GREAT LAKES ARCHITECT ENGINEER SERVICES (GLAES)

CONTRACT

FOCUSED FEASIBILITY STUDY REPORT

Menomonee and Milwaukee Rivers
Milwaukee Estuary Area of Concern
Milwaukee, Wisconsin
Task Order No. 0029/Contract No. EP-R5-11-09

May 2019

PREPARED FOR

United States
Environmental Protection
Agency

PREPARED BY

ch2m

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Executive Summary

This Focused Feasibility Study (FFS) presents the results of the remedial action objectives (RAOs), technology screening, and alternatives development and evaluation completed for the Milwaukee and Menomonee Rivers Site within the Milwaukee Estuary Area of Concern (AOC), in Milwaukee, Wisconsin. The objective of the FFS is to develop a list of remedial alternatives for the Milwaukee and Menomonee Rivers Site such that the U.S. Environmental Protection Agency Great Lakes National Program Office, in partnership with the non-federal sponsor, We Energies, as well as the Wisconsin Department of Natural Resources can select a remedial action to eliminate, reduce, or control risks to human health and the environment and support moving forward with the removal of Milwaukee Estuary AOC beneficial use impairments and ultimately delisting the AOC.

The FFS presents key information to support the development and evaluation of remedial alternatives and includes the following:

- Development of a conceptual site model summarizing physical site characteristics, nature and extent of contamination, and an assessment of potential ongoing sources.
- Statement of site-specific remedial action objectives and development of remedial targets.
- Identification and screening of remedial technologies.
- Description of remedial alternatives for specific site areas, including estimates of sediment removal and surface-weighted average concentration reduction for contaminants of concern.
- Comparative analysis of the alternatives against five separate criteria.
- Identification and justification of a preferred alternative.

Sediment RAOs were developed based on the nature and extent of the contamination to protect human health, the environment and resources that are currently and potentially threatened and to contribute to removing beneficial use impairments and eventually delisting the AOC.

Consistent with the RAOs, representative remedial technologies and process options were identified and screened. Remedial technologies and process options that remained following screening were assembled into five alternatives. Based on the risks present at the site and the remaining remedial technologies and process options available after completion of the screening, the following five dredging alternatives (with subalternatives) were assembled and then evaluated. Alternatives 2 through 5 have the same remedial footprint and removal volume in the Milwaukee River component of the FFS, and therefore only Menomonee River alternative variations are presented below:

- Alternative 1—No Action
- Alternative 2—Dredging based on navigational depths for sand cover placement
  - Alternative 2A—Hydraulic Dredging/CDF Disposal
  - Alternative 2B—Mechanical Dredging/CDF Disposal
- Alternative 3—Dredging taking into account deauthorization of the navigation channel upstream of 16th Street (Reach 4), targeting Areas of Interest (AOIs), and Reach 5 dredged to navigational depths for sand cover placement
  - Alternative 3A—Hydraulic Dredging/CDF Disposal
  - Alternative 3B—Mechanical Dredging/CDF Disposal

- Alternative 4—Dredging taking into account deauthorization of the navigation channel upstream of 16th Street (Reach 4) targeting AOIs, and Reach 5 dredged to navigational depth
  - Alternative 4A—Hydraulic Dredging/CDF Disposal
  - Alternative 4B—Mechanical Dredging/CDF Disposal
  - Alternative 4C—Mechanical Dredging/Landfill Disposal
- Alternative 5—Dredging taking into account deauthorization of the navigation channel upstream of 16th Street (Reach 4) and sand cover placement only in AOIs in Reaches 3 through 5
  - Alternative 5A—Hydraulic Dredging/CDF Disposal
  - Alternative 5B—Mechanical Dredging/CDF Disposal
  - Alternative 5C—Mechanical Dredging/Landfill Disposal

Each alternative, except for Alternative 1 (No Action), which is not applicable, passes the threshold criteria evaluation. Each alternative would require engineering and/or administrative measures to maintain compliance with regulations, but specified measures are achievable. Alternative 5 has the lowest removal volume of Alternatives 2 through 4 and is more protective than Alternatives 1, 2, and 3. Alternative 5 provides the same level of protectiveness as Alternative 4 with 34,500 cubic yards (22 percent) less volume of material needing removal and management. Based on the comparative analysis of alternatives, Alternative 5 is the most effective and efficient at achieving the site-specific RAOs and overall protection of human health and the environment. Alternative 5 has been selected as the preferred alternative and will be developed through the remedial design phase.

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Acronyms and Abbreviations

AOC	area of concern
AOI	area of interest
BRRTS	Bureau for Remediation and Redevelopment Tracking System
bss	below sediment surface
BUI	beneficial use impairment
cfs	cubic feet per second
CDF	confined disposal facility
CDM	CDM Smith
CH2M	CH2M HILL, Inc.
COC	contaminant of concern
CSM	conceptual site model
CSO	combined sewer overflow
EPA	U.S. Environmental Protection Agency
ERP	environmental remediation project
Foth	Foth Infrastructure & Environment, LLC
FFS	focused feasibility study
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
GPS	global positioning system
ISS	in situ stabilization
LUST	leaking underground storage tank
LWD	low water datum
Max	maximum
mg/kg	milligram(s) per kilogram
MGP	manufactured gas plant
Min	minimum
MMSD	Milwaukee Metropolitan Sewerage District
MNR	monitored natural recovery
NAPL	nonaqueous phase liquid
NAVD88	North American Vertical Datum of 1988
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl

PEC	probable effect concentration
POTW	publicly owned treatment works
RAO	remedial action objective
RAP	remedial action plan
SEWRPC	Southeastern Wisconsin Regional Planning Commission
Std Dev	standard deviation
SWAC	surface-weighted average concentrations
TOC	total organic carbon
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WDNR	Wisconsin Department of Natural Resources
WPDES	Wisconsin Pollutant Discharge Elimination System
WWTP	wastewater treatment plant

SECTION 1

Introduction

This focused feasibility study (FFS) report presents the understanding of site conditions, remedial action objectives (RAOs), and the results of remedial technology screening and alternative development for the Menomonee and Milwaukee Rivers site within the Milwaukee Estuary Area of Concern (AOC) in Milwaukee, Wisconsin. It is being submitted pursuant to the U.S. Environmental Protection Agency (EPA) statement of work dated June 2017. The work is being conducted in accordance with Task Order No. 0029, under Contract No. EP-R5-11-09.

This document consists of the following five sections:

- Section 1 provides an introduction and summarizes background information, such as site physical description and beneficial use impairments (BUIs).
- Section 2 presents the conceptual site model (CSM) based on the available physical and chemical data and the nature and extent of contamination from investigations conducted by EPA and the non-federal sponsor. In addition, this section discusses potential sources and an assessment of recontamination.
- Section 3 contains information about the RAOs and details the general and site-specific objectives and remediation targets.
- Section 4 identifies and describes a range of remedial approaches, technologies, and process options based on the RAOs, that could be used to address contaminated sediments. Technologies are then screened and retained for consideration or eliminated based on their potential effectiveness, implementability, and cost to implement at the site. Detailed analysis is then focused on only those technologies most applicable to the site.
- Section 5 presents the development of remedial alternatives for the site by combining the remedial approaches, technologies, and process options that were retained after the screening described in Section 4.
- Section 6 presents the detailed individual and comparative analyses of the remedial alternatives with respect to: compliance with applicable regulations and permits; short- and long-term effectiveness; engineering implementability, reliability, constructability, and technical feasibility; ability to contribute to BUI removal; cost; and stakeholder and community acceptance.
- Section 7 presents the reference documents cited in this memorandum.

1.1 Purpose

The purpose of the FFS is to evaluate remedial alternatives and support selection of a remedy that is protective of human health and the aquatic environment and will move the project toward remediation. The remedy will contribute to the eventual removal of BUIs and delisting of the Milwaukee Estuary AOC. The FFS was completed through a partnership between the non-federal sponsor, We Energies, EPA's Great Lakes National Program Office (GLNPO), as well as the Wisconsin Department of Natural Resources (WDNR).

This FFS was developed following the remedial alternatives evaluation. The remedial alternatives evaluation assembled the viable technologies and process options identified in the technology screening to address the RAOs for the site. The remedial alternatives were developed to support a cost estimate and to enable evaluation individually and against each other. The results of the evaluation were used to select a remedy that is presented in this FFS report.

1.2 Site Description

The project area is located within the Milwaukee Estuary AOC (Figure 1). The Milwaukee Estuary AOC includes portions of three watersheds along the Milwaukee River, Menomonee River, and Kinnickinnic River, as well as the inner and outer Milwaukee Harbor, two former industrial canals, and nearshore areas of Lake Michigan. The scope of this project includes portions of both the Menomonee River (Operable Unit [OU]1) and Milwaukee River (OU2) project reaches. OU1 includes approximately 1.9 river miles of the Menomonee River from the West Canal Street Bridge to the confluence with the Milwaukee River. OU2 is composed of about 0.6 river mile and includes the portion of the Milwaukee River from the Menomonee River to the confluence with the Kinnickinnic River at the Inner Harbor. The N 25th Street Bridge across the Menomonee River is the upstream limit of the federal navigation channel that extends from the Inner Harbor and includes portions of the Menomonee, Milwaukee, and Kinnickinnic Rivers, as well as the South Menomonee and Burnham Canals. The 0.6-mile portion of the Menomonee River from the N 25th Street Bridge (upstream limit of the federal navigation channel) to the 16th Street Bridge was recently deauthorized by Congress in the "America's Water Infrastructure Act of 2018."

The Lake Michigan seiche influences stream flow in the project area, creating flow that alternates between discharging into Lake Michigan, and Lake Michigan water flowing upstream. Based on a shoreline stability qualitative analysis conducted in 2016 and 2017 (Foth 2017 and CH2M HILL, Inc. 2018, respectively), there are thick accumulations of sediment between the navigation channel and bulkhead walls in the project area, and the shoreline consists mainly of vertical walls constructed of various materials (Figure 2). The majority of shoreline is steel sheet pile that is in good to excellent condition based on qualitative assessments above the water line. Section 2.1 contains additional details of the sheet pile wall conditions. Quantitative assessment of wall stability has not been performed.

1.3 Project Background

The Milwaukee Estuary AOC has a long history of ecological degradation and pollution. Under the Great Lakes Water Quality Agreement, the Milwaukee Estuary Stage 1 Remedial Action Plan (RAP) was completed in 1991. The RAP has been updated periodically, with the most recent draft in December 2017. The RAP identifies the project reaches of the Menomonee and Milwaukee Rivers as requiring additional sediment characterization, followed by further evaluation for potential remedial action.

Historical discharges resulted in sediment within the AOC being contaminated with various pollutants, including metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs).
The former We Energies West Side Manufactured Gas Plant (MGP) site is located within the Menomonee River (OU1) immediately downstream of 25th Street and the former We Energies Third Ward MGP site is located within the Milwaukee River (OU2) downstream of the confluence with the Menomonee River. High levels of contamination have been found within the vicinity of the project area, including Lincoln Park and Milwaukee River Channels Phase 1 and 2 Sediment sites, Reach 4 of the Milwaukee River Downstream Sediment site and the Burnham Canal Superfund Alternative site. Additionally, the Cedar Creek Superfund site and Moss-American Co. Inc. Superfund site are located at the upstream extents of the expanded AOC range within Milwaukee River and Little Menomonee River, respectively.

The rivers were historically modified (straightened and dredged) to accommodate large vessel commercial shipping, making the estuary a settling basin for sediments. Over time, sections of the rivers that were previously maintained by dredging were no longer needed for deep draft navigation, but the sediments and their associated contaminants remain. Dredging in portions of the navigation channel within the project area was previously performed by the U.S. Army Corps of Engineers (USACE) in 1987, 1993, 1999, 2007, and 2015.

Sediment characterization of the Menomonee River was performed by GLNPO under the Great Lakes Legacy Act (GLLA) in 2015 and 2016. The study included sampling and analysis of sediment from the confluence of the Little Menomonee River to the confluence of the Milwaukee River.
The characterization results identified elevated PAHs and metals in sediments downstream of Canal Street (CH2M 2016). Prior to the 2015–2016 site characterization, other sediment sampling events were performed on the Menomonee River by We Energies and USACE.

Sediment sampling and probing have also been completed by GLNPO in the Milwaukee River Downstream site located upstream of the confluence with the Menomonee River in 2016 and 2018, which indicated elevated levels of PCBs and metals in surface and subsurface sediments.
An investigation in OU2 was completed by We Energies in 2017. The investigation identified petroleum sheens and nonaqueous phase liquid (NAPL) adjacent to the navigational channel at elevations above native clay both near the Former Third Ward MGP site and just upstream of the Water Street bridge.

The following BUIs exist in the Milwaukee Estuary AOC, with 7 (bold bullets) of the 11 BUIs linked to contaminated sediment in the AOC:

- **Restrictions on fish and wildlife consumption**
- Eutrophication or undesirable algae
- **Degradation of fish and wildlife populations**
- Beach closings
- **Fish tumors or other deformities**
- Degradation of aesthetics
- **Bird or animal deformities or reproduction problems**
- **Degradation of benthos**
- Degradation of phytoplankton and zooplankton populations
- **Restriction on dredging activities**
- **Loss of fish and wildlife habitat**

Constituents in the sediment are a primary pollution concern. Impacted sediments are ingested by bottom-dwelling benthic organisms as they feed and can be toxic to many of the invertebrates inhabiting the sediment. In addition, piscivorous fish, birds, and mammals, including people, may be exposed to bioaccumulative chemicals, such as mercury and PCBs, via diet. Impacted sediments also have the potential to be resuspended and transported by naturally occurring events (such as storms and floods) and human-activities (such as propeller wash from boating/shipping traffic, unpermitted sediment removal in front of piers and docks, etc.).

SECTION 2

Conceptual Site Model

This section summarizes the site conditions of the project area that includes portions of both the Menomonee River (OU1) and Milwaukee River (OU2) project reaches.

The following resources were identified and reviewed to develop the CSM:

- USACE single-beam bathymetry data for OU1 and OU2 from 1996, 2002, 2011, 2015 and 2017.
- Side-scan sonar imaging of OU2 collected in 2017 by the University of Wisconsin–Milwaukee School of Freshwater Sciences (Fresh Water Engineering, LLC 2017).
- 2012 and 2014 Former West Side MGP Sediment Investigation Summary Technical Memorandums (Natural Resource Technology 2013 and 2014).
- *Site Characterization Report, Menomonee River Sediment Investigation, Milwaukee Estuary Area of Concern* (CH2M 2016).
- *Remedial Investigation Technical Memorandum* documenting findings and data collected as part of the OU2 investigation (Foth Infrastructure & Environment [Foth], LLC 2017).
- Draft *Site Characterization Report, Milwaukee River Downstream Sediments, Milwaukee Estuary Area of Concern* (CH2M 2017).
- *Site Sampling Technical Memorandum Menomonee and Milwaukee Rivers, Milwaukee Estuary Area of Concern* (CH2M 2018).

2.1 Physical Site Characteristics

2.1.1 Menomonee River (OU1)

OU1 includes approximately 1.9 river miles of the Menomonee River from the West Canal Street Bridge to the confluence with the Milwaukee River. The Menomonee River from the confluence of the Little Menomonee River to the confluence of the Milwaukee River was investigated by GLNPO in 2015 with additional data-gap sampling conducted in 2017. During the 2015 investigation, the OU1 portion of the Menomonee River was divided into three reaches:

- Reach 3—Begins at the West Canal Street Bridge and extends approximately 0.4 mile to 25th Street.
- Reach 4—Extends from 25th Street to the 16th Street Bridge, approximately 0.6 miles. Reach 4 contains the former West Side MGP facility located immediately downstream of 25th Street.
- Reach 5—Begins at the 16th Street Bridge and extends about 1 mile downstream to the confluence with the Milwaukee River near downtown Milwaukee.

The following subsections summarize relevant physical characteristics of the portion of the Menomonee River included in the OU1 study area. Additional details are provided in the site characterization report (CH2M 2016) and the site sampling technical memorandum for the 2017 investigation (CH2M 2018).

2.1.1.1 Shoreline Characteristics

A shoreline assessment of OU1 was conducted in November 2017 with findings detailed in the site sampling technical memorandum (CH2M 2018) and presented in Figure 2. Assessment findings are based on above-water observations. Property along OU1 is currently dominated by industrial and commercial land use. The north shoreline within the OU1 area consists primarily of steel sheet pile wall. Steel sheet pile bulkhead in excellent or good condition composed about 5,381 feet, or about 51 percent, of the total 10,621 feet of the northern shoreline. There are a few sections of reinforced concrete bulkheads ranging from good to poor condition. Portions of riprap, timber wall, natural shoreline, and one section of drystack wall are also present on the north shoreline. The following are notable features along the northern shoreline:

- **Diedrich Acquisitions, LLC (2115 W Greves Street):** This section of shoreline is composed of a drystack wall, most likely slate, granite, or marble. Several portions of this wall are in disrepair, and some sections have failed. Additionally, there is a concrete wharf, approximately 5 to 6 feet wide behind the drystack wall that has also failed.
- **Guiffre VIII, LLC (2215 W Mt. Vernon Avenue):** The upstream section of shoreline (Station 14+93 to 17+19) contains a critical structure close to the shoreline. Although the riprap shoreline in front of the building is in good condition, the building itself is historic and approximately 20 feet from the water's edge. The downstream portion of property (Station 17+19 to 18+94) is composed of reinforced concrete and is in poor condition. The bulkhead is trapezoidal shaped and about 2 to 4 feet thick. Cracking and scaling is evident in the bulkhead, and the downstream half of the bulkhead appears to be tipping into the river.
- **City of Milwaukee (1313 W Mt. Vernon Avenue):** This section of shoreline is composed of reinforced concrete and is in poor condition. The bulkhead is about 5 feet thick and has small section H piles at 10-foot spacings on the concrete face. Severe scaling, pitting, and crumbling is evident in the bulkhead, and rebar is exposed.
- **City of Milwaukee Redevelopment Authority (825 W Hinman Street):** This section of shoreline is composed of 12- by 12-inch timbers supported by angle iron pilings on the backside at 12-foot spacings. The downstream end of this wall is falling into the river.
- **Soo Line Railroad Company (210 N Plankinton Avenue):** This section of shoreline is composed of 12- by 12-inch timbers with potential 2-inch-diameter anchorages. Circular timber pilings are also present in front of the wall. The timber wall is in serious disrepair, and the exposed shoreline behind the wall is severely eroded.
- **Sidney Harry Hack Julius (324 N Plankinton Avenue):** This section of shoreline is composed of 12- by 12-inch timbers with potential 2-inch-diameter anchorages. Circular timber pilings are also present in front of the wall. The timber wall is in serious disrepair, and the exposed shoreline behind the wall is severely eroded.

The southern shoreline of OU1 also consists mostly of steel sheet pile wall. Steel sheet pile bulkhead composed about 6,550 feet, or 64 percent, of the total 10,185 feet of the southern shoreline, which is in excellent or good condition. There are a few sections of reinforced concrete bulkheads ranging from excellent to fair condition, and one section of composite sheet pile and concrete in good condition. About 940 feet of the southern shoreline, along property owned by the Milwaukee Metropolitan Sewerage District (MMSD), is composed of a natural shoreline with steep banks and heavy vegetation. The following are the notable features along the southern shoreline:

- **Turnbridge, LLC (126 S 2nd Street):** This section of shoreline consists of a stone block building immediately adjacent to the river. Since the building itself is the shoreline, it is considered a critical structure. A timber wall and fender constructed out of timber pilings and 12- by 12-inch timbers are present in front of the structure and constitute the edge of the navigation channel.
- **St. Mary's Cement Inc. (712 W Canal Street):** This section of sheet pile wall is torn.
- **Wisconsin Electric Power Company (1056 W Canal Street):** Cooling-water intakes for We Energies are present year-round. Large steel structures extend into the river and contain signage indicating that no anchoring or mooring is allowed.

Sewer outfalls and combined sewer outfalls (CSOs) were also observed and are identified in Figure 2. Most of the outfalls were small-diameter (less than 10 inches) stormwater discharges that are linked to roof drains, road and parking areas, and walkways. Additionally, several CSOs were identified along both shorelines. In some areas, riprap was observed on either side of CSO and sewer outfalls.

Evidence of additional shoreline features, such as floating docks, finger piers, and removable docks and walkways that extend waterward of the bulkhead were noted during the survey. These features are most likely present along many of the riverfront properties during the recreational summer period and are removed during the winter. The docks by the Canal Street Yacht Club, LLC (1200 Canal Street) were the only features observed during the November 2017 assessment.

2.1.1.2 Hydraulic Characteristics

The currently federally authorized navigational channel in the Menomonee River extends downstream from the 16th Street Bridge to the confluence with the Milwaukee River near downtown Milwaukee. As discussed previously, the section from 25th Street to 16th Street was deauthorized in 2018. Portions of the Menomonee River were last dredged in 1993 to USACE's authorized project depth of 21 feet low-water datum (LWD). The dredge footprint included the stretch from the 25th Street Bridge to about 300 feet downstream of the North 16th Street Bridge and about a 785-foot stretch from the confluence with the South Menomonee Canal to the South 2nd Street (N Plankinton Avenue) (USACE, 2018).

The Menomonee River watershed has been extensively modified to facilitate drainage in agricultural and urban areas and the river channels have been ditched or lined to rapidly move flood waters downstream. Approximately 8 percent of the Menomonee River upstream of the project area is concrete lined or has had significant channel modifications (CDM Smith [CDM] 2016). These modifications have resulted in the river exhibiting flash-flow patterns characterized by rapid fluctuation in water levels. Constructed alterations to the watershed and rapid urbanization have resulted in increased sediment load and accumulation of pollutants in the lower reaches of the watershed. Between runoff events, groundwater discharge baseflow contributes to most of the stream flow (Southeastern Wisconsin Regional Planning Commission [SEWRPC] 2013).

A U.S. Geological Survey (USGS) stream gauge (#04087142) is located at the 16th Street Bridge and has discharge data available from October 2008 (Exhibit 1). The river hydrology within the study area is a complex system influenced by a combination of lake level and river flow. In the Menomonee River, the highest discharge rate is observed after the spring snowmelt (March through and June), and the lowest discharge rates are observed during the late summer and fall (July to October). Based on the average monthly discharge data for steam gauges #04087142 and #04087170 (at Jones Island downstream of OU2), the Menomonee River accounts for an approximately 13 percent of the overall flow to the harbor.

Exhibit 1. Menomonee River Discharge Statistics Based on Data from USGS Gauge #04087142
Menomonee and Milwaukee Rivers Focused Feasibility Study

Flow Rate (cfs)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average[a]	89	108	262	343	203	216	155	68	62	68	82	136
Std Dev	57	73	102	186	67	112	245	29	45	33	66	102
Median	80	101	263	320	216	252	83	66	35	57	59	119
Max	180	218	408	726	322	360	758	106	140	138	220	354
Min	32	17	90	119	109	26	27	39	24	38	26	31
Percent Contribution at Jones Island	18%	20%	19%	20%	21%	23%	30%	16%	20%	18%	20%	24%

Notes:
[a] Average flow rates based on monthly flow rates during October 2008 through August 2016.
cfs = cubic feet per second; Max = maximum; Min = minimum; Std Dev = standard deviation

Water depths during the investigations were generally shallow (between 2 and 7 feet) upstream of the 25th Street Bridge and ranged from 8 feet near the shoreline to about 27 feet within the navigational channel with depths generally increasing downstream. Water depths at sample locations within the navigation channel downstream of the 16th Street Bridge were generally greater than the authorized project depth of 21 feet LWD.

2.1.1.3 Sediment Stability and Bathymetry

The differences in the bathymetric surveys of the navigational channel conducted by USACE in 1996, 2002, 2011, 2015, and 2017 were compared to evaluate long-term sediment deposition and scour within the Menomonee and the Milwaukee Rivers over the 22-year measurement period. Comparing the consecutive surveys provides an average spatial depiction of areas undergoing deposition (positive differentials) and scour (negative differentials) between the two bathymetric surveys and does not portray episodic events that occur during brief time frames, such as during out-of-bank floods or high-flow events.

Recent dredge events completed by USACE took place in 1993, 1999, 2007, and 2015. Appendix A contains figures showing the comparison of the bathymetric surfaces and the extents of the dredge events, and Table 1 contains a bathymetric differential comparison summary.

- The 1993 dredge extent included removal in OU1 from N 25th Street to just downstream of N 16th Street; a section upstream of S 2nd Street to the South Menomonee Canal; and a section in OU2 from N Young Street to E Polk Street.
- The 1999 dredge extent included material within OU2 from E Polk Street to approximately 500 feet upstream of the downstream extent of OU2.
- The 2007 dredge extent included approximately 300 feet of removal downstream of the 1999 event and the 2015 dredge event extended the 2007 removal to include the remaining area to the downstream extent of OU2.

Based on the bathymetric data from 5 surveys over the 22-year measurement period, the majority (between 58 and 70 percent) of the Menomonee River would be considered depositional as indicated by higher surface elevations measured in subsequent years. Between 5 and 15 percent of the area within the Menomonee River was identified as scour areas, and 17 and 37 percent of the area was relatively unchanged. The comparison of the 2015 and 2017 bathymetric data shows a differential of less than 1 foot over most of the Menomonee River. Scour areas were identified downstream of the CSO near 13th Street, beneath the I-94/I-43 overpass and near the N 6th Street Bridge. In addition, the 2002 and 2011 bathymetry comparison showed approximately 400 feet of scour downstream of 25th Street, near the former West Side MGP facility, but not for other years of comparison (1996-2002, 2011-2015, 2015-2017, and 1996-2017). The estimated depositional rates have been relatively consistent over the 21-year period ranging from a high of 0.32 foot per year between 1996 and 2002 to a low rate of 0.18 foot per year between 2002 and 2011, with an average rate between 1996 and 2017 of 0.23 foot per year. Over the 21-year period, an estimated 184,604 cubic yards of material have been deposited within the Menomonee River.

The uppermost portion of OU1, between the N 27th Street Bridge and the N 25th Street Bridge is not within the authorized navigational channel and has not been dredged. During the investigations, this section had an average sediment thickness of about 16 feet, ranging from 5 feet at locations R3-02 and R3-04, in the center of the river, to 34 feet at location R3-06 on the southern shoreline. Minimal sediment was observed along the north shoreline adjacent to locations R3-02 and R3-04. Sediment sampling within the channel upstream of location R3-01 was not performed because of the limited sediment observed during site reconnaissance.

The distribution of sediment within the navigation channel in OU1 (from N 25th Street to the confluence with the Milwaukee River) is greatly influenced by the dredging of the navigational channel and sediment load from upstream. The depositional nature is further supported by the core data that found that the sediment surface at most locations (30 of 35 locations) was between 0.2 to 15.4 feet above USACE's project elevation of 557 feet above mean sea level. The sediment thickness both in and adjacent to the navigational channel generally decreases downstream from greater than 29 feet at location R4-01 to 0.5 foot at location R5-12, with an average sediment thickness of 13.2 feet. Within the navigational channel, the sediment thickness decreased from 25.7 feet (R4-03) feet to 0.5 foot (R5-12), averaging about 10.8 feet. Sediment thickness outside the navigation channel and immediately adjacent to the shoreline ranged from about 29.5 (R4-01) to 3.9 (R5-15) feet and averaged 16.1 feet. Based on the 2017 bathymetric surface, there are approximately 183,100 cubic yards of sediment within the navigational channel above the authorized dredge elevation of 557 feet (depth of -21 feet low water depth).

Native clay material described as grey firm clay with trace gravel was encountered in 28 of the 40 sediment core locations (70 percent) in the Menomonee River at depths ranging from 0.5 (R5-17) to 26.7 (R3-03) feet below sediment surface (bss) (elevations ranging between 545.2 feet at R4-09 and 557.1 feet at R5-18).

2.1.1.4 Physical Parameters

A subset of sediment samples collected in the Menomonee River was submitted for grain-size analysis (sieve and hydrometer). In addition, all samples submitted for chemical analysis were also analyzed for total organic carbon (TOC) and percent moisture. The description of the sediment and the results of the physical analyses are presented in the site characterization report for the Menomonee River (CH2M 2016) and the site sampling technical memorandum (CH2M 2018).

Sediment cores upstream of 25th Street were composed of coarse-grained sand and gravel overlying silt in subsurface samples. The sediment transitions from sand and gravel overlying silt to predominantly silt downstream of the former West Side MGP facility. In general, the higher percentages of fines were found downstream of 25th Street with the sediments in the navigational channel of Reaches 4 and 5 containing about 46 and 68 percent fines, respectively.

Evaluation of the TOC and percent moisture results found that the surface and subsurface sediment in the Menomonee River were relatively similar. Average TOC concentrations ranged from 43,491 milligrams per kilogram (mg/kg) in the surface sediment (0- to 0.5-foot bss) samples to 53,495 mg/kg in the subsurface (greater than 0.5-foot bss) sediment and percent moisture ranged from 49.6 in the surface to 37.8 in the subsurface sediment.

2.1.2 Milwaukee River (OU2)

OU2 includes the 0.6 river mile reach of the Milwaukee River from the Menomonee River to the confluence with the Kinnickinnic River at the Inner Harbor. Remedial investigation activities in the Milwaukee River (OU2) were completed by We Energies in May 2017 with additional information collected by GLNPO in November 2017.

2.1.2.1 Shoreline Characteristics

A shoreline assessment of OU2 was conducted in 2016 by We Energies. Findings are detailed in the remedial investigation technical memorandum (Foth 2017) and presented in Figure 2. The shoreline within the OU2 area is mostly constructed of anchored steel sheet pile wall. The steel sheet pile bulkhead is composed of 4,260 feet, or 63 percent, of the total 6,740 feet of OU2 shoreline. Much of the steel sheet pile bulkheads are in good to excellent condition. There are a few sections of reinforced concrete bulkheads in fair to poor condition. Portions of stone revetment and unstabilized sections are also present on the west shoreline. One section of shoreline at 236 Water Street One (234 S Water Street) consists of 123 feet of unstabilized shoreline that is heavily vegetated and exhibits some failed areas.

Much of the shoreline within the OU2 project area has features that extend waterward of the bulkhead and will need to be considered as part of a future remediation of sediments near the bulkhead. These features include floating docks, finger piers, dock piles, and walkway deck piles. Of the 6,740 feet of the OU2 shoreline, obstructive features represent 77 percent of the shoreline or about 5,700 feet. The following are a few notable features:

- **234 S Water Street:** A portion of this shoreline has miscellaneous timber piles, trees, and other debris present below the waterline.
- **Rotational Train Bridge Abutments (West and East Shorelines):** These two train bridge abutments include pile-support concrete piers at their ends. The west shoreline abutment extends about 40 feet from the river's edge; the east shoreline abutment extends about 100 feet from the river's edge.
- **Milwaukee Institute of Art (273 E. Erie Street):** This property has sizable deck and walkway area over water that is pile-supported and extends up to 30 feet waterward from the bulkhead in areas. Piles are laterally reinforced with cabling underneath the deck (just above the waterline), which may present access issues for sediment remediation.

2.1.2.2 Hydraulic Characteristics

The federally authorized navigational channel in OU2 extends from the confluence with the Menomonee River to the confluence with the Kinnickinnic River at the Inner Harbor. The navigation channel downstream of the railroad swing bridge has an authorized project depth of 27 feet LWD. North of the swing bridge to East Buffalo Street, the authorized project depth is 21 feet LWD. The USACE maintained channel width within OU2 is between 100 and 150 feet. This maintained channel width has resulted in thick accumulations of sediment between the navigation channel and bulkhead walls. The navigational channel between North Young Street and the inner harbor area was dredged in 1993, with the lower section dredged again in 2007 and the very southern end last dredged in 2015 (USACE 2018). Extents for the recent USACE dredging events are shown in the figures within Appendix A.

Approximately 15 percent of the lower Milwaukee River shoreline is lined with concrete or sheet pile or has been significantly modified (CDM 2016). These modifications have resulted in similar flash-flow patterns as reported for the Menomonee River.

Stream gauge #04087170 is located at Jones Island just downstream of OU2 with discharge data available from 1994. The river hydrology within the study area is a complex system influenced by a combination of lake level and river flow. The Milwaukee River discharges approximately 75 percent of the median discharge at Jones Island (SEWRPC 2013). Similar to the Menomonee River, the highest discharge rate observed in the Milwaukee River is typically after the snowmelt (March and April) and spring (May and June), and the lowest discharge rates are observed during the late summer and fall (July to October).

Exhibit 2. Milwaukee River Discharge Statistics Based on data from USGS Gauge #04087170 at the Mouth of Milwaukee Harbor
Menomonee and Milwaukee Rivers Focused Feasibility Study

Flow Rate (cfs)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	482	537	1,396	1,729	963	954	511	421	304	381	417	570
Std Dev	325	325	663	924	349	1,002	510	309	101	119	194	358
Median	394	528	1,443	1,629	942	786	351	304	300	351	423	470
Max	1,374	1,042	2,442	3,842	1,686	4,137	2,167	1,414	493	578	798	1,561
Min	140	149	370	478	357	185	148	186	119	177	195	215

[a] Average flow rates based on monthly flow rates recorded during April 1994 – October 1995, October 2001 – August 2003 and May 2006 - August 2016

The Milwaukee River is characterized by a riverbed steeply sloping towards the center of the navigational channel. Based on field data collected in 2017, water depths in the Milwaukee River are generally deeper, with an average depth of about 23 feet, and range from an average depth of about 18 feet outside of the navigational channel to about 28 feet within the navigational channel.

2.1.2.3 Bathymetry

The bathymetric surveys of the navigational channel within the Milwaukee River from the 1996, 2002, 2011, 2015, and 2017 surveys were compared to evaluate sediment deposition and scour within the Milwaukee River (Appendix A). Based on the bathymetric data, a large portion (between 39 and 60 percent) of the Milwaukee River would be considered depositional as indicated by higher surface elevations measured in subsequent years. Between 5 and 30 percent of the area within the Milwaukee River was identified as scour areas and between 29 and 42 percent of the area was relatively unchanged. The comparison of the 2015 and 2017 bathymetric data shows a differential of less than 1 foot over 42 percent of the Milwaukee River. Scour areas identified through the 21-year period appear to be mainly in the vicinity of the eastern shoreline downstream of North Young Street. The estimated depositional rates have been relatively consistent over the 21-year period ranging from a high of 0.21 foot per year between 2011 and 2015 to a low of 0.07 foot per year between 1996 and 2002, with an average rate between 1996 and 2017 of 0.13 foot per year. Over the 21-year period, an estimated 67,903 cubic yards of material have been deposited within OU2, which is about 35 percent less than was estimated for the Menomonee River.

In 2017, sediment cores were collected within OU2 to delineate the extent of NAPL and to provide additional subsurface information. The OU2 sediment thickness ranged from 0 feet (native clay was encountered at the surface at locations OU2-SD-A2-01 and OU2-SD-A3-02) in the center of the navigation channel to 23.1 feet (OU2-SED-15) along the bulkhead wall at the downstream end of OU2. The dredging of the navigational channel and lower deposition rates in OU2 result in an overall lower thickness of sediment in the navigational channel (average of about 4 feet) compared to outside of the navigation channel (average of about 11 feet). Based on the 2017 bathymetric data, there are approximately 59,700 cubic yards of sediment within the navigation channel above the authorized dredge elevation.

Native clay was encountered at 50 of the 72 core locations (69 percent) in the Milwaukee River. The depth to the top of the native clay ranged from the surface to about 23 feet below the top of sediment (between 17.2 and 35.8 feet LWD).

2.1.2.4 Physical Parameters

A subset of sediment samples collected in OU2 was submitted for grain-size analysis (sieve and hydrometer). Samples submitted for chemical analysis were also analyzed for TOC and percent moisture. The description of the sediment and the results of the physical analyses are presented in the remedial investigation technical memorandum (Foth 2017) and the site sampling technical memorandum (CH2M 2018).

Sediment cores in OU2 were composed of fine sands and silt overlying lean clay. Less soft sediment was observed in the upstream section of OU2 and was composed of sands and some gravel. In general, higher percentages of silts and organics were observed in the further downstream sediment cores within OU2.

Evaluation of the TOC results found that the surface (0 to 0.5 foot) and subsurface sediment in the Milwaukee River were relatively similar. Average TOC concentrations ranged from 36,862 mg/kg in the surface sediment samples to 45,920 mg/kg in the subsurface sediment.

2.2 Nature and Extent of Contamination

The site contaminants of concern (COCs) include select metals, total PCBs, total PAHs and NAPL. The select metals evaluated include arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver. Total PAHs represent the data for 18 congeners (2-methylnapthalene, acenaphthylene, acenaphthene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene). The total PAH concentration was calculated by summing the detected results and one-half of the quantitation limit for nondetected results. Total PCBs represent the data for Aroclors 1016 through 1260 with the summation of detected and nondetected results completed the same as the total PAHs.

COC data were evaluated against both the probable effect concentration (PEC) and three times the PEC as provided in *Consensus-Based Sediment Quality Guidelines* (WDNR 2003). Screening against three times the PEC (3x PEC) allowed heavily contaminated areas that substantially exceed screening values to be identified. In addition, screening using 3x PEC allowed areas with contamination above urban background levels to be distinguished. For example, OU1 background concentrations of COCs are greater than the PEC for total PAHs, see Section 2.3.2 for further discussion (Foth 2018a).

Table 2 contains screening criteria, screening results, and summary statistics of analytical results. Figures 3a to 3d present results for select metals, total PCB Aroclors, and total PAH concentrations screened against the PEC values and identifies areas of NAPL. The analytical results are also shown in reference to the respective USACE dredge depths of 21 and 27 feet LWD.

2.2.1 Menomonee River (OU1)

The results of the sediment investigation conducted in 2015 and 2017 by GLNPO provide a preliminary assessment of contamination in OU1. The major findings were as follows.

- This investigation detected relatively low PCB concentrations in OU1, with no surface or near-surface (less than 1.7 feet bss) samples exceeding the PEC value.
- Surface and near-surface concentrations for PAHs and metals (mainly lead) exceeding three times their respective PEC values were detected at eight locations in OU1 (SD-R4-10, SED103, SD-R5-01, SD-R5-04, SD-R5-05, SD-R5-12, SD-R5-13, and SD-R5-14) (Figures 3a and 3b, Table 2).
- Comparison of the exceedance frequency of the PEC values presented for the surface and subsurface samples in Table 2 illustrate that the sediments above respective PEC criteria are primarily located within subsurface sediments (that is, greater than 1.7 feet bss). The exceedance frequencies are notably higher in subsurface sediments for most parameters.
- Locations within the navigational channel exhibit fewer PEC exceedances above the USACE dredge elevation of 21 feet LWD; nearshore locations and the edge of the navigation channel have more frequent PEC exceedances above the respective USACE dredge elevation. This contaminant distribution is likely due to previous navigational dredge activities performed by USACE, which would have removed contaminated sediments from the area above the dredge elevation within the navigation channel, and sediment nearer the shoreline (outside of the navigation channel) would have been left in place. Sloughing of sediments near the shoreline towards the navigation channel has also likely occurred during subsequent dredging events, and deposition of generally cleaner upstream sediments also may be contributing to the distribution observed.
- Generally, both the number of COCs and the concentration of each COC increases with depth until native clay is encountered.

2.2.2 Milwaukee River (OU2)

The results of the sediment investigations conducted in 2017 by We Energies and GLNPO provide a preliminary assessment of contamination in OU2. The major findings were as follows:

- Low concentrations of PCBs were detected at the upstream portion of OU2 (OU2-SED-01, OU2-SED-03, OU2-SED-05, OU2-SED-06, and OU2-SED-11) and at one location downstream of the railroad swing bridge (OU2-SED-15). The PCB concentrations did not exceed three times the PEC values in the surface or near surface (less than 1.7 feet bss), but higher PCB concentrations were detected in the subsurface samples.
- The frequency of surface and near-surface concentrations of PAHs and metals (mainly lead) exceeding three times their respective PEC values was low. Samples from two locations contained elevated PAH concentrations (OU2-SED-06 and OU2-SED-10) and the lead concentration in one surface/near-surface sample (OU2-SED-11) exceeded the three times PEC criteria.
- Comparison of the exceedance frequency of the PEC values presented for the surface and subsurface samples in Table 2 illustrate that the sediments above respective PEC criteria are primarily located within subsurface sediments (that is, greater than 1.7 feet bss). The exceedance frequencies are notably higher in subsurface sediments for most parameters. The majority of individual sample interval exceedances of total PAHs were associated with two observed NAPL areas (described below) at locations OU2-SED-05, OU2-NAPL-45, OU2-SED-10, OU2-NAPL-43, and OU2-NAPL-54. The depth of PAH contamination appears to be vertically bound, and the elevated PAH concentrations (greater than 3 times the PEC) did not extend to the bottom interval or into the native material.
- Locations within the navigational channel in OU2 exhibit fewer PEC exceedances above the USACE dredge elevation of 21 feet LWD; nearshore locations and the edge of the navigation channel have more frequent PEC exceedances above the respective USACE dredge elevation.

NAPL Delineation

We Energies conducted an investigation in 2017 to characterize and delineate the horizontal and vertical extent of the NAPL reported in previous investigations adjacent to the Former Third Ward MGP site. During the investigation, NAPL was observed in 23 of the 38 (61 percent) delineation cores. In addition to the NAPL delineation cores, sediment chemistry cores were collected at three locations within or adjacent to the identified NAPL area near the Former Third Ward MGP site and one location just south of the railroad swing bridge. Details of the investigation are provided in the remedial investigation technical memorandum (Foth 2017).

Additional core locations were sampled by GLNPO in November 2017 to further bound the extent of the NAPL adjacent to the Former Third Ward MGP site. During the GLNPO investigation, NAPL was observed at two locations (SD-A4-02 and SD-A4-02-A) located immediately adjacent to the NAPL area defined by the investigation performed in 2017 by We Energies (CH2M 2018).

Figures 3c and 3d show the extent of the NAPL and the analytical results of sediment samples. Between the Broadway Bascule Bridge at North Young Street and south to the railroad swing bridge at East Polk Street, the horizontal delineation of NAPL generally did not extend into the navigation channel, except for locations OU2-NAPL-18 and OU2-NAPL-50 (Figure 3d). South of the railroad swing bridge, a slight horizontal extension of NAPL into the navigation channel was observed at locations OU2-NAPL-65 and OU2-NAPL-78 (Figure 3d). NAPL was not found to extend to the south past location OU2-NAPL-65. Vertically, NAPL is observed generally in the silt or silty sand layer beneath the layer of organic silt. NAPL frequently extends to the native till layer or terminates just above this native till elevation. At several NAPL delineation locations between the Broadway Bascule Bridge and the railroad swing bridge, core refusal was observed prior to reaching the lake clay or till layer, with NAPL observed at the core bottom.

The investigation of observed NAPL was also conducted in the southwestern corner of the turning basin at the confluence of the Menomonee and Milwaukee Rivers (Figure 3c). The investigation found that the extent of observed NAPL was limited to two locations outside of the navigational channel (OU2-SED-05 and OU2-NAPL-30).

2.3 Assessment of Potential Ongoing Sources

The Menomonee and Milwaukee Rivers have experienced extensive urban and industrial impacts over the past century or more. Many diverse point sources and industrial and municipal non-point sources throughout the history of the watershed contributed to environmental degradation. The Menomonee and Milwaukee Rivers have benefited from extensive source control and environmental initiatives by federal, state, regional, and local municipal governmental agencies and sewer authorities, as well as actions taken by landowners and industrial entities. Industrial parcels adjacent to the project area have been the focus of a series of remediation measures under federal and state cleanup programs. Improvement initiatives and projects under the GLLA to address contaminated sediments can further restore the quality of the rivers. The sediment recontamination potential of the project area was examined to assess whether the potential improvements would be sustainable. The conclusion of the examination was that with increased municipal, state, and federal regulation and improvement projects in the regions, recontamination is unlikely to substantially diminish benefits for further cleanup of sediments in the project area.

2.3.1 Sources

A limited online literature search was conducted for relevant local studies that could provide quantitative or semiquantitative data on contaminant inputs to and outputs from the Menomonee and Milwaukee River system. The assessment of recontamination potential considered upstream sites and sources such as Superfund sites, CSOs, wastewater treatment plant (WWTP) outfalls; and regional sources such as storm sewers, local watershed tributaries, spills, and unpermitted discharges. Local sources were also considered, such as CSO outfalls and permitted discharges within the project area and source areas along shorelines of the project area.

The potential sources of contaminants to the Menomonee and Milwaukee Rivers can be grouped into three major categories:

- **Point sources** where contaminants are discharged to surface water at discrete locations. These sources include industrial and municipal discharges, wastewater and storm sewer outfalls, and combined sewer overflows.
- **Non-point sources** that consist of various discharges of pollutants that are washed off the rural and urban land surface and transported by runoff into the surface waters.
- **Upstream sites and sources** from which pollutants may be carried into the project area by surface water.

These categories contribute to urban background conditions.

2.3.1.1 Point Sources

Point sources of pollution have discrete discharges, usually from a pipe or outfall. The primary point sources of contaminants to the Menomonee and Milwaukee Rivers can be grouped into three general categories: (1) historical industrial facilities, (2) current industrial facilities, and (3) wastewater and storm sewer outfalls and combined sewer overflows that contribute to surface and near surface sediment conditions.

A review of remediation sites on WDNR's Remediation and Redevelopment Sites map (https://dnr.wi.gov/topic/Brownfields/rrsm.html) adjacent to the Menomonee and Milwaukee Rivers identified the presence of multiple historic and current potential sources of metals (e.g., lead and arsenic) and petroleum (e.g., gasoline, diesel, and fuel oil) contamination (Figures 4 and 5, respectively). Figure 2 also shows the locations of numerous CSOs along the river reaches.

Both shorelines of the Menomonee and Milwaukee Rivers have historically been developed to support industrial and commercial uses, including the former We Energies' West Side MGP Facility and the Third Ward MGP sites. Review of historical records also identified tanneries, scrap metal recycling facilities, a coal-generated power plant, and landfill/disposal sites that may have had permitted or non-permitted discharges to the rivers. Many of the facilities that once operated with discharges to the river have either ceased operations or have been demolished. Few of the facilities remain and much of the land around the urban reaches of both rivers has been redeveloped for commercial, residential and recreational use (public walkways, piers, parks, and boat-launching facilities). However, the historical discharges resulted in sediments being contaminated with various pollutants, including metals, PCBs, and PAHs. Areas with remaining contamination are also potential sources of contaminant loads until such time as those sites are addressed.

At locations where continuing operations are present, modernized operations and monitoring and control of outfall water quality mitigates the contaminant load. Industrial direct discharges to surface waters are regulated through WDNR's Wisconsin Pollutant Discharge Elimination System (WPDES) permits. Table 3 shows the permitted discharges from construction, industrial, and municipal facilities. One municipal and two industrial WPDES permits are active within the project area (Table 3). MMSD holds the municipal WPDES permit for combined sewer discharge within the Menomonee and Milwaukee Rivers. Miller Coors USA LLC, and Wisconsin Electric Power Company Valley Power Plant hold industrial WPDES permits to discharge to the river system.

Sanitary sewage overflows (from a variety of municipalities) and combined sewage overflows (from within the MMSD footprint) have degraded water quality in the AOC, especially following heavy rains. The sewer overflows, entering the river at CSOs, contain both conventional and toxic pollutants from stormwater runoff, residential, commercial, and industrial users of the system. The number and volume of sanitary sewage and CSOs that negatively impact the water quality in the estuary has decreased significantly with the completion of the "deep tunnel" project in 1994 (Short Elliot Hendrickson Inc. and Environmental Consulting & Technology, Inc. 2008). Since 1994, MMSD has captured and treated more than 98 percent of the stormwater and wastewater that has entered the regional sewer system. The MMSD website reports that during 1994 through 2017, the Jones Island and South Shore plants treated between 60.1 to 81.1 billion gallons (averaging about 72.6 billion gallons) per year. Over that same period, the annual overflow of untreated wastewater released through the CSOs to area waterways during heavy rain storms ranged between 1,500 gallons and 4.4 billion gallons (averaging 1.102 billion gallons) (MMSD 2019).

Major reductions in point source activity have been accomplished with the advent of the Clean Water Act and the subsequent regulation and permitting of all outfalls. Further source-control actions are continuing under the WPDES permitting program. Recontamination potential from upstream industrial sources and outfalls is low, especially relative to historical sources and in comparison, to existing levels of sediment contamination.

2.3.1.2 Non-Point Sources

Regional watershed sources of potential recontamination include: runoff from construction sites, paved or other impermeable surfaces, and bulk storage piles; erosion of bank soils; spills; leaking underground storage tanks; and atmospheric deposition of airborne contaminants. A 2007 study with data from SEWRPC reported that after the construction of the deep tunnel system, non-point pollution had now become the major, remaining source of pollution, causing about 90 percent of the region's problems. These are mostly "pollutants washed off the landscape in storms," including "bacteria from birds and animals, dirt and salt from streets and parking lots, vehicle fluids, fertilizers and pesticides" (SEWRPC 2013).

A water quality study of MMSD was performed by the USGS. PAHs were frequently detected, along with several other contaminants, in surface water in this segment of the river (USGS 2007). PAHs were noted to have had a higher detection frequency in water samples with high stream flow (i.e., stormwater runoff) events than during low-flow events. Several studies have reported notable contributions of PAHs to stream sediment in urban areas due to non-point source contributions (e.g., Baldwin et al. 2016; Mahler et al. 2005; Van Metre et al. 2000).

Adjacent land areas are currently occupied by buildings, parking areas, and other paved areas typical of an urban environment. During precipitation events, the majority of stormwater is conveyed into the combined sewer system with a limited amount flowing over land and entering surface water as a non-point source. Releases to the environment associated with urban runoff related to infrastructure and motor vehicle use may include PCBs, PAHs, and metals to the watershed and sediments. A recent study concluded that the primary source of PAHs to sediment in the Milwaukee area are worn particles of coal-tar-based pavement sealants that are transported by stormwater runoff from parking lots (Baldwin et al. 2016).

The 1994 RAP reported that scrap iron storage facilities contributed about 80 percent of the mercury loads and are a source of arsenic, lead, and phenols. Salt storage areas were also reported to be a source of chromium loading. Requirements for covering salt piles during storage have reduced loadings to surface water (WDNR 1994).

Bank and soil erosion sources adjacent to the Menomonee and Milwaukee Rivers and associated canals are minimal due to the armored nature of the shoreline (sheet pile, concrete bulkhead, or riprap present along nearly the entire project area shoreline), and soil cover and maintenance of green space over many historical industrial parcels. Several public parks and shoreline access points have been established in formerly industrial properties. Redevelopment of the areas would be under applicable stormwater and erosion control requirements. In addition, shoreline restoration projects that involve erosion control and other improvements are continually being implemented throughout the AOC.

The potential for unpermitted discharges or spills always exists in urban waterways, especially those that are also transportation hubs like the Milwaukee River and those that are receiving waters for watersheds where significant waste hauling and management activities occur. While the spills represent a potential for recontamination, response and cleanup actions to address them are typically conducted under existing enforcement programs.

Table 4 presents WDNR Bureau for Remediation and Redevelopment Tracking System (BRRTS) sites classified as open and closed leaking underground storage tank (LUST) and environmental remediation project (ERP) sites adjacent to the Milwaukee and Menomonee Rivers. The discharge of contaminated groundwater from landfills, leaking LUST, and ERP sites, and hazardous material spills can represent an additional potential non-point source mechanism to the surface water. Requirements for remedial actions and monitoring to address the LUST and ERP sites are under existing WDNR programs.

The recontamination potential for each of the non-point sources is low, and further reductions are subject to natural processes and continued actions to comply with water and air quality regulations related to releases and emission sources.

2.3.1.3 Upstream Sites and Sources

The Milwaukee Estuary is the recipient of pollution from many sources upstream of the AOC. Agricultural pollutants from the rural areas, contaminated sediments being washed downstream, and point and non-point pollution from upstream urban areas have historically contributed significantly to the pollution found in the AOC. Multiple remedial actions have been performed or are currently being conducted by WDNR and EPA GLNPO or other parties in upstream reaches. The status of the various projects is summarized in the draft *Remedial Action Plan Update for the Milwaukee Estuary AOC* (WDNR 2017). The major sources of upstream contamination included the following sites:

Menomonee River

- **Moss American Superfund Site.** This site comprises 88-acres, including a former wood-preserving facility and 6 miles of the Little Menomonee River. The operations used creosote and a fuel-oil mixture that resulted in soil, sediment, and groundwater being contaminated with PAHs and other petroleum-related compounds. Remediation of the site included removal and treatment or offsite disposal of contaminated soil and in situ treatment of groundwater. Cleanup of the sediments in the Little Menomonee River was completed in December 2009 and involved dredging contaminated sediment and rerouting portions of the river.
- **Burnham Canal Superfund Alternative Site.** The Burnham Canal Superfund Alternative Site is within the Burnham Canal, which enters the South Menomonee Canal that flows into the Menomonee River. The canal's federally authorized navigation channel east of the 11th Street Bridge has been recently decommissioned and has not been dredged since the fall of 1987. From the early 1970s through mid-1980s, Miller Compressing Company operated a wire reclamation furnace at the site, as well as a non-ferrous recycling facility. The operations were determined to be the likely source of metals (cadmium, copper, lead, nickel, silver, and zinc) and PAH concentrations detected in canal sediments and upland soils. The design of a 9-acre artificial wetland within the Burnham Canal is currently ongoing and is anticipated to be implemented in 2019 (WDNR 2017).

Milwaukee River

- **Cedar Creek Superfund Alternative Site.** Cedar Creek is at the upstream end of the Milwaukee Estuary AOC and is a tributary to the Milwaukee River. In 2016 and 2017, approximately 73,000 cubic yards of PCB-contaminated sediment were removed from the Ruck Pond raceway and impoundment areas (Columbia Pond and Wire and Nail Pond) and disposed offsite. Additionally, about 6,000 cubic yards of PCB-contaminated soil from adjacent floodplains was removed. Mercury Marine is currently working on the evaluation of alternatives for the PCB-contaminated sediment and wetland soils downstream of the Wire and Nail Pond to the confluence with the Milwaukee River (WDNR 2017).
- **Lincoln Park and Milwaukee River Channels Phase 1 and 2 Sediment Sites.** Lincoln Creek was a significant source of sediment, heavy metal, and PCB contamination to the AOC. The creek is a tributary to the Milwaukee River draining about 19 square miles of communities of Milwaukee, Glendale, and Brown Deer. In the 1994 RAP, the Lincoln Creek subwatershed was estimated to contribute 40 percent of the urban pollutants and 56 percent (6,500 tons) of sediment entering the Milwaukee River South watershed (WDNR 1994).

  The Lincoln Park/Milwaukee River Sediment Site located upstream of Estabrook Dam was identified as a source of PCB-contaminated sediments to the Milwaukee River that contained sediments transported from Lincoln Creek and the upper reaches of Milwaukee River. A mass balance study conducted in 1997 (Baird & Associates 1997) identified the site as the biggest contributor of PCB loading to the Milwaukee River and Harbor, accounting for up to 70 percent of the total mass loading. The Lincoln Park/Milwaukee River Sediment site was remediated under EPA's Great Lakes Restoration Initiative in a multi-year, multi-phase sediment cleanup effort that was completed in 2015. The remedial action level of 1 mg/kg of total PCBs in sediment was the target for the remediation. Remediation consisted of removing/dredging PCB-and PAH-contaminated soil and sediment.

  During the Phase 1 Lincoln Park/Milwaukee River Site within the eastern oxbow, a significant volume of NAPL-impacted sediments was discovered during excavation activities. As a result, a remedial action level of 20 mg/kg total PAH surface weighted average or 40 mg/kg total PAH maximum concentration was established by EPA and WDNR.

- **Milwaukee River Downstream Sediment Site.** Investigations of floodplain soil and sediment downstream of Estabrook Dam to the confluence of the Menomonee River were conducted by GLNPO in 2016. Results indicate that the sediments in reaches closer to Estabrook Dam (Reaches 1 and 2) were not highly impacted. In Reach 4, between the former North Avenue dam and the confluence with the Menomonee River, the sediment samples exhibited significantly higher, three times PEC and PEC exceedance frequencies for PCBs, PAHs, and metals. Comparison of exceedance frequency for surface and subsurface samples indicates that the highly impacted sediments are primarily located within the subsurface sediments (CH2M 2017).

  An additional investigation was conducted by GLNPO in July 2018 to further delineate the extent of contamination in the Reach 4 sediments. Sediment cores were collected from a total of 58 locations and samples analyzed for PCBs, TOC, PAH-18, and select metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc; CH2M 2018). Initial review of the data indicates that elevated concentrations (exceeding the three times the PEC) of PCBs, PAHs, and metals (mainly chromium, lead, and mercury) are more frequently detected in the subsurface sediment samples. Preliminary PCB concentrations in 18 samples from 15 locations were above the Toxic Substances Control Act regulatory threshold of 50 mg/kg.

Within the project area, comparison of surface sediment and subsurface sediment concentrations of contaminants reflect the reductions of source activity from historical periods. More prevalent contaminant concentrations found at depth rather than at the surface indicate that historical source activity is the main contributor to sediment contamination. The distribution of the contaminants of concern (COCs), especially PCBs and chromium, also indicates that minimal sediment from upstream portions of the Milwaukee and Menomonee Rivers is being transported to OU2.

2.3.2 Recontamination Potential

The surface and near-surface (to a depth of 1.7 feet) sediment data were used to examine the potential for recontamination from current urban sources and the sediment bed load itself. The higher concentrations of COCs in buried sediment (Table 2) compared with the surface sediment reflects a reduction in source impacts under current conditions, historic navigation dredging, and the depositional nature of the estuary. Hence, surficial “background” conditions are one line of evidence to represent the levels of COCs that are currently being released to the system from ongoing sources and could be resuspended and become a recontamination source within the project area and downstream areas.

Several statistical metrics were calculated from the surface and near surface datasets by COC, river reach, and operational unit, as shown in Table 5 (Foth 2018a), to assist with the background and recontamination assessment. Most notably, the average and upper 95 percent upper confidence limits (UCLs) indicate that:

- Compared to other reaches, concentrations are generally the highest for lead and PAHs in the Menomonee River Reach 5 and higher for chromium, lead and PCBs in the Milwaukee River Downstream Sediment Site Reach 4. The contaminated sediment in these upstream reaches are recontamination sources to OU2, if these sediments are resuspended and transported downstream (Foth 2018a).
- The lower concentrations of chromium, lead, PCBs, and PAHs in OU2 than upstream reaches (Milwaukee River Downstream Sediment Site Reach 4 and Menomonee River Reach 5), along with known navigation dredging in OU2, suggests that the transport from upstream reaches is currently not causing widespread contamination above the PEC.

- PAHs are elevated throughout the Menomonee River; the average and UCL metrics both exceed the PEC in Reaches 3, 4, 5 and OU1 overall.
- PAHs are not as elevated in Milwaukee River Downstream Sediment Site Reach 4 and OU2, with the average concentrations being less than the PEC. The UCL is about the PEC at 23 ppm.

2.3.3 Release Mechanisms and Migration Pathways

Except for unpermitted discharge to surface water, current industrial sources share the same release mechanisms. Road/overland runoff may enter the environment via direct release to surface water. Combined sewer overflow may be released to the environment during bypass events.

