cm

LENGTH OF SAMPLE (CM) L = 2.54 cm

AREA OF SAMPLE (CM^2) A = 31.65 cm

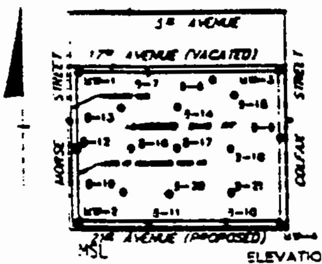
WET DENSITY PCF

$$K = \left(\frac{2.3\,a\,L}{At}\right) \text{LOG} \frac{Ho}{Hi} = 1.5 \times 10^{-7}$$

SOIL BOREHOLE LOG

PROJECT NO [illegible]-141

SITE NAME AND LOCATION: GLENWOOD RIDGE LANDFILL GARY, IN



DATUM: MSL ELEVATION: 611.11

DRILLING METHOD: [illegible]-in. Auger, Tricone rotary wash.

SAMPLING METHOD: 2" O.D. [illegible]-Spoon.

BORING NO: B-12

SHEET: 1 OF 1

WATER LEVEL					
TIME					
DATE					
CASING DEPTH					

DRILLING	
START	FINISH
TIME	TIME
1000	0930
DATE	DATE
3-17-88	3-19-88

DRILL RIG: CME 75

SURFACE CONDITIONS: West gravel road, perimeter of sand pit.

ANGLE: Vertical BEARING: None

SAMPLE HAMMER TORQUE: FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER	DESCRIPTION OF MATERIAL	SAMPLER TYPE AND SIZE	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS
	37,10,14,13 (80%)		1	Medium Dense Brown Fine To Medium Sand, Moist (SP).	2" O.D. SPLIT SPOON			4.8				
	5,8,11,15 (80%)		2					5.4				
5 (606.11)	8,10,10,10 (80%)		3	Medium Dense To Very Dense Brown Fine To Medium Sand, Trace Of Silt, Moist (SP).				4.1				
	6,7,10,13 (70%)		4					4.3				
	9,15,15,18 (70%)		5					23.7				
10 (601.11)	10,20,22,30 (50%)		6					21.0				
	11,19,27,45 (60%)		7					21.2				
15 (596.11)	15,20,21,33 (70%)		8					21.5				
	14,13,21,30 (50%)		9					15.7				
	14,35,40,63 (70%)		10	[illegible]-In. Reddish Brown Gravelly Fine To Coarse Sand Seam At 19.0 Ft.				16.7				
20 (591.11)	17,25,30,34 (80%)		11					12.9				
	23,42,41,52 (100%)		12	[illegible]-In. Reddish Brown Gravelly Fine To Coarse Sand Seam At 21.5 Ft.				24.5				
25 (586.11)	20,25,18,34 (50%)		13					25.4				
	10,12,23,42 (70%)		14	Very Dense Gray Fine To Medium Sand, Some Silt, Moist To Wet (SP-SM).				18.6				
	20,36,30,28 (90%)		15					23.4 21.6				
30 (581.11)	11,7,8,11 (90%)		16	Very Stiff Brown/Gray Clay, Trace Of Silt, Moist (CL).				21.8				
	5,8,9,15 (100%)		17					22.2 21.9				
35 (576.11)	4,5,7,9 (100%)		18					22.6				
	3,3,5,6 (100%)		19	Soft To Stiff Gray Clay, Trace Of Silt, Trace Of Fine Sand, Wet (CL).				23.1				

DRILLING CONTR. FOX DRILLING, INC.

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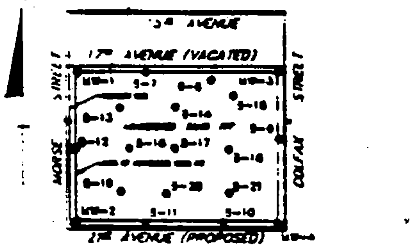
DATE 8-19-88 CHK'D BY

SOIL BOREHOLE LOG

PROJECT NO. -141

SITE NAME AND LOCATION Glenwood Ridge Landfill Gary, IN



DATUM MSL ELEVATION 608.39

DRILLING METHOD 5-in. dia. rotary wash.

SAMPLING METHOD: 2" O.D. split-spoon.

BORING NO. B-11

SHEET 3 of [illegible]

WATER LEVEL				
TIME				
DATE				
CASING DEPTH				

DRILLING	
START	FINISH
TIME	TIME
0940	1500
DATE	DATE
7-25-88	7-25-88

DRILL RIG CME 75

SURFACE CONDITIONS South perimeter of sand pit. Wet sand. Muddy.

ANGLE Vertical BEARING None

SAMPLE HAMMER TORQUE FT-LBS

DEPTH IN FEET (ELEVATION)	BLOWS/ 6 IN. ON SAMPLER (RECOVERY)	SYMBOL	SAMPLE NUMBER AND DESCRIPTION OF MATERIAL	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	WATER CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	SPECIFIC GRAVITY	OTHER TESTS Qu
			Stiff Gray Clayey Silt, Moist (ML).	2" O D SPLIT SPOON							
80 (528.39)	3,6,7 (50%)		17 Medium Stiff Gray Clay, Some Silt, Moist (CL).				20.8				0.75
85 (523.39)	3,5,8 (90%)		18 Stiff Gray Clay, Trace Of Silt, Moist (CL).				22.1				1.25
90 (518.39)	2,5,8 (60%)		19				21.3				1.00
95 (513.39)	3,6,8 (100%)		20				21.6				1.25
100 (508.39)	4,7,9		21 Stiff Gray Clay, Some Silt, Moist				17.6				1.25
			Bottom of Boring At 100.0 Ft.								

DRILLING CONTR FOX DRILLING, INC.

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DATE 7-25-88 CHK'D BY

8

INDIANA HARBOR AND CANAL
MAINTENANCE DREDGING AND DISPOSAL

APPENDIX M
COASTAL HYDRAULICS/ENGINEERING ANALYSIS

June 1993
Geotechnical & Coastal Engineering Branch
Chicago District
U.S. Army Corps of Engineers
111 North Canal Street
Chicago, Illinois 60606-7206

1227

APPENDIX M
COASTAL HYDRAULICS/ENGINEERING ANALYSIS INDIANA HARBOR CONFINED DISPOSAL FACILITY

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INDIANA HARBOR MAINTENANCE DREDGING AND DISPOSAL
COASTAL HYDRAULICS/ENGINEERING ANALYSIS
APPENDIX M

1. PURPOSE

1.1 The purpose of this appendix is to present the coastal design for the Confined Disposal Facility (CDF) site, at the Inland Steel Company landfill/lakefill location. This is the only site being evaluated in this coastal hydraulics engineering appendix due to the special design considerations necessary for assessment and analysis, since it is the only in-lake CDF site considered. The Inland Steel Company site is currently being utilized as a disposal area by the steel company, and is located near Indiana Harbor at the south end of Lake Michigan.

1.2 In this design appendix, the deepwater wave climate will be identified and translated into a shallow water wave climate at the proposed site. An evaluation and analysis of this local wave climate at the Inland Steel Company site will be performed. The proposed location of the CDF, on the leeside of the existing Inland Steel Company steel sheetpile cell breakwater would call for special design considerations and analyses. The CDF structure design will be determined by the design storm criteria, water depths at the breakwater structure and proposed CDF structure, deepwater and significant wave heights, wave runup, overtopping and transmission over the breakwater, wave reflection between the breakwater and the CDF, the resultant wave behind the breakwater, wave runup and overtopping of the CDF and available storage volume to hold the overtopping water for the duration of the design storm. The coastal engineering design process will be explained in further detail within this appendix.

1.3 Three different CDF configurations will be assessed. The CDF design parameters will be determined for each configuration. These parameters are structure slope, stone size, crest width, and structure crest elevation. A recommended configuration and design will be proposed. From the design parameters the recommended cross sections will be presented for each configuration. These designs and their ability to function will be discussed and a plan will be recommended.

2. INTRODUCTION

2.1 SITE CONDITIONS

2.1.1 The site considered for the CDF is located at the Inland Steel Company, leeside of the Inland Steel Company steel sheetpile cell breakwater, to the east of Indiana Harbor, at the south end of Lake Michigan. This breakwater extends lakeward over 2.5 miles of the original shoreline configuration and into water depths that range from 24 to 35 feet. Just north of this breakwater is a topographic feature known as "The Indiana Shoals" which is a slightly shallower environment. On the leeside of this breakwater is an enclosed body of water known as "Lake Inland". Due to the impermeability for wave transmission to travel through the existing sheetpile cell breakwater, the water level of Lake Inland is approximately four feet higher than the long term average water level of Lake Michigan.

2.1.2 The existing breakwater was originally constructed in the 1960's. It is composed of steel sheetpile cells filled with coarse aggregate and topped with an 18 inch concrete cap. A wave absorber was constructed from smaller stone as structural toe protection, on the lakeward side of the breakwater. The steel company is currently using this area behind the breakwater as a landfill/lakefill disposal area. If the proposed CDF is constructed at this site, the steel company will continue to place fill material around it and the CDF will eventually be enclosed and essentially become a land site. When the CDF is filled to its capacity it will be sealed and capped with five feet of capping material.

2.2 BASIC CDF DESIGN

2.2.1 The proposed CDF is to be constructed on the leeside of the existing Inland Steel Breakwater site within the enclosed body of water, Lake Inland, in the landfill/lakefill location. The far northwest end of Lake Inland is currently being utilized as a landfill by the steel plant and prior usage had consisted of disposing maintenance dredging material from Indiana Harbor within the confines of this breakwater. This CDF location being proposed is at the southeast end of Lake Inland. The CDF is to be divided into three equal compartments or "disposal cells". Each "cell" is to contain one million cubic yards of dredged material.

2.2.2 Three different plan configurations are being explored in this appendix and are described below. In addition to the three configurations, significant design parameters were investigated which included CDF structure slope, crest elevation, and stone size. Two different crest widths of 30 feet and 45 feet were investigated, as these two widths would allow for the CDF crest to be utilized as a working platform during the placement of dredge material. For each configuration, waves will be impacting from two different directions, the northeast and the southeast. The waves from the northeast can be predicted to have a larger impact upon the structure, due to the longer fetch across Lake Michigan from the northeasterly direction, and therefore an increased wave height. Because of this difference in directional wave impact, the southeast CDF exposure and the northeast CDF exposure can be expected to have different crest elevation requirements.

2.2.3 The CDF coastal design focused primarily on the structure's stability and overtopping characteristics resulting from fill time requirements determined by the design storm duration of 48 hours. Crest elevations were optimized within these fill time requirements and the CDF structure's capacity for overtopping storage volume.

2.3 PROPOSED PLANS

2.3.1 Plan A

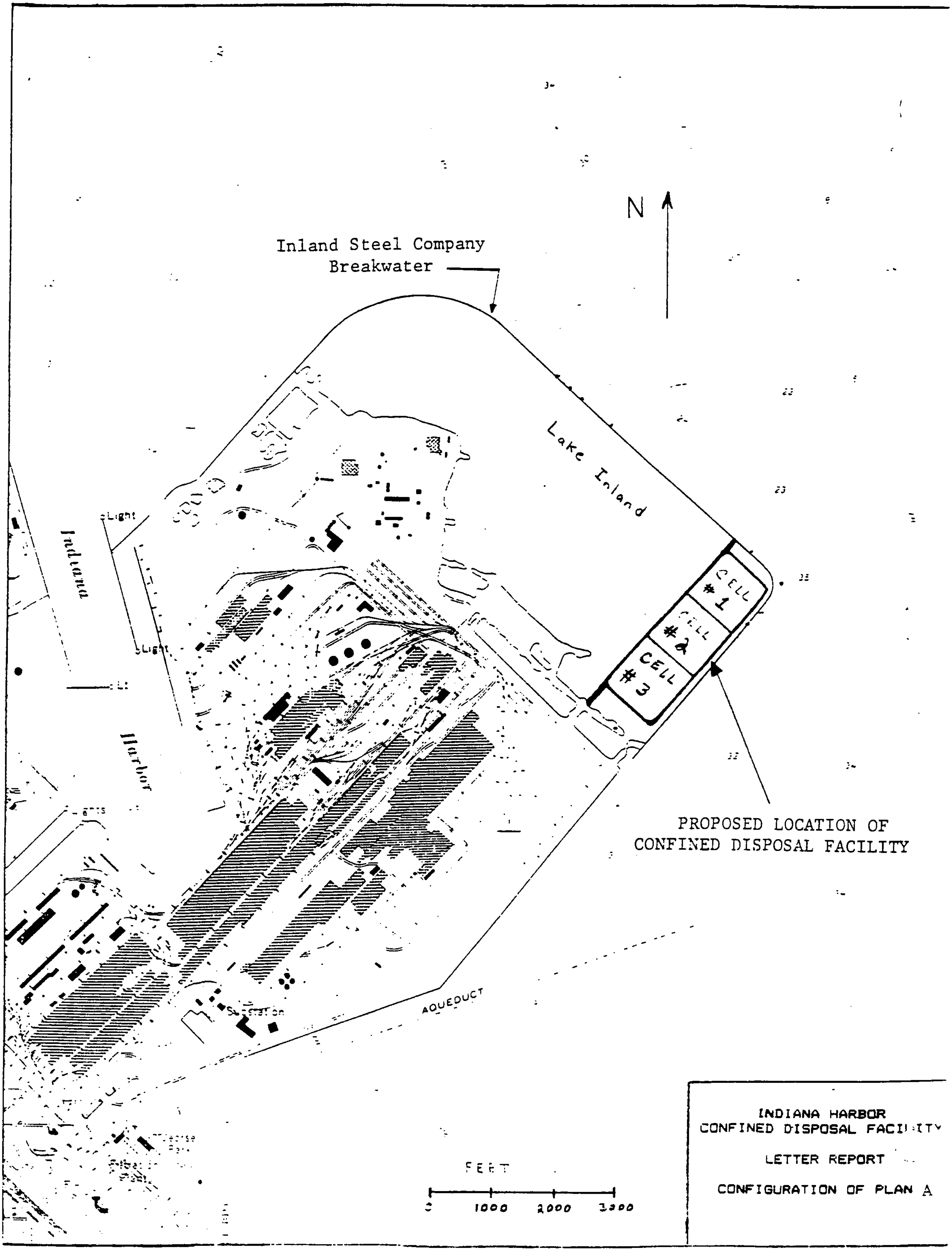
2.3.1.1 Plan A consists of constructing the Confined Disposal Facility (CDF) entirely behind the existing sheetpile cell breakwater, within the enclosed basin known as Lake Inland. In this design the existing breakwater provides protection for the CDF from direct wave attack. The CDF will then be subjected to secondary waves generated from overtopping waves and reflected waves. The northeast and southeast CDF faces will be in water depths determined by the Lake Michigan design elevation. The CDF will be configured to lie parallel to the breakwater along its southeast side and approximately 75 feet away from the breakwater as shown in figure M-1.

