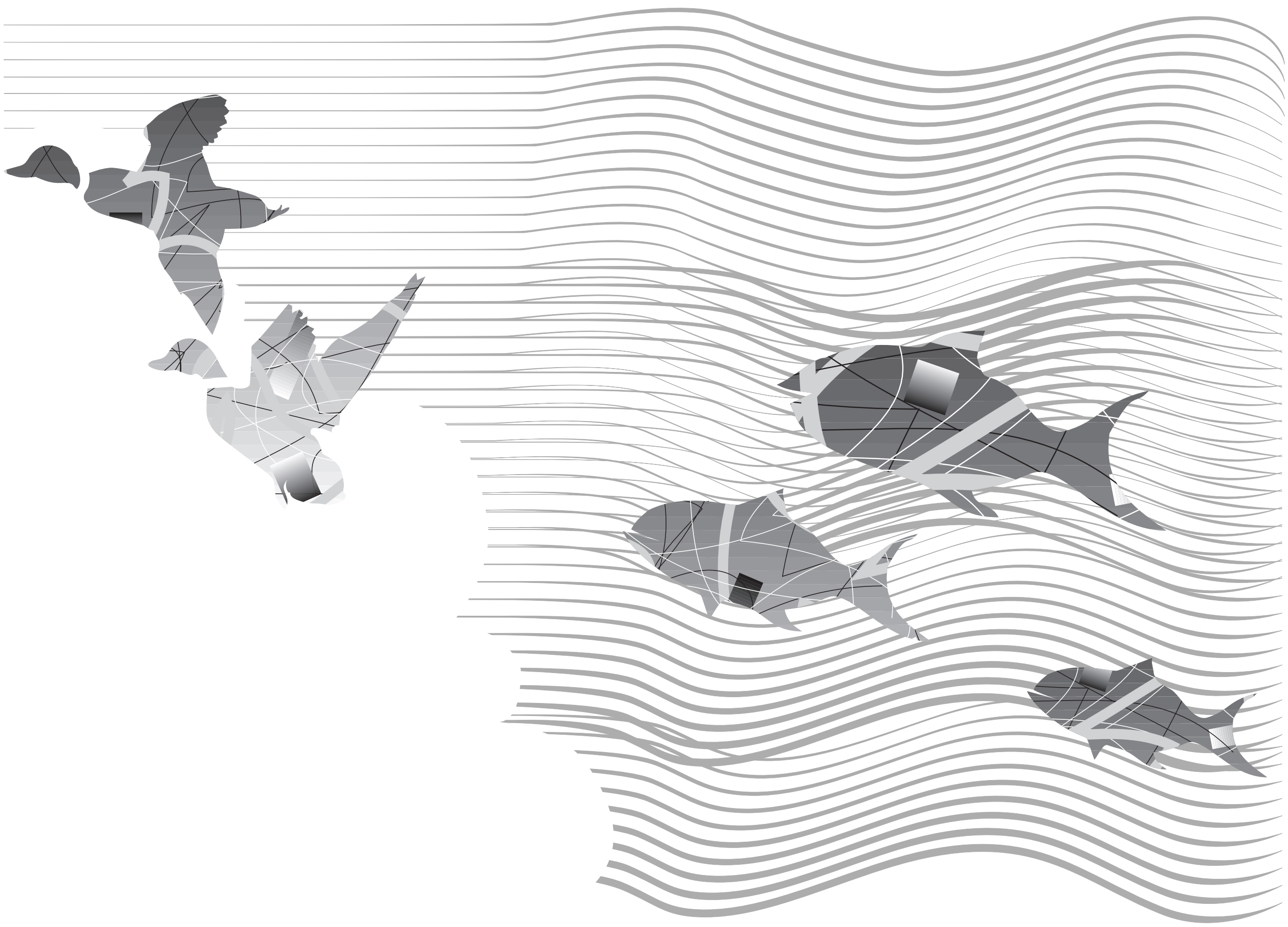
U.S. Fish and Wildlife Service

Final

Restoration Alternatives Development and Evaluation Report

Grand Calumet River/Indiana Harbor Canal, Indiana

December 2000



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USFWS Contract No. 98690-0-M003

GRAND CALUMET RIVER/INDIANA HARBOR CANAL
INDIANA

FINAL REPORT

RESTORATION ALTERNATIVES DEVELOPMENT AND EVALUATION FOR NATURAL RESOURCE DAMAGE ASSESSMENT

December 2000

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CONTENTS

Section **Page**

CONTENTS

CONTENTS

Section | Page

APPENDIXES

FIGURES

TABLES

ACRONYMS

ARAR	applicable or relevant and appropriate requirement
BP	British Petroleum
CAD	confined aquatic disposal
CDF	confined disposal facility
CFR	Code of Federal Regulations
cfs	cubic feet per second
COC	contaminant of concern
cy	cubic yards
cy/hr	cubic yards per hour
CWA	Clean Water Act
DAF	dissolved air flotation
DDE	dichlorodiphenyldichloroethylene
DNAPL	dense nonaqueous phase liquid
DOI	U.S. Department of Interior
DOQ	digital orthographic quad
EBGCR	east branch of the Grand Calumet River
EPA	U.S. Environmental Protection Agency
Foster Wheeler Environmental	Foster Wheeler Environmental Corporation
GCR	Grand Calumet River
GATX	General American Transportation Corporation
GIS	global information system
GPS	global positioning system

ACRONYMS

HDPE	high-density polyethylene
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IEc	Industrial Economics, Inc.
IGLD	International Great Lakes Datum
IHC	Indiana Harbor Canal
IRCDP	Initial Restoration and Compensation Determination Plan
LGC	Lake George Canal
LGP	Low Ground Pressure
LNAPL	light nonaqueous-phase liquid
msl	mean sea level
NCDF	nearshore confined disposal facility
NGVD	National Geodetic Vertical Datum of 1929
NGVD29	NGVD referenced to mean sea levels of 1929
NIPSCO	Northern Indiana Public Service Company
NRDA	natural resource damage assessment
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PEC	probable effect concentration
PEC-Q	probable effect concentration quotient
RCDP	Restoration and Compensation Determination Plan
RCRA	Resource Conservation and Recovery Act

ACRONYMS

RI/FS	remedial investigation/feasibility study
SEC	sediment-effect concentrations
SOW	Statement of Work
SQG	sediment quality guidelines
SQO	sediment quality objective
TEC	threshold effect concentration
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USX	U.S. Steel—Gary Works
UV	ultraviolet
VOC	volatile organic compound
WBGCR	west branch of the Grand Calumet River

1.0 INTRODUCTION

This report was prepared for the United States Fish and Wildlife Service (USFWS)—Bloomington, Indiana Field Office and the Indiana Department of Environmental Management (IDEM), at the request of the USFWS Environmental and Facility Compliance Office. It is to be used as a planning document for developing and evaluating restoration alternatives for the Grand Calumet River (GCR) and Indiana Harbor Canal (IHC), Indiana. The report has been prepared in accordance with the requirements of the Statement of Work (SOW) for Task Order 00-Y004 of USFWS Contract No. 1448-98695-98-C008.

1.1. PROJECT LOCATION

The GCR is located in Lake County in northwestern Indiana. The river's watershed is relatively flat and comprises approximately 22 square miles of northern Indiana (Exponent 1999). The surrounding area, which represents one of the most heavily industrialized areas in the United States, contains steel mills and heavy manufacturing sites associated with the steel industry, petroleum-related land uses, packaging operations, chemical processing plants, and other industrial land uses. The land surrounding the GCR is primarily industrial and commercial interspersed with residential areas. The project area evaluated in this report includes the west branch of the GCR (WBGCR) extending from its junction with the east branch of the GCR (EBGCR) west to Indianapolis Boulevard, the western 5 miles of the EBGCR, and a portion of the Lake George Canal (LGC). The location of the project area is shown on Figure 1-1. The EBGCR originates at the Grand Calumet River Lagoons, east of the U.S. Steel—Gary Works (USX) facility. The east branch flows west from this point for approximately 10 miles to its confluence with the IHC. Portions of the WBGCR generally flow both east and west, with a hydraulic divide typically present near Columbia Avenue.

The IHC flows north for approximately 3 miles from its confluence with the east and west branches of the GCR before turning northeast and flowing an additional 2 miles through Indiana Harbor and into Lake Michigan. The LGC of the IHC extends to the west, approximately 2 miles upstream from the point where the main branch of the IHC turns to the northeast.

1.2. PROJECT DESCRIPTION

The purpose of this evaluation is to provide the USFWS and IDEM with a technical approach and cost estimate for preparing a comprehensive, technically sound, and regulatory-defensible restoration alternative development and evaluation for the GCR/IHC that can be used in completing the Restoration and Compensation Determination Plan (RCDP) component of the natural resource damage assessment (NRDA). The goal is to develop and evaluate alternatives in a manner that conforms with criteria developed in the Initial RCDP (IRCDP) (IDEM et al. 1998).

A review of available data and literature and an assessment of the need to collect additional data was completed prior to developing the restoration alternatives (Foster Wheeler Environmental Corporation [Foster Wheeler Environmental] 2000). Two meetings and a site visit conducted to support this effort are described below:

- A project kickoff meeting was held on January 27, 2000, and included representatives from USFWS, U.S. Environmental Protection Agency (EPA), U.S. Department of the Interior (DOI), Indiana Department of Natural Resources (IDNR), IDEM, Industrial Economics, Inc. (IEc), and Foster Wheeler Environmental. The attendees discussed the independent remedial investigation/feasibility study (RI/FS) process, potential applicable or relevant and appropriate requirements (ARARs), the nature and extent of contamination, chemical and biological sampling and testing conducted to date, and remedy evaluation criteria. Inclement weather forced postponement of a planned site orientation visit until March 2000.

- A second meeting held on February 15, 2000, included representatives from USFWS, IDEM, Foster Wheeler Environmental, and MacDonald Environmental. Discussion topics included the sediment sampling and testing database (with maps) developed by MacDonald Environmental and the evaluation method used to determine level of contamination and whether or not remediation was required based on exceedances of sediment quality objectives (SQOs).

- A site visit was conducted on March 7, 2000, by representatives from USFWS, IDEM, and Foster Wheeler Environmental. A small, flat-bottom boat was used to navigate most of the project reaches, including the GCR, IHC, and Indiana Harbor. Features that were observed and noted included water depths, bankline characteristics, sediment characteristics, vertical and horizontal clearances for bridges and other river crossings, potential equipment access locations, sediment sampling transect locations, and potential upland dredged material disposal sites. A set of maps developed from U.S. Geological Survey (USGS) 7.5-minute series topographic maps was used to document salient features and the locations where photographs were taken. The photographs have been cataloged for reference.

During the two meetings and site visit described above, various reports and other documents that had been generated for the project were identified. A list of the technical information reviewed in support of this Final Report is contained in Appendix A—Site Bibliography. The primary documents used to develop the alternatives in this study are those by Floyd Brown Associates (1991) and Maxim Technologies (1999).

The review of existing information determined that sufficient information was available to establish the areal extent and type of sediment/soil contamination within the project area. There is also some physical information available, including grain size and water content of sediments, that will be used to determine sediment dredging and capping capabilities. These data were used to develop the restoration alternatives. Following acquisition and review of historical data and information, the data quality and completeness were assessed and reported in a Technical Memorandum (Foster Wheeler Environmental 2000). The Technical Memorandum included a work plan to evaluate the existing data, with suggestions for efficiently acquiring missing data considered necessary to complete the project.

The review of existing information identified several data gaps that needed to be filled before or during the alternatives evaluation process. These additional data and information needs included the following:

- Bathymetric survey data to establish the river-bottom topography and locate the core borings, both horizontally and vertically, with relation to the river and canal
- Engineering base drawings
- Transfer of sediment core data to the base drawings
- Information pertaining to river access for implementation of the RCDP
- Assessment of the geotechnical properties of the sediments

1.2.1. Bathymetric Survey

A bathymetric survey of the site was conducted during the week of May 8, 2000, to fill the first data gap identified above. The survey covered approximately 7 miles of the project area. Approximately 246 cross sections were taken from bankline to bankline, which equates to about one section for every 200 feet of river/canal length. The information from the survey was used to develop the bathymetric plan and profile included in Appendix B. The resulting information was used to:

- Establish river bed topography and core sample elevations in relation to the waterway and the project vertical datum
- Develop remedial alternatives and estimate dredging/capping quantities for the various reaches of the project
- Aid the preparation of final restoration plans based on the selected alternative(s)

1.2.2. Engineering Base Maps

On May 11, 2000, Foster Wheeler Environmental received a set of 7.5-minute digital orthographic quad (DOQ) sheets from the USFWS that provided complete coverage of the project area. Each sheet offers 1-meter pictal resolution with an average accuracy of 40 feet. The DOQ sheets were used as the base maps upon which engineering elements such as stationing, cross sections, and feature references (i.e., bridges, shore protection, obstructions, access routes) are based. The maps did not facilitate determination of topographic elevations. Topographic elevations used to construct cross sections were obtained from photographs and referenced to the DOQ sheets for determination of dredge volumes.

Using the DOQ sheets and contour maps resulting from the bathymetric survey, Foster Wheeler Environmental prepared engineering base drawings. These drawings were used for the following purposes:

- Identify the location of core borings and river bed topography
- Show the contaminated sediment profiles
- Identify the preliminary dredge prisms and capping areas
- Compute quantities of dredged material and/or capping material
- Locate potential upland access and dredged material disposal areas adjacent to the waterway

Stationing on the GCR begins at the intersection of the river centerline and the west edge of the Conrail railroad bridge (GCR station 0+00 on the drawings) located southeast of the Gary, Indiana, airport. River stationing runs westward along the river centerline to the Indianapolis Boulevard bridge at GCR station 296+04.

Stationing on the IHC begins (IHC station 0+00) at the intersection of the IHC centerline with the GCR centerline at GCR station 263+80. The stationing runs north along the centerline of the IHC to the confluence with the LGC and the Indiana Harbor channel.

Stationing on the LGC begins (0+00) at the intersection of the LGC centerline and the centerline of the IHC at IHC station 104+63. The stationing runs westward to the end of the canal at LGC station 71+39.

1.2.3. Transfer of Sediment Core Data to the Base Drawings

The sediment core data collected from various sources was transferred to the engineering base drawings so that dredging/capping options could be laid out. The core borings have XYZ coordinates, which were used to locate the horizontal and vertical position of the cores. Core locations were originally established using a differential global positioning system (GPS) unit. These positions were transformed to northing and easting state plane coordinates. The elevation of each core was converted from a depth value to an elevation relative to the National Geodetic Vertical Datum (NGVD) referenced to mean sea level (msl) of 1929 (NGVD29). In addition, the bottom of the contaminated sediment in each core was tied to the project vertical datum.

1.2.4. River Access

Potential river access sites were identified using the engineering base maps discussed in Section 1.2.2.

1.2.5. Assessment of Geotechnical Properties of the Sediments

The sediment sampling and testing conducted to date were principally designed to determine the type and extent of sediment/soil contamination, and not to acquire the engineering property data necessary for remedial alternatives design. To minimize additional project costs and delays, the project team determined that sufficient information existed to complete the alternatives analysis at a level of quality sufficient to meet the project goals. More detailed design analysis will require acquisition of appropriate geotechnical data.

1.3. HISTORY OF THE RIVER

Prior to about 1850, the GCR flowed from west to east, emptying into Lake Michigan near the current site of Marquette Park. As the west end of the river was developed for navigation at the confluence with the Little Calumet River, the mouth of the river was closed by sand dunes. In 1903, construction began on the IHC, bisecting the GCR into its east and west branches. Increasing development caused the course of the river to be changed several times during the twentieth century. A 2-mile stretch of the river near the U.S. Steel plant was moved 1,000 feet to the south sometime between 1906 and 1917. Also, from 1953 to 1959, the construction of Interstate 90 through northern Indiana caused the reaches of the GCR between Clark and Grant Streets in Gary, Indiana, to be straightened.

Much of the original topography around the GCR has been obliterated as areas have been graded for transportation, industrial, and other urban uses. To accommodate the heavy industry, the dunes were leveled and wetlands were filled with sand from the dunes and slag from the steel mills in the region. The

Grand Calumet Lagoons (the former mouth of the river) were formerly connected to the river by an open channel, but that channel was filled and replaced with a culvert sometime after 1951.

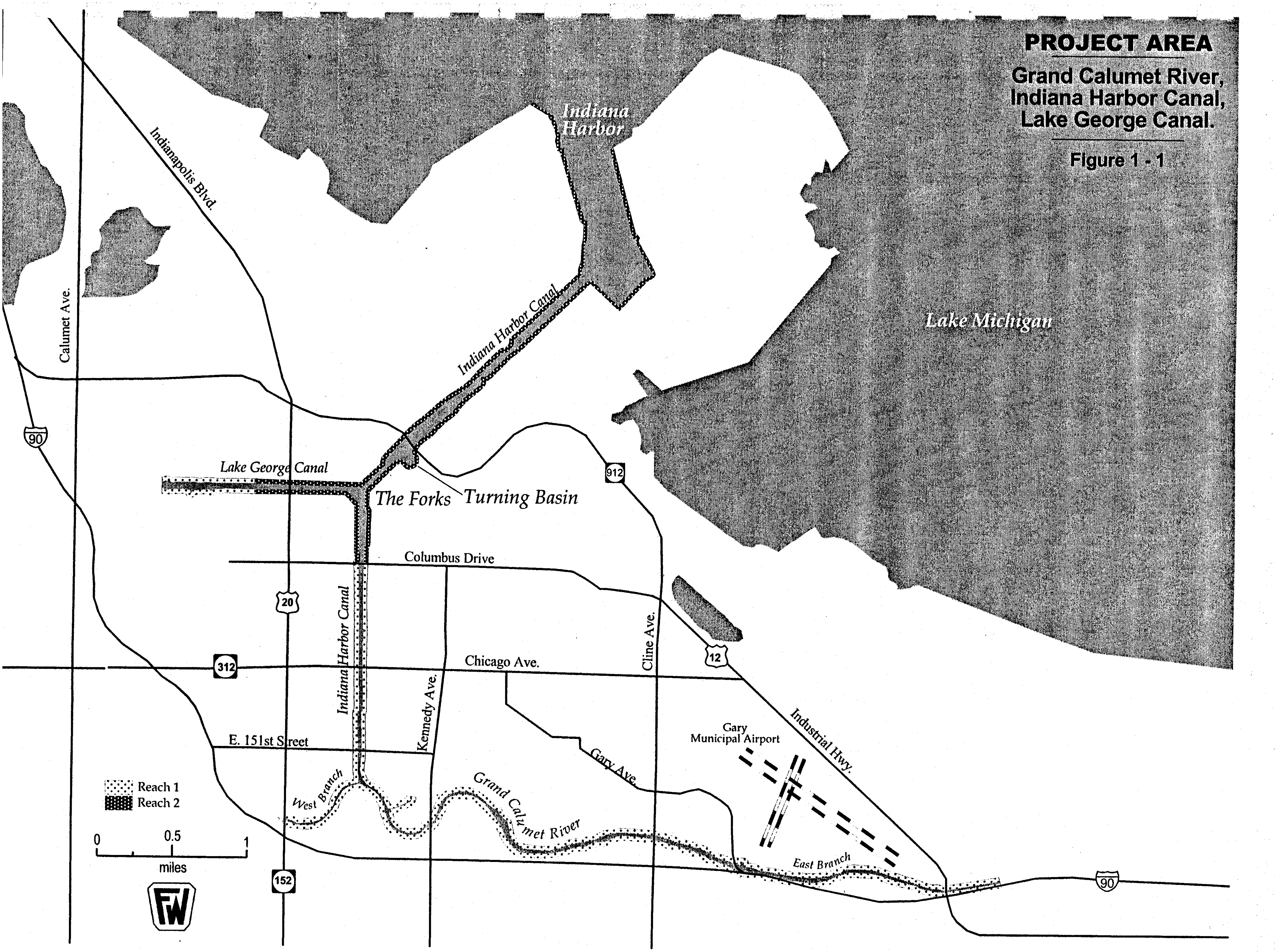
In addition to the relocation of the river channel, several sections of the river have been dredged to either facilitate commercial navigation or enhance the discharge capacity of the river. Most of the previous dredging efforts took place in the EBGCR east of Bridge Street in Gary, Indiana. No previous dredge efforts are known to have taken place in the portion of the GCR evaluated in this report. However, in 1966 and 1967, the U.S. Army Corps of Engineers (USACE) removed more than 293,000 cubic yards (cy) of sediment from the IHC, and in 1972, another 112,500 cy were removed from the same area.

1.4. REPORT ORGANIZATION

In addition to this introduction, the following sections are included in the report:

- Section 2, Physical Setting of the Project Area, describes the river and canal system, the industries along the banks of the river and canal, and the reaches evaluated in this report.
- Section 3, Sediment Properties, summarizes the data and information from prior studies regarding sediment contamination and other pertinent characteristics.
- Section 4, Potential Sediment Remediation Technologies, summarizes a compendium of technologies and their attributes from which appropriate alternatives will be selected.
- Section 5, Screening of Sediment Remediation Technologies, systematically reviews the technologies in Section 4, eliminates unfeasible ones, and retains those that show potential to address the site conditions.
- Section 6, Development of Detailed Restoration Alternatives, uses the technologies retained from Section 5 in appropriate combinations to address several alternatives for sediment management.
- Section 7, Evaluation of Restoration Alternatives, describes the application of each alternative to an entire reach and accounts for costs to implement the alternative.
- Section 8, Application of Restoration Alternatives Within Project Reaches, may be prepared and submitted at a later date.
- Section 9, References, provides the references used to prepare this report.
- Appendix A provides the site bibliography.

- Appendix B contains the bathymetry plan and profiles.
- Appendix C describes the applicable dredge technologies.
- Appendix D provides the outline for the monitoring program work plan.
- Appendix E describes the evaluation criteria.
- Appendix F provides the GCR/IHC/LGC dredge prism volumes.
- Appendix G includes the dredging cost estimate.


PROJECT AREA
Grand Calumet River,
Indiana Harbor Canal,
Lake George Canal.
Figure 1 - 1
Indiana Harbor
Lake Michigan
Indianapolis Blvd.
Calumet Ave.
Indiana Harbor Canal
Lake George Canal
The Forks
Turning Basin
912
90
20
312
12
152
Columbus Drive
Chicago Ave.
Cline Ave.
Kennedy Ave.
E. 151st Street
Gary Ave.
Industrial Hwy.
Gary Municipal Airport
West Branch
Grand Calumet River
East Branch
Reach 1
Reach 2
0
0.5
1
miles
FW

2.0 PHYSICAL SETTING OF THE PROJECT AREA

The GCR is located on a lacustrine plain bordering the southern shore of Lake Michigan. The topography was originally shaped by post-glacial forces including wind, erosion, lake recession, and fluvial development. The low-relief plain consists of a series of sand dune ridges and swales overlying a low-permeability till. Soil profiles are thin except in the swale marshes. The drainage network of the Grand Calumet basin has been severely modified from industrialization along the river. The river is now only 13 miles long and is divided into east and west branches at the confluence with the IHC. The western 5 miles of the east branch and the eastern 1,600 feet of the western branch of the GCR are found in the project area. The natural flow of the river has actually been reversed with construction of the IHC. Much of the dune topography along the river has been filled or graded flat for transportation, industrial, or urban uses. Elevation of the flat industrial land averages about 585 feet above NGVD29.

The conditions in the project area have been heavily influenced by the combination of locally heavy use and the attributes of the natural surroundings. The current contamination of the GCR results from long-term releases by the various industries that have modified and used the river system for wastewater discharge and drainage.

2.1. WATERWAY SETTINGS

In the hydrologic hierarchy of the USGS, the GCR is a subdivision of the Little Calumet-Galien Drainage Basin (Hydrologic Basin No. 04040001). The river/canal system has two streamflow recording stations operated by the USGS. The furthest upstream gage (No. 04092677) is located on the south bank of the GCR near the Industrial Highway bridge, southeast of the Gary airport. The gage includes a water-stage recorder and acoustic doppler velocity meter. The second streamflow gage is located on the east bank of the IHC, 1,200 feet downstream of the Dickey Road bridge. This gage also consists of a water-stage recorder and an acoustic doppler velocity meter. Both gages have been operating since October 1991.

Flow in the river is governed by water levels in Lake Michigan and flows into the river/canal system. Water levels in Lake Michigan, which regulate the base level of the river/canal system at its mouth, are governed by climatic conditions in the Great Lakes Basin. Long-term fluctuations (over a period of several years) are in response to climate fluctuations. Years of low rainfall are followed by low lake levels and, conversely, high rainfall years yield an increase in lake levels. Lake levels also fluctuate seasonally. In the 81 years of record, Lake Michigan has fluctuated between a March low of 576.05 feet relative to the International Great Lakes Datum (IGLD) and an October high of 582.35 feet IGLD, with a mean elevation of 579.02 ±1.28 feet IGLD (Exponent 1999). High lake levels decrease the water surface slope in the river/canal system and tend to slow the flow in the GCR/IHC/LGC. Slower flows favor sediment deposition from the water column and diminished erosion. Conversely, lower lake levels increase the surface water slope and promote relatively more erosion and less deposition with enhanced sediment transport.

Flows in the river/canal system are strongly influenced by industrial discharges with relatively lesser effects from storm events. Over the last 5 years, the mean flow in the EBGCR has been 513 cubic feet per second (cfs), with a range from 473 to 592 cfs. The highest instantaneous recording was 891 cfs, which represents a 5-year flood flow (Exponent 1999). Estimated flood flows are 2,220 cfs for a 10-year flood; 2,720 cfs for a 50-year flood; and 2,895 cfs for a 100-year flood. Major point-source contributors to flow (about 90 percent) in the EBGCR are the USX and the Gary sewage treatment plant.

River and canal banks of the GCR/IHC/LGC system, in decreasing order of occurrence, are characterized by:

- Natural marshes
- Riprap slopes
- Wood-crib or steel sheet-pile walls
- Bridge abutments

Natural marsh banks are characterized by low, moderately sloping banks covered with grasses and low-lying shrubs. Riprap slopes are generally steep banks covered with rock to protect transportation corridors. The wood-crib and steel sheet-pile walls are found along the north shore of LGC. Bridge abutments vary in architecture and accessibility throughout the project area.

2.2. DESCRIPTION OF PROJECT AREA REACHES

The project area is divided into two reaches: Reach 1—GCR/IHC/LGC and Reach 2—Federal Project. The reaches are described below.

2.2.1. Reach 1—Grand Calumet River/Indiana Harbor Canal/Lake George Canal

The EBGCR begins at the west edge of the Conrail railroad bridge (GCR station 0+00 on the drawings) southeast of the Gary, Indiana, airport and meanders west. At station 263+80, the EBGCR joins the WBGCR and the IHC. The WBGCR extends from the juncture at station 263+80 and extends west to the Indianapolis Boulevard bridge at station 296+04. From the juncture at GCR station 263+00/IHC station 0+00, the IHC extends north to the upper limit of the Federal Project at the Columbus Drive bridge and IHC station 78+10. The LGC stationing begins (LGC station 0+00) at the intersection with the centerline of the IHC and extends west. The boundary of the LGC project area begins at the upper limit of the Federal Project at LGC station 37+00 and ends at the upper end of the canal at LGC station 71+39.

Industry or property owners along Reach 1 include the following, in alphabetical order:

- AMG Resources/Vulcan Industries
- Amoco/British Petroleum (BP)
- Dupont East Chicago Facility
- East Chicago Sanitary District
- East Chicago Waterway Management District
- Gary Development Corporation Landfill
- Gary Municipal Airport
- Gary Sanitary District
- General American Transportation Corporation (GATX) (formerly Union Tank Car)
- Georgia Pacific
- Harbison Walker Refractories
- Indiana East-West Tollroad (Interstate 90)
- Mobil Oil
- Northern Indiana Public Service Company (NIPSCO) (formerly Northern Indiana Gas & Electric)
- Phillips Pipeline
- Shell Oil
- U.S.S. Lead

2.2.2. Reach 2—Federal Project

Reach 2—Federal Project includes the federal channel from the upper limit of the Federal Project in the IHC at the Columbus Drive bridge (141st Street) downstream to the Indiana Harbor and the federal channel in the LGC from the upper end of the Federal Project at approximately mile 2.15 (the west boundary of the Energy Cooperative, Inc. property) to the intersection with the IHC.

Industry or property owners along Reach 2 include the following (in alphabetical order):

- Amoco/BP
- Inland Steel
- LTV Steel (formerly American Steel)
- Mobil Oil
- NIPSCO
- Phillips Pipeline
- Safety Kleen
- U.S. Gypsum

3.0 SEDIMENT PROPERTIES

This report characterizes the sediments in the GCR/IHC/LGC system using sampling data summarized by MacDonald et al. (2000a) in their sediment injury assessment. Surface and subsurface sediment samples collected by Floyd Browne Associates (1991) and Maxim Technologies (1999) were the key data used in that report. These samples were taken over the last 10 years and cover the entire project area. The test hole locations are shown in Figure 3-1.

3.1. PHYSICAL SEDIMENT PROPERTIES

The sediments found in the GCR/IHC/LGC system consist of recent industrial-derived deposits overlying native river deposits. The native river deposits are incised on a landscape derived from a receding lakeshore over a formerly glaciated region. The area is referred to as the Calumet Lacustrine Plain. The GCR/IHC/LGC basin consists of sand dunes and swales overlying till of the Wisconsin glacial period. The till overlies Silurian age limestone and dolomite.

Sediments in the river/canal system vary by location and depth. Three distinct layers can be identified in the test holes. The top 1 to 15 feet consists of oily fine to medium sand with a mild- to strong-petroleum odor. The middle layer ranges from 2 to 5 feet thick of nonnative silty fine sand to silt. The bottom layer is native fine to medium sand with some shell fragments. The bottom layer may vary from 20 to 50 feet thick and is composed of lacustrine sand.

The GCR/IHC/LGC sediment is classified as nonplastic. Moisture content ranges from 18 to 77 percent. Bulk density of the sediment ranges from 1.15 to 2.04 grams per cubic centimeter.

3.2. SEDIMENT QUALITY CRITERIA

The following is a synopsis of the information contained in MacDonald et al. (2000a).

Sediment injury in the project area was assessed using the consensus-based sediment-effect concentrations (SECs) developed by Ingersoll and MacDonald (1999) and MacDonald et al. (2000b). As the term implies, consensus-based SECs reflect the agreement among the various sediment quality guidelines (SQGs) by providing an estimate of their central tendency. The consensus-based SECs provide a unifying synthesis of the existing SQGs, reflect causal rather than correlative effects, and account for the effects of contaminant mixtures in sediment (Swartz 1999; MacDonald et al. 2000b, 2000c).

Ingersoll and MacDonald (1999) derived two consensus-based SECs for each contaminant of concern (COC) in the WBGCR, including threshold effect concentrations (TECs) and probable effect concentrations (PECs). The PECs are intended to identify the concentrations of contaminants in whole sediments above which adverse effects are likely to be observed. The SECs for most of the COCs in the project area, including metals (arsenic, cadmium, copper, chromium, lead, nickel, and zinc), total polycyclic aromatic hydrocarbons (PAHs), various individual PAHs, total polychlorinated biphenyls (PCBs), and dichlorodiphenyldichloroethylene (DDE), provide a reliable basis for predicting the presence and absence of sediment toxicity in field-collected sediments (Ingersoll and MacDonald 1999, MacDonald et al. 2000c, EPA 2000). Limited data were available to thoroughly evaluate the PECs for mercury, certain PAHs, and several pesticides (MacDonald et al. 2000b); however, these additional PECs were used in this report to assess sediment quality conditions in the project area.

The consensus-based PECs are used as primary benchmarks for assessing injury to sediments and sediment-dwelling organisms. The PECs were used in two ways to support the assessment of sediment injury within the project area. First, the measured concentrations of each substance in whole sediment samples were compared to the corresponding PEC for that substance to determine if it was present at concentrations that cause or substantially contribute to sediment injury. Second, the PECs were used to support the calculation of mean PEC-quotients (PEC-Qs) for each sediment sample that was collected within the project area. The mean PEC-Q provides a basis for assessing the potential effects of sediment-associated contaminants when they occur in complex mixtures (Swartz 1999; MacDonald et al. 2000b, 2000c; EPA 2000).

Mean PEC-Qs were calculated using the procedure recommended by EPA (2000). Using this methodology, a PEC-Q was first determined for each metal for which a reliable PEC was available (as identified in MacDonald et al. 2000b). Then, an average PEC-Q for metals was calculated by summing the PEC-Qs of each metal and dividing by the number of metals that were included in the calculation. PEC-Qs were also calculated for total PAHs and total PCBs. Finally, the mean of the average PEC-Qs for metals, PAHs, and PCBs was determined for each sediment sample (termed the mean PEC-Q). The PEC-Qs for pesticides were not included in this calculation to assure that the mean PEC-Q reflected the concentrations of the primary COCs in the project area. It was not possible to include PEC-Qs for alkanes or alkenes in this calculation because PECs were not available for these classes of petroleum hydrocarbons. The PEC for total PAHs, rather than the PECs for individual PAHs and total PAHs, was used to calculate the mean PEC-Q to avoid double counting the PAH concentration data.

The EPA (2000) reported that the incidence of toxicity to freshwater amphipods is genreally less than 20 percent at mean PEC-Qs less than 0.1 and increases with increasing levels of sediment contamination. If virtual elimination of sediment toxicity and restoration of the benthic invertebrate community were primary restoration goals, then target clean-up levels for sediments might be in the order of 0.25 for mean PEC-Qs. Such a level of sediment contamination would be predicated to be associated with approximately 20 percent incidence of toxicity to freshwater amphipods (EPA 2000).

EPA (2000) also reported that sediment samples with mean PEC-Qs greater than 0.7 are more likely than not to be toxic to sediment-dwelling organisms (i.e., the incidence of toxicity to amphipods, in 28-day tests, was greater than 50 percent in sediment samples that had these chemical characteristics). In 10- to 14-day tests, the incidence of toxicity to amphipods was high (i.e., greater than 50 percent) when mean PEC-Qs exceeded 4.0 in sediment samples (EPA 2000). Because sediment dwelling organisms are likely to be exposed to contaminated sediments for extended periods of time (i.e., greater than 30 days), sediments with mean PEC-Qs greater than 0.7 were considered to be sufficiently contaminated to injure sediment-dwelling organisms. Therefore, a mean PEC-Q of 0.7 was the value selected to determine whether or not injury to sediment-dwelling organisms is likely to have occurred.

3.3. RESULTS OF SEDIMENT SAMPLING

The following is a synopsis of the information contained in MacDonald et al. (2000a).