Migration pathways through the environment vary across release mechanisms. Direct releases to land may be conveyed via overland runoff to the floodplain soils or waterways (i.e., the Menomonee or Milwaukee Rivers). Permitted and historical unpermitted discharges to surface water release solid and dissolved contaminants directly to surface water. The contaminated solid particles in discharges to the surface water or resuspended from the streambed can be transported downstream and redeposited on the streambed or on floodplains. Impacted streambed sediment may also release dissolved-phase chemicals into the surface water that is then transported within the project area or from one river to another (e.g., from Burnham Canal to the Menomonee River).

Contaminants may be transported from upstream sites and sources to the project area via surface water. The upstream portion of the Menomonee River and South Menomonee and Burnham Canals were identified as potential sources of contaminated sediment to OU1, and the Milwaukee River Downstream site (Reach 4) is an upstream source to OU2 (see Figure 1). In addition, sediments downstream of OU2 may also contribute contaminants to OU2 during seiche events.

2.3.4 Receptors

Seven of the 11 BUIs in the Milwaukee Estuary AOC are related to contaminated sediment. Because the sediment is a primary pollution concern, the main receptors include benthic invertebrates and higher trophic-level organisms, including fish, some wildlife, and humans.

Benthic invertebrates live in direct contact with sediment and surface water and the contaminants present in these environmental media. Impacted sediments are ingested by the bottom-dwelling organisms that form the base of the aquatic food web.

Fish serve as prey to piscivorous birds, wildlife, and humans. Fish are exposed to contaminants in surface water via gill exchange and diet. Fish are also exposed to chemicals in sediment via incidental ingestion and diet.

Piscivorous birds and mammals are primarily exposed to bioaccumulative chemicals, such as mercury and PCBs in surface water and sediment via diet, in that they consume prey—invertebrates and fish—that are in direct contact with such chemicals.

Humans are also receptors of the contaminants through the consumption of fish exposed. This is the primary exposure mechanism from sediment to humans.

Figure 6 shows a graphical summary of the CSM identifying the general sources, transport mechanisms, and receptors.

2.4 Conceptual Site Model Summary

The CSM presents the understanding of the site setting, nature and extent of contamination and the potential ongoing sources gained from past investigations and surveys. This section summarizes the findings of the CSM to be considered in the development of the alternatives.

2.4.1 Menomonee River (OU1)

OU1 includes approximately 1.9 river miles of the Menomonee River from the West Canal Street Bridge to the confluence with the Milwaukee River. The OU1 portion of the Menomonee River was divided into three segments:

Reach 3

The CSM for the Reach 3 segment is summarized as follows:

- Segment begins at the West Canal Street Bridge and extends downstream approximately 0.4 mile to 25th Street.
- The northern shoreline consists primarily of steel sheet pile wall that is in good to excellent condition and riprap. Approximately 200 feet of the northern shoreline is composed of a drystack wall that is in disrepair or has failed and has been identified as a section of concern (Diedrich Acquisitions, LLC at 2115 W Greves Street). The southern shoreline is natural shoreline with fairly steep banks and heavy vegetation. Five storm sewer outfalls, three industrial outfalls and three CSOs were also observed in Reach 3.
- Water depths in Reach 3 during the investigations were generally shallow (between 2 and 7 feet).
- Reach 3 is not within the authorized navigational channel and has not been historically dredged. During the investigations, this section had an average sediment thickness of about 16 feet, ranging from 5 feet, in the center of the river, to 34 feet at location R3-06 on the southern shoreline. Minimal sediment was observed along the north shoreline adjacent to locations R3-02 and R3-04. Sediment sampling within the channel upstream of location R3-01 was not performed because of the limited sediment observed during site reconnaissance.
- Sediment cores upstream of 25th Street were composed of coarse-grained sand and gravel overlying silt in subsurface samples
- Total PAH concentrations exceeding their respective PEC values were detected in surface and near-surface samples from three (R3-01, R3-03, and R3-04) of the six locations sampled. The frequency of detecting concentrations exceeding their respective PECs is notably higher in subsurface sediments for most parameters.

Reach 4

- Reach 4 begins at the 25th Street and extends about 0.6 mile to the 16th Street Bridge and includes the former West Side MGP facility located immediately downstream of 25th Street.
- The northern shoreline consists of steel sheet pile wall and riprap in excellent or good condition and two sections of reinforced concrete in marginal or poor condition. Two notable features were identified in Reach 4, including a section with a critical structure close to the shoreline (Guiffre VIII, LLC at 2215 W Mt. Vernon Avenue) and about 175 feet of reinforced concrete in poor condition. The southern shoreline is composed of steel sheet pile walls in excellent condition. One sewer outfall and two CSOs were also observed in Reach 4.
- Water depths during the investigations ranged from 8 feet near the shoreline to about 17 feet within the navigational channel with depths generally increasing downstream.
- The stretch from the 25th Street Bridge to about 300 feet downstream of the 16th Street Bridge was last dredged in 1993 to USACE's authorized project depth of 21 feet LWD (elevation 557 North American Vertical Datum of 1988 [NAVD88]). The "America's Water Infrastructure Act of 2018" included deauthorization of the segment of the navigational channel extending upstream of the 16th Street Bridge.

- The distribution of sediment within the navigation channel in Reach 4 is greatly influenced by the dredging of the navigational channel and sediment load from upstream. The depositional nature is further supported by the core data that found that the sediment surface elevations at the 15 core locations were between 6.5 to 15.4 feet above USACE's authorized project depth of 21 feet LWD (elevation 557 NAVD88). The sediment thickness both in and adjacent to the navigational channel generally decreases downstream from greater than 24 feet at MR-SD-R4-01 to about 10 feet at MR-SD-R4-15, with an average sediment thickness of 12.5 feet. Based on the 2017 bathymetric surface, there are approximately 151,900 cubic yards of sediment within the navigational channel above the authorized project depth of 21 feet LWD, assuming allowances for 2:1 side slopes and 1 foot of overdredge. Approximately 40,030 cubic yards are outside of the navigational channel.
- Sediment downstream of 25th Street transitions from sand and gravel overlying silt to predominantly silt downstream of the former West Side MGP facility. In general, the higher percentages of fines were found downstream of 25th Street. Based on the grain size analysis, about 54 percent of the sediment within the navigational channel consists of coarser-grained sands or gravels.
- Total PAH concentrations exceeding their respective PEC values were detected in surface and near-surface samples from eight (R4-02, R6-03, R4-08, R4-10, R4-11, R4-12, R4-13, and SED103) and exceeded the three times the PEC at two locations (R4-10 and SED103) of the 22 locations sampled. The frequency of detecting total PAH and metals concentrations exceeding their respective PECs and three times the PECs is notably higher in subsurface sediments (that is, greater than 1.7 feet bss).
- Concentrations of the native clay, except in one sample, did not exceed their respective PEC values. The total PAH concentration in MR-SD-R4-04 contained 24.3 mg/kg in the native clay sample (22.0 to 23.0 ft bss), slightly exceeding the PEC of 22.8 mg/kg.

Reach 5

- Reach 5 begins at the 16th Street Bridge and extends about 1 mile downstream to the confluence with the Milwaukee River near downtown Milwaukee.
- The northern shoreline consists primarily of steel sheet pile walls, which are in excellent or good condition. There are a few sections of reinforced concrete bulkheads ranging from fair to poor condition. Portions of timber wall and natural shoreline are also present on the north shoreline. Four sections of concern were identified along the northern shoreline and include about 180 feet of reinforced concrete in poor condition owned by the City of Milwaukee (1313 W Mt. Vernon Avenue) and three sections of timber wall in poor to very poor condition owned by the City of Milwaukee Redevelopment Authority (825 W Hinman Street), the Soo Line Railroad Company (210 N Plankinton Avenue), and Sidney Harry Hack Julius (324 N Plankinton Avenue) at the confluence with the Milwaukee River.
- The southern shoreline consists mostly of steel sheet pile walls, which are in excellent or good condition, a few sections of reinforced concrete bulkheads ranging from good to fair condition, and one section of composite sheet pile and concrete in good condition. Three sections of concern were identified along the southern shoreline, including a stone block building immediately adjacent to the river (Turnbridge, LLC at 126 S 2nd Street), a torn section of sheet pile wall (St. Mary's Cement Inc. at 712 W Canal Street), and the Wisconsin Electric Power Company (1056 W Canal Street) cooling-water intakes that extend into the river.
- Three storm sewer outfalls and five CSOs were also observed in Reach 5.
- The water depths during the investigations ranged from 14 feet near the shoreline to about 27 feet within the navigational channel, with depths generally increasing downstream.

- The federally authorized navigational channel in the Menomonee River extends downstream from the 16th Street Bridge to the confluence with the Milwaukee River near downtown Milwaukee. The portions of the Menomonee River about 300 feet downstream of the 16th Street Bridge and about a 785-foot stretch from the confluence with the South Menomonee Canal to the South 2nd Street (N Plankinton Avenue) were last dredged in 1993 to USACE's authorized project depth of 21 feet LWD.
- Similar to Reach 4, the distribution of sediment within the navigation channel in Reach 5 is greatly influenced by the dredging of the navigational channel. Although still depositional with most of locations (14 of 19 locations) above USACE's project elevation, the sediment is not as thick as in Reach 4. The sediment thickness generally decreases from upstream to downstream from greater than 17 feet at MR-R5-03 to 0.5 feet at MR-SD-R5-17, with an average sediment thickness of approximately 8 feet. Based on the 2017 bathymetric surface, there are approximately 75,600 cubic yards of sediment within the navigational channel above the authorized dredge elevation of 21 feet LWD. Approximately 51,200 cubic yards are outside of the navigational channel.
- In general, the higher percentages of fines were found downstream of 16th Street. Based on the grain size analysis, sediment within the navigational channel contains about 68 percent fines and 32 percent of coarser-grained sands or gravels.
- Total PAH concentrations exceeding their respective PEC values were detected in surface and near-surface samples from 15 locations (R5-01, R5-02, R5-03, R5-04, R5-5, R5-06, R5-07, R5-08, R5-09, R5-10, R5-12, R5-13, R5-14, R5-15, and R5-17) and exceeded the three times the PEC at three locations (R5-04, R5-05, R5-13, and R5-14) of the 19 locations sampled. Surface or near-surface samples from R5-01 (mercury) and R5-12 (chromium and lead) contained concentrations that exceeded their respective three times the PEC values. The frequencies of exceedances (mainly total PAHs and lead) are notably higher in subsurface sediments (that is, greater than 1.7 feet bss) and typically below the authorized navigational dredge depth. Concentrations of the native clay, except in two samples, did not exceed their respective PEC values. The total PAH concentrations in the native clay samples MR-SD-R5-02 (15.8 to 16.1 ft bss) and R5-14 (5.0 to 6.0 ft bss) of 59.2 and 24.9 mg/kg slightly exceeded the PEC of 22.8 mg/kg.

2.4.2 Milwaukee River (OU2)

- OU2 includes the 0.6 river mile of the Milwaukee River from the Menomonee River to the confluence with the Kinnickinnic River at the Inner Harbor.
- The shoreline within the OU2 area is mostly constructed of anchored steel sheet pile wall that are in good to excellent condition. There are a few sections of reinforced concrete bulkheads in fair to poor condition. Portions of stone revetment and unstabilized sections are also present on the west shoreline. One section of shoreline at 236 Water Street One (234 S Water Street) consists of 123 feet of unstabilized shoreline that is heavily vegetated and exhibits some failed areas. About 77 percent of the shoreline within the OU2 project area has features such as floating docks, finger piers, dock piles, and walkway deck piles that extend waterward of the bulkhead and will need to be considered as part of a future remediation of sediments near the bulkhead. These notable features include: a portion of this shoreline at 234 S Water Street that has miscellaneous timber piles, trees, and other debris within present below the waterline; the rotational train bridge abutments; and the Milwaukee Institute of Art and Design (273 E. Erie Street) that has a pile-supported deck and walkway area that extends up to 30 feet waterward from the bulkhead in areas.
- The federally authorized navigational channel extends from the confluence with the Menomonee River to the confluence with the Kinnickinnic River at the Inner Harbor. The navigation channel downstream of the railroad swing bridge has an authorized project depth of 27 feet LWD. North of the swing bridge to the East Buffalo Street Bridge, the authorized project depth is 21 feet LWD.

USACE maintained the channel width between 100 and 150 feet, resulting in thick accumulations of sediment between the navigation channel and bulkhead walls. The navigational channel between North Young Street and the inner harbor area was dredged in 1993, with the lower section dredged again in 2007 and the very southern end last dredged in 2015. USACE's maintenance to be completed in 2019 includes dredging of the harbor to the confluence with the Kinnickinnic River and does not include upstream sections of the Milwaukee River.

- Similar to OU1, the distribution of sediment within the navigation channel in OU2 is greatly influenced by the dredging of the navigational channel. Based the comparison of bathymetric data from the 1996, 2002, 2011, 2015, and 2017 surveys, a large portion (39 and 60 percent) of the Milwaukee River would be considered depositional, between 5 and 30 percent identified as scour areas, and 29 and 42 percent of the area was relatively unchanged. Scour areas identified during the 21-year period appear to be mainly near the eastern shoreline downstream of North Young Street. The estimated average depositional rates have been relatively consistent over the 21-year period ranging from a high of 0.21 foot per year between 2011 and 2015 to a low of 0.07 foot per year between 1996 and 2002, with an average rate between 1996 and 2017 of 0.13 foot per year.
- Low concentrations of PCBs were detected at the upstream portion of OU2 (OU2-SED-01, OU2-SED 03, OU2-SED-05, and OU2-SD-06) and at one location downstream of the railroad swing bridge (OU2-SED-15). The PCB concentrations did not exceed three times the PEC values in the surface or near surface (less than 1.7 feet bss), but higher PCB concentrations were detected in the subsurface samples. The frequency of surface and near-surface concentrations of PAHs and metals (mainly lead) exceeding three times their respective PEC values was low. Samples from two locations contained elevated PAH concentrations (OU2-SED-06 and OU2-SED-10), and the lead concentration in one surface/near-surface sample (OU2-SED-11) exceeded the three times PEC criteria.
- Comparison of the exceedance frequency of the PEC values between the surface and subsurface samples illustrate that the sediments above respective PEC criteria are primarily located within subsurface sediments (that is, greater than 1.7 feet bss) for most parameters. The majority of individual sample interval exceedances of total PAHs were associated with two observed NAPL areas at locations OU2-SED-05, OU2-NAPL-45, OU2-SED-10, OU2-NAPL-43, and OU2-NAPL-54. The depth of PAH contamination appears to be vertically bound, and the elevated PAH concentrations (greater than three times the PEC) did not extend into the native material. At locations OU-NAPL-43, OU2-NAPL-45 and OU2-NAPL-54 the elevated PAH concentrations did exceed at the bottom interval of each location.
- Chromium and total PCB concentrations in Milwaukee River Downstream Reach 4 (upstream of the confluence with the Menomonee River) are significantly higher than the other river reaches, indicating the potential for recontaminating OU2 if these sediments are resuspended and transported downstream. However, the average concentration levels of chromium and total PCBs detected in the surface and subsurface sediment in OU2 are relatively low, exceeding their respective PECs in only 14 and 17 percent of the samples, respectively. Subsurface sediment samples exceed the PEC for chromium and total PCBs in 61 and 25 percent of the samples analyzed, respectively. The low surface concentrations and high subsurface concentrations indicate that Milwaukee River Downstream Reach 4 is not currently a recontamination source to OU2 sediments.

SECTION 3

Remedial Action Objectives

RAOs are targets that remedial alternatives should achieve to provide adequate protection of human health and the environment and assist with removing BUIs while meeting regulatory requirements and complying with permits.

3.1 General Objectives

GLNPO applies the following general RAOs to the remedial actions conducted as part of the GLLA:

- Reduction of exposure to COCs in sediments and pore water
- Reduction of concentrations of contaminants in biota
- Reduction of sediment-related toxicity
- Improvement of biota and biological communities
- Improvement in habitat quality
- Remediation of sediment contamination based on volume, area, and/or mass basis

In general, RAOs are translated to remediation targets for the COCs that provide more quantitative measures to evaluate remedial alternatives and remedy effectiveness. Remediation targets can span from mass and volume goals to risk-based cleanup goals calculated to protect a specific receptor or receptors.

The following subsections identify site-specific RAOs and present preliminary remediation targets.

3.2 Site-specific Remedial Objectives

The site-specific RAOs are requirements that remedial alternatives should achieve to make improvements to the AOC where the project is located, and support removing BUIs and delisting the AOC.

Site-specific RAOs relate to specific contaminated media such as sediment, potential exposure routes, and the removal levels necessary to meet remediation targets. This analysis is focused on contaminated sediment in the Menomonee and Milwaukee Rivers project area.

The following site-specific RAOs were established for assessing remedial alternatives and remedy effectiveness:

- Support removal of BUIs within the Milwaukee Estuary AOC by reducing the mass, volumes, and concentrations of COCs in the sediment. Specifically, the remediation of contaminated sediment in the project area will make progress towards eliminating the seven BUIs linked to the contaminated sediment in the AOC:
  - Restrictions on fish and wildlife consumption
  - Degradation of fish and wildlife populations
  - Fish tumors or other deformities
  - Bird or animal deformities or reproduction problems
  - Degradation of benthos
  - Restriction on dredging activities
  - Loss of fish and wildlife habitat
- Remediate contaminated sediments to support BUI removal and AOC delisting.
- Provide short- and long-term reductions in risks to human health and the environment. This will largely be affected by supporting the removal of BUIs, but short- and long-term targets were

developed for the primary COCs (including the NAPL-impacted areas) so the greatest environmental gains are achieved, while minimizing risk and exposure during remedial activities to the extent practicable. In addition, the evaluation of the alternatives in the FFS will provide additional analysis of short- and long-term effectiveness in protecting human health and the environment.

- Support navigational depth requirements within the authorized USACE navigation channel.

3.3 Remediation Target Development

The following criteria were used to identify potential areas of interest (AOIs) for remediation:

- Comparison of COC concentrations and surface-weighted average concentrations (SWACs) to the PEC and three times the PECs for total PAHs, total PCBs, and select metals in surface, near-surface, and subsurface sediment taking into consideration both Milwaukee Estuary AOC urban background and recontamination potential.
- Occurrence and distribution of NAPL
- Current federal navigation channel extent and authorized depths for navigation

3.3.1 Application of Probable Effect Concentrations

The COC concentrations in the surface and near surface (depths to 1.7 feet) sediment and subsurface sediment were compared to the PEC and three times PEC values as discussed in the nature and extent of contamination section. The organic (total PAHs and total PCBs) and select metals concentrations (arsenic, cadmium, chromium, lead, and mercury) in surface and near surface sediments greater than three times the PEC value were used to establish approximate boundaries of areas of interest (AOIs) using the Thiessen polygon network developed during the background characterization (Foth 2018a). Additionally, the post-dredge surface sediment concentrations were evaluated to confirm new AOIs would not be created. Figures 7 and 8 depict surface and near-surface COC concentrations relative to PEC values for metals and organics, respectively.

3.3.2 Occurrence and Distribution of Nonaqueous Phase Liquid

The occurrence and distribution of NAPL was investigated by Foth in 2017 with additional data gap sampling performed by CH2M in 2018. NAPL was found in two areas in OU2 (Figures 7c and 8c):

- Turning Basin—NAPL was observed in two borings outside of the navigation channel in the southeastern corner of the turning basin immediately upstream of the Water Street bridge near the confluence of the Menomonee and Milwaukee Rivers (NAPL-A).
- Adjacent to the Former Third Ward MGP Site—NAPL was observed in locations along the northern shoreline from the Broadway Bascule Bridge to just south of railroad swing bridge and limited to outside of the navigation channel, except at two locations south of the railroad bridge (NAPL-B). Vertically, NAPL generally extends to the native clay layer or terminates just above the native clay elevation.

3.3.3 Navigational Depth Requirements

The site can be divided into the following sections based on depth requirements:

- OU1—Menomonee River
  - Upstream of North 25th Street Bridge—Not included within federally authorized navigation channel.
  - Between 25th Street Bridge and 16th Street—Not currently used for commercial vessels but was federally authorized to a depth of 21 feet LWD until October 2018.

   - Downstream of 16th Street to Confluence with Milwaukee River—Federally authorized to a depth of 21 feet LWD.
   - Seldom used for motorized and non-motorized recreational vessel traffic with minimal boat slips present along adjacent properties.
- OU2—Milwaukee River. OU2 is federally authorized to depths as follows:
   - Downstream from the confluence with the Menomonee River to the railroad swing bridge the authorized project depth is 21 feet LWD.
   - Downstream of the railroad swing bridge to the Kinnickinnic River confluence at the Inner Harbor has an authorized project depth of 27 feet LWD.
   - Receives heavy usage by motorized and non-motorized recreational vessel traffic with boat slips and docks present along both shorelines.

3.3.4 Summary of Remediation Target Areas

The data from the various investigations were compared to the criteria to identify potential remediation areas with the ability to achieve the RAOs and discussed with the project partners to arrive at the targeted remediation areas described below. Nine AOIs having surface and near-surface concentrations of COCs greater than 3 times the PEC were identified within OU1. Two remediation target areas were also identified in OU2 and are associated with areas of NAPL-impacted sediments (NAPL-A and NAPL-B). Remediation target areas consisting of nine AOIs and two NAPL areas are summarized in Exhibit 3 below and depicted in Figure 9. Within Exhibit 3, the defining sample location associated with the AOI and each NAPL area is presented, along with the COC and respective surface/near surface concentration and the greatest depth at which the 3 times PEC exceedance occurs.

Exhibit 3. Remediation Target Area Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Defining Sample Location or NAPL Area	COC (Concentration)	Area (square feet / acres)	Depth of Three Times PEC Exceedance (feet bss)	NAPL Occurrence	Navigational Depth Requirement
MR-SD-R3-04	PAH (64.9 mg/kg)	11,100 / 0.3	0.0	None	None
SED103	PAH (71.6 mg/kg)	13,600 / 0.3	6.6	None	None
MR-SD-R4-10	PAH (96.2 mg/kg)	35,500 / 0.8	3.5	None	None
MR-SD-R5-01	Lead (508 mg/kg) PAH (101 mg/kg)	67,000 / 1.5	5.3 (top of clay)	None	21 feet LWD
MR-SD-R5-04	Lead (418 mg/kg) PAH (101 mg/kg)	57,600 / 1.3	3.0 (top of clay)	None	21 feet LWD
MR-SD-R5-05	PAH (103 mg/kg)	50,100 / 1.2	3.6 (top of clay)	None	21 feet LWD
MR-SD-R5-12	Cr (362 mg/kg) Pb (478 mg/kg)	58,500 / 1.3	0.5 (top of clay)	None	21 feet LWD
MR-SD-R5-13	Included due to being between AOIs for MR-SD-R5-12 and MR-SD-R5-14	39,200 / 0.9	8.0 (top of clay)	None	21 feet LWD
MR-SD-R5-14	Pb (399 mg/kg) PAH (72.8 mg/kg)	54,300 / 1.3	5.0 (top of clay)	None	21 feet LWD
NAPL-A	NAPL impacted sediment	18,000 / 0.4	18.9 (top of clay)	OU2-SED-05 OU2-NAPL-30	Adjacent to channel with requirement of 21 feet LWD

Exhibit 3. Remediation Target Area Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Defining Sample Location or NAPL Area	COC (Concentration)	Area (square feet / acres)	Depth of Three Times PEC Exceedance (feet bss)	NAPL Occurrence	Navigational Depth Requirement
NAPL-B	NAPL impacted sediment	96,000 / 2.2	0.2 – 14.2 (top of clay)	OU2-NAPL-01, 03-08, 12-14, 18, 43-46, 48, 50, 54, 63-65, and 78, OU2-SED-10, OU2-SD-A4-02, OU2-SD-A4-02-A.	Adjacent to channel with requirements of 21 and 27 feet LWD

SECTION 4

Identification and Screening of Technologies

This section describes the identification and screening of available remedial technologies and process options based on the identified RAOs for the Menomonee River and Milwaukee River sites. The first step in the process is to identify general remedial alternatives that can meet the RAOs. Remedial alternatives are broad categories that alone or in conjunction with other actions can be used to meet the site RAOs. Within each remedial alternative, technologies and their associated process options were identified. For each remedial alternative, several remedial technologies may exist, each of which may be subdivided according to process options for screening purposes.

Table 6 shows the technologies and process options identified for screening. For each remedial alternative (except the no action), remedial technologies and associated process options considered to be potentially appropriate and effective for the contaminated sediment within the project area were identified based on professional experience, stakeholder input, published sources, computer databases, and other documentation and resources. Some of the process options such as monitored natural recovery, sediment removal, residual management, sediment disposal, and sediment dewatering could apply to all alternatives, except the no-action alternative, for some aspect of the project.

The following general remedial alternatives may be applicable to the project:

- No action
- Monitored natural recovery (MNR)
- Sediment removal (dredging, dewatering, and offsite disposal)
- Sediment containment
- In situ treatment
- Ex situ treatment

The alternatives screening objective is to retain the best technology types and process options and to use them to develop remedial alternatives. Each technology type and process option that passes the screening is either a demonstrated or proven process, or a process that has undergone laboratory trials or bench-scale testing and is likely feasible for implementation to address the contaminated sediment within the project area. Technologies and process options that are screened out based on the defined criteria listed below are highlighted in Table 6.

The screening process of remedial alternatives is based on the following criteria:

- Environmental risk (effectiveness)
- Technical and logistical feasibility (implementability)
- Relative cost
- Public acceptance

The following are specific considerations for each of these criteria:

- **Effectiveness:** Key considerations include (1) the extent the remedial option would be protective of human health and the environment and in meeting RAOs, (2) the level of treatment/removal that could be achieved, and (3) the extent to which the remedial option has been demonstrated at similar sites. Protection of human health and the environment refers to both the construction and implementation (short-term) and operation and maintenance (long-term) considerations for reducing the toxicity and mobility of COCs or meeting RAOs. Level of treatment/removal refers to the degree to which the technology reduces contaminant mass.

- **Implementability:** Implementability refers to the feasibility and/or availability of a given process remedial option for the site. Feasibility is further delineated based on technical and/or administrative considerations. Technical feasibility refers to the ability of the remedial option to adequately treat/remove the COCs given site-specific conditions. Certain options may be able to address the constituents but cannot be implemented because of factors like space limitations and unacceptable subsurface conditions. Administrative feasibility refers to the ability of the remedial option to meet factors such as local and state permitting requirements and regulatory reviews for approval. Availability refers to factors such as the geographic location of the site and the extent to which the remedial option is commercially available.
- **Relative Costs:** For comparative purposes, the initial screening table presents relative cost magnitude (low, moderate, and high) taking into consideration anticipated capital and operation and maintenance costs for each technology. As such, cost considerations are provided for general assessment and were not used singly as a screening tool unless substantial cost differentials were identified that would immediately preclude the technology from further consideration.
- **Public Acceptance:** For comparative purposes, the probability of public acceptance was considered. Among technologies with similar effectiveness and implementability, technology expected to receive a more favorable response were given preference. As part of the FFS process community outreach will be performed, and public comments will be considered.

4.1 No Action

Under a no-action alternative, no remedial response is performed. This alternative is typically used as a baseline to which other remedial options are compared. A no-action alternative may be appropriate where current site conditions present little or no human health or environmental risk. The no-action alternative is retained for comparison with other remedial options.

4.2 Monitored Natural Recovery

MNR involves the reliance upon naturally occurring physical, chemical, and biological processes to reduce the bioavailability and/or toxicity of contaminants to acceptable levels. For example, exposure levels are reduced by a decrease in contaminant concentration levels in the near-surface sediment zone through scour, burial, or mixing-in-place with cleaner sediment. Contaminated sediment located in depositional areas can gradually be buried by cleaner sediment. This alternative can be implemented only after continuing sources of contaminants above background conditions to the system have been eliminated.

Typically, MNR is required to occur within a reasonable amount of time. A remedial alternative that involves MNR will require a comprehensive long-term monitoring program to verify such processes are taking place and that anticipated human health and environmental risk reductions are being achieved. MNR is appropriate at sediment sites with the following conditions:

- Sources are controlled.
- Short-term human health and environmental risks are low or declining.
- Natural recovery processes have a high degree of certainty to continue.
- Institutional controls effectively restrict human exposure.
- The sediment bed is stable and likely to remain stable.
- Decreasing water depths over time does not restrict navigational uses of the waterway.
- The only available sediment excavation techniques could cause significant resuspension and recontamination downstream.

MNR can be implemented as a sole remedy or as part of a larger remedial strategy incorporating more intrusive sediment alternatives, such as dredging (e.g., to address residual concentrations of COCs).

Advantages of this technology include:

- MNR reduces disturbances to the ecosystem that may jeopardize habitat and sensitive aquatic species.
- MNR is readily implementable.
- At sites where MNR satisfies risk-based remedial goals, MNR can effectively manage human and ecological risks.
- Costs are significantly lower than more invasive technologies.

Disadvantages include:

- Contaminants are left in place.
- The timeframe for natural recovery is typically slower than that for invasive remedies, such as capping or removal.
- MNR relies on source reduction.
- MNR requires the continued use of institutional controls for a specific period of time, including dredging restrictions, which is a BUI.
- Requires a post-implementation monitoring program to confirm the expected decreases in risk to human health and the environment over a specific period of time.

Similar to other remedial strategies, natural recovery processes can potentially be undermined if ongoing sources of contamination to sediment are not adequately controlled. For this FFS, it is assumed that additional source control measures, if needed, will be conducted before implementing the final remedy.

Natural sedimentation and mixing can create a surface sediment layer with lower chemical concentrations through the physical burial of contaminated sediments over time. Such natural capping can form a protective barrier that inhibits diffusion of chemicals into the water column, minimizes the potential of contaminated sediment resuspension, and helps isolate contamination from contact with ecological and human receptors. Historically, reduced surface sediment concentrations at the site provide the strongest evidence of natural recovery via sedimentation and contaminant burial. In general, the analytical data reported lower surface sediment concentrations compared to subsurface concentrations for each COC. Average concentrations are typically higher in the subsurface sediments compared to surface sediments in OU1 and OU2. In addition, large portions of the river reaches demonstrate depositional behavior, making these areas suited to MNR.

Future navigation maintenance dredging in the authorized federal channel would disrupt the MNR process; therefore; MNR could only be implemented in those federal channel areas in combination with other technologies, such as sediment removal, that would need to occur below the currently authorized navigation depths. In addition, a comprehensive post-construction monitoring component of an MNR remedy would be required to demonstrate that unacceptable levels of COC concentrations are not present in surface sediments after a specific time period. If so, the decision criteria outlined in an MNR monitoring plan will be followed and potential contingency remedies may need to be implemented should MNR prove to be ineffective at a future point in time.

MNR is not retained for further evaluation as a standalone alternative because there is currently no mechanism for funding long-term operations that may be required and the expected feasibility of other technologies. MNR is also not expected to easily achieve public acceptance due to its failure to support removal of BUIs in a reasonable timeframe compared to other technologies. Based on these concerns, MNR is not retained for consideration.

4.3 Sediment Removal

Removing contaminated sediment offers the advantage of contaminant mass reduction in the aquatic environment and can reduce the bioaccumulation of contaminants in fish, benthos degradation, and toxicity. Furthermore, permanently removing contaminants from the aquatic system, even those deep within the sediment column, removes the possibility that those contaminants can contribute to BUIs or become exposed or mobile in the future due to natural or anthropologic causes such as severe weather, ice dams, or prop wash.

Sediment removal can be performed through several methods. Sediment can be mechanically dredged by an environmental clamshell bucket or excavator and transported to an upland staging area for offsite disposal or directly to a confined disposal facility (CDF) for disposal by barges. Sediment removal also can be achieved by using a hydraulic dredge, which conveys the dredged sediment directly into the dewatering/staging area or CDF through piping.

4.3.1 Mechanical Dredging

Sediment removal using mechanical dredging can be performed using a variety of equipment, including a clamshell bucket, dragline dredge, dipper dredge, backhoe dredge, or bucket ladder dredge. Most of these can either be land-based or placed on a barge. A mechanical dredge with a specially designed level-cut environmental clamshell bucket with smooth cut surface and no teeth to dredge sediment is commonly used. The clamshell bucket can be operated by a crane positioned on the barge. Another commonly used piece of equipment is the backhoe dredge, which can be a land-based excavator placed on a barge to remove sediment. A backhoe dredge is typically more applicable than a clamshell bucket in areas of sloped sediment removal and can also be outfitted with a clamshell bucket. Typically, the bucket on the mechanical dredge is controlled by the operator using global positioning system (GPS) equipment with integrated software that allows the bucket’s position to be monitored in real time.

Mechanical dredging is performed either from the shore adjacent to the area of contaminated sediment or from a barge that is moved throughout the dredging area. Excavated materials are either stockpiled on shore or placed in a watertight scow barge and transported to the dewatering pad, where it is offloaded for dewatering and disposal. Scow barges can also be transported directly to a CDF for direct offloading and disposal. Unless the sediments are granular and drain readily, dewatering and/or stabilization is often required before final disposal to a landfill. Excess water generated from settling of dredged sediments in the scow barges is directly pumped to the temporary onsite water treatment system or CDF. Water treatment depends on the destination for the treated water. Water can be treated and pumped back to the water body. Although free of disposal costs, discharge to surface waters typically requires permitting and several stages of treatment to meet discharge requirements. Water also can be pre-treated and pumped to a municipal WWTP. Municipal WWTPs typically charge for disposal, but requirements for permitting and pretreatment are typically less costly than treating water for surface water discharge.

Management of debris during mechanical dredging is easier when compared with hydraulic dredging because the tolerances of equipment operation are greater. Mechanical dredging equipment has a greater ability to remove or move debris from the dredge footprint with less impact to production compared to hydraulic dredging.

Turbidity control, such as a silt or bubble curtain, may be required to prevent suspended sediment from migrating outside of the project site. During NAPL impacted sediment removal, additional turbidity and sheen control such as sheet pile installation and oil booms may be required to isolate dredge residuals and sheens. Fugitive odor and dust emissions are not likely during the actual excavation activities, since the sediment is wet; however, these may occur as the sediment is processed (that is, dewatered and/or stabilized) for disposal.

Mechanical dredging is retained for further evaluation as a technology to effectively remove the contaminated sediments and, thus, control both exposure and downstream transport.

4.3.2 Hydraulic Dredging

Sediment removal using hydraulic dredging methods at sites with similar physical characteristics is typically conducted using an 8- to 12-inch cutterhead hydraulic dredge to remove the sediment to the specified depths. However, additional specialty hydraulic dredge options are available without cutterheads such as plain suction, pneumatic submersible pumps, and diver-assisted hand-held hydraulic suction, which are typically used in more sensitive areas near critical structures like utilities. A hydraulic dredge is connected to a leak-tight, high-density polyethylene dredge pipeline, and the dredged sediment is conveyed directly to the dewatering area. The dredge pipeline can be submerged in the water to minimize navigational disruption to the waterways and can surface at booster pumps and the shoreline of the dewatering pad. The hydraulic dredge cutterhead is controlled by the operator using GPS equipment with integrated software that allows the dredge positioning to be monitored in real time, tracking the locations and elevations of sediments that have been removed. As the dredge head breaks up the sediments, some suspended sediment particles may be released into the water body, which creates turbidity. Turbidity control, such as a silt or bubble curtain, may be required to prevent suspended sediment from migrating outside of the project site; however, hydraulic dredging typically generates less resuspended sediment than mechanical dredge methods and may not require active turbidity control (e.g., silt curtains) that can impede recreational and commercial vessel traffic. During NAPL impacted sediment removal, additional turbidity and sheen control such as sheet pile installation and oil booms may be required to isolate dredge residuals and sheens.

Using hydraulic dredging to remove contaminated sediments from areas that contain debris is difficult and often inefficient. Large debris (greater than approximately 1.5 feet) can only be removed using mechanical means and smaller debris often clogs hydraulic pipelines and damages pumps. The amount of debris in the Menomonee and Milwaukee Rivers has not been quantified, however it is likely that debris is widespread outside the federal navigation channel due to historical waterfront uses and the urban setting.

Hydraulic dredging is retained for further evaluation. However, several challenges exist if the CDF disposal option is not viable including the need for a 5- to 10-acre staging area, as well as significant water treatment operations.

4.4 Residual Management Cover

Residual management cover is a relatively thin layer of clean material (often sand) placed in or adjacent to areas of sediment removal to manage dredging residuals. Residuals are contaminated sediment remaining in or adjacent to the dredging footprint after completion of the dredging operation. They are broadly grouped into two categories:

- **Undisturbed residuals.** Undisturbed residuals, also commonly termed undredged inventory, are sediments that have been uncovered by dredging and not fully removed, which result from characterization or dredging inaccuracies or the presence of debris or structures.
- **Generated residuals.** These are defined as sediment dislodged, but not removed, by dredging which falls back, spills, sloughs, or settles in or near the dredging footprint and forms a new sediment layer.

The residual management cover provides short-term isolation and long-term reduction in surficial contamination. The cover layer of clean material will be placed over the residual material to reduce the contaminant concentrations to which biota are exposed. The residual management cover is not a cap because the cover material is not intended to remain in place for an extended period of time, but is instead expected to mix with the dredge residuals. Placement of a cover layer can effectively reduce the residual contaminant concentrations to the desired level in areas where sufficient contaminant mass has been removed or where contaminant levels do not pose enough of a risk to require removal. The thickness of the cover layer is based on the depth required to achieve the desired concentration in surface sediment upon completion of the dredging activities and cover layer placement. Because turbidity caused by fines can be excessive when the clean cover layer is placed through the water column by a broadcast system, washed sands are typically required by permit writers under the Chapter 30 permit.

Residual management cover is retained for further evaluation in conjunction with sediment removal technologies as a technology to further decrease potential exposure.

4.5 Sediment Disposal

If a remedial alternative involving sediment removal and dewatering is undertaken, sediment will need to be transported to the final disposal location by truck or barge if mechanically dredged, or by piping with a series of booster pumps if hydraulically dredged. Two offsite disposal options are presented in the following subsections and could be used in combination.

4.5.1 Offsite Disposal—Subtitle D Solid Waste Landfill

Contaminated materials dredged from the project site could be trucked to an offsite Subtitle D landfill for disposal. Sediment sampling and analysis has shown that sediments from the site not subject to disposal restrictions under the Toxic Substance Control Act associated with materials containing concentrations greater than 50 mg/kg of PCBs, are nonhazardous, and can be disposed at licensed landfills in Wisconsin. Multiple landfills may need to be used to process the volume of dewatered sediment without causing issues with landfill operations (that is, delivery of sediment at a pace at which the landfill can effectively mix the sediment into the municipal waste). Disposal of these sediments at a Subtitle D solid waste landfill(s) is a viable option and is retained for further evaluation.

4.5.2 Offsite Disposal—Confined Disposal Facility

The contaminated sediments from the Menomonee and Milwaukee Rivers could be disposed of into either the existing or a new CDF adjacent to the existing CDF prior to or following passive dewatering. The existing CDF facility is a permitted facility specifically designed for the management and disposal of sediments from the Menomonee, Milwaukee, and Kinnickinnic Rivers and Harbor areas. By managing the sediment entering the CDF (e.g., segregation of elevated chemical concentrations within the CDF, and placing a clean cover after sediment placement within the CDF), the CDF can be environmentally protective, and reduces or eliminates risks associated with excess sediment handling, transportation, and disposal.

The existing CDF is an in-lake facility attached to land located at Jones Island in the Milwaukee Harbor (see Figure 1), approximately 1.5 miles south of the confluence with the Milwaukee Harbor. Engineering controls currently in place at the CDF would provide control of potential releases of contaminants to the environment. The existing CDF is owned by the City of Milwaukee – Port of Milwaukee (Port of Milwaukee) and operated and maintained by USACE. It has a total constructed capacity of 510,000 cubic yards, of which 350,000 cubic yards of capacity are reserved for the USACE navigational dredge material and 160,000 cubic yards of capacity reserved for Port Authority. Typically, about 30,000 to 40,000 cubic yards are dredged for navigational purposes every three to four years. The existing CDF has an approximate remaining capacity of less than 400,000 cubic yards and will reach capacity in approximately 15 to 20 years as outlined in the USACE's dredged material management plan (USACE, 2008).

We Energies evaluated options to create capacity within the existing CDF by excavating and beneficially reusing the historically placed dredge material or building an expansion to the CDF with a capacity of an additional 460,000 cubic yards of dredged material. A field investigation was conducted in March 2018 to evaluate the physical and chemical composition of the historical dredged material in the existing CDF. The evaluation of the data concluded that because of highly organic and fine-grained nature of the sediments and the levels of benzo(a)pyrene and PCBs, beneficial reuse is not feasible or cost effective (Foth 2018b). NAPL-impacted sediment could be disposed of in the existing CDF pending further evaluation of disposal requirements and discussion with the USACE and Port of Milwaukee.

In August 2018, We Energies submitted a Harbor Assistance Program Grant application to design a new CDF, adjacent to the existing CDF at Jones Island, that will provide an additional 1,300,000 cubic yards of dredged material storage capacity. The grant was partially funded and We Energies intends to complete the design of CDF expansion upon reaching agreement with the Port of Milwaukee on securing a portion of their allocated space in the existing CDF. If constructed, the CDF expansion could be used for the non-NAPL dredged sediment and would accept materials from either hydraulic or mechanical dredge options.

Coordination between We Energies, WDNR, EPA, the City of Milwaukee, the Port of Milwaukee, and USACE is occurring to assess the possibility, requirements, and cost of disposing dredged sediments in a new CDF; therefore, this option has been retained for further evaluation.

4.6 Sediment Dewatering

4.6.1 Passive Dewatering

Sediment removed by either mechanical and hydraulic dredge operations will undergo passive dewatering prior to disposal. In mechanical dredging operations, the saturated sediment is removed and raised through the water column using a clamshell bucket or backhoe dredge. The saturated sediment is either stockpiled or transported via a water-tight barge to a dewatering area, where it is offloaded for dewatering and disposal. In hydraulic dredging operations, the sediment is loosened by the cutterhead creating a slurry that is pumped from the dredge directly to the dewatering area and dewatered passively until the material meets disposal requirements. The amount of water generated and requiring treatment from hydraulic dredging is often orders of magnitude greater than for mechanical dredging. A common method of dewatering hydraulically dredged sediment is using geotextile tubes, which retain the dredged material inside the tube but allow the entrained water to pass through. Water released from the geotextile tubes is collected and pumped into a temporary water treatment system. For this reason, dewatering with geotextile tubes for hydraulic dredging requires significantly more shoreline laydown area than dewatering efforts for mechanically dredging, and available dewatering/staging area space can often be a limiting factor in determining what type of dredging will be conducted at a site.

As an alternative to an upland staging area, the sediment slurry could be pumped directly to the CDF or for the NAPL-impacted sediment to geotextile tubes that are laid out and filled on the CDF. Because the CDF facility was specifically designed for the management and disposal of sediments, the dewatering of sediment within the CDF would be environmentally protective. Depending on the rate and volume of water generated, the excess water could be discharged to the publicly owned treatment works (POTW) facility operated by MMSD or directly discharged to the harbor under a WPDES permit following water treatment. Upon completion of sediment dewatering using geotextile tubes, they could be left in place and covered or taken offsite for disposal.

Mechanical dredging generally results in less free water than hydraulic dredging. Free water develops during mechanical dredging when it's placed within watertight scow barges and is allowed to settle. At the docking platform, free water on top of the sediment could be pumped directly from the barge to a temporary onsite water treatment system, and then sediment offloaded by an excavator. Alternatively, the sediment could be pumped as a slurry into the CDF.

4.6.2 Water Treatment and Discharge

Water generated from dredged sediments will be treated to reduce the levels of COCs and suspended solids to meet the water quality discharge regulatory requirements. Once the effluent water meets the discharge criteria, it could be pumped back into the waterbody under a regulatory permit or to a POTW facility. The amount of water generated during mechanical dredging may allow for discharge solely to the POTW. However, the amount of water generated during hydraulic dredging would likely exceed the POTW's capacity and preclude discharge solely to the POTW. Rain events may also decrease available POTW capacity and limit the volume of discharge it can accept. Therefore, water generated by hydraulic dredging is anticipated to require a temporary water treatment system either as pretreatment for POTW discharge or treatment to meet regulatory requirements for discharge back into the waterbody. The solids generated during this process will be disposed offsite along with the sediment as a solid waste.

4.7 Sediment Containment

In situ containment measures are intended to reduce dispersion of and leaching of COCs from contaminated sediments to other areas of a waterbody and to reduce direct human and ecological exposure to contaminants. Sediment containment measures, represented by the subaqueous capping technology, are effective technologies for the remediation and management of risk posed by contaminated sediments through the following primary functions:

- Physical isolation of the affected sediment from the benthic environment and potential human exposure.
- Stabilization/erosion protection of the affected sediment, preventing resuspension and transport to other areas.
- Reduction of the flux of dissolved constituents from the sediment bed to the overlying water column.

Capping involves the placement of a physical barrier over an area of impacted sediment to separate contaminants from the biological active zone within the sediment bed, reduce or eliminate chemical exposures by benthic, human, and/or ecological receptors, and minimize the potential for mobilization of these contaminants by resuspension into the overlying water column and transport to downstream areas. Sediment capping is generally most appropriate for locations where routine disturbance (e.g., maintenance dredging) is not required to support local functions such as navigation, and the environment is relatively low-energy, so the cap will be stable.

Caps may be constructed of clean sediment, sand, gravel, and/or amended material, or may, if necessary, involve a more complex design using geotextiles, liners, reactive materials, or sorbent materials. A cap may also require an armor protection layer for stabilization purposes to mitigate potential site-specific scour by currents, waves, or mechanical disturbances such a vessel wakes or propeller wash.

Advantages of this technology include the following:

- Immediately provides a clean sediment surface and it quickly reduces exposure to chemicals in surface sediments.
- Reduces the potential for exposure to contaminants without material handling, treatment, and disposal.

- Cap material often provides a clean and more suitable substrate for the recolonization of benthic organisms.
- Implementation is typically quicker and less expensive than sediment removal.

Disadvantages include the following:

- Contamination remains in the aquatic environment.
- May result in limitations/restrictions on future site use.
- May require routine repair or periodic replenishment if damaged.
- May alter water depths, reducing available habitat, navigation depths, and floodway conveyance capacity.

Sediment capping can be implemented as a sole remedy to provide both physical and chemical isolation of the impacted sediments, or in conjunction with other remedial techniques. Institutional or engineering controls are commonly employed in conjunction with caps; these include navigational restrictions, physical access restrictions, and future dredging restrictions. Such controls minimize the potential for cap disturbance and subsequent exposure to sediment contamination by human or ecological receptors.

A long-term monitoring program is commonly required when capping is selected and constructed as a sediment remedy. Monitoring may include bathymetric surveying and visual observation (e.g., camera or video profiling) to evaluate cap integrity. Biological monitoring may be conducted to evaluate biological recovery of the cap surface, and surface sediment sampling may be conducted to monitor surface sediment deposition and recontamination potential.

The primary types (or process options) of caps applicable to the Menomonee and Milwaukee Rivers considered during this evaluation include isolation caps and active caps. Each of the process options is briefly described in the following subsections.

4.7.1 Isolation Cap

An isolation cap consists of a clean layer of sand, soil, or a mixture thereof, placed on the sediment surface, typically without any prior removal of sediments, to provide immediate, long-term isolation of the underlying contaminated sediment. However, sediment can be removed prior to cap placement if a specific water depth is required to support navigation, preserve aquatic habitat, or address floodplain compensation concerns. The cap thickness and material are designed to provide stability and chemical transport retardation with the potential for natural chemical degradation (attenuation) beneath the cap. The isolation cap may also consist of additional layers (such as geotextile) to improve physical stability between the cap and the existing sediment while allowing advection processes to continue to occur via passage of pore water through the cap. In higher-energy environments, an armor layer may be installed to protect the isolation layer from erosive forces. Habitat reconstruction opportunities for implementation as a component of an isolation cap include options such as creating variations in substrate out of capping materials (for example, sand, gravel, armoring material) to develop fish spawning areas and shelter, as well as providing areas of submerged vegetation and structure for larval and adult fish habitat.

Implementation of an isolation cap would require long-term monitoring and maintenance of cap integrity for its ongoing achievement of project objectives.

4.7.2 Active Cap

Active caps incorporate specific materials or layers to encourage fate processes such as increasing degradation or sequestration of contaminants within the cap. Caps that encourage degradation or sequestration of the contaminants may be more effective at sites characterized by highly contaminated sediments as they provide immediate, long-term contaminant containment and reduction, as opposed to solely providing sediment isolation.

Cap amendment selection is specific to site characteristics, including COCs and concentrations; and is effective at mitigating contaminant transport to surface water and/or potential receptors.

Similar to isolation cap installation, the thickness for an active cap is dependent on bioturbation depth; constituent migration through the cap; consolidation of underlying sediments; effect of total placement volume and accuracy required during placement on project duration; impacts to commercial/industrial navigation; and the precision of, and mixing induced by, the placement methods. In addition, as installation of the cap would inevitably result in the burial of macroinvertebrates, placement of clean materials may promote ecological repopulation without additional habitat restoration activities. Implementation of an active cap requires long-term monitoring of cap integrity and its achievement of project objectives. The degree of maintenance required is dependent on observations and results of the monitoring events; however, continual maintenance and material replacement may be required if the active cap material components become exhausted.

4.7.3 Cap Technology Overview

Capping presents a viable remedial option to meet project goals and has been effectively implemented at other sites with contaminated sediments. Capping has the ability to physically and chemically limit interaction of site contaminants in sediments with the surrounding environment through isolation, sequestration, and chemical interactions while enhancing natural recovery processes via stabilization and in situ containment of sediment. Capping can reduce risk while minimizing construction hazards and implementation risks to the surrounding community, construction workers, and the environment.

While impacts to the benthic community would be expected following placement of a cap, it is expected that the benthic community would recover quickly. There are design considerations that must be evaluated to fully assess the effectiveness of a remedy that includes capping, particularly water depths and flow velocities. Water depths are important to define the maximum allowable thickness of a cap and to identify the potential for cap erosion due to scour and wind-induced waves. Water depths are also important to define the recreational usability of an area following construction of the cap (since a cap could potentially be compromised by, for example, vessel wake or prop wash). In addition, channel flow velocities have the potential to induce cap erosion from bed shear stress, which is compounded by reduced water depths.

Areas suitable for capping within the Menomonee and Milwaukee Rivers are limited to areas outside of the federally authorized navigational channel due to periodic maintenance dredging required to support large commercial vessel drafts. This includes the narrow portions of the rivers that border the navigational channel and the non-navigable portion of the Menomonee River upstream of 16th Street. Capping materials installed within the federally authorized navigation channel would require to be 2 feet below the authorized navigation channel elevation with an overdredge depth allowance for maintenance dredge operations and is not preferred.

Implementation of a capping remedy would leave contaminated sediment in place with the potential for release in the event of a cap disturbance. Hence capping would require long-term monitoring and maintenance to maintain the cap’s integrity and achievement of project objectives. Because there is currently no mechanism for funding the long-term monitoring and maintenance that would be required, the capping technologies were not retained for further evaluation.

4.8 In Situ Treatment

In situ sediment treatment involves applying or mixing of an amendment into sediments. Mixing may be achieved either passively through natural biological processes such as bioturbation or actively through mechanical means (such as using augers). In situ treatment technologies can achieve risk reduction in environmentally sensitive environments such as wetlands and submerged aquatic vegetation habitats, where sediment removal or containment by capping might be harmful. Treatment amendments may be preferred in areas with higher contaminant concentrations, where MNR cannot achieve risk goals in an acceptable time or where immediate risk reduction is needed. Treatment amendments typically reduce concentrations of chemicals that are available for exposure to organisms or that may be mobilized and transferred from sediment to the overlying water column.

In situ stabilization (ISS) treatment involves the addition of chemicals or cements (such as Portland cement, quicklime, and fly ash) to encapsulate contaminated sediments into a solidified mass that reduces contaminant mobility and bioavailability.

Advantages of this technology include:

- Accelerates sediment cleanup using low-impact methods that provides a high level of effectiveness.
- Achieves near-immediate reduction of the bioavailable fraction of contaminants (thus, reducing exposure to contaminants) and reduces erosion potential.
- Implementation is typically less expensive than sediment removal or capping.

Disadvantages include:

- Requires bench-scale testing to determine appropriate amendment mix.
- Contamination remains in the aquatic environment.
- Changes the physical characteristics of the sediment surface, which can affect the benthic community.
- May result in limitations/restrictions on future use.

In situ treatment can be implemented as a sole remedy to provide both isolation of the impacted sediments, or in conjunction with MNR. Institutional or engineering controls may need to remain employed, and may include restrictions for navigation, physical access, and future dredging. Such controls minimize the potential for disturbance of the ISS areas and subsequent exposure to sediment contamination by human or ecological receptors. A monitoring program is commonly required during construction to confirm the effectiveness of the remedy.

ISS has been evaluated as a potential measure for reducing the mobility of NAPL. ISS would be applied to targeted areas into the native sediment to immobilize NAPL with migration potential. ISS would be performed into the top of the native clay and would consist of incorporating pozzolanic additives into the native sediment to solidify the material. The stabilization agent would be delivered to in situ sediment from a barge using large augers without dewatering the river.

ISS has been retained for consideration as a technology to immobilize NAPL-impacted sediments.

4.9 Ex Situ Treatment

Ex situ treatment methods can involve biological, chemical, thermal, or physical processes. One of the primary advantages to performing treatment is to reduce the amount of soil or sediment that require onsite consolidation or offsite disposal. Treatment can allow the sediment to be returned to its original location or to be beneficially reused. Disadvantages to treatment can be the need for additional handling and a longer implementation time than offsite disposal. In addition, some of the treatment technologies do not destroy contaminants, but rather transfer them to an alternative media that subsequently requires its own treatment.

4.9.1 Sediment Stabilization/Solidification

Stabilization or solidification agents such as fly ash, Portland cement, Calciment®, or similar materials may be added to the passively dewatered sediment for further reduction in moisture content and partial solidification.

Chemical stabilization is expected to be highly effective as a method to enhance the passive dewatering of sediments removed during dredging activities. For these sediments, chemical stabilization could improve the physical properties of the sediment for disposal and decrease leachability of contaminants. Addition of an appropriate percentage of binding material to the sediment mixture would occur ex situ at the dewatering pad prior to loading for disposal; thus, would be highly implementable. Pilot treatability tests would be required to choose the most suitable reagent and ratio needed to meet the requirements of the disposal facility. Mixed sediment may be moved by conveyor belt to a drying pad for stacking and further natural drying until ready for loading into a truck. Stabilized sediment would then be directly loaded into trucks for transport to an approved offsite landfill.

Chemical stabilization of sediments through addition of solidification agents or similar material is retained as an ex situ dewatering and treatment technology in conjunction with passive dewatering technologies implemented with sediment removal.

4.9.2 Particle Size Segregation

Inclusion of a particle size segregation step in a remedial alternative involving sediment removal is relatively simple to implement and may be useful if it is determined that contaminants are associated with a certain particle size in the sediment. For example, if contaminants are entirely within the finer grained materials in the sediment, and a significant quantity of clean sand (200 sieve) or larger grained material can be sorted out, then it may be disposed of more cheaply than the contaminated fraction or be used as a beneficial fill. However, its effectiveness as a treatment technology would depend on bench or pilot testing to demonstrate that contaminants are associated with a specific size fraction. Possible methods of particle-size segregation include using vibrating or fixed-based screens, including a hydrocyclone in the processing train, or gravity separation if particles with significant density difference are present within the sediment. Typically, these methods require water to be a part of the process, which would result in creating the need for handling and treatment of the water produced and to establish a designated staging and treatment facilities at the site.

Segregation would likely only be selected for use if the implementation cost is offset by savings associated with transportation and disposal, or if a decreased volume of waste requiring disposal in a landfill or CDF can be realized.

Evaluation of the distribution and quantity of coarser-grained material estimates that approximately 54 and 32 percent of coarse-grained material exists in the Menomonee River navigational channel of Reaches 4 and 5, respectively. Based on discussions with vendors, the process is effective in separating about 60 percent of the coarse-grained materials that could potentially be beneficially used and would not need to be disposed of. Because there is potential net benefit for using particle size segregation, the technology was retained for further evaluation.

4.9.3 Sediment Washing

This technology requires excavated sediments to be treated with bioremediating surfactants and requires specialized equipment within the treatments system, consisting of washing units and tanks, shaker screens, hydrocyclones, water blasters, compressors, and water treatment equipment. This technology can be cost-effective for a site with relatively large volumes of contaminants in high concentrations; however, only small volumes of material can be treated at one time per unit. Multiple units could be implemented; however, multiple unit processes make the technology relatively complex, difficult to implement, and costlier. Implementing this technology may require a staging area for sediment treatment. Because of the potential implementation difficulties and relatively high cost, sediment washing will not be retained for further evaluation.

4.9.4 Thermal Treatment

Vitrification is one thermal treatment process whereby dewatered sediment is heated to above its melting point to form a stable glass state when quenched in water. Organic contaminants such as PAHs and PCBs are volatilized from the sediment and thermally decomposed due to the high process temperatures. Inorganic contaminants such as heavy metals remain in the molten glass pool and are sequestered in the glass matrix upon cooling. This process requires sediments to be excavated, dewatered to a dry state, and then transported to a vitrification facility. The resulting glass aggregate material can then be used for beneficial reuse, such as road construction and asphalt pavement. Implementation of this technology requires offgas collection and treatment, as well as process temperatures in excess of 2,200^{o}F. Due to implementability concerns and relatively high costs, thermal treatment will not be retained for further evaluation.

4.10 Results of Screening Process

The initial screening process evaluated the remedial technologies and process options for effectiveness, implementability, cost, and public acceptance. Remedial technologies and process options that would effectively address sediment contamination and/or NAPL within the Menomonee and Milwaukee Rivers retained from the screening process are carried forward and incorporated into the remedial alternatives discussed in Section 5. Note that often there are multiple process options within a remedial technology type that could be applied within the project area. In many cases, one representative process option was carried forward for use in developing remedial alternatives and estimating the associated costs. During remedial design, other process options may be used in addition to or instead of the representative process options listed in this FFS. The process options incorporated into the remedial design will achieve the established RAOs and support the long-term effectiveness of the selected remedy.

The remedial technologies and process options that will be assembled into alternatives for further evaluation include the following:

- The no-action alternative will be retained for comparison purposes.
- Targeted dredging with offsite landfill or CDF sediment disposal removes contaminant mass from the river and, when combined with a residual cover or natural sedimentation processes, will provide long-term reduction in surface sediment concentrations.
- ISS has been retained for consideration as a technology to immobilize NAPL-impacted sediments located in areas where access to sediment for removal is limited. However, several hydraulic dredging techniques such as plain suction, pneumatic submersible pumps, and diver-assisted handheld hydraulic suctions may also be viable options for these NAPL areas.

Remedial Alternatives Assembly and Descriptions

The remedial technologies and process options remaining after screening were assembled into a range of alternatives that address the RAOs to varying degrees. Following the technology screening, each of the technologies was incorporated into at least one of five assembled alternatives summarized in Table 7. Because the five remedial alternatives incorporate sediment removal, each alternative will be carried forward to the detailed analysis, thus eliminating the need for further screening of alternatives.

As capping was screened out due to the lack of a funding mechanism for long-term monitoring and maintenance, the main distinctions between alternatives developed to address impacted sediment in OU1 are the extent and depth of the dredging. The dredge footprint and target elevation vary based on assumptions relative to the navigational channel and the depth to native clay or COC concentrations greater than 3x PEC.

