AECOM

Remedial Alternatives Definitive Evaluation

C Street Slip

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Table of Contents

Glossary of Acronyms iv
1. Introduction 1
2. Site Background..... 1
2.1 Site Description and Historical Use 1
2.2 Site Investigations 2
3. Conceptual Site Model..... 2
4. Remedial Action Objectives 3
4.1 Remedial Action Objectives..... 3
4.2 Preliminary Remedial Goals 3
4.3 Remediation Target Area Development..... 4
4.4 Engineered Dredge Prism Development..... 4
5. Bench-Scale Treatability Investigation..... 6
5.1 Hydraulic Dredging & Passive Dewatering..... 6
5.1.1 Methods 6
5.1.2 Passive Dewatering Results..... 7
5.2 Mechanical Dredging & Solidification/Stabilization..... 7
5.2.1 Methods 7
5.2.2 Solidification/stabilization Results..... 8
6. Description of Definitive Remedial Alternatives 8
6.1 Evaluation of Alternatives 8
6.1.1 Criteria 9
6.1.2 General Assumptions 11
6.2 Remedial Alternatives Retained for Detailed Evaluation..... 12
6.2.1 No Action 13
6.2.2 Unamended Sediment Cap 13
6.2.3 Amended Sediment Cap 15
6.2.4 Mechanical Dredging..... 18
6.2.5 Hydraulic Dredging 21
6.2.6 Mechanical Dredging with an Amended Sediment Cap 24
7. Definitive Evaluaion and Recommendations 26
7.1.1 Scoring System to Compare Alternatives..... 27
7.1.2 Cost Estimates..... 28
7.1.3 Recommendations..... 28
8. References..... 29

Tables

Table 4-1 Proposed PRGs. 3
Table 4-2 Plume Volumes. 4
Table 4-3 Total Sediment Volume for Removal. 5
Table 5-1 Dewatering of 40,000 CY of C Street Slip Sediment with Geotextile Tubes. 7
Table 5-2 Filter cake from geotextile tubes was stabilized with 5% Calciment™ to increase UCS for loadout and landfill disposal. 7
Table 5-3 Mass of geotextile tube dewatered and stabilized (5% Calciment™) C Street sediment for loadout, transportation, and disposal. 7
Table 5-4 Calciment™ (5%) was used to dewater and stabilize C Street sediment (51.6% solids) to 80.4% solids after 96-h cure time. 8
Table 5-5 C Street sediment (34,900 tons) stabilized with 5% Calciment™ for disposal after 96-hr cure time. 8
Table 6-1 Remedial alternatives were evaluated with site-specific criteria developed from a combination of WDNR and USEPA guidance documents. 8
Table 7-1 Comparison of definitive remedial alternatives for mitigating sediment RAOs in C Street Slip contaminated with tPAHs and/or mercury. .... Follows report
Table 7-2 Definitive remedial alternatives were compared, retained and/or eliminated for recommendation based on effectiveness, restoration time frame, implementability, state and community acceptance, reduction in toxicity and cost. .... Follows report

Figures

Figure 1-1 Site Location
Figure 4-1 Mercury, Surface and Subsurface Analytical Summary, C Street Slip
Figure 4-2 Total PAHs, Surface and Subsurface Analytical Summary, C Street Slip
Figure 4-3 Dredge Prism Design; Plan View (Plumes)
Figure 4-4 Dredge Prism Design; Plan View (Dredge Prisms)
Figure 4-5 Dredge Prism Design; Plan View (Volume Surface)
Figure 4-6 Dredge Prism Design; Profiles
Figure 4-7 Dredge Prism Design; Cross Sections (01)
Figure 4-8 Dredge Prism Design; Cross Sections (02)

Appendices

Appendix A C Street Slip Sediments with Mercury or tPAH concentrations greater than PRG values based on EVS Model Interpolation

Appendix B Definitive Remedial Alternatives Cost Estimates

Glossary of Acronyms

µg	micrograms
3D	three-dimensional
95% UCL	95 percent upper confidence limit of the arithmetic mean
AECOM	AECOM Technical Services, Inc.
ARAR	Applicable Relevant and Appropriate Requirements
ASTM	ASTM International
BMP	Best Management Practices
BRRTS	Bureau for Remediation and Redevelopment Tracking System
BTV	Background Threshold Value
BUI	beneficial use impairments
CDF	confined disposal facilities
CM	construction manager
COC	constituent of concern
CQA	construction quality assurance
CSM	Conceptual Site Model
CSTP2	combined sewer treatment plant #2
CY	cubic yards
d	day
DC	direct contact
EVS	Earth Volumetric Studio, cTech Software
ft	feet
Foth	Foth Infrastructure & Environmental, LLC
gal	[United States] gallons
GIK	geologic indicator kriging
GIS	Geographic Information System
GLLA	Great Lakes Legacy Act
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Agreement
GPS	Geographic Positioning System
h	hours
H&H	Hydrologic and hydraulic
IC	institutional controls
IGLD	International Great Lakes Datum
in	inch
ITRC	Interstate Technology & Regulatory Council's
kg	kilogram
L	liter
lb	[United States] pound
lf	linear feet
MEC	Midpoint Effect Concentration
mg	milligram
MGP	Manufactured gas plant

MPCA	Minnesota Pollution Control Agency
NTE	not-to-exceed
O&M	operation and maintenance
PAH	polycyclic aromatic hydrocarbon
PFT	paint filter test
POTW	publicly operated treatment works
ppm	parts per million
PRG	preliminary remediation goal
RAO	remedial action objective
RAOR	Remedial Action Options Report
RAP	Remedial Action Plan
RCL	residual contamination level
RFP	request for proposal
s/s	solidification/stabilization
Slip	C Street Slip
SLRAOC	St. Louis River Area of Concern
SMA	sediment management area
SOW	scope of work
SVOC	semi-volatile organic compound
SWL&P	Superior Water Light & Power
tPAH	total polycyclic aromatic hydrocarbon
TSS	total suspended solid
UCS	unconfined compressive strength
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound
WDNR	Wisconsin Department of Natural Resources
WWTP	Wastewater Treatment Plant
yd	yard

1. Introduction

AECOM Technical Services, Inc. (AECOM) prepared this Detailed Evaluation of Remedial Alternatives for the C Street Slip (Slip) in accordance with remedial option evaluation guidelines provided in the Wisconsin Department of Natural Resources' (WDNR) request for proposal (RFP) and Scope of Work (WDNR RFP and SOW) (WDNR, 2022), the Wisconsin Administrative Code (Wis. Admin. Code) Department of Natural Resources Chapter NR 722, Standards for Selecting Remedial Options, the Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (United States Environmental Protection Agency [USEPA], 2005), and the Interstate Technology & Regulatory Council's (ITRC) Guidance Document on Remedy Selection for Contaminated Sediments (ITRC, 2014). This report was prepared for the WDNR under a USEPA Great Lakes Restoration Initiative (GLRI) grant (USEPA GLRI Grant No. GL-00E03068), which includes a 35% nonfederal cost share from WDNR. Remedial alternatives were defined, screened, and selected to address impacted sediment at the C Street Slip within the St. Louis River Area of Concern (SLRAOC) in Superior, Wisconsin, in the Remedial Alternatives Screening Evaluation Report by AECOM (AECOM, 2023a). This report focuses on the engineering and construction evaluation results of potential remedial alternatives for the C Street Slip (**Figure 1-1**).

Site investigation and remediation of the C Street Slip are regulated under Chapters NR 700-799 (collectively referred to as the "NR 700 series" or "NR 700 process") of the Wis. Admin. Code administered by the Remediation and Redevelopment Program of the WDNR. Potential remedial options were previously screened based on site-specific conditions, and only those design alternatives that were most likely to be effective were selected as viable options to meet the remedial action goals and remove beneficial use impairments for the SLRAOC (AECOM, 2023a). Consideration was given to those remedial action options that were expected to meet the remedial performance goals of the project, that consider long-term funding criteria and provide options that maintain WDNR funding eligibility requirements outlined in Wis. Admin. Code paragraph NR 722.05(2)(c) and Wisconsin Statute section 281.87.

2. Site Background

2.1 Site Description and Historical Use

The Slip is located in the City of Superior, Douglas County, on the Wisconsin side of the St. Louis River near the confluence with Lake Superior. It is located along the right descending bank of the federal navigation channel in Superior Bay adjacent to the City of Superior Wastewater Treatment Plant (WWTP) and the Former Superior Water Light & Power (SWL&P) Manufactured Gas Plant (MGP) along the St. Louis River in Superior, Wisconsin. The Slip is approximately 1,200-feet (ft) long and 175 to 200-ft wide. The west side of the Slip is maintained, as well as dredged for navigation for deep draft bulk cargo vessels while the east side contains the toe of the berm for the combined sewer treatment plant #2 (CSTP2) located at the Superior WWTP. Present uses near the Slip include the WWTP, lime and cement production, and bulk material handling and storage (coal and limestone). The Slip has two municipal outfalls: a stormwater outfall and an overflow from CSTP2.