The spatial extent of sediment injury was evaluated by linking the sediment chemistry and sediment toxicity information in the project database with global information system (GIS)-based applications. The evaluation was conducted using dry weight concentrations of chemical contaminants. To facilitate spatial analyses of these data, the project area was divided into several segments, or reaches, and each reach was divided into a number of sub-reaches using readily identifiable landmarks (e.g., railway bridges, roadway bridges, major streets, etc.). Sediment chemistry and sediment toxicity data were used as the primary indicators of sediment injury. As described above, because sediment-dwelling organisms are likely to be exposed to contaminated sediments for extended time periods (i.e., longer than 30 days), the spatial extent of sediment injury within the project area was evaluated based on a mean PEC-Q greater than or equal to 0.7. River segments and reaches with two or more sediment samples (separated by more than 100 feet) with elevated levels of sediment-associated contaminants (as indicated by PEC-Q of greater than or equal to 0.7) were considered to have been injured by discharges of oil or releases of other hazardous substances. The results of the toxicity tests and benthic invertebrate community assessments were used to corroborate the assessment of the extent of sediment injury that was conducted using the sediment chemistry data.

The project area identified for this report includes the EBGCR, WBGCR, IHC, and LGC. The evaluation of harmful effects of sediment-associated contaminants (based on a weight-of-evidence approach) demonstrates that sediments throughout the project area have been injured due to discharges of oil or releases of other hazardous substances. The levels of metals, PAHs, PCBs, un-ionized ammonia, and phenols in whole sediments, pore water, and/or fish tissues were sufficient to cause or substantially contribute to the injury of sediments, sediment-dwelling organisms, and/or fish and wildlife resources (Tables 3-1 and 3-2). In surficial sediments, the mean PEC-Q in the WBGCR was 29.5 and 14.0 for the EBGCR. Slightly lower levels of contamination were reported for the IHC (mean PEC-Q of 5.2) and LGB (mean PEC-Q of 4.3).

Levels of chemical contamination in subsurface sediments were somewhat lower than those observed in surficial sediments (Table 3-3). Mean PEC-Qs for subsurficial sediments were calculated for the EBGCR (12.7), the WBGCR (4.8), IHC (3.9), and LGB (5.5). These mean PEC-Qs all exceed 0.7, the level of contamination used to define sediment injury. The areal extent of sediment injury in the surface and subsurface sediments are shown in Figures 3-1 and 3-2).

Table 3-1. Summary of Assessment of Sediment Injury to Sediment-Dwelling Organisms[1]

Reach/Segment	Indicator of Sediment Injury to Sediment-Dwelling Organisms[2]				Number of Lines of Evidence for Demonstrating Injury to Sediment-Dwelling Organisms
	Sediment Chemistry[3]	Pore Water Chemistry[4]	Sediment Toxicity[5]	Benthic Community[6]	
East Branch Grand Calumet River	83% (*n* = 269)	55% (*n* = 20)	73% (*n* = 44)	100% (*n* = 14)	4
West Branch Grand Calumet River	90% (*n* = 31)	100% (*n* = 2)	100% (*n* = 2)	100% (*n* = 3)	4
Indiana Harbor Canal	89% (*n* = 36)	60% (*n* = 5)	80% (*n* = 5)	100% (*n* = 6)	4
Lake George Branch	82% (*n* = 33)	83% (*n* = 6)	57% (*n* = 7)	100% (*n* = 4)	4
Overall	84% (*n* = 369)	64% (*n* = 33)	73% (*n* = 58)	100% (*n* = 27)	4

Notes:

[1] Data from MacDonald et al. (2000a).
[2] For each line of evidence, sediment injury is indicated if two or more samples have conditions sufficient to cause or substantially contribute to sediment injury.
[3] Percent of sediment samples with mean PEC-Qs of $\geq$ 0.7.
[4] Percent of pore water samples with chemical concentrations greater than published toxicity thresholds.
[5] Percent of sediment samples that are toxic to aquatic organisms in laboratory tests.
[6] Percent of samples with altered benthic invertebrate community structure.
n = number of samples.

Table 3-2. Summary of the Distribution of Mean PEC-Qs in Surficial Sediments in the Project Area[1] Page 1 of 2

Reach Segment	Number of Samples	Average of Mean PEC-Q	Minimum Mean PEC-Q	Maximum Mean PEC-Q	10th Percentile	90th Percentile	Median
East Branch Grand Calumet River							
EB and WB Confluence to Kennedy Avenue	29	8.34	0.1120	77.4	0.255	25.90	2.88
U.S.S. Lead Canal	17	27.70	3.6000	72.6	5.450	65.30	13.00
Kennedy Avenue to Cline Avenue	51	7.20	0.4570	58.2	1.200	12.30	4.61
Cline Avenue to Cline/ I-90 Ramps	15	4.59	0.1040	12.1	1.310	7.29	3.73
Cline/I-90 Ramps to Industrial Highway	21	28.90	0.7100	184.0	2.120	45.40	5.94
Industrial Highway to ConRail Bridge	12	36.80	1.9200	357.0	2.240	18.90	3.58
EB Wetland	17	3.99	0.0655	15.7	0.208	6.88	3.23
Overall	**162**	**14.00**	**0.0655**	**357.0**	**0.875**	**30.30**	**4.58**
West Branch Grand Calumet River							
EB and WB Confluence to Indianapolis Blvd.	**19**	**29.5**	**1.13**	**231**	**1.35**	**56.9**	**11.7**
Indiana Harbor Canal							
EB and WB Confluence to 151st Street	7	5.440	2.100	10.400	2.100	8.21	4.85
151st Street to Chicago Avenue	10	3.000	0.191	8.840	0.191	7.19	2.29

Table 3-2. Summary of the Distribution of Mean PEC-Qs in Surficial Sediments in the Project Area[1] Page 1 of 2

Reach Segment	Number of Samples	Average of Mean PEC-Q	Minimum Mean PEC-Q	Maximum Mean PEC-Q	10th Percentile	90th Percentile	Median
Chicago Avenue to Columbus Drive	12	7.290	1.090	25.900	1.690	11.50	5.34
IHC Wetland	1	0.718	0.718	0.718	NA	NA	NA
Overall	**30**	**5.210**	**0.191**	**25.900**	**0.491**	**10.40**	**4.08**
Lake George Branch							
Indianapolis Blvd. to B&O Railroad Bridge	7	4.81	1.7500	14.50	1.7500	6.0	2.910
B&O Railroad Bridge to Fill Area	4	13.90	3.1300	31.50	3.1300	16.4	10.500
Lake George Wetlands	12	0.87	0.0786	1.67	0.0916	1.6	0.729
Overall	**23**	**4.33**	**0.0786**	**31.50**	**0.4840**	**6.0**	**1.670**

Notes:

[1] Data from MacDonald et al. (2000a)
NA = not applicable

Table 3-3. Summary of the Distribution of Mean PEC-Qs in Subsurface Sediments in the Project Area[1] Page 1 of 2

Reach Segment	Number of Samples	Average of Mean PEC-Q	Minimum Mean PEC-Q	Maximum Mean PEC-Q	10th Percentile	90th Percentile	Median
East Branch Grand Calumet River							
EB and WB Confluence to Kennedy Avenue	18	3.510	0.0692	13.100	0.1930	8.30	2.77
U.S.S. Lead Canal	9	24.200	5.6400	80.800	5.6400	54.40	12.10
Kennedy Avenue to Cline Avenue	54	16.900	0.0286	497.000	0.0887	16.90	3.06
Cline Avenue to Cline/ I-90 Ramps	7	1.470	0.0555	4.200	0.0555	2.63	1.21
Cline/I-90 Ramps to Industrial Highway	12	3.550	0.0847	13.600	0.1230	5.50	2.78
Industrial Highway to ConRail Bridge	6	18.600	0.5930	99.100	0.5930	5.15	2.98
EB Wetland	1	0.627	0.6270	0.627	NA	NA	NA
Overall	**107**	**12.700**	**0.0286**	**497.000**	**0.1070**	**16.90**	**2.98**
West Branch Grand Calumet River							
EB and WB Confluence to Indianapolis Blvd.	12	4.8	0.139	13.7	0.368	8.8	3.77
Indiana Harbor Canal							
EB and WB Confluence to 151st Street	4	2.90	0.434	4.36	0.434	4.12	3.41
151st Street to Chicago Avenue	0	NA	NA	NA	NA	NA	NA

Table 3-3. Summary of the Distribution of Mean PEC-Qs in Subsurface Sediments in the Project Area[1] Page 1 of 2

Reach Segment	Number of Samples	Average of Mean PEC-Q	Minimum Mean PEC-Q	Maximum Mean PEC-Q	10th Percentile	90th Percentile	Median
Chicago Avenue to Columbus Drive	2	5.87	2.090	9.64	NA	NA	NA
IHC Wetland	0	NA	NA	NA	NA	NA	NA
Overall	**6**	**3.89**	**0.434**	**9.64**	**0.434**	**4.36**	**3.41**
Lake George Branch							
Indianapolis Blvd.to B&O Railroad Bridge	3	5.8800	2.6600	11.8000	2.6600	3.19	3.1900
B&O Railroad Bridge to Fill Area	6	6.1500	0.3670	14.2000	0.3670	9.87	5.4000
Lake George Wetlands	1	0.0457	0.0457	0.0457	NA	NA	0.0457
Overall	**10**	**5.4600**	**0.0457**	**14.2000**	**0.0457**	**11.80**	**3.2000**

Notes:

[1] Data from MacDonald et al. (2000a)
NA = not applicable

Figure 3-1. Areal Extent of Injury to Surface Sediments in the Project Area (adopted from MacDonald 2000)

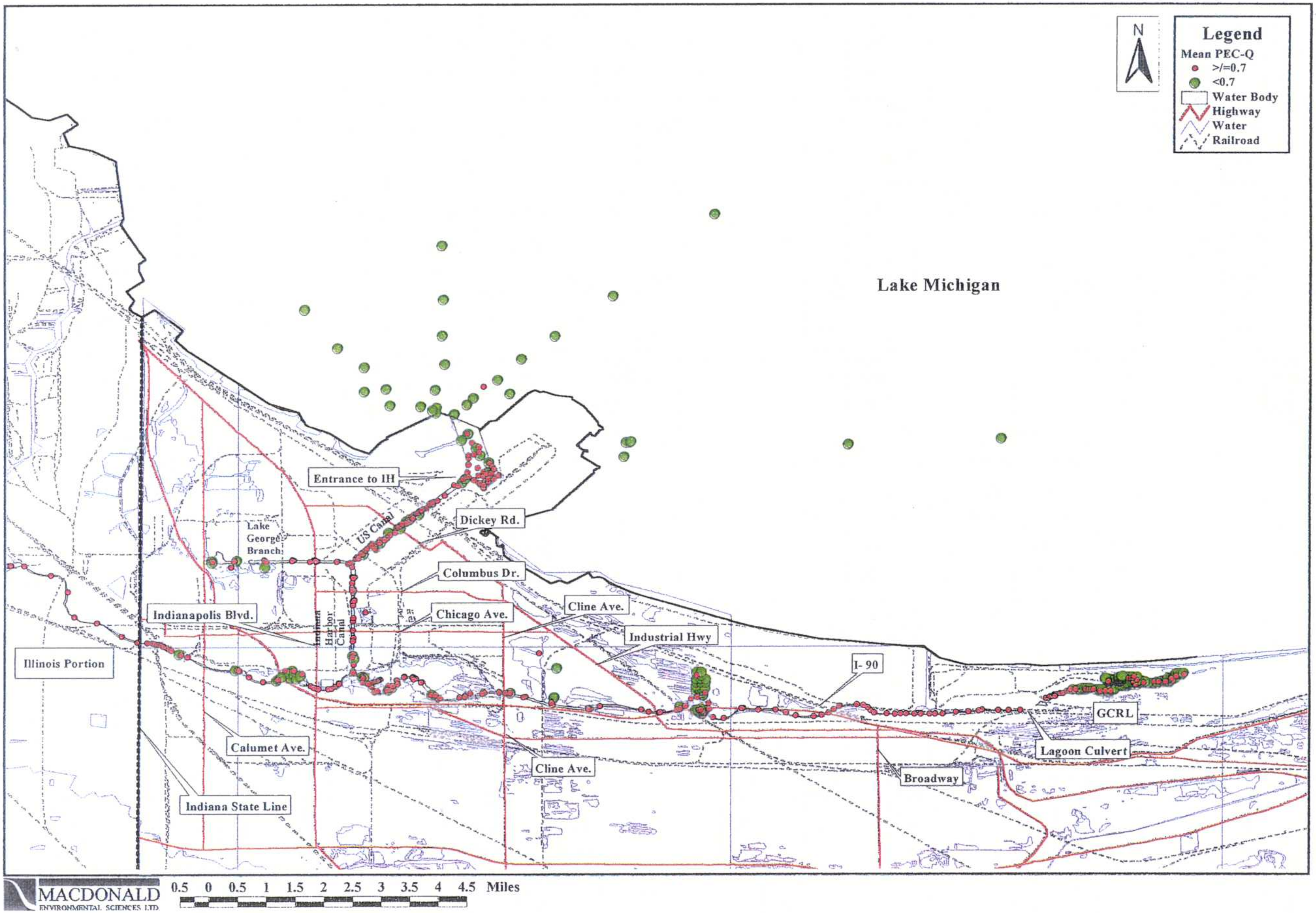
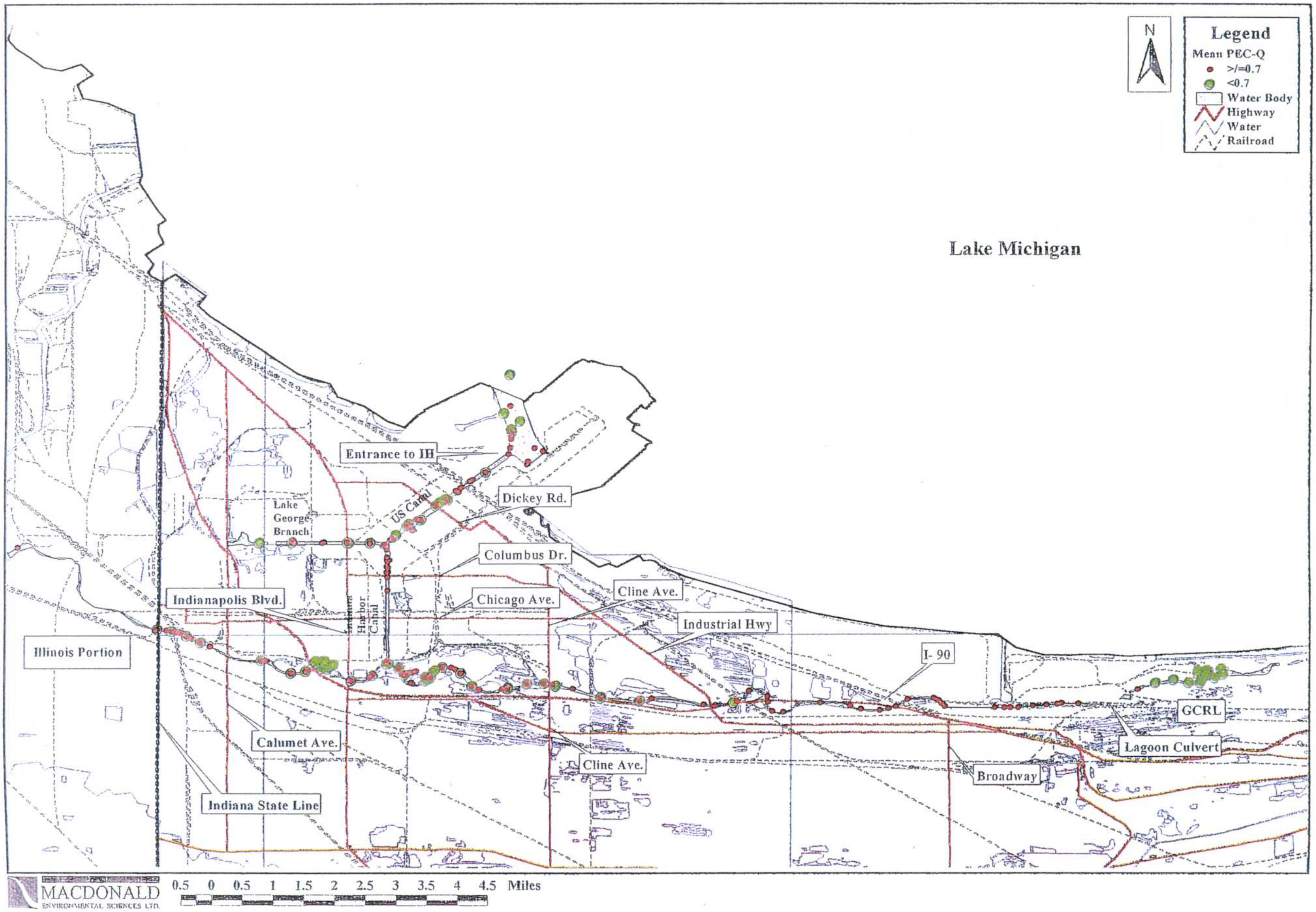


Figure 3-2. Areal Extent of Injury to Sub-Surface Sediments in the Project Area (adopted from MacDonald 2000)



4.0 POTENTIAL SEDIMENT REMEDIATION TECHNOLOGIES

The following section presents a variety of technologies that have been developed to remediate contaminated sediments. These technologies were investigated for their applicability to the GCR/IHC/LGC and include natural recovery, dredging, in-place capping, sediment disposal, and sediment treatment. The primary aspects of these technologies are discussed below and are summarized in Table 4-1. The advantages and disadvantages of these technologies are discussed in Section 5 along with a determination of whether or not they are viable options for use on the GCR/IHC/LGC. The viable options are then carried forward to Section 6 for development into restoration alternatives.

4.1. NATURAL RECOVERY

Natural recovery of contaminated sediments is a technology by which the magnitude and extent of contamination in the upper sediment layers are reduced over a period of time following significant reduction or elimination of contaminant sources. Natural recovery consists of a combination of natural processes (e.g., biodegradation and transformation, dispersion, dilution, sorption, volatilization, and sediment deposition) to improve sediment quality. These technologies and their potential effects are discussed qualitatively in the following subsections.

4.1.1. Biodegradation and Transformation

Biodegradation utilizes naturally occurring organisms (i.e., bacteria, fungi, and enzymes) to transform PCBs, pesticides, and other organic constituents into less harmful end products. However, if degradation is incomplete, end products may include compounds considered more toxic than the original COCs. For example, when sufficient oxygen is present in a river system, aerobic decomposition may take place, producing stable end products such as carbon dioxide, water, and nitrate. However, when oxygen is unavailable, anaerobic decomposition may produce objectionable end products such as hydrogen sulfide and methane. In most river systems, natural mixing keeps dissolved oxygen levels high enough to prevent anaerobic decomposition. The effectiveness of biodegration in transforming contaminants into harmless end products depends on the type of microbial organisms present as well as the amount of oxygen available.

4.1.2. Dispersion

Dispersion is the natural process in which the COC concentrations in a given area are lowered as the COC plume spreads out to cover a wider area than it originally covered. Dispersion does not destroy COCs within a system. For example, COCs spread out by moving with river water or groundwater through pore spaces in the sediment. The rate of dispersion through sediment depends on the velocity of water flowing through the sediment as well as the molecular weight of the COCs present. Dispersion often results in an irregular plume of contamination because velocities and pore spaces vary within a system. Contaminants that do not dissolve in water are called non-aqueous-phase liquids. Dense non-aqueous-phase liquids (DNAPLs), like PCBs and carbon tetrachloride, tend to sink through sediment and disperse at a much slower rate than light non-aqueous phase liquids (LNAPLs), which float above the river and groundwater. LNAPLs, including most fuel hydrocarbons, are carried downstream at the same velocity as the moving water.

4.1.3. Dilution

Dilution is the process in which COC concentrations are decreased by the contaminants mixing with river/canal water. Dilution can lower the concentration of COCs in a river system below the critical levels but does not destroy the COC within the system.

4.1.4. Sorption

Sorption is the combined process of chemicals becoming embedded within sediment and solids in the river and chemicals sticking to the outside of solid material particles. Sorption tends to lower the concentration of COCs in freely flowing water while increasing the contamination in sediment. Within river systems, both physical and chemical sorption can occur. Physical sorption refers to organic COCs joining with carbon compound solids; chemical sorption refers to inorganic COCs joining with clays through ion exchange. In general, sorption slows the remediation process as COCs become trapped in the sediment layer and are not carried downstream in the river water.

4.1.5. Volatilization

Volatilization is the process by which chemicals are transferred from a liquid to a gaseous state. For example, volatile organic compounds (VOCs) are so volatile that they are rarely found in concentrations above a few micrograms in surface water. However, concentrations in sediment can be much higher. The volatilization of VOCs happens readily in free-flowing waters of a river, but volatilizing VOCs from sediments depends on the depth of the river and the amount of mixing that occurs. Slow-flowing rivers may not provide the mixing needed to infuse enough air into the contaminated layers of sediment for adequate volatilization to occur.

4.1.6. Sediment Deposition

Another type of natural recovery process in a river system is the deposition of clean sediments along the river bottom. Sediment originally becomes contaminated as COCs adsorb to fine-grained particles in the river water and eventually settle to the bottom of the waterway. In turbulent rivers, contaminated sediment can be remobilized by erosion and pose a threat to river wildlife. After the contaminant source is removed, clean sediment will begin to form a layer over the contaminated areas. Given time, this layer may prevent contaminants from dissolving back into the river system and provide a physical barrier between buried contaminants and river wildlife. The effectiveness of clean sediment deposition depends on the rate of sediment deposition as well as the contaminant levels in upstream reaches where the sediment originates.

4.2. DREDGING TECHNOLOGIES

Dredging is a remediation technique used to remove material with COC concentrations in excess of remediation goals. When dredging, several site-specific characteristics must be considered, including the depth of the water column, volume of material to be removed, width and depth of the dredge cut, firmness of the sediment, and the presence of debris. Three types of dredging technologies, which are described below, include hydraulic dredging, mechanical dredging, and hybrid or specialty dredging.

4.2.1. Hydraulic Dredging

The main component of a hydraulic dredge is a pump used to move the dredged material. The pump is usually mounted on a barge, but may be located near the submerged excavating end of the dredge. A suction pipeline supplies the dredged material to the pump. A variety of dredging equipment is available for loosening and excavating the sediment at the suction end of the pipeline, including cutter head, bucket wheel, dustpan, auger, and hopper dredges. A discharge pipeline transports the material from the discharge end of the pump to an intermediate or final disposal site. Discharge can be immediately overboard (side casting), to a hold on the dredge, to a barge alongside, to the beach, or to shore. A brief description of some of the more common hydraulic dredges is provided in Appendix C.

4.2.2. Mechanical Dredging

A mechanical dredge uses some type of bucket to excavate the bottom material and raise it to the surface for disposal. Mechanical dredges are classified according to the size, style, and action of the bucket and how the bucket is connected to the dredge. Most mechanical dredges are mounted on barge hulls. Movement of the barge is by tug, walking spuds, or use of a winch on anchor cables. A brief description of some of the more common mechanical dredges is provided in Appendix C and include the clamshell, dragline bucket, backhoe, dipper, and bucket ladder dredges.

4.2.3. Hybrid or Specialty Dredging

Hybrid or specialty dredging technologies have developed in response to the demand for sediment remediation and environmental cleanup over the last decade. These dredges may combine aspects of both hydraulic and mechanical dredges. For example, the *Bonacavor* hybrid dredge combines a hydraulic pump with a mechanical backhoe. The dredges may be modified to meet specific project needs. A concise description of some of these new dredging technologies is provided in Appendix C and include the *Bonacavor* hydraulic excavator, the Amphibex and Aquarius amphibious dredges, the DRE Technologies Dry Dredge, the Elliott hydraulic dredge, IHC Holland Crawl Cat Cutter Suction Dredge, and a variety of low-ground-pressure track-mounted excavators.

4.3. IN-PLACE CAPPING TECHNOLOGIES

In-place capping is generally the most straightforward and least intrusive sediment remediation technique. The technique involves placing clean sediments or silty to gravelly sand over the areas of contaminated sediment. This prevents resuspension of problem sediment and reduces the risk of human or biotic contact with contaminated material. The issues generally associated with in-place capping include obtaining appropriate cap thickness over the entire area of contaminated sediment, placing the capping material without displacing sediment, and maintaining long-term cap integrity.

Several methods of cap installation exist to address these issues. The methods include:

- Surface release from barges—sediment is slowly released from a split-hull barge or pushed off the side of a barge moving slowly over the area of contaminated sediment.

- Submerged diffuser—capping material is pumped through a submerged hydraulic pipeline to the contaminated area. The submerged diffuser is then used to reduce the velocity at the point of contact, minimizing resuspension of contaminated sediments.

- Hydraulic washing—clean sediment is washed off a barge using large water hoses. This method allows capping material to fall onto the contaminated area in a controlled manner, reducing resuspension and encouraging deposition of clean material on top of, rather than displacing, fine, soft creek sediments. Hydraulic washing has been used effectively in shallow water where bed material was predominantly sandy silt and silty sand.

- Hydraulic pipeline with baffle box—much like a submerged diffuser, a baffle box works to reduce the velocity of pumped sediment. However, the baffle box works with a floating pipeline and allows the capping material to fall slowly through the water column.

- Direct mechanical placement—a mechanical dredging device such as a clamshell or backhoe is used to place capping material near the bed surface.

There are two different forms of capping: thick capping and thin capping.

4.3.1. Thick Capping

Thick capping follows dredging (3-foot dredge prism) and returns dredged areas back to grade and, in the process, isolates areas of contaminated sediment and establishes conditions for the creation of a new benthic habitat. At least 3 feet of clean material would be used for a thick cap, which is the deepest bioturbation exhibited by benthic systems. The thickness of the cap and capping material would be determined during design. Total thickness would be comprised of components for bioturbation, consolidation, erosion, operational considerations, and chemical isolation. The performance of the cap would be monitored for physical and chemical isolation of contaminated sediments and for recovery of the benthic system. Physical monitoring activities may include bathymetry, sub-bottom profiles, side-scan sonar, and sediment profile imaging to assess cap integrity. Chemical monitoring activities may include surface grab samples and subsurface cores to assess contaminant migration. Biological monitoring activities may include benthic community evaluation and sediment toxicity tests to evaluate the effectiveness of the cap at reducing toxicity to sediment-dwelling organisms.

4.3.2. Thin Capping

Thin capping, also known as enhanced natural recovery, is often used where hazards presented by contaminated sediment to human health and the environment is low. Thin capping improves the chemical or physical properties of the upper riverbed, which constitute the biologically active zone. Thin capping typically has a target thickness of 1 foot. The cap material would be determined during design. The added material supplements natural sedimentation and enhances the natural recovery process, producing variation in the coverage depths and allowing for considerable mixing between the contaminated and clean layers. The result is a riverbed consisting of mounds of clean material and areas where no cap is evident. Enhanced natural recovery has been successfully applied to the West Harbor Operable Unit of the Wycoff/Eagle Harbor Superfund Site located off of Banbridge Island, Washington (Verduin et al. 1998).

4.4. SEDIMENT DISPOSAL

If dredging is deemed the best alternative for remediation of the contaminated sediment, a site(s) must be chosen for disposal of any dredged material. Consideration must be given to the available geographic alternatives as well as the characteristics of the contaminated sediment when choosing a site. Three options for confined disposal are considered in the following subsections: upland or off-site confined disposal, nearshore confined disposal, and confined aquatic disposal (CAD).

4.4.1. Upland or Off-site Confined Disposal Facilities

For upland or off-site confined disposal facilities (CDFs), contaminated sediment is transported to an adjoining upland site or a permitted off-site disposal area. The goal of off-site disposal is to eliminate contact between contaminated sediment and the water body. Before placing the contaminated sediment at the disposal site, a confinement zone must be built to prevent contaminants from leaking into adjacent soil or groundwater. The confinement zone may include a thin clay layer or thick plastic sheets on the bottom of the containment area. Dikes or a low structural wall may be constructed around the perimeter of the containment area to retain the dredged sediment and the supernatant water. The supernatant water usually requires treatment before it can be released back into the river/canal system or into a local storm water/wastewater system. A typical effluent treatment system could likely be mounted on three flat-bed trailers. After completion of effluent treatment at one stockpile/dewatering site, it could then be transported and set up at another site. A minimum of two systems would be required—one for the CDF in use and one for the CDF under construction.

4.4.2. Nearshore Confined Disposal Facilities

Nearshore confined disposal facilities (NCDFs) are constructed adjacent to the waterway. The contaminated sediment is confined using retaining dike structures that extend out of the water. Retaining structures typically consist of sheet piling or berms constructed from sand, sandy gravel, or other fills. Finer grained material is placed in the core of the berm to limit the movement of soluble contaminants out of the containment zone. Sediment is placed adjacent to the bank using a hydraulic pipeline or through direct mechanical placement. After placing all the contaminated material, the NCDF is capped. Constraints on berm and sheet pile construction as well as impacts to the channel configuration must be carefully considered during the design phase of an NCDF. Loss of contamination from an NCDF occurs through movement of groundwater through the contaminated fill and capping material caused by cover action, rainfall, or settling.

4.4.3. Confined Aquatic Disposal

In CAD, dredged material is placed in a confined, underwater site that is then capped to prevent further exposure of human and ecological receptors to the contaminants. One method is to place the dredged material in a mound at the bottom of the disposal site and then place a layer of capping material over the contaminated mound. Another method is to construct a confining berm to contain the submerged and capped sediment. When using CAD site capping, the same issues must be considered as with in-place capping containment: obtaining sufficient cap thickness over the entire area, placing the capping material without displacing the contaminated sediment, and ensuring the long-term integrity of the confinement zone. The CAD site location is also critical, because the site must be deep enough not to impede water traffic.

In CAD, the supernatant water overflows from the confined disposal area and passes through an effluent treatment system. The effluent treatment system usually consists of a dissolved air flotation (DAF) treatment system. The DAF treats a variety of contaminants, from petroleum to heavy metals to DNAPLs. DAF treatment consists of a chemical mixing tank, to which chemicals that promote precipitation and flocculation would be added. This is followed by the dissolved air tank, which would float contaminants to the surface. Contaminants are skimmed from the surface, dewatered, treated, and/or disposed at a landfill. Bench testing of representative effluent would help define a cost-effective treatment system.

4.5. SEDIMENT TREATMENT TECHNOLOGIES

A variety of methods can be used to treat contaminated sediments. The method chosen depends on the characteristics of the sediment, the COCs that are present, and the concentrations of the COCs. Potential sediment treatment technologies and process options are the same as those used for upland solid waste (soil, sludge, slag, or debris). The main difference between river sediment and upland soil is that river sediments have much higher initial water content than upland soil. Before treating the sediment for specific COCs, dredged material often must be screened, dewatered, and consolidated. These processes are outlined below along with the common processes used to remove COCs.

4.5.1. Screening

Screening dredged material is done to meet removal, transport, treatment, or disposal requirements. Debris is removed using mechanical rakes or as part of the mechanical dredging process. During dredging operations, bulk solids are fed into a hopper. The materials then pass through screens, which remove material according to predefined size constraints. Once separated, rocks and boulders can often be steam-cleaned to remove contamination and are, therefore, managed separately from the remaining sediment.

4.5.2. Dewatering

Dewatering is the process of removing free surface water from dredged materials. Sediments may be dewatered for restoration alternatives that involve dredging and upland consolidation or as a pretreatment step. Dewatering methods include settling basins, clarifier tanks, or filter presses. The need for dewatering and the dewatering method chosen depends on the characteristics of the dredged sediment as well as the ultimate use or disposal of the material.

4.5.3. Consolidation

The goal of consolidation is to reduce the volume of wet dredged material by combining it with sediments or amendments. Consolidation is usually needed because the dredging process can entrain additional water in fine-grained sediment; this process is called bulking. The volume of bulked sediments will vary from 1.1 to 2.0 times the volume of consolidated sediments. To reduce transport, treatment, and disposal costs, it is usually desirable to dewater the wet sediment. This can be done using additives, such as fly ash, to remove the excess water from the dredged material.

4.5.4. Other Treatment Technologies

A total of 18 treatment technologies were investigated in connection with the disposal of potential dredged materials from Indiana Harbor as part of the Final Feasibility Report and Environmental Impact Statement conducted for the IHC (USACE/EPA Region V 1999). These technologies included the following:

- Solidification/stabilization
- Solvent extraction
- Incineration
- Wet air oxidation
- Polyethylene glycol dechlorination
- Supercritical water estraction
- Asphaltic encapsulation
- Pyrolysis
- Vitrification
- Biodegradation
- Steam stripping
- Enzyme degradation
- Composting
- Molten salt
- Ultraviolet (UV)/ozone
- Ozonation
- UV/hydrogen
- Metal extraction

Each technology was analyzed and evaluated based on safety, availability, reliability, processing rate, effectiveness/efficiency, specificity, process limitations, and other factors. The following four treatment technologies were selected as having the greatest potential for application to the IHC sediments: solidification/stabilization, solvent extraction, incineration, and wet air oxidation. Solidification/ stabilization is designed to provide physical immobilization with reduced accessibility of water by entrapment of contaminated solids in a hardened mass and chemical immobilization by alteration of the chemical form of contaminants so that they are less soluble and/or less leachable. Solvent extraction is the transfer of contaminants from a solid or a liquid to another liquid. Incineration uses high temperature thermal oxidation to convert organic wastes to ash and gaseous combustion products. Wet air oxidation is based on aqueous phase oxidation of contaminants at elevated temperatures and pressure. More detailed information pertaining to these technologies is included in USACE 1999.