The assembled alternatives are presented from the most to least extensive removal. Alternatives 3 through 5 address impacted sediment in the AOIs the same. The more extensive removal alternatives (2 and 3) include dredging to 3.5 feet below authorized depth (24.5 feet LWD) within the former and current authorized navigational channel, respectively, to create space for a 6-inch residual management layer consistent with the USACE's requirements for working in the authorized navigation channel. Alternative 4 dredges to the current authorized depth with a 1-foot overdredge allowance (22 feet LWD) within the current navigational channel, with no residual management layer where in conflict with USACE requirements. The target dredge depth for Alternative 5 is based on AOI removal as determined by COC concentrations irrespective of the authorized navigation channel. However, as discussed in Section 5.6.1, the removal of sediment to the authorized navigational depth is a factor in evaluating the alternatives relative to the restrictions on dredging activities BUI.

An optional alternative for addressing the NAPL-impacted areas in OU2 using ISS is also presented in this section as a subalternative that could be implemented. Details of the remedial technologies present representative examples to estimate costs of each alternative. Within each cost estimate description, the specified elevations of removal are reported in the NAVD88 and LWD vertical datums. A summary of the remedial alternatives developed for the evaluation are included in Table 7 and discussed in subsections below[1].

Figures 10 through 13 present conceptual plans and approximate extents of sediment removal for Alternatives 2 through 5, respectively. Table 8 summarizes the estimated removal volumes and areas to be dredged. For organizational purposes, quantities are categorized within each alternative by the following project reaches: OU1 – 25th Street to 16th Street (Reach 4), OU1 – 16th Street to OU2 (Reach 5), and OU2. Appendix B presents three-dimensional interactive models of each alternative for visualization of analytical data discussed in Section 2.2 in comparison to the proposed sediment removal surface. Analytical data are presented relative to each COC's PEC and three times PEC value within existing current conditions, as well as following implementation of the respective alternative. The models also present sediment bathymetric surface data, shoreline condition survey results, and OU2 NAPL visual observations.

[1] Other viable options within the same remedial technology that achieve the same objectives may be evaluated during remedial design.

5.1 Common Elements of Alternatives

The following subsections describe sediment removal, particle size segregation, water treatment, offsite CDF disposal, and residual management cover because they are common elements between alternatives and the discussion is presented only once.

5.1.1 OU1 Sediment Removal

Hydraulic dredging using a 10-inch standard cutterhead is the assumed dredging method. For relatively thin sediment deposits, implementing a cleanup pass for NAPL-impacted sediment residuals, or sediment deposits near critical structures and utilities, it is assumed that the cutterhead will be removed and the dredge will hydraulically "vacuum" the sediment. The sediment slurry loosened by the hydraulic dredge's cutterhead and sucked into the high-density polyethylene piping will be pumped from the dredge directly to the dewatering area. Piping will either float on the water or be intentionally sunk to the bottom of the waterway, as necessary, to allow for non-disrupted vessel traffic, and resurfaced at booster pumps and the shoreline of the dewatering area.

For the purposes of this evaluation, it is assumed that sediments would be directly pumped into a newly constructed CDF. The newly constructed CDF is anticipated to be located north of the existing Milwaukee Harbor (Jones Island) CDF and is between 4 and 1.5 miles away from the upstream and downstream project area extents, respectively. Discussions with USACE and the Port of Milwaukee have been initiated by the non-federal sponsor (We Energies), and the non-federal sponsor has recently submitted a Harbor Assistance Program Grant application to receive funding for the CDF design. The grant was partially funded and We Energies intends to complete the design of a CDF expansion providing an additional 1,300,000 cubic yards of storage capacity. The CDF would be designed and constructed as a separate project to aid in the disposal of contaminated sediments removed within the entirety of the Milwaukee River Estuary AOC. The CDF is anticipated to be owned and operated by the Port of Milwaukee (Foth 2018b).

Prior to disposal into the CDF, sediments would undergo particle size segregation processes targeting removal of course-grain sediments larger than 200 sieve and is anticipated to remove 60 percent of coarse-grained material for beneficial reuse and provide CDF capacity savings. During hydraulic dredging, the volume of water will not exceed the anticipated dredge flow rate of 1,200 gallons per minute resulting in approximately 1,100 to 1,400 gallons per minute for water treatment depending on particle size segregation efficiency. It is assumed that the new CDF will be designed to provide sufficient water retention time to provide adequate settling of suspended solids, to act as a pretreatment prior to discharging to a temporary onsite water treatment plant. For the purposes of this FFS, a temporary onsite water treatment system is assumed. An onsite treatment system would likely require clarification, filtration, and chemical conditioning components prior to the direct discharge to the Milwaukee Harbor under an individual WPDES permit. Further considerations for water treatment could include reducing the number of hours per day of dredge production, while maintaining water discharge for treatment at 24 hours per day. After completion of the dredging activities, the amount of water generated will decrease substantially.

Large debris (greater than approximately 1.5 feet) would need to be removed using mechanical means. Because the amount of debris in the project area has not been quantified, additional surveying such as side-scan sonar and magnetometer surveys may be required prior to remedial action. In addition, a pre-dredge bathymetric survey will be conducted to serve as the baseline for sediment quantities. Periodic bathymetric surveys during sediment removal would be performed to verify that the designed target dredge elevations are being attained. The type of survey or method to confirm target elevations would be determined during the design.

It is assumed for the purposes of cost estimating that continuous turbidity monitoring will be required for regulatory compliance during dredging at established upstream and downstream locations. For the purposes of this evaluation, four monitoring stations have been assumed to be installed at the following general locations: upstream extent of OU1 within the Menomonee River; in the Milwaukee River upstream of its confluence with the Menomonee River; downstream of OU2; and downstream of the dredge. During the removal of NAPL-impacted sediments within OU2, silt curtains or an alternative method will be deployed around the active dredge to contain suspended sediments and sheens generated by the dredging.

Post-dredging sediment verification sampling would be performed to assess the success of dredging to meet the RAOs. It is anticipated that post-dredge sampling would be conducted within pre-established management units that subdivides the project area and performed in accordance with the post-dredge management plan developed during design.

Upon meeting the requirements set forth in the post-dredge management plan, a 0.5-foot thick residual sand cover would be placed within the dredge extents. A residual sand cover places clean sand from an offsite source over the area from which contaminated sediment has been removed. This layer will serve to lower the concentrations of COCs in post-dredge residuals generated from sediment re-suspension and settling within the dredged area. The sand cover will also serve to accelerate re-establishment of aquatic organisms and benthic communities disrupted during the dredging activities. The selected placement methods will provide a controlled application by either casting or directly placing the sand cover material allowing it to accumulate while avoiding displacement or initial mixing with underlying sediment. The final thickness of the residual sand cover will be verified using bathymetric surveys comparing against the surveyed post-dredge surface or sampling methods such as coring or pan testing.

Cover placement will not exceed the USACE requirements for working in the navigation channel or the existing pre-dredge sediment elevations, so there will not be a net increase in the cross-sectional flow area of the river. Therefore, cover placement will not negatively impact flooding potential and conveyance within the river. As discussed in Section 2.1, the project area is primarily depositional, and sediments from the Menomonee and Milwaukee Rivers are expected to deposit within the project area following dredge activities.

5.1.2 OU2 NAPL-Impacted Sediment Removal

Alternatives 2 through 5 have the same remedial footprint and removal volume in OU2. Sediment removal in OU2 targets the NAPL-impacted sediments in areas NAPL-A and -B that are primarily outside of the authorized navigational channel and are anticipated to be hydraulically dredged as described in Section 5.1.1. NAPL-impacted sediments within area NAPL-A were identified from 3.5 feet bss to native clay at 18.9 feet bss (elevation 550.2). The estimated NAPL-A removal volume assumes removal to the native clay, with a 2:1 side slope and a 0.5-foot overdredge allowance. NAPL-impacted sediments within area NAPL-B are assumed to be removed laterally from the shoreline sheet pile wall towards the navigation channel to native clay (0.2 to 14.2 feet bss or elevation 544.8 to 558.9, respectively) with an additional 0.5-foot overdredge allowance. The up and downstream extents of NAPL-B assume a 2:1 side slope to tie into the existing sediment surface.

Portions of NAPL-A and -B include areas immediately adjacent to the railroad bridge pier where old pilings exist, and immediately adjacent to and underneath overhanging docks, as well as several areas of utility crossings. Prior to and during removal of NAPL-impacted sediments, the areas are expected to be addressed with practices and measures to reduce the downstream transport of turbidity and NAPL generated sheens while maintaining constructability. Such practices are expected to include sheet pile, oil booms, turbidity curtains and/or bubble curtains. These measures will be developed and configured in the design process to adequately address environmental concerns while avoiding utilities and allowing marine vessels into and out of the work area, thereby allowing various remedial operations to commence. NAPL- impacted sediment deposits near critical structures and utilities are assumed to be dredged without the cutterhead and hydraulically "vacuumed". In addition, a cleanup pass using a plain-suction hydraulic dredge is anticipated to manage residuals prior to the placement of a 0.5-foot residual sand cover.

For the purposes of this evaluation, it is assumed that the NAPL-impacted sediment slurry will be pumped into geotextile tubes staged at the existing Jones Island CDF for passive dewatering and stabilization. Usage of the tubes will also segregate the NAPL-impacted sediments from the existing CDF sediments. Water released from the geotextile tubes would be collected within the existing CDF and upon completion of sediment dewatering the geotextile tubes could be left in place and covered or taken offsite for disposal. The final disposition of the NAPL-impacted sediments within the existing CDF will be based on further coordination with the USACE and Port of Milwaukee during remedial design.

5.1.3 OU2 In Situ Stabilization of NAPL-Impacted Sediments Subalternative

Alternatives 2 through 5 include the option for ISS treatment of the two areas of NAPL-impacted sediments (NAPL-A and NAPL-B) that are targeted for removal in OU2, as discussed in Section 5.1.2 and shown in Figure 9. Three to four borings will be conducted during the design to collect samples from the two NAPL areas for bench-scale testing to establish reagent mix designs that solidify the material and reduce the contaminant mobility and bioavailability. It is anticipated that compression strength and leachability tests will be also be performed and could take 2 to 3 months to complete.

Prior to implementing ISS during the remedial action, approximately 2,100 cubic yards of sediment within the top 3 feet and USACE navigation channel of NAPL-A and -B areas will be removed. This will allow for material expansion during ISS to occur (typically 15 to 25 percent) without exceeding the existing sediment surface, thus no impacts to the depth requirements within the authorized navigation channel that overlaps with the NAPL-B area will occur. Dredged material would be processed and disposed of as described in the dredging alternatives. Approximately 42,500 cubic yards of in situ sediment over approximately 114,000 square feet (2.6 acres) will then be treated with ISS. Stabilization material will be combined into a slurry, based on the mix design developed during bench-scale testing, and pumped into a large auger for in situ mixing within the sediment column. For cost-estimate purposes, it is assumed that the reagent/sediment mixture will consist of 15 percent reagent, of which 75 percent is blast furnace slag, and 15 percent is Portland cement. ISS will be performed to the full depth of sediment within the NAPL-delineated boundaries and into the top foot of the native clay below.

Upon completion of ISS treatment, a 12-inch layer of clean sand cover will be placed over the entirety of the NAPL areas to facilitate re-establishment of a benthic community and to act as an isolation cap over NAPL-impacted sediments where ISS treatment may not be able to be performed.

Long-term monitoring would be required to verify the effectiveness of the treatment and accompanying isolation cap. For this FFS, it is assumed that five monitoring events will be required, once every 5 years. Monitoring will include bathymetric surveys and visual inspection.

5.2 Alternative 1—No Action

A no-action alternative is typically included in the assembly of alternatives for comparison purposes. Under Alternative 1, there would be no remedial actions conducted to control contaminant exposure. All sediments are left in place, no containment is completed, and no further action is performed. This alternative does not provide any specific response actions for environmental monitoring, controlling the migration of contaminants, or mitigating their concentrations. Existing institutional controls such as fish consumption advisories and BUIs would be required to remain in place. Natural degradation of contaminants is not likely to occur at a measurable rate or within a reasonable time period, although contaminated sediments may be covered by deposition of sediment at urban background concentrations over time.

5.3 Alternative 2

Alternative 2 is essentially a navigational dredging option and is different than the rest of the alternatives in that:

- Alternative 2 is the only alternative that targets the former navigation depth in Reach 4 of OU1 (upstream of 16th Street).
- Alternative 2 is the only alternative that does not incorporate the removal of the AOIs into the targeted dredge footprint and removal depth.

Alternative 2 is based on the removal depth of 24.5 feet LWD, which is 3.5 feet deeper than the former and current navigation channel depth in OU1 Reaches 4 and 5, respectively, of the Menomonee River. Residual sand cover placement in OU1 is assumed to be placed within the entire dredge footprint.

The removal depth accounts for the following:

- 1 foot of overdredge allowance beyond the authorized depth of 21 feet LWD (elevation 557 NAVD88).
- 2 feet of clearance from the residual sand cover surface per USACE recommendations for navigation channels.
- 0.5 foot of depth for application of the residual sand cover.

As with all alternatives:

- The sediment removal, offsite CDF disposal, and residual sand cover methodology is described in Section 5.1.
- Mechanical dredging with offsite CDF disposal was also evaluated for cost comparative purposes and is described in Section 5.3.1 below. Figure 10 depicts the conceptual plan for sediment removal within OU1 and OU2.

Sediments removed from OU1 are assumed to be disposed of at the newly proposed CDF facility as discussed in Section 5.1. Because of the significant volume to be removed from OU1, offsite disposal would be cost prohibitive. Costs were developed for both disposal of the NAPL-impacted sediment in the existing CDF and at an offsite landfill. Utilization of the existing CDF for disposal of NAPL-impacted sediments would be pending further evaluation and discussion with the Port of Milwaukee and USACE.

The total estimated volume of sediment to be dredged in this alternative is approximately 394,000 cubic yards over 21.5 acres, as summarized in Table 8. An estimated 86,000 cubic yards (about 22 percent of total volume) of coarse-grained material could be separated during hydraulic dredging for potential CDF capacity savings and beneficial reuse. Alternative 2 assumes approximately 329 days to complete hydraulic dredging and sediment handling activities at the CDF.

5.3.1 Mechanical Dredging and CDF Disposal Option

Dredging of the sediment was also evaluated using mechanical methods consisting of backhoes and cranes outfitted with environmental and clamshell buckets on floating barges. The dredge buckets would be positioned using GPS. An environmental dredge bucket would provide a smooth, level cut during the closing cycle and would contain escape valves or vents so that when the bucket is withdrawn from the water, the excess water is released, but the dredged sediment is retained. A clamshell bucket would be used for removal of dense sediment or debris. The dredge material would be placed in watertight scows and transported to a temporary barge-docking platform to be constructed at the CDF for offloading. At the docking platform, the sediment would be pumped as a slurry into the CDF for implementation of sand segregation processes within a closed-loop water system, thereby reducing water for treatment. If sand segregation was not implemented free water on top of the sediment could be pumped directly from the barge for treatment, and then sediment would be offloaded by an excavator. For the purposes of this evaluation, it was assumed that a single dredge supported by three scows and two tugs would be utilized requiring approximately 717 days to complete mechanical dredging activities.

5.4 Alternative 3

Alternative 3 differs from Alternative 2 by incorporating the recent deauthorization of the navigation channel in OU1 Reach 4 (upstream of 16th Street) by targeting AOIs as follows:

- SD-R3-04 = 572.8 (5.2 feet LWD). A vertical cut at the edge of the excavation is assumed due to the shallow removal thickness instead of the typical 2:1 side slope allowance.
- SED103 = 562.7 (15.3 feet LWD)
- SD-R4-10 = 564.6 (13.5 feet LWD)

In Reach 5, Alternative 3 targets the removal depth of 24.5 feet LWD, which is 3.5 feet deeper than the authorized navigation depth with additional removal performed in six AOIs. Target removal depths in the six Reach 5 AOIs, represented by locations SD-R5-01, SD-R5-04, SD-R5-05, SD-R5-12, SD-R5-13, and SD-R5-14, are based on the native clay surface enabling removal of COCs with concentrations exceeding their respective three times PEC values. Native clay elevations at each of these AOI locations are as follows:

- SD-R5-01 = 551.5 (26.5 feet LWD)
- SD-R5-04 = 554.8 (23.2 feet LWD)
- SD-R5-05 = 553.3 (24.7 feet LWD)
- SD-R5-12 = 552.7 (25.3 feet LWD)
- SD-R5-13 = 552.0 (26 feet LWD)
- SD-R5-14 = 550.0 (28 feet LWD)

As with all alternatives the sediment removal, offsite CDF disposal, and residual sand cover are to be performed as described in Section 5.1. Mechanical dredging with offsite CDF disposal was also evaluated for cost comparative purposes and is described in Section 5.3.1. Figure 11 depicts the conceptual plan for sediment removal within OU1 and OU2. Sediment removal extent updates are only applicable to OU1, as described above. Sediment removal in OU2 is consistent with Alternative 2.

Residual sand cover placement in OU1 is the same as Alternative 2, over the entire dredge footprint. The total estimated volume of sediment to be dredged in this alternative is approximately 244,800 cubic yards over 19.3 acres (Table 8) and approximates 204 days to complete hydraulic dredging and sediment handling activities at the CDF, compared to 445 days for the mechanical dredge option. An estimated 36,000 cubic yards (about 15 percent of total volume) of coarser-grained material could be separated during hydraulic dredging for potential CDF capacity savings and beneficial reuse.

5.5 Alternative 4

Alternative 4 is different from Alternative 3 in that OU1 Reach 5 is dredged to the authorized navigational depth of 21 feet LWD with an overdredge allowance of 1 foot (22 feet LWD) instead of 3.5 feet below the navigation depth.

As with all alternatives sediment removal, offsite CDF disposal, and residual sand cover are to be performed as described in Section 5.1 and the sediment removal footprint in OU2 is the same. Mechanical dredging with offsite CDF disposal was also evaluated for cost comparative purposes and is described in Section 5.3.1. An additional option of mechanical dredging with offsite landfill disposal was also evaluated for cost comparison within this alternative and is described in the following subsection. Figure 12 depicts the conceptual plan for sediment removal within OU1 and OU2.

Residual sand cover is not assumed to be placed outside of the AOIs downstream of 16th Street or within AOI location SD-R5-04 due to the USACE requiring 3.5 feet of clearance below the authorized dredge elevation of 21 feet LWD. Sand cover within OU2 is consistent with Alternative 2. The total estimated volume of sediment to be dredged in Alternative 4 is approximately 157,900 cubic yards over 19.3 acres (Table 8) and approximates 132 days for hydraulic dredging and sediment handling activities at the CDF compared to 287 days for the mechanical dredge option. An estimated 22,000 cubic yards (about 14 percent of total volume) of coarser-grained material could be separated during hydraulic dredging for potential CDF capacity savings and beneficial reuse.

5.5.1 Landfill Disposal Option for Mechanical Dredging

Dredged sediment to be disposed of in an offsite landfill would require dewatering and stabilization to meet transportation and landfill requirements. The dredged sediment would be mechanically mixed with a suitable drying agent on an upland dewatering pad or in the material scow. Potential upland areas for dewatering and sediment stabilization activities include a designated area within the newly proposed CDF or a series of adjacent properties owned by the city of Milwaukee and Department of Transportation located along the north shore of the Menomonee River adjacent to the I-94 overpass bridge (Figure 12). A temporary water treatment system would be installed to treat water from the dewatering process for discharge directly to the river under the appropriate regulatory permits or to the local wastewater treatment facility. Water that may require treatment would be generated from the following sources:

- Dewatering pad drainage from sediment
- Free water on top of sediment in the barge
- Backwash from the treatment system
- Decontamination water
- Precipitation on the dewatering pad

The components needed to treat the collected wastewater before discharge would be determined during the remedial design; however, for the purposes of this evaluation, it was assumed that the water treatment system would be sized for 100 gallons per minute and would include an asphalt-lined sump, mixing frac tank, an oil/water separator, inclined plate clarifier, sand filters, bag filters, a granular activated carbon treatment system, an effluent holding tank, and a discharge pump. Regular sampling of wastewater would be conducted to verify that the requirements for discharge are met.

After the sediments are sufficiently dewatered for transportation and landfill placement, they would be loaded onto trucks and transported to a Resource Conservation and Recovery Act Subtitle D landfill. Depending on the landfill requirements, a paint filter test would be performed on the sediments prior to loading into the trucks and after the trucks arrive at the landfill.

Haul roads may be required to be constructed and maintained at the upland staging facility. Trucks transporting materials offsite would be required to have sealed gates and retractable tarp. Trucks would be required to be decontaminated after loading and prior to leaving the site. After the completion of the dewatering project, the pad materials will be removed and trucked to the offsite landfill disposal.

5.6 Alternative 5

Under Alternative 5, the sediment removal in OU1 is associated with the nine AOIs and are not based on the current or former navigation channel. The sediment removal, offsite CDF disposal, and residual sand cover are to be performed as described in Section 5.1 and mechanical dredging in OU1 with offsite CDF versus landfill disposal options were also evaluated for cost-comparative purposes and are described in Section 5.3.1 and 5.5.1, respectively. Figure 13 depicts the conceptual plan for sediment removal within OU1 and OU2.

Residual sand cover placement in OU1 is assumed to be placed within AOIs only, except for AOI location SD-R5-04 due to the dredge elevation being shallower than the USACE clearance requirements. Sand cover is not assumed to be placed outside of the AOIs downstream of 16th Street due to the USACE requiring 3.5 feet of clearance below the authorized dredge elevation of 21 feet LWD. Sand cover within OU2 is consistent with Alternative 2. The total estimated volume of sediment to be dredged under Alternative 5 is approximately 123,400 cubic yards over 10.2 acres (Table 8) and is estimated to require approximately 103 days for hydraulic dredging and sediment handling activities at the CDF compared to 224 days for the mechanical dredge option. An estimated 17,000 cubic yards (about 14 percent of total volume) of coarser-grained material could be separated during hydraulic dredging for potential CDF capacity savings and beneficial reuse.

5.6.1 Deauthorization of Reach 5 of the Menomonee River

The extent of dredging for Alternative 5 is limited to the AOIs and is not based on the current or former navigation channel. However, areas outside of the AOIs within the federal navigational channel could be dredged to the authorized depth by the USACE or adjacent property owner in the future. Because future dredging could potentially expose buried contaminated sediment as well as incur additional costs associated with special handling or disposal, the restriction on dredging activities BUI is not addressed.

Reach 4 of the Menomonee River was recently deauthorized. The deeply buried contamination is stable and is expected to be subjected to further deposition; therefore, the possibility of contaminants being exposed or dredged is minimal, and the restriction on dredging activities BUI can be removed.

Reach 5 of the Menomonee River is an authorized federal navigation channel that is not used for commercial shipping (up to the entrance of the South Menomonee Canal) and is not currently being maintained to the authorized depth by the USACE. There is also no future commercial use anticipated for the navigation channel. However, the federal navigational channel designation means that this segment could be dredged by the USACE in the future. Dredging the federal navigational channel would require removal of contaminated sediment and may expose currently buried contamination, as discussed in the conceptual site model. With the federal navigation channel serving no current or desired future purpose, local stakeholders will pursue the deauthorization of the federal navigational channel in Reach 5 of the Menomonee River. With the channel deauthorized, implementing Alternative 5 would then support moving towards the removal of the restriction on dredging activities BUI. Deauthorizing the navigation channel would preclude future dredging by the USACE, places an additional level of permanence on the remedy, and reduces costs associated with the management and disposal of contaminated sediment.

SECTION 6

Detailed Analysis of Alternatives

The detailed analysis provides the relevant information required for comparing the remedial alternatives for the Menomonee and Milwaukee Rivers site. The detailed analysis of alternatives precedes the selection of a remedy. The detailed evaluation is presented below and follows the alternatives as structured in Section 5. Detailed analysis of alternatives consists of the following components:

- A detailed evaluation of each individual alternative against evaluation criteria
- A comparative evaluation of alternatives with respect to the evaluation criteria

6.1 Evaluation Criteria

The remedial alternatives developed in Section 5 were evaluated using the criteria described below to support selection of a recommended remedy. The criteria were established to provide grounds for comparison of the relative performance of the alternatives and to identify their advantages and disadvantages. This approach is intended to provide sufficient information for adequately comparing the alternatives and selecting the most appropriate alternative for implementation at the site as a remedial action. The criteria are divided into three groups: threshold, balancing, and modifying criteria, summarized as follows.

Threshold Criteria

- Compliance with applicable regulations and permits

Balancing Criteria

- Short- and long-term effectiveness in protecting human health and the environment
- Engineering implementability, reliability, constructability, and technical feasibility
- Ability to contribute to BUI removal
- Cost

Modifying Criteria

- Stakeholder and community acceptance

6.1.1 Threshold Criteria

Threshold criteria must be met by a particular alternative for it to be eligible for selection as a remedial action. There is little flexibility in meeting the threshold criteria—either they are met by a particular alternative, or that alternative is not considered acceptable. The single threshold criterion is compliance with applicable federal, state, and local regulations. To be eligible for selection, an alternative must meet applicable federal, state, and local regulations, or justification must be provided that a waiver is appropriate.

6.1.1.1 Compliance with Federal, State, and Local Regulations

Compliance with applicable federal, state, and local regulations is one of the statutory requirements of remedy selection. Applicable regulations are cleanup standards, standards of control, and other substantive environmental statutes or regulations. Applicable requirements address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a site.
The assessment with respect to this criterion describes how the alternative complies with applicable federal, state, and local regulations or presents the rationale for waiving an applicable requirement.

The identification of potentially applicable regulations and associated permits relative to the remedial alternatives is summarized in Appendix C.

6.1.2 Balancing Criteria

Unlike the threshold criteria, the balancing criteria weigh the trade-offs between alternatives. A low rating on one balancing criterion can be compensated for by a high rating on another criterion. The four balancing criteria described in the following subsections are used to weigh the trade-offs between alternatives.

6.1.2.1 Long- and Short-Term Effectiveness in Protecting Human Health and the Environment

This criterion reflects the emphasis on implementing remedies that will ensure protection of human health and the environment in the long term as well as in the short term. A remedy is protective if it adequately eliminates, reduces, or controls current and potential risks posed by the site through each exposure pathway. The assessment of alternatives with respect to this criterion includes the evaluation of the risks at a site during the construction and implementation of a remedy (short term) and after completing a remedial action or enacting a no-action alternative (long term).

Long-Term Effectiveness

The long-term criterion evaluates the adequacy of the alternative to protect human health and the environment until RAOs are achieved. This includes evaluation of the timeframe to meet RAOs and achieve removal of BUIs in the project area, the amount of residual contamination anticipated to be left in-place, the reliability of long-term controls, and the potential for transport of contaminated sediment following the remedial action. A key component of this evaluation is to consider the extent and effectiveness of controls that may be required to manage risk posed by residual or untreated contaminants. As a measurement of effectiveness SWAC calculations were performed representing post remedial conditions following dredging and sand cover placement. A summary of the SWAC methodology and results is within Appendix D.

Short-Term Effectiveness

The short-term criterion assesses the effects of the alternative during its construction and implementation. Potential risks included for consideration against this criterion are as follows: protection of workers during the remedial action, protection of community during the remedial action, and environmental impacts of the remedial action.

6.1.2.2 Engineering Implementability, Reliability, and Constructability

This criterion evaluates the ease of implementation, reliability, constructability, availability of goods and services needed for its implementation materials, as well as the ease of constructing the remedial action.

6.1.2.3 Contribution to BUI Removal

This criterion will evaluate the alternatives for their contribution to removing the seven BUI restrictions linked to the contaminated sediment within the Milwaukee Estuary AOC:

- Restrictions on fish and wildlife consumption
- Degradation of fish and wildlife populations
- Fish tumors or other deformities
- Bird or animal deformities or reproduction problems
- Degradation of benthos
- Restriction on dredging activities
- Loss of fish and wildlife habitat

6.1.2.4 Cost

Cost encompasses the engineering, construction, and operations and maintenance costs incurred over the life of the project. The assessment, with respect to this criterion, is based on the estimated present worth of the costs for each alternative. Present worth is a method of evaluating expenditures such as for construction and operations and maintenance that occur over different lengths of time. This allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented. The present worth of a project represents the amount of money, which if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action. These estimated costs are expected to provide an accuracy of plus 50 percent to minus 30 percent. Appendix E provides a breakdown of the cost estimate for each alternative, including the alternative options described in Section 5 and organized within the cost estimate as follows:

- Alternative 2A – Hydraulic Dredging/CDF Disposal
- Alternative 2B – Mechanical Dredging/CDF Disposal
- Alternative 3A – Hydraulic Dredging/CDF Disposal
- Alternative 3B – Mechanical Dredging/CDF Disposal
- Alternative 4A – Hydraulic Dredging/CDF Disposal
- Alternative 4B – Mechanical Dredging/CDF Disposal
- Alternative 4C – Mechanical Dredging/Landfill Disposal
- Alternative 5A – Hydraulic Dredging/CDF Disposal
- Alternative 5B – Mechanical Dredging/CDF Disposal
- Alternative 5C – Mechanical Dredging/Landfill Disposal

Estimated costs for the OU2 subalternative implementing ISS treatment are included within the detailed cost backup tables provided for each alternative option and reported as a separate line item within the cost comparison summary within Appendix E.

The level of detail required to analyze each alternative with respect to the cost criteria depends on the nature and complexity of the site, the types of technologies and alternatives being considered, and other project-specific considerations. The analysis is conducted in sufficient detail to understand the significant aspects of each alternative and to identify the uncertainties associated with the evaluation.

The cost estimates presented for each alternative have been developed strictly for comparing the alternatives. The final costs of the project and the resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, the implementation schedule, and other variables; therefore, final project costs will vary from the cost estimates. Because of these factors, project feasibility and funding needs must be reviewed carefully before specific financial decisions are made or project budgets are established to help ensure proper project evaluation and adequate funding.

The cost estimates are order-of-magnitude estimates with an intended accuracy range of plus 50 to minus 30 percent. The range applies only to the alternatives as they are described and does not account for changes in the scope of the alternatives. Selection of specific technologies or processes to configure remedial alternatives is intended not to limit flexibility during remedial design but to provide a basis for preparing cost estimates. The specific details of remedial actions and cost estimates would be refined during the final design.

6.1.3 Modifying Criteria

The modifying criteria are stakeholder and community acceptance. For comparative purposes, the probability of public acceptance was considered.

6.2 Alternative Analysis

Alternatives 1 through 5 were evaluated in detail using the threshold and balancing evaluation criteria described above. Table 9 summarizes the detailed evaluations for these alternatives.

6.2.1 Comparative Analysis

This section presents the comparative analysis of the alternatives to evaluate the relative ranking of each alternative with respect to the criteria described in Section 6.1 and summarized in Table 9. A ranking system of high, medium, and low was used for each criterion, where "high" indicates that the alternative is well-suited to meet the objectives of the criterion, and "low" indicates that the alternative does not satisfy the criterion objectives well. Balancing criteria may not be of equal weight, and rankings are not absolute. For instance, a ranking of low does not mean the alternative does not satisfy the criterion, but are relative rankings as compared to the other alternatives. Similarly, a high ranking means the alternative does a better job of satisfying the criterion than the other alternatives. The results of the comparative analysis are summarized below in Exhibit 4.

Exhibit 4. Comparative Analysis of Remedial Alternatives
Menomonee and Milwaukee Rivers Focused Feasibility Study

Criterion	Alternative 1 No Action	Alternative 2	Alternative 3	Alternative 4	Alternative 5
1. Compliance with applicable federal, state, and local regulations					
	N/A	High	High	High	High
2. Short- and Long-term Effectiveness in Protecting Human Health and the Environment					
(a) Overall protection of human health and the environment	Low	Low	Medium	High	High
(b) Protection of workers during remedial action	N/A	Medium	High	High	High
(c) Protection of community during remedial action	N/A	Medium	High	High	High
(d) Minimization of environmental impacts during remedial action	N/A	Low	Medium	High	High
(e) Magnitude of residual risks	Low	Low	Medium	High	High
(f) Adequacy and reliability of controls	Low	Low	Medium	High	High
(g) Minimization of transport of contaminated sediments downstream	Low	Low	Medium	High	High

Exhibit 4. Comparative Analysis of Remedial Alternatives
Menomonee and Milwaukee Rivers Focused Feasibility Study

Criterion	Alternative 1 No Action	Alternative 2	Alternative 3	Alternative 4	Alternative 5
3. Engineering Implementability, Reliability, and Constructability					
(a) Implementability	High	Medium	Medium	High	High
(b) Reliability	High	Medium	Medium	High	High
(c) Constructability	High	Medium	Medium	High	High
4. Ability to Contribute to Removal of BUIs					
(a) Potential for removal of BUI: Restrictions on fish and wildlife consumption	Low	Low	Medium	High	High
(b) Potential for removal of BUI: Degradation of fish and wildlife populations	Low	Low	Medium	High	High
(c) Potential for removal of BUI: Fish tumors or other deformities	Low	Low	Medium	High	High
(d) Potential for removal of BUI: Bird or animal deformities or reproduction problems	Low	Low	Medium	High	High
(e) Potential for removal of BUI: Degradation of benthos	Low	Low	Medium	High	High
(f) Potential for removal of BUI: Restriction on dredging activities	Low	High	High	High	High[a]
(g) Potential for removal of BUI: Loss of fish and wildlife habitat	Low	Medium	Medium	Medium	High
5. Total Cost[b]					
	High	Low	Low	Medium	Medium

Notes:

[a] Assumes that local stakeholders successfully obtain deauthorization of the federal navigational channel within Reach 5 of the Menomonee River.

[b] The cost ranking criteria are based on the alternatives ability of satisfying the cost criterion relative to the other alternatives. Therefore, the alternative(s) with the highest cost have the lowest ranking for meeting the criterion, and the lowest cost alternative is ranked highest.

6.3 Recommended Alternative

The project stakeholders have identified Alternative 5 as the preferred alternative to address the NAPL-impacted sediment in OU2 and contaminated sediment in OU1, concurrent with deauthorizing the navigation channel in Reach 5 of the Menomonee River. The selection of Alternative 5 is based on the conceptual site model, a comparative analysis of alternatives, stakeholder input, and professional judgement, which are summarized in the following subsections.

6.3.1 Rationale for Recommended Alternative

The distribution of contamination in the Menomonee River can be explained by the creation of the navigation channel of up to 36 feet of water depth, subsequent environmental pollution from the Milwaukee Harbor and associated canal system being a worldwide hub for industry, maintenance dredging of the navigation channel to a depth of 21 feet (or less), and substantial deposition in the estuarine conditions. Deposition occurs at an average rate of 0.2 foot per year and over a 21-year period accumulated an estimated 187,000 cubic yards.

This site history is reflected in the sediment core chemistry data. The highest concentrations are found in the oldest and deepest sediment, at the depths between the base of the original channel depth (approximately 36 feet) and the maintenance dredging depth (21 feet). These elevated concentrations are often greater than 3 times the PEC for most of the COCs. This is particularly true in Reach 4 of the Menomonee River.

The sediment concentrations for COCs at depth are generally above the PEC and background levels, primarily for lead and PAHs. In a majority of instances, the surface and near-surface sediment has the lowest concentration of contaminants. For these reasons, none of the alternatives attempt to dredge all the contaminated sediment to the native clay. The AOIs were established based on the review of sediment core chemistry data and focused on high concentrations at and near the surface, as discussed in Section 3.3.4. Because of the site history, a break between the elevated COC concentrations and apparent cleaner sediment could not be delineated in the core data from most AOIs and, therefore the targeted dredging will extend to native clay.

6.3.2 Recommended Alternative

- Alternative 5 is the most effective and efficient at achieving the site-specific RAOs and overall protection of human health and the environment over Alternatives 1, 2, 3, and 4. Removal of sediments from AOIs in OU1 and NAPL-impacted sediment in OU2 results in post-dredge SWAC estimates for COCs at or below their respective PEC values. Placement of a residual sand cover further reduces surface COC concentrations, redistribution potential, and exposure to dredge residuals.
- Alternative 5 has the lowest removal volume of Alternatives 2 through 4 and is more protective than Alternatives 1, 2, and 3. Alternative 5 provides the same level of protectiveness as Alternative 4 with 34,500 cubic yards (22 percent) less volume of material needing removal and management. By targeting dredging based on AOIs instead of depths relative to the navigation channel, more protection is achieved and less of the older contamination located deeper within the navigation channel has the potential to be exposed. A lower volume of removal would also maximize CDF capacity and require the lowest cost for implementation.
- Alternative 5 has the least area of impact by focusing on the removal of sediments with the greatest surface and near surface concentrations, thereby reducing potential risk from elevated COC concentrations in subsurface sediments exposed during dredging. The smaller footprint also

reduces the amount of disturbance, residual transport, and environmental impacts, as well as temporary impacts to the benthos and fish and wildlife habitats.

The completed project will satisfy regulatory requirements and ensure that the specified remediation goals are achieved, short- and long-term risks to human health and the environment in the project area are addressed, and progress is made toward removal of BUIs in the Milwaukee Estuary AOC.

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Tables

Table 1. Bathymetry Differential Comparison Summary

Menomonee and Milwaukee Rivers Focused Feasibility Study

Top	Bottom	Differential Surface[a]				Measurement Uncertainty Range[b] (0.5 to -0.5 ft)		Scour[c] (<-0.5 ft)			Deposition[d] (>0.5 ft)			Delta Volume[e]	Deposition Rate	
Surface	**Surface**	**Min (ft)**	**Max (ft)**	**Avg (ft)**	**Area (sf)**	**Area (sf)**	**%**	**Area (sf)**	**Area %**	**Vol (cy)**	**Area (sf)**	**Area %**	**Vol (cy)**	**(cy)**	**(cy/yr)**	**(ft/yr)**
OU1																
2002	1996	-11.2	16.0	1.8	1074403	203924	19%	161856	15%	-8378	708623	66%	70184	61806	10301	0.32
2011	2002	-5.4	7.5	1.6	1030751	178942	17%	128636	12%	-3900	724792	70%	54984	51084	5676	0.18
2015	2011	-4.8	5.3	1.0	1037159	258456	25%	53283	5%	-1659	725420	70%	25811	24153	6038	0.21
2017	2015	-5.0	4.5	0.6	1120620	414895	37%	52378	5%	-1231	653347	58%	12109	10877	5439	0.21
2017	1996	-5.3	17.4	5.0	1086891	73369	7%	59098	5%	-1877	954424	88%	184604	182728	8701	0.23
OU2																
2002	1996	-6.9	8.6	0.3	854099	260699	31%	259851	30%	-9472	333549	39%	18261	8790	1465	0.07
2011	2002	-4.9	9.2	1.1	836492	242680	29%	158973	19%	-3806	434839	52%	33702	29896	3322	0.15
2015	2011	-3.8	5.5	0.9	832586	291787	35%	38748	5%	-756	502038	60%	17979	17224	4306	0.21
2017	2015	-6.0	4.2	0.3	802745	339280	42%	100639	13%	-4118	362827	45%	8262	4144	2072	0.12
2017	1996	-5.9	11.2	2.6	790250	139024	18%	86802	11%	-2956	564424	71%	70858	67903	3233	0.13

Notes:

[a] Differential surface values are representative of shared lateral extent between top and bottom bathymetric surfaces.

[b] The 0.5 to -0.5 foot differential interval represents an area of relative sediment stability and potential uncertainty for survey measurement comparisons. This range is excluded from scour and deposition area, volume, and rate calculations.

[c] Scour represents quantities with <-0.5 foot of differential from comparison of top surface to bottom surface.

[d] Deposition represents quantities >0.5 foot of differential from comparison of top surface to bottom surface.

[e] Volume difference of respective scour and deposition volumes.

Abbreviations:

% = percent
< = less than
> = greater than
cy = cubic yards
ft = foot (feet)

OU1 = Operable Unit 1
OU2 = Operable Unit 2
sf = square feet
Vol = volume
yr = year

Table 2. Sediment Analytical Summary Statistics

Menomonee and Milwaukee Rivers Focused Feasibility Study

	Total PCBs mg/kg	Total PAH-18 mg/kg	Arsenic mg/kg	Cadmium mg/kg	Chromium mg/kg	Lead mg/kg	Mercury mg/kg
PEC[a]	0.676	22.8	33	5	110	130	1.1
3x PEC[a]	2.028	68.4	99	15	330	390	3.3
OU1 Summary Statistics							
Surface and Near Surface Sediment (0-1.7 ft bss)							
Min	0.016	0.65	0.96	0.20	7.9	8.4	0.01
Max	0.45	154.0	22.60	13.20	362.0	478.0	4.11
Average	0.17	37.2	6.75	2.65	68.2	132.4	0.32
Median	0.10	33.4	5.72	2.11	51.5	102.0	0.17
Standard Deviation	0.15	31.0	3.92	2.67	65.49	105.0	0.58
No. of Samples	19	63	56	56	56	56	56
PEC EF[b]	0/19 (0%)	42/63 (67%)	0/56 (0%)	6/56 (11%)	8/56 (14%)	17/56 (30%)	2/56 (4%)
3x PEC EF[b]	0/19 (0%)	7/63 (11%)	0/56 (0%)	0/56 (0%)	1/56 (2%)	3/56 (5%)	1/56 (2%)
Subsurface Sediment (>1.7 ft bss to Native Clay)							
Min	0.01	0.01	1.1	0.1	3.4	3.0	0.0
Max	6.80	264.0	39.3	19.6	517.0	848.0	8.9
Average	0.66	61.1	9.4	5.5	126.6	269.7	0.6
Median	0.19	45.5	7.7	3.3	106.0	231.0	0.4
Standard Deviation	1.2	55.5	6.2	4.8	102.8	189.4	0.7
No. of Samples	89	312	267	267	267	267	267
PEC EF[b]	24/89 (27%)	219/312 (70%)	1/267 (0%)	115/267 (43%)	128/267 (48%)	194/267 (73%)	33/267 (12%)
3x PEC EF[b]	8/89 (9%)	108/312 (35%)	0/267 (0%)	8/267 (3%)	9/267 (3%)	77/267 (29%)	3/267 (1%)
Native Clay							
Min	0.01	0.06	1.2	0.2	8.2	6.0	0.0
Max	0.24	59.2	7.5	2.6	79.1	104.0	0.7
Average	0.05	6.2	4.4	1.2	23.7	19.8	0.2
Median	0.01	0.7	4.6	1.2	19.3	8.5	0.2
Standard Deviation	0.1	12.9	1.9	0.6	15.9	24.9	0.2
No. of Samples	7	26	26	26	26	26	26
PEC EF[b]	0/7 (0%)	3/26 (12%)	0/26 (0%)	0/26 (0%)	0/26 (0%)	0/26 (0%)	0/26 (0%)
3x PEC EF[b]	0/7 (0%)	0/26 (0%)	0/26 (0%)	0/26 (0%)	0/26 (0%)	0/26 (0%)	0/26 (0%)

Table 2. Sediment Analytical Summary Statistics

Menomonee and Milwaukee Rivers Focused Feasibility Study

	Total PCBs mg/kg	Total PAH-18 mg/kg	Arsenic mg/kg	Cadmium mg/kg	Chromium mg/kg	Lead mg/kg	Mercury mg/kg
PEC[a]	0.676	22.8	33	5	110	130	1.1
3x PEC[a]	2.028	68.4	99	15	330	390	3.3
OU2 Summary Statistics							
Surface and Near Surface Sediment (0-1.7 ft bss)							
Min	0.015	0.01	1.23	0.14	7.2	4.1	0.04
Max	1.31	258.6	16.20	6.76	208.0	473.0	0.87
Average	0.23	17.8	4.21	1.40	57.9	108.2	0.24
Median	0.03	4.5	3.52	0.90	40.2	62.2	0.14
Standard Deviation	0.35	41.7	2.73	1.53	52.52	116.1	0.25
No. of Samples	36	48	28	28	28	28	28
PEC EF[b]	6/36 (17%)	8/48 (17%)	0/28 (0%)	2/28 (7%)	4/28 (14%)	7/28 (25%)	0/28 (0%)
3x PEC EF[b]	0/36 (0%)	3/48 (6%)	0/28 (0%)	0/28 (0%)	0/28 (0%)	1/28 (4%)	0/28 (0%)
Subsurface Sediment (>1.7 ft bss to Native Clay)							
Min	0.02	0.01	1.2	0.2	8.3	4.1	0.0
Max	9.05	6,386.9	36.2	14.5	909.0	5,380.0	4.3
Average	0.57	138.3	10.9	4.7	200.7	278.2	0.9
Median	0.08	8.3	7.6	2.9	152.0	216.0	0.6
Standard Deviation	1.2	581.7	8.0	4.1	183.2	534.5	0.8
No. of Samples	142	194	99	99	99	99	99
PEC EF[b]	36/142 (25%)	67/194 (35%)	2/99 (2%)	39/99 (39%)	60/99 (61%)	70/99 (71%)	35/99 (35%)
3x PEC EF[b]	11/142 (8%)	38/194 (20%)	0/99 (0%)	0/99 (0%)	16/99 (16%)	14/99 (14%)	2/99 (2%)
Native Clay							
Min	0.02	0.00	1.1	0.1	4.7	5.1	0.0
Max	0.04	6.3	5.2	0.9	21.5	107.0	0.2
Average	0.03	0.6	2.1	0.5	14.4	13.2	0.1
Median	0.02	0.1	1.5	0.6	13.4	8.1	0.1
Standard Deviation	0.0	1.4	1.2	0.2	4.1	22.8	0.0
No. of Samples	25	38	19	19	19	19	19
PEC EF[b]	0/25 (0%)	0/38 (0%)	0/19 (0%)	0/19 (0%)	0/19 (0%)	0/19 (0%)	0/19 (0%)
3x PEC EF[b]	0/25 (0%)	0/38 (0%)	0/19 (0%)	0/19 (0%)	0/19 (0%)	0/19 (0%)	0/19 (0%)

Notes:

[a] Probable effect concentration (PEC) values per the Wisconsin Department of Natural Resources (WDNR) Consensus-Based Sediment Quality Guidelines (CBSQG), December 2003. Yellow shading represents results greater than the PEC. Red shading represents results greater than 3x the PEC.

[b] PEC exceedance frequency (EF) summary presents the number of exceedances compared to the total number of samples and exceedance frequency in parentheses.

Abbreviations:

ft bss = feet below sediment surface; PEC = probable effect concentration; mg/kg = milligrams per kilogram; EF = Exceedance Frequency

Table 3. Summary of Permitted Discharges

Menomonee and Milwaukee River Focused Feasibility Study

Figure ID	Site Name	Site Address	Permit Type	Permit	Permittee	Permit Status
1	Wisconsin Paperboard Corp.	1514 E Thomas Avenue	MS4 Industrial	S067849 - Storm Water Industrial Tier 1 Permit	Wisconsin Paperboard Corp	6 - PERMIT COVERAGE GRANTED
11	River House Apartments	1781 North Water Street	MS4 Construction	Construction	Atlantic Realty Partners	6 - PERMIT COVERAGE GRANTED
22	North End IV	1501 N Water Street	MS4 Construction	Construction	Mandel Group	6 - PERMIT COVERAGE GRANTED
32	Fred Usinger Inc.	1030 N Old World Third Street	MS4 Industrial	S067857 - Storm Water Industrial Tier 2 Permit	Fred Usinger, Inc.	6 - PERMIT COVERAGE GRANTED
34	--	Miller Park, One Brewers Way	MS4 Municipal	S049921	Southeast WI Prof Baseball Park District	6 - PERMIT COVERAGE GRANTED
35	Ingeteam Inc.	3550 W Canal Street	MS4 Industrial	S066666 - Storm Water No Exposure	Ingeteam Inc.	9 - NO EXPOSURE CERTIFICATION
36	Rexnord - Falk Gear	3001 W Canal Street	MS4 Industrial	S067857 - Storm Water Industrial Tier 2 Permit	Rexnord Industries LLC	6 - PERMIT COVERAGE GRANTED
37	D. R. Diedrich & Co. LTD	2615 W Greves Street	MS4 Industrial	S067849 - Storm Water Industrial Tier 1 Permit	D. R. Diedrich & Co. LTD	6 - PERMIT COVERAGE GRANTED
39	Canadian Pacific Railway	504 S Layton Boulevard	MS4 Industrial	S067857 - Storm Water Industrial Tier 2 Permit	Canadian Pacific Railway	6 - PERMIT COVERAGE GRANTED
47	Standard Electric Facility Expansion	222 N Emmber Lane; Milwaukee, WI	MS4 Construction	Construction	Standard Electric Supply Company	6 - PERMIT COVERAGE GRANTED
55	Franks Auto Salvage	1144 W Bruce Street	MS4 Industrial	S059145 - Storm Water Auto Parts Recycling	Franks Auto Salvage	6 - PERMIT COVERAGE GRANTED
56	Today's Classics	1000 W Bruce Street Unit D	MS4 Industrial	S066666 - Storm Water No Exposure	Today's Classics	9 - NO EXPOSURE CERTIFICATION
57	A & D Truck and Auto Parts	450 S 11th	MS4 Industrial	S059145 - Storm Water Auto Parts Recycling	A & D Truck and Auto Parts	6 - PERMIT COVERAGE GRANTED
58	Lone Star Industries Inc	745 W Canal Street	MS4 Industrial	S066666 - Storm Water No Exposure	Lone Star Industries Inc	9 - NO EXPOSURE CERTIFICATION
64	Water Tech One	330 W Freshwater Way	MS4 Construction	Construction	Building 41 LLC	6 - PERMIT COVERAGE GRANTED

Table 3. Summary of Permitted Discharges

Menomonee and Milwaukee River Focused Feasibility Study

Figure ID	Site Name	Site Address	Permit Type	Permit	Permittee	Permit Status
66	ZURN Reed Street Yards Office Building	Global Water Technology Park	MS4 Construction	Construction	Klein Development	6 - PERMIT COVERAGE GRANTED
69	Menomonee River Stream Management, River mile 4.24 to 4.07	Along the Menomonee River from river mile 4.24 to 4.07	MS4 Construction	Construction	Milwaukee Metropolitan Sewerage Commission	6 - PERMIT COVERAGE GRANTED
70	US Postal Service Milwaukee Dist. Center	345 W St. Paul Avenue	MS4 Industrial	S066666 - Storm Water No Exposure	U S Postal Service Milwaukee Dist Cntr	9 - NO EXPOSURE CERTIFICATION
81	234 South Water Street	234 South Water Street	MS4 Construction	Construction	D & K Management Site	6 - PERMIT COVERAGE GRANTED
82	Hansen Storage Co. 1	500 S Water Street	MS4 Industrial	S066666 - Storm Water No Exposure	Hansen Storage Company 1	9 - NO EXPOSURE CERTIFICATION
83	Elementis LTP L.P.	546 S Water Street	MS4 Industrial	S066666 - Storm Water No Exposure	Elementis LTP L.P.	9 - NO EXPOSURE CERTIFICATION
87	Miller Compressing Company-Water Street	900 S Water Street	MS4 Industrial	S058831 - Storm Water Scrap Recycling	Miller Compressing Co - Water Street	6 - PERMIT COVERAGE GRANTED
--	MILWAUKEE METRO SEW DIST COMBINED	--	WPDES	0036820	MILWAUKEE METRO SEW DIST COMBINED	Municipal
--	MILLERCOORS USA LLC	--	WPDES	0000744	MILLERCOORS LLC	Industrial - EXP 9/30/2020
--	WISCONSIN ELECTRIC POWER COMPANY VALLEY POWER PLANT	--	WPDES	0000931	WISCONSIN ELECTRIC POWER COMPANY VALLEY POWER PLANT	Industrial - EXP 6/30/2023

Table 4. Summary of Bureau of Remediation and Redevelopment Tracking System Sites
Menomonee and Milwaukee River Focused Feasibility Study

Figure ID	Project Area	Site Location	Site Address	BRRTS Site Status and Type	Impacted Material	Substance Type	Contamination Type
2	Milwaukee River Downstream Reach 4	Milwaukee CTY riverview facility	1300 E Kane Place	Closed LUST	Soil	PET	Fuel Oil
5	Milwaukee River Downstream Reach 4	John Chowanec Property	2060 N Humboldt	Closed ERP	GW, Soil	PET, VOC	PAH, Chlorinated Solvents
8	Milwaukee River Downstream Reach 4	Weiss Property	926 E Kane Place	Closed ERP	GW, Soil	VOC, PET, Solid Waste	VOC, PAH, Solid Waste(MISC FILL)
9	Milwaukee River Downstream Reach 4	Tomich Riverfront Properties LLC - Bulfin Printers INC	1887 N Water Street	Closed ERP	Soil, Vapor	PET, VOC, PCB	PAH, PCB, VOC, PET(un)
10	Milwaukee River Downstream Reach 4	Gallun Site (PMO project)	1759-1881 N Water Street	Closed LUST	Soil	PET	Gas
12	Milwaukee River Downstream Reach 4	The Edge	1902 N Commerce Street	Closed ERP	GW, Soil	PET, Met	Gas, As
13	Milwaukee River Downstream Reach 4	The Edge - undeveloped	1890 N Commerce Street	Closed ERP	GW, Soil	PET, Met	PAH, As
14	Milwaukee River Downstream Reach 4	Forestry Headquarters-Lakefront Brewery	1872 N commerce Street	Closed LUST	GW, Soil	PET, Gas	PET(un) - 10k, Gas - 6k
15	Milwaukee River Downstream Reach 4	Trostel Parcels 1,2 &3	1776 N Commerce Street	Closed ERP	GW, Soil	Met, Pet, Unk	PET(un), Sulfates, Chromium
16	Milwaukee River Downstream Reach 4	Beerline B Apts	306 E Pleasant Street	Closed ERP	Soil, GW(pot.), Direct contact(pot.)	PET, VOC, Met	PAH, VOC, Pb
17	Milwaukee River Downstream Reach 4	Habhegger Auto Repair (FMR)	1693-1729 N Water Street	Open ERP	GW, Soil	VOC, PET, Met	VOC, PAH, As, Pb
18	Milwaukee River Downstream Reach 4	Murphy Industrial - Northern Lights Industries	1661 N Water Street	Closed LUST	Soil	NA	NA
20	Milwaukee River Downstream Reach 4	US Leather FMR	1635 N Water Street	Closed LUST	Soil, GW, SW, Direct Contact	PET	Gas
21	Milwaukee River Downstream Reach 4	Pfister&Vogel Tannery (NW Lot)	1551 N Water Street	Closed ERP	Soil, GW, Direct Contact	PET, VOC, Met	PAH, Chlorinated Solvents, Cr, As, Pb
24	Milwaukee River Downstream Reach 4	Laacke & Joys	1433-1475 N Water Street	Open LUST	Soil, GW(pot.)	PET, Met	Gas, Pb
25	Milwaukee River Downstream Reach 4	Office Building	1421 N Water Street	Open LUST	Soil, GW	PET, Met	PAH, PET(un), Pb
26	Milwaukee River Downstream Reach 4	Fire Boat Station - abandoned	101 W Cherry Street	Closed LUST	Soil	PET	PET(un)

Table 4. Summary of Bureau of Remediation and Redevelopment Tracking System Sites
Menomonee and Milwaukee River Focused Feasibility Study

Figure ID	Project Area	Site Location	Site Address	BRRTS Site Status and Type	Impacted Material	Substance Type	Contamination Type
27	Milwaukee River Downstream Reach 4	Wepco Brewery Parcel 2A	1434 N Commerce Street	Closed ERP	GW, Soil	PET	PAH, PET(un)
28	Milwaukee River Downstream Reach 4	Wepco Brewery Parcel 3A	N Commerce at W Cherry Street	Closed ERP	GW, Soil	PET, Met	PET(un), Metals
29	Milwaukee River Downstream Reach 4	Aloft	1230 N Old World 3rd St	Closed ERP	Soil, GW, Direct Contact, SW(pot.)	PET, Met	PAHm Pb, Hg, As
30	Milwaukee River Downstream Reach 4	Allright Parking	1201 N Edison Street	Closed LUST	Soil, GW(above es), Offsite, Free Product, Direct Contact	PET	Gas, Diesel
31	Milwaukee River Downstream Reach 4	1027 N Edison St	1027 N Edison Street	Closed ERP	GW, Soil, Direct Contact	PET, Met	PAH, Pb
33	Milwaukee River Downstream Reach 4	City Hall Square Property	123-137 E Wells	Closed ERP	Soil, Direct Contact, GW(pot.)	VOC, PET, Met	VOC, PAH, Pb, As, Metals
38	M&M FFS Site	25th St and Canal Bioretention Facility	25th and Canal	Closed ERP	Soil	PET, Met	PET(un), As, Cr, Pb
40	M&M FFS Site	Soo Line Railroad	908 W College Avenue	Closed LUST	Soil	PET	Gas, Diesel
41	M&M FFS Site	MKE CTY Central Repair Garage	2142 W Canal Street	Closed LUST	Soil	PET	PET(un)
42	M&M FFS Site	Former West Side MGP-River Sediments	200 N 25th Street	Open ERP	Other (Sediments)	PET, VOC, Met	VOC, PAH, Metals
43	M&M FFS Site	Tews Co	2001 W Mt Vernon Avenue	Closed LUST	Soil	PET	Waste oil
44	M&M FFS Site	Carpenters Training CTR/Marquette Soccer	1600-1800 W Canal Street	Open ERP	GW, Offsite, Soil	Other	Other
45	M&M FFS Site	Americology Site	1313 W Mt Vernon Avenue	Closed LUST		PET	gas
46	M&M FFS Site	MKE CTY Municipal Serv Building	1540 W Canal Street	Closed LUST	Soil	PET	Gas(Leaded)
48	M&M FFS Site	Standard Electric Supply Co.	222 N Emmber Lane	Open ERP	Soil	PET, VOC, Met,	PAH, VOC, Pb
49	M&M FFS Site	Sigma Environmental Services	1300 W Canal Street	Closed ERP			Benzo(a)pyrene, Chrysene, Pb
50	M&M FFS Site	WI DOT/Basil, Ryan	260 N 12th Street	Closed ERP	Soil, Offsite, GW, Direct, RoW	Met, PET, PCB	PCB, Gas, Pb, As
51	M&M FFS Site	Valley Power Plant Switchyard	1056 W Canal Street	Closed ERP	Soil	Met, Other	Pb, DRO

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Menomonee and Milwaukee River Focused Feasibility Study

Figure ID	Project Area	Site Location	Site Address	BRRTS Site Status and Type	Impacted Material	Substance Type	Contamination Type
52	M&M FFS Site	Balco Metals - former	1135 W Canal Street	Closed LUST	Co-Contamination, GW, Soil	PET, VOC, Met	Gas, PAH, Chlorinated solvents, Metals
53	M&M FFS Site	Wepco Valley Power PLT	1035 W Canal Street	Closed ERP	Free Product(1-3 feet), GW, Soil	PET	PET(un)
54	M&M FFS Site	Didon Grains	920 W Bruce Street	Open ERP	GW, Soil	PET	Diesel(15k)
59	M&M FFS Site	St. Mary's Cement	800 W Canal Street	Closed ERP	GW, Soil	PET, Met	PET(un), PAH, Pb
60	M&M FFS Site	Blue Circle Cement	712 W Canal Street	Closed LUST	Soil, GW(pot.)	PET	Diesel
61	M&M FFS Site	Amtrak Milwaukee Station	225 N Plankinton Avenue	Closed ERP	Soil	PET	Unknown Type
62	M&M FFS Site	Cable Marine - former	131 N 6th Street	Closed ERP	GW, Soil, Direct Contact, RoW	PET, Met	PET(un), PAH, Metals
63	M&M FFS Site	Building & Bridges Field Hdqrts	142 N 6th Street	Closed LUST	Soil	PET	Gas(leaded)
65	M&M FFS Site	Reed Street Rail yard-former	Lot 2 of 339 W Pittsburgh Avenue	Open ERP	GW, Soil	VOC, PET, Met, Food	VOC, PAH, As, Pb, Salt
67	M&M FFS Site	Reed Street Yards-former	Outlot 1 of 339 W Pittsburgh Avenue	Open ERP	GW, Soil	VOC, PET, Met, Food	VOC, PAH, As, Pb, Salt
68	M&M FFS Site	MKE Metropolitan Sewage District	260 W Seeboth St.	Open ERP	Soil, GW(pot.)	PET, PCB	PET(un), PCB, PAH
71	M&M FFS Site	US Post Office	345 W St Paul Avenue	Closed LUST	Free Product, GW, Soil	PET, VOC, Industrial Chem	Acid, VOC,Diesel, gas
72	Milwaukee River Downstream Reach 4	Towne Reality INC	508 N Plankinton Avenue	Closed LUST	Soil	PET	Gas
73	Milwaukee River Downstream Reach 4	Banc One Plaza Pavilion	501 N Water Street	Closed LUST	GW, Soil, Free Product	PET	Gas
74	M&M FFS Site	Walkers Landing Assc	412 N Plankinton Avenue	Open ERP	Soil	PET, Met	PAH, Met
75	Milwaukee River Downstream Reach 4	Minellis Brake Service/CITGO	350 N Plankinton Avenue	Closed LUST	GW, Soil	PET	Gas, Diesel, Fuel oil
76	M&M FFS Site	Sidney&Harry Hack&Julius Bernstein Trust	324 N Plankinton Avenue	Closed LUST	Soil	Met	Pb and polycyclic aromatic hydrocarbon
77	M&M FFS Site	First Place Milwaukee LLC	106 W Seeboth Street	Closed ERP	Soil	PET	Gas
78	M&M FFS Site	Historic River Walk Plaza	201 N Water Street	Closed LUST	Soil	PET	Unknown Type

Table 4. Summary of Bureau of Remediation and Redevelopment Tracking System Sites

Menomonee and Milwaukee River Focused Feasibility Study

Figure ID	Project Area	Site Location	Site Address	BRRTS Site Status and Type	Impacted Material	Substance Type	Contamination Type
79	M&M FFS Site	FHS Reality	141 N Water Street	Closed LUST	Soil, Oil	PET	Unknown Type
80	M&M FFS Site	Admiral Wharf	234 S Water Street	Open ERP	GW(pot.), Soil, Vapor(pot.), Other(Soil vapor)	PET, Met, VOC	Metals(RCRA), As, Pb, Gas, VOC, PAH, PET(un)
84	M&M FFS Site	MKE CTY Sewer Project	600 S Water Street	Closed ERP	Soil	PET	PET(un)
85	M&M FFS Site	CTY MKE, Erie Street Plaza	665 E Erie Street	Closed ERP	Soil, Vapor	PET, VOC, Met	PAH, Chlorinated Solvents, Pb
86	M&M FFS Site	CTY MKE, Parking Lot	642 E Erie Street	Closed ERP	Soil	PET, VOC, Met	PAH, Chlorinated Solvents, Pb
3, 4	Milwaukee River Downstream Reach 4	Lazenby Property FMR	2114 2134 N Riverboat Road	Open ERP	GW, Soil, Other(potential)	VOC, PET, Met, Other	VOC, PAH, Pb, Other
6, 7	Milwaukee River Downstream Reach 4	Walkers Landing Apts	2056-2070 N Riverboat Road	Open ERP	Soil	PET, VOC	PAH, VOC

Abbreviations:

As = arsenic
COM = commercial property
Cr = chromium
CTY MKE = City of Milwaukee
DRO = diesel range organics
ERP = environmental remediation project
Gas = both leaded and unleaded unless otherwise specified
GW = groundwater
LUST = leaking underground storage tank
Met = metals
NA = not applicable
PAH = polynuclear aromatic hydrocarbons
Pb = lead
PET = petroleum products
PET(un) = petroleum - unknown type
pot. = indicates potential impacts
RCRA = Resource Conservation and Recovery Act
RoW = contamination in right-of-way
SW = surface water
Vapor = vapor intrusion pathway
VOC = volatile organic compound

Table 5. Summary Statistics for Surface and Near Surface Datasets

Menomonee and Milwaukee Rivers Focused Feasibility Study

	Arsenic mg/kg	Cadmium mg/kg	Chromium mg/kg	Lead mg/kg	Mercury mg/kg	Total PCB mg/kg	tPAH-18 (ND=0.5xPQL) mg/kg
PEC[b]	33	5	110	130	1.1	0.676	22.8
3xPEC[c]	99	15	330	390	3.3	2.028	68.4
Menomonee River - Reach 3							
Average	2.63	1.13	16.6	33.4	0.040	0.0381	24.7
n	9	9	9	9	9	4	9
Percent Detections	56%	67%	100%	100%	89%	50%	100%
St. Dev.	1.32	0.785	10.5	18.2	0.0262	0.0412	21.3
Upper 95% C.L.[4]	3.45	1.62	23.1	44.7	0.0561	0.0866	37.9
Maximum	5.66	4.02	36.6	65	0.111	0.098	64.86
Menomonee River - Reach 4							
Average	5.34	0.908	42.2	78.9	0.112	0.15	31.3
n	11	11	11	11	11	4	19
Percent Detections	64%	82%	100%	100%	100%	100%	100%
St. Dev.	1.71	0.409	13.7	23.5	0.0433	0.0606	25.5
Upper 95% C.L.[4]	6.27	1.13	49.7	91.7	0.136	0.221	41.4
Maximum	10.2	2.55	57.4	107	0.185	0.23	74.77
Menomonee River - Reach 5							
Average	6.51	2.95	85.5	165	0.436	0.197	40.5
n	38	38	38	38	38	12	38
Percent Detections	82%	71%	100%	100%	95%	92%	100%
St. Dev.	4.26	3.11	72.6	113	0.679	0.179	34.9
Upper 95% C.L.[4]	7.68	3.8	105	196	0.622	0.29	50.1
Maximum	22.6	13.2	362	478	4.11	0.45	154.1
Menomonee River - OU1[a]							
Average	4.83	1.66	48.10	92.43	0.20	0.13	32.2
Average of 95% C.L.	5.80	2.18	59.27	110.80	0.27	0.20	43.1
Milwaukee River - OU2							
Average	4.02	1.22	56.9	99.7	0.263	0.183	14.7
n	34	34	34	34	34	43	58
Percent Detections	100%	79%	100%	100%	79%	42%	91%
St. Dev.	2.92	1.45	61.1	113	0.392	0.331	38.4
Upper 95% C.L.[4]	4.87	1.64	74.6	132	0.377	0.268	23.1
Maximum	16.2	6.76	253	473	2.03	1.31	258.6
Milwaukee River Downstream - Reach 4							
Average	5.88	2.62	241	203	0.349	2.98	14.8
n	38	38	38	38	38	38	38
Percent Detections	100%	95%	100%	100%	92%	100%	100%
St. Dev.	2.44	2.84	489	169	0.282	5.2	18.6
Upper 95% C.L.[d]	6.55	3.4	375	249	0.426	4.4	19.9
Maximum	12.2	12.5	2390	641	1.4	28.4	98.11

Source*: Foth Infrastructure & Environment, LLC. 2018. Development of Data Distributions for Background Characterization. Memorandum Rev. 2. Draft. February.*

Notes:

[a] Values presented for OU1 represent the average value of Menomonee River reaches 3 through 5.