2.3.2 Plan B

2.3.2.1 Plan B also consists of constructing the CDF entirely behind the breakwater in the enclosed basin, however, this design places the CDF parallel to the shoreline and perpendicular to the southeast breakwater face. Again, the CDF will be subjected to secondary waves as opposed to direct wave impact from Lake Michigan. The northeast CDF face will be in water depths determined by the maximum Lake Inland elevation. The southeast CDF face will be in water depths determined by the Lake Michigan design elevation. This plan configuration is shown in figure M-2.

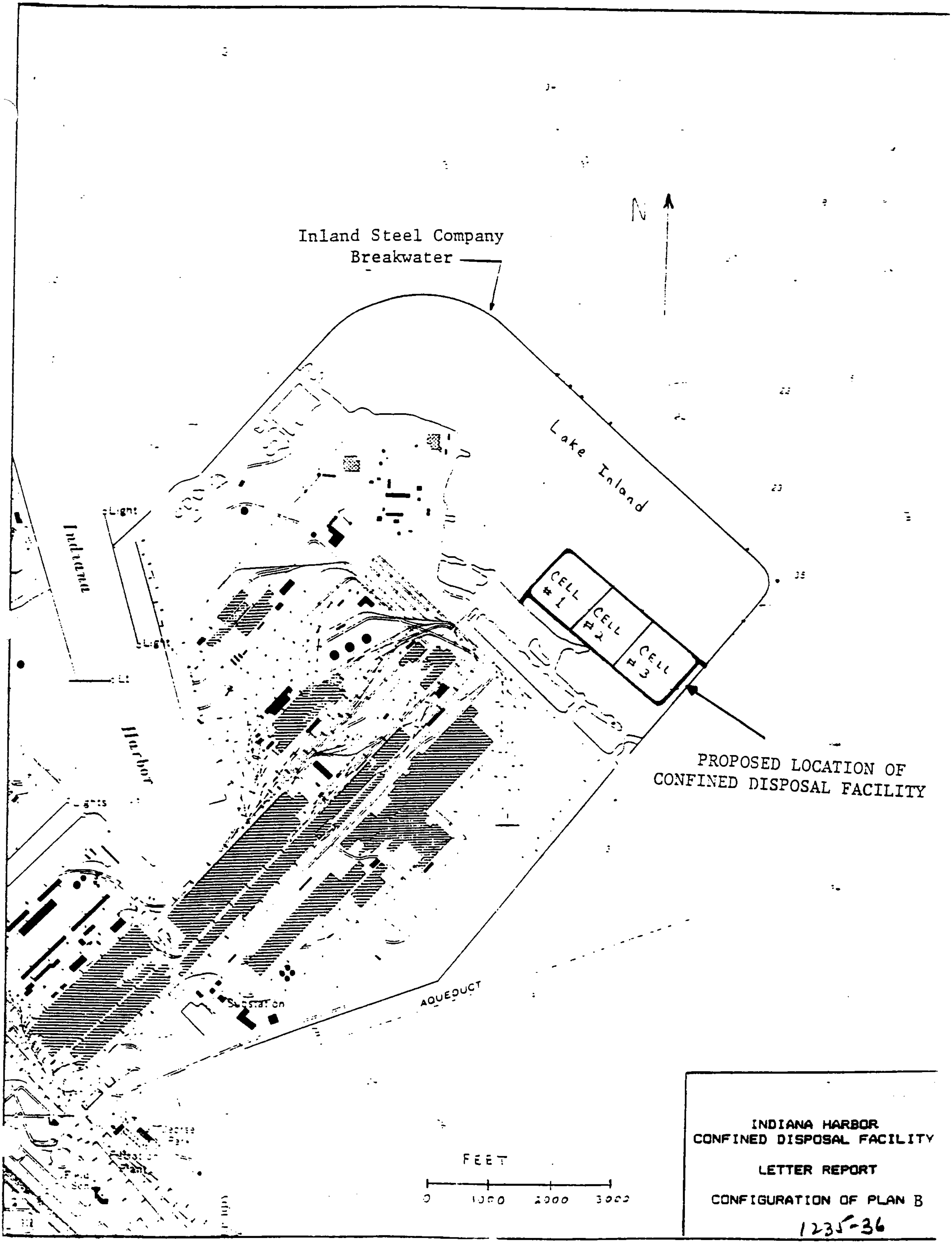
2.3.3 Plan C

2.3.3.1 Plan C consists of the same CDF orientation as in Plan A, running parallel to the southeast breakwater face. However, in this design, the CDF will be positioned directly on the southeast extension of the breakwater, incorporating this section of breakwater into the core of the CDF. This exposes this section of CDF directly to Lake Michigan and impinging wave conditions. The NE section of the CDF will be constructed behind the breakwater as in Plan A. The water depth at the northeast face will be determined by the maximum Lake Inland elevation and the water depths at the southeast face will be determined by the Lake Michigan design elevation. This plan configuration is shown in figure M-3.



INDIANA HARBOR
CONFINED DISPOSAL FACILITY
LETTER REPORT
CONFIGURATION OF PLAN A

Figure M-1



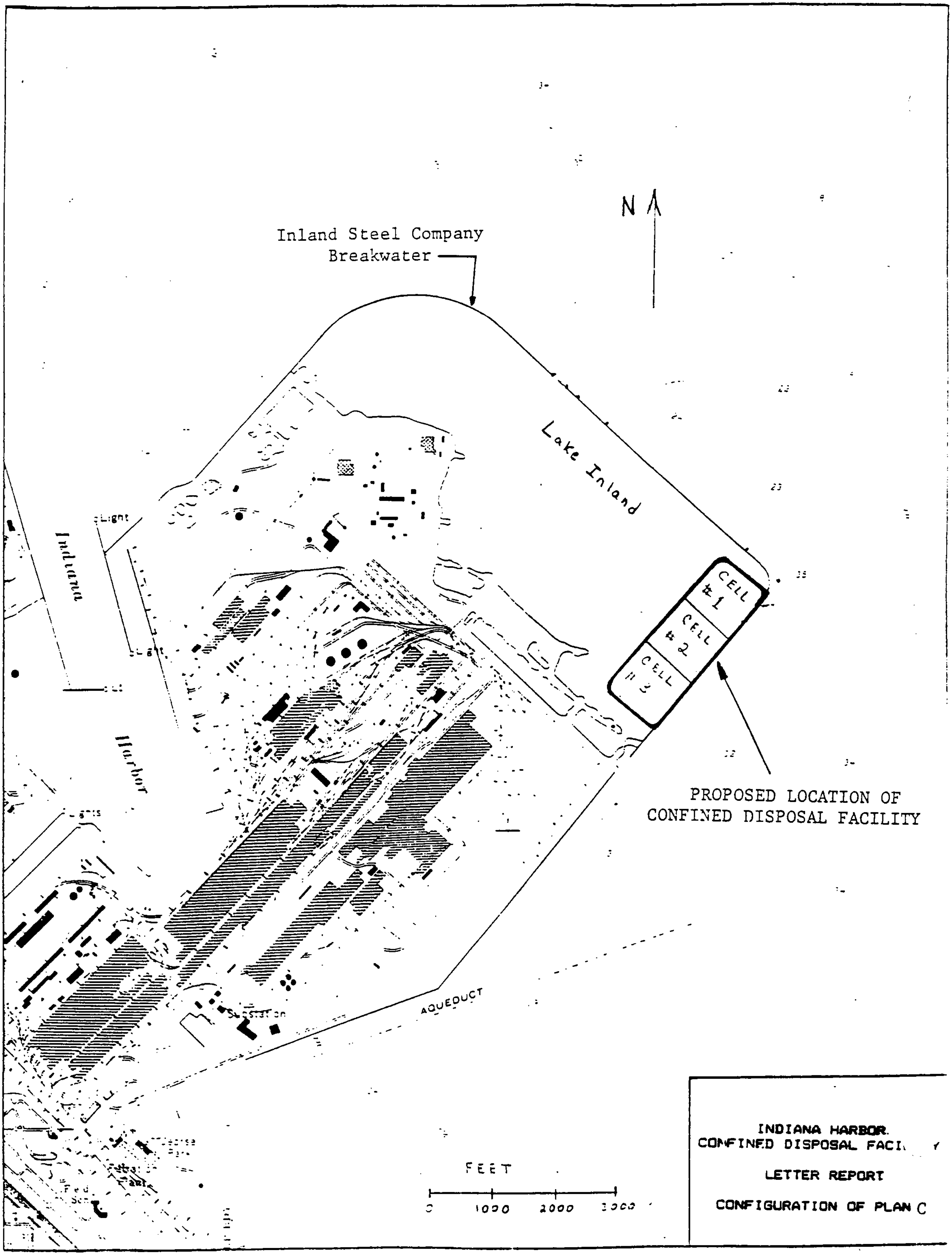
INDIANA HARBOR
CONFINED DISPOSAL FACILITY

LETTER REPORT

CONFIGURATION OF PLAN B

1235-36

Figure M-2



INDIANA HARBOR
CONFINED DISPOSAL FACILITY

LETTER REPORT

CONFIGURATION OF PLAN C

Figure M-3

3. COASTAL DESIGN PROCESS

3.1 The coastal design process follows a logical format based on an analytical methodology. The process includes:

* establishment of existing conditions
* identification of design criteria
* proposal of alternatives
* coastal analysis of existing and proposed structures
* specification of structure parameters
* evaluation of alternatives.

Design parameters need to be obtained at intermediate steps before further analysis may proceed. The design process utilized in this report is illustrated in figures M-4 through M-5.

3.2 Existing design conditions are established. For a 400-year design storm those include a 20-year Lake Michigan water level and a 20-year deepwater wave. Other conditions that affect the design are nearshore lakebottom slope and depth of water at the structure. A windspeed of 30 mph and a storm duration of 48 hours were used in the overtopping and fill time calculations. The wave climate in deep water is transformed into shallower water near the proposed site and along with the nearshore slope, will determine the significant wave height outside the Inland Steel Company breakwater.

3.3 In this case, two design wave configurations are important: (1) the design wave impinging on the Inland Steel breakwater and (2) the design wave, having overtopped the Inland Steel breakwater, impinging on the CDF structure. The design wave generated between the Inland Steel breakwater and the proposed CDF structure is a combination of wave energy overtopping the steel sheetpile breakwater and wave energy reflection between breakwaters. The wave parameters are transformed as the wave passes over the existing steel sheetpile structure and the CDF structure.

3.4 The resultant wave parameters will determine the wave impact forces upon the CDF. The wave height, the structure slope, and the armor stone characteristics are used to determine the necessary stone size for stability. Using the stone size and the relatively impermeable requirements of a confined disposal facility, consecutive stone layers are determined.

3.5 The existing vertical steel sheetpile breakwater surrounding Lake Inland generates different runup, reflection, and overtopping characteristics than the proposed sloped rubblemound CDF structure. Utilizing the significant wave height, the design water level, and structure characteristics, the wave runup on the existing SSP structure and the proposed CDF structure are individually calculated. Specific analyses are performed for each structure type.

3.6 The calculated runup values are used along with the structure characteristics to quantify overtopping volumes. Again, the overtopping that occurs is a function of the structure type. Once the wave overtopping and allowable storage volume for this overtopping are assessed, the crest elevation and crest width for the CDF are evaluated. A cross section is formulated using the design parameters of structure slope, stone size, crest elevation, and crest width.

4. DESIGN CONDITIONS

4.1 DESIGN STORM

The frequency of return for the design storm has been set as a 400 year storm. This correlates to a 20-year wave and a 20-year water level frequency. A windspeed of 30 mph and a storm duration of 48 hours were used in the overtopping and fill time calculations.

4.2 DESIGN WATER LEVEL

4.2.1 The design water level is determined from USACE (April 1988). In this report water levels were recorded for the period of 1903 through 1986. The Lake Michigan shoreline was divided into ten different reaches depending on gage location. Calumet Harbor in Lake Michigan falls within reach D, which is the gage location nearest to our study and contains the shoreline area of interest.

4.2.2 The resultant open coast flood levels are given in terms of 10-year, 50-year, and 100-year elevations. Plotted on probability paper the 20-year level was obtained as 582.5 IGLD. This corresponds to an elevation of +5.7 LWD. Therefore "d_s" (the design depth of water at the toe of the structure) will be equal to the existing lake bottom elevation plus the elevation of +5.7 LWD. (All lake bottom depths and bathymetry information are taken from the USGS quadrangle map for Whiting, Indiana.)

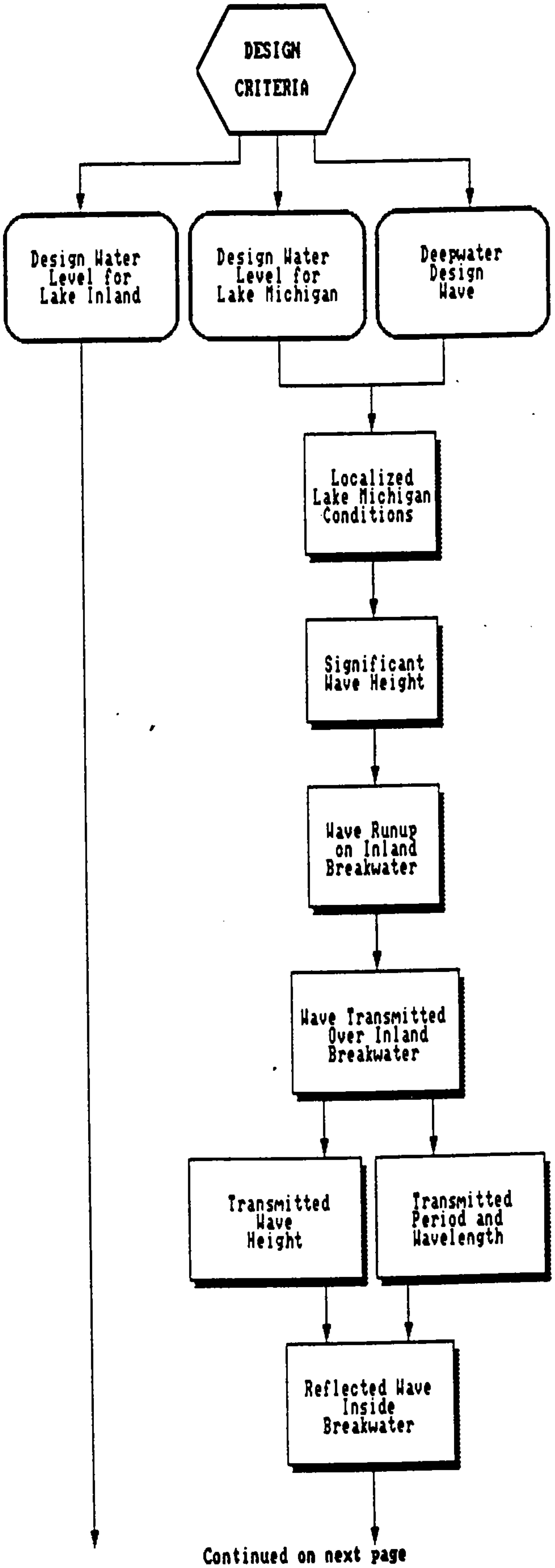
At the NE face of the existing breakwater:

d_s = (-)30 LWD + (+)5.7 LWD = 35.7 feet of water depth

At the SE face of the existing breakwater:

d_s = (-)33 LWD + (+)5.7 LWD = 38.7 feet of water depth

COASTAL DESIGN PROCESS



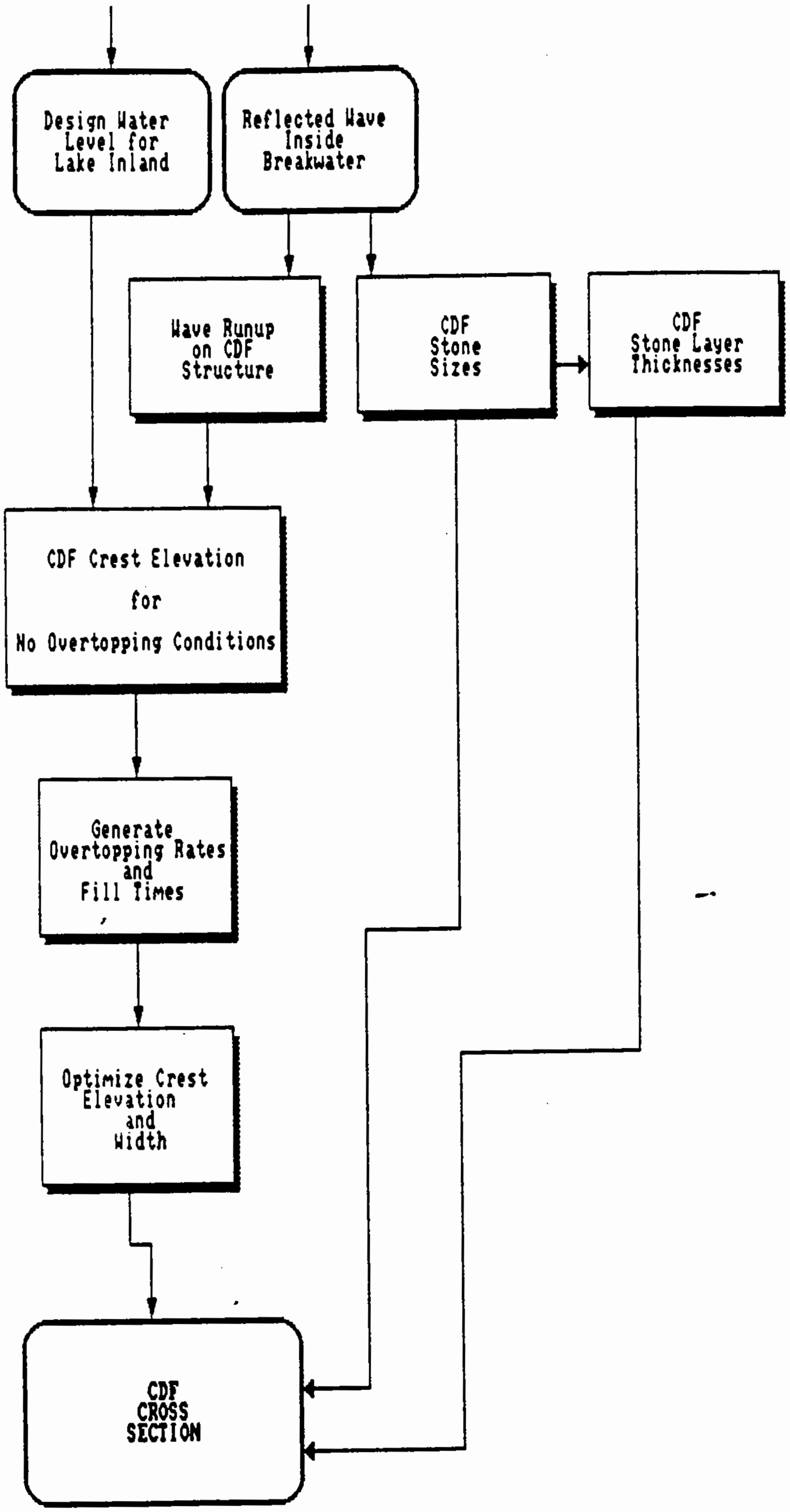
Continued on next page

Indiana Harbor Confined Disposal Facility

Letter Report Design Process

Figure M-4

COASTAL DESIGN PROCESS (con't)



Indiana Harbor Confined Disposal Facility

Letter Report Design Process

Figure M-5

4.3 DESIGN WAVE

4.3.1 Design wave information for Lake Michigan is provided in Resio and Vincent (1976). This data was calculated with a hindcast model using available meteorological data. The resultant information generated from this study is presented primarily for the design of dredged material retaining structures, or CDFs, on the Great Lakes. A hindcasting method was developed for Lake Michigan, utilizing available wind speed information for waves at specific grid points located around the shoreline for deepwater waves. The model provides significant wave height and period information for those grid points.

4.3.2 Grid point 30 provides the nearest data point for the proposed Inland Steel Company CDF site. This location is in approximately 55 feet of water. The most severe case would exist in the winter storm season (no ice conditions). Angle class 2 for the NE face of the existing breakwater, and angle class 1 for the SE face of the existing breakwater, will be the two angles of wave attack considered for the existing breakwater structure.

4.3.3 For the NE face, from angle class 2:
The deepwater significant design wave (Ho') for a 20 year return period is a 19.4 foot wave height. From table E3, interpolation between 19 and 20 feet yields a significant wave period of 10.3 seconds.

Therefore; Ho' = 19.4' , T = 10.3 sec.

4.3.4 For the SE face, from angle class 1:
The deepwater significant design wave (Ho') for a 20 year return period is a 8.5 foot wave height. From table E3, the estimated value between 8 and 9 feet yields a significant wave period of 6.7 seconds.

Therefore; Ho' = 8.5' , T = 6.7 sec.

4.4 THE INDIANA SHOALS

4.4.1. The western half of Lake Michigan experiences net littoral transport in a southward direction. The placement of the Inland Steel Company breakwater acts as a littoral obstruction to the sediment stream moving south, parallel to the shoreline. Because of the introduction of this obstruction, offshore sandbar formation and shoaling, both updrift and lakeward of the breakwater have occurred. This has created a localized shallow water area referred to as "The Indiana Shoals".

4.4.2 The Indiana Shoals are located directly lakeward of the Inland Steel Company cell breakwater. This area extends approximately three and a half miles into Lake Michigan and is approximately three miles wide. Depths within the shoals range from -40 LWD at the northern boundary of the shoals to -15 LWD at the shallowest depth. With the existing lakebed bathymetry, conditions are such that a breaking wave climate could exist over the shoals.

4.4.3 The wave steepness will be limited by the depth of water the wave is propagating through. When the water becomes shallow enough it will initiate breaking of the wave. The wave height at breaking (H_b) and the depth at breaking (d_b) will be obtained to determine if a breaking wave climate will be the focus of consideration. Using USACE (1984):

$$H_b/Ho' = \frac{1}{3.3(Ho'/Lo)^{1/3}} \qquad \text{Eq. 2-90}$$

4.4.4 Substituting the wave parameters for the most conservative condition, waves from the northeast, into the above equation yields:

$$H_b/Ho' = \frac{1}{3.3(19.4/544)^{1/3}}$$

$$H_b/Ho' = .9205$$

$$H_b = 17.9 \text{ feet, say 18 feet at breaking}$$

From figure 2-73, $H_b/gT^2 = .0053$, $m=(40-15/20{,}000)= .0013$:

$d_b/H_b = 1.28$ and $\underline{d_b = 24 \text{ feet}}$

4.4.5 When the design wave is in 24 feet of water, it will begin to break. Since water depths in the Indiana shoals range from 45.7 to 20.7 feet, waves will break when they propagate into water depths shallower than 24 feet. The breaking waves will dissipate much of their energy before reaching the Inland Steel breakwater. The Indiana Shoals provide additional protection at the northeast exposure due to the shallow depths at this location. The existing lake bottom topography, by initiating breaking of the waves, prevents the full force of breaking waves from reaching the existing sheetpile breakwater.

4.5 SIGNIFICANT WAVE HEIGHT

4.5.1 The Goda method (1975) will be used for wave decay in the surf zone to determine significant wave height, H_s. Parameters needed to obtain this wave height are:

Ho'/Lo , d_s/Ho', from the given graph for the flattest slope (.002), H_s/Ho' is obtained.

where : Ho'= deepwater significant wave height

Lo = deepwater wave length, = $gT^2 /2\pi$
d_s = depth of water at the toe of the structure
m = actual slope = .0013

For the NE breakwater face:

Lo = 544 feet

For the SE breakwater face:

Lo = 230 feet

4.5.2 For the NE face: From Goda (1975), $d_s/Ho' = 35.7/19.4 = 1.84$, $Ho'/Lo = 19.4/544 = .036$, figure 1, $H_s/Ho' = 0.92$. Therefore, $H_s = .92(19.4)$ and $H_s = 17.8$ feet, say 18 feet.

H_s (NE) = 18 feet

4.5.3 For the SE face: From Goda (1975); $d_s/Ho' = 38.7/8.5 = 4.55$, $Ho'/Lo = .037$, from, $H_s/Ho' = 0.92$ and $H_s = 8.5(.92)$, $H_s = 8$ feet.

H_s (SE) = 8 feet

4.6 SIGNIFICANT WAVE HEIGHT ACROSS LAKE INLAND

4.6.1 The height of the waves impacting against the northwest side of the CDF were predicted using a 3,000 foot fetch across Lake Inland. Fully developed wave conditions and a water depth of 37.1 feet are used to obtain a maximum height.

$$\frac{gT}{Ua} = 71{,}500$$ eqn. 3-38 (USACE, 1984)

where T = storm duration = 48 hours
g = 32.2 ft/sec/sec
Ua= wind stress factor

$$\frac{32.2(48)(3600)}{Ua} = 71{,}500$$

Ua = 53 mph

4.6.2 From figure 3-24 (USACE, 1984) and a fetch length of approximately 1 mile the significant wave height H_s = 1.6 feet. This value is much less than the wave height transmitted across Lake Michigan. The resultant wave information for significant wave height based on breakwater orientation is shown in table M-1.

1243-44

Table M-1. Resultant wave information

Orientation of breakwater	d_s (feet)	Ho' (feet)	Lo (feet)	T (sec.)	H_s (feet)
NE	35.7	19.4	544	10.3	18
SE	38.7	8.5	230	6.7	8
NW	37.1	-	-	-	1.6

4.7 WAVE RUNUP DETERMINATION ON EXISTING BREAKWATER

4.7.1 The runup on the existing breakwater is determined using the following equation (Seelig, 1980), for an impermeable smooth vertical surface.

equation 4 $$R = HC1(0.123\ L/H)^{(C2\ (H/d)^{1/2} + C3)}$$

Where: $H = H_s$
L = wave length
d = water depth
and C1, C2, & C3 = empirical coefficients

4.7.2 For NE breakwater face:

d/Lo = 35.7/544 = .0657 (USACE, 1984) table C-1,
d/L = .1101, therefore L = 324 feet
H_s = 18 feet
d = 35.7 feet
C1= 0.958
C2= 0.228
C3= 0.0578

Substituting the correct values into the above equation yields :

R = 20.5 feet, say 21 feet

4.7.3 For SE breakwater face:

d/Lo = 38.7/230 = .1683 (USACE, 1984) table C-1,
d/L = .1986, therefore L = 195 feet
H = 8 feet
d = 38.7 feet
C1= 0.958
C2= 0.228
C3= 0.0578

Substituting the correct values into the run-up equation yields:

$$R = 9.15 \text{ feet, say } 9 \text{ feet}$$

4.8 WAVE TRANSMISSION

4.8.1 When a wave strikes an impermeable structure some of the water may be transmitted over the top of the structure and produce waves on the other side. The structure slope, crest width, roughness, and wave period influence the height of the transmitted wave. Guidelines are provided (Seelig, 1980) for estimating wave transmission coefficients for the overtopping of impermeable breakwaters based on these factors.

4.8.2 Formula for Wave Transmission

4.8.2.1 A relationship exists between the significant incident wave (H_s) at the breakwater and the resultant transmitted wave (H_t) over the breakwater transmitted by wave overtopping, such that the ratio between them is utilized in wave transmission analyses. This ratio is known as the transmission coefficient (K_{to}) and the relationship is defined as $H_t/H_s = K_{to}$, which is also equal to $C[1-F/R]$, where C is an empirical coefficient, F is the breakwater freeboard, and R is the wave runup. Therefore:

$$K_{to} = H_t/H = C[1-F/R] \qquad \text{Equation 1 (Seelig, 1980)}$$

and $C = 0.51 - 0.11(B/h)$, where B = breakwater crest width
h = breakwater structure height
and B/h falls between 0 and 3.2

4.8.3 Width of the Existing Breakwater

4.8.3.1 The crest width of the existing breakwater varies at three different locations along the proposed project stretch of breakwater. The NE face of the breakwater is 41 feet wide at the widest cell width and 33 feet wide at the cell joints, with an average width of 37 feet at the northeast side. The SE face of the breakwater is 27.3 feet wide at its widest point and 18.9 feet at the joints, yielding an average width of 23 feet. The eastern corner is 48 feet wide at its widest point and actually the most protected area of the breakwater. This area will be considered briefly for comparison, but will not be a limiting factor in the transmission analysis because of its relatively large width.

4.8.4 Height of the Existing Breakwater

4.8.4.1 The height of the existing breakwater was obtained from drawings provided by the Inland Steel Company. The breakwater elevation was shown to be 585.6 Mean Tide New York (Old Chicago

1245-46

River Datum). Converting this to Low Water Datum (LWD):

```
   585.6 MTNY
 - 578.5
----------
 +7.1 LWD   Existing Breakwater Crest Elevation
```

4.8.4.2 The structure height varies with lake bottom variation. Obtaining the height of the structure:

NE side: +7.1 + 30 feet below LWD = 37.1 feet
say, h = 37 feet
SE side: +7.1 + 33 feet below LWD = 40.1 feet
say, h = 40 feet

Therefore;

NE face : B/h = 37/37 = 1.0
SE face : B/h = 23/40 = 0.58
Eastern corner: B/h = 48/37 = 1.30

4.8.5 Wave Transmission Coefficients

4.8.5.1 The existing width/height ratios fit the criteria necessary to use the above methodology, so the wave transmission coefficients will be determined:

$$C = 0.51 - 0.11(B/h)$$

For the NE face: $C = 0.51 - 0.11(1.0)$

$C = .40$

For the SE face: $C = 0.51 - 0.11(0.58)$

$C = .45$

For the Eastern corner: $C = 0.51 - 0.11(1.30)$

$C = .37$

4.9 WAVE TRANSMITTED OVER BREAKWATER

4.9.1 Transmitted Wave Height (H_t)

4.9.1.1 Now the wave transmission coefficient and the transmitted wave height is determined using the following equation:

$$K_{to} = H_t/H = C[1-F/R]$$

For the NE face: $K_{to} = .40[1-1.4/21]$
$K_{to} = .37$

For the SE face: $K_{to} = .45[1-1.4/9]$
$K_{to} = .38$

For the Eastern corner: $K_{to} = .37[1-1.4/21]$
$K_{to} = .35$

4.9.1.2 The transmitted wave at each section of the breakwater may now be determined using the following relationship:

$$K_{to} = H_t/H \text{ , and } H_t = H(K_{to})$$

NE face : $H_t = .37(18) = 6.7$ feet, say 7 feet

SE face : $H_t = .38(8) = 3.0$ feet, say 3 feet

East corner : $H_t = .35(18) = 6.3$ feet, say 6 feet

Table M-2
Wave transmission over existing breakwater

Breakwater orientation	H_s (*)	R (*)	F (*)	h (*)	C	B (*)	K_{to}	H_t (*)
NE	18	21	1.4	37	.40	37	.37	7
SE	8	9	1.4	40	.45	23	.38	3
East	18	21	1.4	37	.37	48	.35	6

* all parameters are measured in feet.