The Slip has been impacted by industrial and maritime activities since the late 1800s. The area has historically included a lumber mill, coal dock, MGP, shipyard, and bulk petroleum storage facilities. SWL&P is the responsible party for contamination associated with the former MGP according to Bureau for Remediation and Redevelopment Tracking System (BRRTS) Case #02-16-275446. SWL&P and USEPA have an existing Great Lakes Legacy Act (GLLA) project agreement to conduct feasibility and design for both the MGP-impacted sediment at the head of the Slip as well as the total polycyclic aromatic hydrocarbons[1] (tPAHs). SWL&P and USEPA are considering modifications to their existing GLLA project

[1] Total 18 PAHs: 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, and pyrene.

agreement to include feasibility and design for the entire Slip, a source control action for the upland MGP site, and to add WDNR as a nonfederal sponsor. SWL&P hired Foth Infrastructure & Environmental, LLC (Foth) as its consultant for feasibility and remedial design for upland source control and adjacent sediment impacts. The upland site, which was a part of the former MGP southwest of the Slip, has had extensive site investigations and conducted interim remedial actions. Remedial construction for source control action at the upland MGP site is expected to occur in 2023.

2.2 Site Investigations

Site assessments and investigations at the C Street Slip conducted from 1993 through 2022 are summarized herein and discussed in detail in the *C Street Slip Historical Data Review Technical Memorandum* (AECOM, 2022a). As part of the historical data review and supplemental remedial investigation, AECOM developed and presented Figure 2-4 in the *C Street Slip Remedial Investigation Report* to summarize the sample locations from both historical investigations and the 2022 AECOM investigation (AECOM, 2023b). Tables 3-1 and 3-3 of the *C Street Slip Remedial Investigation Report* describe the geotechnical, treatability and sediment sample locations from the 2022 AECOM investigation (AECOM, 2023b). Additionally in the report, Tables 4-1.1 to 4-1.8 summarize and highlight analytical results compared to human health assessment thresholds and Tables 4-2.1 to 4-2.8 summarize and highlight analytical results compared to ecological assessment thresholds (AECOM, 2023b).

Site assessments and investigations that have been conducted, reviewed for data usability and summarized to date at the C Street Slip are listed below.

- Sediment Assessment of Hotspot Areas in the Duluth/Superior Harbor (Minnesota Pollution Control Agency [MPCA], 1997).
- Preliminary Evaluation of the Sediment Sampling Results from the Superior Harbor Inlet Potentially impacted by the Former Operations of the Superior Manufactured Gas Plant (Internal WDNR Memo, 2001).
- Sediment Investigation Report Former Manufactured Gas Plant Superior, Wisconsin (ENSR International Corporation, 2004).
- Sediment Investigation Results, Former MGP Site, Superior, Wisconsin (AECOM, 2010).
- Site Characterization Report Assessment of Contaminated Sediments Superior Waterfront Characterization, St. Louis River and Bay Area of Concern, Superior Wisconsin (EA Engineering, Science, and Technology, Inc. PBC [EA], 2016).
- Supplemental Site Investigation Report for the Former Manufactured Gas Plant (Summit Envirosolutions, Inc., 2017).
- Site Investigation Report, Former Manufactured Gas Plant, WDNR (Foth, 2019).
- Data Gap Treatability Report, C Street Slip (AECOM, 2022b).
- C Street Slip Supplemental Site Investigation Report (AECOM, 2023c).
- C Street Slip, Remedial Investigation Report (AECOM, 2023b)

3. Conceptual Site Model

A Conceptual Site Model (CSM) generally includes information on known contaminant sources and impacted media, potential other sources, transport pathways, exposure pathways, and receptors. A preliminary CSM of the C Street Slip was largely obtained from the *Draft Remedial Action Options Report – Sediment Area Former Manufactured Gas Plant, St. Louis River Area of Concern (*Foth, 2022*)*, which describes a CSM that includes the head of the C Street Slip and surrounding upland site. The CSM has been updated, as necessary, as additional information has been reviewed by AECOM. The updated CSM for the Slip is presented in the *C Street Slip Remedial Investigation Report* (AECOM, 2023b).

4. Remedial Action Objectives

The remedial action objectives (RAOs) and preliminary remediation goals (PRGs) consider the minimization or elimination of risks, or potential risks, from contaminants to human health and the environment and elimination of the contribution of contaminants to beneficial use impairments (BUIs) and contributions towards BUI removal for the SLRAOC. Risk management assessments for the protection of human health and the environment were performed to evaluate analytical and other investigative data collected at the C Street Slip. The detailed risk assessment is discussed in the *C Street Slip Remedial Investigation Report* (AECOM, 2023b).

4.1 Remedial Action Objectives

The RAOs identified for C Street Slip based on the risk assessments are:

- Reduce mercury sediment concentrations to minimize potential human health risk from fish consumption and support achieving fish tissue concentrations that are not significantly elevated from reference samples or fish advisories for mercury, advised for other waterbodies in the region.
- Reduce sediment concentrations of mercury and tPAHs to minimize or eliminate risks to the benthic invertebrate community.
- Reduce or eliminate the degree and extent of constituents of concern (COCs) in the Slip that necessitate special handling procedures during dredging or dredged material disposal.
- Minimize or eliminate the potential for contaminated sediment within the C Street Slip to act as a source of contamination in the St. Louis River Estuary beyond the Slip.

The Remedial Action Plan (RAP) (MPCA and WDNR, 2022) identified nine beneficial uses that were impaired in the SLRAOC under the Great Lakes Water Quality Agreement (GLWQA). The most recent update to the RAP in 2022 for the SLRAOC are listed and defined in the *C Street Slip Remedial Alternatives Screening Evaluation* (AECOM, 2023a), with five of the nine BUIs linked to contaminated sediment. The key focus of RAOs for the C Street Slip are relate to the following BUIs:

- BUI No. 1 – Fish Consumption Advisories – mercury
- BUI No. 4 – Degradation of Benthos – tPAHs and mercury
- BUI No. 5 – Restrictions on Dredging – Exceedances of the industrial direct contact (DC) not-to-exceed (NTE) residual contamination levels (RCLs) and Wisconsin soil background threshold values (BTVs) (if available) - arsenic and benzo(a)pyrene

4.2 Preliminary Remedial Goals

There were two risk drivers pertinent to developing PRGs: mercury and tPAHs. Proposed PRGs are as follows:

Table 4-1 – Proposed PRGs.

Constituent	1x MEC (µg/kg)	SLRAOC BTV (mg/kg)
Mercury	--	**0.59**
Total PAHs	**12,205**	--

These are proposed as the final PRGs for evaluation in the feasibility study. Note that all suggested PRGs are based on the 95 percent upper confidence limit of the arithmetic mean (95% UCL) to be consistent with the approach used in the risk assessment (or statistical comparisons with background).

4.3 Remediation Target Area Development

Areas of interest were identified for remediation by reviewing the data from both historical investigations and the 2022 investigation, which were subsequently compared to PRGs for tPAH and mercury to develop potential remediation target areas. These target areas were developed such that mitigation results in the ability to meet the RAOs (elimination of potential Fish Consumption Advisories, BUI No. 1 and Degradation of Benthos, BUI No. 4).

The Midpoint Effect Concentration (MEC) (12,205 micrograms per kilogram [µg/kg]) was selected for remediation target development for tPAH. While remediation for exceedances with a value greater than 1x MEC could be justified based on uncertainties discussed in the *C Street Slip Remedial Investigation Report* (AECOM, 2023b), the MEC was selected as the PRG since it is the more conservative value for the analytes evaluated. Mercury was evaluated based on the SLRAOC BTV (0.59 mg/kg).

Remedial areas were evaluated using EVS (Earth Volumetric Studio version 2022.10.2) and GIS software ArcGIS (Esri, version 10.8.1), and ArcPro (Esri, version 2.9). The contaminated sediment results represent a three-dimensional (3D) model of the analytes limited to below the bathymetric surfaces surveyed in July 2022. The 3D plumes were generated with an interpolation process called Kriging. The resulting plumes were cut above a confining clay layer using lithology field samples in a variation of Kriging called Geologic Indicator Kriging (GIK). Results were used in EVS volumetric tools to provide the volume of contaminated sediment in cubic yards. The clay layer is the minimum elevation, excluding the model bottom at 570 ft International Great Lakes Datum (IGLD), or any overlapping or non-overlapping clay lithology plume. A detailed summary of assumptions, EVS methods, interpolation, and validation is provided in **Appendix A.**

The remediation areas defined by the plume extents for the Site are identified on **Figures 4-1 and 4-2**.