Table 4-1. Potential Sediment Recovery Technologies **Page 1 of 4**

Remediation Technology	Attributes
Natural Recovery	
Biodegradation and Transformation	• Organic constituents are transformed into less harmful end products via naturally occurring organisms
Dispersion	• Contaminant of concern (COC) concentrations in a given area are lowered as the contaminant plume spreads out to cover a larger area
Dilution	• COC concentrations are decreased by contaminants mixing with river/canal water
Sorption	• Combination of chemicals becoming embedded within sediment and solids and chemicals sticking to the outside of solid material particles
Volatilization	• COCs change from a liquid to a gaseous state
Sediment Deposition	• Clean sediments are deposited along the river bottom • Provides a barrier between buried contaminants and river wildlife
Dredging Technologies	
Hydraulic Dredging	• Uses pumps to move dredged material • Pump usually mounted on a barge • Suction pipeline supplies dredged material to the pump • Discharge pipeline transports dredged material from the pump to the disposal site • Common hydraulic dredges include the cutter head, bucket wheel, dustpan, auger, and hopper
Mechanical Dredging	• Uses a bucket to excavate the bottom material and raise it to the surface for disposal • Usually mounted on barge hulls • Positioning system and underwater monitoring equipment permit greater accuracy and control of the bucket • Common mechanical dredges include the clamshell, dragline, backhoe, dipper, and bucket ladder dredges

Table 4-1. Potential Sediment Recovery Technologies Page 2 of 4

Remediation Technology	Attributes
Hybrid or Specialty Dredging	• Have developed in response to the demand for sediment remediation and environmental cleanup • Combine aspects of both hydraulic and mechanical dredges • Common hybrid/specialty dredges include the *Bonacavor* hydraulic excavator, Amphibex and Aquarius amphibious dredges, the DRE Technologies Dry Dredge, Elliott hydraulic dredge, Crawl Cat Cutter Suction dredge, and low-ground pressure track-mounted excavator
In-Place Capping	
Thick Capping	• Follows dredging • Clean sediments or silty to gravelly sand are placed over areas of contaminated sediment • Returns dredged areas back to grade • Isolates areas of contaminated sediment • Establishes conditions for creation of new benthic habitat • Cap at least 3 feet thick; thickness of cap determined during design • Monitored for effectiveness
Thin Capping	• Also known as enhanced natural recovery • Used where hazards due to contaminated sediments to human health and the environment are low • Improves the chemical or physical properties of the upper riverbed • Clean sediments or silty to gravelly sand are placed over areas of contaminated sediment • Target cap thickness of 1 foot • Produces variation in the coverage depths and allows for mixing between the contaminated and clean layers
Sediment Disposal	
Upland or Off-Site Confined Disposal Facilities	• Used in conjunction with dredging • Contaminated sediment transported to adjoining upland site or permitted off-site disposal area

Table 4-1. Potential Sediment Recovery Technologies Page 3 of 4

Remediation Technology	Attributes
Upland or Off-Site Confined Disposal Facilities (cont.)	• Goal is to eliminate contact between contaminated sediment and the river • Confinement zone prevents migration of contaminants • Supernatant water usually requires treatment before release into the river/canal system or local storm water/wastewater system
Nearshore Confined Disposal Facilities	• Used in conjunction with dredging • Constructed adjacent to the waterway • Confinement zone is built to prevent migration of contaminants • Can be filled to grade to provide a variety of uses • Capped
Confined Aquatic Disposal	• Used in conjunction with dredging • Dredged material is placed in a confined, underwater site • Capped • Site must be deep enough not to impede water traffic • Supernatant water treated by an effluent treatment system
Sediment Treatment	
Screening	• Debris is removed using mechanical rakes or as part of the mechanical dredging process • Debris can often be managed, i.e., disposed of or treated, separately from sediment
Dewatering	• Removes free surface water from dredged material • May be used for dredging and upland consolidation restoration alternative or as pretreatment • Methods include settling basins, clarifier tanks, or filter presses
Consolidation	• Reduces the volume of wet dredged material by combining it with sediments or amendments • Removes excess water from the dredged material

Table 4-1. Potential Sediment Recovery Technologies Page 4 of 4

Remediation Technology	Attributes
Other Treatment Technologies	
Solidification/Stabilization	• Provides physical immobilization with reduced accessibility of water • Traps contaminated sediments in a solid mass
Solvent Extraction	• Removes chemical constituents from contaminated material • Uses physical and chemical processes to transfer contaminants to another medium
Incineration	• Uses high temperature thermal oxidation to convert organic wastes to ash and gaseous combustion products
Wet Air Oxidation	• Contaminants are oxidized at temperatures significantly lower than incineration temperatures • Produces a vent gas that may contain volatile organics and a slurry containing inorganic ash and partially degraded organics

5.0 SCREENING OF SEDIMENT REMEDIATION TECHNOLOGIES

This section screens the sediment remediation technologies discussed in Section 4 against their effectiveness, implementability, and order-of-magnitude costs. Effectiveness is defined as the ability of the technology to attain sediment quality objectives as assessed by the degree to which chronic toxicity to sediment-dwelling organisms (discussed in Section 3) is reduced or eliminated. Implementability includes constructibility of the technology, availability of treatments, associated administrative activities, and availability of materials. It is important to note that the hazardous waste management standards of the Resource Conservation and Recovery Act (RCRA) do not apply to the management of dredged material, provided the dredged material is subject to a permit issued under the Clean Water Act (CWA). This exclusion does not extend to the management of dredged material intended for upland disposal where there are no return flows from the sediment to navigable waters. In that case, no CWA permit would exist.

Other factors which may limit the implementability of a remediation technology include the presence of wetlands and floodplains, the current Lake Michigan water levels (currently at an all-time low), limited access points available to insert equipment into and remove it from the GCR/IHC/LGC system (much of the river/canal bank is comprised of dunes and swales and is not conducive to equipment access or working with land-based equipment from the top of the bank), and numerous bridges and trestles crossing over the river and canal with very restrictive horizontal and vertical clearances (dredging/capping equipment must be repeatedly mobilized into the water or to the adjacent bank [for land-based equipment] for each section of work).

Other factors to be considered when evaluating the implementability of a remediation technology include state and local regulations, degree and speed of remediation, size and availability of equipment, and local and regional public and agency project support.

Order-of-magnitude costs are estimated based on experience with the technology on similar projects and include relative costs for materials, labor, waste management, and permitting, among others.

A table summarizing the results of the sediment remediation technology screening is provided at the end of this section.

5.1. NATURAL RECOVERY

Natural recovery may be an effective remediation technology at various locations throughout the project area when sediment contaminant concentrations are within a range that could recover without additional remedial actions (perhaps a PEC-Q less than 0.25). Based on MacDonald et al. (2000a), there are limited project area reaches containing contiguous surface sediment sample locations with contaminant concentrations within this range. Natural recovery is easily implemented in certain segments of the river/canal system where the use of other technologies is limited or restricted (e.g., shallow water, limited access, bank stability, presence of bridges). The order-of-magnitude costs for natural recovery are considered to be relatively low because no remediation actions are taken. Natural recovery is retained as a viable option for sediment recovery in the GCR/IHC/LGC.

5.2. DREDGING TECHNOLOGIES

The three dredging technologies introduced in Section 4, hydraulic, mechanical, and specialty or hybrid, are evaluated below in terms of their effectiveness, implementability, and order-of-magnitude-costs. For the purposes of dredging, the GCR/IHC/LGC system is subdivided into segments controlled, or limited by, the low overhead bridges and bankline property limits. This subdivision includes the following 14 segments:

1. Conrail railroad bridge at station GCR 0+00 to the Industrial Highway (US-12) bridge at station 19+20, a distance of 1,920 feet. Special dredging equipment may be required directly under the bridge from station 19+20 to 19+80 (Subsegment 1B).

2. Industrial Highway bridge at station 19+80 to the easternmost Gary Avenue bridge (I-90 Toll Road ramp) at station 97+00, a distance of 7,720 feet. Special dredging equipment may be needed under the Gary Avenue bridge from station 97+00 to the western most Elgin Joliet & Eastern railroad bridge at station 102+10, a distance of 510 feet (Subsegment 2B).

3. Elgin Joliet & Eastern railroad bridge at station 102+10 to the old Cline Avenue bridge at station 129+20, a distance of 2,710 feet. It is assumed that the Cline Avenue (SR-912) bridge is high enough so as not to interfere with dredging operations. Special dredging equipment may be required directly under the railroad bridge from station 129+20 to 129+50 (Subsegment 3B).

4. Railroad bridge at station 129+50 to the railroad bridge at station 134+10, a distance of 460 feet. Special dredging equipment will be needed to dredge under the pile-supported railroad bridges from station 134+10 to 134+50 (Subsegment 4B).

5. Railroad bridge at station 134+50 to the Kennedy Avenue bridge at station 225+30, a distance of 9,080 feet. Special dredging equipment may be needed under the Kennedy Avenue bridge and Conrail railroad bridge from station 225+30 to 227+00 (Subsection 5B).

6. Conrail railroad bridge at Station 227+00 to the confluence of the EBGCR and WBGCR and the IHC at station 262+80, a distance of 3,580 feet.

7. Confluence of the EBGCR and WBGCR and at station 262+80 to the Indianapolis Boulevard (US-12 and SR-152) bridge at station 296+04, a distance of 3,324 feet.

8. From the confluence of the IHC and the GCR at IHC station 0+50 to the railroad bridges at station 4+00, a distance of 400 feet. Special dredging equipment may be required to dredge under the railroad bridges from station 4+00 to 4+75 (Subsegment 8B).

9. Railroad bridge at Station 4+75 to the East 151st Street bridge at station 11+50, a distance of 675 feet. Special equipment may be needed under the East 151st Street bridge from station 11+50 to 12+25 (Subsegment 9B).

10. East 151st Street bridge at station 12+25 to the East Chicago Avenue bridge at station 41+15, a distance of 2,890 feet. Special equipment may be needed under the East Chicago Avenue bridge from station 41+15 to 41+85 (Subsegment 10B).

11. East Chicago Avenue bridge at station 41+85 to the railroad bridge at station 46+20. Special equipment may be needed under the railroad bridge from station 46+20 to 46+50 (Subsegment 11B).

12. Railroad bridge at station 46+50 to the Columbus Drive bridge at station 77+50, a distance of 3,100 feet. Special equipment may be needed under the Columbus Drive bridge from station 77+50 to IHC station 78+10 and the upper limit of the Federal Project (Subsegment 12B).

13. The upper limit of the Federal Project on the LGC at LGC station 37+00 to the railroad bridge at station 48+45, a distance of 1,245 feet. Special equipment may be needed under the railroad bridge from station 48+45 to 48+60 (Subsegment 13B).

14. Railroad bridge at Station 48+60 to the end of the Federal Project at LGC station 71+40, a distance of 2,280 feet.

5.2.1. Hydraulic Dredging

Hydraulic dredging is considered to be an effective technology because it will meet sediment quality objectives by removing contaminated sediments. Hydraulic pipeline dredges larger than about 10 inches in diameter are not considered implementable due to their large size. Hydraulic dredging with hydraulic pipelines smaller than 10 inches in diameter is considered implementable because of the transportability and availability of the necessary equipment. These dredges are capable of continuously removing sediments and some, including the auger dredge, have a shallow enough draft and are small enough to be used in confined waterways. The order-of-magnitude costs are considered to be moderate when the dredging area is within pumping distance of the disposal area. Therefore, hydraulic dredging is considered a viable option on the GCR/IHC/LGC waterway and is retained for further evaluation.

5.2.2. Mechanical Dredging

Mechanical dredging is considered to be an effective technology that will meet sediment quality objectives by removing contaminated sediment. However, the implementability of mechanical dredging is considered low because the dredged material would have to be transported to the disposal site. Sediments would be transported by barge from the dredge site to a segment of the river or canal bank, then moved from the barge to trucks or front-end loaders, and transported along a constructed road to the disposal site. Moving the sediment increases the potential for resuspension or spillage of sediment into the river/canal waters. Transportation by trucks or loaders would require construction of temporary roads on top of bank or marsh wetlands. Permitting of such roads is problematic.

The order-of-magnitude costs for mechanical dredging are considered relatively high due to the cost of temporary road construction. Mechanical dredging is eliminated from further consideration due to its high cost and the difficulties associated with obtaining the necessary permits.

5.2.3. Hybrid or Specialty Dredging

Hybrid or specialty dredges are considered effective for this project because they will achieve project goals by removing the contaminated sediment. The hybrid or specialty dredges are also considered implementable because they can be modified to accommodate specific situations. For example, a low-ground-pressure track-mounted excavator could be outfitted with a backhoe dredge and used under some of the bridges crossing the GCR/IHC/LGC. The order-of-magnitude costs are expected to be similar to those associated with hydraulic dredging. Hybrid or specialty dredging is considered a viable option and is retained for further consideration.

5.3. IN-PLACE CAPPING TECHNOLOGIES

5.3.1. Thick Capping

Thick capping is considered an effective remediation option because it will return the river/canal bottom back to grade after dredging and will provide an adequate barrier between benthic systems and any remaining contamination in the sediment. Thick capping is also implementable due to the variety of techniques available for placing the cap and the ready availability of the necessary equipment. The order-of-magnitude costs are considered moderate. Thick capping is considered a viable option and is retained for further evaluation.

5.3.2. Thin Capping

The effectiveness of thin capping is considered to be low in the GCR/IHC/LGC system because of the high contamination levels in the sediments. Although thin capping is implementable and its order-of-magnitude costs are moderate, it is eliminated from further consideration due to its inability to meet sediment quality objectives.

5.4. SEDIMENT DISPOSAL

5.4.1. Upland or Off-Site Confined Disposal Facilities

CDFs are considered effective because they contain contaminated material with very little impact on water quality. CDFs are also considered moderately implementable because, although upland disposal sites are currently limited, negotiation with landowners adjacent to the project area may produce adequate sites. The acreage of CDFs needed to accommodate the anticipated amount of dredged sediment from the project area is presented in Table 5-1. Because allocation of disposal sites has not been resolved with local property owners, the acreage presented in Table 5-1 could consist of one large site or a series of smaller sites. The height of the sediment deposits will be determined by the strength of the underlying soils. Soft soils restrict the height of the confined deposits to control sinking and consolidation. Firmer soils may support confined dredged sediments to a height of 10 to 15 feet. The higher the sediment deposit, the smaller the acreage needed to contain the dredged sediments. CDFs can be filled to grade to provide a variety of upland uses.

Because of the uncertainty in the number of CDFs that would be needed, there is uncertainty associated with the order-of-magnitude costs for this technology. CDFs are considered a viable option and are retained for further consideration.

Table 5-1. Acreage* of Upland or Nearshore Confined Disposal Sites

Height of Deposit (Feet)	3-Foot Dredge Prism (Acres)	Maximum Dredge Prism (Acres)
3	310	589
5	186	353
6	155	294
8	116	221
10	93	177
15	62	118

*Does not include acreage for the dikes.

5.4.2. Nearshore Confined Disposal Facilities

NCDFs are considered an effective remediation technology because they contain contaminated material with little impact on water quality. They are also considered moderately implementable due to the limited presence of potential disposal sites. The most obvious candidate for an NCDF, without considering local project support or permitting requirements, is the LGC beyond the Reach 2—Federal Project limits.

Using the LGC as a confined disposal site would allow for the placement of approximately 220,000 cy of contaminated sediment. This assumes that the dike is constructed across the canal and centered at station 38+00. The dike would have a 10-foot crest at elevation 585 feet above msl and 3 (horizontal):1(vertical) side slopes facing up and down canal. Sheet-pile walls or caissons may be substituted for the dike using the same alignment as the dike. The dredged sediment would be placed behind the dike/wall/caisson, filling the canal up to elevation 580 feet above msl. This would provide for a 5-foot clean cap up to elevation 585 feet. The cap material could then be selected, placed, and graded into shallow wetland habitats for waterfowl.

Because the LGC does not have the capacity to contain all the dredged sediments, other NCDF sites would need to be constructed along or near the GCR/IHC/LGC system. However, using the LGC as an NCDF reduces the acreage needed for other sites, as displayed in Table 5-2.

Because of the uncertainty in the number of NCDFs that would be needed, there is uncertainty associated with the order-of-magnitude costs for this technology. NCDFs are considered a viable option and are retained for further consideration.

Table 5-2. Acreage* of Upland or Nearshore Confined Disposal Sites Needed After Filling the Lake George Canal

Height of Deposit (Feet)	3-Foot Dredge Prism (Acres)	Maximum Dredge Prism (Acres)
3	264	543
5	159	326
6	132	272
8	99	204
10	79	163
15	53	109

* Does not include acreage for the dikes.

5.4.3. Confined Aquatic Disposal

The implementability of CAD is considered to be low because there are no aquatic sites within the Great Lakes area capable of receiving contaminated sediments. Although CAD is considered an effective technology and its order-of-magnitude costs are similar to other types of sediment disposal, it is not considered a viable option due to its low implementability and is eliminated from consideration.

5.5. SEDIMENT TREATMENT TECHNOLOGIES

5.5.1. Screening

Screening of dredged materials is an effective technology because it allows for volume reduction of problem waste and for odd-sized items to be managed separately from the bulk of the sediment waste. Reduced waste volume can result in significant cost savings in all processing steps necessary for disposal and treatment. The need for screening and type of equipment vary from site to site. For fairly homogeneous sediment materials, there may be limited benefit to using screening technologies. However, it is considered a viable technology for the river sediments being considered here.

Screening is also considered implementable because the necessary equipment is readily available. The associated order-of-magnitude costs are relatively low. Screening of dredged materials is retained for further consideration.

5.5.2. Dewatering

Dewatering is considered an effective technology because it reduces the volume and weight of the contaminated sediment materials and reduces the potential for leaching after disposal. However, it is necessary to treat the water generated in the process.

Dewatering is also considered implementable because simple, readily available equipment can be used for this technology. The order-of-magnitude cost varies depending on the ultimate goals or requirements for disposal or treatment but is typically in the low to moderate range compared to other technologies. However, the treatment costs for the liquid waste generated has to be taken into consideration.

Dewatering is retained for further consideration in combination with dredging and screening technologies because of its effectiveness and ease of implementation.

5.5.3. Consolidation

The implementability and order-of-magnitude costs of consolidation depend on availability and nature of the consolidation materials required. The need and practicability should be evaluated against the effectiveness of other technologies, such as dewatering.

Consolidation is eliminated from further consideration because of the difficult implementation associated with large volumes of consolidation materials expected to be needed for GCR/IHC/LGC sediments.

5.5.4. Other Treatment Technologies

The effectiveness of the treatment technologies listed in Section 4.5.4 is considered low because none would treat both organic and inorganic sediment contaminants. A combination of technologies would be needed for them to be effective. For example, for organic contaminants, thermal treatment and biological treatment could be considered. However, metals would not be treated thermally or biologically and would have to be treated with soil washing, extraction technologies, or by solidification. The order-of-magnitude costs for these technologies are expected to be high compared to other technologies.

Based on current knowledge of the GCR/IHC/LGC sediments, these treatment technologies, other than for dewatering purposes, are eliminated from further consideration in this report.

Table 5-3. Screening Sediment Remediation Technologies

Remediation Technology	Effectiveness	Implementability	Order-of-Magnitude Cost	Conclusion
Natural Recovery	Moderate	Easy to implement	Low	Retain
Dredging Technologies				
Hydraulic	High	Easy to implement if hydraulic pipeline size is limited	Moderate	Retain
Mechanical	High	Difficult to implement	High	Eliminate
Hybrid or specialty	High	Easy to implement	Moderate	Retain
In-Place Capping Technologies				
Thick	High	Easy to implement	Moderate	Retain
Thin	Low due to high level of sediment contamination	Easy to implement	Moderate	Eliminate
Sediment Disposal				
Upland or off-site confined disposal facilities	High	Moderately difficult to implement due to limited site availability	Variable	Retain
Nearshore confined disposal facilities	High	Moderately difficult to implement due to limited site availability	Variable	Retain
Confined aquatic disposal	High	Difficult to implement due to lack of available sites	Variable	Eliminate
Sediment Treatment Technologies				
Screening	High	Easy to implement	Low	Retain
Dewatering	High	Easy to implement	Low to moderate	Retain
Consolidation	High	Difficult to implement	Variable	Eliminate
Other Treatment Technologies	Low due to number of technologies required to treat all types of contamination present	Difficult to implement	High	Eliminate

6.0 DEVELOPMENT OF DETAILED RESTORATION ALTERNATIVES

This section develops and combines the sediment remediation technologies that were retained after screening in Section 5 into detailed restoration alternatives. For example, dredging and upland off-site disposal restoration technologies are combined into one restoration alternative. Section 6.1 describes the potential restoration alternatives. Section 6.2 introduces the criteria that will be used to screen the potential restoration alternatives. Sections 6.3 and 6.4 screen the potential restoration alternatives for Reach 1 and Reach 2, respectively, and Section 6.5 identifies the four restoration alternatives that appear to be the most viable.

6.1. POTENTIAL SEDIMENT RESTORATION ALTERNATIVES

The sediment management actions that will be considered when developing the restoration alternatives for each project reach are described below. The potential sediment restoration alternatives are summarized in Table 6-1.

6.1.1. No Action/Natural Recovery

The no action/natural recovery alternative would involve no implementation of any restoration actions or institutional controls. The site would remain as is and no environmental monitoring of the natural recovery of the site would be performed. Accretion and natural recovery would continue at the site at present rates. This alternative is included as a common reference point to which the other alternatives can be compared.

6.1.2. Natural Recovery and Monitoring

Natural recovery and monitoring may be applicable at various locations throughout the project area, assuming that sediment contaminant concentrations are within a range that could recover without additional restoration actions. Natural recovery of contaminated sediments is a process by which the magnitude and extent of sediment exceedences in the upper sediment layers diminish over a period of time following significant reduction or elimination of contaminant sources (source control activities). The natural recovery and monitoring restoration alternative consists of allowing the sediment quality to improve through a combination of natural processes (e.g., biodegradation and transformation, dispersion, dilution, sorption, volatilization, and sediment deposition) to achieve sediment quality objectives. Sediment quality recovery, with respect to the sediment quality objectives, is assessed by determining the degree to which chronic toxicity to sediment-dwelling organisms (as discussed in Section 3) is reduced or eliminated.

As per the "Assessment Plan for the Natural Resource Damage Assessment of the GCR/IHC and Waters of Nearshore Lake Michigan" (IDEM et al. 1997), existing conditions on all aspects of the GCR/IHC (sediment chemistry, sediment characteristics, sediment toxicity, benthic invertebrate communities, and the fish community) have been or are in the final stages of being determined by the Trustees (e.g., MacDonald et al. 2000a). Under this alternative, the Trustees would rely on the information generated from the NRDA evaluation completed in the GCR/IHC that defines existing conditions.

Future monitoring efforts would be conducted in accordance with the existing quality assurance plans to enable comparisons to be made with information developed during the assessment. The assessment provides a critical link between past observations, on-going and future trends in chemical concentrations and biological successions of site sediments, and future site management decisions during a time when the conditions across the entire project area are expected to be in a state of dynamic flux. Monitoring to assess performance and to confirm the predictions of natural recovery will be conducted. Details of the monitoring program will be developed in a separate work plan. The work plan will be based on the National Research Council's (1990) conceptual model of environmental monitoring. An outline of the key conceptual elements that would be the basis of the monitoring work plan is provided in Appendix D.

6.1.3. Dredging with On-Site Upland Disposal

Dredging with upland on-site disposal is based on the removal of all of the contaminated sediments (PEC-Q greater than 0.7) in the project area plus 1 foot of allowable overdepth dredging. This alternative would only be utilized in Reach 1—GCR/IHC/LGC. Dredging in Reach 2—Federal Project would be performed by USACE as part of the authorized federal navigation project. As described in Section 5, the dredging in Reach 1 would be performed by small, portable hydraulic dredges. The material would be pumped into strategically located land-side temporary stockpile/dewatering areas, consisting of lined CDFs. A temporary CDF would be constructed of imported sand and gravel, cantilevered sheet-pile walls, or linked concrete gravity barriers and a geomembrane liner. The dredge material supernatant water would be routed over a weir and conveyed to a DAF (or similar) effluent treatment system. Treatment of supernatant water may or may not be required depending on the results of elutriate tests conducted during pre-restoration design. For the purpose of this evaluation, it is assumed that treatment of the supernatant water will be required.

After the supernatant water is treated to an acceptable water quality standard, it would be discharged back into the waterway. After the dredge material is sufficiently dewatered, it would be loaded onto highway-type trucks for transport to a permanent, upland CDF(s) for disposal. The stockpile/dewatering site liner would also be disposed of in the permanent CDF or commercial landfill, and the temporary CDF site would be filled in and graded to match the surrounding ground.

The permanent CDF would be sized to hold all of the dewatered contaminated sediments. If an area of adequate size is not be found within the project area for the construction of the CDF, several (more than one) permanent CDFs would be constructed. The permanent CDF would consist of a large, diked confined area built to receive dewatered dredged material over the life of the project. A bottom liner and leachate collection system would be installed within the CDF. Dewatered dredged material arriving by truck from the stockpile/dewatering sites would be deposited and advanced within the fill by a conveyor system. As the fill builds, low-ground-pressure equipment would be used to grade and progressively cap the emerging consolidated deposit with a layer of low-permeability soils, geotextile membrane, and topsoil. All site water (drainage, leachate, and surface runoff) would be collected and treated as necessary, based on results of elutriate testing.

6.1.4. Dredging with Upland Disposal at a Regional Landfill

The dredging/dewatering/effluent treatment plan on which this alternative is based is the same as that described in Section 6.1.3. After the dredged material has been sufficiently dewatered to be acceptable for disposal at a commercial landfill (passes the Paint Filter Liquids Test), it would be loaded on highway-type trucks and trailers with lined beds and covers and hauled directly to a commercial landfill or transported to a rail transfer facility for delivery to the landfill in gondola-type railcars. The trucks and operators used to transport the contaminated dredged material would be licensed hazardous waste haulers.

6.1.5. Thick Capping

Placement of the thick cap would be by the diffuser placement process described in Section 4.3. The capping material also could be delivered by bottom-dump barges. The material would be placed while the barge is slowly pushed sideways by a tug. The compartment doors or split-hull would be opened just enough to disperse a light layer of the capping material over the area to be capped. For either method, the amount of material to be placed for a given area is predetermined and the placement is uniformly made using that quantity of material. Initial placement thickness is monitored using pre- and post-cap hydrographic surveys.

6.1.6. Dredging and Capping

The key to dredging and capping is whether suitable land-side areas can be obtained and used as stockpile/pumping sites for pumping the capping material. These areas would have to be located near existing roads or access roads would have to be constructed for delivery of the capping material. The availability of these potential sites, which is not known at this time, will be determined in the early stages of pre-restoration design. The dredging and thick capping operations would be performed as described in Sections 6.1.3, 6.1.4, and 6.1.5. To prevent spread of contaminated sediment over newly dredged but uncapped areas, the dredging and capping should be completed sequentially for any section of the river or canal prior to starting a new section.

Table 6-1. Potential Restoration Alternatives

Potential Alternative	Attributes
No Action/Natural Recovery	• No restoration action or institutional controls implemented
Natural Recovery and Monitoring	• Combination of natural processes following source control activities to allow sediment quality to improve
Dredging with On-Site Upland Disposal	• Utilized only in Reach 1 • Removal of all sediments with a PEC-Q greater than 0.7 plus 1-foot overdepth dredging • Small, portable hydraulic dredges • Dredged material would be pumped into temporary CDFs for stockpiling and dewatering • Supernatant water treated by DAF, if necessary, and discharged back into waterway • Dewatered dredge material transported by highway-type trucks to permanent upland CDF for disposal
Dredging with Upland Disposal at a Regional Landfill	• Similar to above • Dewatered dredge material transported by highway-type trucks and trailers to a commercial landfill or transported to a rail transfer facility for delivery to a landfill in gondola-type railcars
Thick Capping	• Capping material delivered by the diffuser placement process or bottom-dump barges • Material placed while barge is pushed sideways by a tug • Amount of material to be placed for a given area is predetermined • Initial placement thickness monitored using pre- and post-cap hydrographic surveys
Dredging and Capping	• Requires suitable land-side area for stockpile/pumping sites

Table 6-1. Potential Restoration Alternatives

Potential Alternative	Attributes
Dredging and Capping (cont.)	• Removal of all sediments with a PEC-Q greater than 0.7 plus 1-foot overdepth dredging • Small, portable hydraulic dredges • Dredged material would be pumped into temporary CDFs for stockpiling and dewatering • Supernatant water treated by DAF, if necessary, and discharged back into waterway • Dewatered dredge material transported by highway-type trucks to permanent CDF for disposal • Capping material delivered by diffuser placement process or bottom-dump barges • Material placed while barge is pushed sideways by a tug • Amount of material to be placed for a given area is predetermined • Initial placement thickness monitored using pre- and post-cap hydrographic surveys • Completed sequentially for any section of the river/canal to prevent spread of contaminated sediment

6.2. SCREENING CRITERIA FOR THE POTENTIAL RESTORATION ALTERNATIVES

The four criteria described below will be used to screen the potential restoration alternatives described in Section 6.1 to determine the four most viable alternatives, as presented in Section 6.5. The four most viable alternatives will then be carried forward for further evaluation in Section 7.

6.2.1. Technical Feasibility

This criterion evaluates the engineering feasibility of the potential restoration alternative. It addresses the question: Can the intended restoration alternative be implemented in a specific reach of the river/canal? Factors to be considered in the evaluation include geotechnical stability, site access, site topographic and bathymetric conditions, geometry of the river/canal reach, physical obstructions such as roadway or rail crossings, water depths and depths of sediment contamination, dewatering of sediment, and sediment transport and disposal considerations.

6.2.2. Availability

This criterion is used to establish whether or not the potential restoration alternative can be implemented within a particular reach of the project area. For example, if an upland site along sections of the river or canal bank could not be made available for the construction of temporary stockpile/dewatering areas, then restoration alternatives requiring such sites would not be feasible and would be screened out. Property that is actively being used for other purposes would also be screened out.

6.2.3. Environmental Acceptability

This criterion evaluates the long-term adverse effects of the potential restoration alternative on the environment. For example, dredging from the bank using long-stick excavators may adversely impact the natural riparian habitat throughout the site, or some sections of the bank may not be stable enough to support the weight of construction equipment. This method is not considered environmentally sound because it would adversely impact the natural habitat.

6.2.4. Order-of-Magnitude Cost

This criterion evaluates the engineering and construction cost of the potential restoration alternative. The estimate is based on the methods, equipment, personnel, and materials required to design and construct the alternative being evaluated. Order-of-magnitude costs by themselves will not be used to screen out a potential restoration alternative but will be used in consideration of and in combination with the other screening criteria.

6.3. SCREENING OF POTENTIAL RESTORATION ALTERNATIVES FOR REACH 1

6.3.1. No Action/Natural Recovery

6.3.1.1. Technical Feasibility

Not applicable. This criterion does not apply to the no action/natural recovery restoration alternative because no engineering actions are associated with it.

6.3.1.2. Availability

This criterion does not apply to the no action/natural recovery restoration alternative because no engineering actions are associated with it.

6.3.1.3. Environmental Acceptability

The environmental acceptability of this potential restoration alternative is poor because it does not provide an added degree of restoration. Ongoing natural recovery would continue; however, most of the areas of Reach 1 have sediments with contaminant levels above a PEC-Q of 0.7. These areas would not naturally recover in an acceptable period of time (for example 10 years, the period allowed in the State of Washington) or may not recover at all.

6.3.1.4. Cost

There are only minimal costs, if any, associated with this potential restoration alternative.

6.3.2. Natural Recovery and Monitoring

6.3.2.1. Technical Feasibility

This criterion applies only to the monitoring component of this potential restoration alternative. Although the technical feasibility of implementing short- and long-term performance monitoring of site conditions is considered good, based on readily available, proven technology and current engineering practices, the reduction or elimination of contaminant sources through control activities is not addressed by this alternative. Therefore, the overall technical feasibility of this alternative is considered poor.

6.3.2.2. Availability

The site's existing conditions were well established during the assessment phase of this NRDA. However, the availability of this potential restoration alternative is considered poor as source control activities are not addressed.

6.3.2.3. Environmental Acceptability

The environmental acceptability of this potential restoration alternative is poor because it does not provide an added degree of restoration. Ongoing natural recovery would continue; however, most of the areas of Reach 1 have sediments with contaminant levels above a PEC-Q of 0.7. These areas would not naturally recover in an acceptable period of time (for example 10 years, the period allowed in the State of Washington) or may not recover at all.

6.3.2.4. Cost

The cost of this potential restoration alternative is considered low because the site's existing conditions were well established during the assessment phase of this NRDA. The only associated costs are those pertaining to performance monitoring during the natural recovery period.

6.3.3. Dredging with On-Site Upland Disposal

6.3.3.1. Technical Feasibility

The technical feasibility of this potential restoration alternative is considered good because small, portable hydraulic dredges are available for use in the generally shallow water depths and narrow widths of the river and canal in Reach 1. This method of dredging is a proven technology, although production rates are slower and more water must be handled and potentially treated than when using mechanical dredging methods. A long-stick excavator (backhoe) positioned on each bank might be used for excavation; however, the stability of the banks is problematic and the excavating/hauling equipment would destroy or degrade much of the riparian habitat.

Land-side stockpile/dewatering is also technically feasible and has been successfully used on other projects. The DAF effluent treatment methodology is in wide use and can handle the water volumes expected to be generated by two hydraulic dredges working concurrently in the river/canal. A bench test at the start of the work will probably be required to determine the type and addition rates for the chemicals to be used in the treatment process, if effluent treatment is required.

Upland monofills have been used extensively for containment of contaminated soils and sediments. Liners and leachate collection systems effectively isolate the contaminated fill from the outside environment and capture effluent and surface runoff emanating from the fills. USACE has proposed an on-site upland disposal facility in connection with dredging to be performed as part of the authorized federal navigation project.

6.3.3.2. Availability

The availability of this potential restoration alternative is unknown because it has not been determined if suitable land-side areas can be obtained and used as stockpile/dewatering sites and whether an area(s) large enough to contain the dredged sediments can be located to construct a permanent CDF within a reasonable distance from the project area. The availability of these potential sites is not known at this time and would be determined in the early stages of pre-restoration design.

6.3.3.3. Environmental Acceptability

The environmental acceptability of this potential restoration alternative is considered high because it would provide for the cleanup and permanent disposal of all of the contaminated sediments in the river and canal. The method of construction will not have long-term adverse impacts on the surrounding environment. Existing benthic habitat (such that it is, in its currently injured condition) will be temporarily destroyed due to the dredging of the river/canal; however, once this operation is completed, recolonization should follow shortly thereafter. The dredging will introduce short-term effects of turbidity and reduced dissolved oxygen, but these can be minimized with silt curtains or adjustments to the operation if water quality standards are exceeded.

6.3.3.4. Cost

The order-of-magnitude cost for this potential restoration alternative is considered high. Activities included in the cost estimate are mobilization and demobilization of the equipment; dredging and disposal of dredged material; construction and removal of stockpile/dewatering areas; effluent runoff treatment (if required); construction of a permanent, on-site, upland CDF disposal facility; water quality monitoring during construction; engineering and design; construction oversight; and a contingency allowance. Not included are land acquisition costs, mitigation costs, and long-term monitoring costs.

6.3.4. Dredging with Upland Disposal at a Regional Landfill

6.3.4.1. Technical Feasibility

The technical feasibility for the dredging, stockpile/dewatering, and effluent water treatment activities is considered good and is addressed in more detail in Section 6.3.3. Upland disposal at a regional landfill is widely used for both contaminated and hazardous materials and is considered technically feasible.

6.3.4.2. Availability

The availability of on-site lands to implement this potential restoration alternative is unknown. It must be determined during pre-restoration design activities, after the final dredge material quantities have been calculated, whether existing commercial landfills within a reasonable distance of the project area have the capacity to accept the project-generated contaminated sediments. If commercial landfills with adequate capacity are not available within a reasonable distance of the project area, this alternative may not be implementable.

6.3.4.3. Environmental Acceptability

The environmental acceptability for the dredging, stockpile/dewatering, and effluent water treatment activities is considered good and is discussed in more detail in Section 6.3.3. Disposal of the contaminated sediment in a licensed, commercial landfill would be environmentally beneficial for the project area. The large quantity of contaminated sediments from this project would reduce the ability of commercial landfill(s) in the area to accept waste from other projects/sources over the long term.

6.3.4.4. Cost

The order-of-magnitude cost for this potential restoration alternative is considered high. Activities included in the cost estimate are mobilization and demobilization of the equipment; dredging and disposal of dredged material; construction and removal of stockpile/dewatering areas; effluent runoff treatment (if required); transport and disposal of sediment at a commercial landfill, including tipping fees; water quality monitoring during construction; engineering and design; construction oversight; and a contingency allowance. Not included are land acquisition costs, mitigation costs, and long-term monitoring costs.