4.9.1.3 The southeastern side of the existing breakwater is the most protected area along the breakwater, as can be seen from the wave transmission above in table M-2. A seven foot wave will be considered to be transmitted across the NE reach of breakwater and a three foot wave transmitted across the SE reach of breakwater.

4.9.2 Transmitted Wave Period and Wavelength

4.9.2.1 When a wave is transmitted over an impermeable structure its characteristics such as wavelength, period, and height are transformed. A new wave results that contains different characteristics. To obtain the wave period, generally either model studies must be performed or actual data obtained from wave gage measurements. A conservative estimate of wave periods will be obtained from available hindcasting information (Resio and Vincent, 1976) in table E-3.

NE: For a design wave of 7.0 feet, T = 5.9 seconds

SE: For a design wave of 3.0 feet, T = 5.2 seconds

4.9.2.2 According to Goda (1985), waves that are transmitted by overtopping tend to have shorter periods, because the impact of the falling water mass often generates harmonic waves with periods of 1/2 to 1/3 the incident wave period. The incident wave period on the NE was 10.3 seconds. One half of that value would be 5.15 seconds. So the obtained wave periods appear to be reasonable estimates. Therefore, the transmitted wave periods will be assumed to be:

NE: $T_t = 5.9$ seconds

SE: $T_t = 5.2$ seconds

Find Lo for the transmitted wave : $L_o = gT^2/2\pi$

for the NE side :

$$L_o = 32.2(5.9)^2/2(\pi)$$
$$L_o = 178 \text{ feet}$$

for the SE side :

$$L_o = 32.2(5.2)^2/2(\pi)$$
$$L_o = 139 \text{ feet}$$

4.10 LAKE INLAND WATER LEVEL

4.10.1 For Plans A and B an opening will be incorporated into the existing breakwater for the construction of a channel, to allow for the barge to enter into the lee of the breakwater, and transport the dredge material back and forth from the harbor to the CDF structure. Therefore, the design water level inside of the steel cell breakwater will vary with location along the breakwater. For Plan A the NE and SE side of the CDF will have a water elevation equal to the Lake Michigan water elevation. For Plan B, The NE side will have the Lake Inland water elevation and the SE side will have the Lake Michigan water elevation. For Plan C, The NE side will have the water elevation of Lake Inland and the SE side will be directly exposed to Lake Michigan. The fetch across Lake Inland from the NW produces a wave that is approximately 1.5 feet in height. This height is negligible compared to the transmitted wave heights on the NE and SE sides of the CDF.

4.10.2 The design water level for Lake Inland will be the maximum water level during storm conditions. It will be assumed that during severe storms with maximum overtopping of the breakwater, and given the impermeability of the structure, the breakwater will hold the overtopping water. This Lake Inland elevation will be assumed to be the same elevation as the steel sheetpile cell breakwater. Therefore:

Design Water Level of Lake Inland = 37.1 feet = +7.1 LWD

4.11 REFLECTION FROM TRANSMITTED WAVE

4.11.1 On the northeast reach of Plan A and on the SE reach of Plans A and B, there will be a distance of 75 feet between the CDF and the existing breakwater. The resultant transmitted wave, from wave overtopping, will travel over the existing breakwater and propagate towards the CDF where a certain amount of wave energy will be dissipated upon the structure. Some of the wave energy will be reflected away from the CDF, back towards the existing breakwater. The breakwater will then in turn reflect the wave back towards the CDF again. The amount of wave energy reflected back and forth between the two structures depends on the structure slope, surface roughness, permeability of the structure, wave steepness, and angle of wave approach. The resultant wave height will be the wave height considered for design purposes. Reflection coefficients for each structure will be determined and resultant wave height information obtained.

4.11.2 Seelig and Ahrens (1981) developed the curves in figure 2-65 of the SPM (USACE, 1984). These can be used to determine an upper limit of the reflection coefficients (X):

Using a value of:

$$E = \frac{1.0}{\mathrm{Cot}\ \theta\ (H_t/Lo)^{1/2}}$$

4.11.3 Plan A NE side:

$$E = \frac{1.0}{1.5\ (7/178)^{1/2}}$$

$$E = 3.3$$

Using the value of E and figure 2-65:

X_{cdf} = .37 the upper limit of reflection for a rubblemound structure

4.11.3 Plans A & B SE side:

$$E = \frac{1.0}{1.5(3/139)^{1/2}}$$

$$E = 4.5$$

Using the value of E and figure 2-65:

X_{cdf} = .44 the upper limit of reflection for a rubblemound structure

1249-10

4.11.4 The upper limit of reflection for a smooth vertical surface is total reflection and X is assumed to be 1:

$X_{brkwtr} = 1$ the upper limit of reflection for an impermeable vertical structure

4.11.5 The resultant wave from reflection and transmission on the CDF (H_r) will be equal to:

$$H_r = [(X_{cdf} * H_t)^2 + (1.0H_t)^2]^{1/2}$$

4.11.6 For the NE side of Plan A substitute X and H_t into the equation:

$$H_r = [\ \{(.37)(7)\}^2 + \{(1)(7)\}^2\ ]^{1/2}$$

$$H_r = 7.5 \text{ feet, say } 8 \text{ feet}$$

4.11.7 For the SE side substitute X and H_t into the equation:

$$H_r = [\ \{(.44)(3)\}^2 + (1)(3)^2\ ]^{1/2}$$

$$H_r = 3.3 \text{ feet, say } 3.5 \text{ feet}$$

4.11.8 Therefore, the transmitted wave may be reflected between the CDF and the breakwater and result in 8 foot waves on the northeast and 3.5 foot waves on the southeast.

Plan A,	NE :	H = 8 ft.	Reflection & Transmission
	SE :	H = 3.5 ft.	Reflection & Transmission
Plan B,	NE :	H = 7 ft.	Transmission
	SE :	H = 3.5 ft	Reflection & Transmission
Plan C,	NE :	H = 7 ft	Transmission
	SE :	H = 8 ft	Direct Wave

4.11.9 The design wave conditions for the three plans are related to the CDF orientation and the resultant design water level. This affects both the depth of water at the structure as well as the potential for reflection from the existing sheetpile breakwater. The effective design water level for Lake Inland is +7.1 LWD which is at the crest of the existing breakwater. The Lake Michigan design water level is +5.7 LWD. The placement of the structural extension between the CDF and the existing breakwater determines which water level controls.

4.11.10 The Plan A CDF is connected to the existing breakwater by a short member extending from the northwest corner of the CDF to the south face of the existing breakwater and by a second member extending from the southwest corner of the CDF to the Inland

Steel landfill. This configuration causes the depth of water at the northeast and southeast sides of the CDF to equal that of Lake Michigan (+5.7 LWD). Therefore, there is a possibility of wave reflection between the CDF and the existing breakwater.

4.11.11 It is assumed that no reflection will occur between the existing sheetpile breakwater and the northeast side of the Plan B CDF. Since the northeast corner of the Plan B CDF is connected to the existing CDF by a short extension, the maximum water level of Lake Inland is limited to +7.1 feet by the existing breakwater. Therefore, any wave that is reflected from the northeast side of the CDF should wash back over the existing sheetpile breakwater.

4.11.12 A similar situation exists for the northeast side of the Plan C CDF. The water level at the northeast side of the Plan C CDF is also limited to +7.1 feet, so any waves reflected from the northeast side of the CDF will also wash back over the existing breakwater.

4.12 SIGNIFICANT DEEPWATER WAVE HEIGHT, WAVELENGTH AND PERIOD

4.12.1 An analysis was performed to find the deepwater wave height of the eight foot wave resulting from transmission and reflection. The Goda graphs (Goda, 1975) were used, working backward to obtain Ho' when H_s is 8 feet and d_s is 35.7 feet. After several iterations with different wave heights, it became apparent that in water that deep an eight foot wave would be close to its deepwater height. A value of 8.7 feet was obtained, and from Resio and Vincent (1976) the period was obtained. From this period, the deepwater wavelength was obtained:

NE: Ho' = 8.7 feet, say 9 feet

T = 6.6 seconds
Lo = 223 feet

4.12.2 The same procedure was used for the 3.5 foot wave on the southeast. As it turns out, a wave of this size is minimally affected by shoaling or refraction in water depths of this magnitude. As with the northeast side a deepwater significant wave is slightly larger than the significant wave height. Therefore, Ho'= 4 feet.

SE: T = 5.6 seconds
Lo = 161 feet

5. PLAN A

5.1 WAVE RUNUP ON THE PROPOSED CDF STRUCTURE FOR PLAN A

5.1.1 The wave runup on the CDF dike structure is a significant factor in the evaluation of overtopping rates for water overtopping the CDF structure. The wave runup is the vertical limit that the wave will travel as it impinges on the structure.

5.1.2 The following equations were used for these determinations:

$R = [a(z)/1+b(z)]H$ eq. 5 (Seelig, 1980)

where : $z = \tan\theta/(H/Lo)^{1/2}$

5.1.2.1 Plan A With a Slope of 1V:1.5H

5.1.2.1.1 Substitute values into wave runup equations :

NE: $z = .67/(8/223)^{1/2} = 3.5$

$R = [.956(3.5)/1+.398(3.5)]8 =$ 11.2 feet, say 11 feet

5.1.2.1.2 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 11 feet of runup = <u>+17 LWD</u>

SE: $z = .67/(3.5/161)^{1/2} = 4.54$

$R = [.956(4.54)/1+(.398)(4.54)]3.5 = 5.4$ feet

5.1.2.1.3 The crest elevation at the SE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 5.4 feet of runup = <u>+ 11 LWD</u>

5.1.2.2 Plan A With a Slope of 1V:2H

5.1.2.2.1 The wave runup on the CDF dike structure depends on the slope. The runup was recalculated for the 1 on 2 slope using the same method as outlined previously. Substitute values into wave runup equations :

NE: $z = .5/(8/223)^{1/2} = 2.64$

$R = [.956(2.64)/1+.398(2.64)]8 =$ 9.9 feet, say 10 feet

5.1.2.2.2 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 10 feet of runup = <u>+16 LWD</u>

SE: $z = .5/(3.5/161)^{1/2} = 3.39$

$R = [.956(3.39)/1+(.398)(3.39)]3.5 = 4.8$ feet

Say R = 5 feet

5.1.2.2.3 The crest elevation at the SE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 5 feet of runup = + 10.7 LWD

say <u>+ 11 LWD</u>

5.1.2.3 Plan A With a Slope of 1V:3H

5.1.2.3.1 The wave runup on the CDF dike structure with a slope of 1 vertical on three horizontal is calculated as follows, substituting values into wave runup equations:

NE: $z = .333/(8/223)^{1/2} = 1.76$

$R = [.956(1.76)/1+.398(1.76)]8 = 7.9$ feet, say 8 feet

5.1.2.3.2 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 8 feet of runup = <u>+14 LWD</u>

SE: $z = .333/(3.5/161)^{1/2} = 2.26$

$R = [.956(2.26)/1+(.398)(2.26)]3.5 = 3.98$ feet use 4 feet

5.1.2.3.3 The crest elevation at the SE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 4 feet of runup = + 9.7 LWD

<u>Say + 10 LWD</u>

5.2 PLAN A STONE SIZE DETERMINATION

5.2.1 The Shore Protection Manual (USACE, 1984) provides guidelines on stone size calculations. The Hudson equation is used to determine the most stable stone weight for impacting waves. The resultant wave height of 8 feet was used for this calculation for the CDF.

$$W = \frac{W_r \quad H^3}{K_d \ (S_r - 1)^3 \ \text{Cot}\ \theta} \qquad \text{eq.7-116 (USACE, 1984)}$$

Where: W = weight of stone
W_r = unit weight = 165 lb/cubic ft
K_d = stability coefficient= 3.5 (table 7-8)
S_r = specific gravity of armor = Wr/Ww = 2.6
Cot θ = structure slope
H = design wave height = 8 feet

5.2.2 Plan A NE Stone Sizes For a Slope of 1V:1.5H

Substituting :

$$W = \frac{I65\ (8)_3}{3.5(2.6 - 1)_3\ 1.5}$$

W = 3930 lbs = 1.96 tons, say 2 tons

For: Armor stone, A = .9 W - 2 W
A = 1.8 tons - 4 tons

Underlayer stone, B = .06W - .2W
B = 240 lbs. - 800 lbs.

5.2.3 Plan A NE Layer Thickness for Slope of 1V:1.5H

The recommended layer thickness from the Shore Protection Manual (USACE, 1984) is as follows:

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

Where: r = stone layer thickness
n = number of layers = 2
k = layer coefficient = 1.15, from table 7-13 (USACE, 1984)
W = average stone weight
W_r = unit weight = 165 lb./cubic ft.

Substituting:

$$r = 2 \times 1.15(5700/165)^{1/3}$$

$$r = 7.5 \text{ feet}$$

"B" layer:

$$r = 2 \times 1.15(510/165)^{1/3}$$

$$r = 3.34 \text{ feet, say } 3.5 \text{ feet}$$

5.2.4 Plan A NE Stone Sizes For a Slope of 1V:2H

Substituting :

$$W = \frac{165\ (8)^3}{3.5(2.6 - 1)^3\ 2}$$

$$W = 1.47 \text{ tons}$$

<u>"A" Stone: 1.3 to 3 tons</u>

<u>"B" Stone: 175 lbs. to 600 lbs.</u>

5.2.5 Plan A NE Layer Thickness for Slope of 1V:2H

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

$$r = 2 \times 1.15(4300/165)^{1/3}$$
$$r = 6.8 \text{ feet, say 7 feet}$$

"B" layer:

$$r = 2 \times 1.15(388/165)^{1/3}$$
$$r = 3.1 \text{ feet, say 3 feet}$$

5.2.6 Plan A NE Stone Sizes For a Slope of 1V:3H

Substituting :

$$W = \frac{165\ (8)^3}{3.5(2.6 - 1)^3\ 3}$$

$$W = 1964 \text{ lb., say 1 Ton}$$

<u>"A" stone = .9 to 2 Tons</u>

<u>"B" stone = 120 lbs. - 400 lbs.</u>

5.2.7 Plan A NE Layer Thickness for a Slope of 1V:3H

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

$$r = 2 \times 1.15(2900/165)^{1/3}$$
$$r = 5.97 \text{ feet, use 6 feet}$$

"B" layer:

$$r = 2 \times 1.15(260/165)^{1/3}$$
$$r = 2.7 \text{ feet, say 3 feet}$$

5.2.7 Plan A SE Stone Sizes For a Slope of 1V:1.5H

Substituting :

$$W = \frac{165\ (3.5)^3}{3.5(2.6 - 1)^3\ 1.5}$$

$$\underline{W = 330 \text{ lbs}}$$

For: Armor stone, A = .9 W - 2 W
A = 300 lbs. - 660 lbs.