Table 4-2 Plume Volumes.

Constituents	PRG Value	Plume Volume (CY)
Total PAHs	12,205 µg/kg (MEC)	3,212
Mercury	0.59 mg/kg (SLRAOC BTV)	12,548
		14,652 CY total volume (1,108 CY overlap)

The volume of targeted sediment for remediation has a 1,108 cubic yards (CY) collocation overlap. The total sediment volume used for development of the dredge prism was 14,652 CY. If dredging is the selected alternative, this sediment volume estimate does not account for overburden, slope stability, overdredge and other sediment removed as part of the dredge prism development.

4.4 Engineered Dredge Prism Development

Two bathymetric survey files were provided by Affiliated Researchers Inc. on December 6, 2022, following adjustments made in processing due to conflicting elevation data. Plume surfaces are depicted on **Figure 4-3** developed from an EVS software model. Horizontal and vertical data were exported using EVS, guiding the dredge prism design shown on **Figure 4-4.** SWL&P former MGP plant lies to the southwest and the City of Superior's WWTP holding pond lies to the east of the C Street Slip. The slope along the WWTP is armored riprap and is assumed to extend to the toe of the slope of the Slip.

The dredge prisms were developed with 2:1 side slopes (H:V), based on the consolidation of solids greater than 50% of the sediment. A clay surface was used as the "base of excavation" wherever applicable. If the COC plume extends below the contact surface of the clay layer, the clay layer will supersede the COC plume. A six-inch over-dredge was applied in areas where the clay layer is not the base. There is no over-dredging into the clay due to the unit's cohesive consolidated nature.

A primary goal of the dredge prism design was to make the project constructable or "contractor friendly". For example, the horizontal extents were connected between obvious areas (e.g., jagged areas, coves, plumes that are close to each other, hot spots, etc.). The target vertical elevations were based on plume extents as opposed to using the deepest elevation of the COC plume as the extent. Water surface elevation was measured between 602 ft and 603 ft mean sea level.

Table 4-3 Total Sediment Volume for Removal.

Sediment Volume (Plume Estimate)	Surface Area of Dredge Prism	Total Sediment Volume for Removal
14,652 CY	150,500 ft²	**40,000 CY**

The surface area of the dredge prisms is 150,500 ft² with a total volume of 40,000 CY (**Figure 4-5**). Profiles of the dredge prism and cross sections are presented in **Figures 4-6** to **4-8**.

4.5 Geotechnical Assessment of C Street Slip

The following subsections describe available and additional information needed to perform a geotechnical and structural analysis of the existing east shoreline WWTP Berm and west shoreline bulkhead walls for anticipated remediation activities. Recommendations for filling data gaps are also provided.

4.5.1 East Shoreline

The following historical information is available for the WWTP Berm

- As-built drawings
- C Street Bathymetric Survey Data
- Sub-bottom Profiling

Based on site observations documented by AECOM in September 2022 and historical information obtained thus far, the following data gaps would need to be addressed to complete a geotechnical stability analysis of the existing shoreline:
1. Subsurface Profile
2. Topographic Survey

For the east shoreline, a global stability analysis would need to be performed on the slope under proposed conditions. Ideally, the material and strength properties of the embankment and foundation soils would be obtained from a geotechnical subsurface investigation consisting of soil borings and laboratory testing. At a minimum, a topographic survey of the existing shoreline conditions should be completed to confirm the profile matches the provided as-built drawings. During the topographic survey, a qualified engineer should perform a site walk to document any site changes since the September 2022 site visit.

4.5.2 West Shoreline

The following historical information is available for both the Graymont and LaFarge sections of the west shoreline

- As-built drawings
- C Street Bathymetric Survey Data

- Sub-bottom Profiling

Based on site observations documented by AECOM in September 2022 and historical information obtained thus far, the following data gaps would need to be addressed to complete a geotechnical stability analysis of the existing shoreline:

1. Subsurface Profile
2. Topographic Survey

For both sections of bulkhead wall, no geotechnical borings or laboratory testing data was made available. The as-built drawings for the Graymont section of the wall show boring locations, but data from the logs was not provided. For analysis of the bulkhead walls, geotechnical soil borings should be performed behind the existing shoreline to determine the soil profile being retained and current soil conditions. If possible, geotechnical soil borings should also be performed within the C Street Slip.

It should be noted that the as-built drawings for the LaFarge bulkhead wall indicated a design with factor of safety equal to 1, which is not recommended. Additionally, the exposed bulkhead wall along the northern shoreline of the LaFarge property appeared to be in poor condition. At a minimum, geotechnical borings should be performed behind the existing steel sheet pile bulkhead wall to confirm its stability. If dredging is anticipated along the northern shoreline, construction of a new bulkhead wall should be considered unless the condition of the underlying timber crib and timber piles can be determined.

A topographic survey of the existing shoreline conditions should be completed to confirm the profile matches the provided as-built drawings. During the topographic survey, a qualified engineer should perform a site walk to document any site changes since the September 2022 site visit.

5. Bench-Scale Treatability Investigation

Bulk sediment samples were collected for a treatability study to refine efficacy assumptions for potential ex situ sediment management alternatives. This supplemental data collection was necessary to help achieve WDNR's primary objective of evaluating and recommending remedial actions for the C Street Slip. A brief description of the scope of work for the treatability study and results is presented below. Details of the treatability investigation are presented in the *Data Gap Treatability Study* (AECOM, 2022b).

5.1 Hydraulic Dredging & Passive Dewatering

5.1.1 Methods

A bench-scale sediment management treatability test program was conducted to assess the efficacy of various dewatering technologies and subsequently develop the specified criteria for sediment management, effluent discharge and refine full-scale treatment system design parameters (AECOM, 2022b). Each test aliquot was independently homogenized and subsequently slurried with surface water to form a test slurry for chemical conditioning.

Polymer selection was based on the effectiveness of each chemical condition program to generate dry cake solids after 24-hours (h), greatest release of filtrate volume after 5-minutes, and filtrate with low total suspended solids concentration. Recommended slurry samples (200-milliliters [ml]) were subsequently poured through geotextile tube fabric to confirm selection and dose of the polymer(s) selected during jar testing. Geotextile tube pillow testing was conducted by conditioning a 40-liter (L) slurry sample and pouring it through a 40-L geotextile tube pillow in two fill events (0-h and 48-h). Dewatered sediment retained within the pillow was collected over a 7-day (d) period to evaluate solids content as function of dewatering time. Filtrate volume and quality were also evaluated after each fill event.

5.1.2 Passive Dewatering Results

Based on an estimated dredge volume of 40,000 CY (51.6% solids in situ), a hydraulic dredge will slurry and discharge 41.7 MG [million gallons] at approximately 10% solids for chemical conditioning and subsequent containment and consolidation in geotextile tubes (**Table 5-1**). Approximately 5,700 linear feet (lf) of 60-ft circumference geotextile tube will dewater the 40,000 CY to 34,500 CY at 59.9% solids in 7-d (**Table 5-1**). The recommended chemical conditioning program is 208-parts per million (ppm) ChemTreat P822L followed by 177-ppm ChemTreat P816E which equals approximately 16,000 gallons (gal) (160,000 pounds [lbs]) of total polymer.

Table 5-1. Dewatering of 40,000 CY of C Street Slip Sediment with Geotextile Tubes.

C Street sediment - Geotextile tube dewatering	Units	
In situ volume at 51.6% solids	CY	**40,000**
Volume pumped @ 10% solids for chemical conditioning	US gals	**41,700,000**
Volume of sediment in geotextile tubes, 59.9% solids	CY	**34,500**
60' circumference geotextile tubes (6.1 yd^3/lf)	linear ft	**5,650**
45' circumference geotextile tubes (3.9 yd^3/lf)	linear ft	**8,800**

The strength (penetrometer test) of the geotextile tube filter cake after 7-d of dewatering was measured at 0.0 lb/in^2, not suitable for landfill disposal. Additional stabilization of the dewatered material was evaluated and 5% Calciment™ admixture was recommended, increasing the filter cake strength to 4,786 lb/ft^2 after 96-h cure time (**Table 5-2**). With addition of Calciment™, the dewatered 34,500 CY contained in the geotextile tubes will continue to dewater to 21,900 CY @ 94.1% solids after 96-h cure time, 29,800 tons remaining for transportation and disposal (**Table 5-3**).