[b] Yellow shading represents results greater than the PEC per WDNR CBSQG, December 2003.

[c] Red Shading represents results greater than 3x the PEC.

[d] The upper 95% C.L. is an upper 95% confidence bound on the true mean of the dataset. Calculations are based on a small sample Student's t-interval.

Abbreviations:

C.L. = control limit; n = number; ND = nondetect; St. Dev. = standard deviation

Table 6. Remedial Technologies Screening Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Remedial Technologies	Process Options	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Relative Cost	Screening Criteria: Public Acceptance	Screening Comment
No Action							
	None	No further actions to address contaminated sediment.	Some natural attenuation will occur as contaminants slowly biodegrade over time. COCs in sediment will be redistributed through erosion and deposition and/or covered by clean sediment. Does not meet the ROs for the project.	Not applicable.	None	Unfavorable	Required for comparison.
Natural Recovery							
	Monitored Natural Recovery (MNR)	Allow naturally occurring physical, chemical, and biological processes to reduce the bioavailability and/or toxicity of COCs to acceptable levels. Burial of contaminated sediment by cleaner sediment is occurring in both the Menomonee and Milwaukee Rivers as evidenced by the bathymetric data and sampling results.	Some natural attenuation will occur as COCs slowly biodegrade over time. Both Menomonee and Milwaukee Rivers are identified as mainly depositional areas where contaminated subsurface sediments are buried by cleaner sediment. Evaluation of background and potential sources indicate the quality of sediment currently being deposited represents typical urban background conditions.	Easily implementable. Requires coordination with USACE for bathymetric data to document sedimentation rates and distribution within the federally authorized navigation channel. In project areas with no federally authorized navigation channel, third-party bathymetric surveys would be required. Chemical analysis of sediment is not anticipated due to existing site characterization data documenting typical urban background conditions within the project area. May also require institutional controls.	Low	Unfavorable if used alone	Not retained for further evaluation. Use of MNR would require long-term monitoring and potentially contingency remedies should it prove to be ineffective in the future and there is currently no mechanism of funding these long-term operations. In addition, implementation would not support removal of BUIs in a reasonable timeframe compared to other technologies.
Sediment Removal							
	Mechanical Dredging	An environmental clamshell bucket operated either by a crane or excavator is operated from a floating barge or the shoreline is used to remove the sediment to a specified dredge-cut elevation. The clamshell bucket location is controlled by GPS-integrated software for real-time positioning.	Effective. Contaminated sediment is removed from the river, eliminating the direct contact human exposure and the fish/benthic community exposure. Suspended solids that are released during the dredging activities can be minimized using engineering controls. May disrupt the fish/benthic community initially, but provides cleaner substrata.	Easily implementable but requires permits. Limitations may include removal of sediments adjacent to sheetpile walls and other shoreline structures, which may require the addition of shoreline stabilization materials following dredging activities. Also limited by transportation of dredged sediment by barges, affecting the waterway traffic, and requiring coordination with the waterway users. Debris has relatively small impact to production rate using this technology. It typically generates a greater amount of sediment residuals than other dredge methods and requires implementation of mechanical dredge BMPs and active turbidity control (e.g., silt curtains). Generates relatively small volume of water to be treated.	Moderate to High	Favorable	Retained for further evaluation.
	Hydraulic Dredging	Hydraulic dredging removes sediments with hydraulic suction to a specified dredge-cut elevation. Common hydraulic dredges include cutterhead, plain suction, pneumatic submersible pumps, and diver assisted hand-held hydraulic suctions. The dredge location and elevation is controlled by GPS-integrated software for real-time positioning. Sediments are then pumped through a pipeline to a staging area (e.g., dewatering site).	Effective. Contaminated sediment is removed from the river eliminating the direct contact, human exposure, and the fish/benthic community exposure. May release suspended solids during the dredging activities that can be minimized using engineering controls. May disrupt the fish/benthic community initially, but provides cleaner substrata.	Implementable but requires permits. Limitations may include removal of sediments adjacent to sheetpile walls and other shoreline structures, which may require the addition of shoreline stabilization materials following dredging activities. Constant monitoring of pipeline for leaks and water treatment for a relatively large volume of water from the dredged sediment needed. The dredged sediment can be readily transported through a pipeline up to the dewatering pad with limited effects on waterway traffic and, therefore, requires less coordination with waterway users. This typically generates fewer sediment residuals than mechanical dredge methods and may not require active turbidity control (e.g., silt curtains). Presence of debris can severely reduce production rate.	Moderate to High	Favorable	Retained for further evaluation and subject to a staging area of appropriate size and proximity to project site. Potential staging areas include an upland area on property owned by the City of Milwaukee or on the existing CDF.

Table 6. Remedial Technologies Screening Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Remedial Technologies	Process Options	Description	Screening Criteria: Effectiveness	Implementability	Relative Cost	Public Acceptance	Screening Comment
Residuals Management							
	Residual Management Cover	After sediment removal, a 6-inch cover layer of clean sand is placed over the residual material to reduce the contaminant concentrations to which biota are exposed. This clean cover layer is not a cap because the clean cover is intended to mix with the dredge residuals and dilute the concentration, not to encapsulate the underlying sediment. Placement of a cover layer can effectively reduce the residual contaminant concentrations to the desired level in areas where sufficient contaminant mass has been removed.	Can effectively reduce the residual contaminant concentrations, to the desired level in areas where contaminated sediment has been removed. However, will require additional dredging to enable clean layer placement below the authorized navigational channel depth. Provides cleaner surface for the biota and may replenish the benthic community.	Easily implementable. Needs oversight to confirm that the required thickness of clean cover material is placed. Insufficient material may be ineffective.	Low to Moderate	Favorable	Retained for further evaluation in conjunction with sediment removal technologies.
Sediment Disposal							
	Offsite Disposal - Subtitle D Landfill	Disposal of dewatered sediments to an offsite facility. Characterization data collected to date demonstrates sediments with PCB concentrations less than 50 mg/kg and other constituents at levels below the RCRA hazardous waste toxicity levels allowing sediment to be permanently disposed in a non-TSCA landfill approved for special waste disposal.	Effective. Would permanently remove contaminant mass from the project site.	Local landfills within the area are approved for special waste disposal of the less than 50 mg/kg PCB-contaminated sediment and other non-hazardous waste toxicity levels. The acceptability of the sediment by the disposal facility would need to be evaluated in greater detail during remedial design.	Moderate	Favorable	Retained for further evaluation.
	Offsite Disposal - Confined Disposal Facility (CDF)	A CDF is an extension of land or an island area designed for containment of contaminated dredged sediments that provides control of potential releases of contaminants to the environment. Disposal of removed sediment prior to dewatering is placed directly into the Milwaukee Harbor CDF.	Effective. The engineering controls implemented in the CDF provide control of potential releases of contaminants to the environment and reduces or eliminates risks associated with excess sediment handling, transportation, and disposal. Verification of engineering controls may be required to confirm containment of contaminants.	Implementable, but requires negotiation and approvals from the Port of Milwaukee and USACE. CDF constraints on chemical composition of acceptable sediments and free water generated may preclude the disposal of large volumes of dredged sediments. May require removal of equivalent sediment volume from CDF to maintain capacity.	Low to Moderate. Expected to be less expensive than offsite disposal, due to savings on transportation and disposal fees.	Favorable	Retained for further evaluation. Discussions with USACE and the Port of Milwaukee have been initiated by the non-federal sponsor. The Port of Milwaukee has recently submitted an application to fund the CDF design. The CDF would be designed to provide a minimum of 460,000 cubic yards of capacity for dredge materials within the Area of Concern. The CDF expansion could be used for the non-NAPL dredged sediment and would accept materials from either hydraulic or mechanical options. The NAPL-impacted sediment could be disposed of in the existing CDF. Coordination will continue, and it is anticipated that further information will be supplied that will allow a more complete evaluation.
Sediment Dewatering							
	Mechanical Dredging – Passive Dewatering	Excess free water generated from mechanical removal of sediment is pumped from watertight scow barges to a collection sump for the onsite water treatment system. Water is then physically and chemically treated to remove contaminants before discharging it back into the river or POTW.	Dependent on the discharge criteria and the efficiency of the water treatment processes. Removes contaminants and turbidity before discharging into the river or POTW. An effluent monitoring system is required to monitor the discharge concentrations.	Limited by availability of areas for staging and construction of dewatering pad and water treatment system. Typically requires testing for the water treatment system design.	Moderate to High	Favorable	Retained for further evaluation. Potential staging areas include an upland area on property owned by the City of Milwaukee or on the existing CDF.

Remedial Technologies	Process Options	Description	Screening Criteria: Effectiveness	Implementability	Relative Cost	Public Acceptance	Screening Comment
	Hydraulic Dredging - Passive Dewatering	The sediment slurry could be pumped directly to the CDF constructed to manage dredged material. Excess water could be pumped to the POTW for treatment or an onsite water treatment system to remove solids and contaminants before discharging it back into the waterbody. Alternatively, pumping of dredged sediment slurry into geotextile tubes, containing a thickening agent, to promote drying on a dewatering pad. Excess water from sediment filtering out of geotextile tubes is collected, and directly pumped to an onsite water treatment system. It is then physically and chemically treated to remove solids and contaminants before discharging it back into the river or the POTW. The dewatered sediment is typically stabilized and/or solidified with a suitable amendment before offsite disposal. Tubes would be allowed to dewater and then be covered or opened and the material disposed offsite.	Controlled water flow from the geotextile tubes into the water treatment system. Requires pilot testing to select suitable reagent for preconditioning of the dredge slurry prior to pumping into the tubes and for stabilization. After dewatering, sediment can be easily loaded into trucks for offsite disposal or left in the CDF. Dependent on the discharge criteria and the efficiency of the treatment processes. Removes contaminants and turbidity before discharging into the river or to the POTW. An effluent monitoring system is required to monitor the discharge concentrations. Because the CDF facility was specifically designed for the management and disposal of sediments, the dewatering of sediment within the CDF would be environmentally protective.	Requires large upland staging area for geotextile tubes, extended dewatering duration and water treatment system. Constant monitoring of pipeline for leaks and water treatment for a relatively large volume of water from the dredged sediment needed. Typically requires pilot testing to select reagent and mix for sediment processing and for design of water treatment system. Pumping the sediment slurry to geotextile tube within the CDF would eliminate the need of an upland staging area and needing an onsite water treatment system prior to discharge to the POTW.	Moderate to High	Favorable	Retained for further evaluation and subject to utilization of the existing Jones Island CDF, construction of a new CDF, or a staging area of appropriate size and proximity to project site. Potential staging areas include an upland area on property owned by the City of Milwaukee or on the CDF.
Containment							
	Isolation Cap	Place one or more layers of clean material over the surface of partially dredged contaminated sediment to isolate the remaining contaminated sediment left in place and reduce the amount of contaminant flux to the environment. The isolation cap could be applicable in areas along the shoreline where existing sediment cannot be disturbed for stabilization/restoration of the shoreline. This layer of clean material acts as an isolation cap over the contaminated sediment left in place and provides long-term risk reduction to human and ecological receptors.	Can be effective if cap remains in place. This method isolates the contaminants from human and ecological receptors. This also controls the contaminated sediment from resuspending into the water column. Regular cap inspection and maintenance is required for eroded or disturbed areas. This also provides new surface for the benthic organisms. The cap dimensions and materials should be carefully designed to avoid head cutting and scouring effects. Could provide high- or low-quality habitat following capping.	Installation implementable for areas outside of federally authorized navigation channel. Installation within the federally authorized navigation channel would require the cap surface to be 3 feet below the authorized channel elevations prohibiting implementation. Requires permits and coordination with the sediment dredging part of the project. May be challenging with high river currents and may disrupt the existing dock areas and waterway users. May require some additional institutional controls. Requires staging areas closer to the remedial location.	Low to Moderate. Long-term costs include periodic monitoring of the cap and cap maintenance by a non-federal sponsor, as required.	Uncertain	Not retained for further evaluation, due to challenges with implementability and currently no mechanism of funding long-term monitoring and maintenance of an isolation cap.
	Active Cap	Active caps use various products and installation techniques to encourage fate and transport processes such as sequestration or degradation of contaminants beneath the cap and discourage recontamination of the cap. Performance goals for active caps include physical isolation of contaminated sediments, permeability control to discourage upwelling through contaminated sediment by diverting groundwater flow, contaminant migration control through sorption-related retardation and as contaminant degradation aids. Long-term monitoring and maintenance activities are required to ensure the long-term effectiveness of this remedial technology. Additionally, institutional controls may be employed. An active cap would likely be less thick than an isolation cap.	Can be effective if cap remains in place. Placement would provide immediate reduction in bioavailability and isolation to impacted sediments. Provides long-term isolation and containment of constituents within underlying sediments and reduces constituent mass/concentration by increasing sorptive capacity and/or by encouraging chemical reactions and degradation. Long-term effectiveness in isolating and reducing constituent mass/concentration would be reliant upon cap thickness, material selection, and maintenance. Since this technique is combined with partial sediment removal, the river bottom elevation will be maintained at navigable elevations and the flooding potential is not increased. Ultimately effectiveness is reliant upon erosive forces within the water body, cap thickness, and reactive material selection based on site-specific constituents.	Implementable with limitations and permits. Installation within the federally authorized navigation channel would require the cap surface to be 3 feet below the navigation channel elevation. Slower construction may be necessary to reduce placement variability of layers containing reactive materials. Most materials and equipment would likely be readily available. Placement techniques and equipment would be dependent upon site characteristics (for example, water depths, hydraulics), proximity of a remedial area to the shoreline, and cap material properties. However, mechanical equipment is required for placement of certain cap components (that is, geotextile and active mats). Filter component (that is, geotextile) placement may increase complexity of cap construction. Site constraints, such as debris within remedial areas and existing bank structures, could pose implementability concerns. Requires long-term monitoring of cap integrity and to verify that active cap material component has not been exhausted.	Moderate to High. Reactive materials could be costly. Long-term costs include periodic monitoring of the cap and cap maintenance by a non-federal sponsor, as required.	Uncertain	Not retained for further evaluation, due to challenges with implementability and relatively higher cost than isolation cap. Ensuring long-term effectiveness would require monitoring and maintenance.

Table 6. Remedial Technologies Screening Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Remedial Technologies	Process Options	Description	Screening Criteria: Effectiveness	Screening Criteria: Implementability	Screening Criteria: Relative Cost	Screening Criteria: Public Acceptance	Screening Comment
In Situ Treatment							
	Fixation/ Stabilization	Involves applying or mixing of an amendment into sediments through mechanical means (using augers, for instance) to immobilize contaminants by physically binding or enclosing the sediments within a stabilized mass or chemically treating these to become immobile.	In situ treatment technologies can achieve immediate risk reduction by reducing the bioavailability and mobility of a range of organic and metal contaminants in environmentally sensitive environments or in areas where sediment removal or containment by capping may not be implementable.	Implementable with limitations and requires permits. Can be implemented at discrete depth intervals to target a specific layer of impacted sediment. May allow for management of contaminated sediment adjacent to retaining and support structures, which are often aged and require structural analysis and support prior to dredging or removal activities. Requires bench-scale testing for selecting the suitable stabilization/solidification amendment. May require a protective surface structure (such as, riprap, articulated mat) depending on the strength of treated sediment and erosional forces present. Requires staging area for the storage and preparation of stabilization/solidification amendment.	Moderate to High	Uncertain	Retained for further evaluation within NAPL areas.
Ex Situ Treatment							
	Sediment Stabilization/ Solidification	Dewatered sediment is mixed with an additive (such as, fly ash, Portland cement) to decrease the leachability of contaminants and to meet transportation and disposal requirements.	Effective as a secondary dewatering technology for sediments following passive dewatering techniques. Can improve the chemical and physical properties of the sediment for disposal.	Requires mixing amendments into the sediment following excavation and passive dewatering prior to disposal. Typically requires pilot testing for selecting the suitable stabilization/solidification amendment. After stabilization/solidification, sediment will be loaded into trucks for offsite disposal.	Moderate	Favorable	Retained for further evaluation in conjunction with passive dewatering technologies.
	Particle Size Segregation	Vibrating or fixed screens, hydrocyclones, or gravity separation used to segregate particle sizes in a sediment slurry allowing separate disposal of fine-grained material with higher contaminant concentrations.	Effective. Can be a good source of fill materials for beneficial use if sufficient quantity of sands/gravels exists within sediments to be removed.	Easily implemented. Requires sediment excavation, dewatering, and staging area for implementation. The quantity of sand/gravel that exists within the dredged sediments to be further evaluated for cost effectiveness and reduction of volume of material to be disposed of. Pilot/bench-scale testing is required. Areas with NAPL impacted sediments would not be considered for this technology.	Moderate	Favorable	Retained for further evaluation .
	Sediment Washing	PCBs sorbed onto fine soil particles are separated from bulk soil in an aqueous-based system based on particle size. Wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics. Separation of small particles, which preferentially accumulate PCBs and PAHs, from the excavated sediment, in an aqueous system, allowing separate disposal of the fine-grained material with higher contaminant concentrations.	Considered a transfer technology in that the contaminants are not destroyed but transferred to another media. Consequently, the resulting concentrated sediment must be disposed of appropriately. Varying concentrations and mix of contaminants at the site creates a complex washing solution.	Requires sediment excavation. Pilot/bench-scale testing would be required. Equipment and utility requirements are substantial.	High	Uncertain	Not retained for further evaluation due to implementability and high cost concerns.
	Vitrification	Dewatered and dried sediment heated to a glass state resulting in the incineration of contaminants.	Effective. Contaminants are vaporized. Post process soil can be used for beneficial reuse.	Requires excavation and dewatering of sediments. Drying process requires large amounts of energy. Offgas vapors require collection and treatment.	High	Uncertain	Not retained for further evaluation due to implementability and high cost.

Abbreviations:

BMP = best management practice
CDF = confined disposal facility
COC = contaminant of concern
MNR = monitored natural recovery
PCB = polychlorinated biphenyl
POTW = publicly owned treatment works
RO = remedial objective
TSCA = Toxic Substance Control Act
NAPL = non-aqueous phase liquid
USACE = U.S. Army Corps of Engineers

Table 7. Post-Screening Alternative Summary

Menomonee and Milwaukee Rivers Focused Feasibility Study

General Response Action	Remedial Technology/ Process Option	Alternative 1 No Action	Alternative 2 2a	Alternative 2 2b	Alternative 3 3a	Alternative 3 3b	Alternative 4 4a	Alternative 4 4b	Alternative 4 4c	Alternative 5 5a	Alternative 5 5b	Alternative 5 5c
No Action		X										
Sediment Removal	Hydraulic Dredging		X		X		X			X		
	Mechanical Dredging			X		X		X	X		X	X
OU1 - W. Canal St. to 16th St.	Basis		Removal of sediments within former authorized navigation channel from 25th St. to 16th St.		Removal of sediments from AOIs (SD-R3-04, SED103 and SD-R4-10)		Same as Alternative 3			Same as Alternative 3		
	Removal depth		24.5 ft LWD (includes overdredge allowance and 2ft offset for sand cover placement)		Depth based on 3 times PEC exceedance		Same as Alternative 3			Same as Alternative 3		
	Side-slope allowance		2:1		2:1 or assumed vertical cuts for shallow cut thickness (2 ft or less)		Same as Alternative 3			Same as Alternative 3		
	Overdredge allowance		1 ft		0.5 ft		Same as Alternative 3			Same as Alternative 3		
	Estimated volume		174,000 yd^3		9,100 yd^3		Same as Alternative 3			Same as Alternative 3		
OU1 - 16th St. to OU2	Basis		Removal of sediments within authorized navigation channel.		Removal of sediments within navigation channel and AOIs (SD-R5-01, SD-R5-04, SD-R5-05, SD-R5-12, SD-R5-13 and SD-R5-14)		Same as Alternative 3			Removal of sediments from AOIs (SD-R5-01, SD-R5-04, SD-R5-05, SD-R5-12, SD-R5-13 and SD-R5-14)		
	Removal depth		24.5 ft LWD (Includes overdredge allowance and 2ft offset for sand cover placement)		Navigational channel: 24.5 ft LWD (Includes overdredge allowance and 2ft offset for sand cover placement) AOIs: Depth to native clay or 3 times PEC exceedance		Navigational channel: 22 ft LWD (Includes overdredge allowance) AOIs: Depth to native clay or 3 times PEC exceedance			Depth to native clay or 3 times PEC exceedance		
	Side-slope allowance		2:1		Same as Alternative 2		Same as Alternative 2			Same as Alternative 2		
	Overdredge allowance		1 ft		1 ft outside AOIs and 0.5 ft within AOIs		Same as Alternative 3			0.5 ft		
	Estimated volume		175,800 yd^3		191,100 yd^3		104,200 yd^3			69,700 yd^3		
OU2	Basis		Removal of sediment in NAPL-A and NAPL-B areas		Same as Alternative 2		Same as Alternative 2			Same as Alternative 2		
	Removal depth		Native clay		Same as Alternative 2		Same as Alternative 2			Same as Alternative 2		
	Side-slope allowance		NAPL-A: 2:1 NAPL-B: Vertical cut at shoreline and 2:1 slopes at remaining boundaries		Same as Alternative 2		Same as Alternative 2			Same as Alternative 2		
	Overdredge allowance		0.5 ft		Same as Alternative 2		Same as Alternative 2			Same as Alternative 2		
	Estimated volume		44,600 yd^3		Same as Alternative 2		Same as Alternative 2			Same as Alternative 2		
Residuals Management	Residual Sand Cover		0.5 ft over dredged area and 1 ft over ISS treatment area		Same as Alternative 2		Same as Alternative 2			Same as Alternative 2		
Sediment Transport	Slurry pipeline		X		X		X	X		X	X	
	Truck								X			X
Sediment Disposal	CDF		X		X		X	X		X	X	
	Subtitle D Landfill								X			X
Sediment Dewatering[1]	Geotextile Tubes		X		X		X			X		
Water Treatment	Treatment anticipated to include processes for removal of COCs per MMSD or WPDES permit requirements.		X		X		X		X	X		X
Ex Situ Treatment[1]	Sediment stabilization/ solidification						X	X		X	X	
	Particle Size Separation (NAPL-impacted sediment not included)		Coarse grain fraction = 41% Estimated CDF volume reduction = 86,000 cy.		Coarse grain fraction = 30% Estimated CDF volume reduction = 36,000 cy.		Coarse grain fraction = 32% Estimated volume CDF reduction = 22,000 cy.			Coarse grain fraction = 35% Estimated CDF volume reduction = 17,000 cy.		
In situ Treatment[1]	In situ stabilization (OPTIONAL)		Treatment of NAPL-A and NAPL-B areas		Same as Alternative 2		Same as Alternative 2			Same as Alternative 2		

Notes:

[1] Shaded response actions representative for OU2 NAPL sediments only and does not apply to sediments removed within OU1.

Table 8. Estimated Sediment Removal Volumes and Areas

Menomonee and Milwaukee Rivers Focused Feasibility Study

	OU1 25th to 16th St.	OU1 16th St. to OU2	OU2	Total Volume (yd^3) / Area (sf)
Alternative 2				
USACE Navigation Maintenance[a]	151,900	75,600	--	227,500
GLNPO[b]	22,100	100,200	--	122,300
NAPL removal[c]	--	--	44,600	44,600
Volume (yd^3)	174,000	175,800	44,600	**394,400**
Area (ac)	5.4	13.5	2.6	**21.5**
Alternative 3				
USACE Navigation Maintenance[a]	--	75,600	--	75,600
GLNPO[b]	9,100	115,500	--	124,600
NAPL removal[c]	--	--	44,600	44,600
Volume (yd^3)	9,100	191,100	44,600	**244,800**
Area (ac)	1.4	15.3	2.6	**19.3**
Alternative 4				
USACE Navigation Maintenance[a]	--	75,600	--	75,600
GLNPO[b]	9,100	28,600	--	37,700
NAPL removal[c]	--	--	44,600	44,600
Volume (yd^3)	9,100	104,200	44,600	**157,900**
Area (ac)	1.4	15.3	2.6	**19.3**
Alternative 5				
USACE Navigation Maintenance[a]	--	--	--	-
GLNPO[b]	9,100	69,700	--	78,800
NAPL removal[c]	--	--	44,600	44,600
Volume (yd^3)	9,100	69,700	44,600	**123,400**
Area (ac)	1.4	6.2	2.6	**10.2**

Notes:

[a] USACE navigation channel maintenance removal volumes for each alternative represent the navigational boundary to 21 feet LWD plus an overdredge allowance of 1 foot and 2:1 side slope allowance. USACE navigation channel maintenance removal within OU2 has not been added to the alternatives and is approximately 85,600 CY.

[b] GLNPO removal quantities represent additional volume for removal to meet RAOs.

[c] NAPL removal volumes represent complete removal within both OU2 NAPL areas
(NAPL-A = 7,600 CY / 0.4 ac and NAPL-B = 34,900 CY / 2.2 ac) inclusive of 2:1 side slopes and a 0.5 ft overdredge allowance.

ac = acres; yd^3 = cubic yards

Table 9. Remedial Alternative Evaluation Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Criterion	Alternative 1 No Action	Alternative 2	Alternative 3	Alternative 4	Alternative 5
1. Compliance with applicable federal, state, and local regulations	No remedial action; therefore, not applicable.	Multiple permits would be required. Compliance would be met without significant exceptions. **ISS subalternative within OU2 NAPL-A and NAPL-B areas:** Regulatory compliance is uncertain.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.
2. Short and Long-term Effectiveness in Protecting Human Health and Environment					
(a) Overall protection of human health and the environment	RAOs to reduce the potential ingestion of contaminants through fish tissue and potential for dermal contact or ingestion of contaminated sediment not likely to be met within a reasonable timeframe.	Removal of targeted sediments reduces contaminants that bioaccumulate in fish and reduces potential for dermal contact or ingestion. The removal of the contaminated sediment and placement of the residual sand cover will result in an assumed 90 percent reduction in the SWAC for COCs. Offsite disposal of contaminated sediment to the CDF or a landfill is protective of human health and the environment. **ISS subalternative within OU2 NAPL-A and NAPL-B areas:** NAPL-impacted sediments adjacent to existing shoreline features (i.e., docks, piers, etc.) are not likely to be treated with ISS due to proximity to structures and may need to be capped or removed.	Consistent with Alternative 2 except for the following: • The removal of the contaminated sediment is anticipated to result in location SD-R5-06 exceeding three times the PEC criteria for lead (505 mg/kg) and SD-R5-16 for chromium (412 mg/kg) • The post-dredge SWAC for tPAH is above the PEC level prior sand cover. Placement of the residual sand cover will reduce the post-dredge SWACs for COCs below respective PEC levels.	Consistent with Alternative 2 except for the following: • Removal of contaminated sediment is anticipated to result in a post-dredge SWAC exceeding the PEC criteria for tPAH prior sand cover. Placement of the residual sand cover will further reduce the post-dredge SWACs for COCs to below respective PEC levels.	Consistent with Alternative 2 except for the following: • The removal of the contaminated sediment prior sand cover is anticipated to result in post-dredge SWACs for COCs below respective PEC levels. Placement of the residual sand cover will further reduce post- dredge SWACs.
(b) Protection of workers during remedial action	No remedial action; therefore, not applicable.	Sediment dredging may result in potential exposure of workers via direct contact. Disposal of contaminated sediment in the CDF using a sediment slurry will reduce potential exposure via dust. Proper health and safety procedures such as use of appropriate PPE, and air monitoring procedures and engineering controls can be implemented to reduce impacts.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3 except for the following if offsite disposal at a landfill is conducted: • Processing of sediment and water treatment operations on upland dewatering pad, as well as transporting dewatered sediment to an offsite landfill may result in potential exposure to workers via direct contact or dust.	Consistent with Alternative 4.
(c) Protection of community during remedial action	No remedial action; therefore, not applicable.	Limited risks to the community during dredging and offsite disposal to the CDF due to limited access to operational areas. Dust not likely using slurry transport and pumping into CDF. If dust emissions exist air monitoring and engineering controls can be implemented to protect the community. Noise and odor control plans would protect the community from these disturbances.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3 except for the following if offsite disposal at a landfill is conducted: • Limited risks due to trucks hauling impacted material to the offsite landfill. • Decontamination of trucks used to transport contaminated materials prevents the spread of contamination along haul routes.	Consistent with Alternative 4.

Table 9. Remedial Alternative Evaluation Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Criterion	Alternative 1 No Action	Alternative 2	Alternative 3	Alternative 4	Alternative 5
(d) Minimalization of environmental impacts during remedial action	No remedial action; therefore, not applicable.	Limited environmental impacts are possible due to disturbance and resuspension of contaminated sediment into the water column. Resuspension of contaminated sediment will be monitored and managed using engineering controls during dredging. Impacts may result from discharge of temporary water treatment system, if treatment train is ineffective. Impacts may also result from work adjacent to natural shorelines. However, shoreline disturbance will be limited in this urban environment with the dominance of developed shoreline. **ISS subalternative within OU2 NAPL-A and NAPL-B areas**: To reestablish a benthic community and further minimize the exposure pathway, a sand isolation cap is assumed to be placed over the solidified mass.	Consistent with Alternative 2 except for the following: Decreased area of impact and a shorter dredge duration due to reduced sediment removal footprint and quantity as compared to Alternative 2.	Consistent with Alternatives 2 and 3 except for the following: Same removal footprint as Alternative 3, but additional decrease in dredge duration due to decreased removal quantity compared to Alternative 3.	Consistent with Alternatives 2 through 4 except for the following: Smallest dredge footprint and quantity of removal resulting in least potential environmental impact during remedial action.
(e) Magnitude of residual risks	Unchanged from existing conditions.	Sediments with greatest surface and near surface contaminant concentrations will be removed. Exposure to elevated COC concentrations exposed by the dredging will be reduced through placement of residual sand cover complemented by natural sediment deposition at background concentrations. Residual risks anticipated to be low except in areas where dredging extents expose contamination that cannot be removed due to shoreline stability and presence of utilities (does not change magnitude of contaminated sediment at depth).	Consistent with Alternative 2 except for the following: Exposure to concentrations exceeding the PEC levels in surface and near surface sediment upstream of 16th Street outside of the AOIs will remain and present low residual risks. Natural sediment deposition at background concentrations will reduce risks over time. Sediment removal is anticipated to result in location SD-R5-06 exceeding the three times PEC criteria for lead (505 mg/kg), SD-R5-16 for chromium (412 mg/kg) and a post-dredge SWAC for tPAH (prior to sand cover placement) to exceed its PEC criteria. Placement of the residual sand cover will further reduce the post-dredge SWACs for COCs to below respective PEC levels.	Consistent with Alternative 3 except for the following: Sediment removal is anticipated to result in a post-dredge SWAC for tPAH (prior to sand cover placement) exceeding its PEC criteria. Placement of the residual sand cover will further reduce the post-dredge SWACs for COCs to levels below respective PECs.	Consistent with Alternative 3 except for the following: The post-dredge SWACs for COCs are anticipated to be below respective PEC levels prior sand cover. Placement of the residual sand cover will further reduce post-dredge SWACs.
(f) Adequacy and reliability of controls	Fish consumption advisories and warnings regarding dermal contact or ingestion of contaminated sediment can reduce, but not eliminate risks.	Removal of contaminated sediment and placement of the residual sand cover can reliably reduce the overall exposure to COCs. Institutional controls may continue in the short-term, and in the long-term will likely be removed. All disposal options will provide adequate containment of the dredged sediment. **ISS subalternative within OU2 NAPL-A and NAPL-B areas:** Will require long-term maintenance and monitoring for determining reliability. Limited control over disturbance of solidified mass by human impacts.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.

Table 9. Remedial Alternative Evaluation Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Criterion	Alternative 1 No Action	Alternative 2	Alternative 3	Alternative 4	Alternative 5
(g) Minimization of transport of contaminated sediments downstream	Unchanged from existing conditions.	Usage of engineering controls (such as silt curtains and a sheetpile turbidity control structure within NAPL areas) during dredging would minimize the transportation of contaminated sediments downstream. In addition, placement of the residual cover and natural deposition will minimize transport of residuals and contaminated sediment exposed by dredging. However, contamination that remains within undredged inventory (not dredged or covered) due to the shoreline offsets and utility offsets are potentially available for transport.	Consistent with Alternative 2 except for the following: Decreased area of impact and a shorter dredge duration due to reduced sediment removal footprint and quantity as compared to Alternative 2.	Consistent with Alternatives 2 and 3 except for the following: Same removal footprint as Alternative 3, but additional decrease in dredge duration due to decreased removal quantity compared to Alternative 3.	Consistent with Alternatives 2 through 4 except for the following: Smallest dredge footprint and quantity of removal resulting in least potential environmental impact during remedial action.
3. Engineering Implementability, Reliability, Constructability, and Technical Feasibility					
(a) Implementability	No impediments.	All services and necessary materials are readily available and have been successfully implemented on similar projects. CDF disposal dependent on construction of newly proposed CDF. Coordination with local stakeholders (industry and property owners, the Port of Milwaukee, USACE Detroit District, and city of Milwaukee) will be required to limit impacts to their operations during dredging and processing operations. This coordination will be especially critical for bridge operations for barge traffic to the CDF under the mechanical dredging option. **Water Treatment:** Coordination with MMSD for wastewater discharge requirements and capacity for sediment dewatering operations. **ISS subalternative within OU2 NAPL-A and NAPL-B areas:** Portion of NAPL impacted sediment also lies within USACE Navigation Channel.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.
(b) Reliability	No impediments.	No impediments. This remedial alternative has been implemented regularly at other sites and has been proven to be reliable. **ISS subalternative within OU NAPL-A and NAPL-B areas 2:** Treatability and pilot testing will need to be performed to determine the effectiveness and implementability of ISS.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.

Table 9. Remedial Alternative Evaluation Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

Criterion	Alternative 1 No Action	Alternative 2	Alternative 3	Alternative 4	Alternative 5
(c) Constructability	No impediments.	This remedial alternative has been implemented regularly at other sites and has been proven to be constructible. NAPL-impacted sediments are anticipated to require a sheetpile turbidity control structure and oil booms to contain NAPL and manage sheens. A constructability review of this alternative would be performed as a part of the remedial design. **ISS subalternative within OU2 NAPL-A and NAPL-B areas:** ISS treatment of sediments is still an emerging technology; therefore, fewer contractors with experience in this treatment process.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.
4. Contribution to BUI Removal					
(a) Restrictions on fish and wildlife consumption	Unchanged from existing conditions.	Supportive of addressing BUI.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.
(b) Degradation of fish and wildlife populations	Unchanged from existing conditions.	Supportive of addressing BUI.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.
(c) Fish tumors or other deformities	Unchanged from existing conditions.	Supportive of addressing BUI.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.
(d) Bird or animal deformities or reproduction problems	Unchanged from existing conditions.	Supportive of addressing BUI.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Consistent with Alternatives 2 through 4.
(e) Degradation of benthos	Unchanged from existing conditions.	Temporary degradation of benthos due to dredging, but long-term positive impact.	Results in a 10% decreased removal extent, thereby reducing the temporary degradation of benthos compared to Alternative 2.	Consistent with Alternative 3.	Smallest extent of temporary degradation of benthos as compared to Alternatives 2 through 4. Alternative 5 results in a 53% decreased sediment removal extent compared to Alternative 2.
(f) Restriction on dredging activities	Unchanged from existing conditions.	Supportive of addressing BUI. Sediment removed to authorized navigational depth in Reach 5 of OU1 and NAPL-impacted sediment remediation in OU2 will eliminate additional costs due to special handling and or disposal requirements, associated with future dredging of impacted sediment within the navigation channel by the USACE or adjacent property owners.	Consistent with Alternative 2.	Consistent with Alternatives 2 and 3.	Reach 5 of the Menomonee River is currently designated as a federal navigational channel and although not currently maintained, it could be dredged to the authorized depth by the USACE in the future. To address this BUI, local stakeholders will pursue deauthorization of federal navigational channel in Reach 5 to preclude future navigational dredging in the area. With the channel deauthorized, Alternative 5 would then support moving towards the removal of this BUI. The rationale for deauthorization of the navigational channel in Reach 5 is further discussed in Section 5.6.1.
(g) Loss of fish and wildlife habitat	Unchanged from existing conditions.	Potential temporary loss of fish habitat due to dredging, but long-term positive impact. Loss of habitat expected to be limited due to urban environment dominated by developed shoreline.	Consistent with Alternative 2.	Consistent with Alternative 2 and 3.	Consistent with Alternatives 2 through 4.
5. Total Cost	$0	2A (Hydraulic Dredge / CDF disposal): $36,058,000 2B (Mechanical Dredge / CDF disposal): $66,065,000	2A (Hydraulic Dredge / CDF disposal): $24,846,000 2B (Mechanical Dredge / CDF disposal): $43,950,000	4A (Hydraulic Dredge / CDF disposal): $18,121,000 4B (Mechanical Dredge / CDF disposal): $29,563,000 4C (Mechanical Dredge / Landfill disposal): $42,214,000	5A (Hydraulic Dredge / CDF disposal): $15,654,000 5B (Mechanical Dredge / CDF disposal): $24,528,000 5C (Mechanical Dredge / Landfill disposal): $33,366,000

Figures

LEGEND

Milwaukee River Downstream Project
- Reach 4

Menomonee River Project Reaches
- Reach 3
- Reach 4
- Reach 5

FFS Project Boundary
- OU-1: Menomonee River
- OU-2: Milwaukee River
- 3rd Ward MGP Site
- Former West Side MGP Facility

N

0 850 1700
Feet

Figure 1
Project Overview Map
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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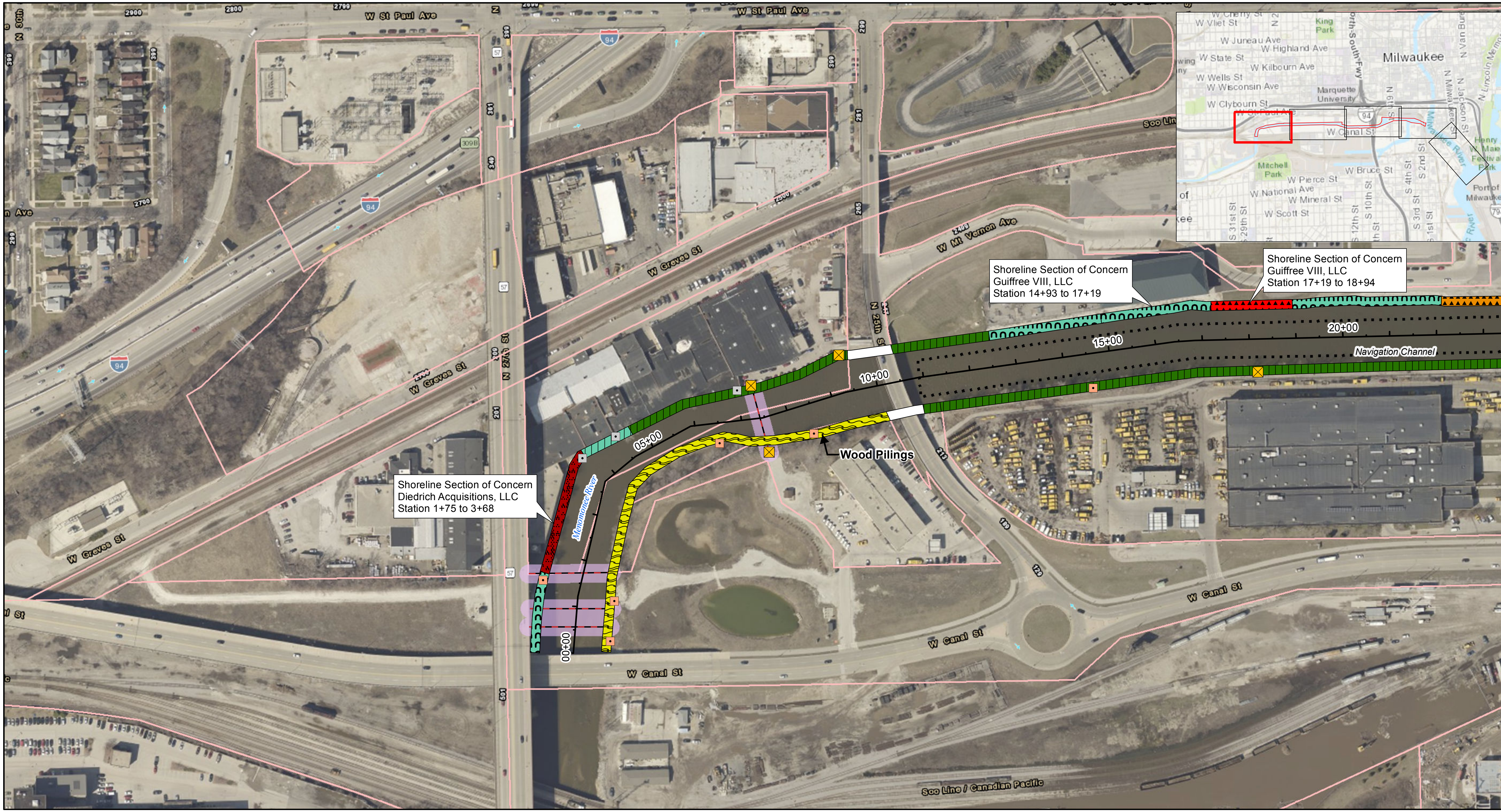

LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Parcel Boundary

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Riprap
- Steel Sheet Pile
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 100 200

Feet

Figure 2a

Shoreline Assessment

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

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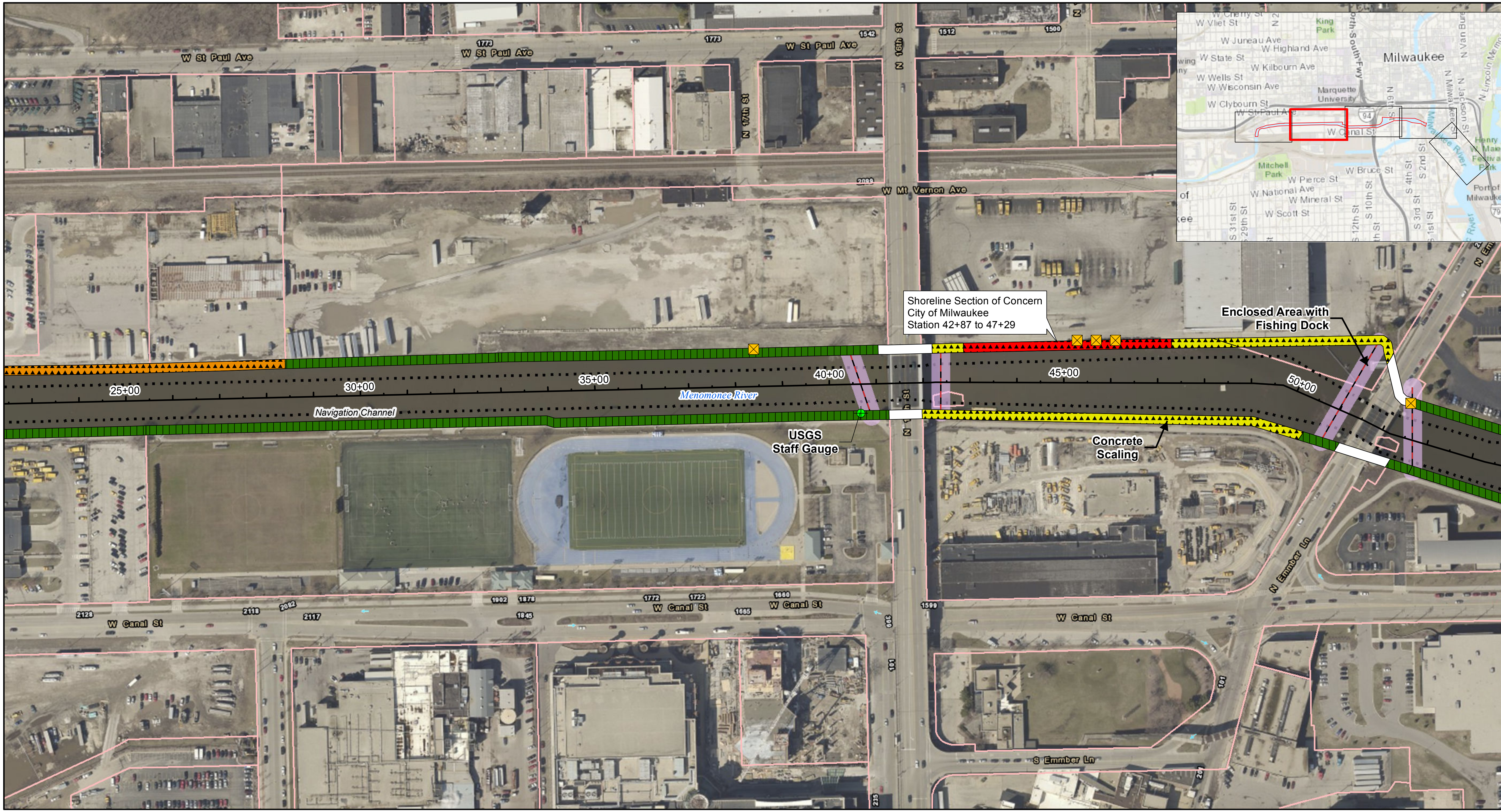

LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
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- Underground Utility with 20' Setback
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- Parcel Boundary

Bulkhead Construction

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- Concrete
- Drystack Wall
- Natural Shoreline
- Riprap
- Steel Sheet Pile
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 100 200
Feet

EPA, ESRI World Imagery

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Figure 2b
Shoreline Assessment
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

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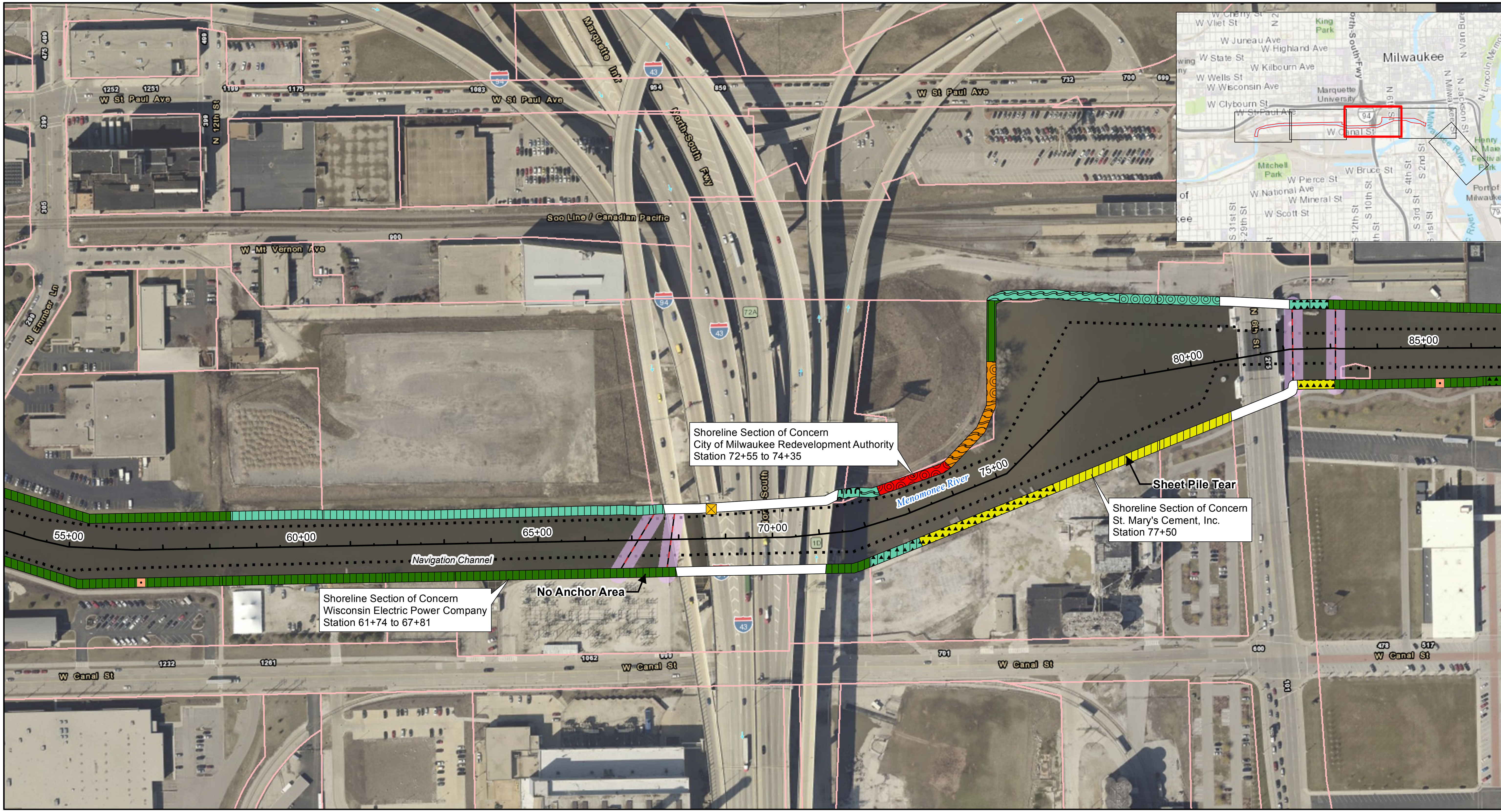

LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Parcel Boundary

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Riprap
- Steel Sheet Pile
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 100 200
Feet

EPA, ESRI World Imagery

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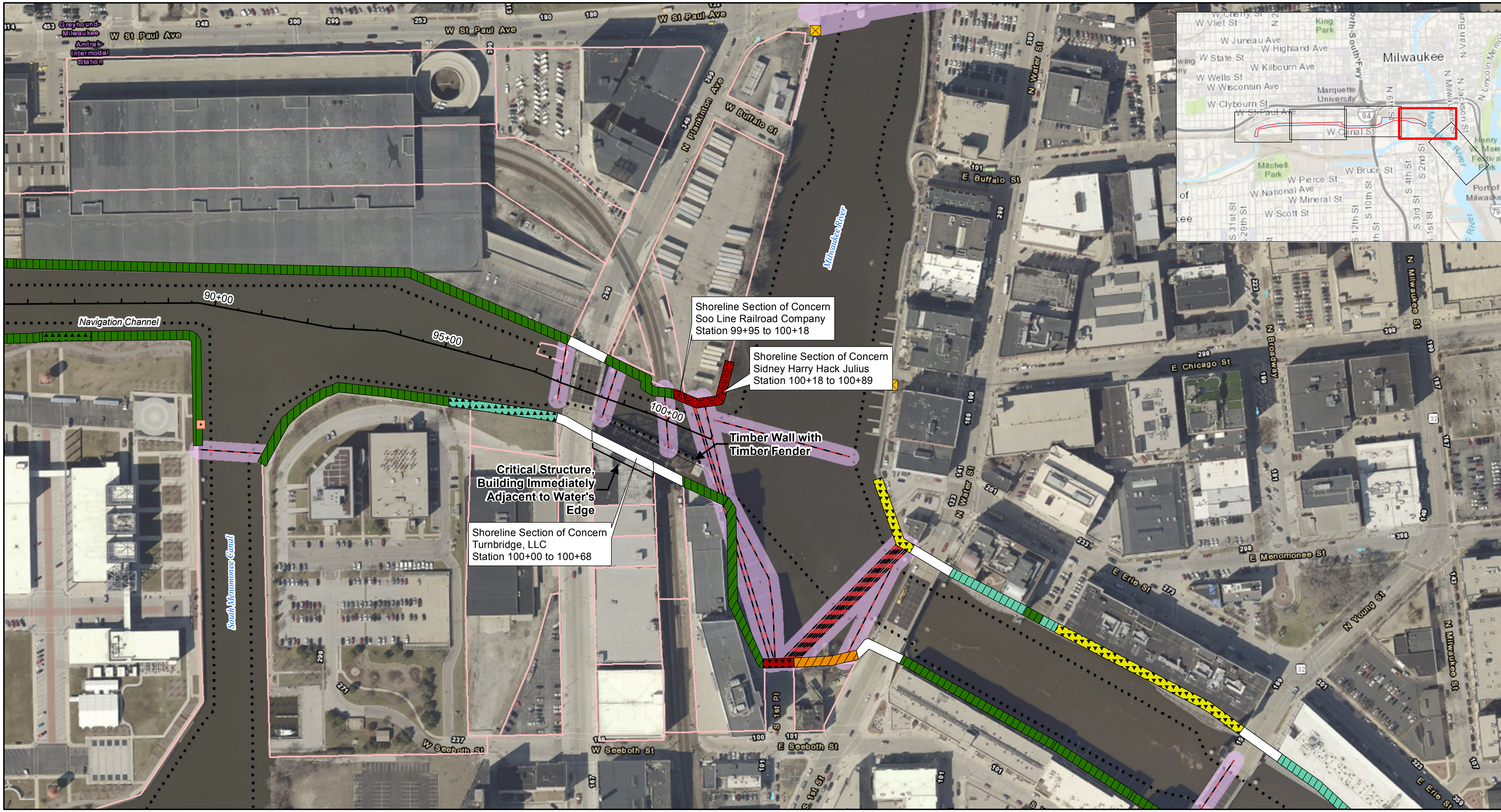
Figure 2c
Shoreline Assessment
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

ch2m



LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Parcel Boundary

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Riprap
- Steel Sheet Pile
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 100 200
Feet

EPA, ESRI World Imagery

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Figure 2d
Shoreline Assessment
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

ch2m.

LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Parcel Boundary

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Riprap
- Steel Sheet Pile
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

0 100 200
Feet

EPA, ESRI World Imagery

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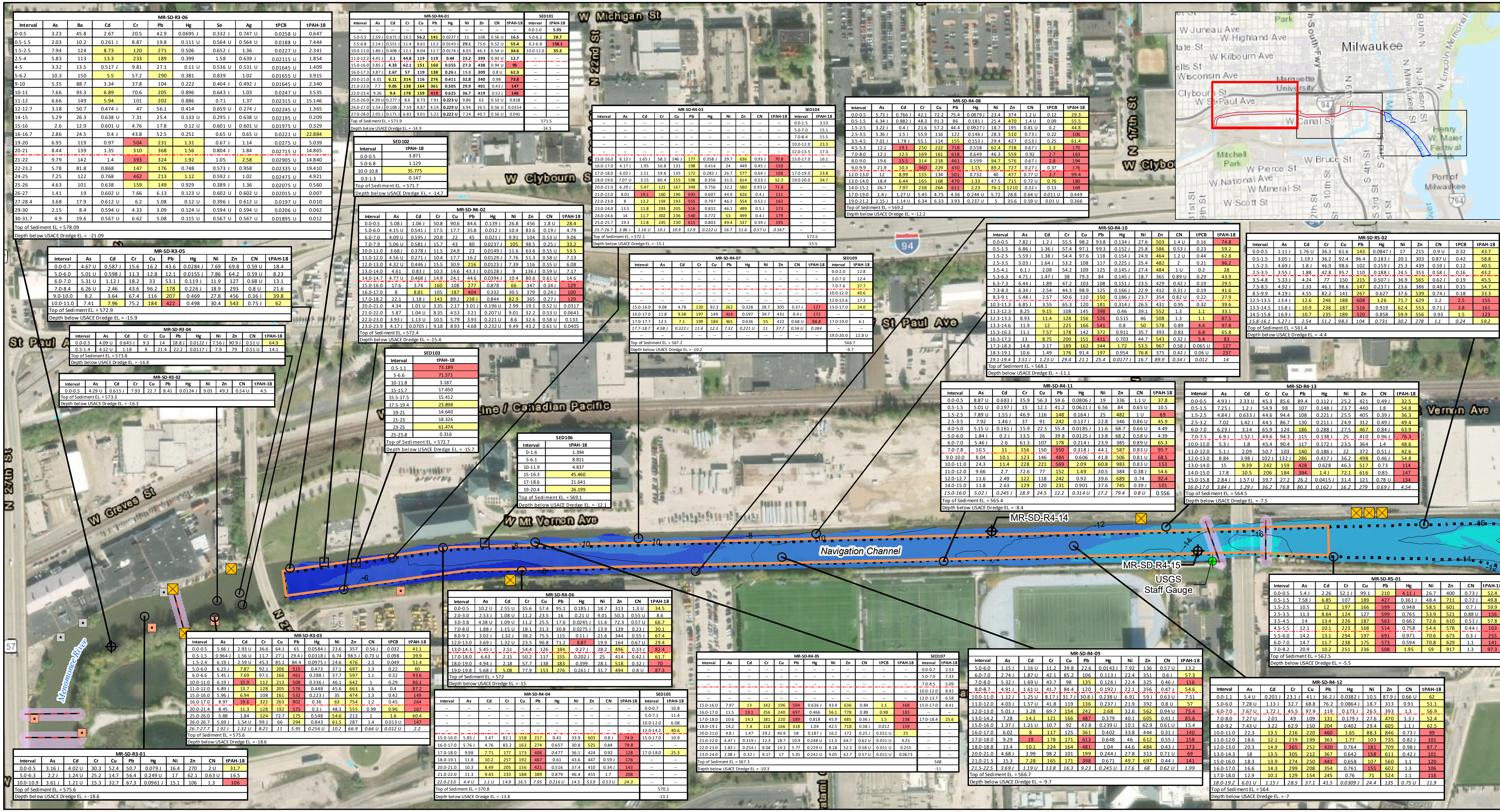
Figure 2e
Shoreline Assessment
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

ch2m



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

- Bathymetry Contour
- -2.27
- -13
- -20
- -26.83

0 150 300

Feet

General Notes:

1. All concentrations are presented in mg/kg.
2. All intervals are presented in feet below sediment surface (ft bss).
3. Location IDs beginning with "SED" = Former West Side Manufactured Gas Plant (MGP) April 2014 Sediment Investigation Results (sampling performed by Natural Resource Technology). Results are not TOC-normalized.
4. Yellow shading represents results greater than the Probable Effect Concentration (PEC). Red Shading represents results greater than 3x the PEC, Italics = native material.
5. Concentrations are screened against values listed within the Wisconsin Department of Natural Resources Consensus-Based Sediment Quality Guidelines (CBSQG), December 2003. tPCB and tPAH values are non-TOC normalized.
6. tPAH-18 includes 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(e)pyrene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-Cd)Pyrene, Naphthalene, Phenanthrene, Pyrene.
7. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
8. Top of sediment elevations referenced to NAVD88.
9. Depth's below the USACE dredge elevation are reported as feet below the USACE dredge depth of 21 feet LWD (557 NAVD88).
10. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:

AMSL = Above Mean Sea Level
ft bss = feet below sediment surface
IGLD85 = International Great Lakes Datum of 1985
LWD = Low Water Datum
NAVD88 = North American Vertical Datum of 1988
PEC = Probable Effect Concentration
- = sample not collected
= Represents depth below USACE dredge depth of 21 feet LWD in results tables.
= Implies NAPL observed within the interval range.

Figure 3a

Summary of Analytical Results

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

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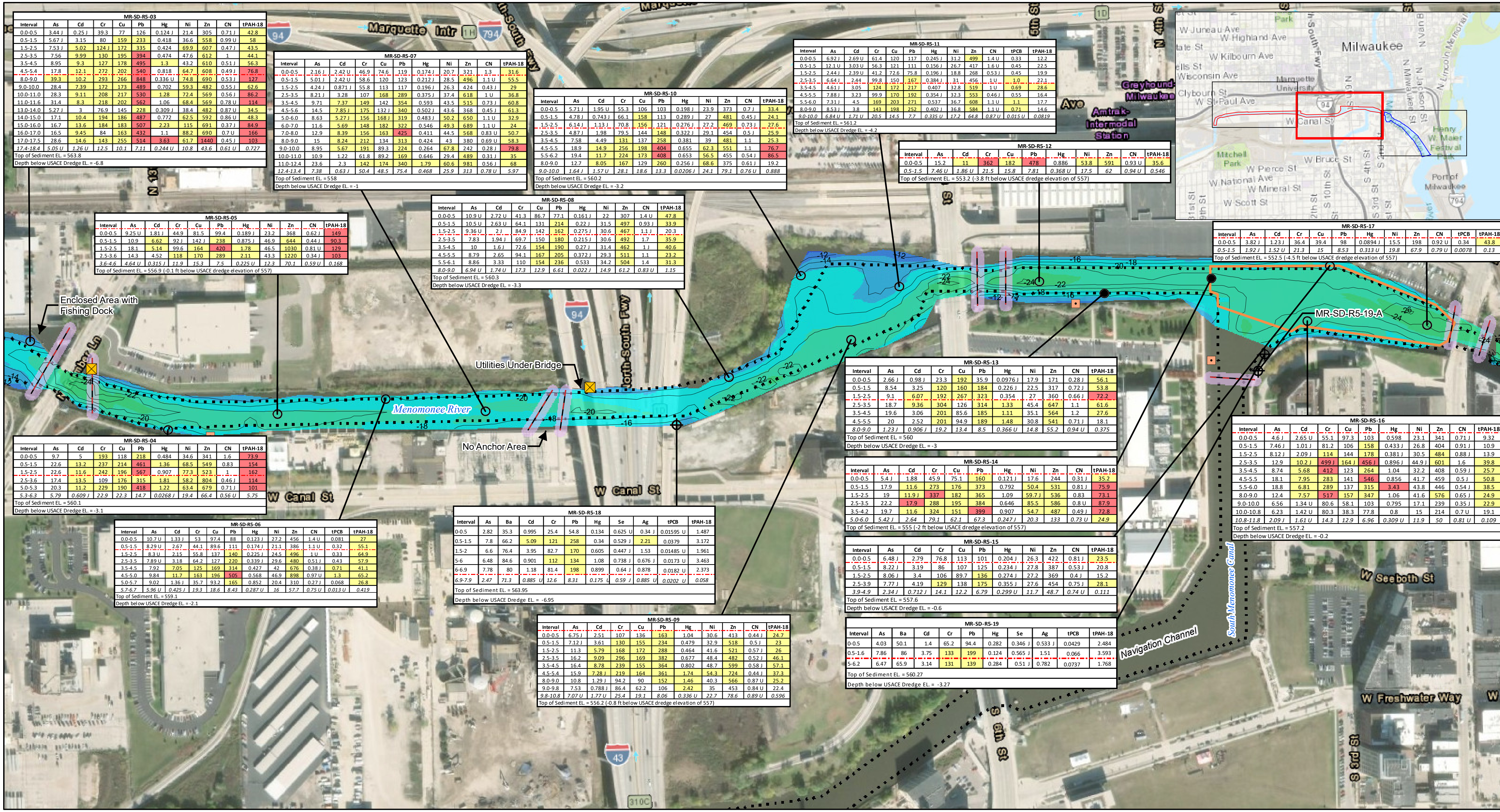

MR-SD-R5-03										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	3.44 J	0.25 J	39.3	77	126	0.124 J	21.4	305	0.71 J	42.8
0.5-1.5	5.67 J	3.15	80	159	233	0.418	36.6	558	0.99 U	58
1.5-2.5	7.53 J	5.02	124 J	172	335	0.424	69.9	607	0.47 J	43.5
2.5-3.5	7.56	9.99	130	195	394	0.474	47.6	612	1	44.1
3.5-4.5	8.95	9.3	127	178	495	1.3	43.2	610	0.51 J	56.3
4.5-5.4	17.8	12.1	272	202	540	0.818	64.7	608	0.49 J	76.8
8.0-9.0	39.3	10.2	293	266	848	0.336 U	74.8	690	0.53 J	127
9.0-10.0	28.4	7.39	172	173	489	0.702	59.3	482	0.55 J	62.6
10.0-11.0	28.3	9.11	208	217	530	1.28	72.4	569	0.56 J	86.2
11.0-11.6	31.4	8.3	218	202	562	1.06	68.4	569	0.78 U	114
13.0-14.0	5.27 J	3	76.9	145	228	0.309 J	38.4	482	0.87 U	34.5
14.0-15.0	17.1	10.4	194	186	487	0.772	62.5	592	0.86 U	48.3
15.0-16.0	16.7	13.6	184	183	507	2.23	115	691	0.37 J	84.9
16.0-17.0	16.5	9.45	84	163	432	1.1	88.2	690	0.7 U	166
17.0-17.5	28.6	14.6	143	255	514	3.63	61.7	1440	0.45 J	103
17.4-18.4	*5.05 U*	*1.26 U*	*12.5*	*10.1*	*7.11*	*0.244 U*	*10.8*	*43.6*	*0.61 U*	*0.727*
Top of Sediment EL. = 563.8										
Depth below USACE Dredge EL. = -6.8										

MR-SD-R5-07										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	2.16 J	2.42 U	46.9	74.6	119	0.174 J	20.7	321	1.3	31.6
0.5-1.5	5.01 J	2.42 U	58.6	120	123	0.212 J	28.5	496	1.1 U	55.5
1.5-2.5	4.24 J	0.871 J	55.8	113	117	0.196 J	26.3	424	0.43 J	29
2.5-3.5	8.21 J	3.28	107	168	289	0.375 J	37.4	618	1 U	36.8
3.5-4.5	9.71	7.37	149	142	354	0.593	43.5	515	0.73 J	60.8
4.5-5.6	14.5	7.85 J	175	132 J	340	0.502 J	43.6	368	0.45 J	61.3
5.0-6.0	8.63	5.27 J	156	168 J	319	0.483 J	50.2	650	1.1 U	32.9
6.0-7.0	11.6	5.69	148	182	322	0.546	49.3	689	1.1 U	24
7.0-8.0	12.9	8.39	156	163	425	0.411	44.5	568	0.83 U	50.7
8.0-9.0	15	8.24	212	134	313	0.424	43	380	0.69 U	58.3
9.0-10.0	8.95	5.67	191	89.3	224	0.264	67.8	242	0.28 J	79.8
10.0-11.0	10.9	1.22	61.8	89.2	169	0.646	29.4	489	0.31 J	35
11.0-12.4	23.6	2.3	142	174	340	1.79	60.6	981	0.56 J	68
12.4-13.4	*7.38*	*0.63 J*	*50.4*	*48.5*	*75.4*	*0.468*	*25.9*	*313*	*0.78 U*	*5.97*
Top of Sediment EL. = 558										
Depth below USACE Dredge EL. = -1										

MR-SD-R5-10										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	5.71 J	1.95 U	55.3	106	103	0.198 J	23.9	373	0.7 J	33.4
0.5-1.5	4.78 J	0.743 J	66.1	158	113	0.289 J	27	481	0.45 J	24.1
1.5-2.5	6.14 J	1.13 J	70.8	156	121	0.276 J	27.2	469	0.73 J	27.6
2.5-3.5	4.87 J	1.98	79.5	144	148	0.322 J	29.1	454	0.5 J	25.9
3.5-4.5	7.58	4.49	131	137	258	0.381	39	481	1.1	25.3
4.5-5.5	18.9	14.9	256	198	404	0.655	62.3	551	1.1	76.7
5.5-6.2	19.4	11.7	224	173	408	0.653	56.5	455	0.54 J	86.5
8.0-9.0	12.7	8.05	167	129	260	0.256 J	68.6	375	0.61 J	19.2
9.0-10.0	*1.64 J*	*1.57 U*	*28.1*	*18.6*	*13.3*	*0.0206 J*	*24.1*	*79.1*	*0.76 U*	*0.888*
Top of Sediment EL. = 560.2										
Depth below USACE Dredge EL. = -3.2										

MR-SD-R5-11											
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPCB	tPAH-18
0.0-0.5	6.92 J	2.69 U	61.4	120	117	0.245 J	31.2	499	1.4 U	0.33	12.2
0.5-1.5	12.1 U	3.03 U	56.3	121	111	0.156 J	26.7	417	1.6 U	0.45	22.5
1.5-2.5	2.44 J	2.39 U	41.2	72.6	75.8	0.196 J	18.8	268	0.53 J	0.45	19.9
2.5-3.5	6.64 J	2.44	99.8	150	167	0.384 J	31	456	1 U	1.0	22.1
3.5-4.5	4.61 J	3.05	124	172	217	0.407	32.8	519	1 U	0.69	28.6
4.5-5.5	7.88 J	3.23	99.9	170	192	0.354 J	32.3	553	0.46 J	0.55	16.4
5.5-6.0	7.31 J	4.5	169	203	271	0.537	36.7	608	1.1 U	1.1	17.7
8.0-9.0	8.53 J	3.8	143	198	252	0.402 J	36.8	584	1.1 U	0.71	14.6
9.0-10.0	*6.84 U*	*1.71 U*	*20.5*	*14.5*	*7.7*	*0.335 U*	*17.2*	*64.8*	*0.87 U*	*0.015 U*	*0.0819*
Top of Sediment EL. = 561.2											
Depth below USACE Dredge EL. = -4.2											

MR-SD-R5-12										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	15.2	11	362	182	478	0.886	53.8	591	0.93 U	35.6
0.5-1.5	*7.46 U*	*1.86 U*	*21.5*	*15.8*	*7.81*	*0.368 U*	*17.5*	*62*	*0.94 U*	*0.546*
Top of Sediment EL. = 553.2 (-3.8 ft below USACE dredge elevation of 557)										

MR-SD-R5-05										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	9.25 U	1.81 J	44.9	81.5	99.4	0.189 J	23.2	368	0.62 J	149
0.5-1.5	10.9	6.62	92 J	142 J	238	0.875 J	46.9	644	0.44 J	90.3
1.5-2.5	18.1	5.14	99.6	164	420	1.78	46.5	1030	0.81 U	129
2.5-3.6	14.3	4.52	118	170	289	2.11	43.3	1220	0.34 J	103
3.6-4.6	*4.64 U*	*0.315 J*	*11.9*	*15.3*	*7.5*	*0.225 U*	*12.3*	*70.1*	*0.59 U*	*0.168*
Top of Sediment EL. = 556.9 (-0.1 ft below USACE dredge elevation of 557)										

MR-SD-R5-08										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	10.9 U	2.72 U	41.3	86.7	77.1	0.161 J	22	307	1.4 U	47.8
0.5-1.5	10.5 U	2.63 U	64.1	131	214	0.22 J	31.5	497	0.93 J	33.9
1.5-2.5	9.36 U	2 J	84.9	142	162	0.275 J	30.6	467	1.1 J	20.3
2.5-3.5	7.83	1.94 J	69.7	150	180	0.215 J	30.6	492	1.7	35.9
3.5-4.5	10	1.6 J	72.6	154	190	0.27 J	31.4	462	1 J	40.6
4.5-5.5	8.79	2.65	94.1	167	205	0.372 J	29.3	511	1.1	23.2
5.5-6.1	8.86	3.33	110	154	236	0.533	34.2	504	1.4	31.3
8.0-9.0	*6.94 U*	*1.74 U*	*17.3*	*12.9*	*6.61*	*0.022 J*	*14.9*	*61.2*	*0.83 U*	*1.15*
Top of Sediment EL. = 560.3										
Depth below USACE Dredge EL. = -3.3										

MR-SD-R5-17											
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPCB	tPAH-18
0.0-0.5	3.82 J	1.23 J	36.4	39.4	98	0.0894 J	15.5	198	0.92 U	0.34	43.8
0.5-1.5	*1.92 J*	*1.52 U*	*21.3*	*15*	*8.53*	*0.313 U*	*19.8*	*67.9*	*0.79 U*	*0.0078*	*0.13*
Top of Sediment EL. = 552.5 (-4.5 ft below USACE dredge elevation of 557)											

MR-SD-R5-13										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	2.66 J	0.98 J	23.3	192	35.9	0.0976 J	17.9	171	0.28 J	56.1
0.5-1.5	8.54	3.25	120	160	184	0.226 J	22.5	317	0.72 J	53.8
1.5-2.5	9.1	6.07	192	267	323	0.354	27	360	0.66 J	72.2
2.5-3.5	18.7	9.36	304	126	314	1.33	45.4	647	1.1	61.6
3.5-4.5	19.6	3.06	201	85.6	185	1.11	35.1	564	1.2	27.6
4.5-5.5	20	2.52	201	94.9	189	1.48	30.8	541	0.71 J	18.1
8.0-9.0	*1.23 J*	*0.906 J*	*19.2*	*13.4*	*8.5*	*0.366 U*	*14.8*	*55.2*	*0.94 U*	*0.375*
Top of Sediment EL. = 560										
Depth below USACE Dredge EL. = -3										

MR-SD-R5-16										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	4.6 J	2.65 U	55.1	97.3	103	0.598	23.1	341	0.71 J	9.32
0.5-1.5	7.46 J	1.01 J	81.2	106	158	0.433 J	26.8	404	0.91 J	10.9
1.5-2.5	8.12 J	2.09 J	114	144	178	0.381 J	30.5	484	0.88 J	13.9
2.5-3.5	12.9	10.2 J	499 J	164 J	456 J	0.896 J	44.9 J	601	1.6	39.8
3.5-4.5	8.74	5.68	412	123	264	1.04	32.2	408	0.59 J	25.7
4.5-5.5	18.1	7.95	283	141	546	0.856	41.7	459	0.5 J	50.8
5.5-6.0	18.8	6.81	289	137	315	3.43	43.8	446	0.54 J	38.5
8.0-9.0	12.4	7.57	517	157	347	1.06	41.6	576	0.65 J	24.9
9.0-10.0	6.56	1.34 U	80.6	58.1	103	0.795	17.1	239	0.35 J	22.9
10.0-10.8	6.23	1.42 U	80.3	38.3	77.8	0.8	15	214	0.7 U	19.1
10.8-11.8	*2.09 J*	*1.61 U*	*14.3*	*12.9*	*6.96*	*0.309 U*	*11.9*	*50*	*0.81 U*	*0.109*
Top of Sediment EL. = 557.2										
Depth below USACE Dredge EL. = -0.2										

MR-SD-R5-14										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	5.4 J	1.88	45.9	75.1	160	0.121 J	17.6	244	0.31 J	35.2
0.5-1.5	17.9	11.6	273	176	373	0.792	50.4	531	0.81 J	75.9
1.5-2.5	19	11.9 J	337	182	365	1.09	59.7 J	536	0.83	73.1
2.5-3.5	22.2	17.9	288	195	384	0.646	85.5	586	0.8 U	87.9
3.5-4.2	19.7	11.6	324	151	399	0.907	54.7	487	0.49 J	72.8
5.0-6.0	*5.42 J*	*2.64*	*79.1*	*62.1*	*67.3*	*0.247 J*	*20.3*	*133*	*0.73 U*	*24.9*
Top of Sediment EL. = 555 (-2 ft below USACE dredge elevation of 557)										

MR-SD-R5-15										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	6.48 J	2.79	76.8	113	101	0.204 J	26.3	422	0.81 J	23.5
0.5-1.5	8.22 J	3.19	86	107	125	0.234 J	27.8	387	0.53 J	20.8
1.5-2.5	8.06 J	3.4	106	89.7	136	0.274 J	27.2	369	0.4 J	15.2
2.5-3.9	7.77 J	4.19	129	138	175	0.355 J	27.6	454	0.75 J	28.1
3.9-4.9	*2.34 J*	*0.712 J*	*14.1*	*12.2*	*6.79*	*0.299 U*	*11.7*	*48.7*	*0.74 U*	*0.111*
Top of Sediment EL. = 557.6										
Depth below USACE Dredge EL. = -0.6										

MR-SD-R5-19										
Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	4.03	50.1	1.4	65.2	94.4	0.282	0.346 J	0.533 J	0.0429	2.484
0.5-1.6	7.86	86	3.75	133	199	0.124	0.565 J	1.51	0.066	3.593
5-6.2	6.47	65.9	3.14	131	139	0.284	0.51 J	0.782	0.0737	1.768
Top of Sediment EL. = 560.27										
Depth below USACE Dredge EL. = -3.27										

MR-SD-R5-18										
Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	2.82	35.3	0.995	25.4	54.8	0.134	0.625 U	0.34 J	0.01595 U	1.487
0.5-1.5	7.8	66.2	5.09	121	258	0.34	0.529 J	2.21	0.0379	3.172
1.5-2	6.6	76.4	3.95	82.7	170	0.605	0.447 J	1.53	0.01485 U	1.961
5-6	6.48	84.6	0.901	112	134	1.08	0.738 J	0.676 J	0.0173 U	3.463
6-6.9	7.78	80	1.18	81.4	198	0.899	0.64 J	0.878	0.0182 U	2.373
6.9-7.9	*2.47*	*71.3*	*0.885 U*	*12.6*	*8.31*	*0.175 U*	*0.59 J*	*0.885 U*	*0.0202 U*	*0.058*
Top of Sediment EL. = 563.95										
Depth below USACE Dredge EL. = -6.95										

MR-SD-R5-09										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	6.75 J	2.51	107	136	163	1.04	30.6	413	0.44 J	24.7
0.5-1.5	7.12 J	3.61	130	155	234	0.479	32.9	518	0.5 J	23
1.5-2.5	11.3	5.79	168	172	288	0.464	41.6	521	0.57 J	26
2.5-3.5	16.2	9.09	296	169	382	0.677	48.4	482	0.52 J	46.1
3.5-4.5	16.4	8.78	239	155	364	0.802	48.7	599	0.58 J	57.1
4.5-5.4	15.9	7.28 J	219	164	361	1.74	54.3	724	0.44 J	37.3
8.0-9.0	10.8	1.29 J	94.2	90	152	1.46	40.3	566	0.87 U	25.2
9.0-9.8	7.53	0.788 J	86.4	62.2	106	2.42	35	453	0.84 U	22.4
9.8-10.8	*7.07 U*	*1.77 U*	*25.4*	*19.1*	*8.06*	*0.336 U*	*22.7*	*78.6*	*0.89 U*	*0.596*
Top of Sediment EL. = 556.2 (-0.8 ft below USACE dredge elevation of 557)										

MR-SD-R5-04										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	9.7	5	193	118	218	0.484	34.6	341	1.6	73.9
0.5-1.5	22.6	13.2	237	214	461	1.36	68.5	549	0.83	154
1.5-2.5	22.6	11.6	242	196	567	0.907	77.3	523	1	162
2.5-3.6	17.4	13.5	109	176	315	1.81	58.2	804	0.46 J	114
5.0-5.3	20.3	11.2	229	190	418	1.22	63.4	679	0.71 J	101
5.3-6.3	*5.79*	*0.609 J*	*22.9*	*22.3*	*14.7*	*0.0268 J*	*19.4*	*66.4*	*0.56 U*	*5.75*
Top of Sediment EL. = 560.1										
Depth below USACE Dredge EL. = -3.1										

MR-SD-R5-06											
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPCB	tPAH-18
0.0-0.5	10.7 U	1.33 J	53	97.4	88	0.123 J	27.2	456	1.4 U	0.081	27
0.5-1.5	8.29 U	2.67	44.1	89.6	111	0.174 J	21.1	386	1.1 U	0.32	55.1
1.5-2.5	8.3 U	2.15	55.8	137	140	0.225 J	24.5	496	1 U	0.33	64.9
2.5-3.5	7.89 U	3.18	64.2	127	220	0.339 J	29.6	480	0.51 J	0.43	57.9
3.5-4.5	7.92	7.05	125	169	314	0.427	42	676	0.38 J	0.71	41.1
4.5-5.0	9.84	11.7	163	196	505	0.568	46.9	898	0.97 U	1.3	65.2
5.0-5.7	9.02	1.36 J	35.7	93.2	165	0.852	20.4	310	0.27 J	0.068	26.8
5.7-6.7	*5.96 U*	*0.425 J*	*19.3*	*18.6*	*8.43*	*0.287 U*	*16*	*57.7*	*0.75 U*	*0.013 U*	*0.419*
Top of Sediment EL. = 559.1											
Depth below USACE Dredge EL. = -2.1											

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

- Bathymetry Contour
- -2.27
- -13
- -20
- -26.83

N

0 150 300
Feet

EPA, ESRI World Imagery

General Notes:
1. All concentrations are presented in mg/kg.
2. All intervals are presented in feet below sediment surface (ft bss).
3. Location IDs beginning with "SED" = Former West Side Manufactured Gas Plant (MGP) April 2014 Sediment Investigation Results (sampling performed by Natural Resource Technology). Results are not TOC-normalized.
4. Yellow shading represents results greater than the Probable Effect Concentration (PEC). Red Shading represents results greater than 3x the PEC, Italics = native material.
5. Concentrations are screened against values listed within the Wisconsin Department of Natural Resources Consensus-Based Sediment Quality Guidelines (CBSQG), December 2003. tPCB and tPAH values are non-TOC normalized.
6. tPAH-18 includes 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(e)pyrene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-Cd)Pyrene, Naphthalene, Phenanthrene, Pyrene.
7. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
8. Top of sediment elevations referenced to NAVD88.
9. Depth's below the USACE dredge elevation are reported as feet below the USACE dredge depth of 21 feet LWD (557 NAVD88).
10. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:
AMSL = Above Mean Sea Level
ft bss = feet below sediment surface
IGLD85 = International Great Lakes Datum of 1985
LWD = Low Water Datum
NAVD88 = North American Vertical Datum of 1988
PEC = Probable Effect Concentration
- = sample not collected
= Represents depth below USACE dredge depth of 21 feet LWD in results tables.
= Implies NAPL observed within the interval range.

Figure 3b
Summary of Analytical Results
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

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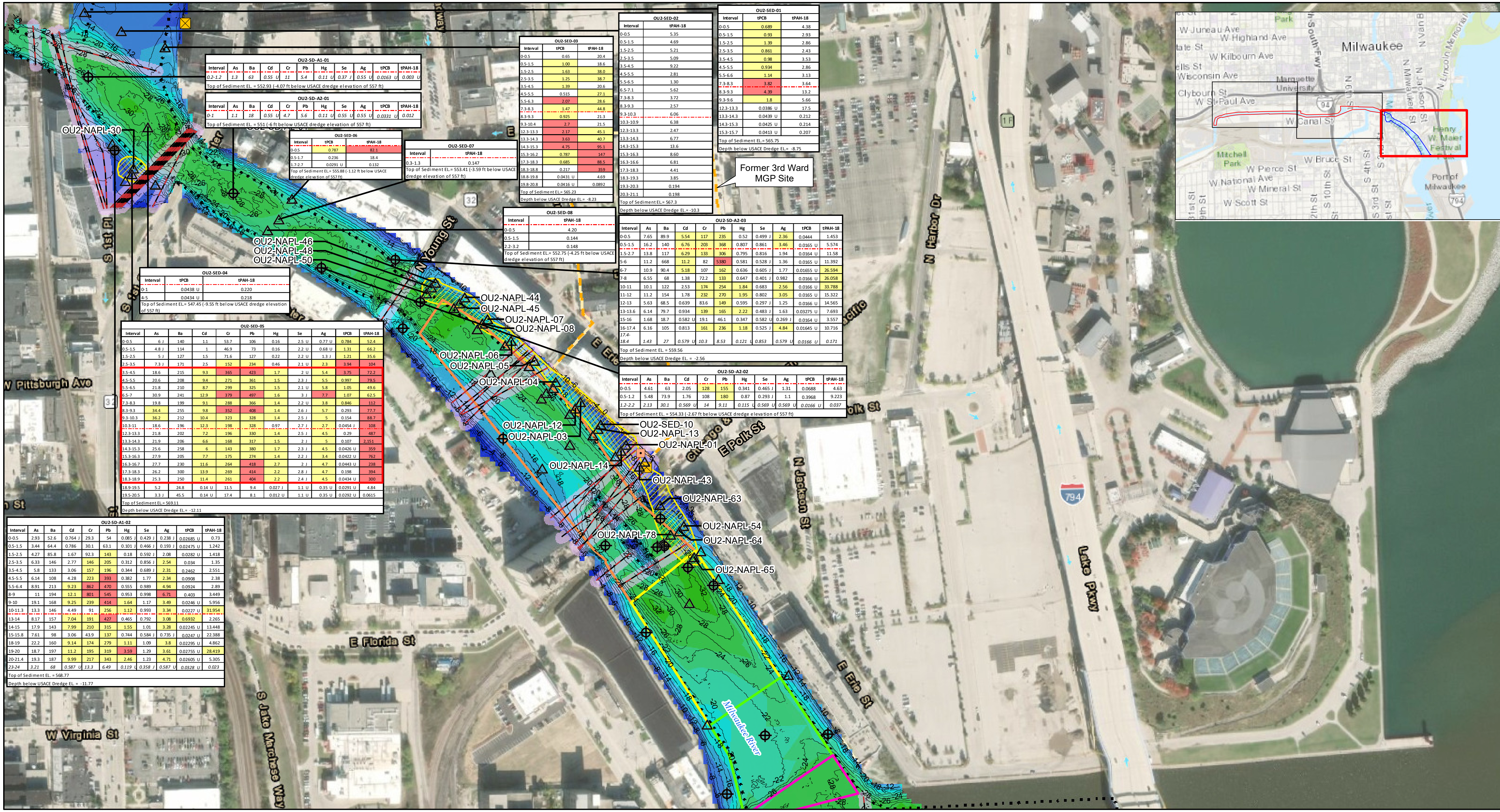

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

- Bathymetry Contour
- -5.47
- -12
- -23
- -34.04

N

0 150 300

Feet

General Notes:
1. All concentrations are presented in mg/kg.
2. All intervals are presented in feet below sediment surface (ft bss).
3. Location IDs beginning with "SED" = Former West Side Manufactured Gas Plant (MGP) April 2014 Sediment Investigation Results (sampling performed by Natural Resource Technology). Results are not TOC-normalized.
4. Yellow shading represents results greater than the Probable Effect Concentration (PEC). Red Shading represents results greater than 3x the PEC, Italics = native material.
5. Concentrations are screened against values listed within the Wisconsin Department of Natural Resources Consensus-Based Sediment Quality Guidelines (CBSQG), December 2003. tPCB and tPAH values are non-TOC normalized.
6. tPAH-18 includes 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(e)pyrene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-Cd)Pyrene, Naphthalene, Phenanthrene, Pyrene.
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8. Top of sediment elevations referenced to NAVD88.
9. Depth's below the USACE dredge elevation are reported as feet below the USACE dredge depth of 21 feet LWD (557 NAVD88).
10. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:
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IGLD85 = International Great Lakes Datum of 1985
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PEC = Probable Effect Concentration
- = sample not collected
- - - = Represents depth below USACE dredge depth of 21 feet LWD in results tables.
= Implies NAPL observed within the interval range.

Figure 3c
Summary of Analytical Results
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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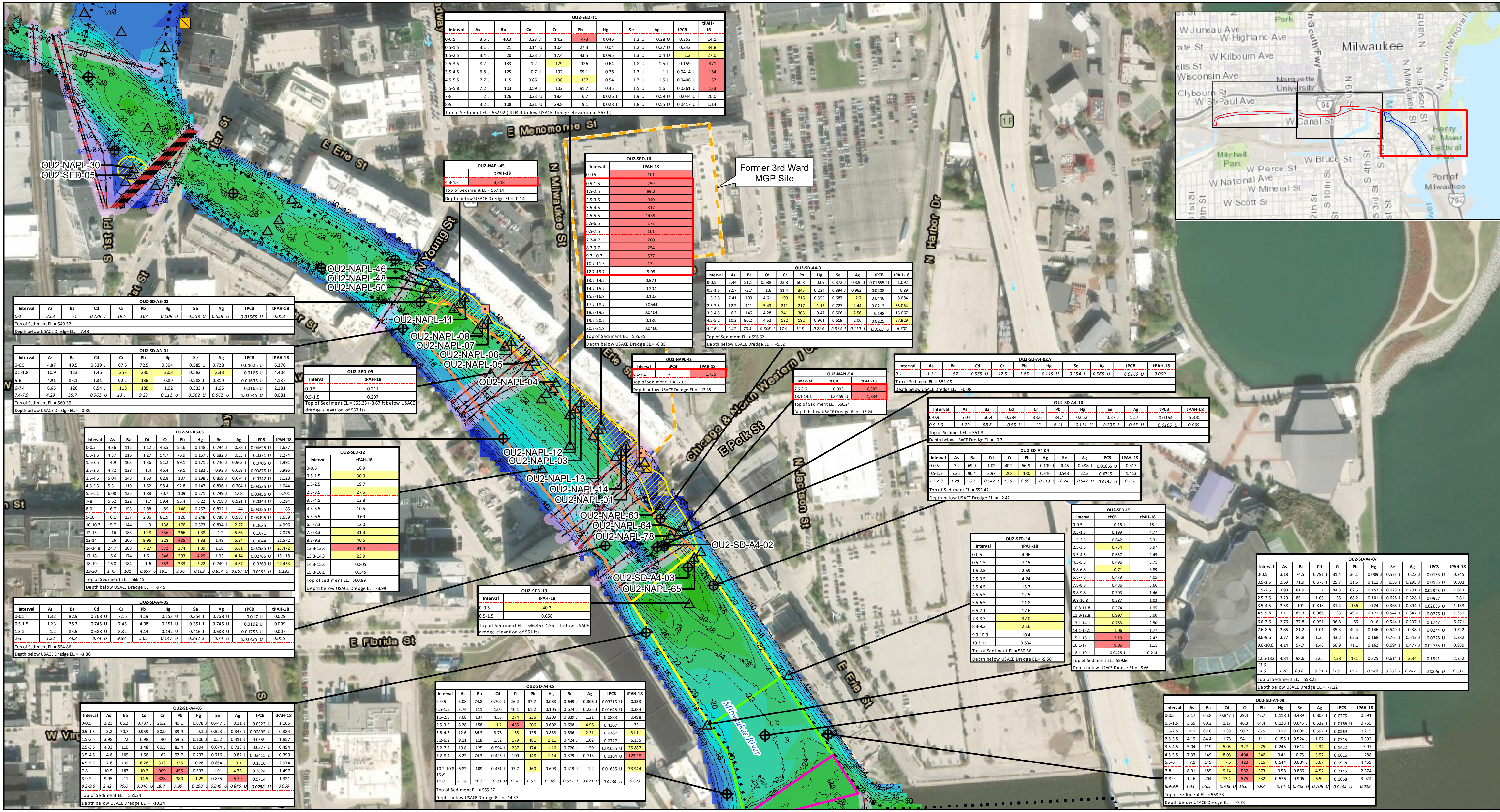

OU2-SED-11

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	3.6 J	40.3	0.23 J	14.2	473	0.046	1.2 U	0.38 U	0.353	14.1
0.5-1.5	3.1 J	21	0.14 U	10.4	27.3	0.04	1.2 U	0.37 U	0.242	34.8
1.5-2.5	3.4 J	20	0.33 J	17.4	43.5	0.095	1.3 U	0.4 U	1.2	27.0
2.5-3.5	8.2	133	1.2	129	126	0.64	1.8 U	1.5 J	0.159	371
3.5-4.5	6.8 J	125	0.7 J	102	99.1	0.76	1.7 U	1 J	0.0414 U	154
4.5-5.5	7.7 J	115	0.86	136	137	0.54	1.7 U	1.5 J	0.0406 U	137
5.5-5.8	7.2	103	0.59 J	102	91.7	0.45	1.5 U	1.6	0.0361 U	133
7-8	2 J	126	0.23 U	18.4	6.7	0.026 J	1.9 U	0.59 U	0.044 U	20.0
8-9	3.2 J	108	0.21 U	29.8	9.1	0.028 J	1.8 U	0.55 U	0.0417 U	1.14

Top of Sediment EL.= 552.92 (-4.08 ft below USACE dredge elevation of 557 ft)

OU2-NAPL-45

	tPAH-18
4.3-4.8	3,348

Top of Sediment EL.= 557.14
Depth below USACE Dredge EL.= -0.14

OU2-SED-10

Interval	tPAH-18
0-0.5	101
0.5-1.5	259
1.5-2.5	89.2
2.5-3.5	940
3.5-4.5	817
4.5-5.5	1439
5.5-6.5	172
6.5-7.5	101
7.7-8.7	200
8.7-9.7	254
9.7-10.7	537
10.7-11.5	132
12.7-13.7	3.09
13.7-14.7	0.571
14.7-15.7	0.204
15.7-16.9	0.103
17.7-18.7	0.0644
18.7-19.7	0.0404
19.7-20.7	0.139
20.7-21.9	0.0460

Top of Sediment EL.= 565.35
Depth below USACE Dredge EL.= -8.35

OU2-SD-A4-01

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	2.44	51.1	0.688	23.8	60.8	0.09 J	0.372 J	0.326 J	0.01655 U	1.092
0.5-1.5	3.17	72.7	1.6	81.4	345	0.234	0.394 J	0.962	0.0208	0.89
1.5-2.5	7.41	100	4.61	190	216	0.555	0.687	2.7	0.0446	8.084
2.5-3.5	12.2	111	5.43	211	217	1.15	0.727	2.44	0.0212	55.054
3.5-4.5	6.2	146	4.28	241	305	0.47	0.506 J	2.56	0.198	15.067
4.5-5.2	10.3	96.2	4.52	132	182	0.961	0.619	2.06	0.0225	57.929
5.2-6.1	*1.42*	*70.4*	*0.306 J*	*17.9*	*12.5*	*0.224*	*0.334 J*	*0.119 J*	*0.0163 U*	*6.307*

Top of Sediment EL. = 556.62
Depth below USACE Dredge EL. = -5.62

OU2-NAPL-43

Interval	tPCB	tPAH-18
6.1-7.1	-	1,735

Top of Sediment EL.= 570.35
Depth below USACE Dredge EL.= -13.35

OU2-NAPL-54

Interval	tPCB	tPAH-18
7.6-8.6	0.093	6,387
13.1-14.1	0.0459 U	1,889

Top of Sediment EL.= 566.24
Depth below USACE Dredge EL.= -15.24

OU2-SD-A4-02A

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-1	*1.31*	*57*	*0.565 U*	*12.5*	*5.85*	*0.115 U*	*0.254 J*	*0.565 U*	*0.0166 U*	*0.009*

Top of Sediment EL. = 551.08
Depth below USACE Dredge EL. = -0.08

OU2-SD-A4-10

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.9	5.04	60.9	0.584	88.6	84.7	0.652	0.37 J	1.17	0.0164 U	5.381
0.9-1.9	*1.29*	*58.6*	*0.55 U*	*13*	*6.11*	*0.111 U*	*0.235 J*	*0.55 U*	*0.0165 U*	*0.069*

Top of Sediment EL. = 551.3
Depth below USACE Dredge EL. = -0.3

OU2-SD-A4-04

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	3.2	69.9	1.02	40.2	56.9	0.109 J	0.45 J	0.488 J	0.01655 U	0.317
0.5-1.7	5.25	96.4	3.97	208	180	0.346	0.543 J	2.13	0.0715	1.413
1.7-2.3	*1.28*	*56.7*	*0.547 U*	*15.5*	*8.89*	*0.113 U*	*0.24 J*	*0.547 U*	*0.0164 U*	*0.156*

Top of Sediment EL. = 553.42
Depth below USACE Dredge EL. = -2.42

OU2-SD-A3-02

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-1	*2.63*	*71*	*0.229 J*	*19.5*	*107*	*0.109 U*	*0.558 U*	*0.558 U*	*0.01665 U*	*0.013*

Top of Sediment EL. = 549.52
Depth below USACE Dredge EL. = 7.48

OU2-SD-A3-01

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	4.87	49.5	0.339 J	67.6	72.5	0.804	0.585 U	0.728	0.01625 U	6.376
0.5-1.8	10.9	123	1.46	253	230	2.03	0.582	3.33	0.0166 U	4.404
5-6	4.91	84.1	1.31	92.2	136	0.89	0.288 J	0.819	0.01635 U	4.137
6-7.4	6.65	126	0.54 J	118	185	1.02	0.333 J	1.65	0.0165 U	2.181
7.4-7.9	*4.29*	*35.7*	*0.562 U*	*13.1*	*9.23*	*0.112 U*	*0.562 U*	*0.562 U*	*0.01645 U*	0.081

Top of Sediment EL. = 560.39
Depth below USACE Dredge EL. = -3.39

OU2-SED-09

Interval	tPAH-18
0-0.5	0.211
0.5-1.5	0.207

Top of Sediment EL.= 553.33 (-3.67 ft below USACE dredge elevation of 557 ft)

OU2-SD-A3-03

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	4.36	112	1.12 J	45.5	55.6	0.148 J	0.794 J	0.38 J	0.04625 U	1.637
0.5-1.5	4.37	116	1.27	54.7	76.9	0.157 J	0.682 J	0.53 J	0.0371 U	1.274
1.5-2.5	4.9	103	1.36	51.2	99.1	0.171 J	0.746 J	0.903 J	0.0705 U	1.991
2.5-3.5	4.72	138	1.4	46.4	79.1	0.182 J	0.93 J	0.658 J	0.03875 U	0.996
3.5-4.5	5.04	148	1.59	62.8	107	0.198 J	0.869 J	0.674 J	0.0342 U	1.128
4.5-5.5	5.31	119	1.62	58.4	92.8	0.147 J	0.836 J	0.704 J	0.03535 U	1.044
5.5-6.1	6.08	125	1.88	70.7	109	0.271	0.799 J	1.08	0.03455 U	0.701
7-8	5.62	122	1.7	59.4	95.4	0.22	0.718 J	0.921 J	0.0344 U	0.294
8-9	6.7	153	2.88	85	146	0.257	0.802 J	1.44	0.03255 U	1.85
9-10	6.1	137	2.06	81.9	126	0.248	0.788 J	0.988 J	0.03495 U	1.639
10-10.7	5.7	144	3	138	176	0.373	0.834 J	2.27	0.0635	4.996
12-13	16	183	10.8	336	366	1.38	1.2	5.66	0.1071	7.076
13-14	26	206	9.96	328	435	1.33	1.48	5.34	0.0644	21.572
14-14.8	24.7	208	7.27	372	374	1.39	1.18	5.61	0.02935 U	23.472
17-18	16.6	174	1.61	348	293	4.29	1.03	4.14	0.02765 U	18.118
18-19	16.8	184	1.6	352	333	3.22	0.749 J	4.67	0.0269 U	24.453
19-20	*1.45*	*101*	*0.857 U*	*19.5*	*9.36*	*0.169 U*	*0.857 U*	*0.857 U*	*0.0281 U*	*0.193*

Top of Sediment EL. = 566.45
Depth below USACE Dredge EL. = -9.45

OU2-SED-12

Interval	tPAH-18
0-0.5	16.9
0.5-1.5	30.3
1.5-2.5	19.7
2.5-3.5	27.5
3.5-4.5	13.8
4.5-5.5	10.5
5.5-6.5	9.69
6.5-7.3	12.0
7.3-8.3	31.3
8.3-9.3	40.6
12.3-13.3	91.4
13.3-14.3	23.9
14.3-15.3	0.805
15.3-16.1	0.345

Top of Sediment EL.= 560.99
Depth below USACE Dredge EL.= -3.99

OU2-SD-A4-05

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	1.32	82.9	0.768 U	7.16	4.19	0.153 U	0.354 J	0.768 U	0.017 U	0.029
0.5-1.5	1.23	75.7	0.745 U	7.45	4.08	0.151 U	0.351 J	0.745 U	0.0192 U	0.009
1.5-2	1.2	84.5	0.688 U	8.32	4.14	0.142 U	0.416 J	0.688 U	0.01755 U	0.007
2-3	*1.22*	*74.8*	*0.74 U*	*9.93*	*5.05*	*0.147 U*	*0.332 J*	*0.74 U*	*0.01835 U*	*0.016*

Top of Sediment EL. = 554.86
Depth below USACE Dredge EL. = -3.86

OU2-SED-13

Interval	tPAH-18
0-0.5	40.3
0.5-1.5	0.658

Top of Sediment EL.= 546.45 (-4.55 ft below USACE dredge elevation of 551 ft)

OU2-SED-14

Interval	tPAH-18
0-0.5	4.96
0.5-1.5	7.15
1.5-2.5	2.59
2.5-3.5	4.24
3.5-4.5	15.7
4.5-5.5	12.5
5.5-6.5	11.8
6.5-7.1	17.6
7.3-8.3	37.0
8.3-9.3	25.6
9.3-10.3	10.4
10.3-11	0.634

Top of Sediment EL.= 560.56
Depth below USACE Dredge EL.= -9.56

OU2-SED-15

Interval	tPCB	tPAH-18
0-0.5	0.15 J	15.1
0.5-1.5	0.199	4.77
1.5-2.5	0.642	3.31
2.5-3.5	0.734	5.97
3.5-4.5	0.657	2.45
4.5-5.5	0.496	3.71
5.8-6.8	0.71	3.89
6.8-7.8	0.479	4.05
7.8-8.8	0.486	3.66
8.8-9.8	0.393	1.46
9.8-10.8	0.587	1.03
10.8-11.8	0.574	1.95
11.8-12.8	0.997	3.00
13.1-14.1	0.753	2.50
14.1-15.1	1.06	1.77
15.1-16.1	2.23	2.42
16.1-17	9.05	11.1
18.1-19.1	0.0425 U	0.214

Top of Sediment EL.= 559.66
Depth below USACE Dredge EL.= -8.66

OU2-SD-A4-07

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	3.18	74.5	0.791 J	31.4	36.1	0.089 J	0.573 J	0.23 J	0.0153 U	0.245
0.5-1.5	2.69	71.9	0.676 J	25.7	31.5	0.111 J	0.56 J	0.295 J	0.0165 U	0.303
1.5-2.5	3.93	81.9	1	44.3	62.5	0.157 J	0.628 J	0.701 J	0.02945 U	1.043
2.5-3.5	3.29	85.1	1.05	35	68.2	0.101 J	0.628 J	0.328 J	0.0977	2.81
3.5-4.5	2.58	101	0.818	31.4	136	0.24	0.368 J	0.394 J	0.02685 U	1.133
4.5-5.8	3.11	85.3	0.966	33	49.7	0.121 J	0.542 J	0.347 J	0.0276 U	1.351
6.6-7.6	2.76	77.8	0.951	36.8	66	0.16	0.544 J	0.237 J	0.1747	6.471
7.6-8.6	2.85	81.2	1.01	35.3	49.4	0.146 J	0.549 J	0.38 J	0.0244 U	0.722
8.6-9.6	3.77	86.8	1.25	43.2	62.6	0.168	0.765 J	0.542 J	0.0278 U	1.382
9.6-10.6	4.14	97.7	1.46	50.9	71.1	0.162	0.694 J	0.477 J	0.02765 U	0.989
12.6-13.6	4.84	98.6	2.65	128	131	0.325	0.614 J	2.34	0.1941	2.252
13.6-14.6	*1.78*	*83.6*	*0.34 J*	*21.5*	*11.7*	*0.149 U*	*0.362 J*	*0.747 U*	*0.0246 U*	*0.637*

Top of Sediment EL. = 558.22
Depth below USACE Dredge EL. = -7.22

OU2-SD-A4-06

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	3.23	66.2	0.737 J	26.2	40.1	0.078 J	0.447 J	0.31 J	0.0323 U	1.105
0.5-1.5	3.2	70.7	0.959	30.9	39.9	0.1 J	0.523 J	0.343 J	0.02805 U	0.384
1.5-2.5	3.98	72	0.98	40	59.5	0.106 J	0.52 J	0.411 J	0.0359	1.857
2.5-3.5	4.03	110	1.48	60.5	81.4	0.194	0.674 J	0.713 J	0.0277 U	0.494
3.5-4.5	4.8	109	1.66	62	92.7	0.237	0.716 J	0.82 J	0.03415 U	0.399
4.5-5.7	7.6	139	6.26	313	325	0.28	0.864 J	3.1	0.1516	2.974
7-8	10.5	187	10.2	909	455	0.633	1.01 J	4.75	0.3624	1.497
8-9.2	9.95	211	14.5	828	380	1.29	0.835 J	6.79	0.5714	1.321
9.2-9.6	*2.42*	*76.6*	*0.846 U*	*18.7*	*7.99*	*0.168 U*	*0.846 U*	*0.846 U*	*0.0288 U*	*0.069*

Top of Sediment EL. = 561.24
Depth below USACE Dredge EL. = -10.24

OU2-SD-A4-08

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	3.08	74.8	0.792 J	26.2	37.7	0.083 J	0.649 J	0.306 J	0.03315 U	0.353
0.5-1.5	3.74	111	1.06	40.1	61.2	0.105 J	0.674 J	0.225 J	0.01645 U	0.384
1.5-2.5	7.68	137	4.55	274	235	0.209	0.839 J	1.21	0.0883	0.498
2.5-3.5	8.28	158	11.2	455	306	0.602	0.698 J	4.96	0.4367	1.731
3.5-4.3	12.6	86.3	3.78	158	125	0.838	0.596 J	2.31	0.0787	31.11
5.2-6.2	9.11	118	1.32	179	181	1.11	0.424 J	1.02	0.0727	5.235
6.2-7.2	10.8	125	0.594 J	237	174	1.16	0.726 J	1.59	0.01655 U	35.887
7.2-8.4	8.22	74.3	0.425 J	109	148	1.14	0.379 J	0.713	0.0164 U	123.28
10.2-10.8	6.82	109	0.451 J	97.7	160	0.693	0.419 J	1.2	0.01655 U	33.944
10.8-11.8	*1.55*	*103*	*0.83 U*	*13.4*	*6.57*	*0.169 U*	*0.511 J*	*0.874 U*	*0.0166 U*	*0.873*

Top of Sediment EL. = 565.37
Depth below USACE Dredge EL. = -14.37

OU2-SD-A4-09

Interval	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	tPCB	tPAH-18
0-0.5	2.17	65.8	0.847 J	29.4	42.7	0.118 J	0.489 J	0.308 J	0.0275	0.591
0.5-1.5	3.65	80.2	1.17	46.3	64.4	0.123 J	0.645 J	0.532 J	0.0166 U	0.755
1.5-2.5	4.1	87.8	1.38	50.2	76.5	0.17	0.604 J	0.597 J	0.0269	0.215
2.5-3.5	4.19	84.4	1.78	94.1	111	0.155 J	0.524 J	1.07	0.0315	0.392
3.5-4.5	5.04	119	5.05	327	275	0.245	0.614 J	2.34	0.1422	3.97
4.5-5.5	7.33	149	8.08	494	346	0.41	0.75	3.97	0.0616	1.288
5.5-6	7.1	149	7.6	423	315	0.544	0.684 J	3.67	0.1918	4.469
7-8	8.91	185	9.14	552	373	0.58	0.856	4.52	0.2145	2.374
8-8.9	12.6	204	13.4	575	332	0.576	0.906 J	6.59	0.1668	3.024
8.9-9.9	*1.41*	*65.5*	*0.708 U*	*16.6*	*6.98*	*0.14 U*	*0.708 U*	*0.708 U*	*0.0164 U*	*0.012*

Top of Sediment EL. = 558.73
Depth below USACE Dredge EL. = -7.73

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

- Bathymetry Contour
- -5.47
- -12
- -23
- -34.04

N

0 150 300

Feet

General Notes:
1. All concentrations are presented in mg/kg.
2. All intervals are presented in feet below sediment surface (ft bss).
3. Location IDs beginning with "SED" = Former West Side Manufactured Gas Plant (MGP) April 2014 Sediment Investigation Results (sampling performed by Natural Resource Technology). Results are not TOC-normalized.
4. Yellow shading represents results greater than the Probable Effect Concentration (PEC). Red Shading represents results greater than 3x the PEC, Italics = native material.
5. Concentrations are screened against values listed within the Wisconsin Department of Natural Resources Consensus-Based Sediment Quality Guidelines (CBSQG), December 2003. tPCB and tPAH values are non-TOC normalized.
6. tPAH-18 includes 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(e)pyrene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-Cd)Pyrene, Naphthalene, Phenanthrene, Pyrene.
7. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
8. Top of sediment elevations referenced to NAVD88.
9. Depth's below the USACE dredge elevation are reported as feet below the USACE dredge depth of 21 feet LWD (557 NAVD88).
10. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:
AMSL = Above Mean Sea Level
ft bss = feet below sediment surface
IGLD85 = International Great Lakes Datum of 1985
LWD = Low Water Datum
NAVD88 = North American Vertical Datum of 1988
PEC = Probable Effect Concentration
- = sample not collected
= Represents depth below USACE dredge depth of 21 feet LWD in results tables.
= Implies NAPL observed within the interval range.

Figure 3d
Summary of Analytical Results
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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ch2m:

Notes:
1. Bureau of Remediation and Redevelopment Tracking System (BRRTS) sites are adjacent to the project area, per the RR Mapping tool (https//dnrmaps.wi.gov/H5/?viewer=rrsites).
2. MS4 permits are stormwater permits through the National Pollutant Discharge Elimination System (NPDES).

Figure 4
Milwaukee River Downstream Reach 4 - Potential Point Sources
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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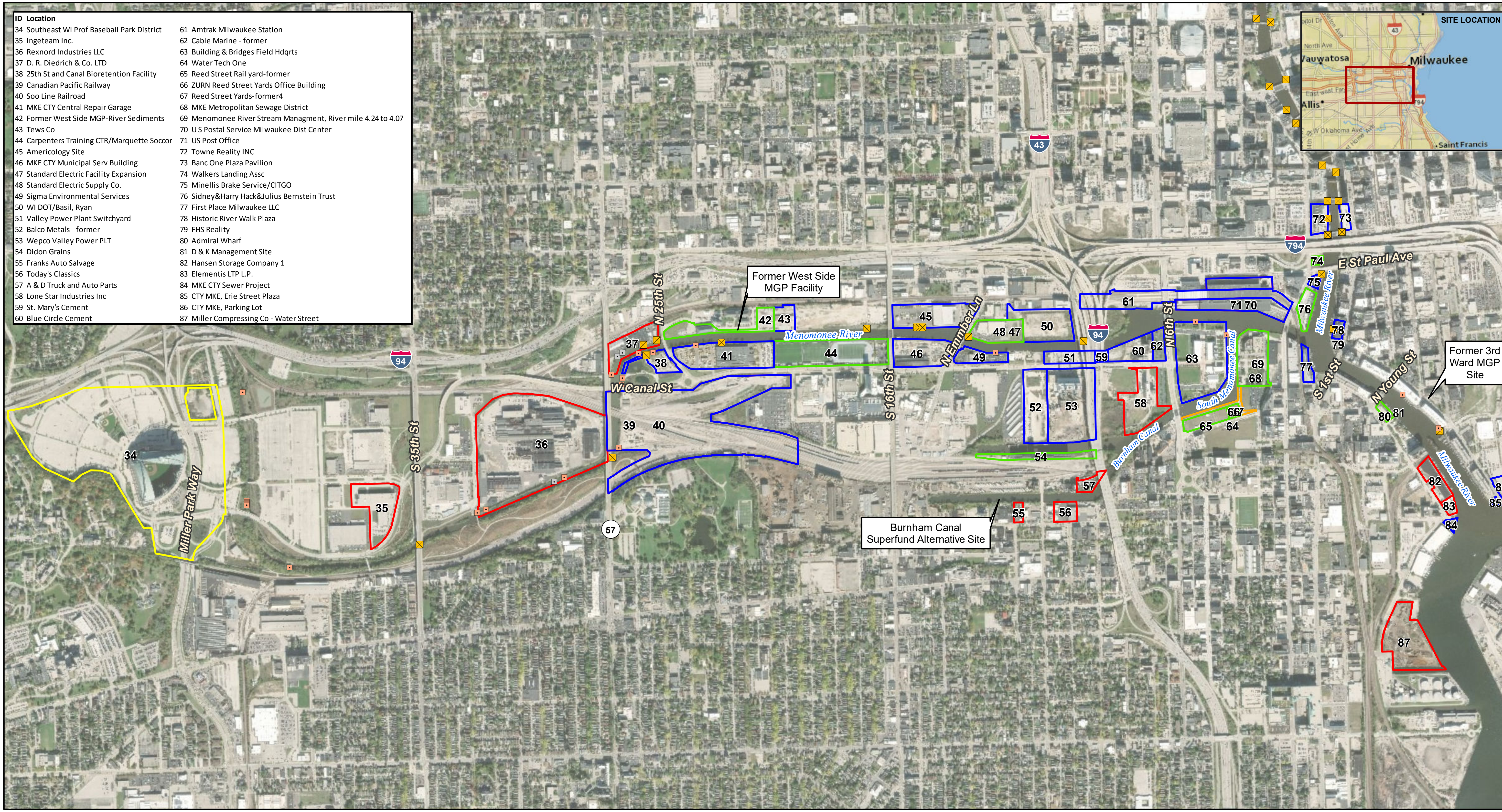

LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- Open BRRTS Site
- Closed BRRTS Site
- MS4 Industrial
- MS4 Construction
- MS4 Municipal

Notes:

1. Bureau of Remediation and Redevelopment Tracking System (BRRTS) sites are adjacent to the project area, per the RR Mapping tool (https//dnrmaps.wi.gov/H5/?viewer=rrsites).
2. MS4 permits are stormwater permits through the National Pollutant Discharge Elimination System (NPDES).