Underlayer stone, B = .06W - .2W
B = 20 lbs. - 70 lbs.

5.2.9 Plan A SE Layer Thickness for Slope of 1V:1.5H

The recommended layer thickness from the Shore Protection Manual (USACE, 1984) is as follows:

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

Where: r = stone layer thickness
n = two layers = 2
k = 1.15, from table 7-13
W = average stone weight
W_r = 165 lb./cubic ft.

Substituting:

$$r = 2 \times 1.15(480/165)^{1/3}$$
$$r = 3.3 \text{ feet, say 3.5 feet}$$

"B" layer:

$$r = 2 \times 1.15(43/165)^{1/3}$$
$$r = 1.5 \text{ feet}$$

5.2.10 Plan A SE Stone Sizes For a Slope of 1V:2H

Substituting :

$$W = \frac{165\ (3.5)^3}{3.5(2.6 - 1)^3\ 2}$$

$W = 247$ lbs.

<u>"A" Stone: 220 lbs. - 500 lbs.</u>

<u>"B" Stone: 15 lbs. to 50 lbs.</u>

5.2.11 Plan A SE Layer Thickness for Slope of 1V:2H

Armor Stone:

$r = n\ k\ (W/Wr)^{1/3}$ eqn. 7-121

$r = 2 \times 1.15(360/165)^{1/3}$
$r = 2.98$ feet, say 3 feet

"B" layer:

$r = 2 \times 1.15(32.5/165)^{1/3}$
$r = 1.34$ feet, say 1.5 feet

5.2.12 Plan A SE Stone Sizes For a Slope of 1V:3H

Substituting :

$$W = \frac{165\ (3.5)^3}{3.5(2.6 - 1)^3\ 3}$$

$W = 165$ lb

<u>"A" stone = 150 lbs. - 330 lbs.</u>

<u>"B" stone = 10 lbs. - 35 lbs.</u>

5.2.13 Plan A SE Layer Thickness for a Slope of 1V:3H

Armor Stone:

$r = n\ k\ (W/Wr)^{1/3}$ eqn. 7-121

$r = 2 \times 1.15(240/165)^{1/3}$
$r = 2.6$ feet, use 3 feet

"B" layer:

$r = 2 \times 1.15(22.5/165)^{1/3}$
$r = 1.2$ feet, use a minimum value of 1.5 feet.

5.3 WAVE OVERTOPPING RATES FOR PLAN A

5.3.1 A wave overtopping rate is the amount of water volume that passes over a structure, per linear foot of the structure. The overtopping rate is dependent upon structure configuration and wave conditions at the structure. Overtopping rates were obtained for different proposed crest elevations of the CDF. From these rates, fill times are generated. From the overtopping rates and fill times an optimum crest elevation can be selected. Crest elevations that provide a fill time of 48 hours or greater were chosen.

5.3.2 Overtopping Equation

5.3.2.1 The overtopping rates were calculated using equation 7-10 (USACE, 1984). Alpha and Qo* are overtopping coefficients from figure 7-28. The overtopping equation is:

$$Q = (gQo{*}Ho'^3)^{1/2} \quad e^{-([.217/Alpha]} \quad \tanh^{-1} \quad (h-ds)/R)$$

$$\text{and} \quad 0 < (h-d_s)/R < 1.0$$

5.3.3 Wave Overtopping Parameters

NE: $(Ho'/(gT^2)) = 9/((32.2)(5.9)^2) = 0.008$
$d_s/Ho' = 35.7/9 = 3.97$

SE: $(Ho'/(gT^2)) = 4.0/((32.2)(5.2)^2) = 0.0046$
$d_s/Ho' = 35.7/4.0 = 8.9$

where Ho' is the deepwater wave height, T is the period, d_s is the depth of the water at the toe of the structure, and g is 32.2 ft/s/s. Using figure 7-28 in the SPM, these ratios give an alpha = 0.053 and Qo* = 0.018 for both the northeast and southeast sides of the CDF.

5.3.4 Overtopping For Various Crest Widths

5.3.4.1 The above methodology is provided as guidance for designing a structure with a crest that is five feet wide. Very little information is available on the variation of overtopping volumes with variation in crest width. Mr. John Ahrens, a coastal research engineer at the Waterways Experiment Station is currently gathering data through model tests on this subject, but has not yet provided design guidelines and hopes to complete these tests soon. Mr. Bill Baird, a coastal engineer in Ottawa Canada, has stated that from his model studies, a decrease in crest elevation of one foot can require as much as a ten foot increase in crest width (Ahrens and Baird, 1988).

5.3.4 Overtopping Rates and Wave Transmission

5.3.4.1 The general trend is for the overtopping rate to decrease with an increase in crest width. Previous Corps studies have assumed the decrease in overtopping rate to be proportional to the decrease in wave transmission due to overtopping. The wave transmission coefficient, K_{to}, is the ratio of the transmitted wave height to the incident wave height. A wave transmission coefficient is dependent upon structure crest width. Proportionalities of wave transmission coefficients are set up for crest widths of 5, 30, and 45 feet and are used here in the determination of overtopping rates. The amount of water overtopping the CDF is assumed to be proportional to the amount of wave transmission that occurs due to overtopping of the breakwater.

5.3.4.2 This relationship between wave transmission and overtopping rates will be utilized to determine overtopping rates for slopes of 1V:1.5H, 1V:2H, and 1V:3H. Crest widths of 30 and 45 feet are to be evaluated because these are the two widths that are being considered for the purpose of driving a crane along the top of the CDF structure. The cranes will be necessary for the fill process.

5.3.5 Wind Correction Factor

5.3.5.1 The overtopping rates obtained were increased by the wind correction factor, k' (USACE, 1984) Eqn. 7-12.

$$k' = 1.0 + W_f((h-d_s)/R + 0.1)\sin\theta$$

where W_f is a coefficient depending on windspeed and θ is the structure slope. To determine W_f the Shore Protection Manual (USACE, 1984) provides values for W_f for windspeeds of 0 mph, 30 mph or 60 mph. For this analysis a windspeed of 30 mph will be assumed. This is a safe assumption because two significant storms of 1987 in the Chicago area had windspeeds of 27 mph and 28 mph. The value of $W_f = 0.5$ for windspeeds of 30 mph will be used here.

5.3.6 Mean Overtopping Rates For a Five Foot Crest

5.3.6.1 The mean overtopping value divided by the overtopping rate (Qmean/Q) was then determined using figure 7-35 from the shore protection manual (USACE, 1984). These values were then multiplied by the previously obtained overtopping rates (Q) to get the mean overtopping rates (Qmean) for a five foot crest width. These rates were obtained for slopes of 1V:1.5H, 1V:2H and for 1V:3H.

5.3.7 Wave Transmission Coefficients

5.3.7.1 Ratios of transmission coefficients were developed to be utilized in obtaining overtopping rates for crests larger than 5 feet wide. Transmission coefficients (K_{to}) for a 5 foot width, a 30 foot width, and a 45 foot width were obtained using the method suggested by Seelig (1980).

5.3.8 Mean Overtopping Rates For 30 and 45 Foot Crests

5.3.8.1 The transmission coefficient ratios were multiplied by the existing overtopping rates corresponding to a 5 foot crest to obtain overtopping rates for 30 and 45 foot crest widths. For example,

$$Q_{B=5} \times (K_{to})_{B=30} \quad / (K_{to})_{B=5} = Q_{B=30} \quad .$$

The resulting overtopping rates for the 30 foot and 45 foot crest widths are shown in tables M-3 through M-5.

5.3.9 Storage Volume Fill Times

5.3.9.1 The storage volume fill time is the time it would take for overtopping waves to fill the available volume for overtopping storage volume in a CDF cell. A design storm for this area is estimated at 48 hours in duration. Overtopping rates utilizing a 48 hour limitation were used for the fill time calculations. These fill times were calculated using a frontal length along the northeast side of 950 feet, and along the southeast side of 900 feet. These dimensions, are used with a 5 ft depth that will eventually be used for capping the CDF. This volume is used as the available storage volume for overtopping.

5.3.9.2 As each cell is filled with dredged sediment, five feet of height will be allowed for storage between the top of the dredged sediment and the CDF structure crest. After the dredging is completed and the cell is filled, this storage area will be covered with a five foot cap. Until the structure is capped, the design of the structure must ensure that no water in the CDF will wash back into Lake Michigan during the design storm conditions.

5.3.9.3 The ability of the structure to prevent backwashing was determined by calculating the fill times for the structure with varying crest elevations and slopes. Fill times were calculated for varying crest elevations and widths. A summary of the results for the Plans A, B, and C, CDF is shown in tables M-3 through M-5, for three different slopes.

5.3.10 Typical Cross Section for Plan A

5.3.10.1 A typical cross section was drawn for Plan A using a CDF structure slope of 1V:2H and a no overtopping crest elevation of +16 LWD for the NE exposure and +11 LWD for the SE exposure. This cross section for cell 1 of Plan A can be seen in plate M-1. Cell 2 and 3 cross sections can be seen in plate M-2.

6. PLAN B

6.1 WAVE RUNUP ON THE PROPOSED CDF STRUCTURE FOR PLAN B

6.1.1 The wave runup on the CDF dike structure is a significant factor in the evaluation of overtopping rates for water overtopping the CDF structure. The wave runup is the vertical limit of distance that the wave will travel as it impinges on the structure. The following equations were used for these determinations:

$$R = [a(z)/1+b(z)]H \qquad \text{eq. 5 (Seelig, 1980)}$$

where : $z = \tan\theta/(H/Lo)^{1/2}$

6.1.2 Plan B With a Slope of 1V:1.5H

Substitute values into wave runup equations :

NE: $z = .67/(7/178)^{1/2} = 3.38$

$$R = [.956(3.38)/1+.398(3.38)]7 = 9.6 \text{ feet}$$

6.1.2.1 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+ 7.1 LWD + 9.6 feet of runup =

<u>+ 16.7, say + 17 LWD</u>

SE: $z = .67/(3.5/161)^{1/2} = 4.54$

$$R = [.956(4.54)/1+(.398)(4.54)]3.5 = 5.4 \text{ feet}$$

6.1.2.2 The crest elevation at the SE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 5.4 feet of runup = <u>+ 11 LWD</u>

6.1.3 Plan B With a Slope of 1V:2H

6.1.3.1 The wave runup on the CDF dike structure depends on the slope. The runup was recalculated for the 1 on 2 slope using the same method as outlined previously. Substitute values into wave runup equations :

NE: $z = .5/(7/178)^{1/2} = 2.52$

$$R = [.956(2.52)/1+.398(2.52)]7 = 8.4 \text{ feet}$$

6.1.3.2 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+ 7.1 LWD + 8.4 feet of runup =

+ 15.5 , say + 16 LWD

SE: $z = .5/(3.5/161)^{1/2} = 3.39$

$R = [.956(3.39)/1+(.398)(3.39)]3.5 = 4.8$ feet

Say R = 5 feet

6.1.3.3 The crest elevation at the SE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 5 feet of runup = + 10.7 LWD

say + 11 LWD

6.1.4 Plan B With a Slope of 1V:3H

6.1.4.1 The wave runup on the CDF dike structure with a slope of 1 vertical on three horizontal is calculated as follows, substituting values into wave runup equations:

NE: $z = .333/(7/178)^{1/2} = 1.68$

$R = [.956(1.68)/1+.398(1.68)]7 = 6.7$ feet

6.1.4.2 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+ 7.1 LWD + 6.7 feet of runup =

+ 13.8, say + 14 LWD

SE: $z = .333/(3.5/161)^{1/2} = 2.26$

$R = [.956(2.26)/1+(.398)(2.26)]3.5 = 3.98$ feet use 4 feet

6.1.4.3 The crest elevation at the SE face of the CDF that would allow no overtopping to take place would be:

+5.7 LWD + 4 feet of runup = + 9.7 LWD

Say + 10 LWD

6.2 PLAN B STONE SIZE DETERMINATION

6.2.1 The Shore Protection Manual (USACE, 1984) provides guidelines on stone size calculations. The Hudson equation is used to determine the most stable stone weight for impacting waves. The transmitted wave heights of 7 feet on the NE exposure and 3.5 on the SE exposure were used for these calculation.

$$W = \frac{W_r\ (H)^3}{K_d\ (S_r - 1)^3 \cot \theta} \qquad \text{eq.7-116 (USACE, 1984)}$$

Where: W = weight of stone
W_r = unit weight
= 165 lb/cubic ft
K_d = 3.5 (table 7-8)
$S_r = W_r/W_w = 2.6$
$\cot \theta$ = structure slope
H = wave height in feet

6.2.2 Plan B NE Stone Sizes For a Slope of 1V:1.5H

Substituting :

$$W = \frac{165\ (7)^3}{3.5(2.6 - 1)^3\ 1.5}$$

W = 2632 lbs , say 1.3 ton

For: Armor stone, A = .9 W - 2 W
A = 1.2 tons - 2.6 tons

Underlayer stone, B = .06W - .2W
B = 156 lbs. - 520 lbs.

6.2.3 Plan B NE Layer Thickness for Slope of 1V:1.5H

The recommended layer thickness from the Shore Protection Manual (USACE, 1984) is as follows:

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

Where: r = stone layer thickness
n = two layers = 2
k = 1.15, from table 7-13
W = stone weight
W_r = 165 lb./cubic ft.