Table 5-2. Filter cake from geotextile tubes was stabilized with 5% Calciment™ to increase UCS for loadout and landfill disposal.

C Street dewatered sediment amended with 5% Calciment™	Units	
In situ volume at 59.9% solids	CY	**34,500**
Volume of stabilized sediment, 94.1% solids	CY	**21,900**

Table 5-3. Mass of geotextile tube dewatered and stabilized (5% Calciment™) C Street sediment for loadout, transportation, and disposal.

bulk density = 1.36	5% Calciment™	disposal
tons	tons	tons
29,830	**1,492**	**31,300**

5.2 Mechanical Dredging & Solidification/Stabilization

5.2.1 Methods

Solidification/stabilization (s/s) treatability tests were performed to identify reagents and mix ratios that may be used to successfully dewater and/or stabilize the dewatered sediment for loadout, transportation and disposal. S/S tests used to support the feasibility study include stacking/gravity dewatering of bulk sediment (24-h), reagent screening with 20% admixtures and 96-h cure time (evaluated by penetrometer measurements), and optimized mix development with 5% and 10% admixtures and 96-h cure time (evaluated by unconfined compressive strength [UCS] via ASTM International [ASTM] D2216) measurements).

5.2.2 Solidification/stabilization Results

In order to expedite dewatering and strengthening of mechanically dredged sediment from C Street Slip, 5% Calciment™ admixture was recommended. Calciment™ dewatered and consolidated the C Street sediment (51.6%) from 40,000 CY to 25,700 CY (80.4% solids) after 96-h cure time and increased the strength of the dewatered sediment to 2,970 lb/ft^2 (**Table 5-4**). With a bulk density of 1.36, sediment dewatered and stabilized equals approximately 36,700 tons for disposal including 1,750 tons of Calciment™ (**Table 5-5**).

Table 5-4. Calciment™ (5%) was used to dewater and stabilize C Street sediment (51.6% solids) to 80.4% solids after 96-h cure time.

C Street sediment amended with 5% Calciment™	Units	
In situ volume at 51.6% solids	CY	**40,000**
Volume of stabilized sediment, 80.4% solids	CY	**25,700**

Table 5-5. C Street sediment (34,900 tons) stabilized with 5% Calciment™ for disposal after 96-hr cure time.

bulk density = 1.36	5% Calciment™	disposal
tons	tons	tons
34,900	**1,750**	**36,700**

6. Description of Definitive Remedial Alternatives

6.1 Evaluation of Alternatives

During the process of identifying remedial options, alternatives were discussed and screened, with some alternatives not carried forward for evaluation. The alternatives were initially evaluated against criteria including technical feasibility (i.e., long-term effectiveness, short-term effectiveness, restoration time frame and implementability), economic feasibility and other considerations (e.g., onsite engineering controls) as defined in Wis. Admin. Code NR 722.07. A short list of alternatives was retained for evaluation in this definitive remedial alternatives' evaluation as presented in the *C Street Slip Remedial Alternatives Screening Evaluation* (AECOM, 2023a).

Potential definitive remedial alternatives were subsequently evaluated based on technical, economic and regulatory feasibility and other site conditions to specifically address tPAHs and mercury measured in sediment within the C Street Slip above PRGs. As part of this evaluation, remedial alternatives were evaluated using site-specific criteria specified by WDNR (**Table 6-1**). Results of this detailed evaluation will serve as the basis for the selection of the preferred remedy to be documented in a future Remedial Action Options Report (RAOR) for the C Street Slip (to be developed by others).

Table 6-1. Remedial alternatives were evaluated with site-specific criteria developed from a combination of WDNR and USEPA guidance documents.

Criterion	Basis
Overall Protection of Human Health and the Environment	Implied throughout Wis. Admin. Code chs. NR 700 – 799 NCP Threshold Criteria
Compliance with Applicable Relevant and Appropriate Requirements (ARARs)	Wis. Admin. Code subsection NR 722.09(2) NCP Threshold Criteria
Long-term effectiveness	Wis. Admin. Code subdivision NR 722.07(4)(a)1. NCP Balancing Criteria
Short-term effectiveness	Wis. Admin. Code subdivision NR 722.07(4)(a)2.

Criterion	Basis
	NCP Balancing Criteria
Implementability	Wis. Admin. Code subdivision NR 722.07(4)(a)3. NCP Balancing Criteria
Restoration Time Frame	Wis. Admin. Code subdivision NR 722.07(4)(a)4.
Economic Feasibility	Wis. Admin. Code paragraph NR 722.07(4)(b) NCP Balancing criteria
Additional Requirements **State and Community Acceptance**	Wis. Admin. Code subsection 722.07(5) Wis. Admin. Code section 722.15 Wis. Admin. Code subsection 714

6.1.1 Criteria

The criteria evaluated below are a hybrid of NR 722 and the NCP criteria to satisfy both state and EPA needs.

Overall Protection of Human Health and the Environment

This criterion evaluates how the alternative maintains and achieves protection of human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

Evaluation of this criterion determines whether it complies with chemical-specific, action-specific, and location-specific ARARs or if a waiver is justified. In addition to ARARs, this criterion considers whether other criteria, advisories, and guidance should be considered at the site.

Long-Term Effectiveness

The evaluation of remedial options for long-term effectiveness assesses the residual risk that remains after the remedial alternative has been implemented. This assessment includes an analysis of the magnitude of residual risk and the adequacy and reliability of engineering controls or continuing obligations to control that risk. The magnitude of residual risk analysis considers the following:

- Residual risk, expressed in cancer risk levels, volumes, or concentrations, remaining from untreated waste or treatment residuals at the conclusion of remedial activities.
- The volume, toxicity, and mobility of residuals remaining after remedial activities.
- The degree of adequacy and reliability the remedial option will provide to the overall protection of human health and the environment over time.

The adequacy and reliability of engineering controls, or continuing obligations, is evaluated in terms of the long-term reliability of controls used to manage treatment residuals or untreated waste remaining at the Site, and considers the following:

- The likelihood that the technology would meet required process efficiencies or performance specifications.
- The type and degree of long-term management and monitoring.
- Operation and maintenance (O&M) functions required to maintain process efficiencies or performance specifications.
- Difficulties of long-term maintenance, including the potential need for replacement of technical components and the degree of confidence that controls can adequately handle potential problems.

Short-Term Effectiveness

Short-term effectiveness addresses the effects of the remedial alternative during the construction and implementation phases until RAOs are met and considers the following:

- The risks to Site remediation workers and building occupants and the methods used to mitigate the risks, which could not be readily controlled during the remedial action.
- The risks to the community during the remedial action and how the risks would be mitigated.
- Environmental impacts, which can be expected during construction and implementation, the mitigation measures and their reliability, and the impacts which cannot be avoided or controlled.
- The duration of time until remedial objectives are met.

Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedial option and the availability of various services and materials required during its implementation. Specific considerations include the following:

- The ability to construct and operate the remedial option, the difficulties and uncertainties that may be encountered during construction, and the likelihood of technical problems that may lead to schedule delays.
- The ease of undertaking additional remedial action and what those additional actions may be.
- The coordination required between agencies over the long term, and the ability to obtain permits for the remedial activities.
- The availability of capacity at treatment, storage, and/or disposal services, and the measures required to ensure that capacity is available.
- The availability of necessary equipment and specialists, and whether a lack of equipment and specialists prevents implementation.
- The degree to which technologies are available and sufficiently demonstrated for the specific full-scale application.

Restoration Time Frame

This screening criterion evaluates the time for the remedy to meet the RAOs. This criterion also considers the disturbance to the community and ecosystem over time. In addition, the volume, mobility and toxicity of contamination including the degradation potential of the COCs is considered as part of the restoration potential of the alternative. Specific considerations include the following:

- Proximity of contamination to receptors identified.
- Risk of remedy to sensitive receptors as well as threatened or endangered species or habitats.
- COC fate and transport and the degree of natural attenuation of residual contaminants considering the post-remedy geologic and hydrogeologic conditions.
- The effectiveness and enforceability of continuing obligations by the stakeholders and/or community.

Economic Feasibility

Cost analysis includes estimates of capital costs (both direct and indirect initial costs) and annual O&M costs associated with each component of a remedial option. The target level of accuracy is +50% to -30%.

The cost may play a significant role in comparing remedial options, which are similar in long-term effectiveness or when treatment methods provide a similar performance. The remedial options with costs that are high when compared to the overall effectiveness of the remedial option will not be selected as the final remedy. Similarly, non-treatment options that have low initial capital costs may be more costly overall than a treatment option when long-term O&M costs are considered. An improved performance or greater long-term risk reduction may justify higher costs. The preferred remedial option is generally the one that satisfies the criteria at the most reasonable cost.