Figure 5

OU1 and OU2 - Potential Point Sources

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

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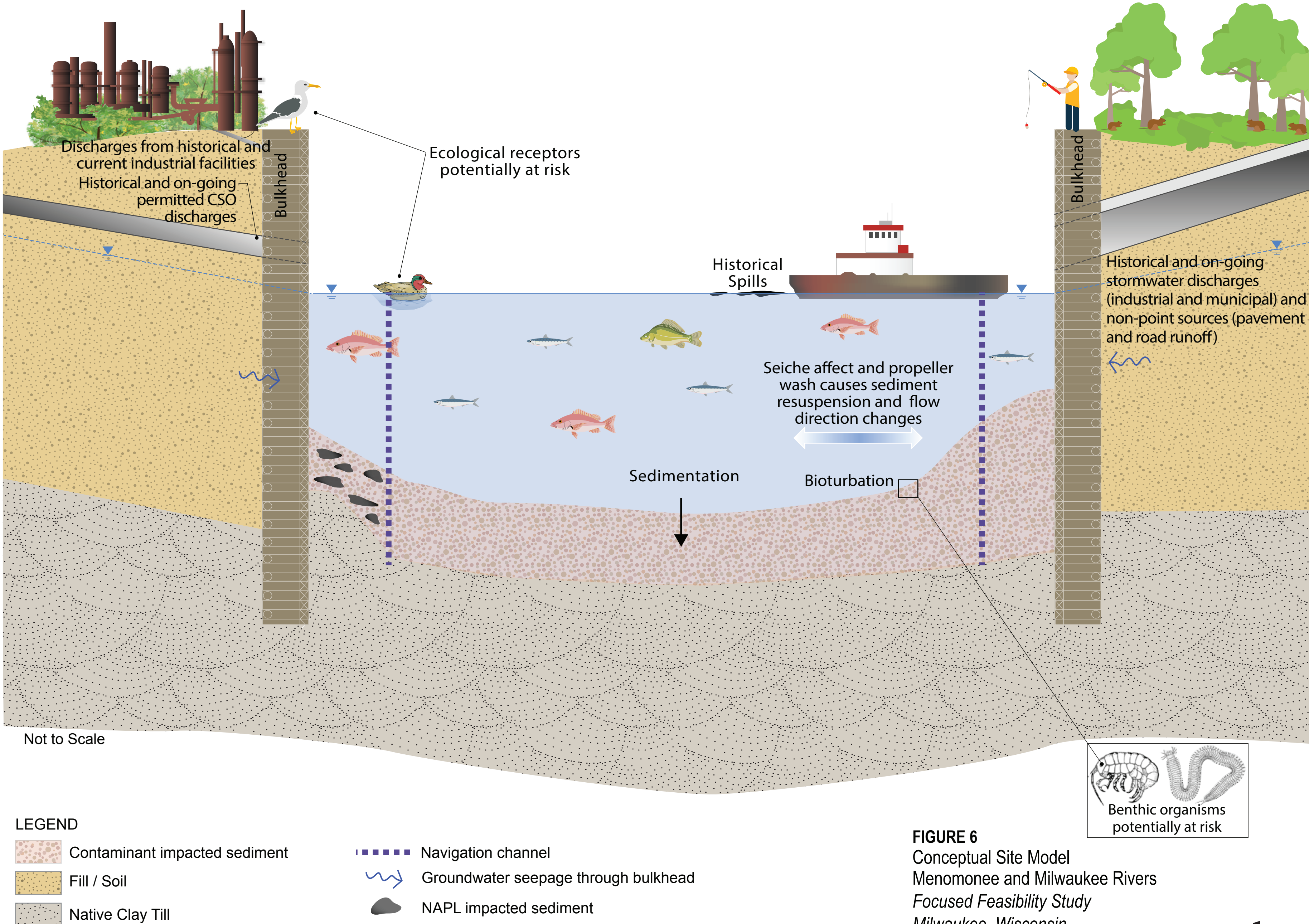
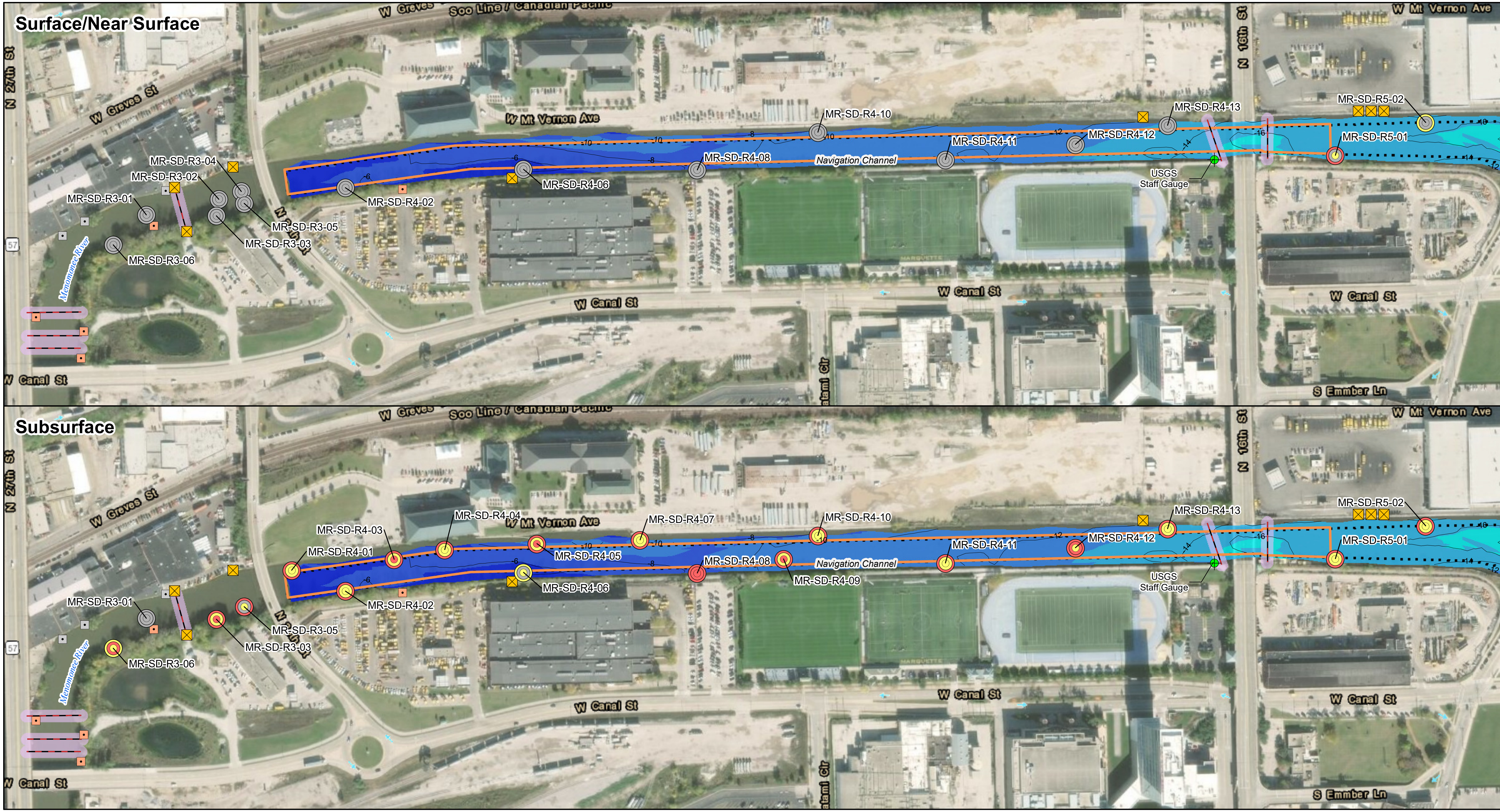
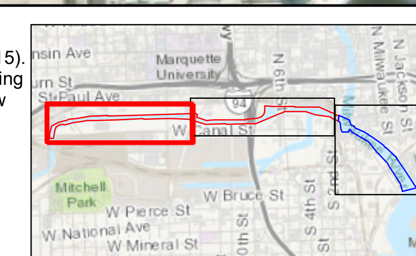


FIGURE 6
Conceptual Site Model
Menomonee and Milwaukee Rivers
Focused Feasibility Study
Milwaukee, Wisconsin





LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

Bathymetry Contour

-2.27
-13
-20
-26.83

Cadmium Exceedance
Chromium Exceedance
Lead Exceedance

Grey = Concentration below PEC (5 mg/kg for Cadmium, 110 mg/kg for Chromium and 130 mg/kg for Lead)
Yellow = Concentration above PEC (5 mg/kg for Cadmium, 110 mg/kg for Chromium and 130 mg/kg for Lead)
Red = Concentration above3x PEC (15 mg/kg for Cadmium, 330 mg/kg for Chromium and 390 mg/kg for Lead)

N

0 150 300
Feet

General Notes:
1. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
2. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:
AMSL = Above Mean Sea Level
PEC = Probable Effect Concentration
NAVD88 = North American Vertical Datum of 1988
IGLD85 = International Great Lakes Datum of 1985

Figure 7a
Select Metals Surface/Near Surface (<1.7ft) and Subsurface (>1.7ft) Analytical Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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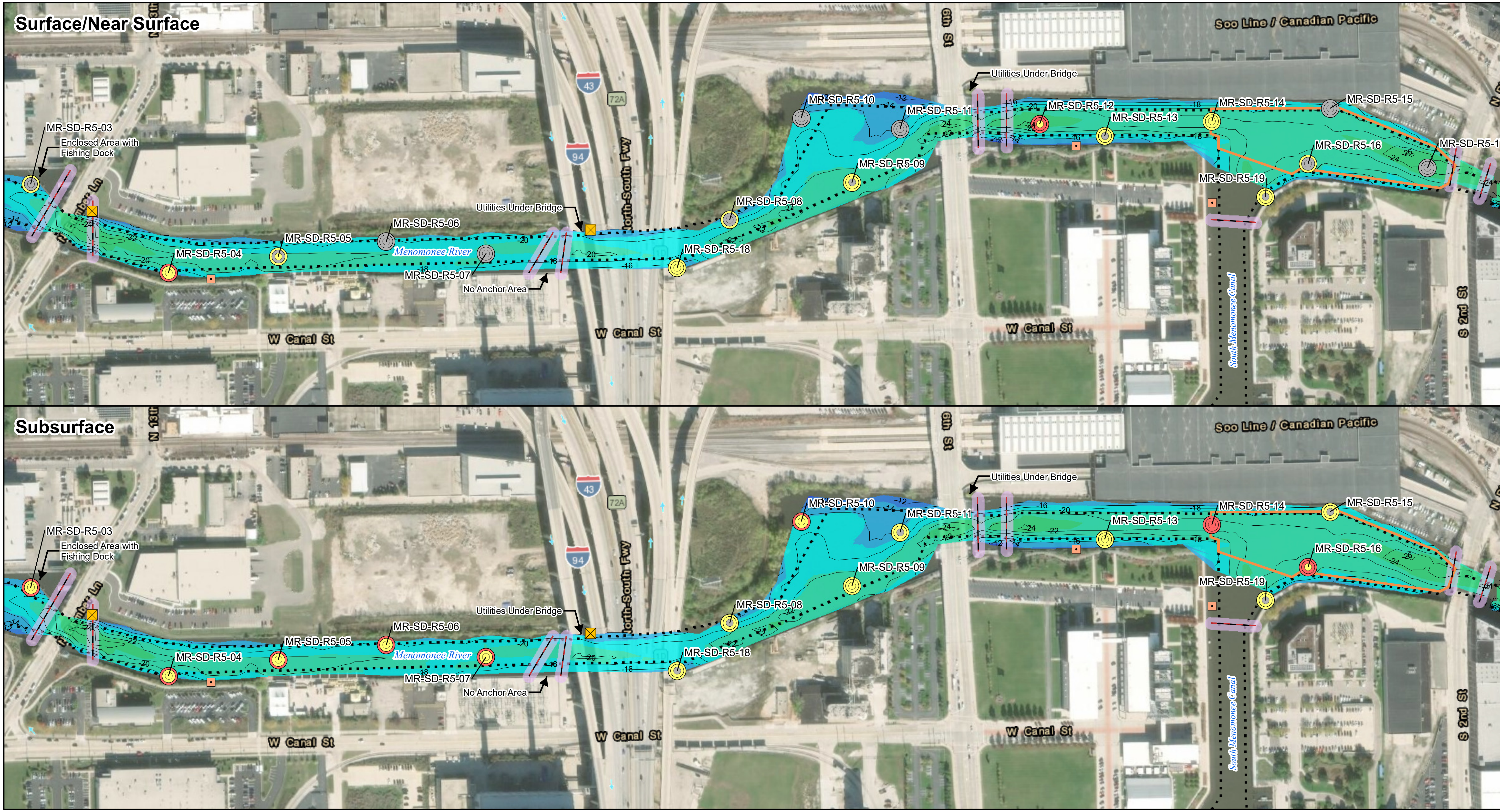

LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

- Bathymetry Contour
- -2.27
- -13
- -20
- -26.83

- Cadmium Exceedance
- Chromium Exceedance
- Lead Exceedance

Grey = Concentration below PEC (5 mg/kg for Cadmium, 110 mg/kg for Chromium and 130 mg/kg for Lead)

Yellow = Concentration above PEC (5 mg/kg for Cadmium, 110 mg/kg for Chromium and 130 mg/kg for Lead)

Red = Concentration above3x PEC (15 mg/kg for Cadmium, 330 mg/kg for Chromium and 390 mg/kg for Lead)

N

0 150 300

Feet

General Notes:

1. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
2. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:

AMSL = Above Mean Sea Level
PEC = Probable Effect Concentration
NAVD88 = North American Vertical Datum of 1988
IGLD85 = International Great Lakes Datum of 1985

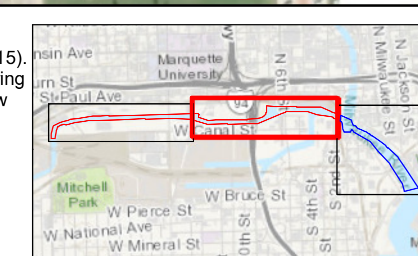

Figure 7b

Select Metals Surface/Near Surface (<1.7ft) and Subsurface (>1.7ft) Analytical Summary

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

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LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

Bathymetry Contour

-5.47
-12
-23
-34.04

- Cadmium Exceedance
- Chromium Exceedance
- Lead Exceedance

Grey = Concentration below PEC (5 mg/kg for Cadmium, 110 mg/kg for Chromium and 130 mg/kg for Lead)
Yellow = Concentration above PEC (5 mg/kg for Cadmium, 110 mg/kg for Chromium and 130 mg/kg for Lead)
Red = Concentration above3x PEC (15 mg/kg for Cadmium, 330 mg/kg for Chromium and 390 mg/kg for Lead)

N

0 175 350
Feet

General Notes:
1. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
2. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:
AMSL = Above Mean Sea Level
PEC = Probable Effect Concentration
NAVD88 = North American Vertical Datum of 1988
IGLD85 = International Great Lakes Datum of 1985

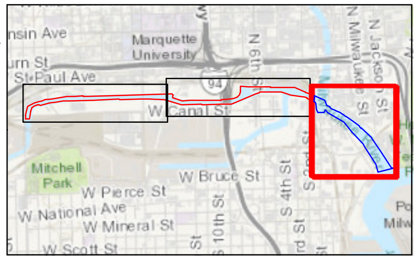

Figure 7c
Select Metals Surface/Near Surface (<1.7ft) and Subsurface (>1.7ft) Analytical Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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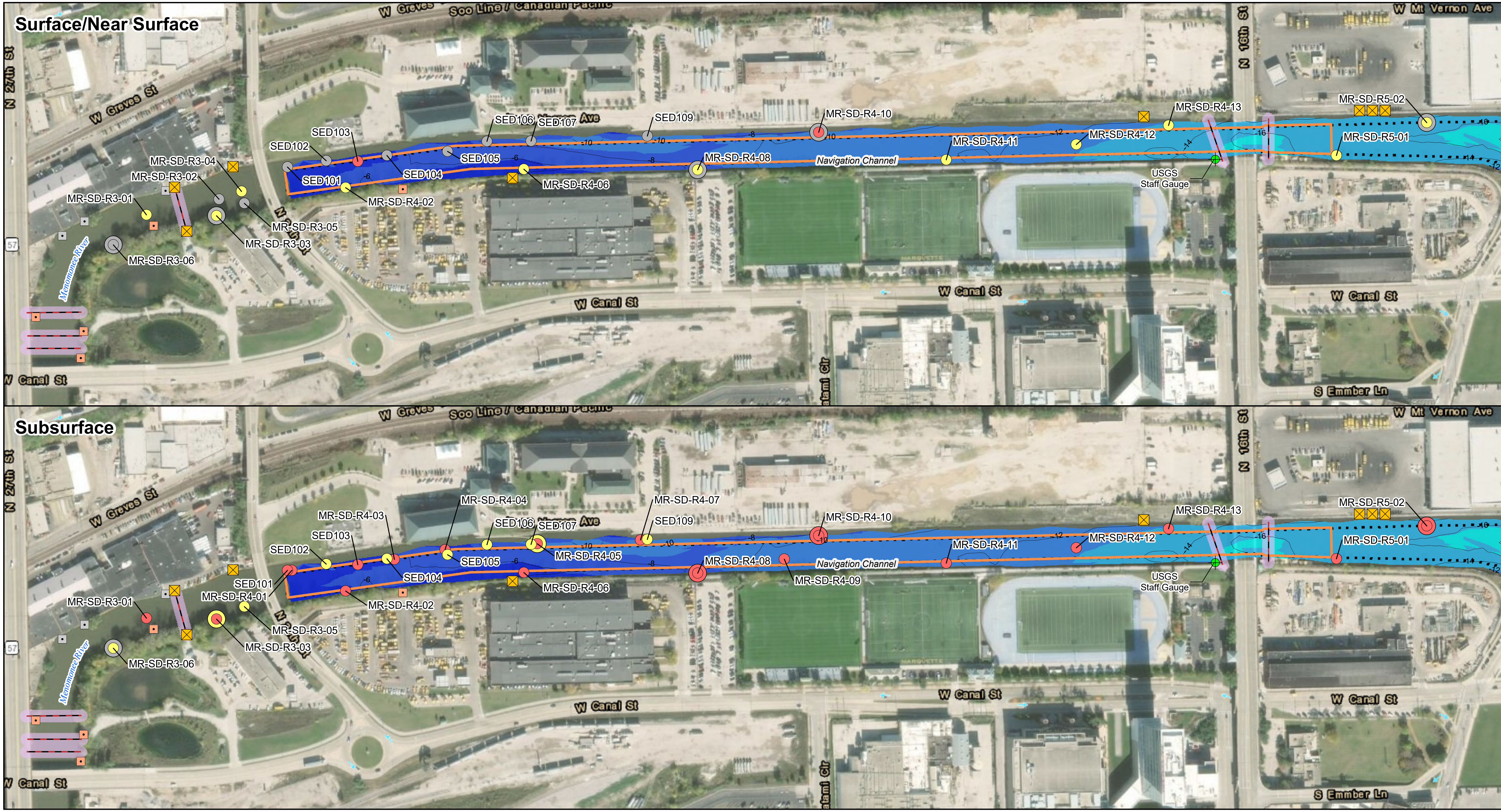

LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

- Bathymetry Contour
- -2.27
- -13
- -20
- -26.83

- PAH Exceedance
- PCB Exceedance

Grey = Concentration below PEC (22.8 mg/kg for tPAH-18 and 0.676 mg/kg for PCBs)
Yellow = Concentration above PEC (22.8 mg/kg for tPAH-18 and 0.676 mg/kg for PCBs)
Red = Concentration above 3xPEC (68.4 mg/kg for tPAH-18 and 2.028 mg/kg for PCBs)

N

0 150 300
Feet

General Notes:
1. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
2. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:
AMSL = Above Mean Sea Level
PEC = Probable Effect Concentration
NAVD88 = North American Vertical Datum of 1988
IGLD85 = International Great Lakes Datum of 1985

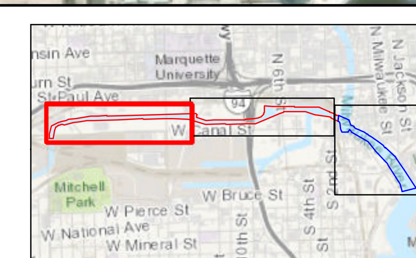

Figure 8a
Organics Surface/Near Surface (<1.7ft) and Subsurface (>1.7ft) Analytical Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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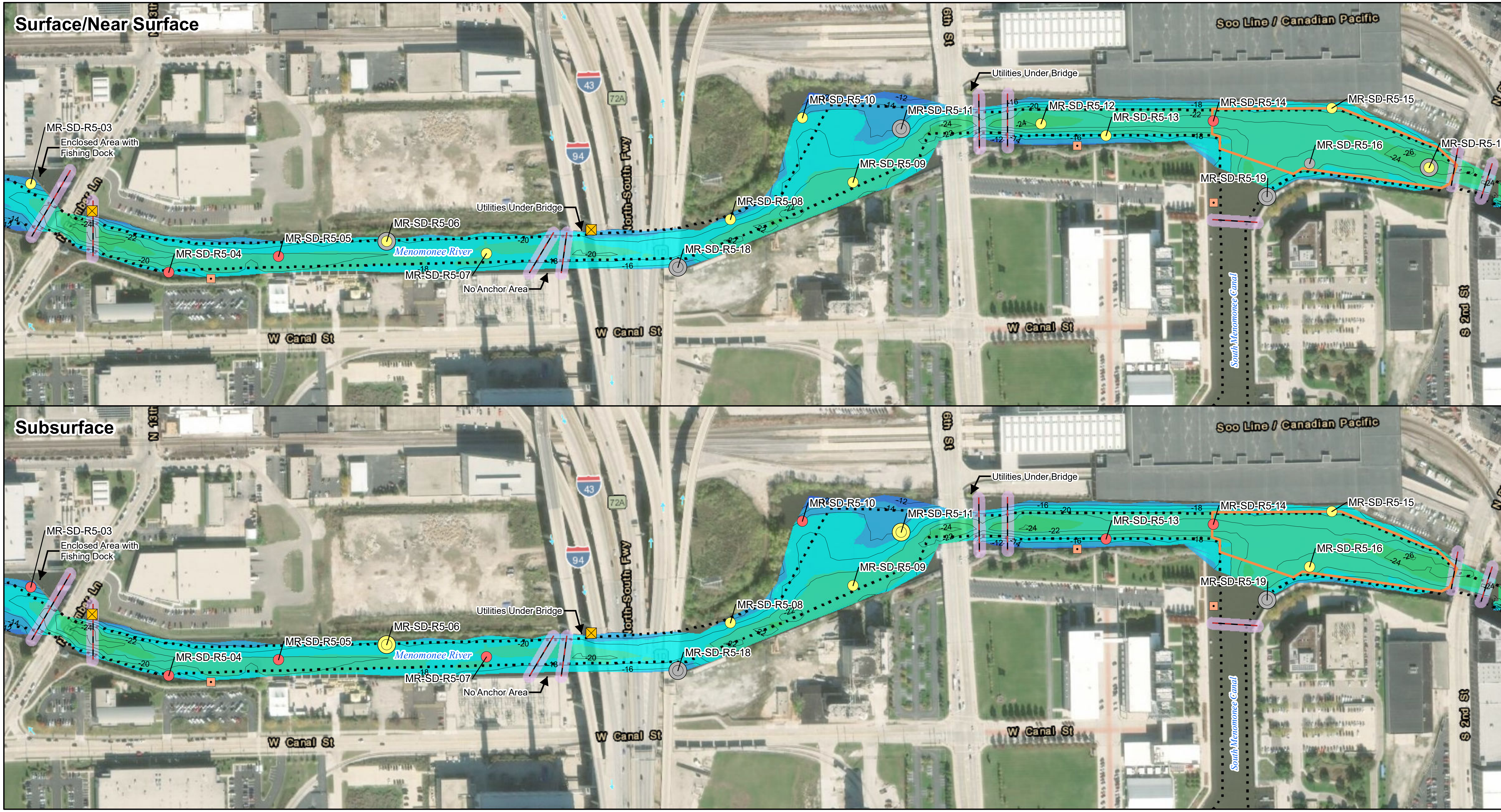

LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

- Bathymetry Contour
- -2.27
- -13
- -20
- -26.83

- PAH Exceedance
- PCB Exceedance

Grey = Concentration below PEC (22.8 mg/kg for tPAH-18 and 0.676 mg/kg for PCBs)
Yellow = Concentration above PEC (22.8 mg/kg for tPAH-18 and 0.676 mg/kg for PCBs)
Red = Concentration above 3xPEC (68.4 mg/kg for tPAH-18 and 2.028 mg/kg for PCBs)

N

0 150 300
Feet

General Notes:
1. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
2. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:
AMSL = Above Mean Sea Level
PEC = Probable Effect Concentration
NAVD88 = North American Vertical Datum of 1988
IGLD85 = International Great Lakes Datum of 1985

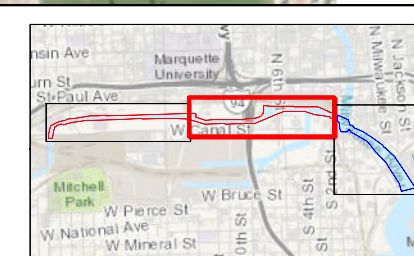

Figure 8b
Organics Surface/Near Surface (<1.7ft) and Subsurface (>1.7ft) Analytical Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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LEGEND

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry (feet)

- Bathymetry Contour
- -5.47
- -12
- -23
- -34.04

- PAH Exceedance
- PCB Exceedance

- Grey = Concentration below PEC (22.8 mg/kg for tPAH-18 and 0.676 mg/kg for PCBs)
- Yellow = Concentration above PEC (22.8 mg/kg for tPAH-18 and 0.676 mg/kg for PCBs)
- Red = Concentration above 3xPEC (68.4 mg/kg for tPAH-18 and 2.028 mg/kg for PCBs)

N

0 175 350

Feet

General Notes:

1. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
2. Ordinary High Water Mark (OHWM) = 581.5 FT AMSL

Abbreviations:

AMSL = Above Mean Sea Level
PEC = Probable Effect Concentration
NAVD88 = North American Vertical Datum of 1988
IGLD85 = International Great Lakes Datum of 1985

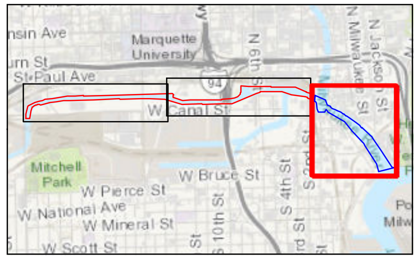

Figure 8c
Organics Surface/Near Surface (<1.7ft) and Subsurface (>1.7ft) Analytical Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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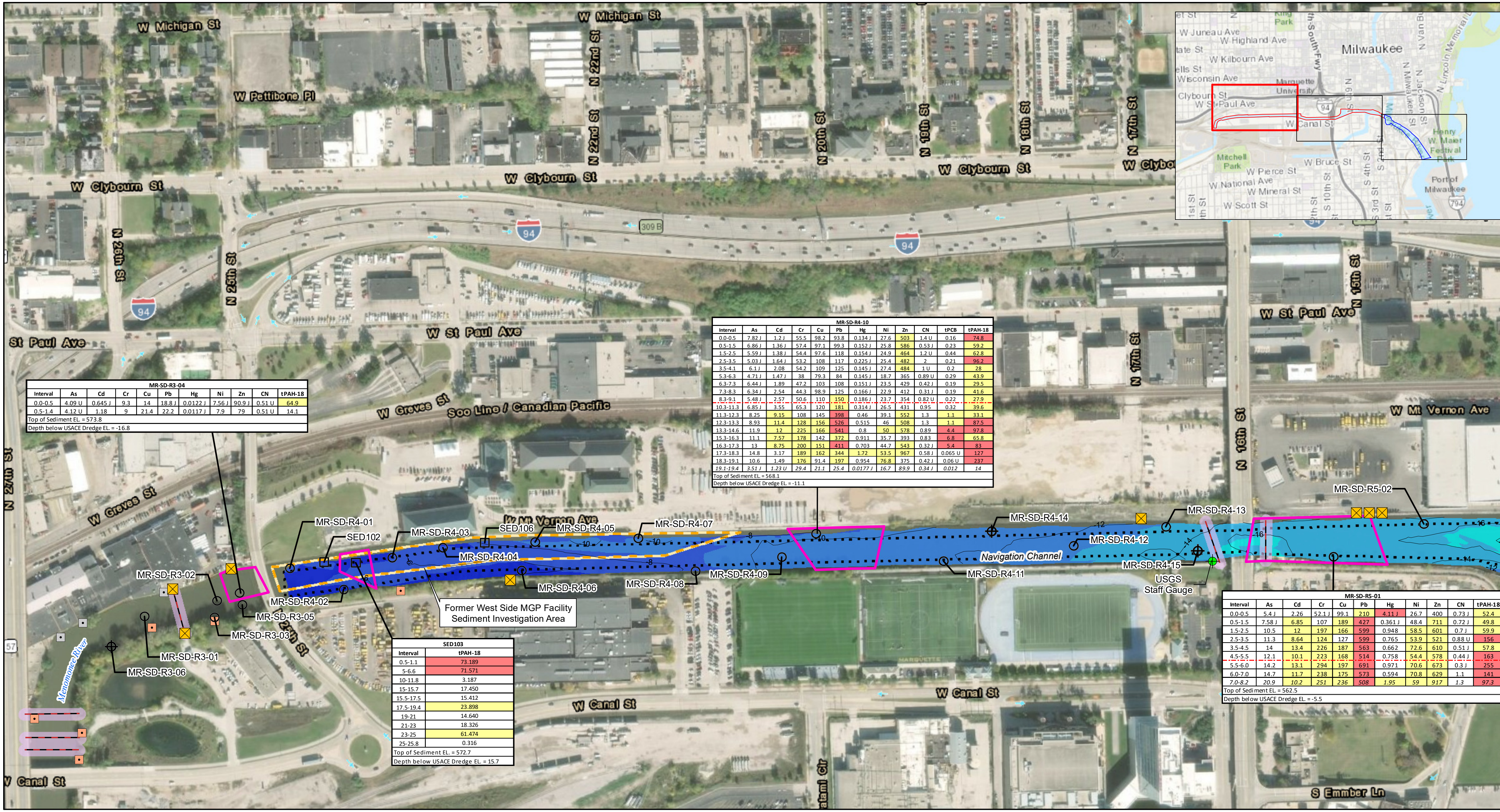


MR-SD-R3-04										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	4.09 U	0.645 J	9.3	14	18.8 J	0.0122 J	7.56 J	90.9 J	0.51 U	64.9
0.5-1.4	4.12 U	1.18	9	21.4	22.2	0.0117 J	7.9	79	0.51 U	14.1
Top of Sediment EL. = 573.8										
Depth below USACE Dredge EL. = -16.8										

MR-SD-R4-10											
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPCB	tPAH-18
0.0-0.5	7.82 J	1.2 J	55.5	98.2	93.8	0.134 J	27.6	503	1.4 U	0.16	74.8
0.5-1.5	6.86 J	1.36 J	57.4	97.1	99.3	0.152 J	25.8	586	0.53 J	0.23	59.2
1.5-2.5	5.59 J	1.38 J	54.4	97.6	118	0.154 J	24.9	464	1.2 U	0.44	62.8
2.5-3.5	5.03 J	1.64 J	53.2	108	117	0.225 J	25.4	482	2	0.21	96.2
3.5-4.1	6.1 J	2.08	54.2	109	125	0.145 J	27.4	484	1 U	0.2	28
5.3-6.3	4.71 J	1.47 J	38	79.3	84	0.145 J	18.7	365	0.89 U	0.29	43.9
6.3-7.3	6.44 J	1.89	47.2	103	108	0.151 J	23.5	429	0.42 J	0.19	29.5
7.3-8.3	6.34 J	2.54	44.3	98.9	125	0.166 J	22.9	412	0.31 J	0.19	41.6
8.3-9.1	5.48 J	2.57	50.6	110	150	0.186 J	23.7	354	0.82 U	0.22	27.9
10.3-11.3	6.85 J	3.55	65.3	120	181	0.314 J	26.5	431	0.95	0.32	39.6
11.3-12.3	8.25	9.15	108	145	398	0.46	39.1	552	1.3	1.1	33.1
12.3-13.3	8.93	11.4	128	156	526	0.515	46	508	1.3	1.1	87.5
13.3-14.6	11.9	12	225	166	541	0.8	50	578	0.89	4.4	97.8
15.3-16.3	11.1	7.57	178	142	372	0.911	35.7	393	0.83	6.8	65.8
16.3-17.3	13	8.75	200	151	411	0.703	44.7	543	0.32 J	5.4	83
17.3-18.3	14.8	3.17	189	162	344	1.72	53.5	967	0.58 J	0.065 U	127
18.3-19.1	10.6	1.49	176	91.4	197	0.954	76.8	375	0.42 J	0.06 U	237
19.1-19.4	*3.51 J*	*1.23 U*	*29.4*	*21.1*	*25.4*	*0.0177 J*	*16.7*	*89.9*	*0.34 J*	*0.012*	*14*
Top of Sediment EL. = 568.1											
Depth below USACE Dredge EL. = -11.1											

SED103	
Interval	tPAH-18
0.5-1.1	73.189
5-6.6	71.571
10-11.8	3.187
15-15.7	17.450
15.5-17.5	15.412
17.5-19.4	23.898
19-21	14.640
21-23	18.326
23-25	61.474
25-25.8	0.316
Top of Sediment EL. = 572.7	
Depth below USACE Dredge EL. = 15.7	

MR-SD-R5-01										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	5.4 J	2.26	52.1 J	99.1	210	4.11 J	26.7	400	0.73 J	52.4
0.5-1.5	7.58 J	6.85	107	189	427	0.361 J	48.4	711	0.72 J	49.8
1.5-2.5	10.5	12	197	166	599	0.948	58.5	601	0.7 J	59.9
2.5-3.5	11.3	8.64	124	127	599	0.765	53.9	521	0.88 U	156
3.5-4.5	14	13.4	226	187	563	0.662	72.6	610	0.51 J	57.8
4.5-5.5	12.1	10.1	223	168	514	0.758	54.4	578	0.44 J	163
5.5-6.0	14.2	13.1	294	197	691	0.971	70.6	673	0.3 J	255
6.0-7.0	14.7	11.7	238	175	573	0.594	70.8	629	1.1	141
7.0-8.2	*20.9*	*10.2*	*251*	*236*	*508*	*1.95*	*59*	*917*	*1.3*	*97.3*
Top of Sediment EL. = 562.5										
Depth below USACE Dredge EL. = -5.5										

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location

Bathymetry (feet)

- Bathymetry Contour
- 1.48
- -10
- -20
- -34.04

- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- Area of Interest (AOI)

N

0 150 300
Feet

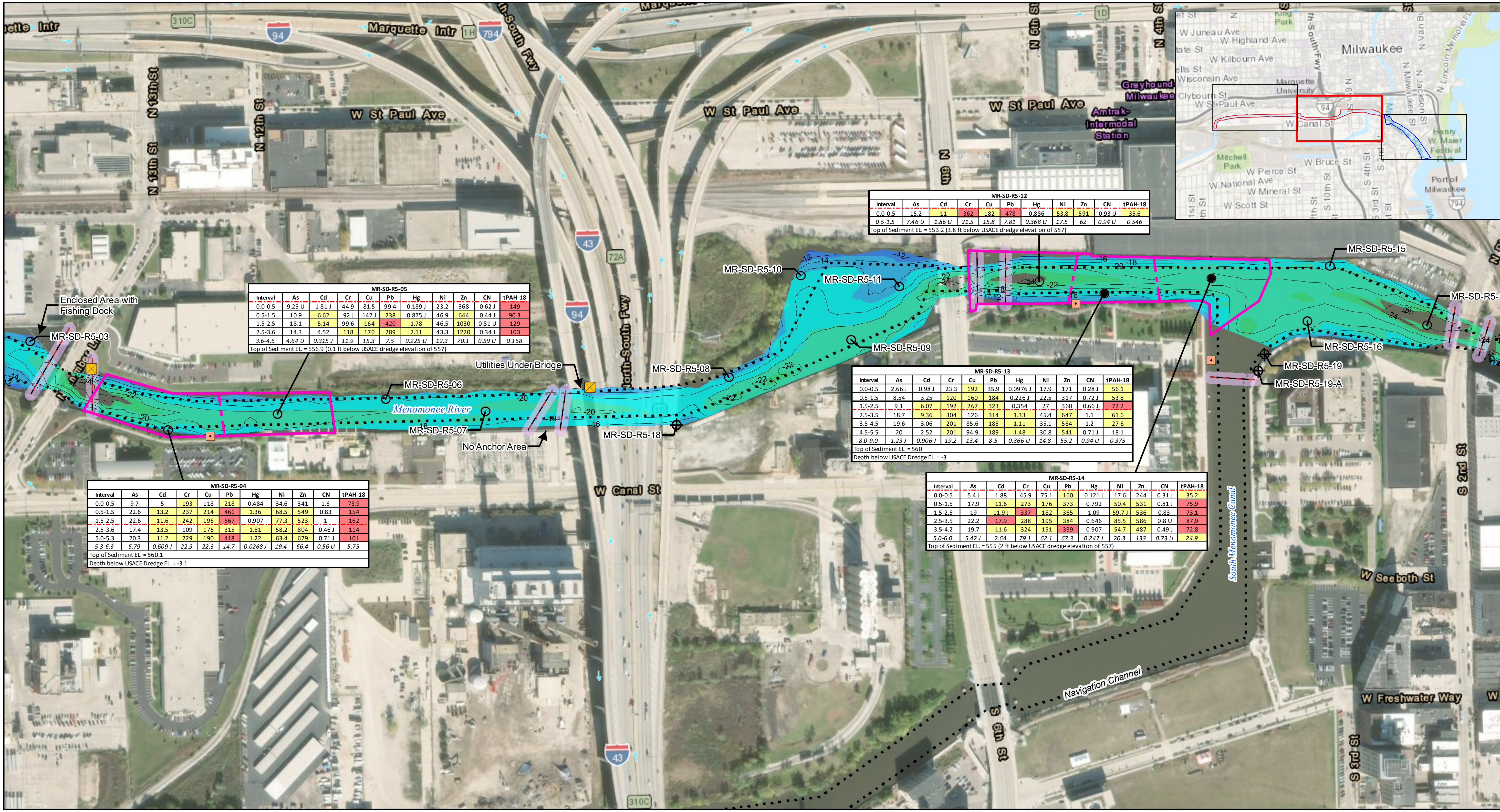
EPA, ESRI World Imagery

General Notes:
1. All concentrations are presented in mg/kg.
2. All intervals are presented in feet below sediment surface (ft bss).
3. Location IDs beginning with "SED" = Former West Side Manufactured Gas Plant (MGP) April 2014 Sediment Investigation Results (sampling performed by Natural Resource Technology). Results are not TOC-normalized.
4. Yellow shading represents results greater than the Probable Effect Concentration (PEC). Red Shading represents results greater than 3x the PEC, Italics = native material.
5. tPCB, tPAH, and metals concentrations are screened against TEC and PEC values listed within the Wisconsin Department of Natural Resources Consensus-Based Sediment Quality Guidelines (CBSQG), December 2003. tPCB and tPAH values are non-TOC normalized.
6. tPAH-18 includes 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(e)pyrene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-Cd)Pyrene, Naphthalene, Phenanthrene, Pyrene.
7. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
8. Top of sediment elevations referenced to NAVD88.
9. Depth's below the USACE dredge elevation are reported as feet below the USACE dredge depth of 21 feet LWD (557 NAVD88).

Abbreviations:
PEC = Probable Effect Concentration
LWD = Low Water Datum
NAVD88 = North American Vertical Datum of 1988
IGLD85 = International Great Lakes Datum of 1985
ft bss = feet below sediment surface
- = sample not collected
— - - = Represents depth below USACE dredge depth of 21 feet LWD in results tables.

Figure 9a
Remediation Target Area Summary
Menomonee and Milwaukee Rivers
Focused Feasibility Study
Milwaukee, Wisconsin

R:\ENBG\00_Proj\E\EPA\Menomonee_MKE_River_FFS\MapFiles\RASTM\Fig9a_Remediation_Target_Area_Summary.mxd AESPEJO (11/28/2018)



MR-SD-R5-05										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	9.25 U	1.81 J	44.9	81.5	99.4	0.189 J	23.2	368	0.62 J	149
0.5-1.5	10.9	6.62	92 J	142 J	238	0.875 J	46.9	644	0.44 J	90.3
1.5-2.5	18.1	5.14	99.6	164	420	1.78	46.5	1030	0.81 U	129
2.5-3.6	14.3	4.52	118	170	289	2.11	43.3	1220	0.34 J	103
3.6-4.6	*4.64 U*	*0.315 J*	*11.9*	*15.3*	*7.5*	*0.225 U*	*12.3*	*70.1*	*0.59 U*	*0.168*
Top of Sediment EL. = 556.9 (0.1 ft below USACE dredge elevation of 557)										

MR-SD-R5-04										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	9.7	5	193	118	218	0.484	34.6	341	1.6	73.9
0.5-1.5	22.6	13.2	237	214	461	1.36	68.5	549	0.83	154
1.5-2.5	22.6	11.6	242	196	567	0.907	77.3	523	1	162
2.5-3.6	17.4	13.5	109	176	315	1.81	58.2	804	0.46 J	114
5.0-5.3	20.3	11.2	229	190	418	1.22	63.4	679	0.71 J	101
5.3-6.3	*5.79*	*0.609 J*	*22.9*	*22.3*	*14.7*	*0.0268 J*	*19.4*	*66.4*	*0.56 U*	*5.75*
Top of Sediment EL. = 560.1										
Depth below USACE Dredge EL. = -3.1										

MR-SD-R5-12										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	15.2	11	362	182	478	0.886	53.8	591	0.93 U	35.6
0.5-1.5	*7.46 U*	*1.86 U*	*21.5*	*15.8*	*7.81*	*0.368 U*	*17.5*	*62*	*0.94 U*	*0.546*
Top of Sediment EL. = 553.2 (3.8 ft below USACE dredge elevation of 557)										

MR-SD-R5-13										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	2.66 J	0.98 J	23.3	192	35.9	0.0976 J	17.9	171	0.28 J	56.1
0.5-1.5	8.54	3.25	120	160	184	0.226 J	22.5	317	0.72 J	53.8
1.5-2.5	9.1	6.07	192	267	323	0.354	27	360	0.66 J	72.2
2.5-3.5	18.7	9.36	304	126	314	1.33	45.4	647	1.1	61.6
3.5-4.5	19.6	3.06	201	85.6	185	1.11	35.1	564	1.2	27.6
4.5-5.5	20	2.52	201	94.9	189	1.48	30.8	541	0.71 J	18.1
8.0-9.0	*1.23 J*	*0.906 J*	*19.2*	*13.4*	*8.5*	*0.366 U*	*14.8*	*55.2*	*0.94 U*	*0.375*
Top of Sediment EL. = 560										
Depth below USACE Dredge EL. = -3										

MR-SD-R5-14										
Interval	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	CN	tPAH-18
0.0-0.5	5.4 J	1.88	45.9	75.1	160	0.121 J	17.6	244	0.31 J	35.2
0.5-1.5	17.9	11.6	273	176	373	0.792	50.4	531	0.81 J	75.9
1.5-2.5	19	11.9 J	337	182	365	1.09	59.7 J	536	0.83	73.1
2.5-3.5	22.2	17.9	288	195	384	0.646	85.5	586	0.8 U	87.9
3.5-4.2	19.7	11.6	324	151	399	0.907	54.7	487	0.49 J	72.8
5.0-6.0	*5.42 J*	*2.64*	*79.1*	*62.1*	*67.3*	*0.247 J*	*20.3*	*133*	*0.73 U*	*24.9*
Top of Sediment EL. = 555 (2 ft below USACE dredge elevation of 557)										

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- Area of Interest (AOI)

Bathymetry (feet)

- Bathymetry Contour
- 1.48
- -10
- -20
- -34.04

N

0 150 300
Feet

EPA, ESRI World Imagery

General Notes:
1. All concentrations are presented in mg/kg.
2. All intervals are presented in feet below sediment surface (ft bss).
3. Location IDs beginning with "SED" = Former West Side Manufactured Gas Plant (MGP) April 2014 Sediment Investigation Results (sampling performed by Natural Resource Technology). Results are not TOC-normalized.
4. Yellow shading represents results greater than the Probable Effect Concentration (PEC). Red Shading represents results greater than 3x the PEC, Italics = native material.
5. tPCB, tPAH, and metals concentrations are screened against TEC and PEC values listed within the Wisconsin Department of Natural Resources Consensus-Based Sediment Quality Guidelines (CBSQG), December 2003. tPCB and tPAH values are non-TOC normalized.
6. tPAH-18 includes 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(e)pyrene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-Cd)Pyrene, Naphthalene, Phenanthrene, Pyrene.
7. OU1 bathymetry data collected by USACE (October 2015). OU2 bathymetry data collected by Freshwater Engineering (June 2017). Bathymetry data referenced to depth below LWD 578 NAVD88 (577.5 IGLD85).
8. Top of sediment elevations referenced to NAVD88.
9. Depth's below the USACE dredge elevation are reported as feet below the USACE dredge depth of 21 feet LWD (557 NAVD88).

Abbreviations:
PEC = Probable Effect Concentration
LWD = Low Water Datum
NAVD88 = North American Vertical Datum of 1988
IGLD85 = International Great Lakes Datum of 1985
ft bss = feet below sediment surface
- = sample not collected
— - - = Represents depth below USACE dredge depth of 21 feet LWD in results tables.

Figure 9b
Remediation Target Area Summary
Menomonee and Milwaukee Rivers
Focused Feasibility Study
Milwaukee, Wisconsin

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Figure 9c
Remediation Target Area Summary
Menomonee and Milwaukee Rivers
Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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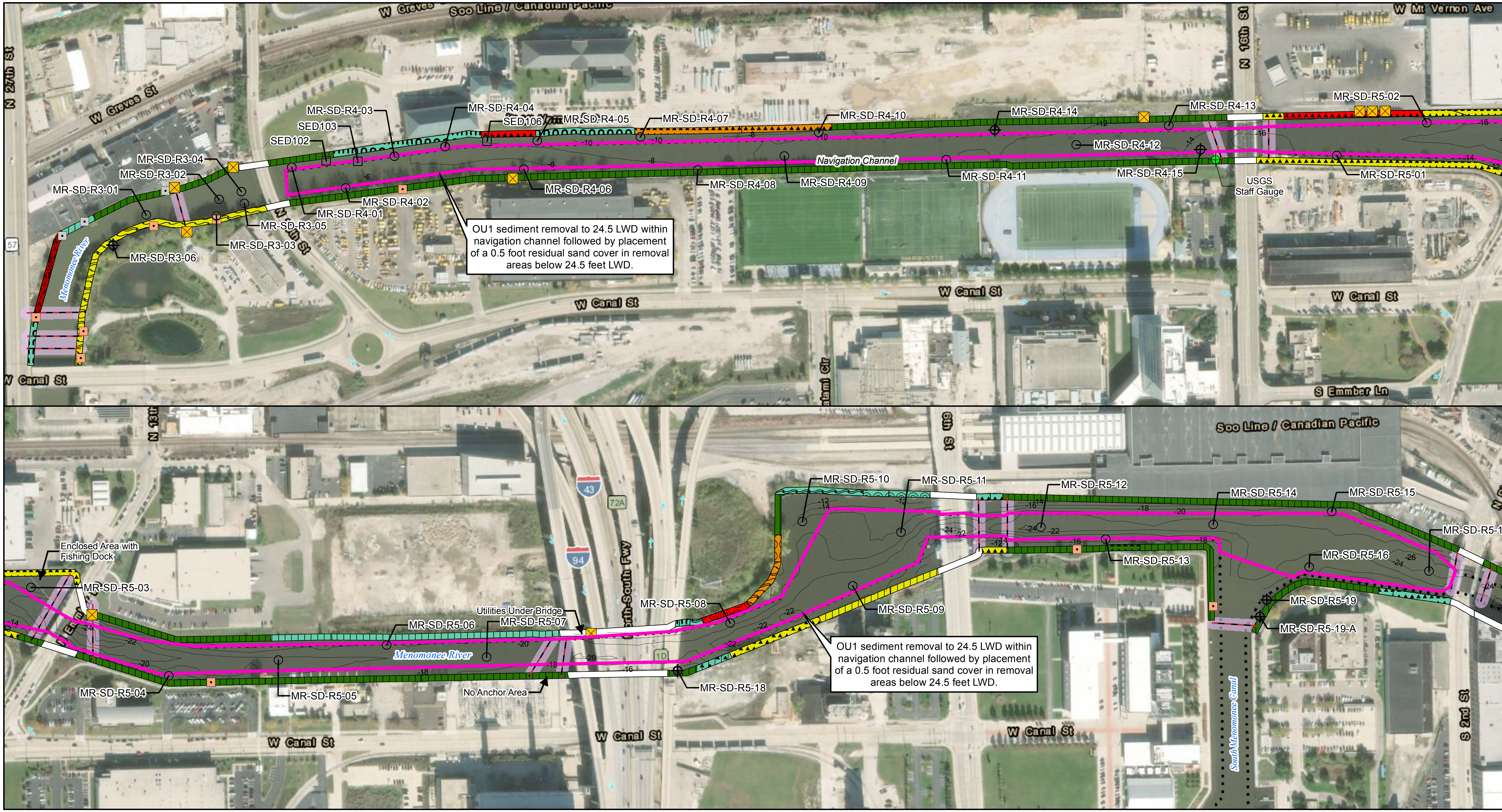

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Bathymetry Contour (feet)
- Underground Utility with 20' Setback
- Navigation Channel
- Alternative 2
- Lateral Extent of Observed NAPL

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Unstabalized Shoreline
- Riprap
- Steel Sheet Pile
- Stone Revetment
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 150 300

Feet

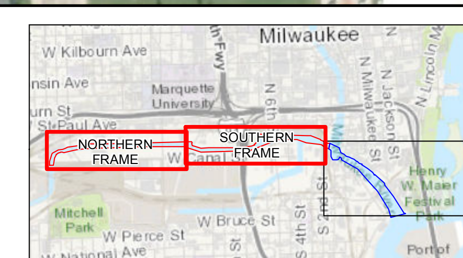

Figure 10
Alternative 2 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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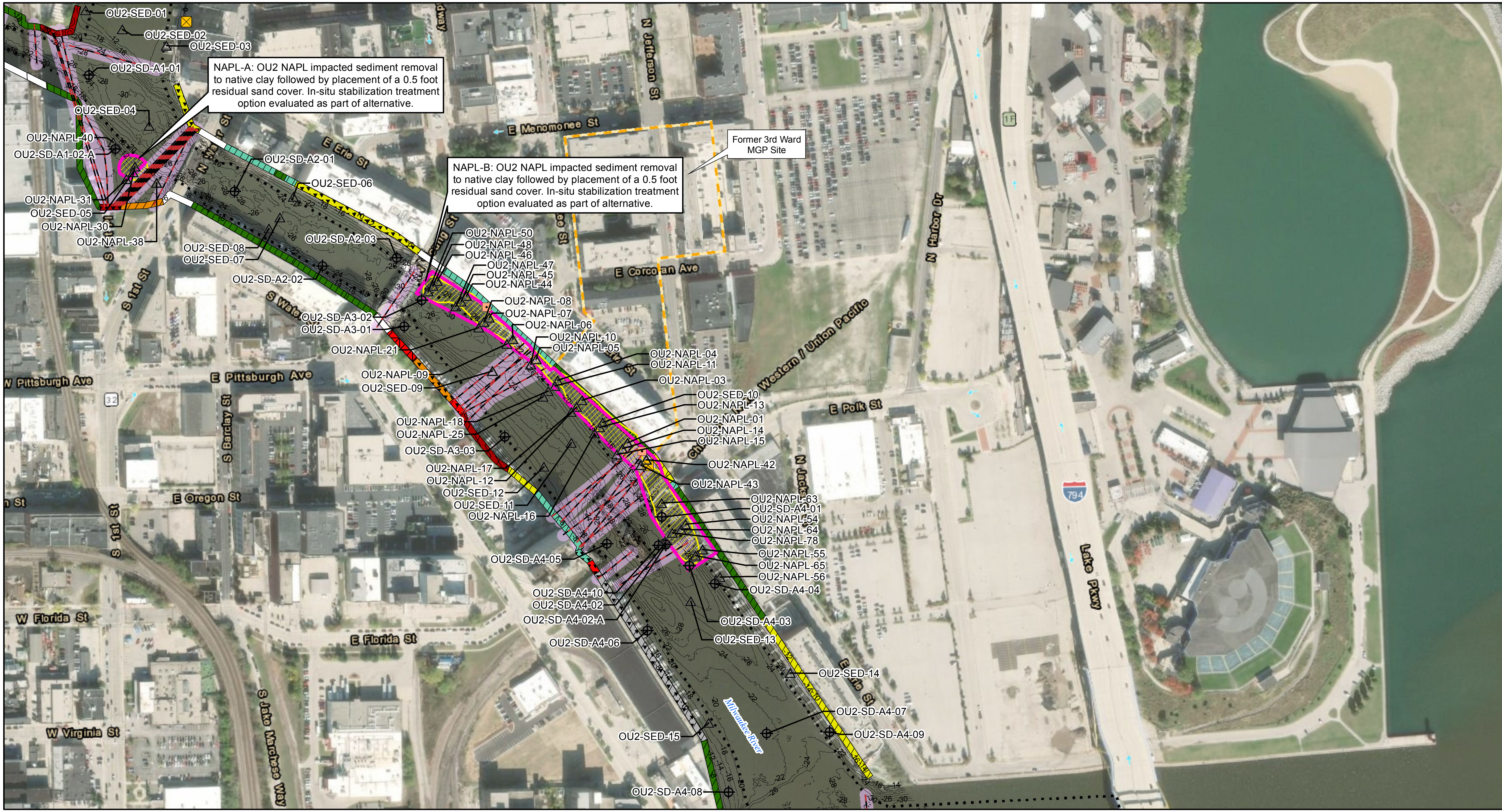

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Bathymetry Contour (feet)
- Underground Utility with 20' Setback
- Navigation Channel
- Alternative 2
- Lateral Extent of Observed NAPL

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Unstabalized Shoreline
- Riprap
- Steel Sheet Pile
- Stone Revetment
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 150 300
Feet