6.3.5. Thick Capping

6.3.5.1. Technical Feasibility

The technical feasibility of thick capping is considered good. It is a proven technology that has been demonstrated to be an effective method for containing contaminated sediments and isolating them from the aquatic environment. Thick capping is accepted by EPA, USACE, and the London Dumping Convention, to which the United States is a signatory. Pumping the cap material through a pipe with a diffuser at the outlet end is considered a technically feasible method that will produce the most uniform surface with the least impact on the surface sediments. There may be some difficulty in obtaining the sand-capping material if the project is conducted during the winter months, due to the potential for adverse ice and snow conditions at the sand supplier's plant. There also may be some difficulty in navigating the skiff or diffuser barge in the very shallow areas of the river or canal, especially if Lake Michigan is low at the time of the year that the work is being performed.

6.3.5.2. Availability

The availability of this potential restoration alternative is not known at this time because suitable land-side areas for stockpiling/pumping sites for the capping material have not been identified. These areas would have to be located near existing roads or access roads would have to be constructed for the delivery of the capping material. The availability of land-side areas would be determined in the early stages of pre-restoration design.

6.3.5.3. Environmental Acceptability

The environmental acceptability of thick capping is fair. It effectively contains contaminated sediments and isolates them from the aquatic environment. This restoration method has been successfully used on both the east and west coasts of the United States. EPA endorses this method for its environmental protectiveness, as evidenced by Report EPA 905-896-004, Assessment and Remediation of Contaminated Sediments (ARCS) Program, Guidance for In-Situ Subaqueous Capping of Contaminated Sediments, dated September 1998. There will be some short-term water column impacts (i.e., increases in turbidity, total suspended solids, or dissolved oxygen) during the capping operation, but the capping operation would be performed in compliance with water quality certification requirements.

6.3.5.4. Cost

The order-of-magnitude cost for this potential restoration alternative is considered medium. Activities included in the cost estimate are mobilization and demobilization of the equipment; furnishing and installing the capping material; water quality monitoring during construction; engineering and design; construction oversight; and a contingency allowance. Not included are land acquisition costs, mitigation costs, and long-term monitoring costs.

6.3.6. Dredging with On-Site Upland Disposal and Thick Capping

6.3.6.1. Technical Feasibility

The technical feasibility of dredging and thick capping is considered good and is described in more detail in Sections 6.3.3 and 6.3.5. Dredging and capping would be employed as a alternative where existing core borings are not deep enough to establish the bottom of the zone of contamination or where the depth of contamination is so great that dredging to remove all contaminated material would be infeasible. This alternative would retain the present navigability of the river and canal because the bed elevations would be approximately the same after completion of the work.

6.3.6.2. Availability

The availability of this potential restoration alternative is not known at this time because suitable land-side areas for stockpiling/pumping sites for the capping material have not been identified. These areas would have to be located near existing roads or access roads would have to be constructed for the delivery of the capping material. The availability of land-side areas would be determined in the early stages of pre-restoration design.

6.3.6.3. Environmental Acceptability

The environmental acceptability of this potential restoration alternative is considered fair to good because it would provide a reasonable degree of environmental protectiveness and acceptability. Not all of the contaminated sediments would be removed; however, those remaining would be contained and isolated from the aquatic environment by the thick cap.

There will be some short-term water column impacts (i.e., increases in turbidity, total suspended solids, or dissolved oxygen) during the dredging and capping operations, but these operations would be performed in compliance with water quality certification requirements.

6.3.6.4. Cost

The order-of-magnitude cost for this potential restoration alternative is considered medium. Activities included in the cost estimate are mobilization and demobilization of the equipment; dredging and disposal of dredged material; construction and removal of stockpile/dewatering areas; effluent runoff treatment (if required); construction of a permanent, on-site, upland CDF disposal facility; furnishing and installing capping material; water quality monitoring during construction; engineering and design; construction oversight; and a contingency allowance. Not included are land acquisition costs, mitigation costs, and long-term monitoring costs.

6.3.7. Dredging with Disposal at a Regional Landfill and Thick Capping

6.3.7.1. Technical Feasibility

The technical feasibility of this potential restoration alternative is considered good because small, portable hydraulic dredges are available for use in the generally shallow water depths and narrow widths of the river and canal in Reach 1. Additionally, thick capping is considered technically feasible for containing contaminated sediments and isolating them from the aquatic environment. Further discussion of these potential restoration alternative attributes is provided in Sections 6.3.3 and 6.3.5. Dredging and capping would be employed as an alternative where existing core borings are not deep enough to establish the bottom of the zone of contamination or where the depth of contamination is so great that dredging to remove all contaminated material would be infeasible. This potential restoration alternative would retain the present navigability of the river and canal since the bed elevations would be approximately the same after completion of the work. Upland disposal at a regional landfill is widely used for both contaminated and hazardous materials and is considered technically feasible.

6.3.7.2. Availability

The availability of this potential restoration alternative is not known at this time because suitable land-side areas for stockpiling/pumping sites for the capping material. These areas would have to be located near existing roads or access roads would have to be constructed for the delivery of the capping material. The availability of land-side areas would be determined in the early stages of pre-restoration design. In addition, it must be determined if existing commercial landfills capable of accepting the contaminated sediments are located within a reasonable distance of the project area.

6.3.7.3. Environmental Acceptability

Based on the discussions in Sections 6.3.3, 6.3.4, and 6.3.5, this potential restoration alternative would provide a fair to good degree of environmental acceptability. Not all of the contaminated sediments would be removed; however, those remaining would be contained and isolated from the aquatic environment by the thick cap.

There will be some short-term water column impacts (i.e., increases in turbidity, total suspended solids, or dissolved oxygen) during the dredging and capping operations, but these operations would be performed in compliance with water quality certification requirements.

6.3.7.4. Cost

The order-of-magnitude cost for this potential restoration alternative is considered medium. Activities included in the cost estimate are mobilization and demobilization of the equipment; dredging and disposal of dredged material; construction and removal of stockpile/dewatering areas; effluent runoff treatment (if required); transport and disposal of sediment at a commercial landfill, including tipping fee; furnishing and installing capping material; water quality monitoring during construction; engineering and design; construction oversight; and a contingency allowance. Not included are land acquisition costs, mitigation costs, and long-term monitoring costs.

6.4. SCREENING OF POTENTIAL RESTORATION ALTERNATIVES FOR REACH 2—FEDERAL PROJECT

The only potential restoration alternative being considered for Reach 2 is dredging and thick capping. This alternative will be implemented only if the current restoration being conducted by the USACE does not remove all of the contaminated sediment. Disposal of sediments will be directed by the USACE/EPA Region V, Final Environmental Impact Statement and Comprehensive Management Plan (1999).

6.5. RESTORATION ALTERNATIVES TO BE CARRIED FORWARD

6.5.1. Reach 1

Results of the alternative screening are presented in matrix form in Table 6-2. The descriptors—Good, Fair, Poor, and Unknown—have been assigned to indicate the overall evaluation of technical feasibility, availability, and environmental acceptability. The descriptors—High, Medium, and Low—are assigned to indicate the overall evaluation of cost.

Table 6-2. Evaluation of Potential Alternatives for Reach 1

Alternative	Screening Criteria				Evaluation
	Technical Feasibility	Availability	Environ. Accept.	Cost	
No Action/Natural Recovery	N/A	N/A	Poor	None	Poor
Natural Recovery and Monitoring	Poor	Poor	Poor	Low	Poor

Alternative	Screening Criteria				Evaluation
	Technical Feasibility	Availability	Environ. Accept.	Cost	
Dredging With On-Site Upland Disposal	Good	Unknown	High	High	Good
Dredging With Upland Disposal at a Regional Landfill	Good	Unknown	Good	High	Good
Thick Capping	Good	Unknown	Fair	Medium	Fair to Good
Dredging with On-Site Upland Disposal and Thick Capping	Good	Unknown	Fair to Good	Medium	Good
Dredging with Disposal at a Regional Landfill and Thick Capping	Good	Unknown	Fair to Good	Medium	Good

Based on the above alternative screenings, the following four restoration alternatives are considered to be the most viable and are carried forward for further evaluation in Section 7:

Alternative 1: Dredging with On-Site Upland Disposal

Alternative 2: Dredging with Upland Disposal at a Regional Landfill

Alternative 3: Dredging with On-Site Upland Disposal and Thick Capping

Alternative 4: Dredging with Upland Disposal at a Regional Landfill and Thick Capping

6.5.2. Reach 2

The restoration alternative of dredging and thick capping is carried forward for further evaluation in Section 7.

7.0 EVALUATION OF RESTORATION ALTERNATIVES

For the level of analysis required at this stage of the project, a simplified evaluation of each of the alternatives was completed for Reach 1 and Reach 2. The evaluation entailed describing the application of each alternative to an entire reach and accounting for all costs to implement the alternative. A total order-of-magnitude cost estimate to implement each alternative was developed.

Section 7.1 discusses evaluation of four alternatives for Reach 1: Alternative 1: dredging with on-site upland disposal, Alternative 2: dredging with upland disposal at a regional landfill, Alternative 3: dredging with on-site upland disposal and thick capping, and Alternative 4: dredging with upland disposal at a regional landfill and thick capping. Section 7.2 describes implementation of the alternative for Reach 2, dredging with upland disposal either on-site or at a regional landfill. The alternative for Reach 2 will only be implemented if residual contamination remains following the USACE dredging action.

Project category-specific evaluation criteria were developed for the management of contaminated sediment, as specified in the IRCDP (IDEM et al. 1998), to be used for a comparative analysis of the alternatives. Category-specific criteria were identified to ensure that the evaluation of alternatives remains focused on key considerations when the identification of preferred alternatives is undertaken. The evaluation criteria are provided in Appendix E.

7.1. EVALUATION OF ALTERNATIVES FOR REACH 1

Two of the alternatives being considered for Reach 1 involve dredging to the maximum depth of contamination (maximum dredge prism), Alternative 1: dredging with on-site upland disposal and Alternative 2: dredging with upland disposal at a regional landfill. The difference in the alternatives is whether the dredged sediment is permanently deposited in an upland on-site CDF or whether the upland on-site CDF is only used temporarily for dewatering and final deposition of the dredged sediment is in a regional landfill. The former is a one-step process: maximum dredging and transport to an on-site upland CDF. The latter has the same first step but adds the second step of transport to a regional landfill after dewatering.

The two additional alternatives being considered for Reach 1 involve dredging the upper 3 feet of contaminated sediment (3-foot dredge prism) with the additional step of thick capping, Alternative 3: dredging with on-site upland disposal and thick capping, and Alternative 4: dredging with upland disposal at a regional landfill and thick capping. The difference in the alternatives is whether the dredged sediment is permanently deposited in a upland on-site CDF or whether the upland on-site CDF is only temporary for dewatering and the final resting place of the dredged sediment is a regional landfill. The former is a two-step process: maximum dredging and transport to an on-site upland CDF followed by capping. The latter has the same two first steps but adds the third step of transport to a regional landfill after dewatering.

The following section discusses the volumes of material to be dredged by segment, size of the CDFs, and preliminary order-of-magnitude costs for implementing a single alternative over the entire reach. The 14 segments of Reach 1 were introduced in Section 5.3. The test holes used to define the depth of contamination are shown on Figures 3-1 and 3-2; the level of contamination used to define the depth of maximum dredging is presented in Table 7-1.

The dredge volumes were calculated by end-area method (see Appendix F) and are presented in Table 7-2. The volume of material to be dredged from the GCR/IHC/LGC system is based on an evaluation of the Floyd Brown and Maxim Technologies samples collected previously. The samples were screened using a PEC-Q developed by MacDonald (2000b). Of 98 samples collected and evaluated, all but 22 were above the PEC-Q threshold of 0.7. In the LGC, there were four test holes yielding 10 samples. One deep sample (10 to 14 feet below mudline) had an index quotient between 0.3 and 0.7. All other samples were greater than 0.7. In the IHC, there were 11 test holes yielding 15 samples. Two surface samples had an index quotient between 0.1 and 0.3 and one surface sample had an index quotient between 0.3 and 0.7. All other samples were greater than 0.7. The cleaner surface samples were interspersed spatially with samples greater than 0.7. In the GCR, there were 28 test holes yielding 73 samples. Three deep samples (greater than 5 feet deep) had an index quotient less than 0.1. Nine samples had index quotients between 0.1 and 0.3; only three were surface samples. Six samples, two of them surface samples, had an index quotient between 0.3 and 0.7. All other samples were greater than 0.7. The cleaner surface samples were interspersed spatially with samples greater than 0.7.

The 3-foot dredge prism would involve the least amount of dredging. All material in the 3-foot dredge prism is assumed to be polluted and should be removed. The volume of material to be dredged from the LGC is 108,000 cy, or a total of 144,000 cy allowing for 1 foot of overdredge. The volume of material to be dredged from the IHC is 180,000 cy, or a total of 239,000 cy allowing for 1 foot of overdredge. The volume of material to be dredged from both branches of the GCR is 690,000 cy, or a total of 920,000 cy allowing for 1 foot of overdredge. The total amount of material to be dredged from the entire GCR/IHC/LGC system is approximately 1,303,000 million cy.

The maximum dredge prism would involve the most amount of dredging. The maximum dredge limits are shown on the bathymetry profiles in Appendix B. The depth limits of maximum dredging were drawn and are shown to be below a PEC-Q of 0.7 in the test hole profiles or to the depth of the test hole if the contamination level of 0.7 extended down the full length of the test hole. In the LGC, all material from station 37+30 (the upper limit of Reach 2) to 41+00 and above an elevation of 548 feet above msl is assumed to be contaminated and should be removed. From station 41+00 to 71+40, the floor of the dredge prism is raised to elevation 556 feet above msl. The volume of material to be dredged from the LGC is 413,000 cy for the contaminated prism and a total of 447,000 cy allowing for 1 foot of overdredge. In the IHC, all material above elevation 556 feet above msl from station 0+50 to 78+10 (the upper limit of Reach 2) is assumed to be contaminated and should be removed. The volume of material to be dredged is 443,000 cy for the maximum prism and a total of 492,000 cy allowing for 1 foot of overdredge. In the GCR, the bottom of the dredge prism stair-steps along the river. The volume of material to be dredged is 1,361,000 cy for the maximum prism and a total of 1,538,000 cy allowing for 1 foot of overdredge. The maximum amount of material to be dredged from the GCR/IHC/LGC system is approximately 2,443,000 million cy.

Six locations have been identified as potential CDF sites. They are located as follows:

- North bank of the GCR near the Gary Municipal Airport
- North bank of the GCR at the Gary Development Corporation Landfill near Cline Avenue
- North bank of the GCR on Dupont East Chicago facility property
- North bank of the GCR on U.S.S. Lead property
- East bank of the IHC just north of the East Chicago railroad bridge
- North bank of the LGC between the Indianapolis Avenue bridge and the railroad bridge (USACE cited and approved CDF location)

The potential area of each site is presented in Table 7-3. It is assumed that the bulking of dredged sediments is negligible after dewatering. If the sediment bulks appreciably, more disposal area will be needed. The total potential acreage is 207 acres, excluding the area for the containment dike or structure. This indicates that the height of the CDF must average 8 feet for the maximum dredge prism and 5 feet for the 3-foot dredge prism. Using the LGC as a CDF lowers the average deposit heights to 6 feet and 3 feet, respectively.

The order-of-magnitude cost estimate for the 3-foot dredge prism with thick capping is $190 million. The order-of-magnitude cost estimate for maximum dredge prism with no capping is $270 million. Refer to Appendix G for a summary of the assumptions that were used to develop the feasibility cost estimates for this project.

7.2. EVALUATION OF ALTERNATIVES FOR REACH 2

The one alternative being considered for Reach 2 is applicable if dredging by USACE does not remove all the contaminated sediments. Based on MacDonald 2000a, the subsurface sediment in the IHC exceeds PEC-Q of 0.7 in the canal portion of the Federal Project channel to be capped. Therefore, for costing purposes, it was assumed that the entire reach (excluding the harbor) would have to be dredged to an additional 3 feet of contaminated sediment (3-foot dredge prism) with the additional step of thick capping. Additional design and implementation of the USACE CMP will allow for further characterization of the reach and determination of the extent to which capping is required. This will allow refinement of the cost analysis.

The undetermined factor in this alternative is whether the dredged sediment would be permanently deposited in an upland on-site CDF or whether the upland on-site CDF would be a temporary holding spot for dewatering and the final deposit location would be a regional landfill.

The order-of-magnitude cost estimate for the 3-foot dredge prism with thick capping for all of Reach 2 is $60 million. The details are presented in Appendix G. It is possible that the full extent of Reach 2 will not need to be dredged to remove contaminated sediment. This will not be known unless and until further sediment sampling is conducted in Reach 2 following completion of the USACE dredging action. If the amount of dredging needed is reduced, the cost will be reduced accordingly.

Table 7-1. Grand Calumet River/Indiana Harbor Canal/Lake George Canal Test Hole Samples by Floyd Brown and Maxim **Page 1 of 4**

Test Hole No.	Northing	Easting	Mudline Elevation	Sample Depth Interval	PEC-Q*
GC99T07L1	2317066.75	2863006.75	577.75	0-5	4.17
GC99T06CS	2318945.50	2849150.00	575.43	0–0.33	1.06
GC99T07CS	2320125.50	2847364.25	571.03	0–0.33	3.00
GC99T05CS	2318230.75	2854420.00	576.63	0–0.33	2.47
GC99T05C1	2318230.75	2854420.00	576.63	0–5	2.41
GC99T05C2	2318230.75	2854420.00	576.63	5–6.63	2.06
GC99T05L1	2318224.25	2854488.50	573.69	0–5	1.33
GC99T04CS	2318484.75	2857593.25	576.32	0–0.33	1.53
GC99T04C1	2318484.75	2857593.25	576.32	0–5	3.73
GC99T03RS	2317501.50	2860515.50	576.68	0–0.33	36.16
GC99T03R1	2317501.50	2860515.50	576.68	0-5	28.54
GC99T03CS	2317477.00	2860570.00	574.84	0-0.33	3.34
GC99T03C1	2317477.00	2860570.00	574.84	0–5	30.76
GC99T03C2	2317477.00	2860570.00	574.84	5–10	2.98
GC99T02L1	2317066.75	2863034.25	577.82	0–3	1.47
GC99T02C1	2317096.25	2863221.25	577.88	0–5	2.82
GC99T02CS	2317096.25	2863221.25	577.88	0–0.33	4.50
GC99T02RS	2317139.50	2863084.50	574.90	0–0.33	20.56
GC99T02R1	2317139.50	2863084.50	574.90	0–5	2.35
GC99T02R2	2317139.50	2863084.50	574.90	5–7.25	3.11
GC99T01R1	2316744.50	2868033.00	577.32	0–5	3.03
GC99T01R2	2316744.50	2868033.00	577.32	5–7.92	4.79

Table 7-1. Grand Calumet River/Indiana Harbor Canal/Lake George Canal Test Hole Samples by Floyd Brown and Maxim **Page 2 of 4**

Test Hole No.	Northing	Easting	Mudline Elevation	Sample Depth Interval	PEC-Q*
GC99T01R3	2316744.50	2868033.00	577.32	7.92–10	1.17
IHC99T09CS	2322023.25	2846725.50	574.00	0–0.33	2.19
IHC99T09C1	2322023.25	2846725.50	574.00	0–0.33	1.70
IHC99T10C1	2327191.50	2846721.50	570.94	0–5	5.66
IHC99T10CS	2327191.50	2846721.50	570.94	0–0.33	2.06
IHC99T10L1	2327106.50	2846707.25	570.69	0–5	1.69
GC-SD-PN-036	2317297.00	2869789.75	576.38	0–7.9	1.92
GC-SD-PN-037	2317043.25	2869433.25	573.37	0–7.9	3.46
GC-SD-PN-037	2317043.25	2869433.25	573.37	8–12.9	5.15
GC-SD-PN-038	2316934.75	2869186.75	575.33	0–7.9	2.24
GC-SD-PN-039	2316972.75	2866723.00	575.13	0–7.9	0.71
GC-SD-PN-040	2317329.75	2863828.25	577.53	0–7.9	33.88
GC-SD-PN-040	2317329.75	2863828.25	577.53	8–12.9	13.59
GC-SD-PN-041	2317139.50	2863089.25	574.67	0–7.9	2.12
GC-SD-PN-041	2317139.50	2863089.25	574.67	8–12.9	2.98
GC-SD-PN-042	2317139.75	2863007.00	577.88	0–7.9	2.83
GC-SD-PN-042	2317139.75	2863007.00	577.88	8–12.9	0.97
GC-SD-PN-043	2318582.75	2857379.50	574.46	0–7.9	2.78
GC-SD-PN-043	2318582.75	2857379.50	574.46	8–12.9	1.21
GC-SD-PN-044	2318601.50	2857300.25	577.01	0–7.9	3.56
GC-SD-PN-044	2318601.50	2857300.25	577.01	8–12.9	4.20
GC-SD-PN-048	2318375.00	2852163.75	573.86	0–7.9	4.88

Table 7-1. Grand Calumet River/Indiana Harbor Canal/Lake George Canal Test Hole Samples by Floyd Brown and Maxim **Page 3 of 4**

Test Hole No.	Northing	Easting	Mudline Elevation	Sample Depth Interval	PEC-Q*
GC-SD-PN-048	2318375.00	2852163.75	573.86	8–12.9	3.99
GC-SD-PN-049	2319921.00	2851068.25	572.57	0–7.9	6.04
GC-SD-PN-049	2319921.00	2851068.25	572.57	8–12.9	33.24
GC-SD-PN-049	2319921.00	2851068.25	572.57	13–?	8.54
GC-SD-PN-050	2319813.75	2849725.25	574.01	0–7.9	4.54
GC-SD-PN-053	2320442.75	2846780.50	569.91	0–7.9	2.10
GC-SD-PN-056	2319040.50	2844255.50	577.44	0–7.9	8.44
GC-SD-PN-056	2319040.50	2844255.50	577.44	8–12.9	13.73
GC-SD-PN-056	2319040.50	2844255.50	577.44	13–?	3.98
GC-SD-PN-057	2320680.00	2846713.00	572.51	0–7.9	10.44
GC-SD-PN-057	2320680.00	2846713.00	572.51	8–12.9	4.12
GC-SD-PN-058	2322199.25	2846711.75	573.56	0–7.9	8.84
GC-SD-PN-059	2323737.00	2846743.25	570.72	0–7.9	3.16
GC-SD-PN-060	2325242.00	2846733.50	571.11	0–7.9	2.81
GC-SD-PN-061	2326736.00	2846721.25	570.81	0–7.9	12.14
GC-SD-PN-061	2326736.00	2846721.25	570.81	8–12.9	2.09
GC-SD-PN-062	2327883.75	2846729.00	569.35	0–7.9	8.93
GC-SD-PN-062	2327883.75	2846729.00	569.35	8–12.9	9.64
GC-SD-PN-055	2318999.75	2844353.75	577.44	0–7.9	33.24
GC-SD-PN-055	2318999.75	2844353.75	577.44	8–12.9	2.45
IHC99T12C1	2330905.75	2840656.75	566.59	0–5	31.52
IHC99T12C2	2330905.75	2840656.75	566.59	5–10	14.20

Table 7-1. Grand Calumet River/Indiana Harbor Canal/Lake George Canal Test Hole Samples by Floyd Brown and Maxim **Page 4 of 4**

Test Hole No.	Northing	Easting	Mudline Elevation	Sample Depth Interval	PEC-Q*
IHC99T12CS	2330905.75	2840656.75	566.59	0–0.33	4.54
IHC99T12R1	2330796.00	2840784.00	575.02	0–5	3.13
IHC99T12R2	2330796.00	2840784.00	575.02	5–7.17	3.20
IHC99T11C1	2330926.75	2842679.50	562.97	0–5	9.37
IHC99T11C2	2330926.75	2842679.50	562.97	5–10	11.80
IHC99T11CS	2330926.75	2842679.50	562.97	0–0.33	4.98
IHC99T11C3	2330926.75	2842679.50	562.97	10–14.5	3.19
IHC99T11R1	2330860.25	2842574.50	570.34	0–5	1.75
IHC99T11R2	2330860.25	2842574.50	570.34	5–9.67	2.66
IHC99T11RS	2330860.25	2842574.50	570.34	0–0.33	4.30
GC99T07L2	2863006.75	2317066.75	577.75	5–10	0.63
GC99T05C3	2854420.00	2318230.75	576.63	6.63–10.72	0.32
IHC99T09LS	2846698.50	2322078.00	574.30	0–0.33	0.49
GC-SD-PN-038	2869186.75	2316934.75	575.33	8–12.9	0.59
GC-SD-PN-052	2849396.75	2319090.25	573.37	0–7.9	0.36
GC-SD-PN-052	2849396.75	2319090.25	573.37	8–12.9	0.52
GC-SD-PN-053	2846780.50	2320442.75	569.91	8–12.9	0.43
IHC99T12C3	2840656.75	2330905.75	566.59	10–14	0.37
GC99T06R2	2318909.00	2849149.75	573.32	5.25–9.5	0.07
GC99T05L2	2318224.25	2854488.50	573.69	5–8	0.06
GC99T04C3	2318484.75	2857593.25	576.32	6.5–9.29	0.06

Table 7-2. Grand Calumet River/Indiana Harbor Canal/Lake George Canal Project Segment Volumes Page 1 of 2

Reach ID	Segment ID	River Station		Distance (ft)	3-Ft Dredge Prism			Maximum Dredge Prism		
		From	To		Neatline Volume (cy)	Overdredge Volume (cy)	Total Volume (cy)	Neatline Volume (cy)	Overdredge Volume (cy)	Total Volume (cy)
GCR	1	0	1920	1920	38,400	12,800	51,200	72,900	11,200	84,100
GCR	1B	1920	1980	60	1,300	400	1,700	2,000	300	2,300
GCR	2	1980	9700	7720	171,600	57,200	228,700	446,800	49,900	496,700
GCR	2B	9700	10210	510	14,700	4,900	19,600	31,800	3,900	35,700
GCR	3	10210	12920	2710	57,200	19,100	76,300	119,300	14,800	134,100
GCR	3B	12920	12950	30	800	300	1,100	2,300	200	2,500
GCR	4	12950	13410	460	11,200	3,700	15,000	39,900	3,400	43,300
GCR	4B	13410	13450	40	1,200	400	1,700	3,900	300	4,200
GCR	5	13450	22530	9080	272,700	91,900	363,600	453,200	58,600	511,800
GCR	5B	22530	22700	170	4,300	1,500	5,800	3,600	800	4,400
GCR	6	22700	26280	3580	71,600	23,900	95,500	82,600	20,500	103,100
GCR	7	26280	29604	3324	44,300	14,800	59,100	102,200	12,900	115,100
IHC	8	50	400	350	8,600	2,900	11,400	19,200	2,100	21,300
IHC	8B	400	475	75	1,900	600	2,600	4,700	500	5,200

Table 7-2. Grand Calumet River/Indiana Harbor Canal/Lake George Canal Project Segment Volumes **Page 2 of 2**

Reach ID	Segment ID	River Station		Distance (ft)	3-Ft Dredge Prism			Maximum Dredge Prism		
		From	To		Neatline Volume (cy)	Overdredge Volume (cy)	Total Volume (cy)	Neatline Volume (cy)	Overdredge Volume (cy)	Total Volume (cy)
IHC	9	475	1150	675	15,800	5,300	21,000	43,000	4,300	47,300
IHC	9B	1150	1225	75	1,800	600	2,400	4,300	500	4,800
IHC	10	1225	4115	2890	64,200	21,400	85,600	175,800	18,400	194,200
IHC	10B	4115	4185	70	1,800	600	2,400	3,500	500	4,000
IHC	11	4185	4620	435	10,200	3,400	13,600	22,800	2,800	25,600
IHC	11B	4620	4650	30	700	200	1,000	1,900	200	2,100
IHC	12	4650	7750	3100	72,300	24,100	96,400	164,200	19,700	183,900
IHC	12B	7750	7810	80	1,900	600	2,500	3,200	400	3,600
LGC	13	3700	4845	1145	33,500	11,200	44,700	128,00	11,100	139,100
LGC	13B	4845	4860	15	500	200	700	1,200	200	1,400
LGC	14	4860	7140	2280	73,500	24,500	98,000	283,300	22,800	306,100
				Totals	979,300	325,500	1,304,800	2,215,600	260,300	2,475,900

* Based on bridges and property lines.

Table 7-3. Potential Acreage of Confined Disposal Facilities Along the Grand Calumet River/Indiana Harbor Canal/Lake George Canal.

Site	Stationing	Potential Acreage
North bank of Calumet River near Gary municipal airport	GCR 50+00 to 85+00	50
North bank of the Calumet River at Gary Development Corporation landfill near Cline Avenue	GCR 121+00 to 126+00	3
North bank of the Calumet River on DuPont East Chicago facility property	GCR 140+00 to 190+00	64
North bank of the Calumet River on U.S.S. Lead property	GCR 230+00 to 262+00	16
East bank of the Indiana Harbor Canal just north of the East Chicago railroad bridge	IHC 50+00 to 60+00	24
North bank of the Lake George Canal between the Indianapolis Avenue bridge and the railroad bridge (USACE sited and approved CDF location)	LGC 27+00 to 48+00	50+

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APPENDIX A

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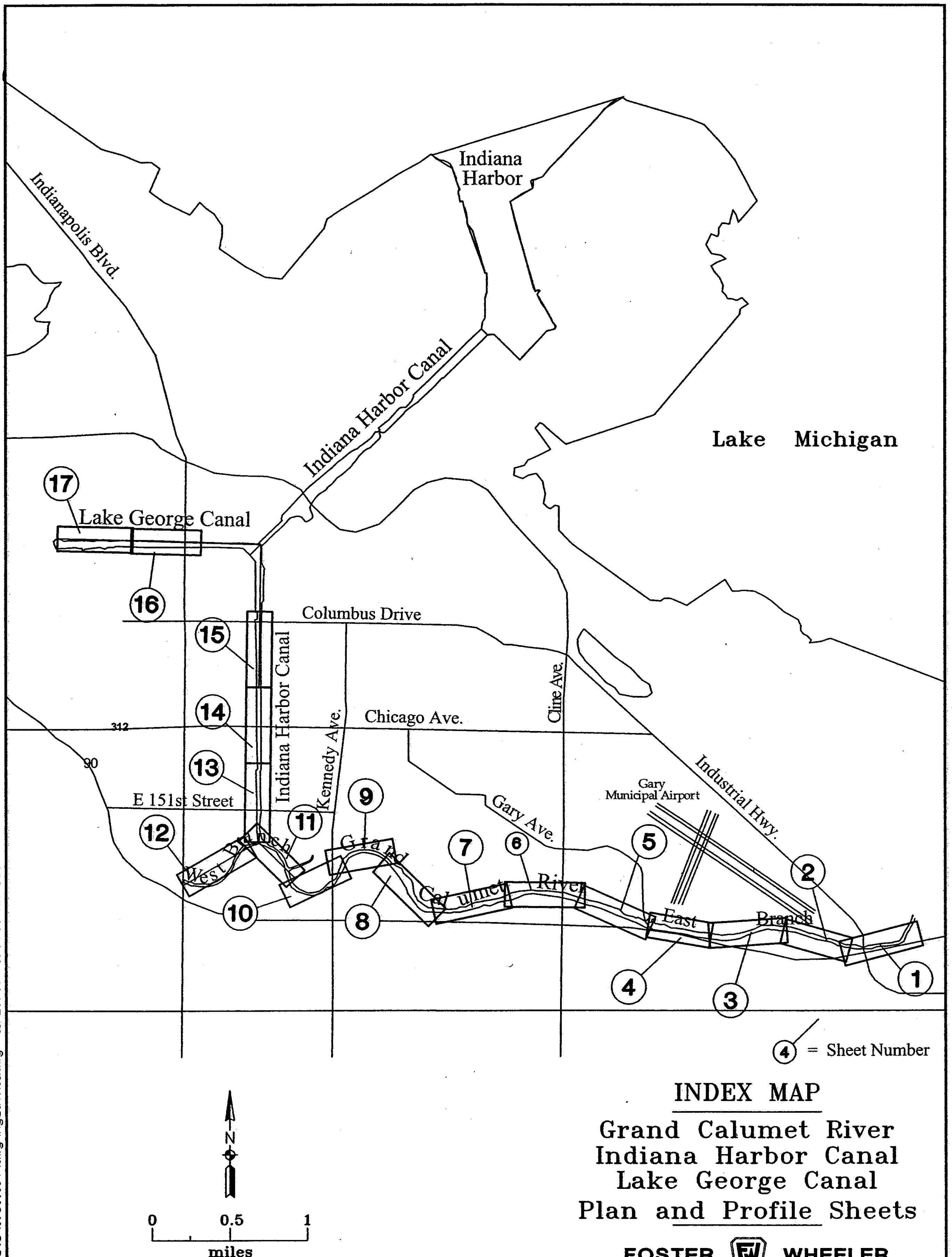
APPENDIX B

BATHYMETRY PLAN AND PROFILES

BATHYMETRY PLAN AND PROFILES

The plan and profile drawings for the GCR/IHC/LGC were produced from a hydrographic survey of the waterways supplemented by U.S. Geological Survey map data. The river and canal bottom contours were produced from a field hydrographic survey performed in May 2000 by Foster Wheeler Environmental. The river and canal banks were not included in the survey. As a guide for bank configuration, the 585-foot elevation contour from the U.S. Geological Survey 7.5-Minute Quad Sheet Maps for the river/canal system was transferred to the hydrographic maps at the same scale of the river/canal bottom.

Test hole locations from the Floyd Browne Associates (1991) and Maxim Technologies (1999) studies were included. The test hole samples were used elsewhere to set the limits of dredging in the river/canal system. The 3-foot depth of dredging and the maximum depth of dredging (discussed in Appendix F) are shown on the drawings. Outfalls were located during the field survey and are included on the drawings.