State Acceptance

This criterion is used to evaluate the technical and administrative concerns of the state regarding alternatives, which can include an assessment of the state's position and key concerns regarding the alternative, as well as comments on ARARs or proposed used of waivers. Tribal acceptance, if applicable, is also evaluated under this criterion. Regulatory permitting and compliance requirements are considerable when dealing with disturbance of wetlands and freshwater resources. Multiple federal, state and local permitting agencies typically need to be engaged to perform this work which is significantly complicated by the additional engineering and offsets required by proposing work in and around these resources. A permitting workplan and regulatory "roadmap" are being developed for this remedial project to be presented under Task 13, *Permits Needed to Implement the Selected Remedial Action(s)*. This criterion will be further evaluated when the RAOR is prepared as part of public participation and notification and considered in decision-making prior to remedy selection and implementation.

Community Acceptance

This criterion involves evaluation of the concerns of the public regarding the proposed alternatives and determines which component of the alternatives interested persons in the community support or oppose. C Street Slip and the proposed sediment management site are both situated near industrial parcels that residents and workers may frequent. Odor, noise, and traffic caused by project execution present the potential to cause a public disturbance and/or impact quality of life for nearby residents. Public perception and potential for interference in traffic and quality of life present a risk as public complaints may cause project delays. This project also involves several public stakeholders including local government and non-government organizations which have a vested interest in keeping the wellbeing of the residents in mind. The criteria scores are based on the assumptions that the public is generally supportive of the project and will not interfere with construction. A comprehensive public communication strategy will be developed to mitigate many of the questions and concerns about the project plan and schedule. This criterion will be further evaluated when the RAOR is prepared as part of public participation and notification and considered in decision-making prior to remedy selection and implementation.

Additional Requirements

Additional requirements may include state and community acceptance, engineering controls, continuing obligations or other requirements as deemed necessary on a site-specific basis as described in NR 722.07(5)(c). For the Site, additional requirements include continuing obligations for groundwater monitoring and WDNR GIS Registry, per NR 714.05(1). This category also includes the evaluation of stakeholder and community acceptance of the remedial option as well as State Acceptance of the design per NR 722.15.

6.1.2 General Assumptions

The following general assumptions were developed for the purpose of evaluating the remedial alternatives:

- There are additional costs associated with lease or purchase of the sediment management area (SMA) locations required for access and/or sediment management but costs are not included as part of the alternative's evaluation.
- Relative costs associated with different sizes of SMA and other landside footprints are considered.

- On-water activities of all remedial alternatives can be completed within one construction season. Loadout, disposal and/or restoration may be completed in the same season or a subsequent season(s). Costs associated with this multi-season approach are not included.
- The SMA and other project impacts can be engineered and designed to avoid wetland and floodplain impacts.
- Ingress/egress can be engineered and coordinated such that no pinch-points are realized.
- Treated contact water can be discharged directly to C Street Slip or any other nearby part of the watershed with minimal scour and diffusion protection.
- If used, geotextile tube fabric and dewatered sediment will need to be segregated and cannot go to the landfill mixed.
- All dewatered ex situ sediment will go to an off-site permitted landfill(s) for disposal or to an approved reuse option.
- A crane will not be required for mobilization or SMA construction.
- Public stakeholders are supportive of this project.
- Permitting coordination and approval will not be difficult and will not impact construction schedule.
- Potential wetland mitigation, best management practices (BMPs) and/or engineering offsets are not required.
- Stabilization of dewatered sediment with a low admixture ratio will be required for commercial landfill disposal for all ex-situ approaches.
- C Street Slip use will be restricted until contaminated sediment is removed.
- All required permits will be approved.
- No anticipated underground utilities.
- Fuel prices are expected to remain constant.

6.2 Remedial Alternatives Retained for Detailed Evaluation

The following remedial alternatives were screened and subsequently identified to have the potential to meet the RAOs for sediments in C Street Slip:

- **No Action**
- **Sediment Cap (unamended and amended)**
- **Mechanical Dredging**
- **Hydraulic Dredging**
- **Mechanical “Hot-spot” Dredging followed by an Unamended Sediment Cap**

A short description of each remedial alternative as it would be engineered and implemented for application in C Street Slip is provided in Sections 6.2.1 to 6.2.6 below. Water treatment is assumed to be required for all ex-situ sediment management alternatives, including filtrate water from sediment dewatering as well as contact water generated from precipitation. Additional treatability testing for a water treatment system design is required prior to final design. Design details and costs of the water treatment system are not evaluated as part of this definitive document other than a cost comparison accounting for flow and size differences for each alternative. It is assumed all water treatment systems will require filtration/settling and some level of adsorption with activated carbon for targeted soluble constituents.

Additionally, access to the Slip (using a public or private boat launch) is available for marine equipment used for dredging and/or cap placement without using an onsite crane. Also, suitable space within a mile of the Slip is assumed to be available for equipment and material staging, sediment or cap material processing, hopper barge transloading and loadout of dewatered sediment, as necessary.

6.2.1 No Action

This alternative is included for baseline comparison to other alternatives and does not allow for RAOs to be met in C Street Slip. The no action alternative assumes that no remedial activities or site monitoring of the C Street Slip are performed in either the short- or long-term. With the “no action” alternative, sediment containing COCs at concentrations greater than the PRGs would remain in place.

Technical Feasibility

Under this alternative, no remedial activities would be performed and therefore “no action” is not an effective remedy to address impacted sediment in the C Street Slip.

This alternative is highly implementable from both technical and administrative perspectives.

Restoration Time Frame

Restoration is not expected to occur in any time frame as this Slip is within an active, industrial waterway.

Economic Feasibility

No remediation or O&M costs are associated with this alternative since no actions are proposed as part of this remedy.

Additional Requirements

This alternative is unlikely to be accepted by federal or state regulatory authorities as the remedial alternative for C Street Slip as it does not meet addressing the SLRAOC BUIs.

This alternative is unlikely to be accepted by community stakeholders as the remedial alternative for C Street Slip.

The no action alternative is only included for baseline comparison to other alternatives.

6.2.2 Unamended Sediment Cap

Installation of an unamended cap (i.e., stone, sand, fines and/or a blended fill) is used to physically isolate impacted sediment from the aquatic environment, subsequently decreasing the potential for COC(s) adsorbed to sediment to transfer into the water column. A sediment cap is generally an appropriate remedial strategy for contaminated locations where future construction or disturbances (e.g., dredging, prop wash, current, waves, ice scour) are minimal or can be mitigated with cap engineering and design (e.g., armoring). Cap material(s) selection, modeling, treatability tests, recontamination potential, ebullition, potential for natural sediment deposition and cap thickness selection will need to be considered as part of a detailed alternative evaluation.

Installation of a sediment cap is assumed to be performed in the wet. Cap materials can be applied using mechanical placement (excavator or crane) and/or hydraulic methods involving a combination of land-based staging, mixing plants to slurry cap materials and/or a barge and/or boat system to expedite delivery. Turbidity controls and water quality monitoring would be installed during remedial activities to manage suspended sediment that may be generated during remedy implementation. Mechanical dredging of debris and/or leveling of the cap placement area prior to sediment cap installation may be used, if necessary. Sediment dredging may also be required prior to cap installation to accommodate for any potential loss of water depth in the Slip depending on the future use of the Slip.

Habitat restoration design or Engineering with Nature principles as per US Army Corps of Engineers Guidance can be implemented as part of a cap installation to provide habitat quality improvements for benthos, fish and other aquatic biota. A long-term monitoring program would be required following installation of the unamended sediment cap to assess the stability and long-term effectiveness of the remedy and to document compliance with the RAO(s). Implementation of institutional controls (ICs) would also be required as part of this remedial alternative to protect the integrity of the remedy.

1. Pre-design Investigation
    a. Bathymetric survey of the sediment surface of the target area prior to cap placement.
    b. Hydrologic and hydraulic (H&H) modeling to evaluate stability of cap material, requirements for armoring (if necessary) and requirements for venting for ebullition and other gas flux in the C Street Slip.
    c. Column tests are recommended to evaluate cap placement techniques and settling efficacy.
    d. Measure in-situ sediment deposition rate and subsequently perform sediment transport modeling.
2. Mechanical placement of a three-foot sand cap or cap composed of blended construction fill across the target area with a cable arm bucket or hydraulic placement of the cap by slurring and pumping from a mix tank or hopper barge.
3. Turbidity controls and water quality monitoring would be installed during remedial activities to manage suspended sediment that may be generated during remedy implementation.
4. Confirmation sampling and surveying to verify cap thickness and coverage across the target area.
5. Stone armoring will be required for this active, industrial waterway.
6. Engineering with nature principles will be engineered into the cap design to encourage fish and benthos recolonization.
7. Minimal site restoration.
8. Long-term monitoring for cap and armor stone stability and integrity as well as benthos community recolonization.
9. ICs may be required for all or part of the Slip.