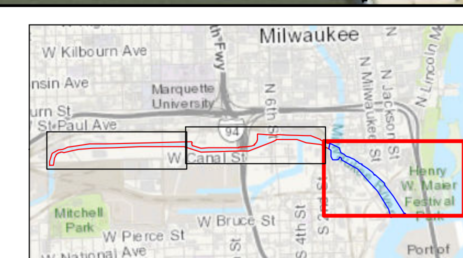

Figure 10
Alternative 2 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery
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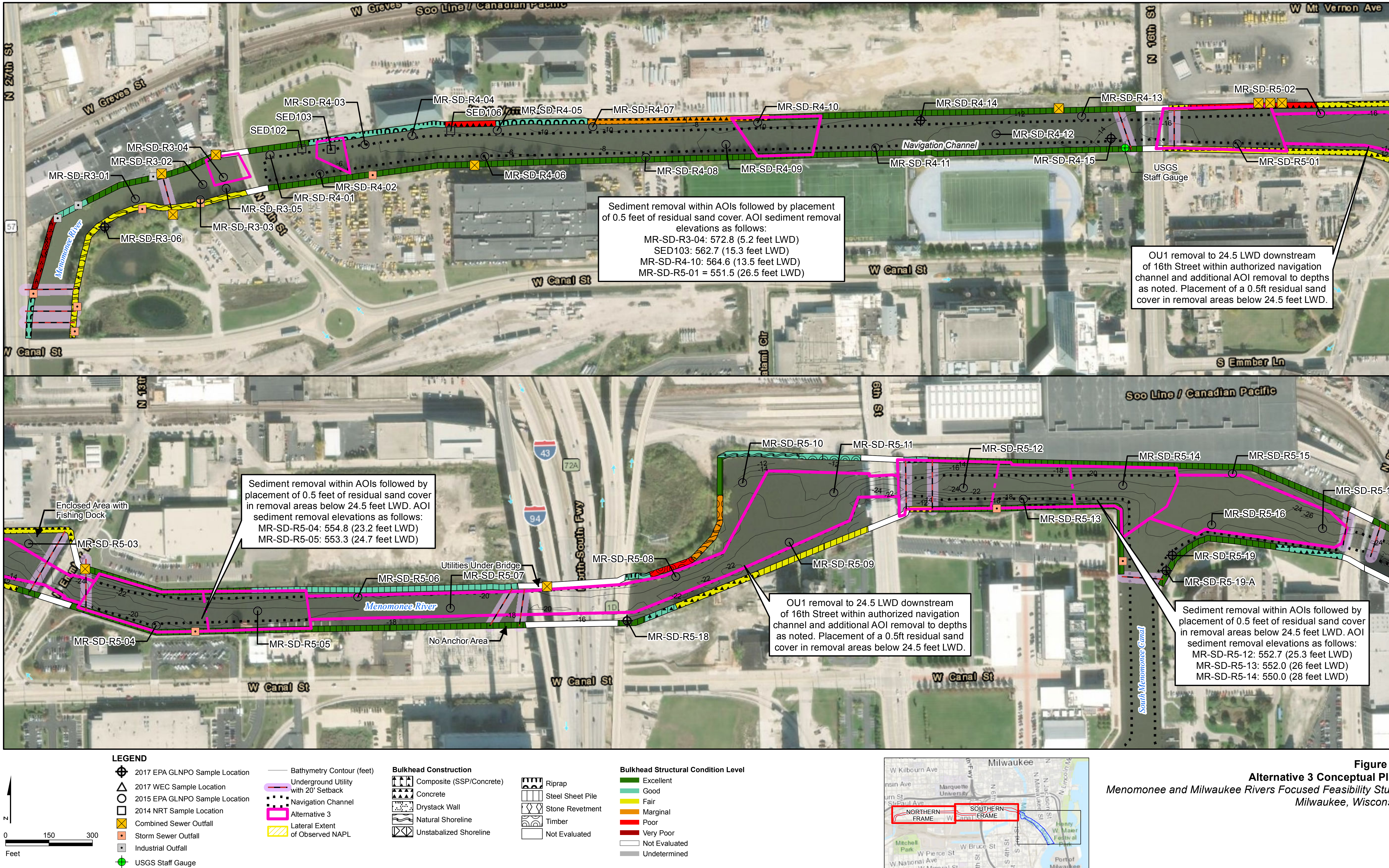
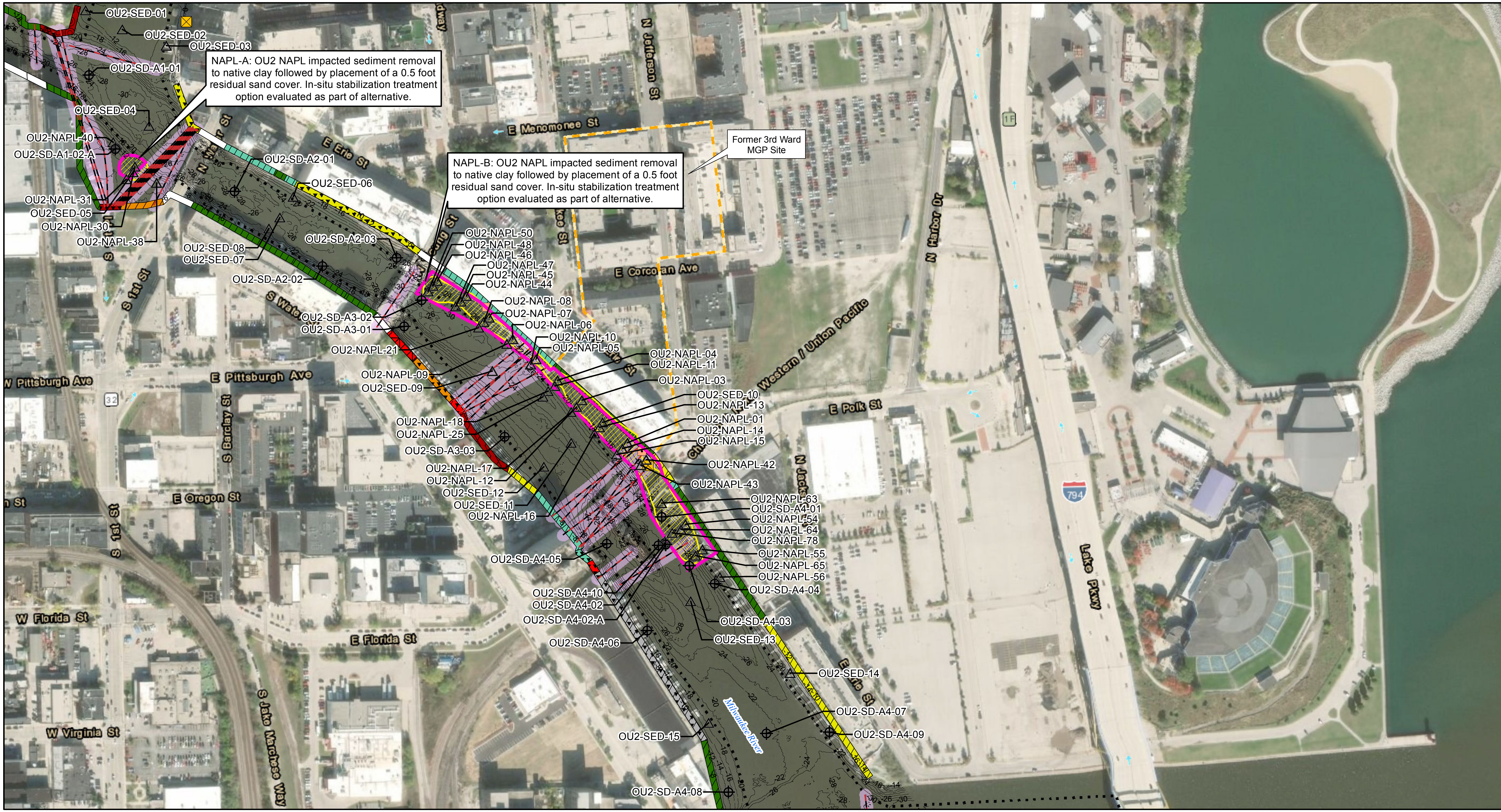


Figure 11
Alternative 3 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Bathymetry Contour (feet)
- Underground Utility with 20' Setback
- Navigation Channel
- Alternative 3
- Lateral Extent of Observed NAPL

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Unstabalized Shoreline
- Riprap
- Steel Sheet Pile
- Stone Revetment
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 150 300
Feet

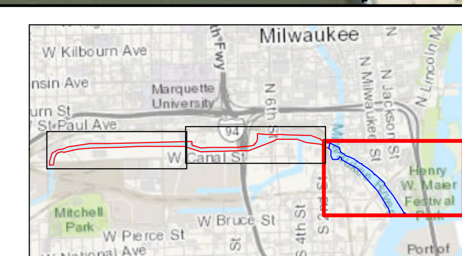


Figure 11
Alternative 3 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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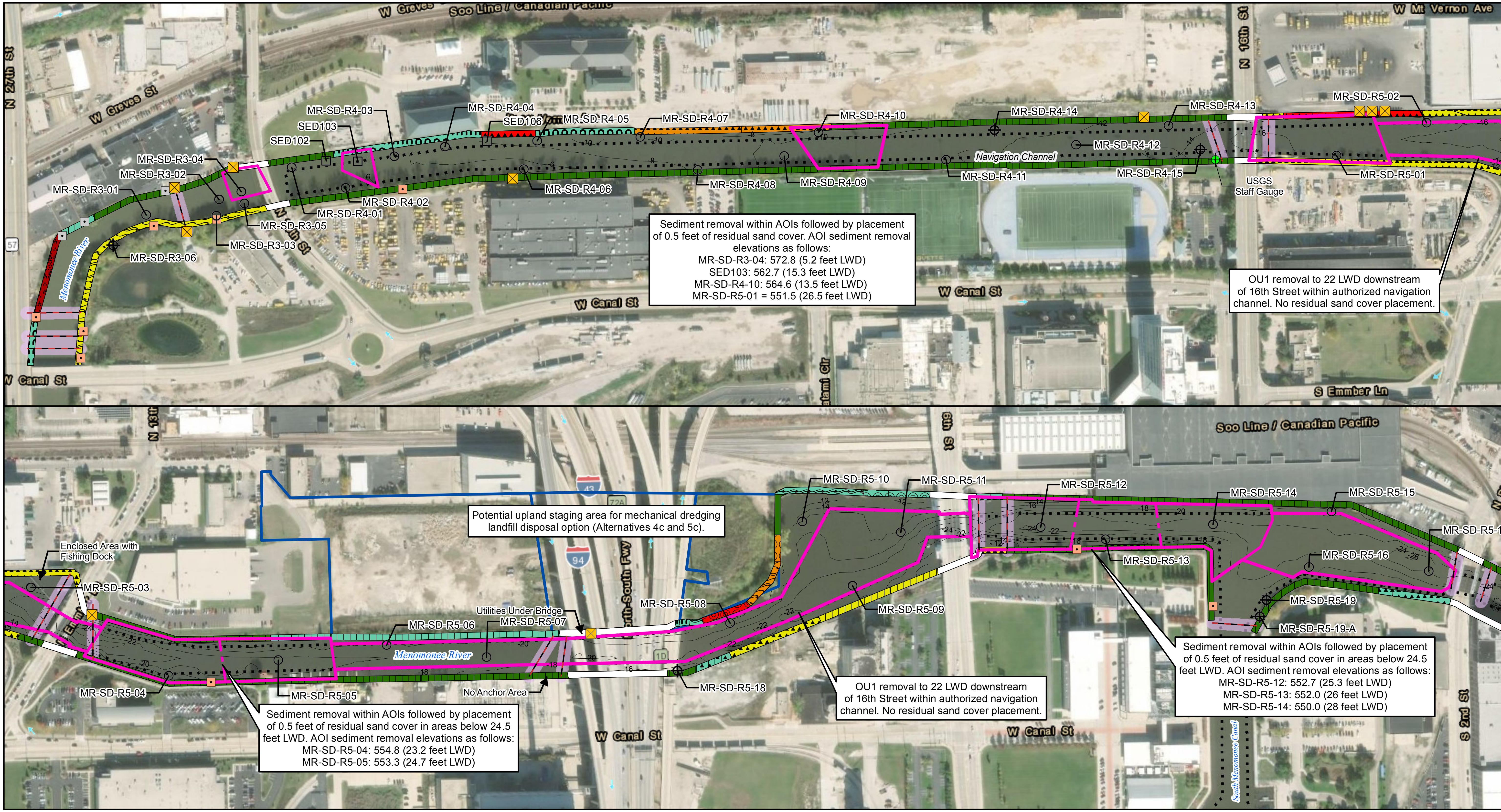

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Bathymetry Contour (feet)
- Underground Utility with 20' Setback
- Navigation Channel
- Alternative 4
- Lateral Extent of Observed NAPL

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Unstabalized Shoreline
- Riprap
- Steel Sheet Pile
- Stone Revetment
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 150 300
Feet

Milwaukee
NORTHERN FRAME
SOUTHERN FRAME

EPA, ESRI World Imagery

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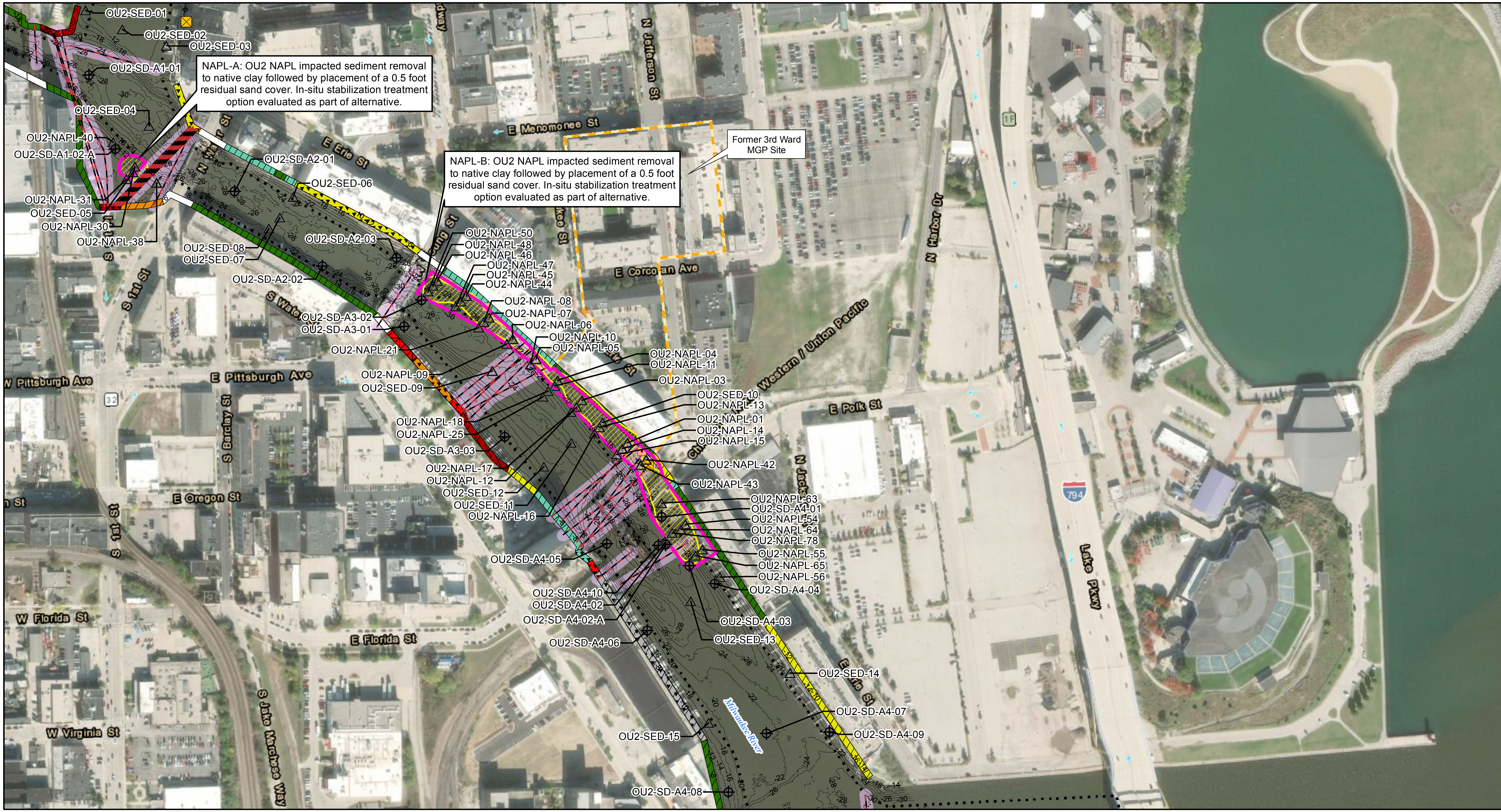
Figure 12
Alternative 4 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

ch2m.



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Bathymetry Contour (feet)
- Underground Utility with 20' Setback
- Navigation Channel
- Alternative 4
- Lateral Extent of Observed NAPL

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Unstabilized Shoreline
- Riprap
- Steel Sheet Pile
- Stone Revetment
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 150 300

Feet

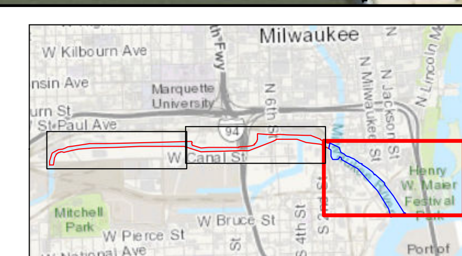


Figure 12
Alternative 4 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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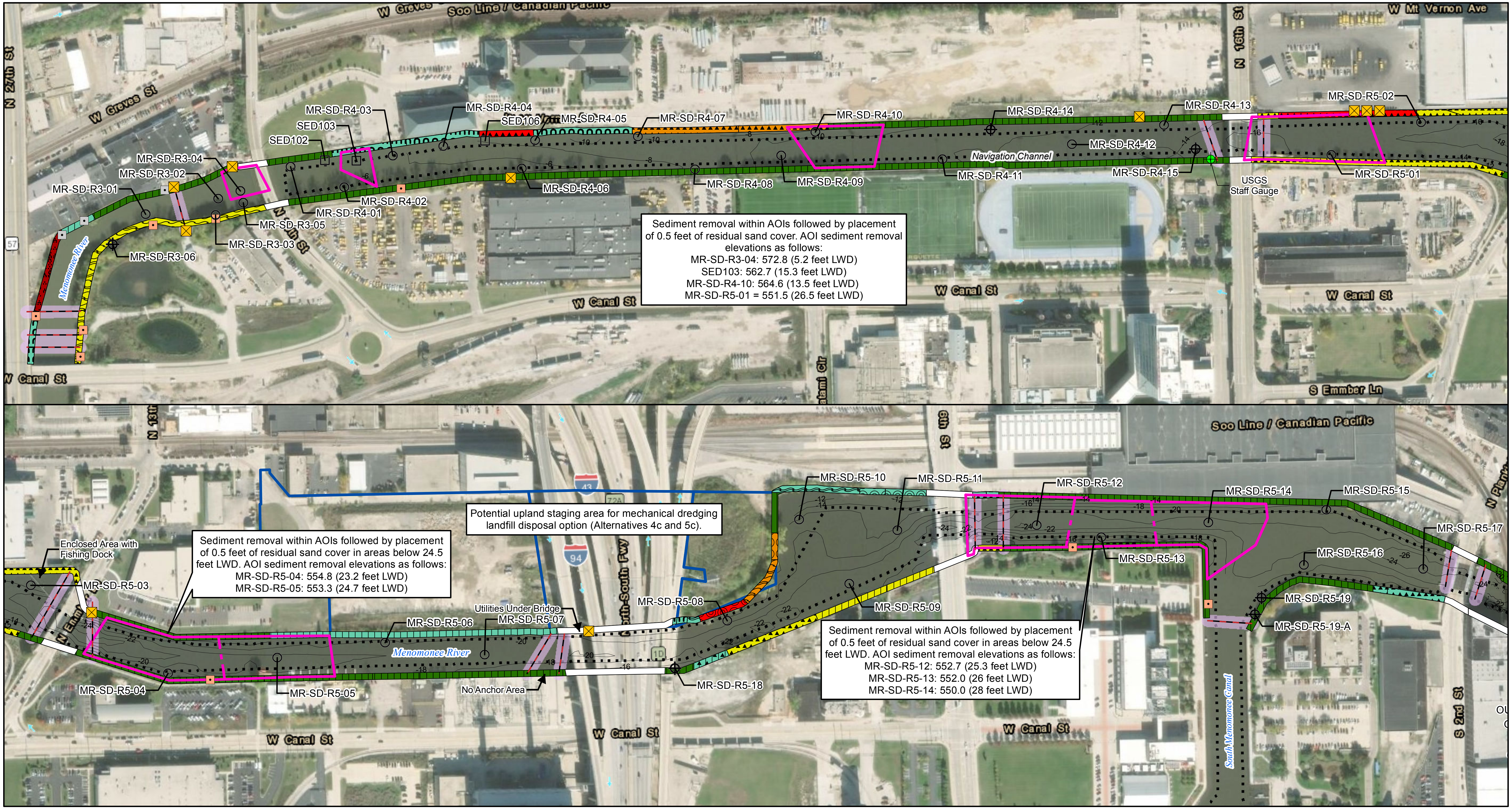

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Bathymetry Contour (feet)
- Underground Utility with 20' Setback
- Navigation Channel
- Alternative 5
- Lateral Extent of Observed NAPL

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Unstabilized Shoreline
- Riprap
- Steel Sheet Pile
- Stone Revetment
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 150 300
Feet

EPA, ESRI World Imagery

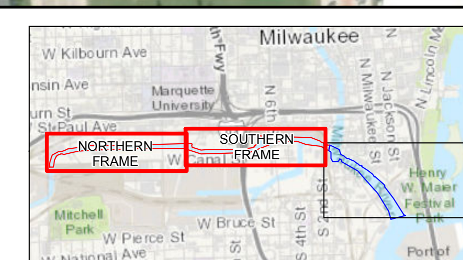

Figure 13
Alternative 5 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

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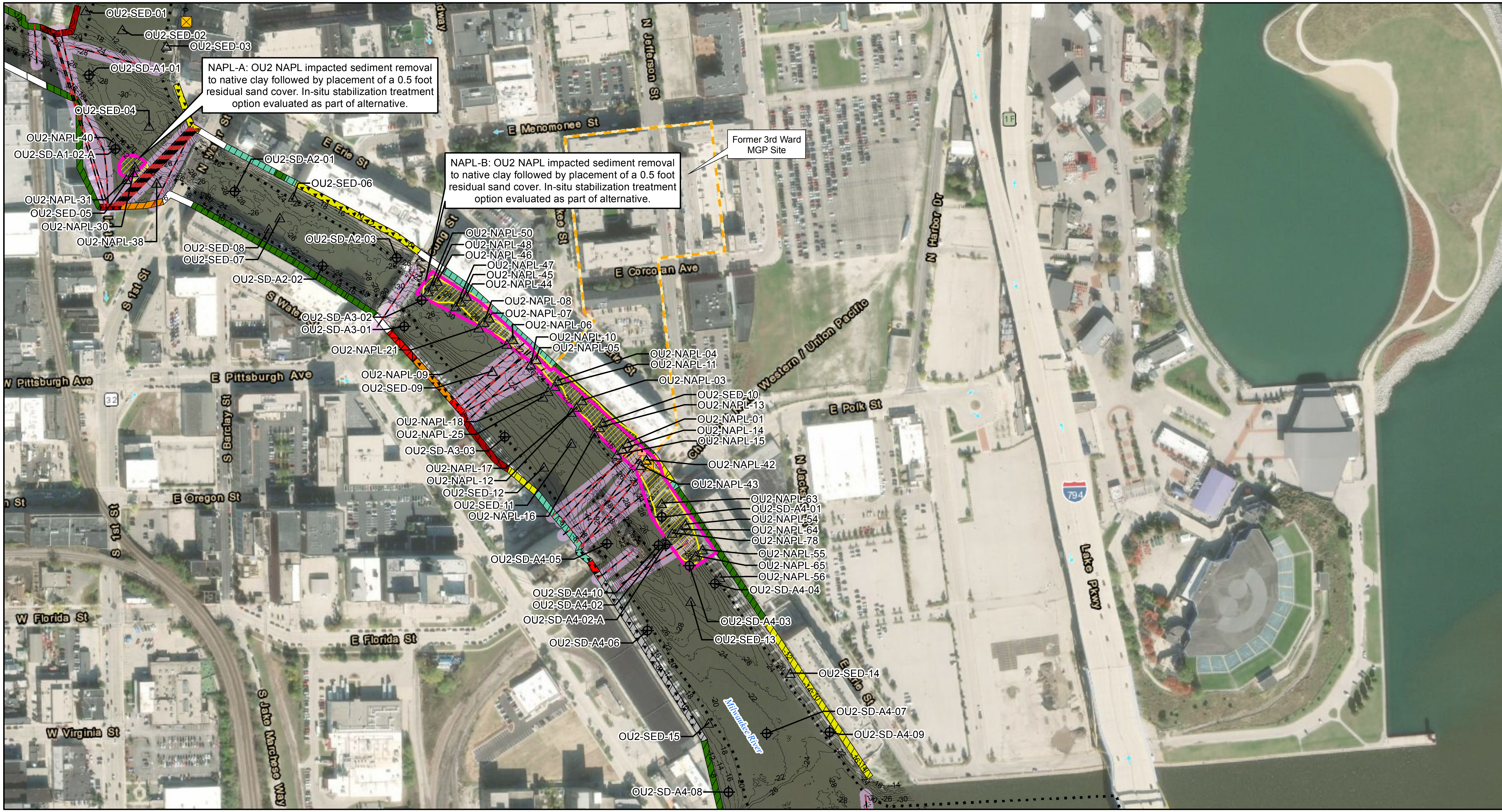

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Storm Sewer Outfall
- Industrial Outfall
- USGS Staff Gauge
- Bathymetry Contour (feet)
- Underground Utility with 20' Setback
- Navigation Channel
- Alternative 5
- Lateral Extent of Observed NAPL

Bulkhead Construction

- Composite (SSP/Concrete)
- Concrete
- Drystack Wall
- Natural Shoreline
- Unstabalized Shoreline
- Riprap
- Steel Sheet Pile
- Stone Revetment
- Timber
- Not Evaluated

Bulkhead Structural Condition Level

- Excellent
- Good
- Fair
- Marginal
- Poor
- Very Poor
- Not Evaluated
- Undetermined

N

0 150 300

Feet

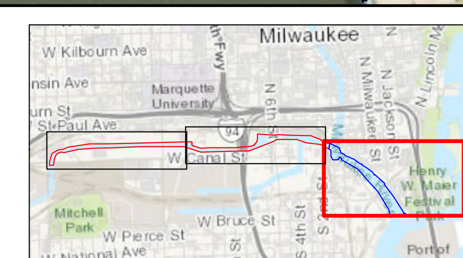

Figure 13
Alternative 5 Conceptual Plan
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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ch2m

Appendix A
Comparison of Bathymetry Figures

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Contour

Bathymetry (feet)

- 25 - 33.42
- 20 - 25
- 15 - 20
- 10 - 15
- 5 - 10
- < 5

N

0 150 300
Feet

General Note:
1996 bathymetry data collected by USACE.

Figure 1a
1996 Bathymetry
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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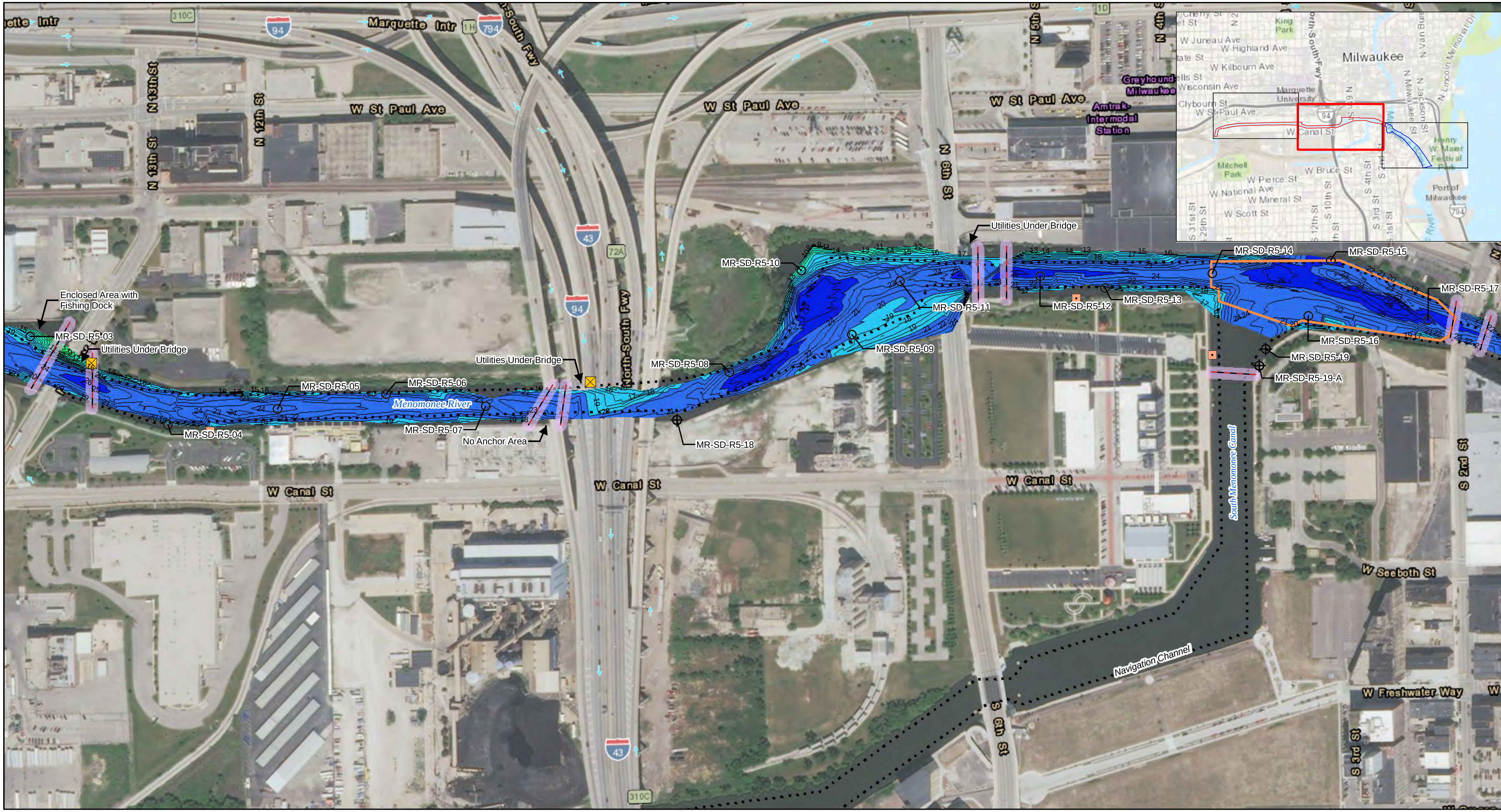

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Contour

Bathymetry (feet)

- 25 - 33.42
- 20 - 25
- 15 - 20
- 10 - 15
- 5 - 10
- < 5

N

0 150 300
Feet

General Note:
1996 bathymetry data collected by USACE.

Figure 1b
1996 Bathymetry
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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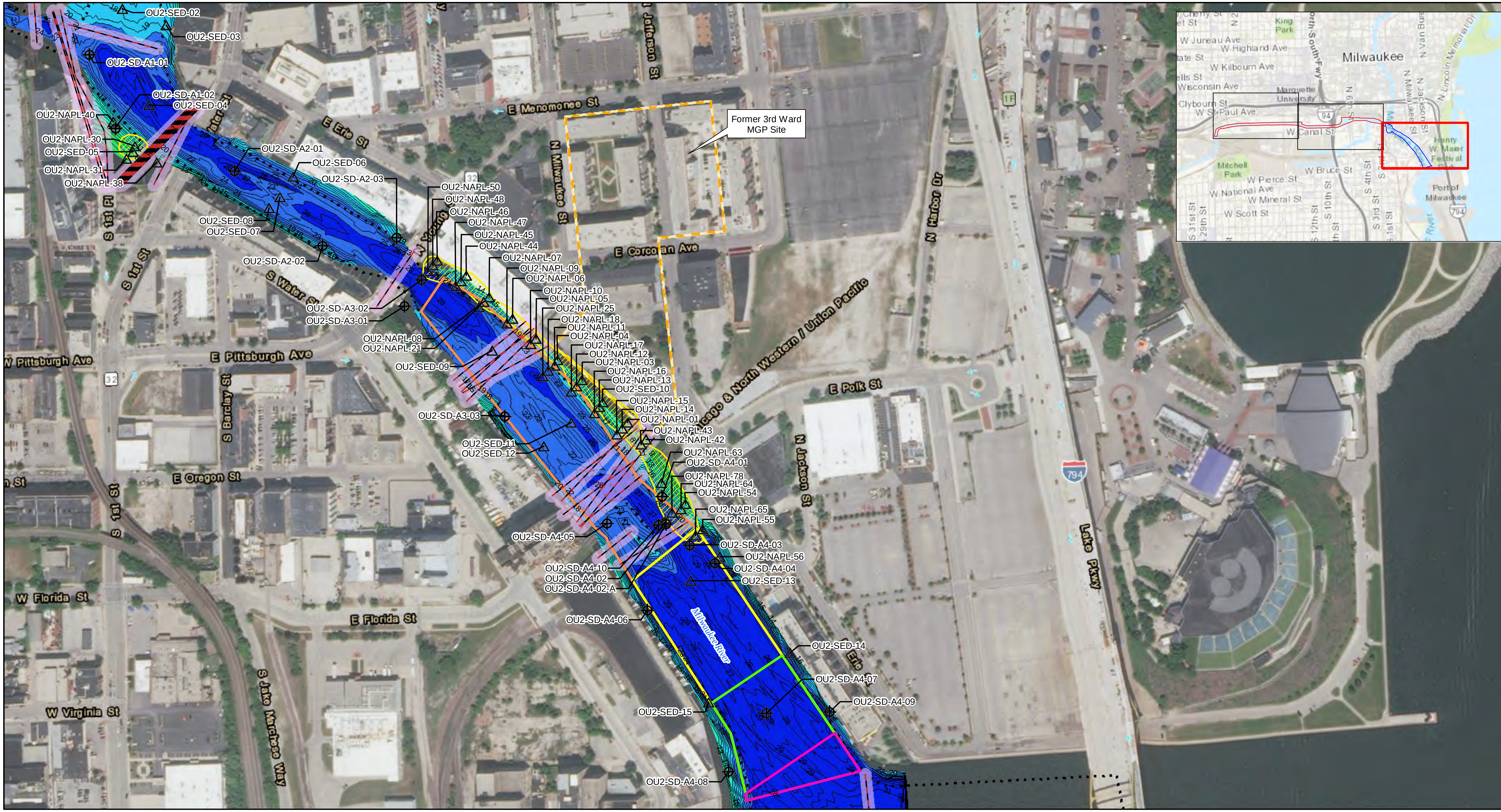

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Contour

Bathymetry (feet)

- 25 - 33.42
- 20 - 25
- 15 - 20
- 10 - 15
- 5 - 10
- < 5

0 150 300
Feet

General Note:
1996 bathymetry data collected by USACE.

Figure 1c
1996 Bathymetry
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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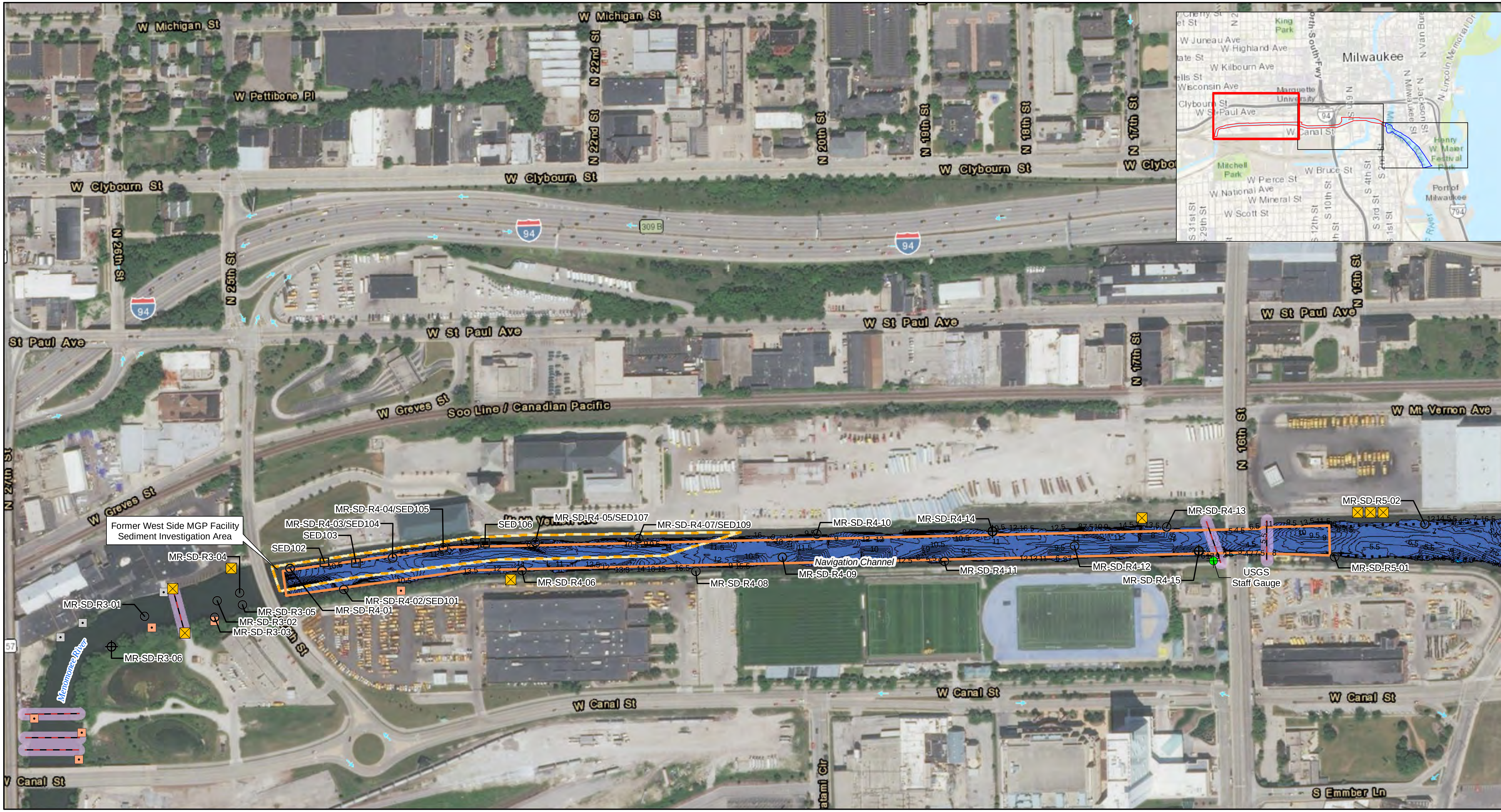

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300

Feet

General Note:
2017 and 1996 bathymetry data collected by USACE.

Figure 2a

2017 and 1996 Bathymetry Differential Comparison

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

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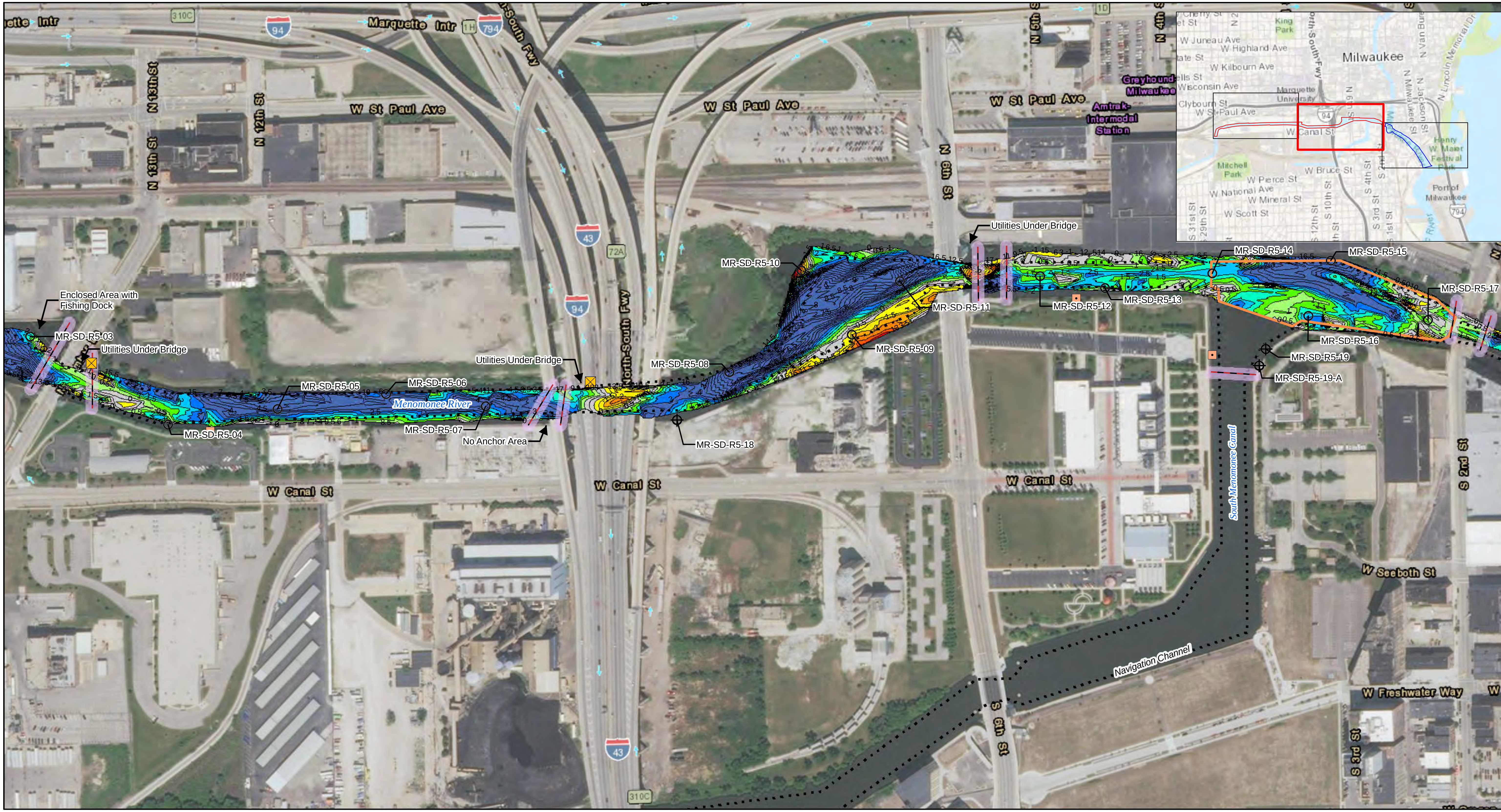
ch2m



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300

Feet

General Note:
2017 and 1996 bathymetry data collected by USACE.

Figure 2b

2017 and 1996 Bathymetry Differential Comparison

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

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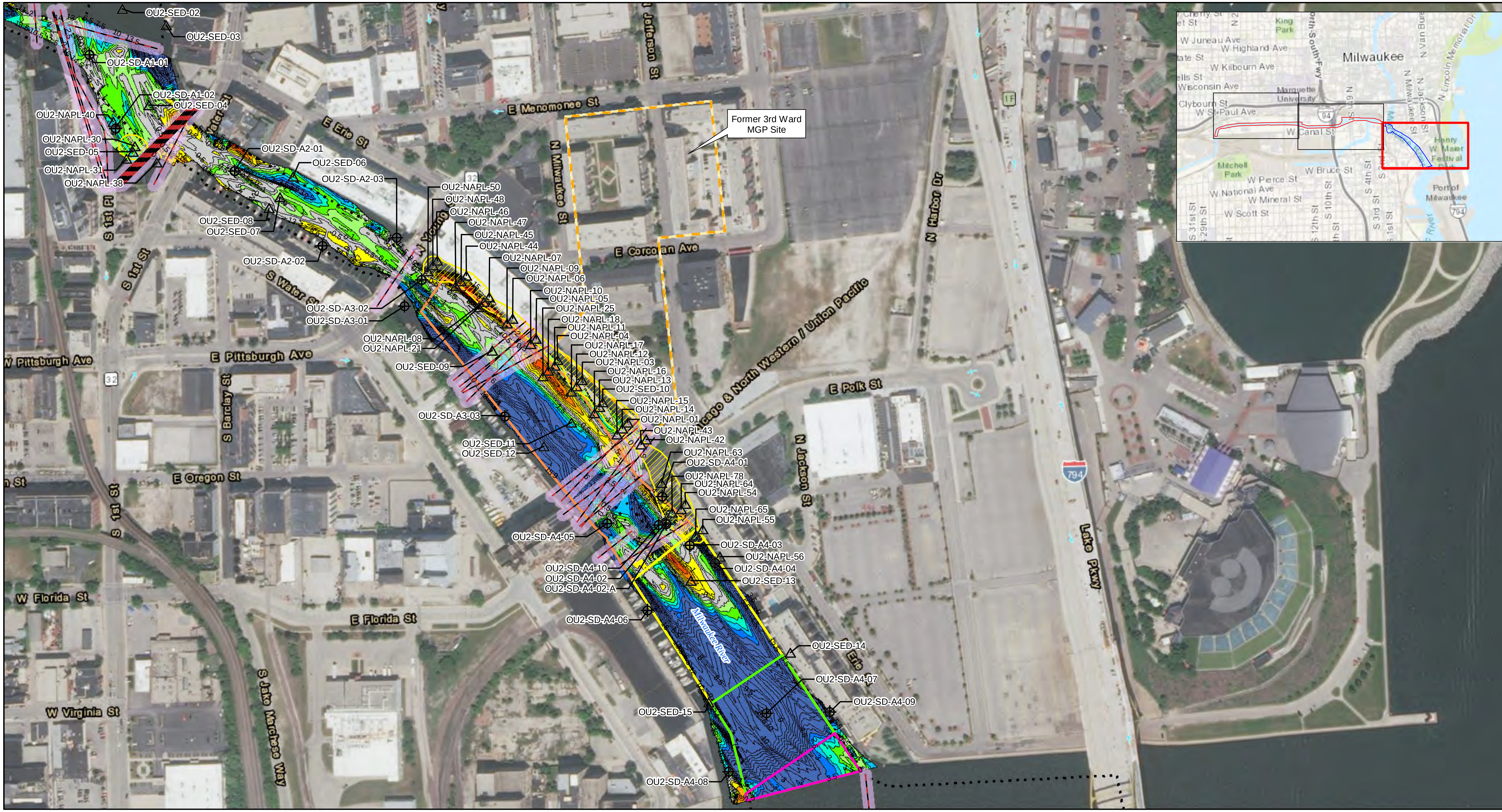

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300

Feet

General Note:
2017 and 1996 bathymetry data collected by USACE.

Figure 2c

2017 and 1996 Bathymetry Differential Comparison

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

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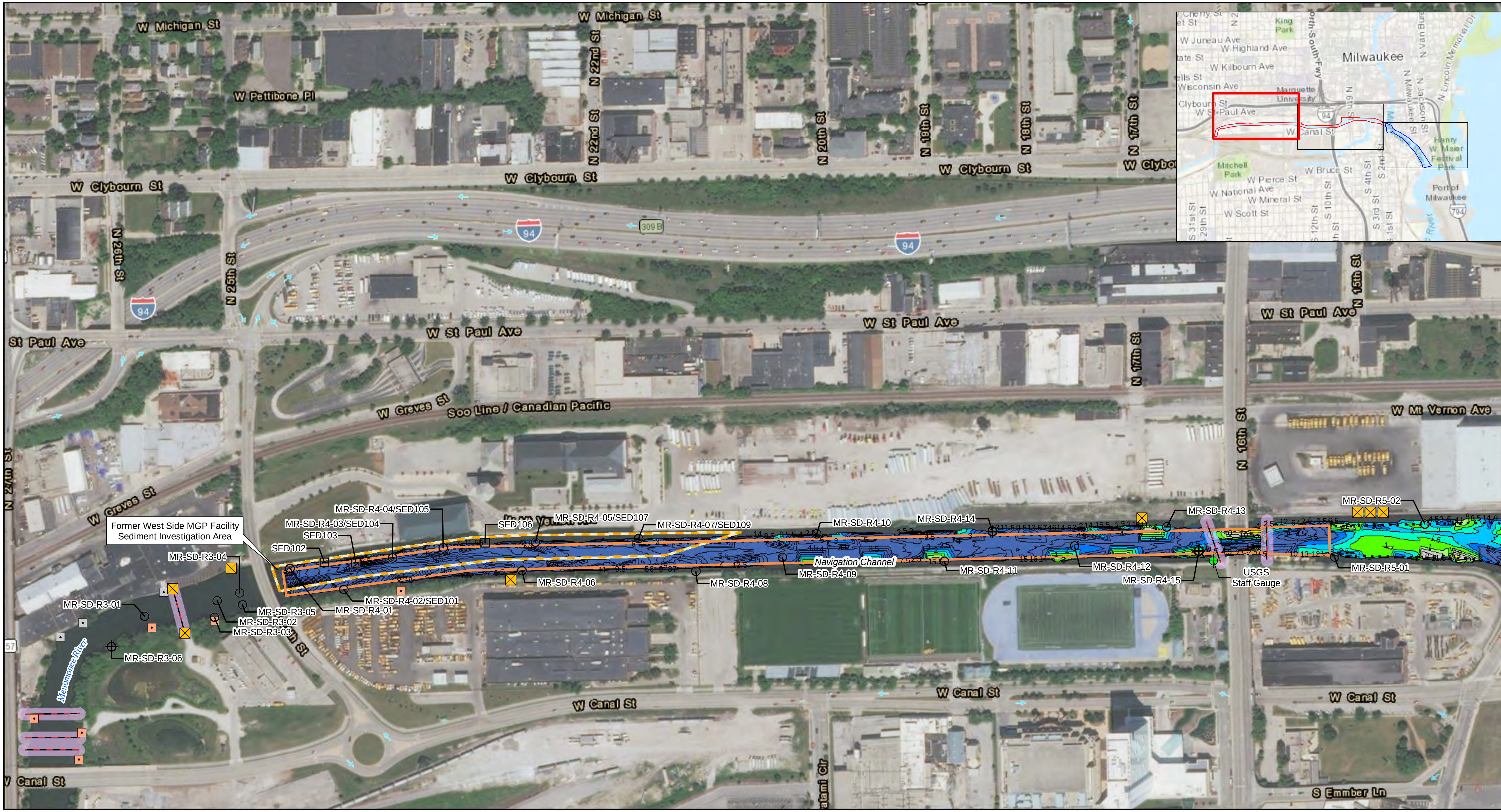

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
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- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300
Feet

General Note:
2002 and 1996 bathymetry data collected by USACE.

Figure 3a
2002 and 1996 Bathymetry Differential Comparison
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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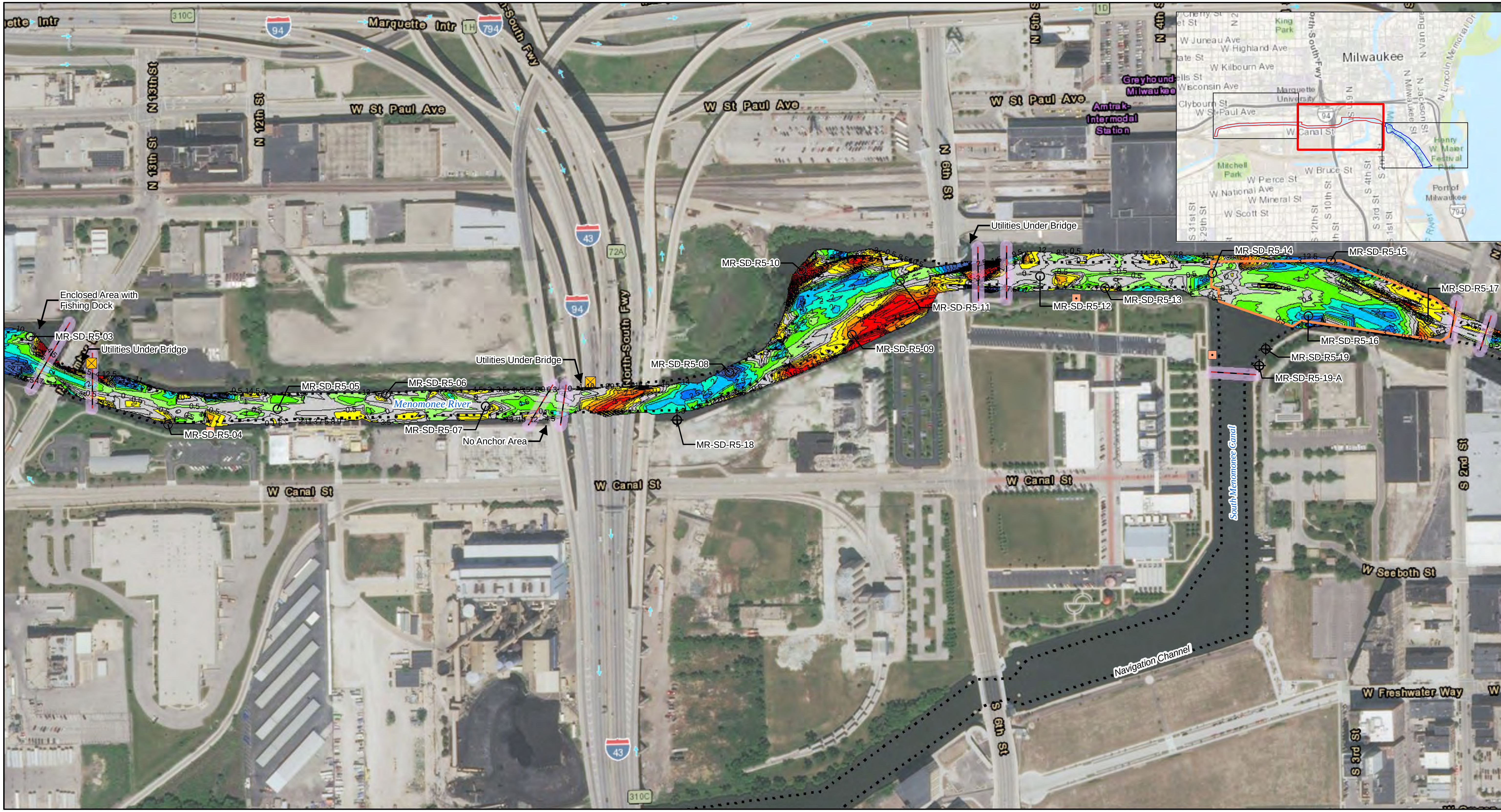

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

0 150 300
Feet

General Note:
2002 and 1996 bathymetry data collected by USACE.

Figure 3b
2002 and 1996 Bathymetry Differential Comparison
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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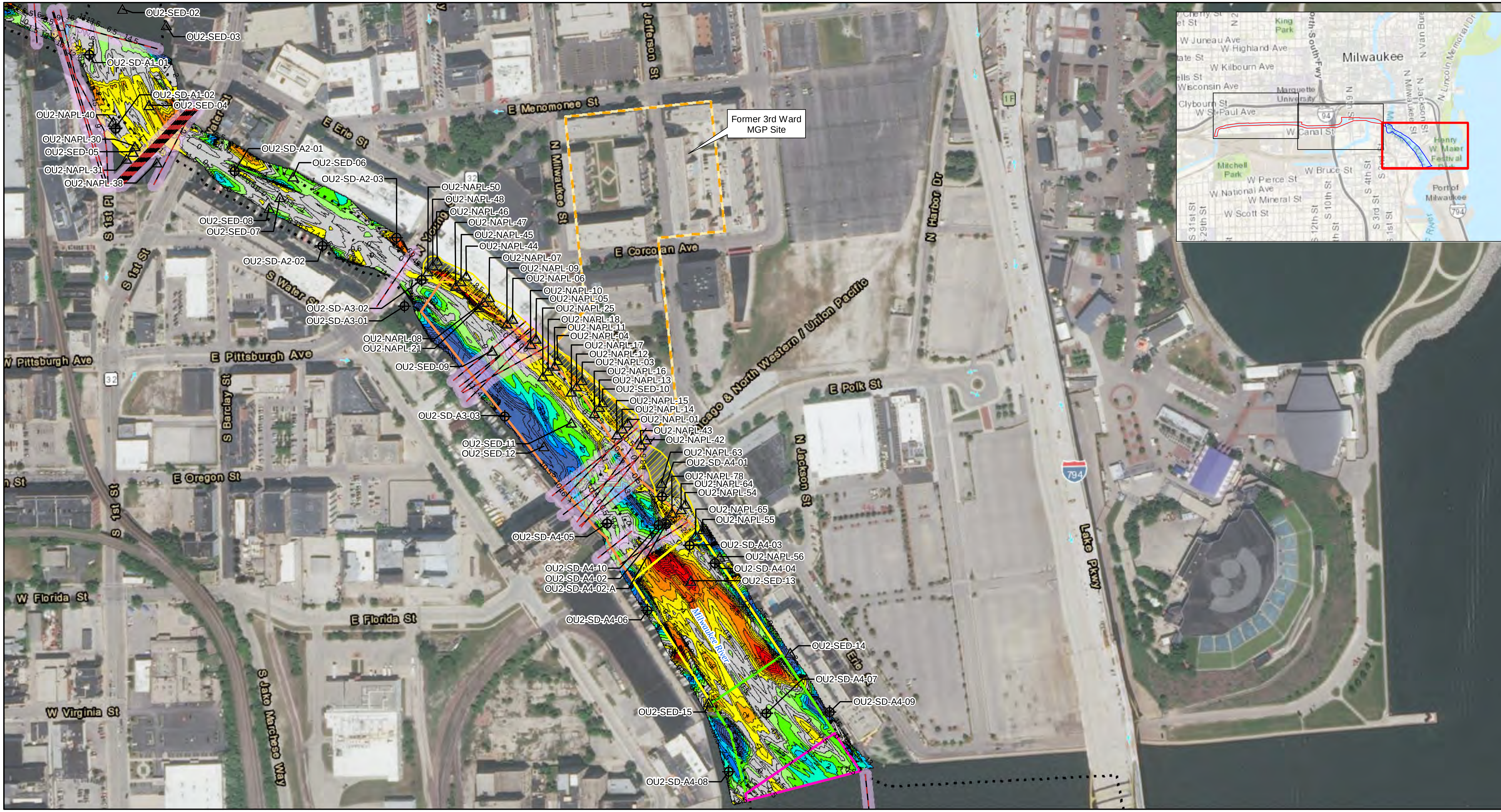

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300

Feet

General Note:
2002 and 1996 bathymetry data collected by USACE.

Figure 3c
2002 and 1996 Bathymetry Differential Comparison
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

R:\ENBG\00_Proj\E\EPA\Menomonee_MKE_River_FFS\MapFiles\Bathy\Fig1a-c_2002_and_1996_Bathymetry_Differential_Comparison.mxd AESPEJO (4/8/2018)

ch2m.

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
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- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300
Feet

General Note:
2011 and 2002 bathymetry data collected by USACE.

Figure 4a
2011 and 2002 Bathymetry Differential Comparison
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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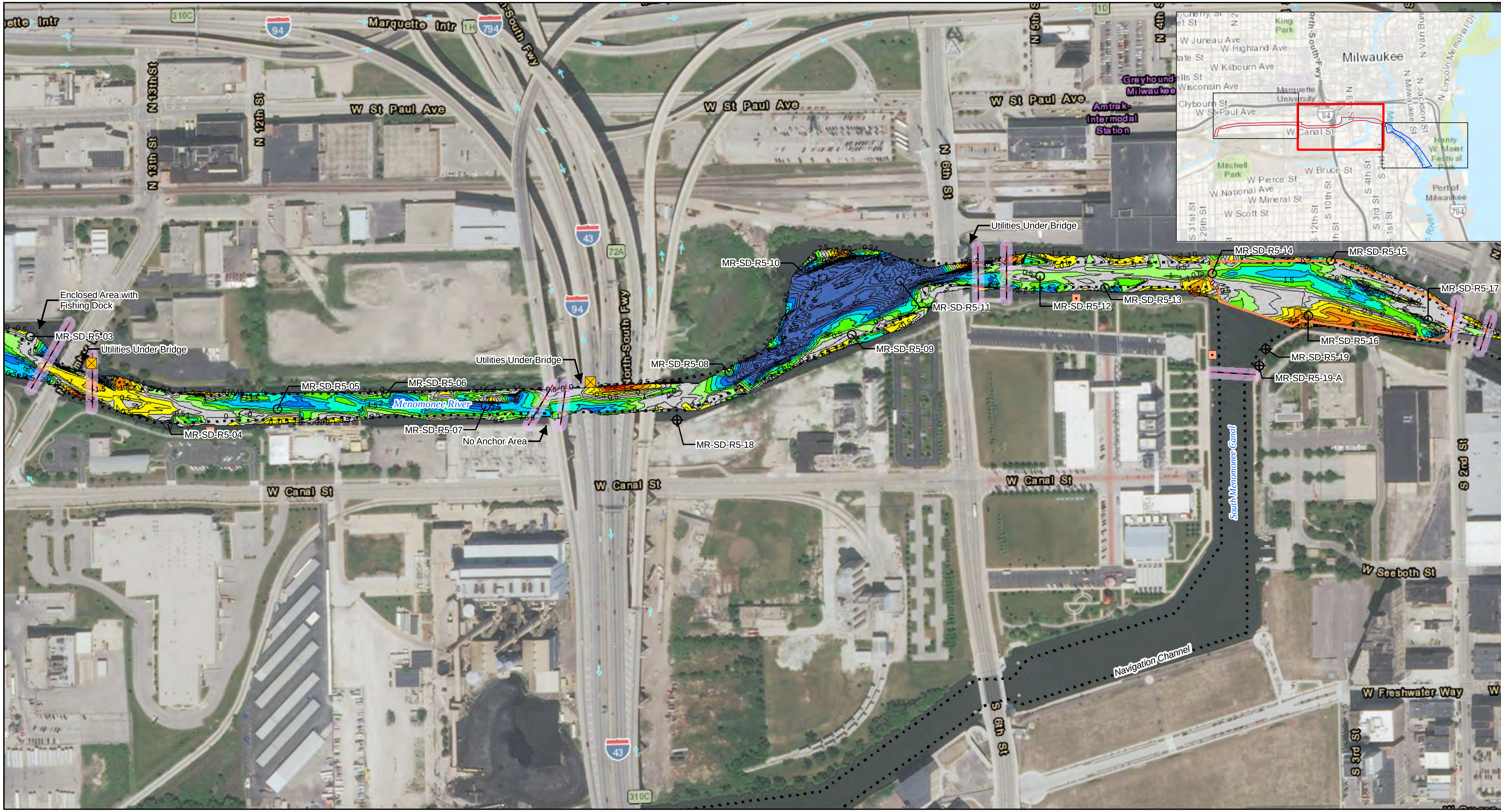
ch2m



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event

Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

General Note:
2011 and 2002 bathymetry data collected by USACE.