INDEX MAP

Grand Calumet River
Indiana Harbor Canal
Lake George Canal
Plan and Profile Sheets

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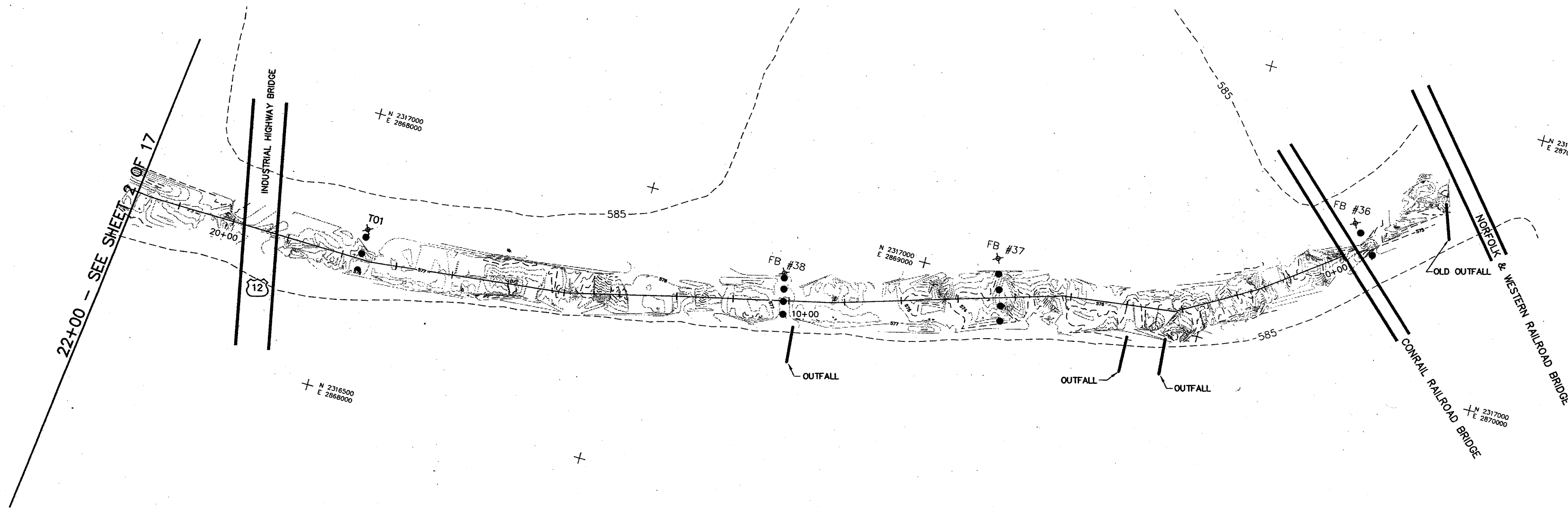

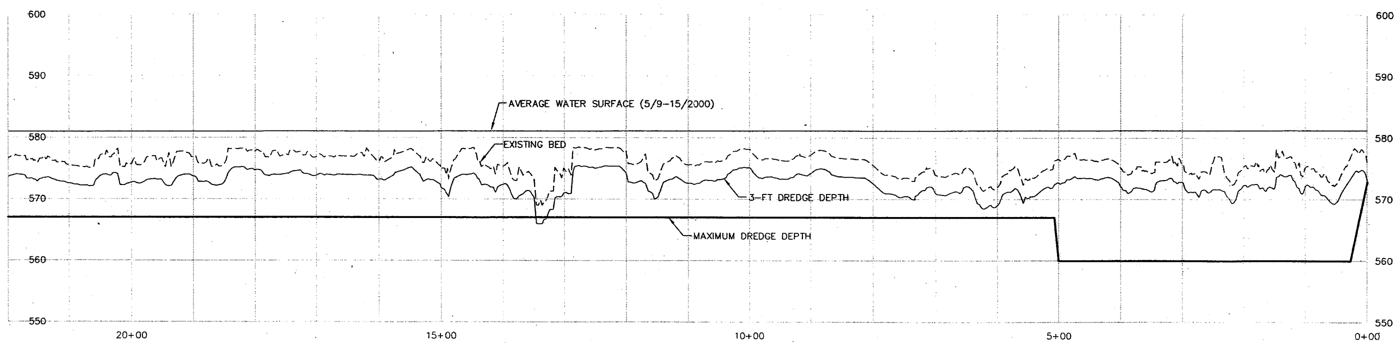

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- TRANSECT STAKES
- TEST HOLES
- FB FLOYD BROWN ASSOCIATES TEST HOLE TRANSECTS
- T01 MAXIM TECHNOLOGIES AND IDEM TRANSECTS
- – – – APPROX. 585 FT ELEVATION FROM USGS QUAD MAPS

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HORIZONTAL SCALE IN FEET

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VERTICAL SCALE IN FEET

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NOTES:

1. HORIZONTAL DATUM = INDIANA STATE PLANE COORDINATES, WEST 1302 ZONE, NAD83
2. VERTICAL DATUM = NGVD29
3. 1 FOOT BATHYMETRY CONTOURS SHOWN
4. ORIGINAL FIELD WORK PERFORMED ON 5/9 TO 5/15/00 BY FOSTER WHEELER ENVIRONMENTAL CORPORATION
5. ALL DIMENSIONS IN FEET

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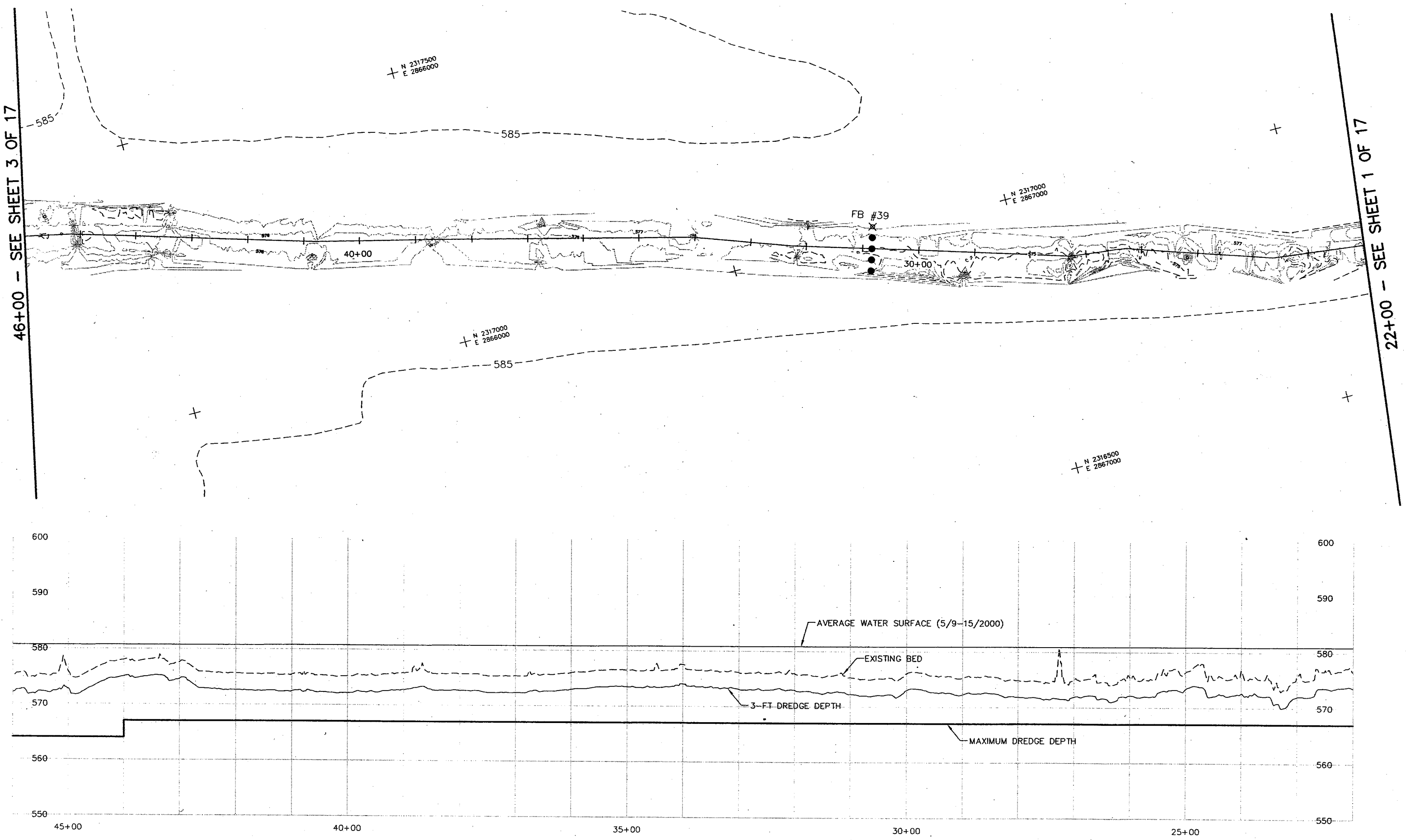

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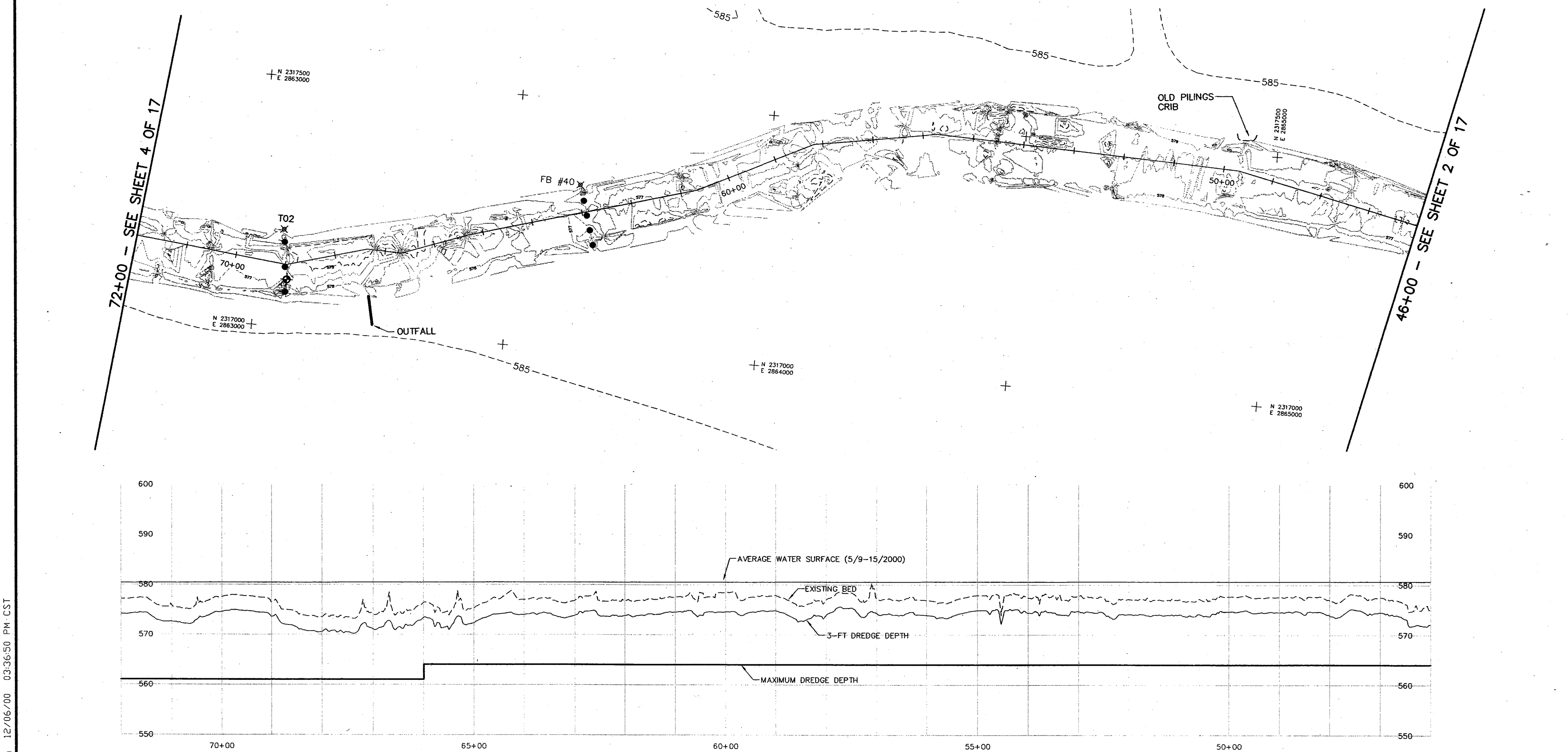

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PLAN & PROFILE

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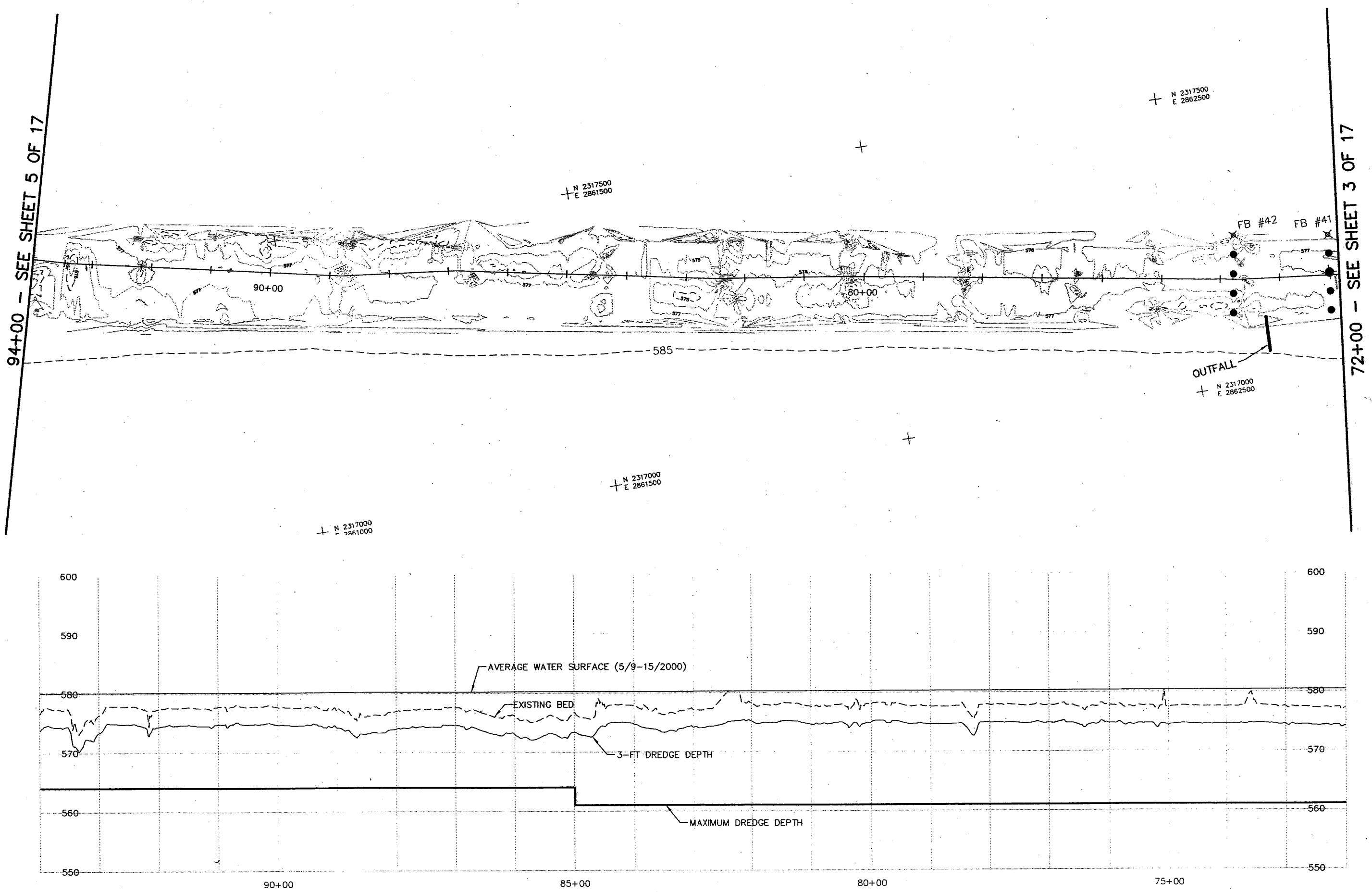

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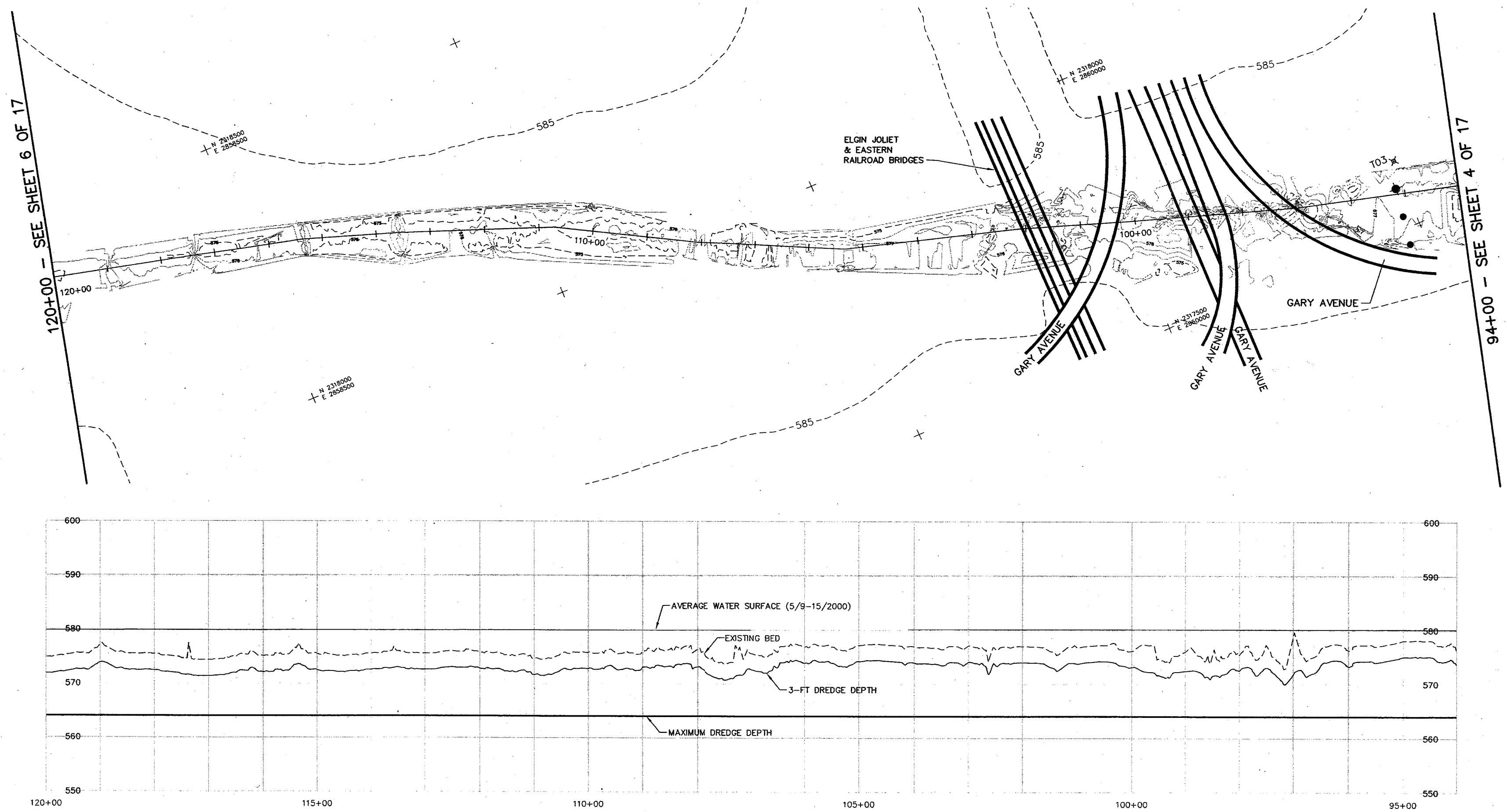

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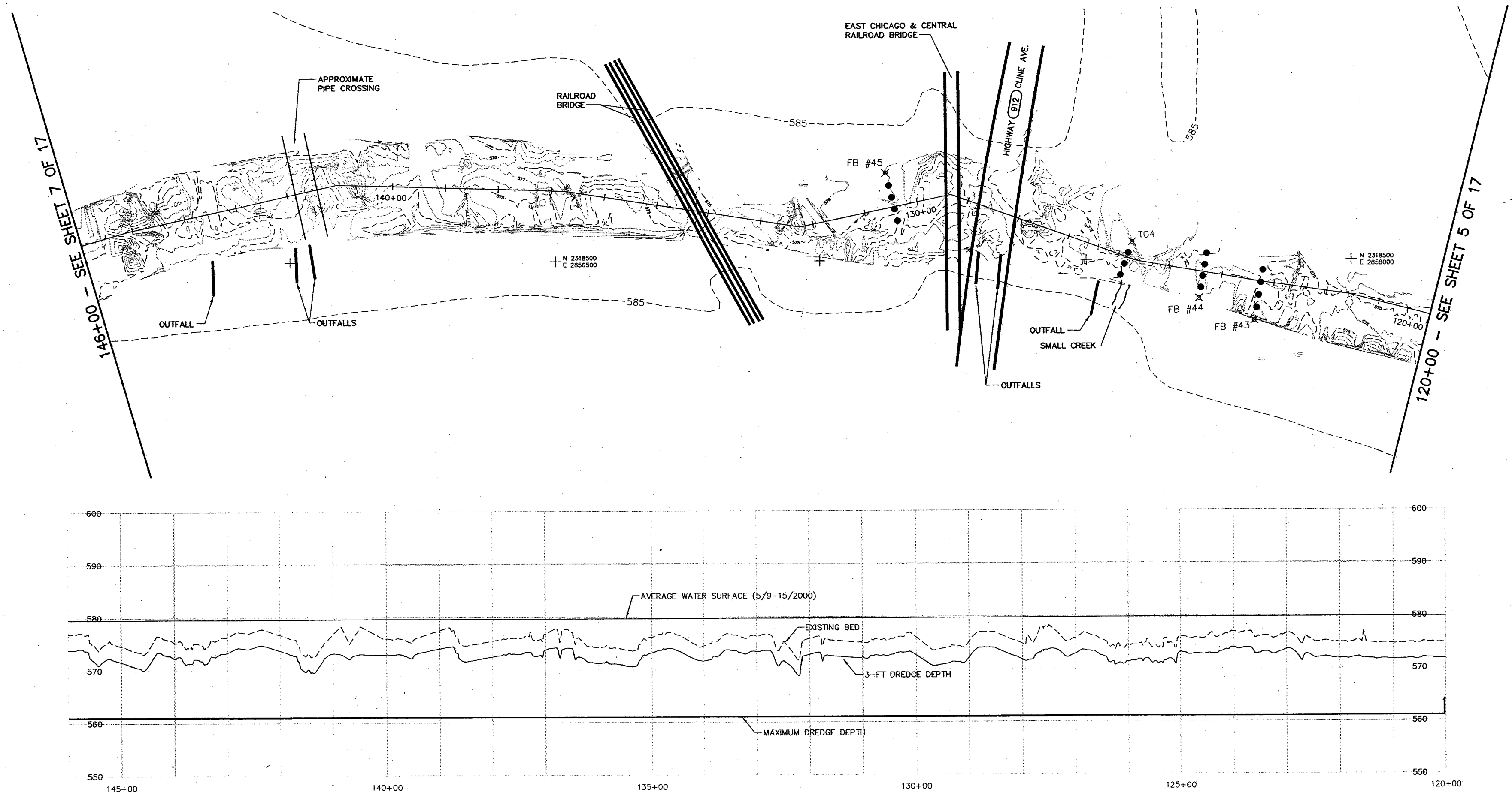

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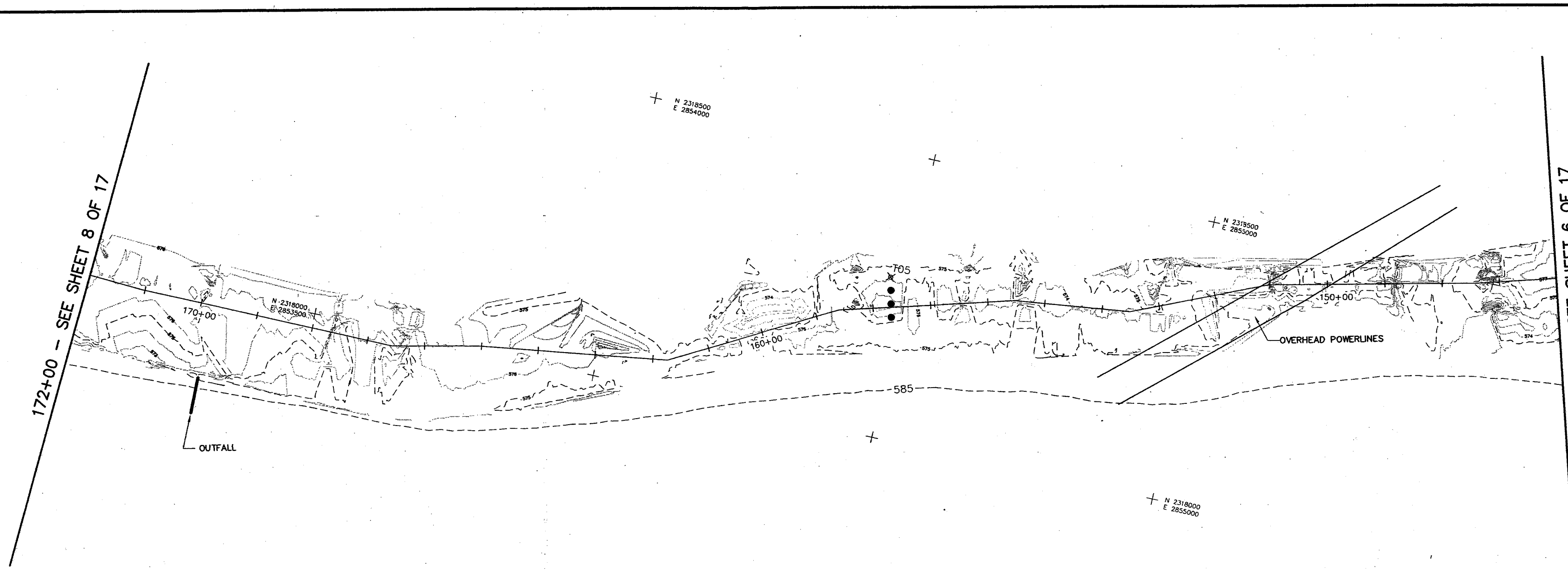

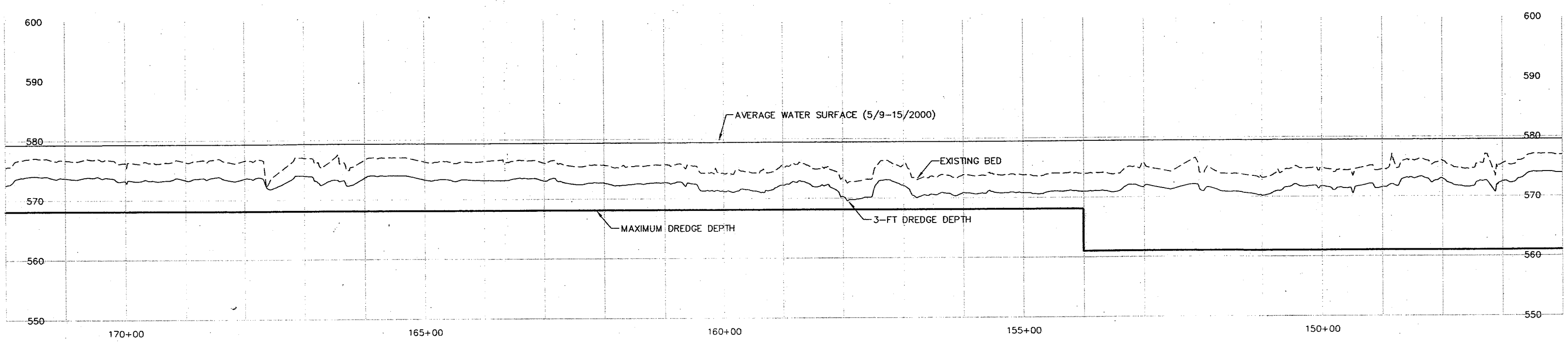

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- FB FLOYD BROWN ASSOCIATES TEST HOLE TRANSECTS
- T01 MAXIM TECHNOLOGIES AND IDEM TRANSECTS
- — — — APPROX. 585 FT ELEVATION FROM USGS QUAD MAPS

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NOTES:

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2. VERTICAL DATUM = NGVD29
3. 1 FOOT BATHYMETRY CONTOURS SHOWN
4. ORIGINAL FIELD WORK PERFORMED ON 5/9 TO 5/15/00 BY FOSTER WHEELER ENVIRONMENTAL CORPORATION
5. ALL DIMENSIONS IN FEET

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DRAWING REDUCED HALFSIZE

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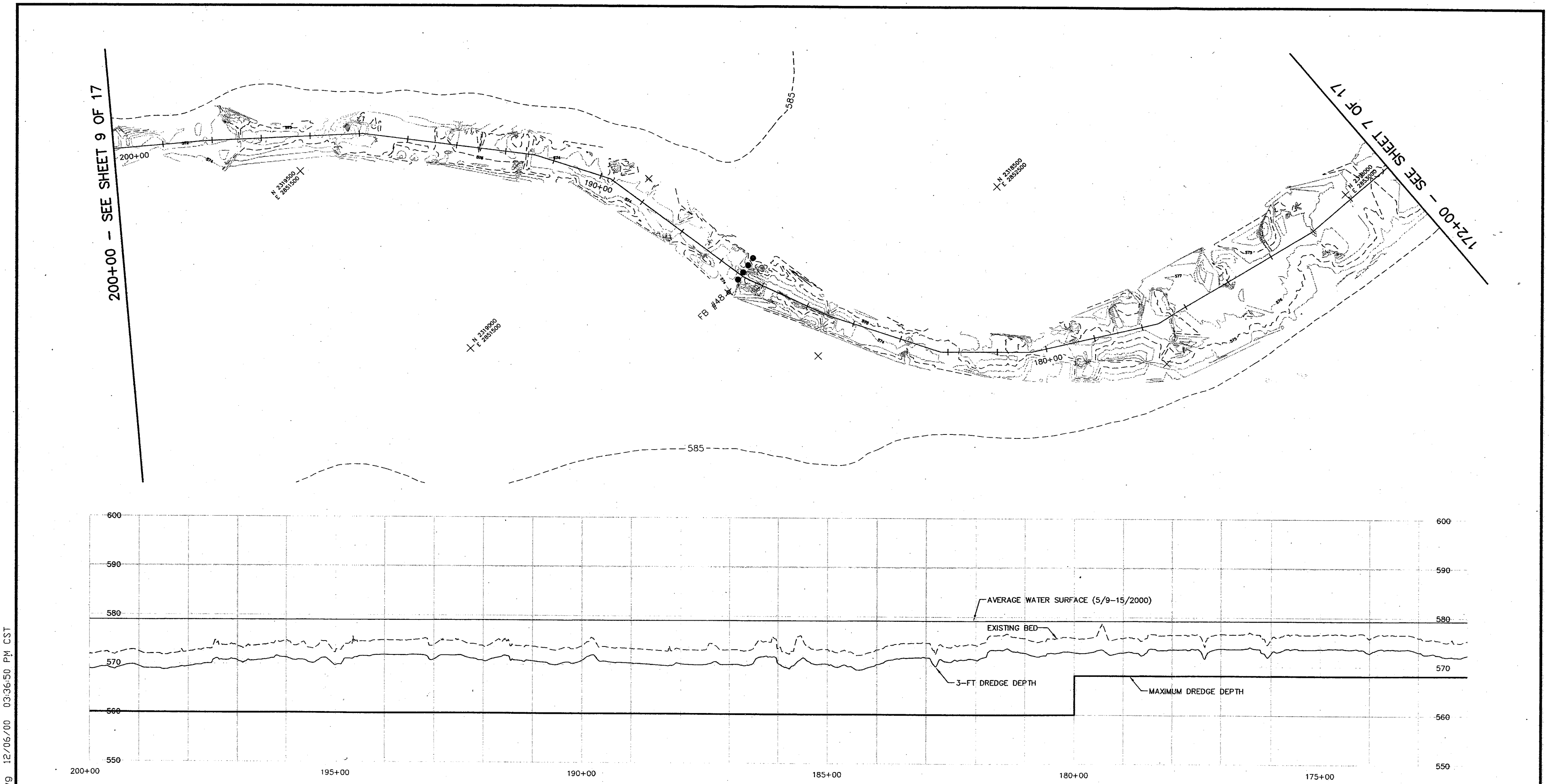

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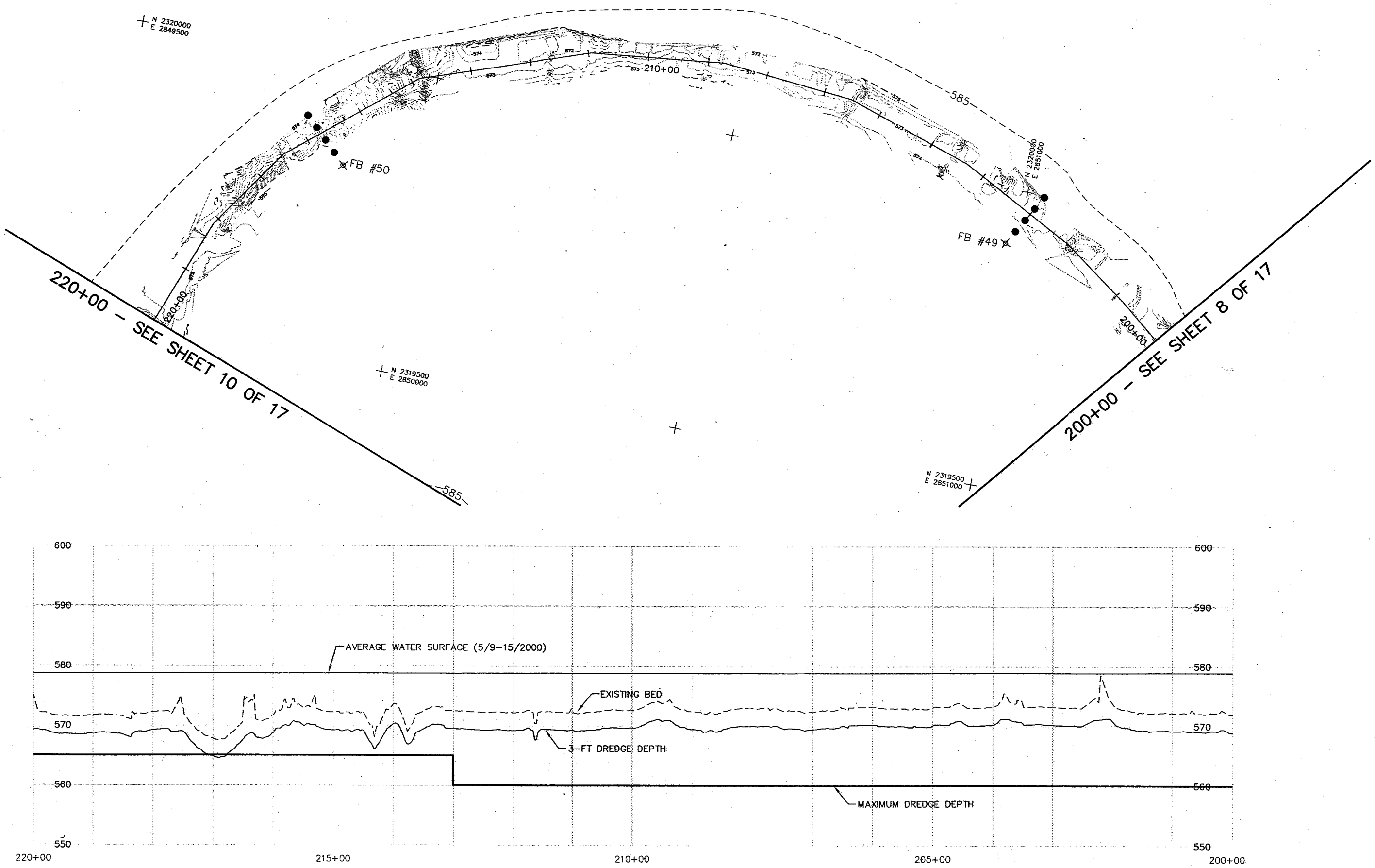