Assumptions

- Upland and groundwater sources of future contamination have been identified but require additional mitigation.
- The addition of an unamended sediment cap will not require dredging of sediment to accommodate for any potential loss of water depth in the Slip.
- Removal of debris is not required prior to cap placement.
- Infrastructure and other debris will not interfere with cap placement and stability.
- Prop wash, scour and other Slip activities may impact cap integrity. Design and placement of an armoring layer is required.
- Materials for cap construction and armoring are locally available.
- Potential for recontamination of a sediment cap from landside sources is highly probable.
- Potential for flux from groundwater sources is uncertain.
- Natural sediment deposition of fine sediment is slow in the Slip such that efficient recolonization does not occur in a reasonable time frame.

Technical Feasibility

An unamended sediment cap is an ineffective, long-term alternative for mitigating the RAOs of the C Street Slip as a standalone option. A sediment cap cannot be engineered and designed for C Street Slip to permanently eliminate or minimize exposure of fish and benthos to contaminated sediment in the long-term. In the short-term, a sediment cap would eliminate the exposure pathway from sediment to the aquatic community but would simultaneously eliminate the existing benthos community. C Street Slip is an industrial, high traffic waterway and thus sustainable, natural recovery processes are not anticipated to occur. Based on the implementation assumptions described under **Additional Requirements**, an unamended cap composed of sand would be relatively easy to install and armor across the target area as suitable construction materials are expected to be locally available. No specialized equipment or long-lead items have been identified. Qualified contractors and equipment are located throughout the Great Lakes region.

Restoration Time Frame

Restoration of the benthos community is not expected in a reasonable time frame without additional engineering (Engineering with Nature), additional fine material deposited on top of the armor, ICs and associated costs.

Economic Feasibility

Costs of sediment cap installation for C Street Slip is predicted to be lower than sediment removal alternatives that include costs associated with ex situ sediment management and disposal. However, ICs, maintenance and long-term monitoring will be in place for perpetuity.

Additional Requirements

A sediment cap may be implemented in C Street Slip with engineering controls and BMPs to manage resuspension of contaminated sediments and cap materials during installation. Additionally, a significant pre-design investigation will be required prior to the full design of the cap installation. This includes but is not limited to, a bathymetric survey, H&H modeling and/or sediment transport modeling.

Additionally, sediment contamination would remain in the aquatic environment and potential for future risk remains if the cap integrity would be compromised due to a storm or scour from prop wash or ice. ICs would be required in perpetuity in order to eliminate dredging, construction, prop wash and scour to limit damage to the capped area. This alternative will not be accepted by federal or state regulatory authorities as the remedial alternative for C Street Slip as a cap would be difficult to maintain for the design life of the project and the future use of the Slip.

This alternative is unlikely to be accepted by community stakeholders as the remedial alternative for C Street Slip as tPAH and mercury concentrations greater than PRG values will remain in the Slip.

Although an Unamended Sediment Cap may be a cost-effective, short-term alternative, long-term effectiveness on the RAOs (BUIs Nos. 1 and 4) are not expected in C Street Slip. A cap constructed with sand or blended fill is eliminated from consideration as a standalone remedial alternative for C Street Slip as exposure of sediment contaminants to the fish and benthos communities is not permanently eliminated.

6.2.3 Amended Sediment Cap

Installation of an engineered sediment cap (i.e., stone, sand, fines and/or a blended fill) amended with activated carbon, activated carbon-based products (e.g., SediMite or AquaGate), organoclays, or other engineered materials are used to sequester tPAH and mercury concentrations from sediment porewater and physically isolate impacted sediment from the aquatic environment. A sediment cap is generally recommended for contaminated locations where future construction or disturbances (e.g., dredging, prop wash, current, waves, ice scour) are minimal or can be mitigated with engineering in the cap design (e.g., armoring). Selection of an amendment and mix ratio, cap thickness, cap material(s) selection, modeling, treatability tests, recontamination potential, ebullition and potential for natural deposition will need to be considered as part of a detailed evaluation.

Amended sediment cap installation is assumed to be performed in the wet. An amendment layer is typically added between the sediment cap and the target area or may be blended with the cap material in a 0.5 to 1-ft lift to provide additional adsorption potential for tPAH and/or mercury that transfers from the sediment pore water and migrates towards the aquatic environment. Use of amendments in the initial layer may decrease the overall thickness of the unamended portion of the cap. Cap materials can be applied using mechanical and/or hydraulic methods involving a combination of land-based staging, mixing plants to activate and/or dilute cap materials and/or a barge or boat system to expedite delivery. Turbidity controls and water quality monitoring would be installed during remedial activities to manage suspended sediment that may be generated during remedy implementation. Mechanical dredging may be required to remove debris and/or level the sediment surface prior to construction of the cap. Sediment dredging may also be required prior to cap installation to accommodate for any potential loss of water depth in the Slip.

Habitat restoration or engineering with nature principles can be implemented as part of a cap remedy to provide habitat quality improvements for benthos, fish and other aquatic biota. A long-term monitoring program would be used following installation of the amended cap to assess the stability and long-term effectiveness of the remedy and to document compliance with the RAO(s). Implementation of ICs would be required as part of this remedial alternative to protect the integrity of the remedy.

Requisite design, construction steps and assumptions for this evaluation are detailed below.

1. Pre-design Investigation
    a. Bathymetric survey of the sediment surface of the target area prior to cap placement.
    b. H&H modeling to evaluate stability of cap material, requirements for armoring (if necessary) and requirements for venting for ebullition and other flux in the C Street Slip.
    c. Measure natural sediment deposition rate and perform sediment transport modeling.
    d. Treatability tests to identify amendment(s), mix ratios, cap thickness and cap placement strategy.
2. Mechanical dredging to remove debris and/or level sediment surface prior to cap installation.
3. Mechanical or hydraulic placement of an amendment layer or sand/amendment blended layer from a mix tank or hopper barge.
4. Confirmation sampling and surveying to verify amendment thickness and coverage across the target area.
5. Mechanical placement of a sand cap or cap composed of blended construction fill across the target area with a cable arm bucket or hydraulic placement of the cap by slurring and pumping from a mix tank or hopper barge.
6. Confirmation sampling and surveying to verify cap thickness and coverage across the target area.
7. Stone armoring if required.
8. Long-term monitoring for cap and armor stone stability and integrity as well as benthos community recolonization.
9. ICs are required for all or part of the Slip.

Assumptions

- Upland and groundwater sources of future contamination have been identified and will require additional mitigation.
- Prop wash, scour and other Slip activities may impact cap integrity. Design and placement of an armoring layer is required.

- Materials for cap and armoring construction are locally available.
- Potential for recontamination of the cap from landside sources is undetermined.
- Potential for flux from groundwater sources is uncertain.
- Natural sediment deposition of fine sediment is slow in the Slip such that efficient recolonization does not occur in a timely manner.

Technical Feasibility

An amended sediment cap is an effective, short-term alternative for mitigating the RAOs of the C Street Slip as a standalone option. However, an amended sediment cap cannot be engineered and designed for C Street Slip to permanently eliminate or minimize exposure of fish and benthos to contaminated sediment in the long-term. In the short-term, an amended cap would eliminate the exposure pathway of tPAH and mercury from sediment to the aquatic community but would simultaneously eliminate the existing benthos community. C Street Slip is an industrial, high traffic waterway and thus sustainable, natural recovery processes are not anticipated to occur.

Based on the implementation assumptions described under **Additional Requirements**, an amended cap composed of sand would be relatively easy to install and armor across the target area as suitable construction materials are locally available. No specialized equipment or long-lead items have been identified. Qualified contractors and equipment are located throughout the Great Lakes region.

Restoration Time Frame

Restoration of the benthos community is not expected in a reasonable time frame without additional engineering (Engineering with Nature), deposition materials placed on top of the armor, ICs and associated costs.

Economic Feasibility

Costs of an amended sediment cap constructed in C Street Slip is predicted to be lower than sediment removal alternatives due to the additional costs associated with ex situ sediment management and disposal. Amendment materials can be quite costly and are long-lead items. ICs, maintenance, and long-term monitoring will be in place for perpetuity.