Substituting: $r = 2 \times 1.15(3800/165)^{1/3}$

$r = 6.5$ feet

"B" layer:

$$r = 2 \times 1.15(338/165)^{1/3}$$

$$r = 2.9 \text{ feet, say } 3 \text{ feet}$$

6.2.4 Plan B NE Stone Sizes For a Slope of 1V:2H

Substituting :

$$W = \frac{165\ (7)^3}{3.5(2.6 - 1)^3\ 2}$$

$$W = 1974 \text{ lbs., say } 2000 \text{ lbs or } 1 \text{ ton}$$

<u>"A" Stone: .9 to 2 tons</u>

<u>"B" Stone: 120 lbs. to 400 lbs.</u>

6.2.5 Plan B NE Layer Thickness for Slope of 1V:2H

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$
$$r = 2 \times 1.15(2900/165)^{1/3}$$

$$r = 6 \text{ feet}$$

"B" layer:

$$r = 2 \times 1.15(260/165)^{1/3}$$

$$r = 2.7 \text{ feet, say } 3 \text{ feet}$$

6.2.6 Plan B NE Stone Sizes For a Slope of 1V:3H

Substituting :

$$W = \frac{165\ (7)^3}{3.5(2.6 - 1)^3\ 3}$$

$$W = 1300 \text{ lb.}$$

<u>"A" stone = 1200 lbs. to 2600 lbs</u>

<u>"B" stone = 78 lbs. - 260 lbs.</u>

6.2.7 Plan B NE Layer Thickness for a Slope of 1V:3H

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$
$$r = 2 \times 1.15(1900/165)^{1/3}$$

$$r = 5.2 \text{ feet, use } 5 \text{ feet}$$

"B" layer:

$$r = 2 \times 1.15(170/165)^{1/3}$$

$$r = 2.3 \text{ feet, say } 2.5 \text{ feet}$$

6.2.8 Plan B SE Stone Sizes For a Slope of 1V:1.5H

Substituting :

$$W = \frac{165\ (3.5)^3}{3.5(2.6 - 1)^3\ 1.5}$$

$$\underline{W = 330 \text{ lbs}}$$

For: Armor stone, $A = .9\ W - 2\ W$
$A =$ 300 lbs. - 660 lbs.

Underlayer stone, $B = .06W - .2W$
$B =$ 20 lbs. - 66 lbs.

6.2.9 Plan B SE Layer Thickness for Slope of 1V:1.5H

6.2.9.1 The recommended layer thickness from the Shore Protection Manual (USACE, 1984) is as follows:

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

Where: r = stone layer thickness
n = two layers = 2
k = 1.15, from table 7-13
W = stone weight
W_r = 165 lb./cubic ft.

Substituting:

$$r = 2 \times 1.15(330/165)^{1/3}$$
$$r = 2.9 \text{ feet, say } 3 \text{ feet}$$

"B" layer:

$$r = 2 \times 1.15(43/165)^{1/3}$$
$$r = 1.5 \text{ feet}$$

6.2.10 Plan B SE Stone Sizes For a Slope of 1V:2H

Substituting :

$$W = \frac{165\ (3.5)^3}{3.5(2.6 - 1)^3\ 2}$$

$$W = 247 \text{ lbs.}$$

"A" Stone: 220 lbs. - 500 lbs.
"B" Stone: 15 lbs. to 50 lbs.

6.2.11 Plan B SE Layer Thickness for Slope of 1V:2H

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

$$r = 2 \times 1.15(247/165)^{1/3}$$

$$r = 2.6 \text{ feet, say } 2.5 \text{ feet}$$

"B" layer:

$$r = 2 \times 1.15(32.5/165)^{1/3}$$

$$r = 1.34 \text{ feet, say } 1.5 \text{ feet}$$

6.2.12 Plan B SE Stone Sizes For a Slope of 1V:3H

Substituting :

$$W = \frac{165\ (3.5)^3}{3.5(2.6 - 1)^3\ 3}$$

$$W = 165 \text{ lb}$$

<u>"A" stone = 150 lbs. - 330 lbs.</u>

<u>"B" stone = 10 lbs. - 35 lbs.</u>

6.2.13 Plan B SE Layer Thickness for a Slope of 1V:3H

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

$$r = 2 \times 1.15(165/165)^{1/3}$$

$$r = 2.3 \text{ feet, use } 2.5 \text{ feet}$$

"B" layer:

$$r = 2 \times 1.15(22.5/165)^{1/3}$$

$$r = 1.2 \text{ feet}$$

6.3 WAVE OVERTOPPING RATES FOR PLAN B

6.3.1 A wave overtopping rate is the volume of water per unit time that passes over a structure, per linear foot of the structure. The overtopping rate is dependent upon structure configuration and wave conditions at the structure. Overtopping rates were obtained for different proposed crest elevations of the CDF. From these rates, fill times are generated. A forty-eight hour storm was recorded as the most significant storm event in Gary, Indiana, in a previous Indiana Harbor study and is the recommended storm duration to use to generate fill times. From the overtopping rates and fill times an optimum crest elevation can be selected.

6.3.2 Overtopping Equation

6.3.2.1 The overtopping rates for the CDF in Plan B were determined using the same method as in Plan A. The overtopping rates were calculated using equation 7-10 (USACE, 1984). Alpha and Qo* are overtopping coefficients from figure 7-28. The overtopping equation is:

$$Q = (gxQoxHo'^{3})^{0.5} \; x \; e^{-([.217/Alpha] \; \tanh^{-1} \; (h-ds)/R)}$$

$$\text{and} \quad 0 < (h-d_s)/R < 1.0$$

The overtopping rates were only determined for the NE side of the Plan B CDF, since the SE values are consistent with the values in Plan A.

6.3.3 Overtopping Rates and Wave Transmission

6.3.3.1 Proportionalities of wave transmission coefficients are set up for crest widths of 5, 30, and 45 feet as with Plan A. The amount of water overtopping the CDF is assumed to be proportional to the amount of wave transmission that occurs due to overtopping of the breakwater.

6.3.3.2 As in the Plans A & B analyses, this relationship between wave transmission and overtopping rates will be utilized to determine overtopping rates for slopes of 1V:1.5H, 1V:2H, and 1V:3H. Crest widths of 30 and 45 feet are evaluated.

6.3.4 Wind Correction Factor

6.3.4.1 The overtopping rates obtained were increased by the wind correction factor, k' (USACE, 1984) Eqn. 7-12.

$$k' = 1.0 + W_f((h-d_s)/R + 0.1)\sin\theta$$

where W_f is a coefficient depending on windspeed and θ is the structure slope. $W_f = 0.5$ for windspeeds of 30 mph.

6.3.5 Mean Overtopping Rates For a Five Foot Crest

6.3.5.1 The mean overtopping value divided by the overtopping rate (Qmean/Q) was then determined using figure 7-35 from the Shore Protection Manual (USACE, 1984). These values were then multiplied by the previously obtained overtopping rates (Q) to get the mean overtopping rates (Qmean) for a five foot crest width.

6.3.6 Typical Cross Section for Plan B

6.3.6.1 A typical cross section was drawn for Plan B using a CDF structure slope of 1V:2H and a crest elevation of +15 LWD. Each cell in the Plan B configuration is directly exposed to transmitted waves from the northeast. With this structure slope, a crest elevation of +15 LWD is necessary for all sides of the Plan B CDF to contain the overtopping from the design storm. A summary of the results for the Plans A, B, and C, CDF is shown in tables M-3 through M-5, for three different slopes. A cross section for Plan B can be seen in plate M-3.

7. PLAN C

7.1 For Plan C, the SE side of the CDF is to be constructed directly on top of the existing breakwater, incorporating the existing structure into the core of the CDF. This will expose the CDF directly to Lake Michigan and significant wave heights of 8 feet. In Plans A & B, the existing breakwater sheltered the CDF on the NE side and the SE side, reducing incident waves significantly. For Plan C, the NE side will still be sheltered by the breakwater.

7.2 The deepwater significant wave information outside the breakwater, for Plans A & B, will also apply here. The main difference between this design and the previous designs is that this design allows for direct wave impact on the southeast side of the CDF as opposed to transmitted wave impact, resulting in higher wave runup on the structure. This higher runup will require a higher crest elevation to decrease overtopping water volume. The larger impacting waves will also require larger stone for stability. This will result in a much larger structure. The northeast side of the CDF will be the same as in Plans A & B. The SE side of the CDF, Plan C is as follows.

7.3 SIGNIFICANT WAVE HEIGHT

7.3.1 The design wave information outside the breakwater will be consistent with the information obtained for Plans A & B, so the significant wave heights are:

SE:

d_s = 38.7 feet
Ho' = 8.5 feet
Lo = 230 feet
H_s = 8 feet

NE:

d_s = 37.1 feet
Lo = 178 feet
$H_s = H_t$ = 7 feet

7.4 WAVE RUNUP ON THE PROPOSED CDF STRUCTURE FOR PLAN C

7.4.1 The wave runup on the CDF dike structure is a significant factor in the evaluation of overtopping rates for water overtopping the CDF structure. The wave runup is the vertical limit of distance that the wave will travel as it impinges on the structure. The following equations were used for these determinations:

$$R = [a(z)/1+b(z)]H \qquad \text{eq. 5 (Seelig, 1980)}$$

where : $z = \tan\theta/(H/Lo)^{1/2}$
$a = .956$
$b = .398$

7.4.2 Runup With a Slope of 1V:1.5H

Substitute values into wave runup equations :

NE: $z = .67/(7/178)^{1/2} = 3.38$

$$R = [.956(3.38)/1+.398(3.38)]7 = 9.6 \text{ feet}$$

7.4.2.1 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+ 7.1 LWD + 9.6 feet of runup =

+ 16.7, say + 17 LWD

SE: Substituting, $z = .67/(8/230)^{1/2} = 3.59$

$$R = [(.956)(3.59)/(1+(.398)(3.59))]8$$

$$R = 11.3 \text{ feet}$$

7.4.2.2 A "no overtopping" crest elevation would be:

+5.7 LWD + 11.3 feet of runup

= + 17 LWD

7.4.3 Runup With a Slope of 1V:2H

NE: $z = .5/(7/178)^{1/2} = 2.52$

$$R = [.956(2.52)/1+.398(2.52)]7 = 8.4 \text{ feet}$$

7.4.3.1 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+ 7.1 LWD + 8.4 feet of runup = + 15.5 , say + 16 LWD

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SE: Substituting, $z = .5/(8/230)^{1/2} = 2.68$

$$R = [(.956)(2.68)/\{1+(.398)(2.68)\}]8$$

$$R = 9.9 \text{ feet, } 10 \text{ feet}$$

7.4.3.2 A "no overtopping" crest elevation would be:

+5.7 LWD + 10 feet of wave runup

<u>= + 15.7 LWD , say + 16 LWD</u>

7.4.4 Runup With a Slope of 1V:3H

NE: $z = .333/(7/178)^{1/2} = 1.68$

$$R = [.956(1.68)/1+.398(1.68)]7 = 6.7 \text{ feet}$$

7.4.4.1 The crest elevation at the NE face of the CDF that would allow no overtopping to take place would be:

+ 7.1 LWD + 6.7 feet of runup =

<u>+ 13.8, say + 14 LWD</u>

SE: Substituting, $z = .33/(8/230)^{1/2} = 1.77$

$$R = [(.956)(1.77)/\{1+(.398)(1.77)\}]8$$

$$R = 7.94 \text{ feet, say } 8 \text{ feet}$$

7.4.4.2 A "no overtopping" crest elevation would be:

+5.7 LWD + 8 feet of wave runup

<u>= + 13.7 LWD , say + 14 LWD</u>

7.5 PLAN C STONE SIZE DETERMINATION

7.5.1 The Shore Protection Manual (USACE, 1984) provides guidelines on stone size calculations. The Hudson equation is used to determine the most stable stone weight for impacting waves. The transmitted wave height of 7 feet was used for the NE exposure and the significant wave height of 8 feet on the SE exposure.

$$W = \frac{W_r \, (H)^3}{K_d \, (Sr - 1)^3 \, \text{Cot } \theta} \qquad \text{eq.7-116 (USACE, 1984)}$$

Where: W = weight of stone
W_r = unit weight
= 165 lb/cubic ft
K_d = 3.5 (table 7-8)
$S_r = W_r/W_w = 2.6$
Cot θ = structure slope
H =design wave height

7.5.2 Plan C Stone Sizes For a Slope of 1V:1.5H

NE: Substituting :

$$W = \frac{165\ (7)^3}{3.5(2.6 - 1)^3\ 1.5}$$

<u>W = 2632 lbs , say 1.3 ton</u>

For: Armor stone, A = .9 W - 2 W
A = 1.2 tons - 2.6 tons

Underlayer stone, B = .06W - .2W
B = 156 lbs. - 520 lbs.

SE : Substituting :

$$W = \frac{165\ (8)^3}{3.5(2.6 - 1)^3\ 1.5}$$

<u>W = 3930 lbs = 1.96 tons, say 2 tons</u>

For: Armor stone, A = .9 W - 2 W
A = 1.8 tons - 4 tons

Underlayer stone, B = .06W - .2W
B = 240 lbs. - 800 lbs.

7.5.3 Plan C NE Layer Thickness for Slope of 1V:1.5H

7.5.3.1 The recommended layer thickness from the Shore Protection Manual (USACE, 1984) is as follows:

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

Where: r = stone layer thickness
n = two layers = 2
k = 1.15, from table 7-13
W = stone weight
W_r = 165 lb./cubic ft.

Substituting:

$r = 2 \times 1.15(3800/165)^{1/3}$
$r = 6.5$ feet

"B" layer:

$r = 2 \times 1.15(338/165)^{1/3}$
$r = 2.9$ feet, say 3 feet

7.5.4 Plan C SE Layer Thickness for Slope of 1V:1.5H

7.5.4.1 The recommended layer thickness from the Shore Protection Manual (USACE, 1984) is as follows:

Armor Stone:

$r = n\ k\ (W/W_r)^{1/3}$ eqn. 7-121

Where: r = stone layer thickness
n = two layers = 2
k = 1.15, from table 7-13
W = stone weight
W_r = 165 lb./cubic ft.

Substituting:

$r = 2 \times 1.15(5700/165)^{1/3}$

$r = 7.5$ feet

"B" layer:

$r = 2 \times 1.15(510/165)^{1/3}$

$r = 3.34$ feet, say 3.5 feet

7.5.5 Plan C NE Stone Sizes For a Slope of 1V:2H

Substituting :

$$W = \frac{165\ (7)^3}{3.5(2.6 - 1)^3}$$

$W = 1974$ lbs., say 2000 lbs or 1 ton

"A" Stone: .9 to 2 tons

"B" Stone: 120 lbs. to 400 lbs.

7.5.6 Plan C NE Layer Thickness for Slope of 1V:2H

Armor Stone:

$r = n\ k\ (W/W_r)^{1/3}$ eqn. 7-121

$r = 2 \times 1.15(2900/165)^{1/3}$
$r = 6$ feet

"B" layer:

$r = 2 \times 1.15(260/165)^{1/3}$

$r = 2.7$ feet, say 3 feet

7.5.7 Plan C SE Stone Sizes For a Slope of 1V:2H

Substituting :

$$W = \frac{165\ (8)^3}{3.5(2.6 - 1)^3\ 2}$$

W = 1.47 tons

"A" Stone: 1.3 to 3 tons

"B" Stone: 175 lbs. to 600 lbs.

7.5.8 Plan C SE Layer Thickness for Slope of 1V:2H

Armor Stone:

$r = n\ k\ (W/W_r)^{1/3}$ eqn. 7-121

$r = 2 \times 1.15(4300/165)^{1/3}$

$r = 6.8$ feet, say 7 feet

"B" layer:

$r = 2 \times 1.15(388/165)^{1/3}$

$r = 3.1$ feet, say 3 feet

7.5.9 Plan C NE Stone Sizes For a Slope of 1V:3H

Substituting :

$$W = \frac{165\ (7)^3}{3.5(2.6 - 1)^3\ 3}$$

W = 1300 lb.