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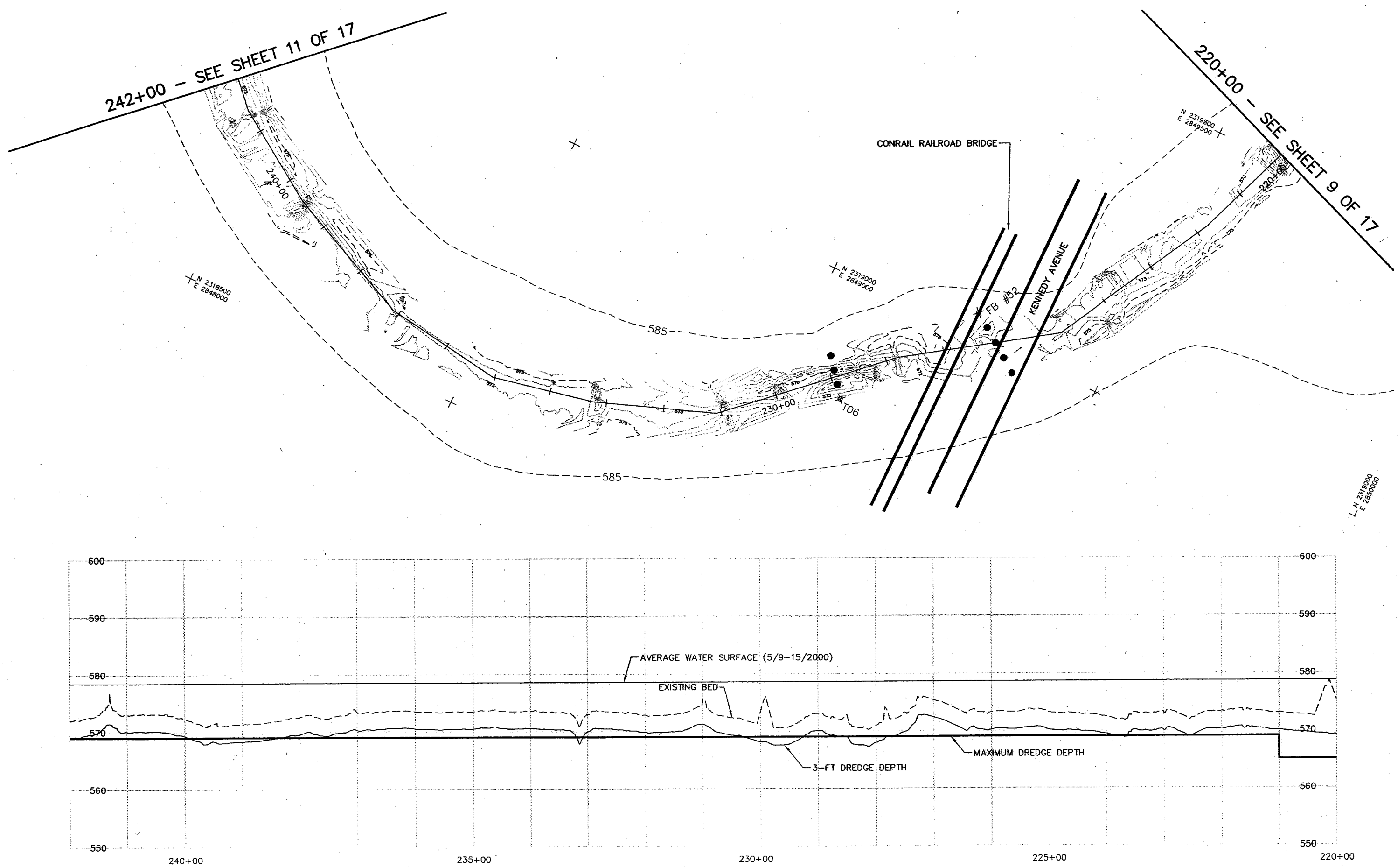

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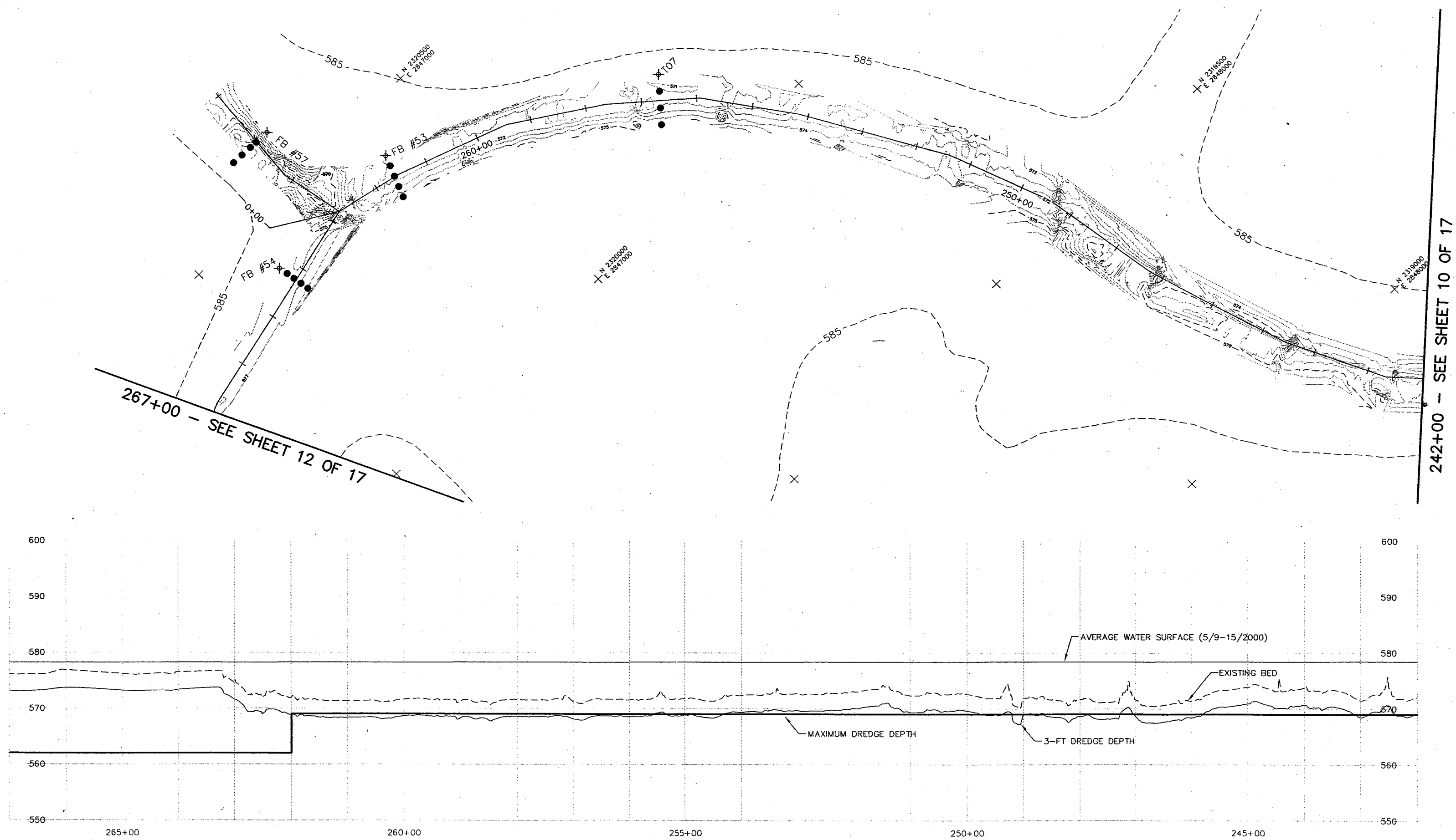

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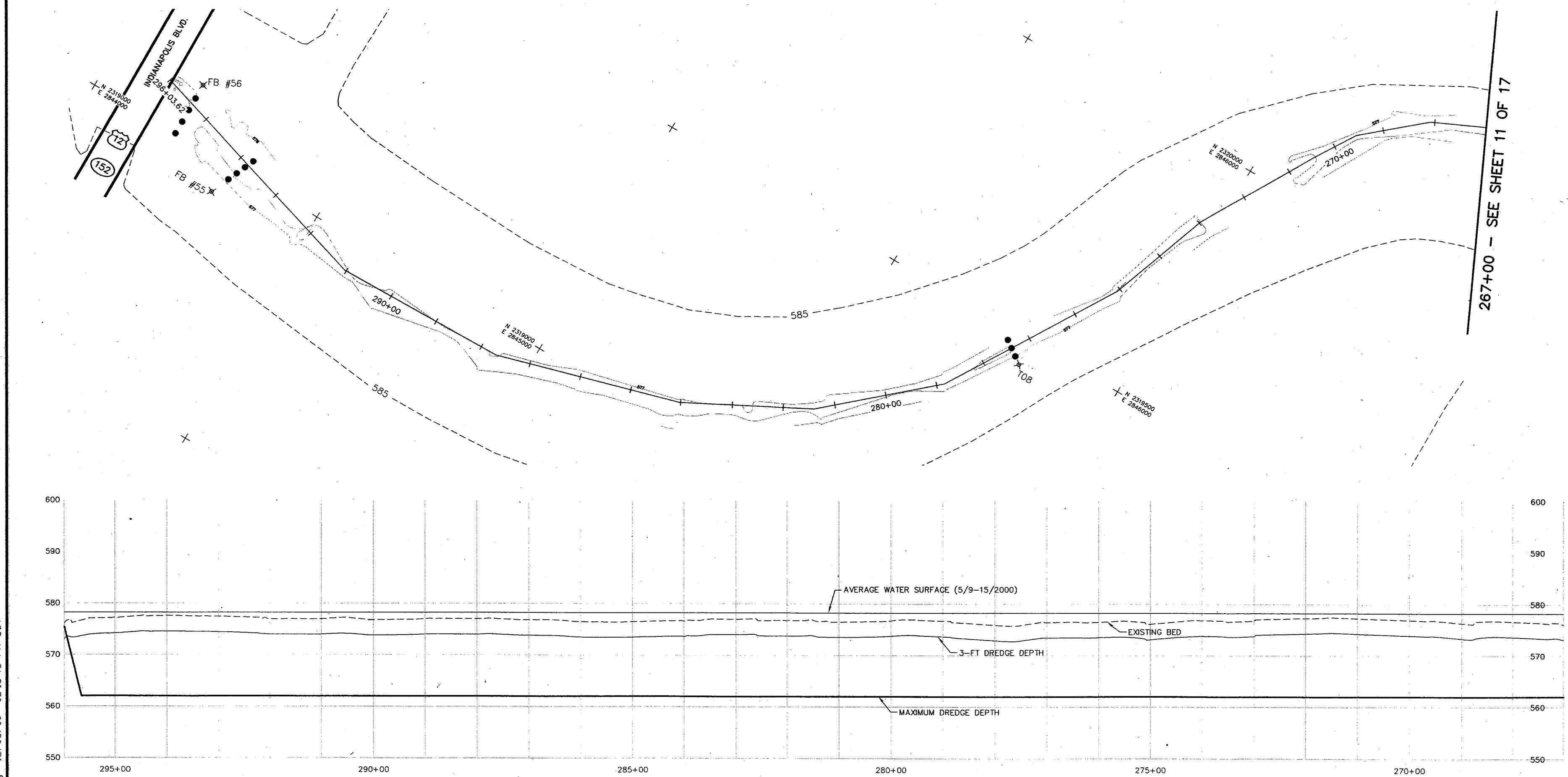

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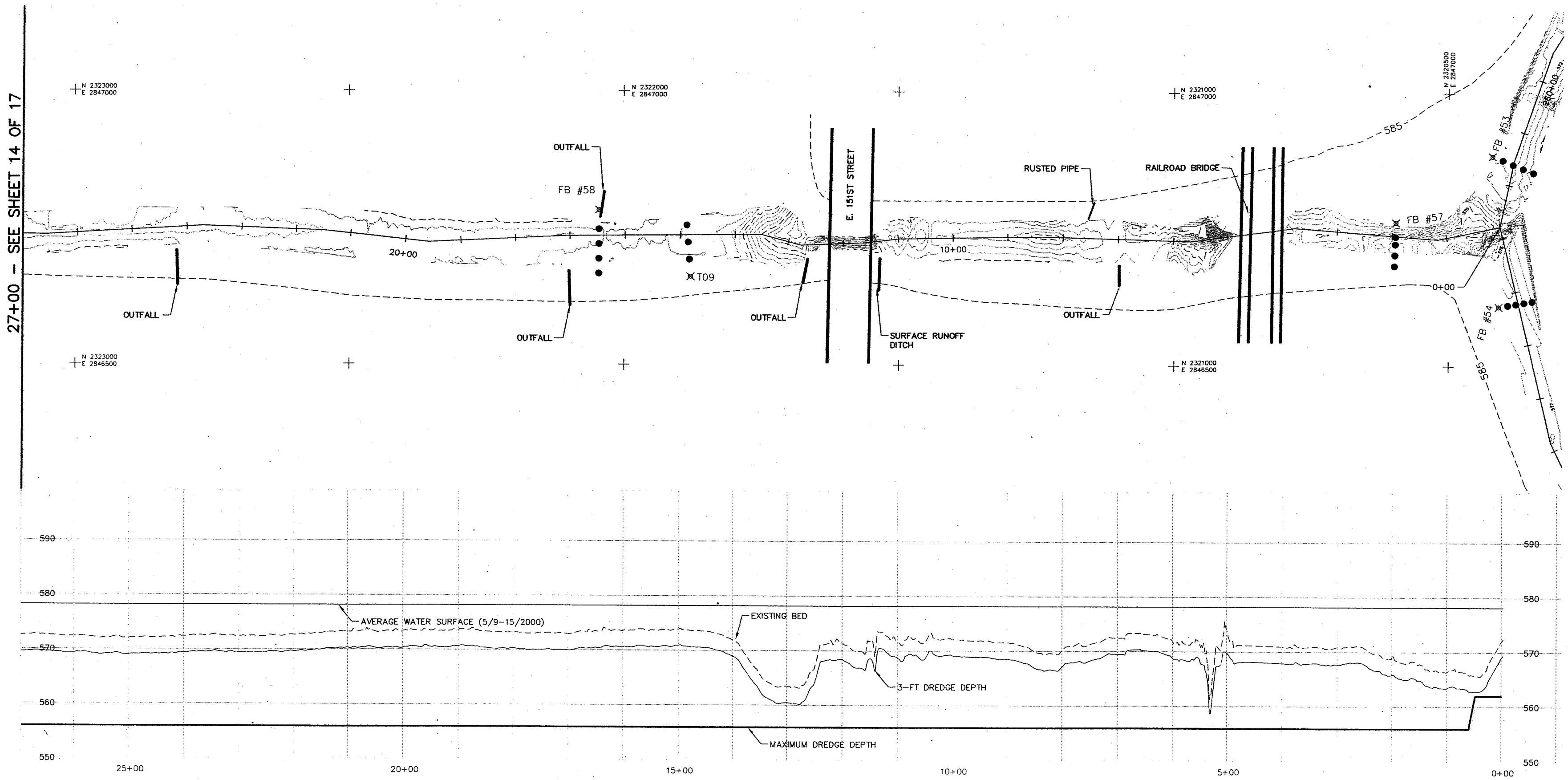

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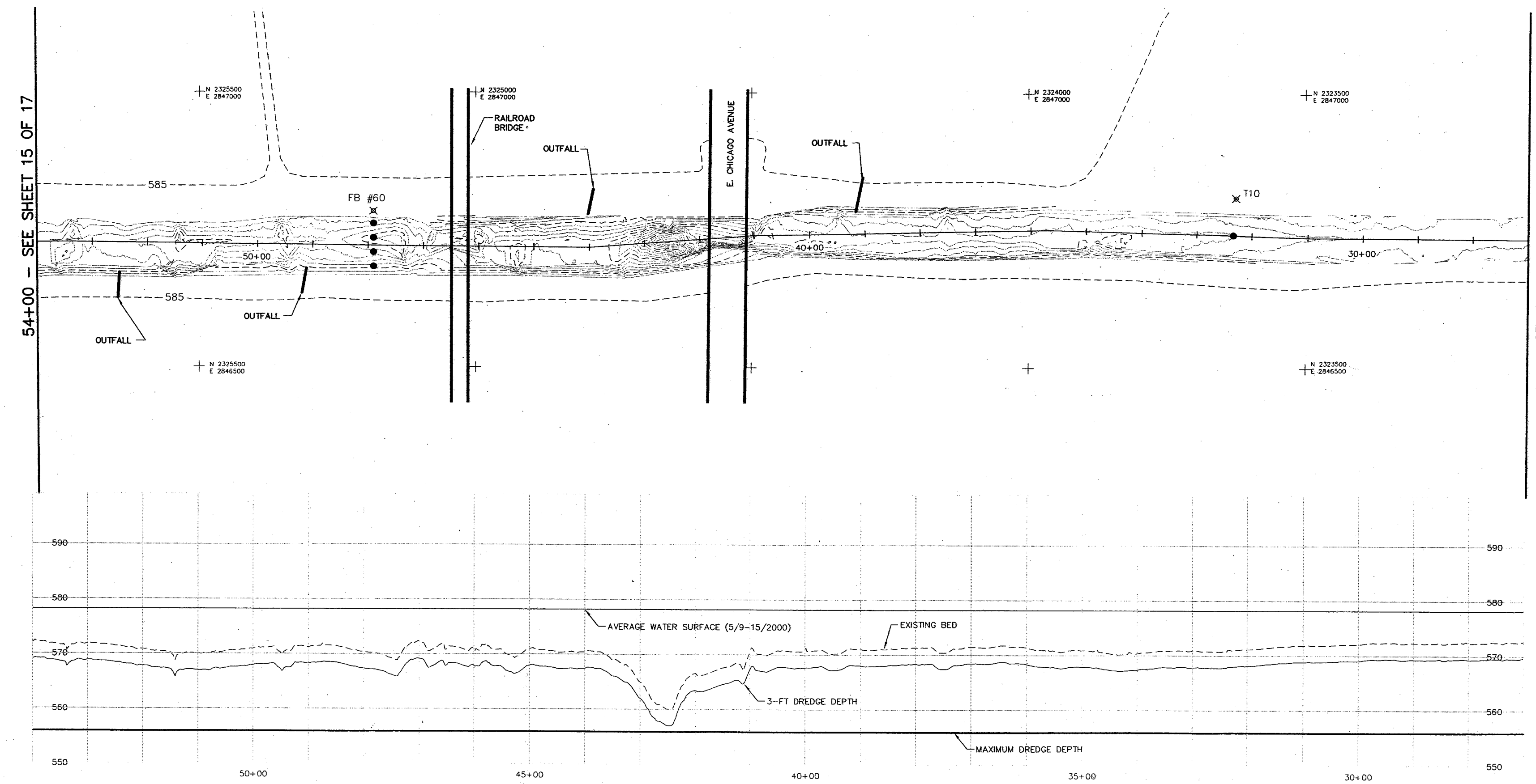

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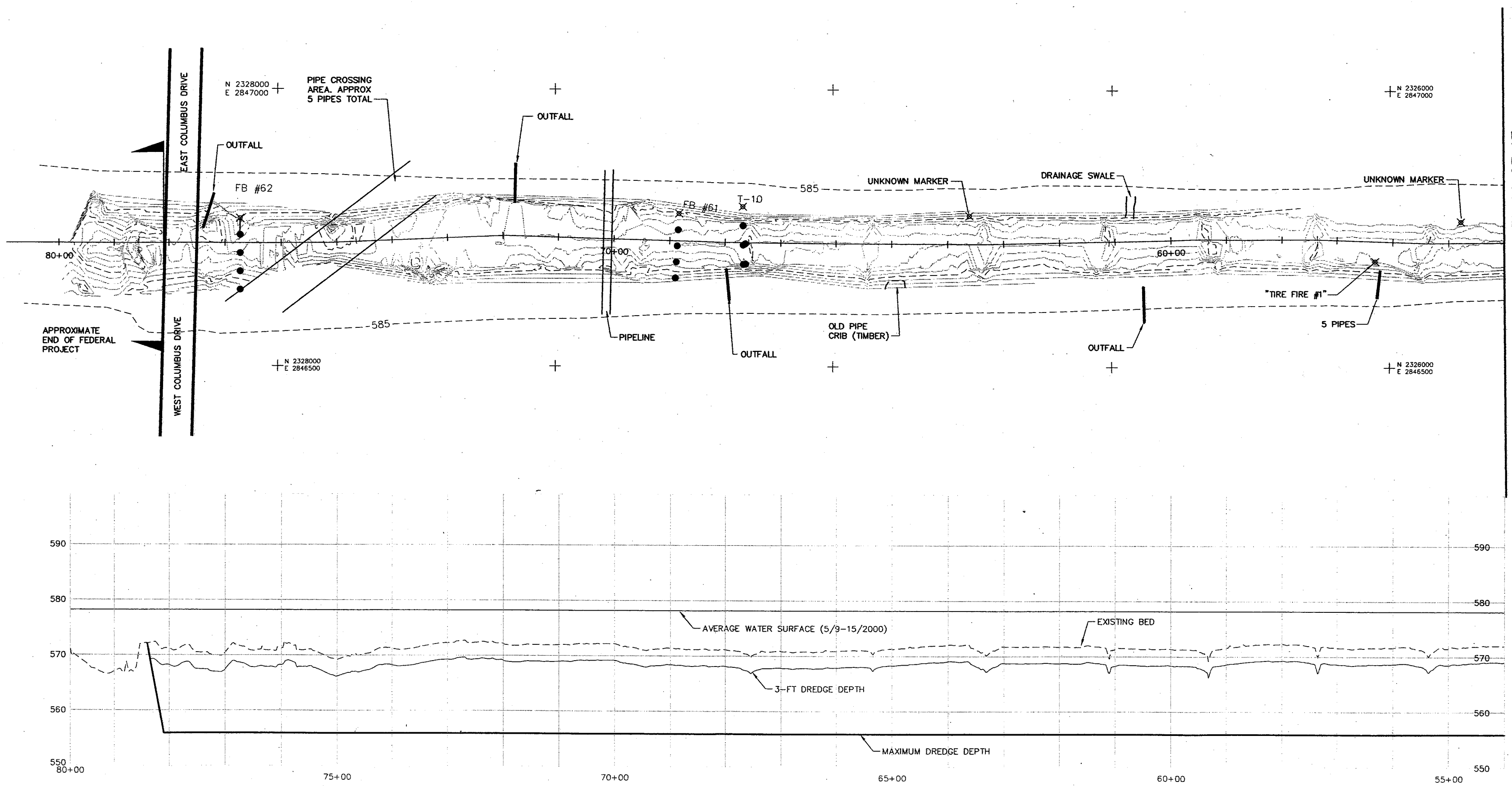

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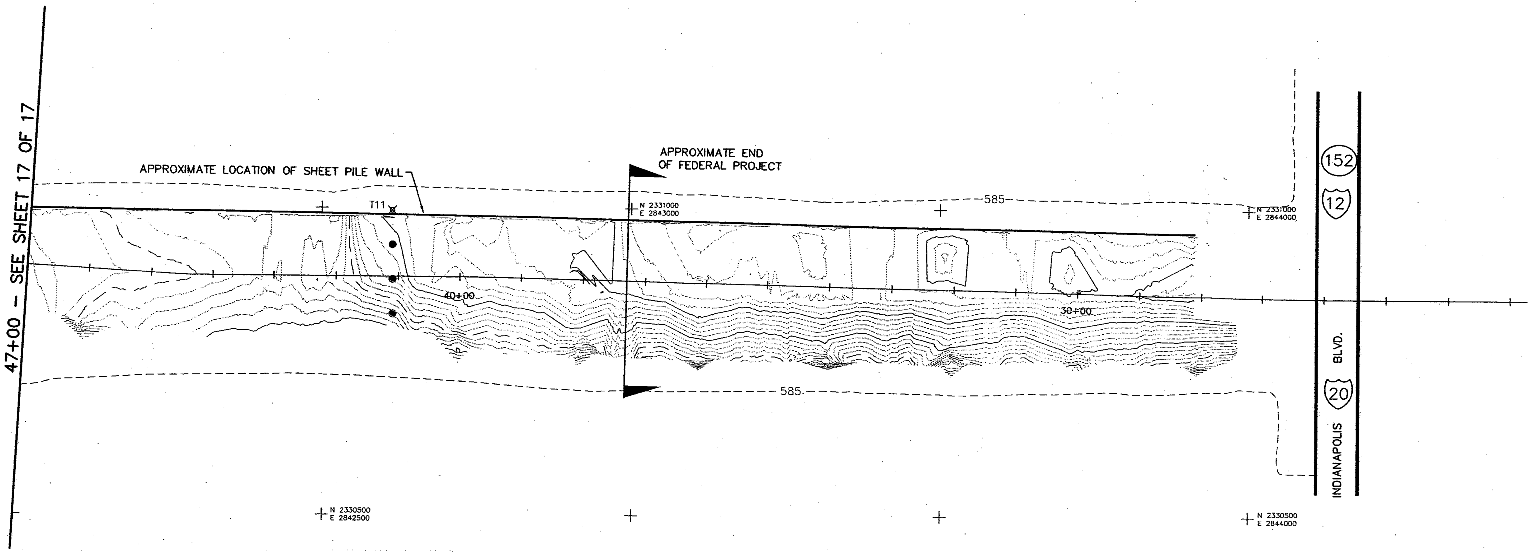

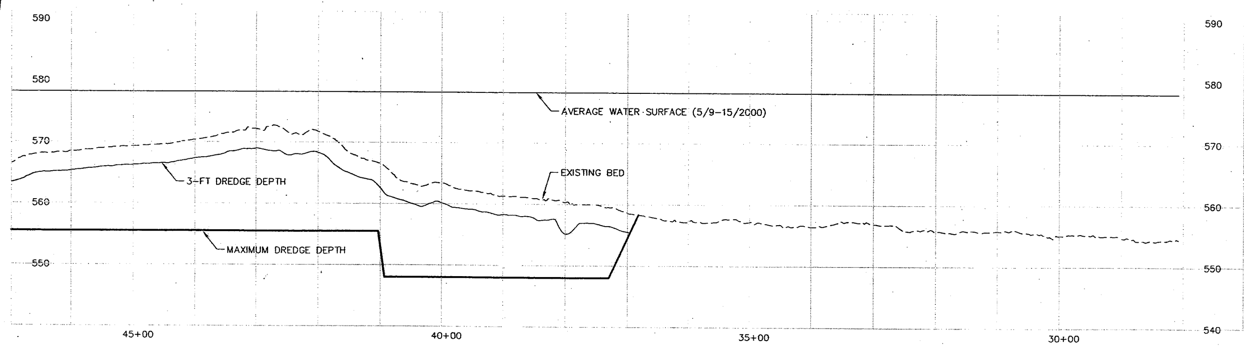

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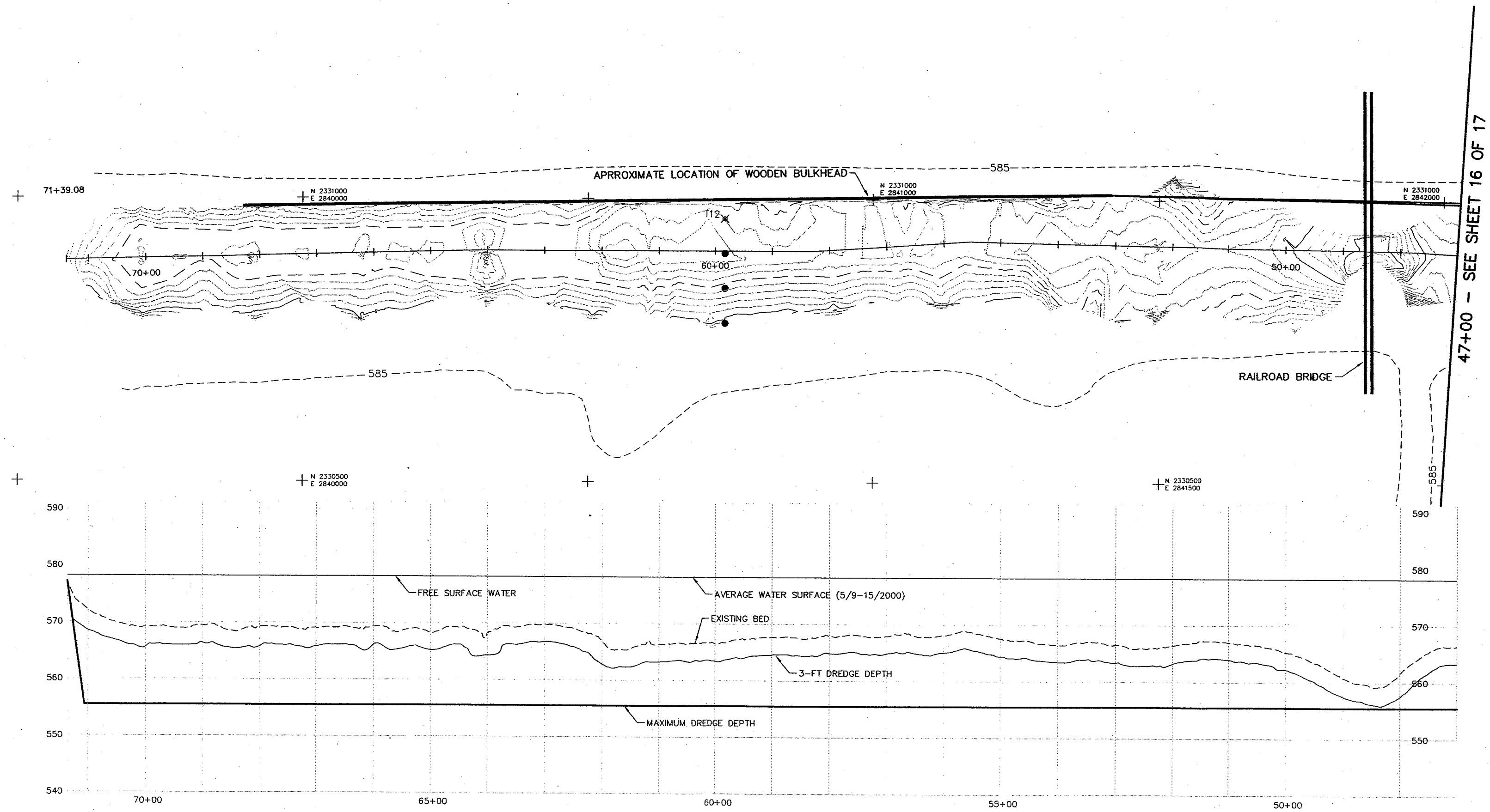

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APPENDIX C

DREDGE TECHNOLOGIES

HYDRAULIC DREDGING TECHNOLOGIES

HYDRAULIC PIPELINE DREDGE WITH CUTTER HEAD

The most common type of hydraulic dredge is the hydraulic pipeline dredge with cutter head. It consists of a basket cutter head, with or without teeth, at the end of a ladder. The cutter head turns and loosens the sediment for transport by the suction pipeline to a pump mounted and enclosed on a barge. The discharge pipeline then carries the sediment as a slurry to a disposal site. The dredge advances the cut by swinging back and forth and pivoting on spuds. The swing is controlled by barge-mounted winches, which pull on anchored cables. Hydraulic pipeline dredges are classified by the internal diameter of the discharge pipeline. Common sizes range from 2 inches to 42 inches, with production rates that vary from 30 to about 2,500 cubic yards per hour (cy/hr). The advantages of a hydraulic pipeline dredge include continuous removal of sediment, cost effectiveness when the dredging area is within pumping distance of the disposal area, and efficiency for small dredge cut thickness. Disadvantages include the potential for the discharge pipeline and anchor cables to interfere with shipping traffic, the addition of 9 to 10 parts water to 1 part dredged material, debris that can foul the cutter head, and a hydraulic pipeline dredge that cannot work in heavy sea conditions.

BUCKET WHEEL DREDGE

The bucket wheel dredge is similar to the hydraulic pipeline dredge, except that the cutter head is replaced with a bucket wheel. The bucket wheel excavator consists of a series of buckets mounted on a wheel at the end of a ladder. As the wheel turns, the buckets pick up material and deliver it by way of a hopper to the suction pipeline. The major advantage of a bucket wheel dredge is that it can excavate harder material than other types of dredges. However, bucket wheel dredges tend to be large and ponderous machines. Production rates vary from 600 to 3,000 cy/hr.

DUSTPAN DREDGE

The dustpan dredge is a self-propelled barge or ship with a dustpan at the end of a ladder for excavating material. The flat, rectangular dustpan is at the suction end of the pipeline (much like the end of a vacuum cleaner). It may have jets around the perimeter of the mouth to help loosen the material to be dredged. Dustpan dredges, because of their mobility, usually discharge the material overboard (side cast), but they are capable of discharging into the hold of an accompanying barge or through a discharge pipeline that they drag along behind. An advantage of the dustpan dredge is that it can dredge continuously. Production rates typically vary, depending on dustpan and ancillary equipment size, from 100 to 4,500 cy/hr. A major disadvantage is its inability to dredge consolidated sediment.

AUGER DREDGE

An auger dredge is a variant of the cutter head hydraulic pipeline dredge. The cutter head is replaced with an auger. The auger is a rotating horizontal screw that plows the dredged material to the suction pipe. Advantages of the auger dredge are small size, shallow draft, continuous operation, and the ability to work in confined spaces. Disadvantages include a relatively low production rate and the need for calm water.

HOPPER DREDGE

The hopper dredge is similar to the dustpan dredge, except the dredged material is discharged into a hopper or hold of the dredge. The dredge is a self-propelled ship with the suction pipe either trailing over the side of the vessel or through a well in the hull. The suction pipe is fitted with a dustpan or drag head on the excavation end. The hopper dredge transports the material to a disposal site where it can either dump the material into an open-water disposal site or pump the sediment out of the hopper. Dumping of material in the hopper is done either through bottom dump doors or by splitting open the hull. The latter is constructed with each side of the hull split down the center and connected with fore and aft hinges. When the dredge reaches the disposal site, the two halves of the hull are separated by hydraulic rams and the dredge material falls through the slit. The size of a hopper dredge is characterized by the capacity of the hopper. They typically range in size from 300 to 10,000 cy with production rates of 100 to 2,500 cy/hr. Advantages of the hopper dredge are its ability to operate in relatively high seas and its ability to not interfere with shipping traffic. Disadvantages include no production during steaming to and from the disposal site, the tendency for marine animals to get caught in the drag heads, inability to dredge hard material, increased turbidity during dumping operations, and have a high superstructure.