Additional Requirements

An amended sediment cap may be implemented in C Street Slip with engineering controls and BMPs to manage resuspension of contaminated sediments and cap materials during installation. A significant pre-design investigation will be required prior to the full-scale design of the cap installation project including but not limited to a bathymetric survey, H&H modeling and/or sediment transport modeling.

Additionally, sediment contamination would remain in the aquatic environment and potential for future risk remains if cap integrity would be compromised due to a storm or scour due to prop wash or ice. ICs are required in perpetuity in order to eliminate dredging, construction, prop wash and scour to limit damage to the capped area.

This alternative is unlikely to be accepted by federal or state regulatory authorities as the remedial alternative for C Street Slip as an amended cap would be difficult to implement and maintain for the design life of the Slip.

This alternative is unlikely to be accepted by by community stakeholders for C Street Slip as the tPAH and mercury concentrations greater than PRG values will remain in the Slip.

Although an Amended Sediment Cap may be a cost-effective, short-term alternative, long-term effectiveness for the RAOs (BUIs Nos. 1 and 4) are not expected in C Street Slip. A cap with amendments and sand is eliminated from consideration as a standalone remedial alternative for C Street Slip as exposure of fish and benthos communities to COCs is not permanently eliminated.

6.2.4 Mechanical Dredging

Mechanical dredges excavate material at almost in situ densities using some form of bucket to carry dredged material up through the water column and place it into a barge, scow, hopper barge or other disposal transport for off-site processing and/or disposal. Mechanical dredges are designed to remove loose to hard, compacted materials. Mechanical dredges may be used to excavate most types of materials except for the most cohesive consolidated sediments and solid rock. Mechanical dredges are typically used in areas where hydraulic dredges cannot work because of the proximity of the dredge cut to piers, docks, and other structures, or where the disposal area is too far from the dredge site for it to be feasible for a hydraulic dredge to pump the dredged material.

Clamshell Dredges are the most common type of bucket dredges, consisting of a clamshell bucket operated from a crane or derrick mounted on a barge or other floating structure. The clamshell dredge usually leaves an irregular, cratered bottom. Although the dredging depth is practically unlimited, because of production efficiency and accuracy clamshell dredges are usually used in water not deeper than 30 meters. This style of dredge is used almost extensively for removing relatively small volumes of material (i.e., a few tens or hundreds of thousands of cubic yards) at nearly its in-situ density. The dredged material is subsequently placed in barges or scows for transportation to a transloading area, the SMA and/or disposal area. Due to longer turn times for moving the bucket up and down through deep water and multiple material re-handling steps, production rates of mechanical dredging are relatively low compared to hydraulic dredges. Variations of the clamshell dredge have been developed in recent years in an attempt to improve precision and minimize loss of sediment, water, and associated contaminants.

A cable arm bucket works on a two-cable system. One cable is attached to four spreader cables, which control opening and closing of the bucket. The second cable draws the clams together and lifts, thus creating a level-cut in the sediment that is essential for precision dredging. Other features such as one-way vents in the top of the dredge to reduce downward pressure during deployment and rubber seals to prevent loss of sediments have been added to further reduce sediment resuspension. Other, similar designs have been developed to mimic these features and are collectively referred to as “environmental” buckets. Other dredge operations that are evaluated to improve efficiency are cycle time (i.e., speed of the bucket through the water column up and down), spill (i.e., resuspension due to material falling out of the bucket), fall-back (i.e., displacement of the sediment as the bucket hits the bottom), slope stability and cut slope.

Mechanical dredging “in the wet” includes use of a barge-mounted clamshell (e.g., crane or derrick). The dredge will excavate sediment from the dredge prism using geographic positioning system (GPS) guidance (e.g., DredgePak) and transfer the material to a temporary and/or bermed shoreline staging area with scows or hopper barges for subsequent transfer to a nearshore SMA. The lined SMA will be designed to accommodate all of the excavated material as well as contain a sump to manage filtrate and precipitation during the project period. Excavated sediments will be mechanically stacked to facilitate gravity drainage. Methods such as turning, mechanical augers, windrowing, and/or addition of s/s reagents may be used to enhance the dewatering process (i.e., 5% Calciment™ identified during treatability testing). A temporary cover system may also be used over the dried sediments to limit re-saturation until the material is transloaded for disposal.

Solidification/stabilization (S/S) includes processes that mix inorganic cementitious/pozzolanic reagents into stacked dredged material to transform it into a durable, solid, low–hydraulic conductivity material. Cementitious reagents are the most common commercially employed S/S process options due, in part, to low cost and availability. Cementitious and/or pozzolanic reagents include Portland cement, Calciment™, fly ash, ground granulated blast furnace slag, silica fume, cement kiln dust, various forms of lime, and lime kiln dust. These reagents may be used singly or in various combinations. In low admixture concentrations, cement is used for dewatering, consolidation and geotechnical stability of the sediment. Most soil stabilization treatment ranges from 5 to 10% admixture; sediment can be more (5 to 20%) depending on the percent moisture of the sediment matrix.

Implementation costs vary widely based on reagent availability, transportation costs for delivery to the site, and mixing technique (in situ or ex situ). The s/s process typically involves either the addition of reagents to water (to form a grout or paste) or the addition of dry reagents to the dredge material and using the in-situ water for activation. The selection of the type of reagent is influenced by sediment characteristics and site conditions such as depth of mixing and moisture content. In situ dry addition is typically feasible for only relatively shallow mixing operations; however, the generation of fugitive dust may be a concern unless it is mitigated by use of suitable equipment and controls. Recommendations for s/s reagent types and mix ratios were provided as part of the *Data Gap Treatability Test Report* (AECOM, 2022b).

Disposal of dredged or excavated sediment is the placement of materials into a controlled site or facility (e.g., sanitary landfills, hazardous material landfills, confined disposal facilities (CDFs), or confined aquatic disposal facilities). Off-site landfills are generally used for dredged material disposal when on-site disposal is not feasible or when off-site disposal is more cost effective. Alternatively, off-site landfilling is favored for smaller or moderately sized sites, where transportation to the site is feasible via truck or barge. The associated hazards and cost of transporting and landfilling large volumes of sediment make offsite disposal a less desirable solution for large sediment volumes.

Excess water generated from dredged sediments in the scows or barges and during sediment processing will be collected and pumped into either an onsite water treatment system or transported to the nearby municipal wastewater treatment facility. Turbidity control and water quality monitoring would be implemented as part of this remedy and fugitive odor and dust emissions would need to be controlled during sediment processing.

By removing the contaminated sediments with tPAH and mercury concentrations that are greater than PRG values from C Street Slip, the risk of contaminated sediment exposure to fish and benthos communities is eliminated. The remedial activities for Mechanical Dredging are:

1. Pre-design Investigation
    a. Bathymetric survey of the sediment surface of the target area.
    b. Dewatering and S/S treatability tests to identify sediment management strategies and associated efficacy to refine design assumptions.
2. Mechanical dredging of the contaminated sediment with a clam shell bucket mounted on a spudded-barge conveyed into a hopper barge.
3. Transportation of dredge material to a waterside offloading area.
4. Transload dredged sediment from hopper barges to a lined SMA with mechanical handling processes.
5. Sediment is dewatered through mechanical stacking followed by s/s, if necessary.
6. Addition of a stabilization reagent to the sediment may be required to enhance dewatering processes as well as improve the compaction potential and/or strength of the dewatered sediment prior to transportation and disposal in a commercial landfill. See additional considerations below.
7. Filtrate water is collected in a sump and pumped to the water treatment plant prior to discharge.
8. Confirmation sampling and surveying to verify contaminated sediment was removed and target depths were reached, respectively.

Assumptions

- The dredge prism is accessible by the dredge equipment.
- A nearby footprint with water access for transloading is available for construction of the SMA.
- Mechanical dredging can simultaneously remove debris and sediment from the dredge prism.
- Sediment management strategies were evaluated as if all sediment were managed together as a blend. Advantages of sand separation and collection will be evaluated by using hydrocyclones or other screening equipment.

- No long lead items have been identified and s/s reagents are locally available.
- Experienced contractors are regionally located, and dredging equipment is readily available.
- A sediment cap or ICs may be required post-dredging as recontamination potential is uncertain. Confirmation sampling is required.
- Potential for flux from groundwater sources is uncertain.
- Recolonization of benthos is predicted to occur quickly.

Technical Feasibility

Mechanical dredging with s/s is an effective alternative for mitigating RAOs of C Street Slip as potential exposure of fish and benthos would be eliminated in both the short- and long-term. In the short-term, dredging simultaneously eliminates the contaminated sediment as well as the existing benthos community. Mechanical dredging is effective for dredging some clay and/or other consolidated sediment layers compared to hydraulic dredging methods. If vertical delineation is incomplete or it's unclear if the confining clay layer is contaminated with tPAH or mercury, confirmation sampling may be recommended prior to a polishing pass or additional dredging until "clean" sediment is reached.