"A" stone = 1200 lbs. to 2600 lbs

"B" stone = 78 lbs. - 260 lbs.

7.5.10 Plan C NE Layer Thickness for a Slope of 1V:3H

Armor Stone:

$r = n\ k\ (W/W_r)^{1/3}$ eqn. 7-121

$r = 2 \times 1.15(1900/165)^{1/3}$

$r = 5.2$ feet, use 5 feet

"B" layer:

$$r = 2 \times 1.15(170/165)^{1/3}$$

$$r = 2.3 \text{ feet, say } 2.5 \text{ feet}$$

7.5.11 Plan C SE Stone Sizes For a Slope of 1V:3H

Substituting :

$$W = \frac{165\ (8)^3}{3.5(2.6 - 1)^3\ 3}$$

$$W = 1964 \text{ lb., say } 1 \text{ Ton}$$

"A" stone = .9 to 2 Tons

"B" stone = 120 lbs. - 400 lbs.

7.5.12 Plan C SE Layer Thickness for a Slope of 1V:3H

Armor Stone:

$$r = n\ k\ (W/W_r)^{1/3} \qquad \text{eqn. 7-121}$$

$$r = 2 \times 1.15(2900/165)^{1/3}$$

$$r = 5.97 \text{ feet, use } 6 \text{ feet}$$

"B" layer:

$$r = 2 \times 1.15(260/165)^{1/3}$$

$$r = 2.7 \text{ feet, say } 3 \text{ feet}$$

7.6 WAVE OVERTOPPING RATES FOR PLAN C

7.6.1 A wave overtopping rate is the volume of water per unit time that passes over a structure, per linear foot of the structure. The overtopping rate is dependent upon structure configuration and wave conditions at the structure. Overtopping rates were obtained for different proposed crest elevations of the CDF. From these rates, fill times are generated. A forty-eight hour storm was recorded as the most significant storm event in Gary, Indiana, in a previous Indiana Harbor study and is the recommended storm duration to use to generate fill times. From the overtopping rates and fill times an optimum crest elevation can be selected.

7.6.2 Overtopping Equation

7.6.2.1 The overtopping rates for the CDF in Plan C were determined using the same method as for Plans A & B. The overtopping rates were calculated using equation 7-10 (USACE, 1984). Alpha and Qo* are overtopping coefficients from figure 7-28. The overtopping equation is:

$$Q = (gxQoxHo'^{3})^{0.5} \ x \ e^{-([.217/Alpha] \ \tanh^{-1} \ (h-ds)/R)}$$

$$\text{and} \quad 0 < (h-d_s)/R < 1.0$$

7.6.2.2 The overtopping rates were only determined for the SE side of the Plan C CDF, since the NE values are consistent with the values in Plan B.

7.6.3 Overtopping Rates and Wave Transmission

7.6.3.1 Proportionalities of wave transmission coefficients are set up for crest widths of 5, 30, and 45 feet as with Plans A and B and are used here in the determination of overtopping rates. The amount of water overtopping the CDF is assumed to be proportional to the amount of wave transmission that occurs due to overtopping of the breakwater.

7.6.3.2 As in the Plans A & B analyses, this relationship between wave transmission and overtopping rates will be utilized to determine overtopping rates for slopes of 1V:1.5H, 1V:2H, and 1V:3H. Crest widths of 30 and 45 feet are evaluated.

7.6.4 Wind Correction Factor

7.6.4.1 The overtopping rates obtained were increased by the wind correction factor, k' (USACE, 1984), Eqn. 7-12.

$$k' = 1.0 + W_f((h-d_s)/R + 0.1)\sin\theta$$

where W_f is a coefficient depending on windspeed and θ is the structure slope. $W_f = 0.5$ for windspeeds of 30 mph.

7.6.5 Mean Overtopping Rates For a Five Foot Crest

7.6.5.1 The mean overtopping value divided by the overtopping rate (Qmean/Q) was then determined using figure 7-35 from the Shore Protection Manual (USACE, 1984). These values were then multiplied by the previously obtained overtopping rates (Q) to get the mean overtopping rates (Qmean) for a five foot crest width.

7.6.6 Wave Transmission Coefficients

7.6.6.1 Ratios of transmission coefficients were developed to be utilized in obtaining overtopping rates for crests larger than 5 feet wide. Transmission coefficients (K_{to}) for a 5 foot width, a 30 foot width, and a 45 foot width were obtained. Then the ratios were used to multiply the existing overtopping rates for a 5 foot crest, to obtain overtopping rates for a 30 and 45 foot crest. For example, $Q_{B=5} \ x \ (K_{to})_{B=30} / (K_{to})_{B=5} = Q_{B=30}$.

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7.6.7 Mean Overtopping Rates For 30 and 45 Foot Crests

7.6.7.1 Mean overtopping rates were generated for various crest elevations for crest widths of 30 and 45 feet. A summary of these results is shown in tables M-3 through M-5.

7.6.8 Storage Volume Fill Times

7.6.8.1 The storage volume fill time is the time it would take for overtopping waves to fill the available volume for overtopping storage volume in a CDF cell. A design storm for this area is estimated at 48 hours in duration. Overtopping rates utilizing a 48 hour limitation were used for the fill time calculations. These fill times were calculated using a frontal length along the northeast side of 950 feet, and along the southeast side of 900 feet. These dimensions are used with a 5 ft depth that will eventually be used for capping the CDF. This volume is used as the available storage volume for overtopping.

7.6.8.2 As each cell is filled with dredged sediment, five feet of height will be allowed for storage between the top of the dredged sediment and the CDF structure crest. After the dredging is completed and the cell is filled, this storage area will be covered with a five foot cap. Until the structure is capped, the design of the structure must ensure that no water in the CDF will wash back into Lake Michigan during the design storm conditions.

7.6.8.3 The ability of the structure to prevent backwashing was determined by calculating the fill times for the structure with varying crest elevations, crest widths and slopes. A summary of the results for the Plans A, B, and C, CDF is shown in tables M-3 through M-5, for three different slopes.

7.6.9 Typical Cross Section for Plan C

7.6.9.1 A typical cross section was drawn for Plan C using a CDF structure slope of 1V:2H and a no overtopping crest elevation of +16 LWD for the NE exposure and +16 LWD for the SE exposure. This cross section can be seen in plate M-4.

8. RECOMMENDATIONS

8.1 Throughout this appendix, three distinct plan configurations for the CDF structure design were evaluated with specific considerations being given for the impact due to the lake generated environment which produced a secondary wave climate on the leeside of the breakwater. Plans A and B specify the positioning of the CDF completely behind the existing steel sheetpile cell breakwater. Plan C has its entire southeast exposure in direct contact with Lake Michigan. Two significant design impacts need to be considered as a result of the distance between the CDF and the SSP breakwater, (1) the reflection that will occur, and (2) the energy dissipation that results from the wave propagation distance.

8.2 Assessing the configuration of Plan A, it is noted that the CDF structure is proposed for placement along the inside section of the SE extent of breakwater. This also includes a small section along the northeast extent and the east corner. A passageway of 75 feet will be allowed between the two structures for barge mobility. The water level within this passage would be at the Lake Michigan elevation, which is a few feet below the elevation of the SSP breakwater. It has been presented within this appendix that these settings will create conditions for wave energy reflection to occur between the two structure faces. The CDF would also be situated directly behind the overtopping waves, with not much distance for dissipation of wave energy prior to impact and reflection.

8.3 The configuration of Plan B proposes CDF placement as far landward as the existing Lake Inland shoreline. The CDF will also be placed parallel to the shore, which places the largest CDF reflective surface as far as possible from the SSP breakwater and overtopping waves from Lake Michigan, and provides a much larger distance for waves to propagate before reaching the CDF structure, than in Plan A. This provides a greater chance for dissipation of wave energy before reaching the CDF structure and should result in a much smaller reflected wave propagating back toward the breakwater. Waves that do reflect back toward the breakwater have to travel that distance again, dissipating more wave energy. Also, the design water level would be at the SSP breakwater elevation and waves that make it to the SSP breakwater may wash back over the breakwater and back into Lake Michigan, with minimal reflection occurring back toward the CDF. This should provide a more tranquil setting than that presented in Plan A.

8.4 In the proposed configuration of Plans A & B, all CDF structure faces are enclosed within the breakwater lee, adding the benefit of additional protection from the existing SSP breakwater. In the proposed configuration of Plan C, the southeast reach will be in direct contact with Lake Michigan. This will provide larger wave impact on the southeast CDF exposure than in Plans A & B. This is also the longest exposure of the structure. This greater wave impact, results in larger waves, increased runup, and therefore, a higher crest elevation is needed to prevent excessive overtopping. A larger stone size will also be needed for the structure to remain stable with larger impacting waves. The issue of constructability for Plan C, which calls for building a CDF directly on the existing SSP cell breakwater along the southeast section also needs to be addressed, as this may not be practical or structurally sound.

8.5 The location of the existing breakwater in Lake Michigan is such that the northeast exposure is subject to greater wave impact than the southeast exposure. Therefore, the plan configurations closest to the northeast breakwater exposure will receive the largest wave impact from overtopping waves generated from the northeast. Plans A and C propose placement of the CDF structure directly behind the southeast extent of breakwater, which extends to the northeast reach.

8.6 In summary, Plan A is susceptible to a greater amount of reflected wave energy and greater wave overtopping impact from Lake Michigan than Plan B. Plan C will be subjected to greater wave impact on the southeast than Plans A or B, requiring a higher crest elevation and larger stone sizes, and may be difficult to construct. Due to the design considerations presented for the three configurations of Plans A, B, and C, the recommended design plan configuration, from a coastal engineering standpoint is that of Plan B.

8.7 The CDF design parameters determined included stone sizes, crest width, crest elevation, and structure slope for both the northeast and southeast exposure for each of the three plans. There is always a trade off with these parameters. Generally, if the structure slope is flattened, the crest elevation may be slightly lowered (to a minimum elevation), or if the crest width is decreased the crest elevation may be slightly increased. In this case, the crest elevation and crest width were limited by overtopping rates and storage volume fill times. The storage volume capacity, the duration of the design storm, and water overtopping rates were evaluated and assessed in the fill time determination. The design parameters, and their effect on overtopping rates and fill times, for a CDF with a structure slope of 1V:1.5H, 1V:2H, and 1V:3H are presented in tables M-3, M-4, and M-5, respectively.

8.8 The crest widths being considered for the CDF are 30 feet and 45 feet, since these widths would allow the crest to function as a working platform for two different cranes. It can be seen in these tables, that there is minimal difference in fill time due to the variance in crest width. This difference in crest width was not a limiting factor in crest elevation selection. The recommended crest elevations are shown in table M-6 for a crest width of either 30 feet or 45 feet, for both zero overtopping and allowable overtopping conditions.

Table M-3. Summary of Overtopping Rates
Structure Slope = 1V:1.5H
Crest Widths equal 30 and 45 feet

Plan/ Exposure	Crest El. (LWD)	Slope	B = 30 Q	B = 45 Q	B = 30 T	B = 45 T
Plan A						
North	+17	1:1.5	0.00	0.00	-	-
East	+16	1:1.5	0.05	0.05	23.8	25.6
	+15	1:1.5	0.09	0.08	14.4	15.5
Plans A						
South	+11	1:1.5	0.00	0.00	-	-
East	+10	1:1.5	0.04	0.04	30.6	33.6
	+ 9	1:1.5	0.12	0.11	11.0	12.2
Plan B						
North	+17	1:1.5	0.00	0.00	-	-
East	+16	1:1.5	0.04	0.03	35.2	38.8
	+15	1:1.5	0.11	0.10	11.9	12.9
Plan B						
South	+11	1:1.5	0.00	0.00	-	-
East	+10	1:1.5	0.04	0.04	30.6	33.6
	+ 9	1:1.5	0.12	0.11	11.0	12.2
Plan C						
North	+17	1:1.5	0.00	0.00	-	-
East	+16	1:1.5	0.04	0.03	35.2	38.8
	+15	1:1.5	0.11	0.10	11.9	12.9
Plan C						
South	+17	1:1.5	0.00	0.00	-	-
East	+16	1:1.5	0.05	0.05	24.8	27.0
	+15	1:1.5	0.11	0.10	12.4	13.5

Q - Overtopping rate in cubic feet per second (cfs) per linear foot of breakwater.

Slope is given in format of "vertical:horizontal".

B - Crest width is in feet.

T - Fill time in hours.

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Table M-4. Summary of Overtopping Rates
Structure Slope = 1V:2H
Crest Widths equal 30 and 45 feet

Plan/ Exposure	Crest El. (LWD)	Slope	B = 30 Q	B = 45 Q	B = 30 T	B = 45 T
Plan A						
North	+17	1:2	0.00	0.00	-	-
East	+16	1:2	0.00	0.00	-	-
	+15	1:2	0.04	0.04	28.2	31.3
	+14	1:2	0.10	0.10	12.0	13.0
Plan A						
South	+11	1:2	0.00	0.00	-	-
East	+10	1:2	0.03	0.02	50.6	56.2
	+ 9	1:2	0.09	0.08	15.4	17.2
Plan B						
North	+16	1:2	0.00	0.00	-	-
East	+15	1:2	0.03	0.02	48.1	52.1
	+14	1:2	0.06	0.06	19.8	21.7
Plans B						
South	+11	1:2	0.00	0.00	-	-
East	+10	1:2	0.03	0.02	50.6	56.2
	+ 9	1:2	0.09	0.08	15.4	17.2
Plan C						
North	+16	1:2	0.00	0.00	-	
East	+15	1:2	0.03	0.02	48.1	52.1
	+14	1:2	0.06	0.06	19.8	21.7
Plan C						
South	+16	1:2	0.00	0.00	-	-
East	+15	1:2	0.04	0.03	36.7	39.6
	+14	1:2	0.10	0.09	13.7	15.0

Q - Overtopping rate in cubic feet per second (cfs) per linear foot of breakwater.
Slope is given in format of "vertical:horizontal".
B - Crest width is in feet.
T - Fill time in hours.

Table M-5. Summary of Overtopping Rates
Structure Slope = 1V:3H
Crest Widths equal 30 and 45 feet

Plan/ Exposure	Crest El. (LWD)	Slope	B = 30 Q	B = 45 Q	B = 30 T	B = 45 T
Plan A North East	+14	1:3	0.00	0.00	-	-
	+13	1:3	0.05	0.05	24.1	26.2
	+12	1:3	0.12	0.11	10.3	11.4
Plan A South East	+10	1:3	0.00	0.00	-	-
	+ 9	1:3	0.03	0.02	51.7	57.1
	+ 8	1:3	0.14	0.12	9.7	10.8
Plan B North East	+14	1:3	0.00	0.00	-	-
	+13	1:3	0.07	0.06	17.7	19.6
	+12	1:3	0.18	0.17	6.8	7.5
Plan B South East	+10	1:3	0.00	0.00	-	-
	+ 9	1:3	0.03	0.02	51.7	57.1
	+ 8	1:3	0.14	0.12	9.7	10.8
Plan C North East	+14	1:3	0.00	0.00	-	-
	+13	1:3	0.07	0.06	17.7	19.6
	+12	1:3	0.18	0.17	6.8	7.5
Plan C South East	+14	1:3	0.00	0.00	-	-
	+13	1:3	0.05	0.05	25.5	27.7
	+12	1:3	0.12	0.11	10.7	11.8

Q - Overtopping rate in cubic feet per second (cfs) per linear foot of breakwater.
Slope is given in format of "vertical:horizontal".
B - Crest width is in feet.
T - Fill time in hours.