N

0 150 300
Feet

EPA, ESRI World Imagery

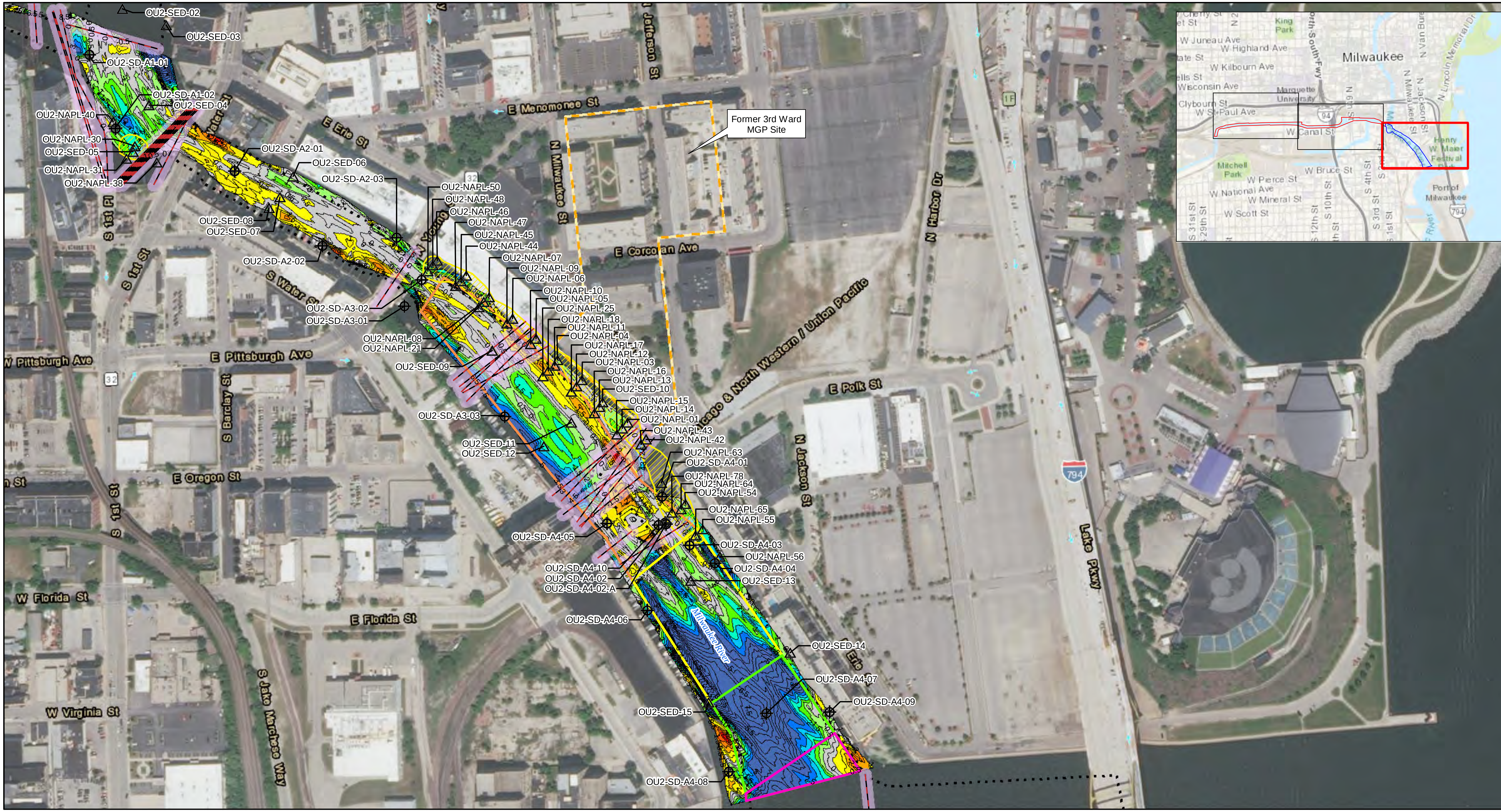
Figure 4b

2011 and 2002 Bathymetry Differential Comparison

Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

R:\ENBG\00_Proj\E\EPA\Menomonee_MKE_River_FFS\MapFiles\Bathy\Fig1a-c_2011_and_2002_Bathymetry_Differential_Comparison.mxd AESPEJO (4/8/2018)

ch2m



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300

Feet

General Note:
2011 and 2002 bathymetry data collected by USACE.

Figure 4c

2011 and 2002 Bathymetry Differential Comparison

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

R:\ENBG\00_Proj\E\EPA\Menomonee_MKE_River_FFS\MapFiles\Bathy\Fig1a-c_2011_and_2002_Bathymetry_Differential_Comparison.mxd AESPEJO (4/8/2018)

ch2m.

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300
Feet

General Note:
2015 and 2011 bathymetry data collected by USACE.

Figure 5a
2015 and 2011 Bathymetry Differential Comparison
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery

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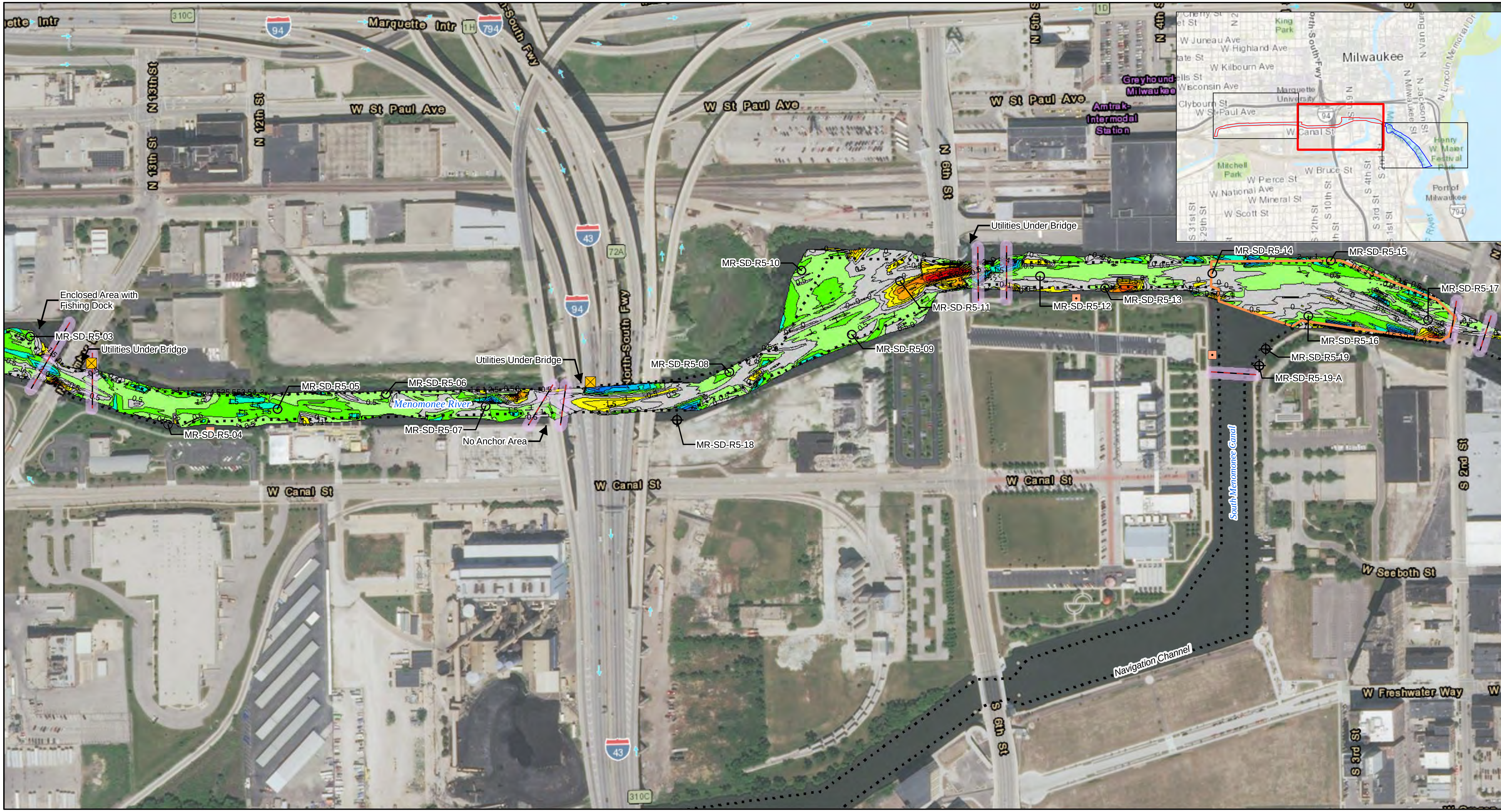

LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300
Feet

General Note:
2015 and 2011 bathymetry data collected by USACE.

Figure 5b
2015 and 2011 Bathymetry Differential Comparison
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

EPA, ESRI World Imagery
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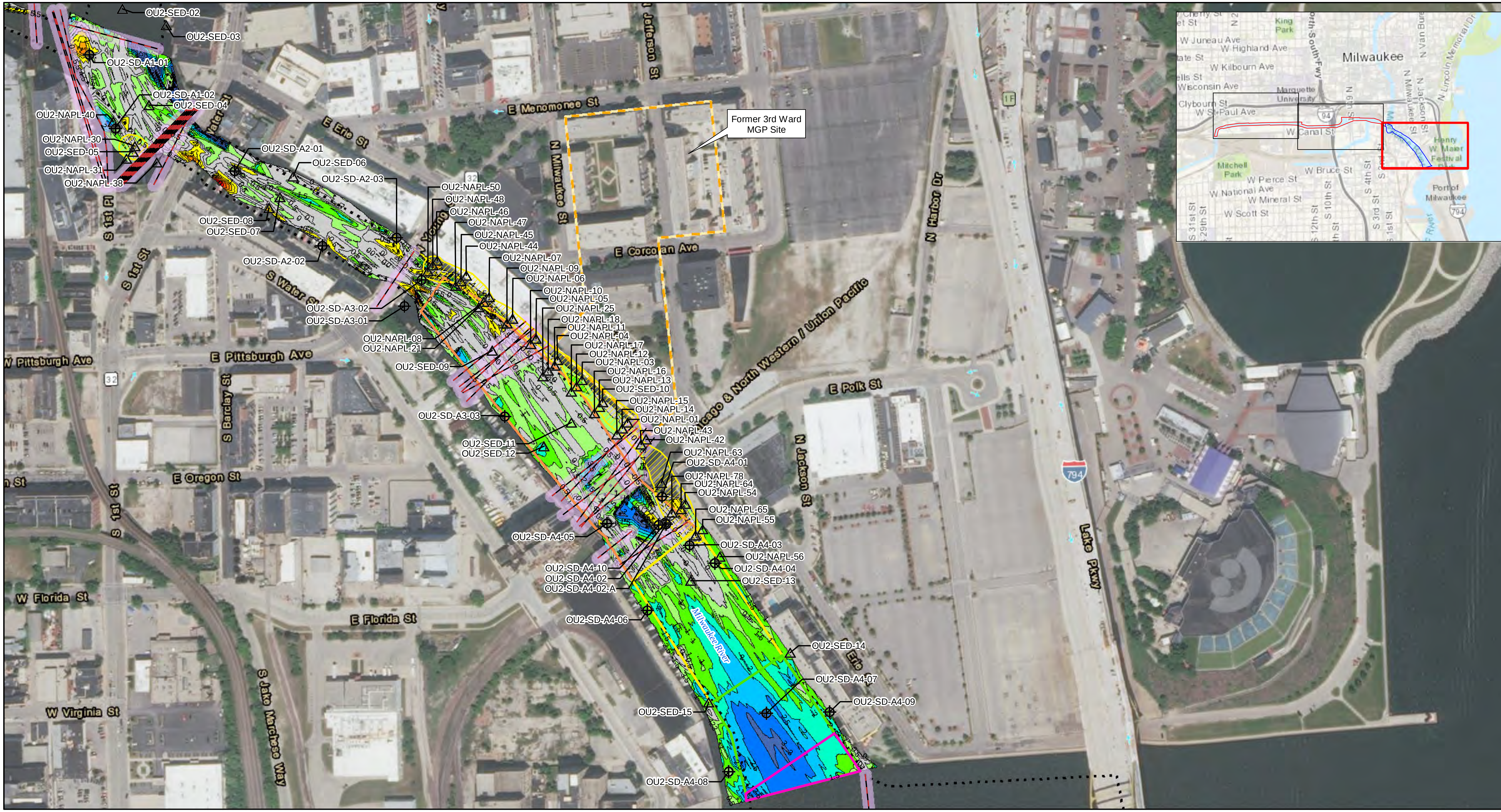


LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300

Feet

General Note:
2015 and 2011 bathymetry data collected by USACE.

Figure 5c

2015 and 2011 Bathymetry Differential Comparison

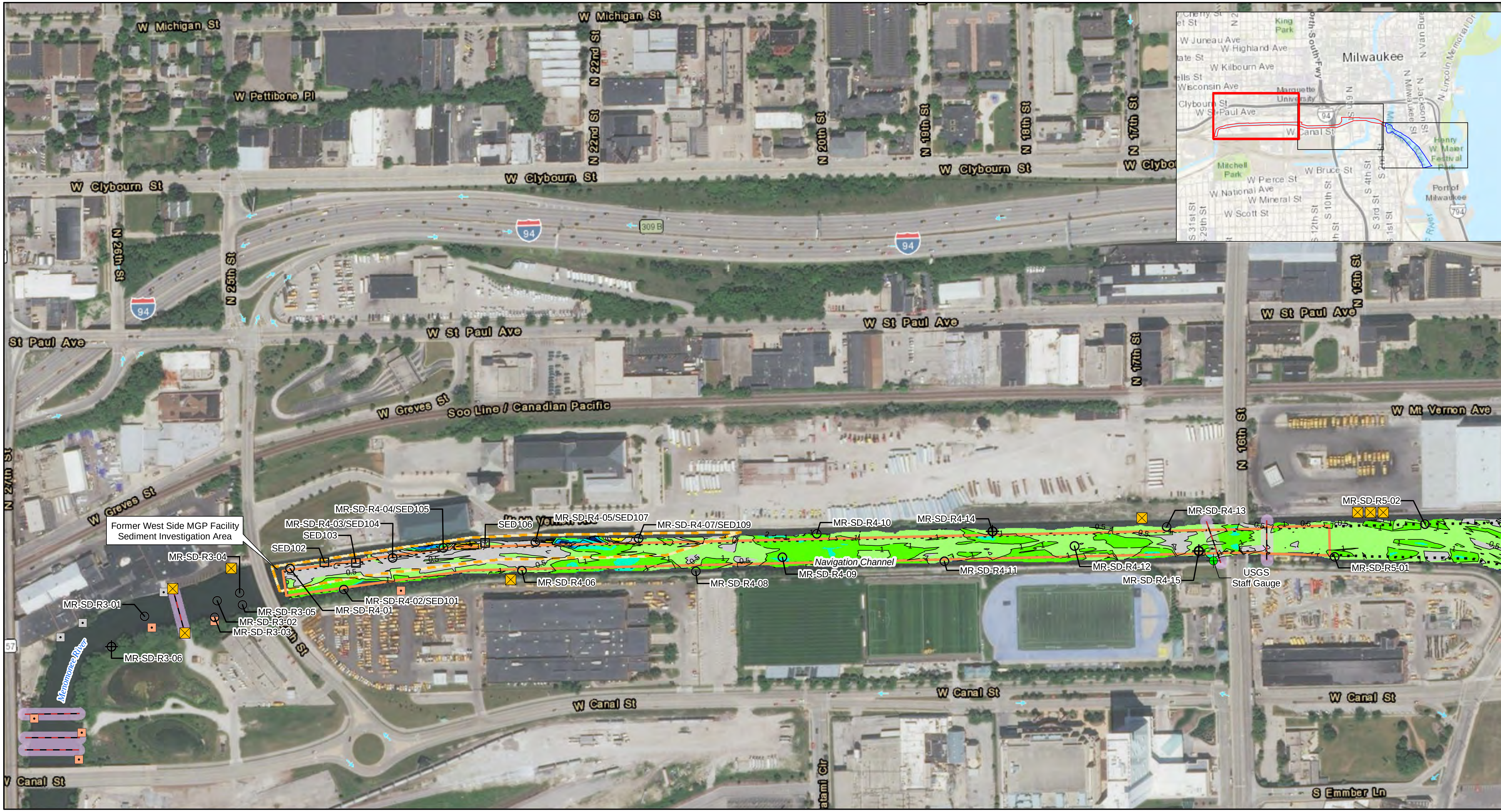
Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

R:\ENBG\00_Proj\E\EPA\Menomonee_MKE_River_FFS\MapFiles\Bathy\Fig1a-c_2015_and_2011_Bathymetry_Differential_Comparison.mxd AESPEJO (4/8/2018)

ch2m.



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300

Feet

General Note:
2017 and 2015 bathymetry data collected by USACE.

Figure 6a

2017 and 2015 Bathymetry Differential Comparison

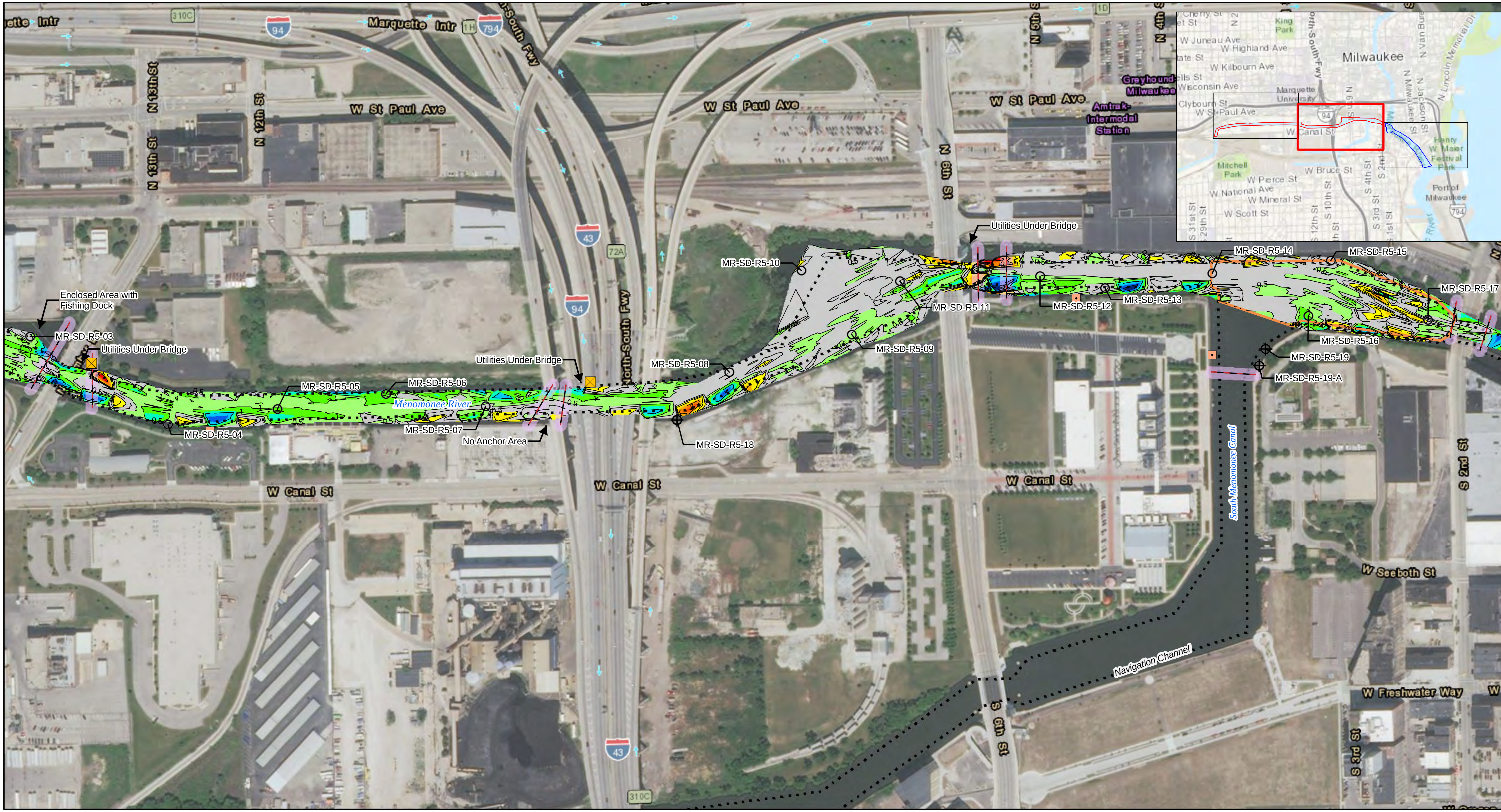
Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

R:\ENBG\00_Proj\E\EPA\Menomonee_MKE_River_FFS\MapFiles\Bathy\Fig1a-c_2017_and_2015_Bathymetry_Differential_Comparison.mxd AESPEJO (4/8/2018)

ch2m



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300
Feet

General Note:
2017 and 2015 bathymetry data collected by USACE.

Figure 6b

2017 and 2015 Bathymetry Differential Comparison

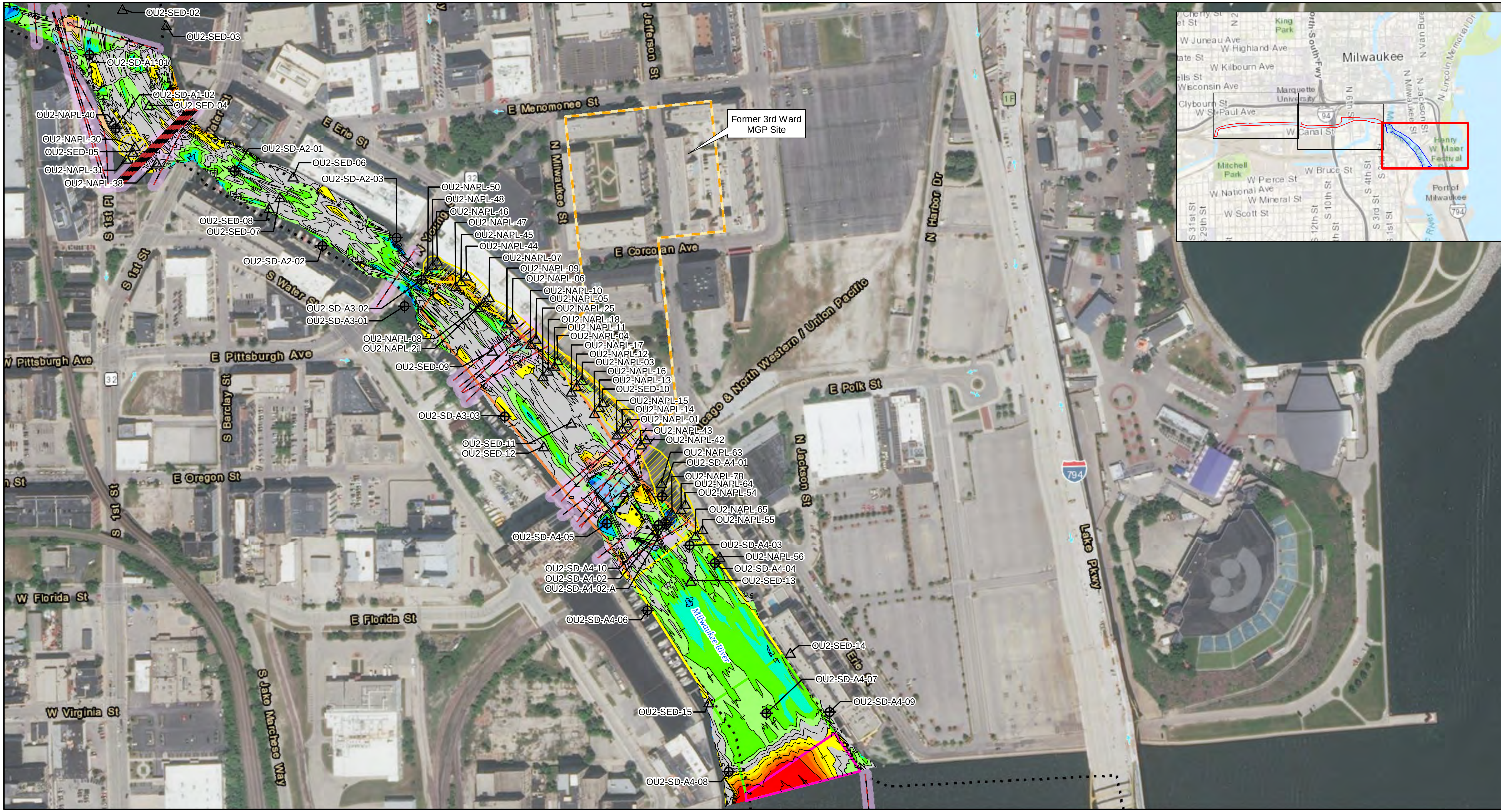
Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

EPA, ESRI World Imagery

R:\ENBG\00_Proj\E\EPA\Menomonee_MKE_River_FFS\MapFiles\Bathy\Fig1a-c_2017_and_2015_Bathymetry_Differential_Comparison.mxd AESPEJO (4/8/2018)

ch2m.



LEGEND

- 2017 EPA GLNPO Sample Location
- 2017 WEC Sample Location
- 2015 EPA GLNPO Sample Location
- 2014 NRT Sample Location
- Combined Sewer Outfall
- Stormwater Outfall
- Industrial Outfall
- USGS Staff Gauge
- Underground Utility with 20' Setback
- Navigation Channel
- Lateral Extent of Observed NAPL
- 1993 Dredge Event
- 1999 Dredge Event
- 2007 Dredge Event
- 2015 Dredge Event
- Bathymetry Differential Contour

Bathymetry Differential Value (feet)

- > 3.0
- 2.5 - 3.0
- 2.0 - 2.5
- 1.5 - 2.0
- 1.0 - 1.5
- 0.5 - 1.0
- -0.5 - 0.5
- -1.0 - -0.5
- -1.5 - -1.0
- -2.0 - -1.5
- -2.5 - -2.0
- -3.0 - -2.5
- < -3.0

N

0 150 300
Feet

General Note:
2017 and 2015 bathymetry data collected by USACE.

Figure 6c
2017 and 2015 Bathymetry Differential Comparison
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

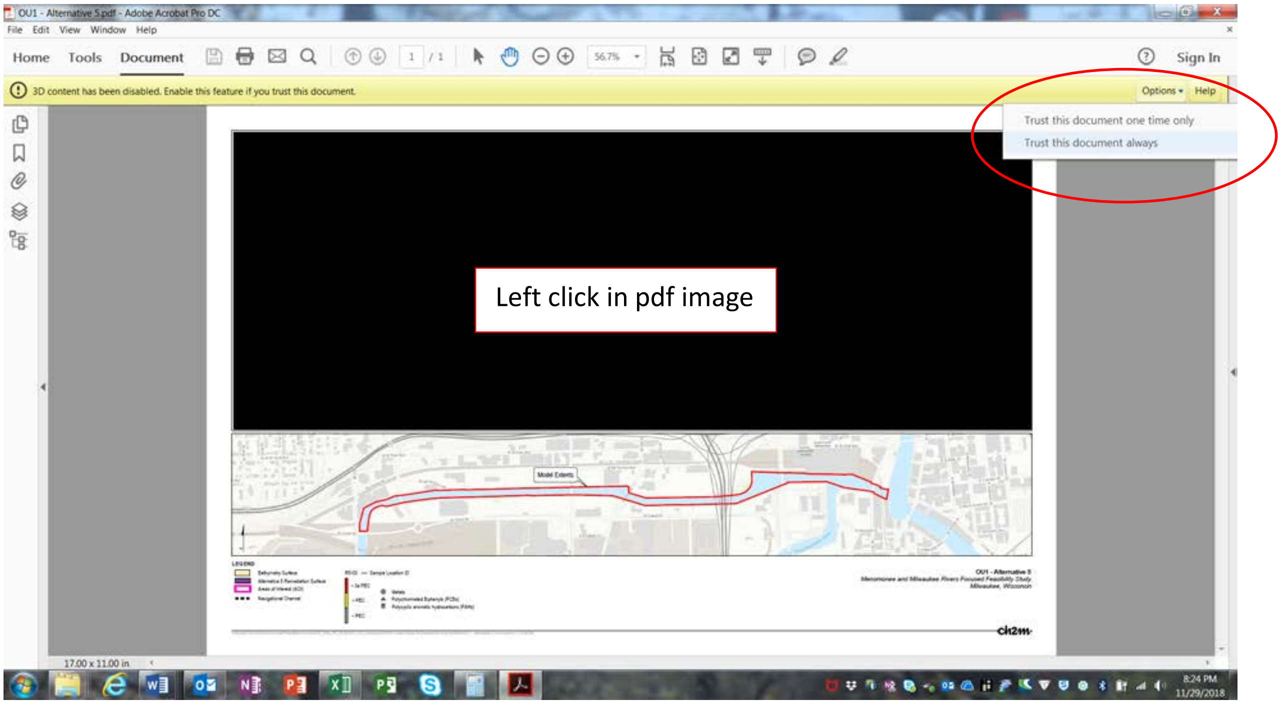
EPA, ESRI World Imagery
R:\ENBG\00_Proj\E\EPA\Menomonee_MKE_River_FFS\MapFiles\Bathy\Fig1a-c_2017_and_2015_Bathymetry_Differential_Comparison.mxd AESPEJO (4/8/2018)

ch2m.

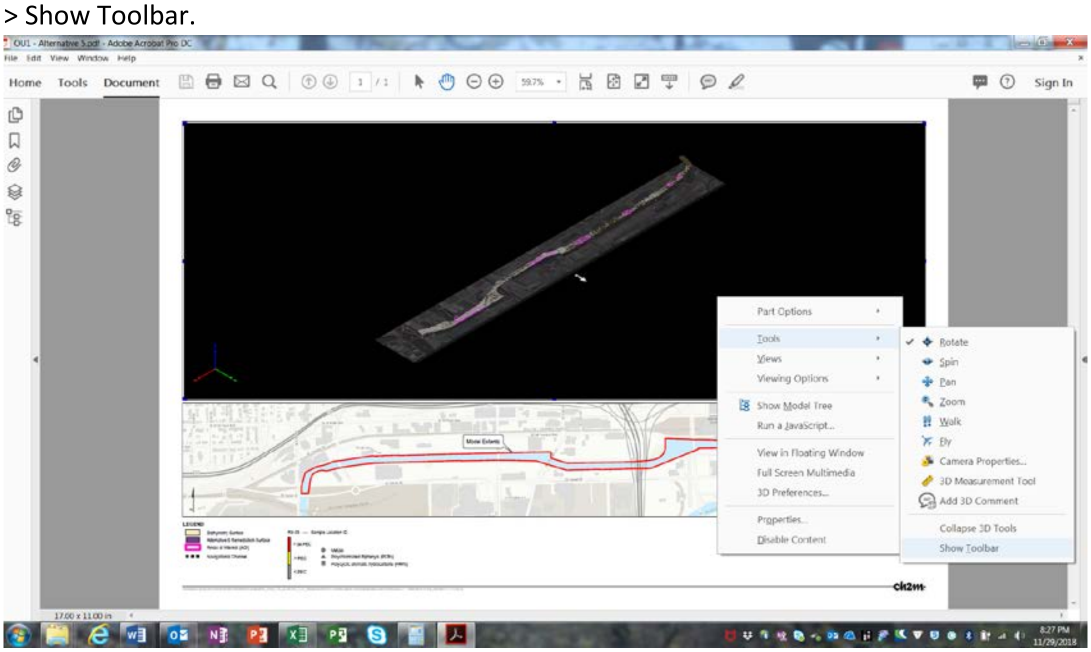
Appendix B
EVS Model Interactive 3D PDFs of Alternatives 2 through 5

3D pdf Operation Instructions

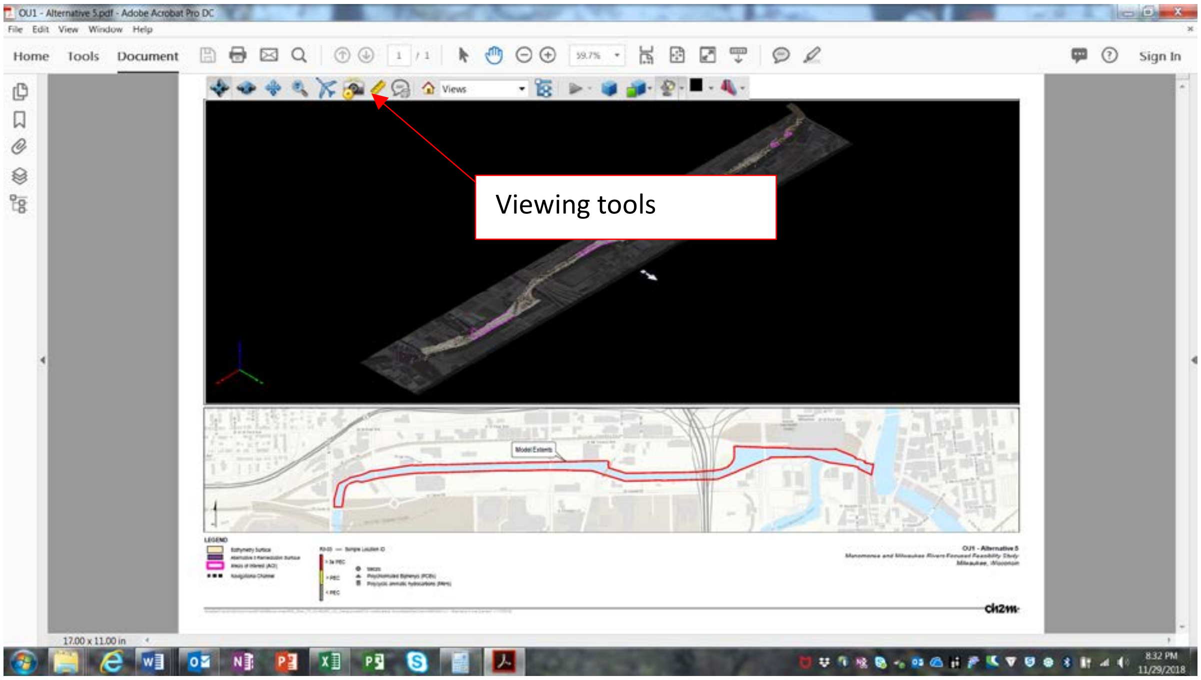
1. Copy file to computer and open file. Enable 3D content by selecting > Options> Trust this document always. After enabling 3D content, left click within the black area of pdf file to activate and select "enable content".



2. Once content is enabled the 3d model should appear. Right click within the pdf and select Tools > Show Toolbar.

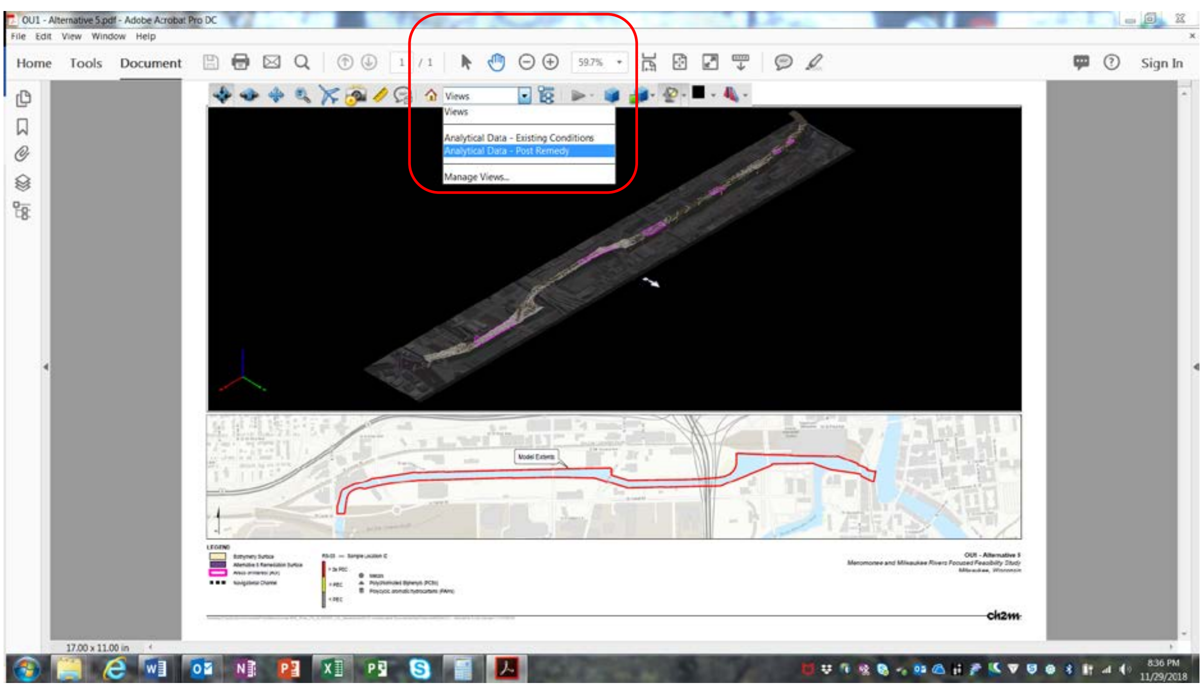


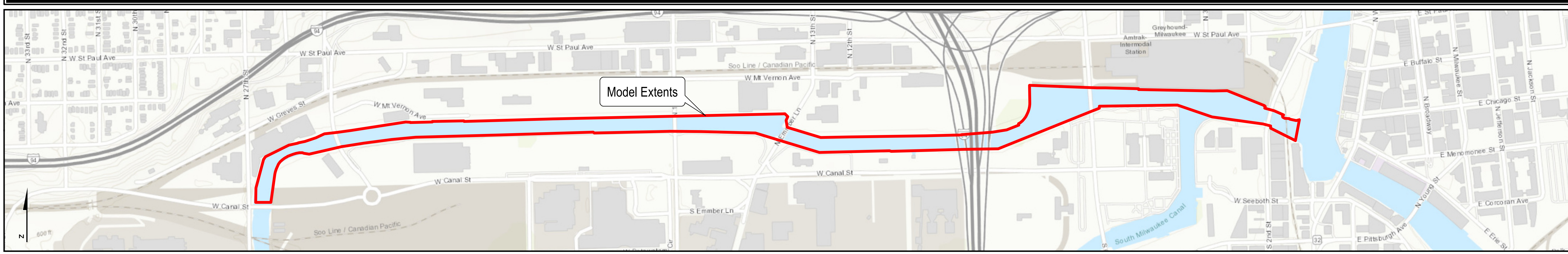
3. A series of viewing tools will appear within a tool bar at top of pdf. Viewing functions include rotate, pan, zoom, views, etc.)



4. Select from several pre-built views within drop down tool menu.
   Each of the OU1 Alternative files (2 through 5) contain the following views:
   - Analytical Data – Existing Conditions
   - Analytical Data – Post Remedy

   OU2 Alternative 2 through 5 file contains an additional view of location borehole data representing NAPL impacted sediments.





LEGEND

- Bathymetry Surface
- Alternative 2 Remediation Surface
- Areas of Interest (AOI)
- Navigational Channel

R5-03 — Sample Location ID

- > 3x PEC
- > PEC
- < PEC

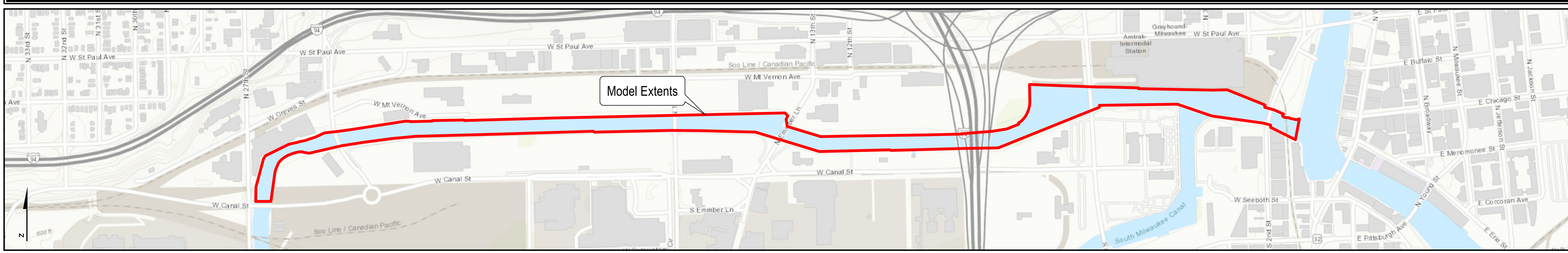
- Metals
- Polychlorinated Biphenyls (PCBs)
- Polycyclic aromatic hydrocarbons (PAHs)

OU1 - Alternative 2

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

ch2m.

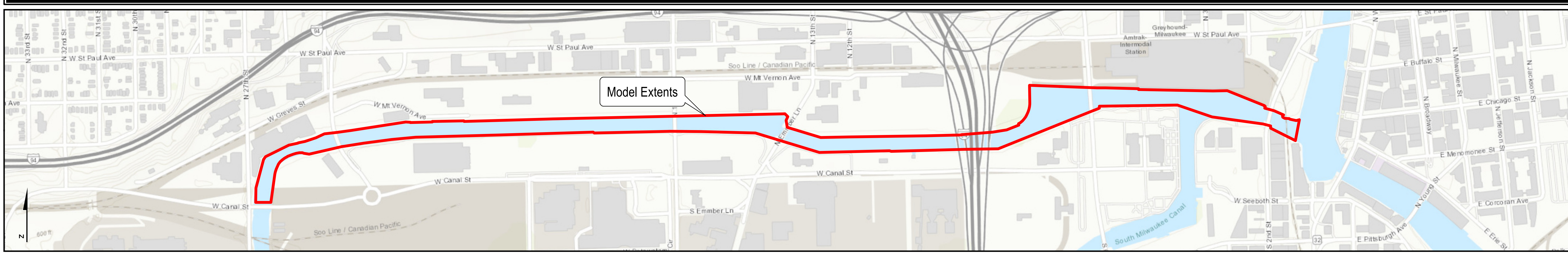


LEGEND

Bathymetry Surface	R5-03 — Sample Location ID
Alternative 3 Remediation Surface	> 3x PEC
Areas of Interest (AOI)	> PEC
Navigational Channel	< PEC

- Metals
- Polychlorinated Biphenyls (PCBs)
- Polycyclic aromatic hydrocarbons (PAHs)

OU1 - Alternative 3
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin



LEGEND

Bathymetry Surface

Alternative 4 Remediation Surface

Areas of Interest (AOI)

Navigational Channel

R5-03 — Sample Location ID

> 3x PEC

> PEC

< PEC

Metals

Polychlorinated Biphenyls (PCBs)

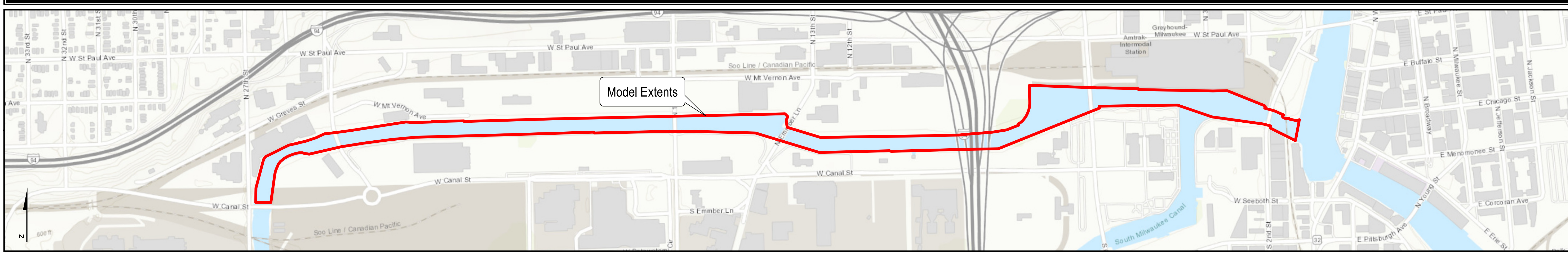
Polycyclic aromatic hydrocarbons (PAHs)

OU1 - Alternative 4

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

ch2m



LEGEND

Bathymetry Surface

Alternative 5 Remediation Surface

Areas of Interest (AOI)

Navigational Channel

R5-03 — Sample Location ID

> 3x PEC

> PEC

< PEC

Metals

Polychlorinated Biphenyls (PCBs)

Polycyclic aromatic hydrocarbons (PAHs)

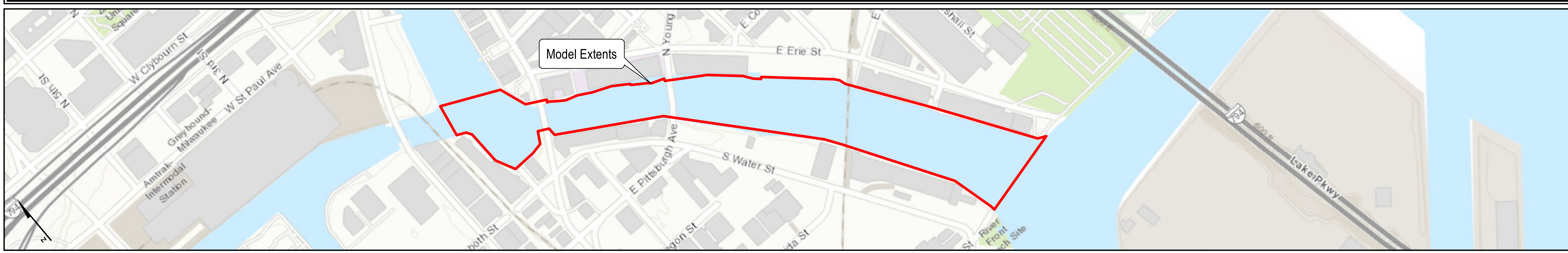
OU1 - Alternative 5

Menomonee and Milwaukee Rivers Focused Feasibility Study

Milwaukee, Wisconsin

\\mkefpp01\proj\UsEnvironmentalProte\Menomonee-MKE_River_FS_GLAES\07_CG_Development\EVS model\Lateral Boundaries\NavChannel\MXDs\OU1 - Alternative 5.mxd jhansen1 (11/7/2018)

ch2m



LEGEND

Bathymetry Surface
OU2 Remediation Surface
Navigational Channel

R5-03 — Sample Location ID

> 3x PEC
> PEC
< PEC

Metals
Polychlorinated Biphenyls (PCBs)
Polycyclic aromatic hydrocarbons (PAHs)

OU2-NAPL-42 — Sample Location ID

Sediment
NAPL Present

OU2 - Alternative 2-5
Menomonee and Milwaukee Rivers Focused Feasibility Study
Milwaukee, Wisconsin

Appendix C
Summary of Applicable Federal, State, and Local Regulations

Citation	Requirement/Purpose	Alternatives Affected	Regulation Status
Chemical-Specific Federal, State, and Local Regulations			
Clean Water Act Section 404 33 USC 1344; 33 CFR 320 – 330 Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material 33 USC 1344, 33 USC 1361; 40 CFR Part 230 Water Quality Guidance for the Great Lakes System 33 USC 1251 et seq.; 40 CFR Part 132	Requires approval from USACE for discharge of dredged or fill material into waters of the United States (CWA Section 404 Permit). USACE and EPA regard the use of mechanized earth-moving equipment to conduct land-clearing, ditching, channelization, in-stream mining, or other earth-moving activity in waters of the United States as resulting in a discharge of dredged material unless project-specific evidence shows that the activity results in only incidental fallback. Discharges of dredged or fill materials are not permitted unless there is no practicable alternative that would have less adverse impact on the aquatic ecosystem. Any proposed discharge must avoid, to the fullest extent practicable, adverse effects, especially on aquatic ecosystems. Unavoidable impacts must be minimized, and impacts that cannot be minimized, must be mitigated. 40 CFR Part 132 provides guidance for setting discharge limits for bioaccumulative contaminants such as PCBs.	2, 3, 4, 5	The requirements of a permit for discharge of dredged materials will be met. Though actual discharge of dredged material back to the waterbody is not anticipated, dredging within the waterbody constitutes discharge of dredged material. Requirements are likely to include measures to minimize re-suspension of sediments and turbidity control during dredging.
Federal Water Pollution Control Act as amended by the Clean Water Act of 1977, Section 208(b) USC 33 1288	The proposed action must be consistent with regional water quality management plans as developed under Section 208 of Clean Water Act.	2, 3, 4, 5	Requirements adopted by the state pursuant to Section 208 of the Clean Water Act would be applicable to direct discharge of treatment system effluent or other discharges to surface water.
Water Quality Standards 33 USC 1251 et seq.; 40 CFR 131	States are granted enforcement jurisdiction over direct discharges and may adopt reasonable standards to protect or enhance the uses and qualities of surface water bodies in the state.	2, 3, 4, 5	Applicable to direct discharge of treatment system effluent.
Water Quality Standards for Wisconsin Surface Waters Wis. Admin. Code NR 102 Uses and Designated Standards Wis. Admin. Code NR 104 Surface Water Quality Criteria and Secondary Values for Toxic Substances	Referenced water quality standards are established for protection of waters of the state, public health, fish, and wildlife.	2, 3, 4, 5	Applicable to migration of contaminants to the waterbody.

Appendix C. Summary of Applicable Federal, State, and Local Regulations
Menomonee and Milwaukee Rivers Focused Feasibility Study

Citation	Requirement/Purpose	Alternatives Affected	Regulation Status
Wis. Admin. Code NR 105			
Action-Specific Federal, State, and Local Regulations			
Clean Air Act 42 USC 7401 et seq.; 40 CFR 50-98	Specifies requirements for air emissions such as particulates, sulfur dioxide, VOCs, hazardous air pollutants, and asbestos.	2, 3, 4, 5	Particulates may be generated if utilization of stabilization / solidification agents are implemented as part of the remedy. Best available practices to control particulates will be used, as needed, during the excavation and dewatering of sediments.
Criteria for Classification of Solid Waste Disposal Facility and Practices 40 CFR 257, Subpart A	Sets standards for land disposal facilities for nonhazardous waste.	2, 3, 4, 5	Applicable to the transport and disposal of any nonhazardous solid waste offsite.
Hazardous Waste Management System: General – 40 CFR 260 Identification and Listing of Hazardous Waste – 40 CFR 261 Standards Applicable to Generators of Hazardous Waste – 40 CFR 262 Standards Applicable to Transporters of Hazardous Waste – 40 CFR 263 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities – 40 CFR 264	Regulates hazardous waste identification, classification, generation, management and disposal.		Not Applicable. The sediments do not have to be managed as containing listed hazardous waste because specific documentation of the release of a listed waste to the sediments is not available. The sediments also are not characteristic waste and are exempted from regulation under RCRA because CWA Section 404 applies to the cleanup activity (40 CFR 261).
Land Disposal Restrictions 40 CFR 268	The land disposal restrictions require treatment before land disposal for a wide range of hazardous wastes.		Not Applicable. The sediments are not hazardous waste.
Pipeline and Hazardous Materials Safety Administration, Department of Transportation 49 CFR 100 – 199	Regulates transportation of hazardous materials.		Not Applicable. The sediments are not hazardous waste.

Appendix C. Summary of Applicable Federal, State, and Local Regulations
Menomonee and Milwaukee Rivers Focused Feasibility Study

Citation	Requirement/Purpose	Alternatives Affected	Regulation Status
The National Pollutant Discharge Elimination System 40 CFR 122 Criteria and Standards for the National Pollutant Discharge Elimination System 40 CFR 125	Requires the development and implementation of a stormwater pollution prevention plan or a stormwater best management plan. Also outlines monitoring and reporting requirement for a variety of facilities.	2, 3, 4, 5	Applicable for management of runoff from construction activities.
Storm Water Discharge Permits Wis. Admin. Code NR 216	State permitting requirements for construction storm water pollutant discharge elimination (WPDES). WDNR Completion of a Water Resources Application for Project Permits (WRAPP) is required to request permit coverage.		
Navigable Waters, Harbors and Navigation Wis. Statutes Chapter 30 Dredging in Navigable Waterways Wis. Admin. Code NR 345	Permit to remove materials from the bed of a river and permit to place structures (such as fill material, sheet pilings, coffer dams) on the bed of a river.	2, 3, 4, 5	Applicable for activities including dredging and placement of residual sand cover.
Grading on the Banks of Navigable Waterways Wis. Admin. Code NR 341 Shore Erosion Control Structures in Navigable Waterways Wis. Admin. Code NR 328	Standards address procedures and limitation for dredging within navigable waterways and address erosion control protection, grading and dredging along and within a navigable waterway.		Applicable for modifying the river bank or performing excavation.
Wis Admin. Code NR 700	Administrative rules which govern the investigation and remediation of environmental contamination.		Applicable as it pertains to the 3rd Ward MGP site
Location-Specific Federal, State, and Local Regulations			
Great Lakes Water Quality Agreement of 1978, as amended 2012	Calls for prohibition of the discharge of toxic substances in toxic amounts and for the virtual elimination of the discharge of persistent substances.		Potentially applicable. Standards established by the agreement are policies to be considered.
Great Lakes Water Quality Initiative Antidegradation Policy 40 CFR 132, Appendix E	Provides guidance to Great Lakes states regarding wastewater discharge, stating that lowering of water quality standards via wastewater discharge should be minimized.		Potentially applicable. Considered as guidance.

Appendix C. Summary of Applicable Federal, State, and Local Regulations

Menomonee and Milwaukee Rivers Focused Feasibility Study

Citation	Requirement/Purpose	Alternatives Affected	Regulation Status
Fish and Wildlife Coordination Act 16 USC 661 et seq. 16 USC 742a 16 USC 2901 Interagency Cooperation – Endangered Species Act of 1973, as Amended 50 CFR 402	Requires consultation when a modification of a stream or other water body is proposed or authorized and requires protection of fish and wildlife from adverse effects of site action.	2, 3, 4, 5	Applicable. Relevant and appropriate for removal of contaminated sediment at the site.
Milwaukee Metropolitan Sewerage District Discharge Regulations and Enforcement Procedures MMSD Rules, Chapter 11	Requires that a permit be granted to discharge treated groundwater and storm water to a sanitary sewer before any action is initiated.	2, 3, 4, 5	Applicable for discharge to sanitary sewer.
Endangered Species Act 16 USC 1531 et seq. 50 CFR - Wildlife and Fisheries	Requires that Federal agencies insure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any threatened or endangered species or destroy or adversely modify critical habitat.	2, 3, 4, 5	Potentially applicable pending agency consultation during permitting process.
Rivers and Harbors Act, Section 10 33 USC 403	Requires approval from USACE for dredging and filling work performed in a navigable waterway of the U.S. Activities that could impede navigation and commerce are prohibited.	2, 3, 4, 5	The requirements of a permit will be met. Typical requirements of dredging permits include measures to minimize re-suspension of sediments and erosion of sediments and stream banks during excavation.
National Historical Preservation Act 16 USC 661 et seq. National Historic Landmarks Program 36 CFR 65.1 – 65.10	Establishes procedures to provide for preservation of scientific, historical, and archaeological data that might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program. If scientific, historical, or archaeological artifacts are discovered at the site, work in the area of the site affected by such discovery will be halted pending the completion of any data recovery and preservation activities required pursuant to the act and its implementing regulations.	2, 3, 4, 5	Potentially applicable. Pending agency consultation during permitting process.

Appendix D
SWAC Methodology and Results Summary

SWAC Methodology and Results Summary

Surface-weighted average concentrations (SWACs) were calculated to evaluate post-removal conditions in OU1 for remedial Alternatives 3 through 5. SWAC calculations were not performed for OU2 because the remedial options are consistent between alternatives and sediment removal will be to the top of the uncontaminated native clay. SWACs were calculated for the COCs, including total PAHs and the five select metals (cadmium, chromium, lead, arsenic, and mercury), to evaluate surface and near-surface concentrations (Section 2.3.2) and establish remediation targets (Section 3.3). Post-removal SWACs were calculated for both no residual sand cover and with sand cover placement scenarios. For comparative purposes, the sand cover placement scenario assumes that the post-removal sediment surface concentration is represented using a 90 percent reduction of current concentrations, as demonstrated by the Kinnickinnic River remedial action project within the Milwaukee Estuary AOC. Sand cover placement is assumed to be applied within AOIs upstream of 16th Street regardless of the post-dredge elevation because they are located within the de-authorized portion of the navigation channel. Sand cover placement within the authorized navigation channel downstream of 16th street would be restricted to areas at or below 24.5 feet LWD.

SWAC calculations were performed by establishing a Thiessen polygon network around the sample locations used in the calculation. Each OU1 sample location was used in the calculation, which includes the nine AOI locations. For locations which analytical data are not available at the proposed dredge elevation, linear interpolated values from sample intervals above and below missing intervals were used in the SWAC calculations. For sample locations where sediment removal is not to be performed, the sediment surface concentrations for each COC was used. After defining the area of Thiessen polygons and post-sediment removal surface sediment concentration for each sample location, the weighted concentration for each polygon was calculated by multiplying the concentration by the area. The products of the surface sediment concentrations and surface area of each polygon were summed and divided by the total area of OU1 Thiessen polygons to get a SWAC.

Table D-1 summarizes the calculated SWAC concentrations of OU1 sediments for Alternatives 3 through 5. SWACs were compared against PEC and three times PEC values for each respective COC. SWACs exceeding respective PEC values are highlighted yellow. Alternatives 3, 4 and 5 with sand cover placement resulted in no anticipated PEC exceedances. Alternative 3 would result in locations SD-R5-06 and SD-R5-16 having post dredge surface concentrations above the 3 times PEC criteria. Location SD-R5-06 is anticipated to exceed the lead criteria (505 mg/kg) and location SD-R5-16 the chromium criteria (412 mg/kg). Alternatives 3 and 4 results in a SWAC prior sand cover above the PEC criteria for tPAH.

Table D-1. Alternatives 3 through 5 Surface Weighted Average Summary
Menomonee and Milwaukee Rivers Focused Feasibility Study

	tPAH	Cd	Cr	Pb	As	Hg
PEC >>>	22.8	5	110	130	33	1.1
3x PEC >>>	68.4	15.0	330.0	390.0	99.0	3.3
Alternative 3 (No Sand Cover)	25.0	2.7	74.5	116.2	6.4	0.3
Alternative 3 (Sand Cover - 90% reduction)	12.0	0.7	21.1	37.8	2.5	0.1
Alternative 4 (No Sand Cover)	23.0	1.7	50.3	94.4	5.6	0.2
Alternative 4 (Sand Cover - 90% reduction)	20.6	1.4	43.5	88.1	4.6	0.2
Alternative 5 (No Sand Cover)	22.6	1.6	43.3	77.3	5.3	0.2
Alternative 5 (Sand Cover - 90% reduction)	20.0	1.3	35.6	70.4	4.1	0.2