MECHANICAL DREDGING TECHNOLOGIES

CLAMSHELL DREDGE

The clamshell dredge is the most common mechanical dredge. The clamshell is a hinged, split-barrel bucket that hangs by wire rope from a derrick crane. Buckets range in size from ½ to 32 cy, with production rates varying from 30 to 1,800 cy/hr. The clamshell dredge is versatile in that a range of bucket sizes and forms can be used from the same derrick crane. The clamshell bucket works well for picking up mud, gravel, and loose rock, but light, fine sediment often flows freely from the bucket. The clamshell is also not suitable for dredging in firm material. Other advantages of a clamshell dredge are good production rates and the ability to dredge in relatively deep water.

DRAGLINE BUCKET DREDGE

The dragline bucket dredge is similar to the clamshell dredge, but the bucket is rigid, hangs by wire rope from the derrick crane, and excavates by dragging the bucket toward the crane. Dragline buckets vary in size from 1 to 10 cy and production rates are comparable to those of the typical clamshell dredge (20 to 300 cy/hr). Dragline buckets are open, so resuspension of sediments is always of concern.

BACKHOE DREDGE

The backhoe dredge is a back-acting bucket on the end of a rigid arm or boom. The arm and bucket are hydraulically controlled from a barge-mounted console and power unit. Buckets range in size from 1 to 30 cy and production rates vary from 30 to 300 cy/hr. Advantages of the backhoe dredge include the ability to accurately position the bucket for cutting and the ability to dig relatively firm material.

DIPPER DREDGE

The dipper dredge uses an open face shovel similar to the bucket of the dragline dredge, but the shovel is rigidly attached to an arm or boom, which itself pivots off a dredge ladder. The rig is mounted on a spud barge. Digging is accomplished by scooping the shovel forward into the cut face. Shovel sizes range from 1 to 16 cy and typical production rates vary from 30 to 300 cy/hr. The dipper dredge has the ability to dig accurately and can dig in relatively hard material. However, it has only moderate production rates.

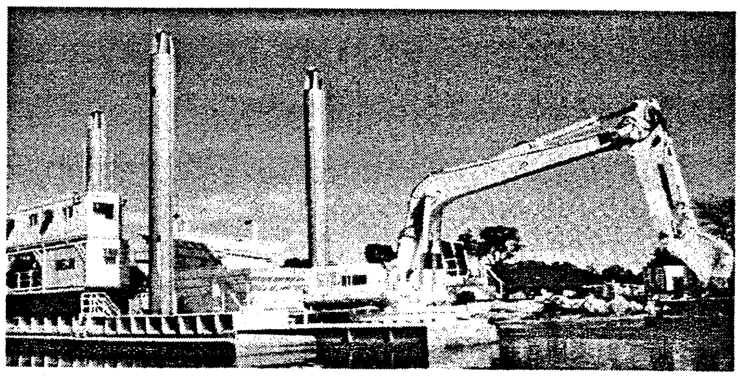
BUCKET LADDER DREDGE

The bucket ladder dredge consists of a large number of buckets linked together in an endless chain, which is carried on a ladder. The ladder is raised and lowered by hoisting wires. The buckets dig into the face of the cut and the sediment is carried up the ladder and dumped onto a conveyor belt. Dredging is almost continuous. Bucket sizes range from ½ to 5 cy and production rates vary from 100 to 900 cy/hr.

HYBRID OR SPECIALTY DREDGING TECHNOLOGIES

BEAN TEC HYDRAULIC EXCAVATOR *BONACAVOR*

The Bean Technical Excavation Corporation hydraulic excavator *Bonacavor* was designed and built to meet the requirements of rigid dredging accuracy, low percent solids concentration, and good debris handling.



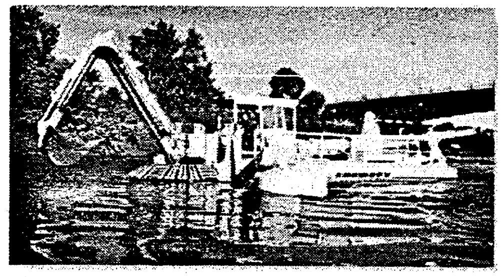
The *Bonacavor* is a hybrid dredge combining a backhoe bucket excavator with a sediment pumping unit (SPU) for discharging the material through a pipeline. The SPU consists of a hopper and pump connected to a discharge pipeline. The dredge is advanced using a spud carriage system; however, the dredge can be configured to work on winches with wires and anchors.

The SPU was designed and is integrated with the *Bonacavor* hydraulic excavator. The SPU measures and monitors the in situ water content of the material dredged and placed in a hopper and injects only as much water as is necessary to keep the slurry moving to the treatment and disposal site. The *Bonacavor* can achieve an average percent solids concentration of 27 percent by weight (approximately 70 percent by volume).

This hydraulic excavator dredge offers high production capacity in terms of setup and cycle time. The dredge can achieve an overall production rate in the range of 50 cy/hr. The production output of the hydraulic excavator is not as significantly affected by debris as other mechanical and hydraulic dredge systems. Debris retrieved by the excavator bucket is separated out over a grizzly atop the SPU hopper and placed on debris barges floated alongside the dredge, which will be placed in the CDF or other approved off-site facility once the debris barge is full.

The overall dredging accuracy has been measured to be 3 inches in both the horizontal and vertical planes. This level of accuracy was achieved by installing a excavator positioning system, which measures and monitors the dredge (barge) position relative to the waterway and dredge prism with a laser plane system established on shore and on the dredge. The tight horizontal and vertical accuracy of the excavator bucket is obtained over the dredge cut (grid) using a series of pressure sensors located along the excavator arm and leading edge of the bucket. Measurements from the sensors are translated to the operator's heads-up display, which shows the position of the excavator in relationship to the dredge prism in real time. With moderate waves, currents, and tides, it is likely that the *Bonacavor*-type hydraulic excavator could attain a dredging accuracy of ± 20 inches in the horizontal plane and ± 6 inches vertically.

AMPHIBEX AND AQUARIUS AMPHIBIOUS DREDGES



The Amphibex and Aquarius Amphibious excavators are barge-mounted backhoes, capable of turning 360 degrees. These systems work optimally in water depths of 8 to 13 feet but according to the manufacturers can also work on emergent shoreline and tide flats. The backhoe excavator is mounted atop barges that have been fitted with "legs" equipped with cylindrical wheels that provide mobility.

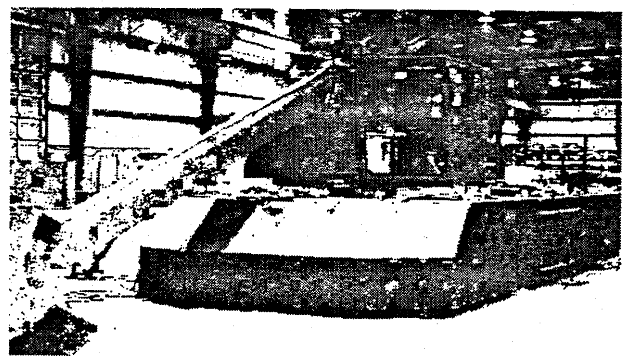
The Amphibex Amphibious excavator can operate in either straight mechanical or hydraulic discharge modes. Accordingly, the discharge percent solids concentration can vary from as low as 2 percent solids by weight (hydraulic) to perhaps as high 70 percent solids (mechanical). The Aquarius Amphibious excavator only operates in mechanical dredging and transport modes. The addition of a high solids content SPU-type or DRE-Dredge positive-displacement-type material-transport system could be considered for adaptation to the amphibious dredges if high solids content is required.

The sediment resuspension by the amphibious dredges on an overall operations basis is low due to control of the bucket and to the high degree of contact of the dredge "legs" and "wheels" with the bottom sediment.

The theoretical production capacity of an amphibious dredge is good considering that the dredge can operate continuously in shallow and intertidal areas. In mechanical dredging mode, an Amphibex Amphibious excavator is rated for 50 cy/hr production. In hydraulic mode, the production rate is in the range of 20 cy/hr. The Aquarius Amphibious excavator is rated for production in the 20 cy/hr range. Both excavators have good debris handling capability.

The excavation accuracy of the amphibious excavators is good if the systems are outfitted with an accurate positioning system. It is anticipated that the hydraulic excavator could attain a dredging accuracy of ± 20 inches in the horizontal plane and ± 6 inches vertically.

DRE TECHNOLOGIES—DRY DREDGE



The DRE Technologies—Dry Dredge is a barge-mounted hybrid dredge that integrates a closed bucket mechanical dredge with a positive-displacement pump for high-solids dredged material transport.

The bucket is a hydraulically actuated clamshell at the end of a hydraulically actuated boom. The clamshell is pressed into the dredge cut and closed with hydraulic actuators. The material is brought to the surface and placed in a hopper located on the barge deck in front of the operator console. The Dry Dredge provides the highest percent solids concentration of any of the dredges with pipeline transport systems evaluated in this study, due to the use of a positive-displacement pump. Excavated sediments are screened, mixed, and pumped with solids contents as high as 70 percent solids by weight (95 percent solids by volume). The system has been designed to eliminate the need for large disposal areas and expensive water treatment facilities.

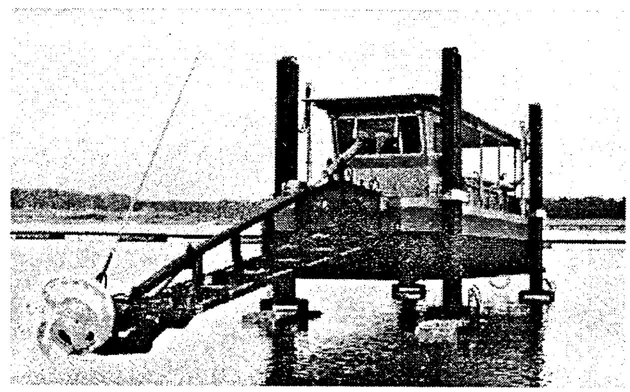
Depending on bucket size used, the Dry Dredge has a production capacity of from 30 to 75 cy/hr. The maximum pumping distance of the dredge is 2,000 feet. The dredge can easily handle debris up to a weight of 1,000 pounds. Larger debris will require other arrangements for removal. The dredge advance mechanism is a walking spud system; however, the system can be reconfigured to work on winches with wires and anchors.

Sediment resuspension is minimal at the point of dredging since the bucket can be closed slowly and sealed firmly. With good operational controls, the Dry-Dredge enclosed bucket should offer low resuspension of bottom sediments. Since the dredged material is transported from the barge to the disposal site through a sealed pipeline, sediment resuspension is further minimized.

The excavation accuracy of the Dry Dredge is high due to the rigid boom connection between the excavator and barge. The boom used to locate the bucket provides good control and positioning accuracy of the bucket. The Dry Dredge, making use of state-of-the-art positioning equipment, is able to attain a dredging accuracy of ± 20 inches in the horizontal plane and ± 6 inches vertically.

CRAWL CAT CUTTER SUCTION DREDGE—IHC HOLLAND

The Crawl Cat Cutter Suction Dredge, developed by the Dutch dredge developer IHC Holland, is essentially a hydraulic cutterhead dredge with legs. The Crawl Cat is an amphibious dredge in that it can work as a floating dredge, on tide flats, and along shorelines. The hydraulic cutterhead dredge is mounted on a jackup barge with four independently controlled height-adjustable trackpoles. Mobility of the dredge is provided by hydraulically driven tracks located at the base of each trackpole.



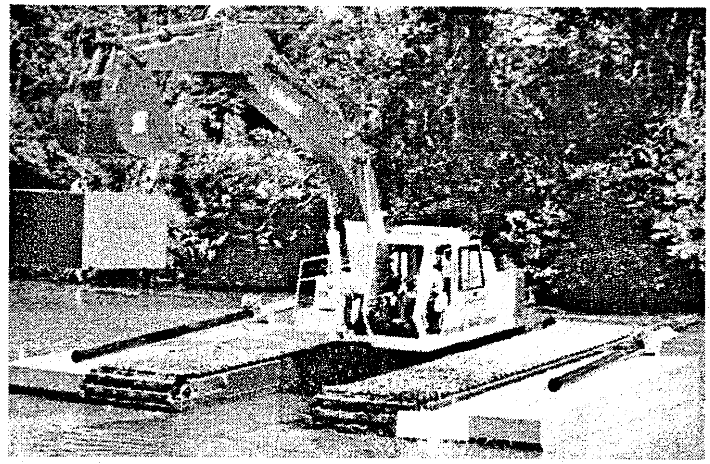
The sediment resuspension characteristics at the point of dredging for the Crawl Cat are much the same as that for the Ellicott or other hydraulic cutterhead dredge. With good operational controls, the hydraulic cutterhead dredge should minimize the resuspension of bottom sediments at the point of dredging. It is advised that a valve be installed on the suction line to minimize backflushing and significant resuspension of sediments when dredge pumping must cease to clear the cutterhead, suction pipe, or pump of debris. However, some sediment resuspension is expected during movement of the dredge since the Crawl Cat has four legs and crawler tracks that are always in contact with the bottom sediments.

The production capacity of the Crawl Cat dredge is in the range of 25 to 35 cy/hr, provided significant debris is not encountered. However, because hydraulic suction dredge systems require water over the suction intake, it would likely not be able to work in water depths shallower than 2.5 to 3 feet. The hydraulic pipeline dredge system lends itself well to pumping long distances with booster pumps. The Crawl Cat provides the typical percent solids concentrations for a hydraulic cutterhead dredge, approximately 5 percent (by weight).

Hydraulic cutterhead dredges such as the Crawl Cat can be configured to work in "surgical" dredging mode. While the location of the cutterhead is more difficult to monitor against the dredge surface than an excavator bucket, advanced positioning systems can be used to locate the cutterhead in the horizontal and vertical planes with a dredging accuracy of ± 20 inches in the horizontal plane and ± 9 inches vertically.

LOW-GROUND-PRESSURE TRACK-MOUNTED EXCAVATOR

A variety of track-mounted excavators have been developed to access shallow water marsh environments for dike construction, dredge material disposal operations, pipeline crossings, and other tasks where low-ground-pressure (LGP) vehicles are required. The primary manufacturers of these machines are the WILCO Company and Quality Industries, both located in Louisiana. Both companies adapt conventional backhoe, crane bucket, dragline, and other excavator types to ruggedized, self-propelled tracked assemblies that can travel over soils with low bearing capacity and shallow water environments. Quality Industries also produces a floating amphibious tracked excavator that makes use of outboard pontoons and spuds for flotation and mobility in deeper water. These systems work optimally in shallow water and emergent shoreline and tide flats and can turn 360 degrees.



The LGP track-mounted excavator can only operate in mechanical mode. There appears to be no efficient way of adapting a high slurry concentration transport system to the LGP track-mounted excavator, which has no deck space for a pump. The percent solids concentration can be as high 70 percent solids due to the mechanical excavation means of the LGP track-mounted excavator, but the material transport would have to be by haul barge or more likely over roads using trucks.

The LGP track-mounted excavator is likely to perform best on the project in a complementary role to other types of dredging equipment. The LGP track-mounted excavator could perform well in shallow areas that are difficult to access for other types of dredges. The production capacity of the LGP track-mounted excavator would vary depending on the bearing capacity of the sediments and the size of equipment that could access the dredge areas. Production capacity of the LGP track-mounted excavator will also depend on the available mode of material transport from the point of excavation to the disposal site.

With modifications to the excavator bucket, such as an enclosed bucket and strict material handling and operational controls, the resuspension of sediments at the point of dredging for the LGP track-mounted excavator is minimal. The excavator bucket is probably the best digging tool in terms of debris handling. The potential for sediment resuspension while moving the LGP track-mounted excavator is high due to the high degree of contact between the tracks and the bottom sediment.

The excavation accuracy of the LGP track-mounted excavator is expected to be good. Where a floating track-mounted excavator is used, the dredge could be outfitted with an excavator positioning system to provide real-time excavator control while dredging below the waterline. It is anticipated that the LGP track-mounted excavator can attain a dredging accuracy of ± 20 inches in the horizontal plane and ± 6 inches vertically.

APPENDIX D

OUTLINE FOR MONITORING PROGRAM WORK PLAN

Table D-1. Outline for Monitoring Program Work Plan **Page 1 of 2**

1.0 Introduction
- 1.1 Program Goals and Objectives
- 1.2 Adaptive Management Strategy

2.0 Regulatory Setting

3.0 Environmental Setting

4.0 Environmental Quality Objectives
- 4.1 Remedial Action Objectives
- 4.2 Water Quality
- 4.3 Sediment Quality

5.0 Technical Design
- 5.1 Approach
  - 5.1.1 Baseline Survey
  - 5.1.2 Tier 1
  - 5.1.3 Tier 2
  - 5.1.4 Tier 3
  - 5.1.5 Confirmation Sampling
- 5.2 Methods
  - 5.2.1 Field Sampling Locations
  - 5.2.2 Field Sampling Methods
  - 5.2.3 Frequency of Sampling
  - 5.2.4 Sample Handling and Processing
  - 5.2.5 Sediment Chemistry
  - 5.2.6 Sediment Toxicity
  - 5.2.7 Benthic Community Sampling and Analysis

6.0 Data Management and Analysis
- 6.1 Data QA
- 6.2 Data Base Management System (DBMS)
- 6.3 Geographic Information System (GIS)
- 6.4 Data Analysis Methods

7.0 Technical Interpretation
- 7.1 Temporal Patterns of Chemical and Biological Succession
- 7.2 Spatial Patterns of Chemical and Biological Succession

Table D-1. Outline for Monitoring Program Work Plan **Page 1 of 2**

8.0	Decision Making	
	8.1	Criteria for Tiered Approach and Site Closure
	8.2	Technical Interpretation
	8.3	Regulatory Requirements (e.g., Water Quality Standards)
	8.4	Stakeholder Involvement
9.0	Quality Assurance Project Plan	
	9.1	Sample Custody Procedures
	9.2	Quality Control Checks
	9.3	Performance and System Audits
	9.4	Data Validation
	9.5	Standard Operating Procedures
10.	Health and Safety Plan	

Reference: Adapted from National Research Council (1990).

APPENDIX E

EVALUATION CRITERIA

EVAULATION CRITERIA

Specific evaluation criteria were developed for the category of contaminated sediment management as specified in the IRCDP (IDEM et al., 1998). Category-specific criteria were identified to ensure that the evaluation of alternatives remained focused on key considerations. Category-specific criteria are divided into two groups: threshold and ranking. Threshold criteria represent the requirements the alternative must satisfy, due to statutory mandates, or may satisfy, due to state and federal policies, procedures, or other factors in order for the alternative to be considered for the selected remedy. The alternatives that meet the threshold criteria are then analyzed based on the ranking criteria. Ranking criteria take into account technical, cost, environmental, and risk concerns, providing relative measures by which actions can be compared and evaluated.

The evaluation of alternatives is intended to be consistent with current federal regulatory guidelines. In particular, the category-specific criteria developed by the trustees are intended to include and go beyond the evaluation criteria specified by the Department of the Interior's regulations for natural resource damage assessment (NRDA) (43 CFR Part 11) (DOI 1994).

The management of contaminated sediment category-specific criteria from the IRCDP are:

- Threshold Criteria
  - Does the project clearly address injuries to natural resources or losses of natural resource services?
  - Does the project comply with applicable federal, state, and tribal laws and regulations?
  - Is there general public support for implementation of the project?
- Ranking Criteria
  - Is the project technically feasible?
  - Will the project cause collateral injuries or other undesirable short-term impacts?
  - Can the project provide the desired habitat improvements within a reasonable timeframe?
  - Are the resource-based benefits of the project reasonable relative to the project's cost?

- Is the project consistent or compatible with ongoing or planned response activities?

- Will the project simultaneously achieve one or more of the objectives defined under a comparable restoration effort?

The IRCDP incorporates, by reference, the other NRDA criteria not explicitly stated above. These additional criteria include:

- Are the resources able to recover with or without alternative actions?

- What are the potential effects of the project on human health and safety?

- What is the natural recovery period?

- Is the project cost effective?

- Is the project consistent with relevant federal, state, and tribal policies?

The individual criteria are discussed in more detail below. The criteria and their components are presented in Table E-1.

Does the project clearly address injuries to natural resources or losses of natural resource services?

This criterion assesses if the alternative restores, rehabilitates, replaces, or acquires the equivalent of the natural resources and natural resource services that have been injured. Alternatives are evaluated to determine if they restore or rehabilitate the injured resources to their baseline condition. This is measured in terms of the physical, chemical, or biological properties that the injured resources would have exhibited or the services that would have been provided by those resources had the discharge of oil or release of hazardous substance under investigation not occurred. Alternatives are also evaluated to determine if they replace or acquire the equivalent of the natural resource or natural resource service with a resource that provides the same or substantially similar services.

Does the project comply with applicable federal, state, and tribal laws and regulations?

Alternatives are assessed to determine whether they will comply with relevant federal, state, and tribal laws and regulations. Applicable laws and regulations may include the Clean Water Act, Clean Air Act, Endangered Species Act as amended, Resource Conservation and Recovery Act, and the National Environmental Policy Act.

Is there general public support for implementation of the project?

This criterion addresses the public's concerns, if any, for each alternative.

Is the project technically feasible?

This evaluation criterion is used to measure the technical feasibility of an alternative. The technology and management skills necessary to implement an alternative should be well known and each element of the alternative should have a reasonable chance of successful completion in an acceptable period of time. Feasibility includes the ability and time required to obtain any necessary approvals from agencies.

Will the project cause collateral injuries or other undesirable short-term impacts?

This criterion evaluates the potential for additional injury to the injured resources or other resources resulting from the proposed alternative, including long-term and indirect impacts. For example, will sediment removal activities impact functioning aquatic or riparian communities?

Can the project provide the desired habitat improvements within a reasonable timeframe?

The estimated amount of time needed for recovery based on completion of each alternative will be compared to the amount of time needed for natural recovery if no restoration, rehabilitation, replacement, and/or acquisition of equivalent resource efforts are undertaken beyond response actions performed or anticipated. The time estimate will be based on the best available information and, where appropriate, may be based on cost-effective models.

Are the resource-based benefits of the project reasonable relative to the project's cost?

This evaluation criterion is used to assess the relationship of the expected cost of the proposed alternative to the expected benefits from the restoration, rehabilitation, replacement, and/or acquisition of equivalent resources. This criterion addresses the costs associated with the alternative, including direct capital costs (i.e., construction, equipment, land, services), indirect capital costs (i.e., engineering, contingency), long-term monitoring costs, and operation and maintenance costs. An evaluation methodology that takes into account project costs and quantifiable and nonquantifiable benefits will be developed. For example, a sediment quality index that measures toxicity to sediment-dwelling organisms may be used to quantify restoration benefits related to sediment management. An example of a nonquantifiable benefit is lifting the recreational fishing advisory.

Is the project consistent or compatible with ongoing or planned response activities?

This criterion evaluates the alternatives in conjunction with the results of any actual or planned response actions. Alternatives should be in addition to response actions completed or anticipated pursuant to the National Contingency Plan.

Will the project simultaneously achieve one or more of the objectives defined under a comparable restoration effort?

This criterion evaluates the effects of implementing the alternatives on other restoration efforts. For example, it would evaluate how they will effect the development and implementation of the Remedial Action Plan for the International Joint Commission's Grand Calumet Area of Concern.

Are the resources able to recover with or without alternative actions?

This criterion evaluates the likelihood that the injured natural resources will recover with or without implementing the alternative. For example, what is the likelihood that the Grand Calumet River will return to its natural state if the contaminated sediment is not removed?

What is the natural recovery period?

Alternatives are evaluated relative to the time needed for the injured resource to recover if no restoration, replacement, and/or acquisition of equivalent resource efforts are undertaken beyond response actions performed or anticipated. This time period is used as the "No Action–Natural Recovery" period in the alternatives evaluation.

What are the potential effects of the alternative on human health and safety?

This evaluation criterion is used to measure how an alternative will achieve and maintain human health and safety. It assesses whether the risk posed to humans is eliminated, reduced, or controlled through each pathway by natural recovery, treatment, engineering, or institutional controls. This criterion also addresses the short-term risks posed to the community during implementation of an alternative and the potential effects on workers during remedial action.

Is the alternative cost effective?

This evaluation criterion is used if two or more alternatives provide the same or a similar level of benefits. When this occurs, the least costly alternative that provides that level of benefits will be selected.

Is the project consistent with relevant federal, state, and tribal policies?

Alternatives are assessed to determine whether they are consistent with relevant Federal, state, and tribal policies. The first step in assessing this criterion is to identify the relevant policies.

Table E-1. Detailed Evaluation Criteria **Page 1 of 2**

Group	Evaluation Criteria	Criteria Component
Threshold criteria	Does the project clearly address injuries to natural resources or losses of natural resource services?	Has the injured resource been restored to baseline conditions? Have any recreational or economic opportunities generated by the resource been restored?
	Does the project comply with applicable federal, state, and tribal laws and regulations?	What are the applicable federal, state, and tribal laws? Do all aspects of the alternative comply with these laws?
	Is there general public support for the implementation of the project?	Have any comments from the public been addressed and/or incorporated into the alternative?
Ranking criteria	Is the project technically feasible?	Are the technical components of the alternative implementable? What is the timeframe for resource restoration? Does each element of the alternative have a reasonable chance of successful completion?
	Will the project cause collateral injuries or other undesirable short-term impacts?	Will there be any long-term or indirect impacts to the injured resource? Will there be any long-term or indirect impacts to other resources?
	Can the project provide the desired habitat improvements within a reasonable timeframe?	What is the duration of the alternative? Is that duration reasonable?
	Are the resource-based benefits of the project reasonable relative to the project's cost?	What are the direct capital costs and indirect capital costs of the alternative? Will there be any long-term costs or operation and maintenance costs? What is the total net present value of the injured resource?

Table E-1. Detailed Evaluation Criteria

Page 2 of 2

Group	Evaluation Criteria	Criteria Component
Ranking criteria (continued)	Is the project consistent or compatible with ongoing or planned response activities?	What other response activities are ongoing or planned? Do the projects complement or hinder each other?
	Will the alternative simultaneously achieve one or more of the objectives defined under a comparable restoration effort?	Is any component of the alternative beneficial to other projects in the area?
Other NRDA criteria	Are the resources able to recover with or without alternative actions?	What is the likelihood that the injured resources will return to baseline conditions without any alternative actions?
	What are the potential effects of the alternative on human health and safety?	Does the alternative expose people to chemical or physical risk? If so, what is the magnitude of the risk? Can the risk be mitigated?
	What is the natural recovery period?	What is the time needed for the injured resource to recover if no restoration, replacement, and/or acquisition of equivalent resource efforts are undertaken beyond response actions?
	Is the alternative cost effective?	Do other alternatives provide the same or similar level of benefits? If so, which is the least costly?
	Is the project consistent with relevant federal, state, and tribal policies?	What are the applicable federal, state, and tribal policies? Do all aspects of the alternative comply with these policies?

APPENDIX F

DREDGING VOLUMES

DREDGING VOLUMES

REACH 1

The volume of material to be dredged from project Reach 1 was calculated using scaled drawings and two dredging scenarios. The area calculations for Reach 1 (portions of the GCR/IHC/LGC) were obtained from the plan and profile drawings in Appendix B. Dredging scenario one (3-foot dredge prism) involves dredging the upper 3 feet along the bottom of the waterways followed by backfilling or capping with 3 feet of clean sand. The total dredge volumes include 1 foot of overdredge. Overdredging compensates for construction survey inaccuracies and the lack of dredging equipment precision.

The second dredging scenario (maximum dredge prism) requires dredging to the bottom of contamination. The bottom of contamination was determined from test hole samples collected by Floyd Browne Associates (1991) and Maxim Technologies (1999). The samples were screened using a probable effects concentration quotient (PEC-Q) developed by MacDonald Environmental (2000a). Of 98 samples collected and evaluated, all but 22 were above the PEC-Q threshold of 0.7, the preliminary screening level for contamination.

3-FOOT DREDGE PRISM

METHODOLOGY

The volume of material to be dredged was calculated by multiplying the length of each waterway segment by the average width of the segment and by the 3-foot depth of dredge cut. Segment lengths and average widths were scaled off the drawings in Appendix B. The volumes of each segment were summed appropriately for each waterway. The volumes were calculated in feet and then divided by 27 to convert from cubic feet to cy. The average width includes the wetted perimeter of the waterway below the 581-foot contour, rounded up to the nearest 10 feet. The rounding adjusts for scaling inaccuracies and undulations in the bottom contours. Considering the scaling of the dimensions and the feasibility level of this study, the results are reported in the text by rounding up to the nearest 1,000 cy.

CALCULATION RESULTS

The GCR's volume of material to be dredged is 690,000 cy for the 3-foot prism and a total of 920,000 cy allowing for 1 foot of overdredge. The volume of material to be dredged from the IHC is 180,000 cy for the 3-foot prism and a total of 239,000 cy allowing for 1 foot of overdredge. The volume of material to be dredged from the LGC is 108,000 cy for the 3-foot prism and a total of 144,000 cy allowing for 1 foot of overdredge. The results are presented in Table F-1.

SUMMARY

The total amount of material to be dredged from the GCR/IHC/LGC system under this scenario is approximately 1,303,000 million cy.

MAXIMUM DREDGE PRISM

METHODOLOGY

The maximum volume of material to be dredged was based on 98 samples collect and evaluated from the Floyd Browne Associates (1991) and Maxim Technologies (1999) studies. The floors of the maximum dredge prism was set as the lowest elevation of test hole data in which the PEC-Q was at or above 0.7 for a representative reach of river/canal. In the GCR, there were 28 test holes yielding 73 samples. Three deep samples (greater than 5 feet deep) had an index quotient less than 0.1. Nine samples had index quotients between 0.1 and 0.3, only three were surface samples. Six samples, two of them surface samples, had an index quotient between 0.3 and 0.7. All other samples were greater than 0.7.

In the IHC, there were 11 test holes yielding 15 samples. Two surface samples had an index quotient between 0.1 and 0.3, and one surface sample had an index quotient between 0.3 and 0.7. All other samples were greater than 0.7. The cleaner surface samples were interspersed spatially with samples greater than 0.7. Therefore, all material above elevation 556 feet msl from Station 0+50 to 78+10 (the upper limit of the Federal Project) is assumed to be contaminated and should be removed.

In the LGC, there were four test holes yielding 10 samples. One deep sample (10 to 14 feet below mudline) had an index quotient between 0.3 and 0.7. All other samples were greater than 0.7. Therefore, all material from Station 37+00 (the upper limit of the Federal Project) to 41+00 and above an elevation of 548 feet above msl is assumed to be contaminated and should be removed. From Station 41+00 to 71+40, the floor of the dredge prism is raised to elevation 556 feet msl.

The maximum dredge depths were shown on the drawings in Appendix B. The side slopes of the maximum dredge prism were assumed to stand at 2 (horizontal):1 (vertical) and meet the existing ground at elevation 581 feet msl. The waterway segment lengths were divided by property boundaries, low bridges, or changes in the dredge cut elevations. To account for the variation in waterway banks on opposite sides of the river/canals, the waterways were divided down the center into two halves for purposes of calculation. Photographs taken March 7, 2000, were used to assess the existing bank slopes. The data were entered onto a spreadsheet and geometric algorithms used to calculate volumes for the various segments. Considering the scaling of the dimensions and the feasibility level of this study, the results are reported in the text by rounding up to the nearest 1,000 cy.

CALCULATION RESULTS

The GCR's volume of material to be dredged is 1,361,000 cy for the maximum prism and a total of 1,538,000 cy allowing for 1 foot of overdredge. The volume of material to be dredged from the IHC is 443,000 cy for the maximum prism and a total of 492,000 cy allowing for 1 foot of overdredge. The volume of material to be dredged from the LGC is 413,000 cy for the maximum prism and a total of 447,000 cy allowing for 1 foot of overdredge. The results are presented in Table F-2.

SUMMARY

The total amount of material to be dredged from the GCR/IHC/LGC system under this scenario is approximately 2,443,000 million cy.

REACH 2

The volume of material to be dredged from Project Reaches 2 was calculated using scaled drawings and one dredging scenario (3-foot dredge prism). Reach 2 is the Federal Project portions of the GCR/IHC/LGC and includes the Turning Basin along the IHC and the Forks, where the rivers/canals meet. The area calculations for Reach 2 were taken from maps entitled *Indiana Harbor, Indiana* (September 1984), obtained from the U.S. Army Corps of Engineers, Chicago District. The dredging volumes for Reach 2 assume that the USACE dredging of the Federal Reach will be followed by dredging the upper 3 feet of the waterways followed by placement of a 3-foot cap of clean sand. The total dredge volumes include 1 foot of overdredge. Overdredging compensates for construction survey inaccuracies and the lack of dredging equipment precision.

3-FOOT DREDGE PRISM

METHODOLGY

The scenario for Reach 2 assumed that after the USACE has dredged the waterways to the authorized depths, the remaining bottom sediments may still be contaminated. Reach 2 waterways will be dredged an additional 3 feet and backfilled with 3 feet of clean sand to the original Corps bottom elevation. The volume of material to be dredged was calculated by multiplying the length of each waterway segment by the authorized width of the segment and by the 3-foot depth of dredge cut. Segments were based on bridges and changes in authorized channel widths. Segment lengths and widths were scaled off the USACE drawings. The volumes of each segment were summed appropriately for each waterway. The volumes were calculated in feet and then divided by 27 to convert from cubic feet to cy. Considering the scaling of the dimensions and the feasibility level of this study, the results are reported in the text by rounding up to the nearest 1,000 cy.

CALCULATION RESULTS

The volume of material to be dredged from the IHC is 188,000 cy for the 3-foot prism and a total of 251,000 cy allowing for 1 foot of overdredge. The Turning Basin volume of material to be dredged is 22,000 cy for the 3-foot prism and a total of 30,000 cy allowing for 1 foot of overdredge. The volume of material to be dredged from the LGC is 55,000 cy for the 3-foot prism and a total of 73,000 cy allowing for 1 foot of overdredge. The Forks volume of material to be dredged is 38,000 cy for the 3-foot prism and a total of 51,000 cy allowing for 1 foot of overdredge. The results are presented in Table F-3.

SUMMARY

The total amount of material to be dredged from Reach 2 under this scenario is 405,000 cy.