Table M-6. Crest Elevations Which Allow Zero/Minimum Overtopping For Crest Widths of 30 and 45 feet

	STRUCTURE SLOPE	EXPOSURE	CREST ELEVATION No Overtopping	CREST ELEVATION Minimum Overtopping
PLAN A	1:1.5	NE	+17 LWD	+17 LWD
	1:1.5	SE	+11 LWD	+11 LWD
	1:2	NE	+16 LWD	+16 LWD
	1:2	SE	+11 LWD	+10 LWD
	1:3	NE	+14 LWD	+14 LWD
	1:3	SE	+10 LWD	+ 9 LWD
PLAN B	1:1.5	NE	+17 LWD	+17 LWD
	1:1.5	SE	+11 LWD	+11 LWD
	1:2	NE	+16 LWD	+15 LWD
	1:2	SE	+11 LWD	+10 LWD
	1:3	NE	+14 LWD	+14 LWD
	1:3	SE	+10 LWD	+ 9 LWD
PLAN C	1:1.5	NE	+17 LWD	+17 LWD
	1:1.5	SE	+17 LWD	+17 LWD
	1:2	NE	+16 LWD	+15 LWD
	1:2	SE	+16 LWD	+16 LWD
	1:3	NE	+14 LWD	+14 LWD
	1:3	SE	+14 LWD	+14 LWD

9. REFERENCES

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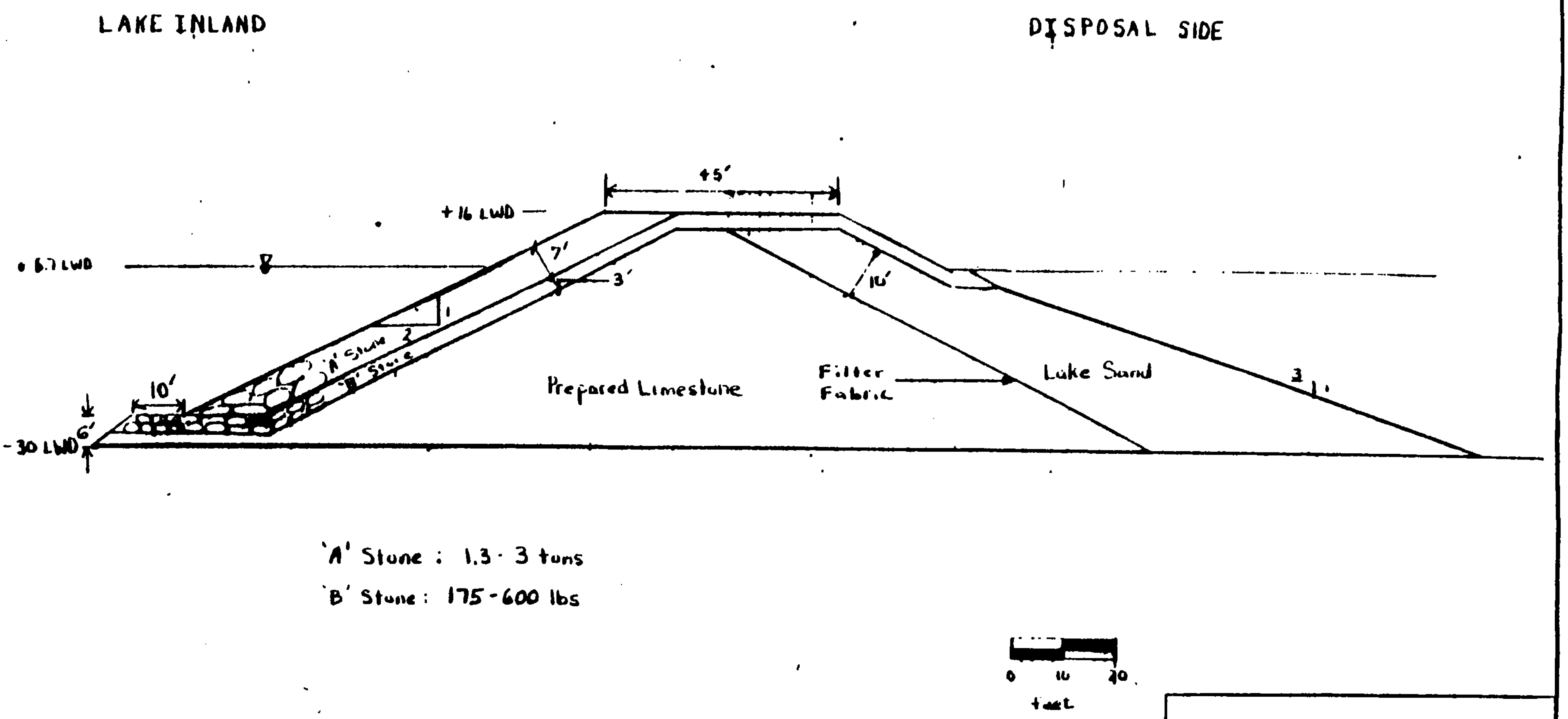
TYPICAL SECTION

PLAN A, CELL 1



INDIANA HARBOR
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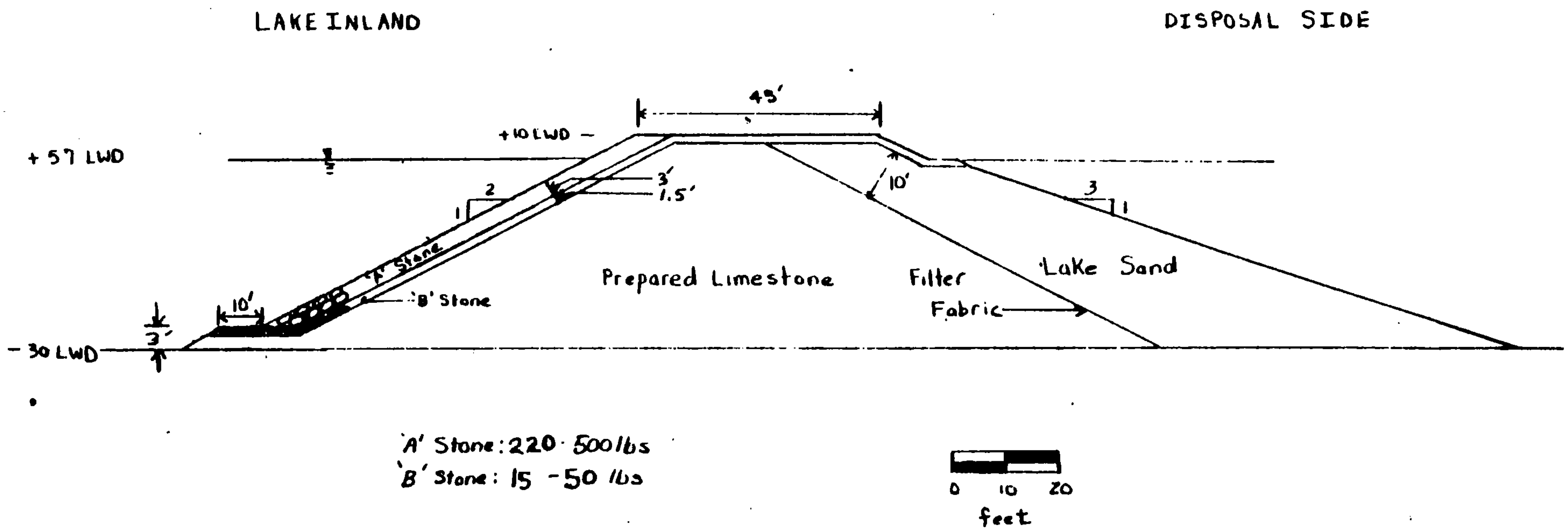
TYPICAL SECTION

Plate M-1

TYPICAL SECTION

PLAN A, CELLS 2 & 3



'A' Stone: 220 · 500 lbs
'B' Stone: 15 - 50 lbs

INDIANA HARBOR
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LETTER REPORT

TYPICAL SECTION

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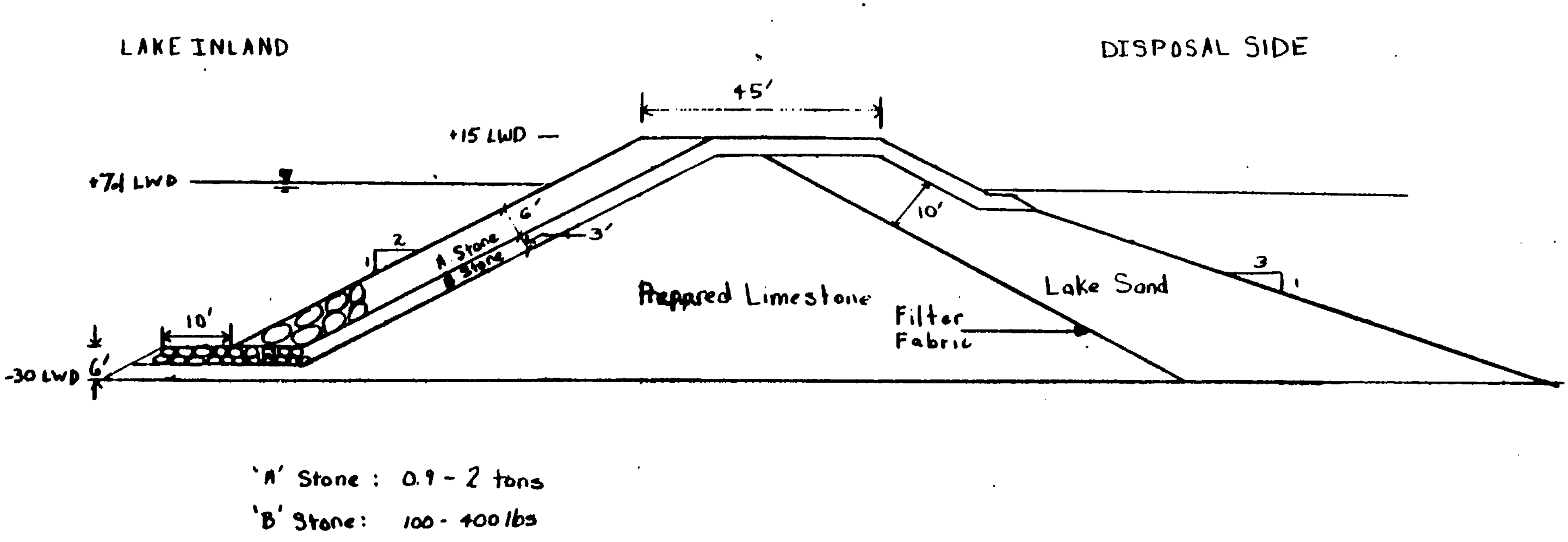
TYPICAL SECTION

PLAN B, CELLS 1,2 & 3



0 10 20
feet

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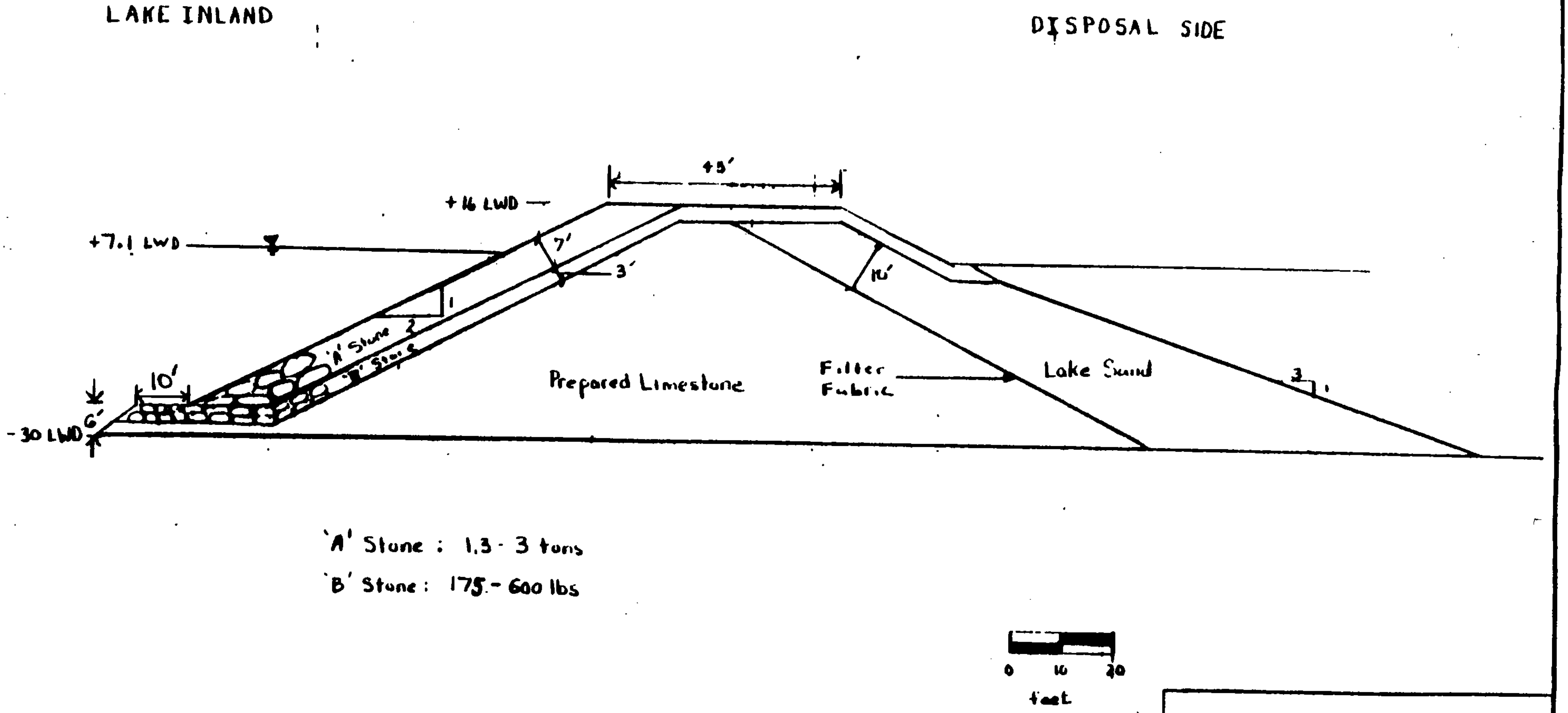
TYPICAL SECTION

TYPICAL SECTION

PLAN C, CELLS 1,2 & 3



'A' Stone : 1.3 - 3 tons
'B' Stone : 175 - 600 lbs

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TYPICAL SECTION