Table F-1. 3-Foot Dredge Prism Volumes for Reach 1—GCR/IHC/LGC **Page 1 of 1**

Segment ID	Stationing		Length (ft)	Width[1] (ft)	Neatline Volume (cy)	Overdredge Volume (cy)	Total Volume (cy)
	From	To					
Grand Calumet River							
1	0	1920	1920	180	38400	12800	51200
1B	1920	1980	60	190	1267	422	1689
2	1980	9700	7720	200	171556	57185	228741
2B	9700	10210	510	260	14733	4911	19644
3	10210	12920	2710	190	57211	19070	76281
3B	12920	12950	30	250	833	278	1111
4	12950	13410	460	220	11244	3748	14993
4B	13410	13450	40	280	1244	415	1659
5	13450	18000	4550	240	121333	40444	161778
5	18000	22530	9080	150	151333	50444	201778
5B	22530	22700	170	230	4344	1448	5793
6	22700	26280	3580	180	71600	23867	95467
7	26280	29604	3324	120	44320	14773	59093
				Totals	**689420**	**229807**	**919227**
Indiana Harbor Canal							
8	50	400	350	220	8556	2852	11407
8B	400	475	75	230	1917	639	2556
9	475	1150	675	210	15750	5250	21000
9B	1150	1225	75	220	1833	611	2444
10	1225	4115	2890	200	64222	21407	85630
10B	4115	4185	70	230	1789	596	2385
11	4185	4620	435	210	10150	3383	13533
11B	4620	4650	30	220	733	244	978
12	4650	7750	3100	210	72333	24111	96444
12B	7750	7810	60	280	1867	622	2489
				Totals	**179150**	**59717**	**238867**
Lake George Canal							
13	3700	4100	400	270	12000	4000	16000
13	4100	4845	745	260	21522	7174	28696
13B	4845	4860	15	320	533	178	711
14	4860	7140	2280	290	73467	24489	97956
				Totals	**107522**	**35841**	**143363**

Note: [1] Width represents wetted perimeter below elevation 581 feet.
Segments and subsegments were broken out further when widths varied.

cy = cubic yards
ft = feet

Table F-2. Maximum Dredge Prism Volumes for Reach 1—GCR/IHC/LGC

Station ID	1	1	1B	2	2	2	2	2B	3	3	3B
Grand Calumet River											
Station from, ft	0	500	1920	1980	4400	6600	8500	9700	10210	12000	12920
Station to, ft	500	1920	1980	4400	6600	8500	9700	10210	12000	12920	12950
Right dredge cut slope, 1(vertical):(horizontal)	2	2	2	2	2	2	2	2	2	2	2
Right dredge cut width, ft	20	50	40	40	50	50	60	50	30	40	50
Right dredge cut elevation, ft	560	567	567	567	564	561	564	564	564	561	561
Right mudline elevation, ft	575	575	576	575	577	576	576	574	575	575	576
Right bankline elevation, ft	581	581	581	581	581	581	581	581	581	581	581
Right bank slope, 1(vertical):(horizontal)	2	4	3	4	4	5	4	4	4	5	6
Left dredge cut slope, 1(vertical):(horizontal)	2	2	2	2	2	2	2	2	2	2	2
Left dredge cut width, ft	30	50	40	40	50	60	60	80	30	40	50
Left dredge cut elevation, ft	560	567	567	567	564	561	564	564	564	561	561
Left mudline elevation, ft	575	575	576	576	576	576	577	575	575	574	576
Left bankline elevation, ft	581	581	581	581	581	581	581	581	581	581	581
Left bank slope, 1(vertical):(horizontal)	2	2	3	4	4	6	5	4	5	5	6
Overdredge depth, ft	1	1	1	1	1	1	1	1	1	1	1
Dredge segment length, ft	500	1420	60	2420	2200	1900	1200	510	1790	920	30
Right canal/river trapezoid volume, cy	9722	21879	930	30116	62496	60694	35733	10011	25524	21467	917
Left canal/river trapezoid volume, cy	12500	24403	930	35493	55733	68611	38711	17661	23336	18826	917
Right cut slope length, ft	47	31	31	31	38	45	38	38	38	45	45
Right bank slope length, ft	13	25	16	25	16	25	21	29	25	31	30
Right dredge slope length, ft	34	9	16	9	22	21	18	12	15	17	18
Left cut slope length, ft	47	31	31	31	38	45	38	38	38	45	45
Left bank slope length, ft	13	13	16	21	21	30	20	25	31	36	30
Left dredge slope length, ft	34	18	16	12	18	18	19	15	12	14	18
Right bank wedge volume, cy	0	4418	78	7529	5541	10556	3778	2248	6762	6133	222
Left bank wedge volume, cy	0	0	78	6274	6926	14074	4533	1927	10143	7156	222
Total segment neatline volume, cy	22222	50699	2016	79412	130696	153935	82756	31847	65766	53581	2278
Total overdredge volume, cy	2665	8552	317	12782	14343	14035	8712	3892	9018	5774	210

Shaded cells denote input

Table F-2. Maximum Dredge Prism Volumes for Reach 1—GCR/IHC/LGC

Station ID	4	4B	5	5	5	5	5	5B	6	6	7
Grand Calumet River											
Station from, ft	12950	13410	13450	15400	18000	21300	22100	22530	22700	26200	26280
Station to, ft	13410	13450	15400	18000	21300	22100	22530	22700	26200	26280	29604
Right dredge cut slope, 1(vertical):(horizontal)	2	2	2	2	2	2	2	2	2	2	2
Right dredge cut width, ft	55	100	50	90	20	20	30	40	50	50	10
Right dredge cut elevation, ft	561	561	561	568	560	565	569	569	569	562	562
Right mudline elevation, ft	577	576	576	576	573	571	573	573	573	573	577
Right bankline elevation, ft	581	581	581	581	581	581	581	581	581	581	581
Right bank slope, 1(vertical):(horizontal)	7	6	5	5	5	5	5	5	4	6	7
Left dredge cut slope, 1(vertical):(horizontal)	2	2	2	2	2	2	2	2	2	2	2
Left dredge cut width, ft	55	40	50	90	20	30	40	40	50	50	10
Left dredge cut elevation, ft	561	561	561	568	560	565	569	569	569	562	562
Left mudline elevation, ft	577	576	576	576	573	572	573	574	572	573	577
Left bankline elevation, ft	581	581	581	581	581	581	581	581	581	581	581
Left bank slope, 1(vertical):(horizontal)	6	5	4	2	4	5	6	5	6	6	7
Overdredge depth, ft	1	1	1	1	1	1	1	1	1	1	1
Dredge segment length, ft	460	40	1950	2600	3300	800	430	170	3500	80	3324
Right canal/river trapezoid volume, cy	16628	2333	62292	69719	33367	1956	1401	806	23852	1467	27700
Left canal/river trapezoid volume, cy	17173	1056	65000	75496	39722	4874	1784	1086	13611	1467	27700
Right cut slope length, ft	45	45	45	29	47	36	27	27	27	42	42
Right bank slope length, ft	28	30	25	25	41	51	41	41	33	49	28
Right dredge slope length, ft	20	18	21	8	13	19	16	16	9	15	18
Left cut slope length, ft	45	45	45	29	47	36	27	27	27	42	42
Left bank slope length, ft	24	25	21	11	33	46	49	36	55	49	28
Left dredge slope length, ft	23	21	25	18	16	15	24	12	30	15	18
Right bank wedge volume, cy	3407	296	10833	9389	30800	7111	2293	907	12444	901	23391
Left bank wedge volume, cy	2726	222	7222	0	20533	6400	3058	793	28000	901	23391
Total segment neatline volume, cy	39935	3907	145347	154604	124422	20341	8536	3592	77907	4735	102182
Total overdredge volume, cy	3398	340	13682	22932	16367	3602	1969	842	19920	548	12923
										Neatline Dredge Volume, cy	1360717
										Overdredge Volume, cy	176822
										Total Dredge Volume, cy	1537539

Table F-2. Maximum Dredge Prism Volumes for Reach 1—GCR/IHC/LGC

Station ID	8	8B	9	9B	10	10B	11	11B	12	12B
Indiana Harbor Canal										
Station from, ft	50	400	475	1150	1225	4115	4185	4620	4650	7750
Station to, ft	400	475	1150	1225	4115	4185	4620	4650	7750	7810
Right dredge cut slope, 1(vertical):(horizontal)	2	2	2	2	2	2	2	2	2	2
Right dredge cut width, ft	30	30	20	30	30	30	30	30	30	30
Right dredge cut elevation, ft	556	556	556	556	556	556	556	556	556	556
Right mudline elevation, ft	569	571	572	570	571	568	567	572	568	568
Right bankline elevation, ft	581	581	581	581	581	581	581	581	581	581
Right bank slope, 1(vertical):(horizontal)	6	5	4	4	5	4	5	5	5	5
Left dredge cut slope, 1(vertical):(horizontal)	2	2	2	2	2	2	2	2	2	2
Left dredge cut width, ft	20	30	40	30	30	30	30	30	30	30
Left dredge cut elevation, ft	556	556	556	556	556	556	556	556	556	556
Left mudline elevation, ft	568	572	573	570	572	568	568	572	568	568
Left bankline elevation, ft	581	581	581	581	581	581	581	581	581	581
Left bank slope, 1(vertical):(horizontal)	5	5	5	5	4	4	4	4	4	4
Overdredge depth, ft	1	1	1	1	1	1	1	1	1	1
Dredge segment length, ft	350	75	675	75	2890	70	435	30	3100	60
Right canal/river trapezoid volume, cy	3202	1250	10800	1283	48167	902	3544	578	31000	600
Left canal/river trapezoid volume, cy	1944	1444	19125	1069	63366	902	5607	658	39956	773
Right cut slope length, ft	56	56	56	56	56	56	56	56	56	56
Right bank slope length, ft	73	51	37	45	51	54	71	46	66	66
Right dredge slope length, ft	26	15	21	15	15	12	23	17	19	19
Left cut slope length, ft	56	56	56	56	56	56	56	56	56	56
Left bank slope length, ft	66	46	41	56	37	54	54	37	54	54
Left dredge slope length, ft	19	17	20	15	21	12	12	21	12	12
Right bank wedge volume, cy	7778	1042	5625	764	40139	843	8458	375	55972	1083
Left bank wedge volume, cy	6319	938	7500	1146	24083	843	5236	250	37315	722
Total segment neatline volume, cy	19244	4674	43050	4263	175755	3490	22846	1861	164243	3179
Total overdredge volume, cy	2097	477	4295	477	18389	445	2768	191	19726	382
Neatline Dredge Volume, cy										442602
Overdredge Volume, cy										49248
Total Dredge Volume, cy										491850

Shaded cells denote input

Table F-2. Maximum Dredge Prism Volumes for Reach 1—GCR/IHC/LGC

Station ID	13	13	13	13B	14	14
Lake George Canal						
Station from, ft	3730	4100	4700	4845	4860	6200
Station to, ft	4100	4700	4845	4860	6200	7140
Right dredge cut slope, 1(vertical):(horizontal)	2	2	2	2	2	2
Right dredge cut width, ft	110	110	120	80	110	110
Right dredge cut elevation, ft	548	556	556	556	556	556
Right mudline elevation, ft	561	568	565	560	568	570
Right bankline elevation, ft	562	570	572	581	570	573
Right bank slope, 1(vertical):(horizontal)	0	0	0	2	0	0
Left dredge cut slope, 1(vertical):(horizontal)	2	2	2	2	2	2
Left dredge cut width, ft	60	70	40	80	70	70
Left dredge cut elevation, ft	548	556	556	556	556	556
Left mudline elevation, ft	565	572	572	560	572	571
Left bankline elevation, ft	581	581	581	581	581	581
Left bank slope, 1(vertical):(horizontal)	6	6	6	9	10	11
Overdredge depth, ft	1	1	1	1	1	1
Dredge segment length, ft	370	600	145	15	1340	940
Right canal/river trapezoid volume, cy	22090	33067	6573	187	73849	61901
Left canal/river trapezoid volume, cy	10483	24178	3265	23	39704	20889
Right cut slope length, ft	31	31	36	56	31	38
Right bank slope length, ft	1	2	7	47	2	3
Right dredge slope length, ft	31	30	33	9	30	37
Left cut slope length, ft	74	56	56	56	56	56
Left bank slope length, ft	97	55	55	190	90	110
Left dredge slope length, ft	34	16	16	139	43	62
Right bank wedge volume, cy	192	622	601	0	1390	1776
Left bank wedge volume, cy	14471	10000	2417	1021	44667	39167
Total segment neatline volume, cy	47237	67867	12857	1231	159609	123732
Total overdredge volume, cy	3770	5938	1352	151	13261	9536
					Neatline Dredge Volume, cy	412532
					Overdredge Volume, cy	34008
					Total Dredge Volume, cy	446540

Table F-2. Maximum Dredge Prism Volumes for Reach 1—GCR/IHC/LGC

Notes:

Station from, ft	X_1		Right mudline width, ft	W_{rm}
Station to, ft	X_2		Left mudline width, ft	W_{lm}
Right dredge cut slope, 1(vertical):(horizontal)	S_{rc}		Right canal/river trapezoid volume, cy	V_{rt}
Right dredge cut width, ft	W_{rc}		Left canal/river trapezoid volume, cy	V_{lt}
Right dredge cut elevation, ft	E_{rc}		Right cut slope length, ft	L_{rc}
Right mudline elevation, ft	E_{rm}		Right bank slope length, ft	L_{rb}
Right bankline elevation, ft	E_{rb}		Right dredge slope length, ft	L_{rd}
Right bank slope, 1(vertical):(horizontal)	S_{rb}		Left cut slope length, ft	L_{lc}
Left dredge cut slope, 1(vertical):(horizontal)	S_{lc}		Left bank slope length, ft	L_{lb}
Left dredge cut width, ft	W_{lc}		Left dredge slope length, ft	L_{ld}
Left dredge cut elevation, ft	E_{lc}		Right bank wedge volume, cy	V_{rw}
Left mudline elevation, ft	E_{rm}		Left bank wedge volume, cy	V_{lw}
Left bankline elevation, ft	E_{lb}		Total segment neatline volume, cy	V_s
Left bank slope, 1(vertical):(horizontal)	S_{lb}		Total overdredge volume, cy	V_o
Overdredge depth, ft	D_o		Total Dredge Volume, cy	V_t
Dredge segment length, ft	L_s			

$L_s = X_2 - X_1$

$W_{rm} = W_{rc} + S_{rc}(E_{rb} - E_{rc}) - S_{rb}(E_{rb} - E_{rm})$

$W_{lm} = W_{lc} + S_{lc}(E_{lb} - E_{lc}) - S_{lb}(E_{lb} - E_{lm})$

$V_{rt} = L_s(E_{rm} - E_{rc})[(W_{rc} + W_{rm})/2]/27$

$V_{lt} = L_s(E_{lm} - E_{lc})[(W_{lc} + W_{lm})/2]/27$

$L_{rc} = \{[S_{rc}(E_{rb} - E_{rc})]^2 + (E_{rb} - E_{rc})^2\}^{0.5}$

$L_{rb} = \{[S_{rb}(E_{rb} - E_{rm})]^2 + (E_{rb} - E_{rm})^2\}^{0.5}$

$L_{rd} = \{[S_{rb}(E_{rb} - E_{rm}) - S_{rc}(E_{rb} - E_{rc})]^2 + (E_{rm} - E_{rc})^2\}^{0.5}$

$L_{lc} = \{[S_{lc}(E_{lb} - E_{lc})]^2 + (E_{lb} - E_{lc})^2\}^{0.5}$

$L_{lb} = \{[S_{lb}(E_{lb} - E_{lm})]^2 + (E_{lb} - E_{lm})^2\}^{0.5}$

$L_{ld} = \{[S_{lb}(E_{lb} - E_{lm}) - S_{lc}(E_{lb} - E_{lc})]^2 + (E_{lm} - E_{lc})^2\}^{0.5}$

$V_{rw} = \{[(L_{rc} + L_{rb} + L_{rd})/2][(L_{rb} + L_{rd} - L_{rc})/2][(L_{rc} + L_{rd} - L_{rb})/2][L_{rc} + L_{rb} - L_{rd})/2]\}^{0.5}$

$V_{lw} = \{[(L_{lc} + L_{lb} + L_{ld})/2][(L_{lb} + L_{ld} - L_{lc})/2][(L_{lc} + L_{ld} - L_{lb})/2][L_{lc} + L_{lb} - L_{ld})/2]\}^{0.5}$

$V_s = V_{rt} + V_{lt} + V_{rw} + V_{lw}$

$V_o = D_o L_s(W_{rc} + W_{lc} + L_{rc} + L_{lc})$

$V_t = S(V_s + V_o)$

Table F-3. 3-Foot Dredge Prism Volumes for Reach 2—Federal Project

Stationing		Length (ft)	Width[1] (ft)	Neatline Volume (cy)	Overdredge Volume (cy)	Total Volume (cy)
From	To					
Indiana Harbor Canal						
7810	8515	705	160	12533	4178	16711
8515	9660	1145	260	33078	11026	44104
9660	9915	255	218	6177	2059	8236
11167	12170	1003	160	17831	5944	23775
12170	12335	165	80	1467	489	1956
12335	15835	3500	160	62222	20741	82963
15835	16885	1050	210	24500	8167	32667
16885	17195	310	170	5856	1952	7807
17195	17985	790	210	18433	6144	24578
17985	18065	80	180	1600	533	2133
18065	18155	90	150	1500	500	2000
18155	18505	350	70	2722	907	3630
			Totals	**187919**	**62640**	**250559**
Turning Basin						
12918	13340	422	450	21100	7033	28133
0	100	100	100	1111	370	1481
			Totals	**22211**	**7404**	**29615**
Lake George Canal						
520	1770	1250	160	22222	7407	29630
1770	2580	810	130	11700	3900	15600
2580	3730	1150	160	20444	6815	27259
			Totals	**54367**	**18122**	**72489**
The Forks						
0	520	520	160	9244	3081	12326
9915	10463	548	160	9742	3247	12990
10463	11167	704	80	6258	2086	8344
0	678	678	169	12731	4244	16975
			Totals	**37976**	**12659**	**50634**

[1] Width represents authorized channel width only.

cy = cubic yards
ft = feet

APPENDIX G

DREDGING COST ESTIMATES

DREDGING COST ESTIMATES

REACH 1

3-Foot Dredge Prism

There are two major steps involved in the 3-foot dredge prism process:

- Dredging and disposal
- Capping

Dredging and disposal includes the following tasks:

- Pumping dredged material to land-side stockpile dewatering areas, consisting of CDFs
- Treating effluent water from the CDFs by a DAF treatment system
- Discharging treated effluent water back into the waterway
- Disposing of dewatered dredge material at a commercial landfill
- Disposing of used CDF material at a commercial landfill
- Filling in and revegetating the CDF sites

Dredging and Disposal

It is anticipated that two 10-inch MudCat dredges (or equivalent) will pump dredged material into each land-side CDF. There are numerous bridge and trestle crossings of the waterway that, because of limited vertical clearance, would not allow a floating plant to pass under them. Therefore, the hydraulic dredge will be lifted out of the water with a truck crane at each of these crossings and then transported by truck to the next access point and placed in the water by the crane.

Each CDF will have a nominal capacity of 100,000 cy (solids and water). The CDFs would be constructed of imported sand that have a gravel perimeter dike or low sheet-pile perimeter wall or concrete linked-barrier perimeter wall. All CDFs would be lined with a geomembrane. The CDF perimeter dike or wall material may be removed and used in constructing subsequent CDFs. If the CDFs are constructed 15 feet high, typical dimensions will include a circular footprint diameter of 660 ft with a perimeter dike (568 ft with a perimeter wall) or a square footprint of 592 ft on a side with a perimeter dike (560 ft with a perimeter wall).

Based on the geometry of the waterway and the dredged materials, ten CDFs would be constructed for the segments of the GCR to accommodate the approximately 920,000 cy that would be dredged from it. However, digging the sediment and transporting it to the CDFs as a slurry will cause the sediment to bulk an additional 15 percent over its in-situ density. Therefore, the amount of material to be settled in the CDFs will total about 1,058,000 cy. Three additional CDFs would be constructed along the IHC segment from the junction of the GCR to the junction with the LGC. Approximately 239,000 cy would be dredged along this waterway, with approximately 275,000 cy being settled in the CDFs. Finally, two additional CDFs would be constructed along the LGC where approximately 144,000 cy are anticipated to be dredged, and 166,000 cy requiring accomodation in the CDFs. During design, it may be determined, based on availability of CDF sites, that fewer CDFs can be constructed, but this cost estimate is based on the number indicated.

The effluent treatment systems would consist of a DAF treatment system. DAF treatment consists of a chemical addition tank (promoting precipitation and flocculation) and followed by the dissolved air tank. Contaminants would be skimmed from the surface, dewatered, and further treated and/or disposed at a landfill. Treated effluent water would be discharged back into the waterway. A typical effluent treatment system would be mounted on three flat-bed trailers allowing the unit to be transported and set up at another site where treatment was complete at the previous site. A minimum of two systems would be required—one for the CDF in use and one for the CDF under construction. Approximate capital costs for a 3,500-gallons per minute treatment system would be $300,000 to $450,000.

After the dredged material has dewatered enough to be acceptable for disposal at a commercial landfill (passes the paint filter test), it would be loaded on trucks and hauled directly to the commercial landfill or transported to a rail transfer facility for delivery to the landfill in gondola-type railcars. The CDF liner would also be disposed of in the commercial landfill, and the CDF site would be filled in and graded to match the surrounding ground.

Capping

Under this restoration plan, all areas to be dredged would be covered with a 3-foot-thick sand cap. The estimated quantities of capping materials are 1,303,000 cy. A land-based 10-inch-diameter centrifugal dredge pump and motor would be used to place the sand cap. The cap material would be delivered from a supplier near Gary, Indiana. A 5-cy front-end loader would transfer the material into a free-standing

10-cy prefabricated steel hopper located next to the dredge pump. The cap material in the hopper would be fed into the suction line of the pump. This system will pump the slurry at the rate of about 75 cy/hr of solids at an approximate solids content of 15 percent by volume. The slurry would be pumped through a 10-inch inside diameter high density polyethylene (HDPE) floating pipe to the discharge point.

To protect pilings and embankments against erosion, armor stone (course gravel) will be placed under low bridges and trestles.

The assumptions used for the dredging and capping order-of-magnitude cost estimate in Table G-1 are as follows:

- The quantity of dredged material in the side slopes has not been included but is considered to be within the accuracy of the data and method used to calculate the quantities for each segment of dredging work.
- Land and permission necessary for construction of land-side CDFs and access roads will be provided.
- The estimate does not include the cost of land acquisition.
- The estimate does not include costs for any required mitigation.
- The estimates are at the conceptual level only and are within a rough order of magnitude.
- Actual dredged material quantities may vary significantly from those estimated due to actual bathymetry and topography or increased required dredge depths.
- Equipment costs and production rates upon which the estimate is based are those experienced in other similar types of work.
- Sufficient quantities of imported cap materials can be supplied for the project from local suppliers.
- The cost estimate is based on year 2000 dollars.

Maximum Dredge Prism Plan

The dredge plan for the maximum dredge prism is similar to that of the 3-foot dredge prism, except that the depth of dredging is taken to deeper and variable depths plus 1 foot of allowable overdepth dredging and there would be no capping. Dredging and disposal includes the following tasks:

- Pumping dredged material to land-side stockpile dewatering areas, consisting of CDFs
- Treating effluent water from the CDFs by a DAF treatment system
- Discharging treated effluent water back into the waterway
- Disposing of dewatered dredge material at a commercial landfill
- Disposing of used CDF material at a commercial landfill
- Filling in and revegetating the CDF sites

Based on the geometry of the waterway and the dredged materials, 17 CDFs would be constructed for the segments of the Grand Calumet River. Approximately 1,538,000 cy would be dredged from the Grand Calumet River. However, during dredging and transporting sediment to bulk an additional 15 percent over the in-situ density. Therefore, the total amount of material to be settled in the CDFs is 1,769,000 cy. Six CDFs would be constructed along the IHC. Approximately 492,000 cy would be dredged along this waterway, with approximately 566,000 cy being settled in the CDFs. Six CDFs would be constructed along the LGC where approximately 447,000 cy would be dredged, and 514,000 cy settled in the CDFs. During design, it may be determined, based on availability of CDF sites that fewer CDFs can be constructed.

Please see the 3-foot dredge prism section for the details of dredging and disposal.

The assumptions used for the maximum dredging cost estimate in Table G-2 are as follows:

- The quantity of dredged material in the side slopes has not been included but is considered to be within the accuracy of the data and method used to calculate the quantities for each segment of dredging work.
- Land and permission necessary for construction of land-side CDFs and access roads will be provided.

- The estimate does not include the cost of land acquisition.
- The estimate does not include costs for any required mitigation.
- The estimates are at the conceptual level only and are within a rough order of magnitude.
- Actual dredged material quantities may vary significantly from those estimated due to actual bathymetry or increased required dredge depths.
- Equipment costs and production rates upon which the estimate is based are those experienced in other similar types of work.
- Sufficient quantities of imported cap materials can be supplied for the project from local suppliers.
- The estimate does not include capping.
- The cost estimate is based on year 2000 dollars.

REACH 2

The dredge plan, upon which this estimate is based, is similar to the plan for the 3-foot dredge prism in Reach 1. There are two major steps involved in the 3-foot dredge prism process:

- Dredging and disposal
- Capping

Dredging and disposal includes the following tasks:

- Pumping dredged material to land-side stockpile dewatering areas, consisting of CDFs
- Treating effluent water from the CDFs by a DAF treatment system
- Discharging treated effluent water back into the waterway
- Disposing of dewatered dredge material at a commercial landfill
- Disposing of used CDF material at a commercial landfill.
- Filling in and revegetating the CDF sites.

Based on the geometry of the waterway and the dredged materials, four CDFs would be constructed for the segments of the IHC, the Turning Basin and the Forks. Approximately 332,000 cy would be dredged from the IHC. However, during dredging and transporting sediment to bulk an additional 15 percent over the in-situ density. Therefore, the total amount of material to be settled in the CDFs is 382,000 cy. One CDF would be constructed along the LGC where approximately 73,000 cy would be dredged, and 84,000 cy settled in the CDF. During design, it may be determined, based on availability of CDF sites that fewer CDFs can be constructed.

Please see the Reach 1 3-foot dredge prism section for the details of dredging and disposal and capping.

The assumptions used for the dredging and capping cost estimate in Table G-3 are as follows:

- The quantity of dredged material in the side slopes has not been included but is considered to be within the accuracy of the data and method used to calculate the quantities for each segment of dredging work.
- Land and permission necessary for construction of land-side CDFs and access roads will be provided.
- The estimate does not include the cost of land acquisition.
- The estimate does not include costs for any required mitigation.
- The estimates are at the conceptual level only and are within a rough order of magnitude.
- Actual dredged material quantities may vary significantly from those estimated due to actual bathymetry and topography or increased required dredge depths.
- Equipment costs and production rates upon which the estimate is based are those experienced in other similar types of work.
- Sufficient quantities of imported cap materials can be supplied for the project from local suppliers.
- The cost estimate is based on year 2000 dollars.

Table G-1. Cost Estimate for the 3-Foot Dredge Prism with Capping Page 1 of 2

Category	Quantity	Unit	Unit Cost ($)	Cost [1] ($)
Dredge 1,303,000 Sediment, Dispose 1,499,000 cy Sediment, Cap 1,303,000 cy Sand				
DREDGING AND DISPOSAL				
Mobilization: 2 Mudcat 10" dredges w/pipe, 2 Workboats, Crane, 2 Loaders, 2 DAF Effluent Treatment Systems & Misc. Eqmt.	1	LS	1,100,000	1,100,000
Dredge Sediment and Pump to Landside Stockpile/Dewatering Areas (Includes Full-Time Survey Crew)	1,303,000	CY	5	6,500,000
Dredge Equipment Setup and Relocation	12	EA	10,000	120,000
Construct & Remove 2-100,000 cy CDFs w/Geomembrane Liner and Weir	1	LS	2,900,000	2,900,000
Construct and Remove Additional CDFs	13	EA	600,000	7,800,000
Dewater Sediment	1,499,000	CY	2	3,000,000
Load Sediment into Lined highway trucks and Haul to Commercial Landfill	1,499,000	CY	10	15,000,000
Commercial Landfill Disposal Fee	1,499,000	CY	50	75,000,000
Clean Up, Regrade and Reseed 15 CDF Sites	15	EA	2000	30,000
Water Quality Monitoring During Dredging	1	LS	200,000	200,000
Direct Cost: Dredging and Disposal				**110,000,000**
CAPPING				
Mobilization to Site and Initial Setup of Pumping and Placing Equipment and 5,000' HDPE Pipe (10-inch Dredge Pump, Motor, Hopper, Conveyor, Piping, HDPE, Discharge Barge & Diffuser, Workboat, Winches & Anchors)	1	LS	200,000	200,000
Relocation and Setup of Pumping Stations	8	EA	25,000	200,000
Disassembling, Moving and Reassembling 5,000' HDPE Pipe	8	EA	3,000	24,000

Table G-1. Cost Estimate for the 3-Foot Dredge Prism with Capping **Page 2 of 2**

Category Dredge 1,302,000 Sediment, Dispose 1,499,000 cy Sediment, Cap 1,302,000 cy Sand	Quantity	Unit	Unit Cost ($)	Cost [1] ($)
CAPPING				
Sand Cap Material Delivered to Stockpile Sites	1,303,000	CY	15	20,000,000
Place Sand Cap Material	1,303,000	CY	8	10,000,000
Armoring under Bridges and Trestles	60,000	CY	35	2,100,000
Water Quality Monitoring	1	LS	100,000	100,000
Cleanup, Regrade and Reseed Pump Station Sites	8	EA	2,000	16,000
Direct Cost: Capping				**33,000,000**
Subtotal Dredging & Disposal & Capping				140,000,000
Engineering & Design			5%	7,000,000
Construction Oversight			5%	7,000,000
Contingency			20%	31,000,000
Total Estimated Dredging and Disposal & Capping Cost				**190,000,000**

Notes:

[1] Cost estimates are order-of-magnitude and are provided to two significant figures.
CY-cubic yards
EA-each
LS-lump sum

Table G-2. Cost Estimate for the Maximum Dredge Prism **Page 1 of 2**

Category	Quantity	Unit	Unit Cost ($)	Cost[1] ($)
Dredge 2,477,000 Sediment, Dispose 2,849,000 cy Sediment, No Cap				
DREDGING AND DISPOSAL				
Mobilization: 2 Mudcat 10" dredges w/pipe, 2 Workboats, Crane, 2 Loaders, 2 DAF Effluent Treatment Systems & Misc. Eqmt.	1	LS	1,100,000	1,100,000
Dredge Sediment and Pump to Landside Stockpile/Dewatering Areas (Includes Full-Time Survey Crew)	2,477,000	CY	5	12,000,000
Dredge Equipment Setup and Relocation	12	EA	10,000	120,000
Construct & Remove 2-100,000 cy CDFs w/Geomembrane Liner And Weir	1	LS	2,900,000	2,900,000
Construct and Remove Additional CDFs	27	EA	600,000	16,000,000
Dewater Sediment	2,849,000	CY	2	5,700,000
Load Sediment into Lined highway trucks and Haul to Commercial Landfill	2,849,000	CY	10	28,000,000
Commercial Landfill Disposal Fee	2,849,000	CY	50	140,000,000
Clean Up, Regrade and Reseed 12 CDF Sites	29	EA	2000	58,000
Water Quality Monitoring During Dredging	1	LS	200,000	200,000
Direct Cost: Dredging and Disposal				**210,000,000**

Table G-2. Cost Estimate for the Maximum Dredge Prism **Page 2 of 2**

Category	Quantity	Unit	Unit Cost ($)	Cost[1] ($)
Dredge 2,477,000 Sediment, Dispose 2,849,000 cy Sediment, No Cap				
CAPPING				
Armoring under Bridges and Trestles	80,000	CY	35	2,800,000
Water Quality Monitoring	1	LS	50,000	50,000
Direct Cost: Capping				**2,900,000**
Subtotal Dredging & Disposal & Capping				210,000,000
Engineering & Design			5%	11,000,000
Construction Oversight			5%	11,000,000
Contingency			20%	42,000,000
Total Estimated Dredging and Disposal & Capping Cost				**270,000,000**

Notes:

[1] Cost estimates are order-of-magnitude and are provided to two significant figures.
CY-cubic yards
EA-each
LS-lump sum

Table G-3. Cost Estimate for the Federal Reach (3-Foot Dredge Prism with Capping)

Category	Quantity	Unit	Unit Cost ($)	Cost[1] ($)
Dredge 405,000 cy Sediments, Dispose 466,000 cy Sediment, Cap 405,000 cy Sand				
DREDGING AND DISPOSAL				
Mobilization: 1 Mudcat 10" dredges w/pipe, 2 Workboats, Crane, Loader, DAF Effluent Treatment System & Misc. Eqmt.	1	LS	300,000	300,000
Dredge Sediment and Pump to Landside Stockpile/Dewatering Areas (Includes Full-Time Survey Crew)	405,000	CY	5	2,000,000
Dredge Equipment Setup and Relocation	5	EA	10,000	50,000
Construct & Remove 2-100,000 cy CDF's w/Geomembrane Liner And Weir	1	LS	2,900,000	2,900,000
Construct and Remove Additional CDFs	3	EA	600,000	1,800,000
Dewater Sediment	466,000	CY	2	930,000
Load Sediment into Lined highway trucks and Haul to Commercial Landfill	466,000	CY	10	4,700,000
Commercial Landfill Disposal Fee	466,000	CY	50	23,000,000
Clean Up, Regrade and Reseed 5 CDF Sites	5	EA	2000	10,000
Water Quality Monitoring During Dredging	1	LS	100,000	100,000
Direct Cost: Dredging and Disposal				**36,000,000**
CAPPING				
Mobilization to Site & Initial Setup: 10-inch Dredge Pump, Motor, Hopper, Conveyor, Piping, 5,000' HDPE, Discharge Barge & Diffuser, Workboat, Winches & Anchors	1	LS	200,000	200,000
Relocation and Setup of Pumping Stations	5	EA	25,000	130,000

Table G-3. Cost Estimate for the Federal Reach (3-Foot Dredge Prism with Capping)
Page 2 of 2

Category Dredge 405,000 cy Sediments, Dispose 466,000 cy Sediment, Cap 405,000 cy Sand	Quantity	Unit	Unit Cost ($)	Cost[1] ($)
CAPPING (continued)				
Disassembling, Moving and Reassembling 5,000' HDPE Pipe	5	EA	3,000	15,000
Sand Cap Material Delivered to Stockpile Sites	405,000	CY	15	6,100,000
Place Sand Cap Material	405,000	CY	8	3,200,000
Water Quality Monitoring	1	LS	100,000	100,000
Cleanup, Regrade and Reseed Pump Station Sites	5	EA	2,000	10,000
Direct Cost: Capping				**9,800,000**
Subtotal Dredging & Disposal & Capping				46,000,000
Engineering & Design			5%	2,300,000
Construction Oversight			5%	2,300,000
Contingency			20%	9,200,000
Total Estimated Dredging and Disposal & Capping Cost				**60,000,000**

Notes:

[1] Cost estimates are order-of-magnitude and are provided to two significant figures
CY-cubic yards
EA-each
LS-lump sum