Mechanical dredging may be implemented in C Street Slip with engineering controls and best management practices (e.g., turbidity curtains) to manage resuspension of contaminated sediments during dredging. A pre-design investigation will be required prior to a full design of the project including but not limited to a bathymetric survey, H&H modeling and/or sediment transport modeling. No specialized equipment or long-lead items have been identified. Qualified contractors and equipment are located throughout the Great Lakes region. The construction window for the site is small and thus mobilization efficiency will be crucial to make the most of the time for dredging and sediment processing. In addition to a nearby SMA, a transloading location will be required in order to transfer dredged material from scows/barges to the SMA.

Restoration Time Frame

Sustainable restoration of the benthos community is expected in a reasonable time frame without additional engineering or ICs.

Economic Feasibility

Costs of mechanical dredging and ex situ sediment management for C Street Slip is predicted to be high compared to other sediment removal alternatives (other than hydraulic dredging and/or mechanical dewatering) due to the additional costs associated with ex situ sediment management, s/s and disposal. ICs will not be required but long-term monitoring may be required.

Additional Requirements

Gravity stacking tests performed with C Street Slip sediment (51.6% solids) passed paint filter test (PFTs) at 0-h and 24-h indicating the material may be sufficiently consolidated to mechanically dredge, stack and transport to an offsite facility for disposal. The UCS of this material was insufficient for receipt at a commercial landfill. Bench-scale treatability tests subsequently identified that a 5% Calciment™ admixture mixed and cured (96-h) with stacked sediment will exceed the 1,000 lb/ft^2 UCS threshold for most landfills. Additionally, 10% Portland cement and Calciment™ stabilized contaminated sediment and eliminated leachability of mercury and tPAHs from amended sediment. Dry weight solids of these amended sediment samples increased from 51.6% to 83.6% and 90.6% for 10% Calciment™ and 10% Portland cement, respectively.

Mechanical dredging into hopper barges and transloading from the barges to a SMA requires double-handling and the potential for occupational exposure as well as loss of contaminated material into the environment. BMPs and other measures will be required in order to ensure all sediment is managed properly.

Mechanical dredging may be implemented in C Street Slip with engineering controls and best management practices (e.g., turbidity curtains) to manage resuspension of contaminated sediments during dredging. A pre-design investigation will be required prior to a full design of the project including but not limited to a bathymetric survey, H&H modeling and/or sediment transport modeling.

Natural recovery processes and benthos recolonization in surficial sediment would occur quickly. ICs would not be required. C Street Slip is an industrial waterway and this alternative does not eliminate the potential for recontamination of surficial sediment if contaminant sources were not identified and eliminated. Monitoring of the Slip is assumed to be required to track recovery and confirm that recontamination does not occur over time.

This alternative will be accepted by federal or state regulatory authorities as mechanical dredging and gravity stacking with s/s of dewatered sediment would be relatively easy to implement and subsequently maintain for the design life of C Street Slip.

This alternative will be accepted by community stakeholders as mechanical dredging of tPAH and mercury concentrations greater than PRGs would be permanently removed from C Street Slip.

Mechanical Dredging is a long-term, sustainable alternative, mitigating fish consumption advisories (BUI No. 1) and risk to the benthos community (BUI No. 4) in C Street Slip. Removing the contaminated sediment removes a potential exposure pathway of COCs to benthos communities and is selected for further consideration as a standalone option.

6.2.5 Hydraulic Dredging

Hydraulic dredges are typically used for unconsolidated sediment, such as those typically found in waterway maintenance removal projects. Hydraulic dredges are self-contained units that handle both the dredge and disposal phases of dredging operations. They not only dig the material up, but also convey the sediment slurry to a placement or management area by pumping the material through a pipeline, or by storing it in hoppers that can be subsequently emptied over the disposal area or to a SMA for processing. The pump produces a vacuum on its intake side, which forces water and sediment through the suction pipe. In a hydraulic dredge the material to be removed is first loosened and mixed with water by a cutterhead or by agitation with water jets and then pumped as a fluid. Sediments are directed into the suction end of a hydraulic pipeline by various methods (e.g., rotating cutterhead or horizontal auger) and transported to the water surface inside a pipeline and then to a selected discharge point.

Cutterhead Suction Dredge is the most common hydraulic dredge used in North America and is generally the most efficient and versatile. With this type of dredge, a rotating cutter at the end of a ladder excavates the bottom sediment and guides it into the suction. The excavated material is lifted and pumped by a centrifugal pump to a designated disposal area through a pipeline as slurry with a typical solids content of 10% to 20% by weight. The typical cutterhead dredge is swung in an arc from side to side by alternately pulling on port and starboard swing wires connected to anchors through pulleys mounted on the ladder just behind the cutter. Pivoting on one of two spuds at the stern, the dredge "steps" forward.

Jet-Suction Dredges are hydraulic suction dredges that use a widely flared dredge head along which water jets are mounted. The jets loosen and agitate sediment particles, which are then captured in the dredge head as the dredge moves forward. This type of dredge works best in free-flowing granular material and is not generally used to dredge fine-grained sediment. Similar to a cutter suction dredges, jet-suction dredges agitate and slurry the sediment with fine water jets at the end of the ladder and subsequently suction the slurry into the pipeline for conveyance and disposal at the sediment processing facility.

Hydraulic dredging in C Street Slip requires a swinging-ladder, cutterhead hydraulic dredge connected to a floating, high-density polyethylene dredge pipeline to remove sediments containing COCs at concentrations greater than the PRGs from the Slip. Dredging progress and productivity will be tracked and monitored real-time with GIS-based surveying technology (e.g., HyPack, DredgePack or similar software). The sediment slurry generated during hydraulic dredging is conveyed directly to a SMA where the sediments are conditioned with polymers, contained, dewatered and consolidated using geotextile tubes, belt presses, plate-and-frame presses, centrifuges and/or a combination of all of the above.

Disposal of dredged or excavated sediment is the placement of materials into a controlled site or facility (e.g., sanitary landfills, hazardous material landfills, CDFs, or confined aquatic disposal facilities). Off-site landfills are generally used for dredged material disposal when on-site disposal is not feasible or when off-site disposal is more cost effective. Alternatively, off-site landfilling is favored for smaller or moderately sized sites, where transportation to the site is feasible via truck or barge. The associated hazards and cost of transporting and landfilling large volumes of sediment make offsite disposal a less desirable solution for large sediment volumes.

Turbidity control and water quality monitoring would be implemented as part of this remedy to prevent suspended sediment from migrating outside of the project area during water-based activities. Fugitive odor and dust emissions would need to be controlled during sediment processing. Additional s/s of the dewatered sediment may be required to further dewater and strengthen the sediment to meet transportation and disposal requirements. By removing the tPAH and mercury-contaminated sediments from C Street Slip that are greater than PRG values, the risk of contaminated sediment exposure to the fish and benthos communities are eliminated. The remedial activities for Hydraulic Dredging are:

1. Pre-design Investigation
    a. Bathymetric survey of the sediment surface of the target area.
    b. Dewatering and S/S treatability tests to identify sediment management strategies and associated efficacy to refine design assumptions.
2. Hydraulic dredging of contaminated sediment with a cutterhead with pipeline conveyance to the SMA.
3. Sediment is dewatered with geotextile tubes or mechanical dewatering equipment (e.g., presses or centrifuges). Both passive and mechanical dewatering options will require polymer conditioning to facilitate solids/water separation and consolidation.
4. Addition of a stabilization reagent to the sediment may be required to enhance dewatering processes as well as improve the compaction potential and/or strength of the dewatered sediment prior to transportation and disposal in a commercial landfill.
5. Filtrate water is collected in a sump and pumped to the water treatment plant prior to discharge. Design of the sump and water treatment system are based on dredge discharge rate to the SMA.
6. Confirmation sampling and surveying to verify that contaminated sediment was removed, and target depths were reached, respectively.

Assumptions

- The dredge prism is easily accessible by dredge equipment and support watercraft.
- A nearby landside footprint with water access is available for construction of the sediment management area and transloading sediment from barges or scows.
- If debris is present, additional mechanical dredge equipment may be required to remove the debris prior to hydraulic dredging.
- All dredged sediment will be processed simultaneously, and sand separation and collection provide no advantages but will be evaluated further.
- Hydraulic dredging is not an efficient strategy for removing clay or another confining sediment layer within the dredge prism.
- Large hydraulic dredges can work in the Slip but may be limited in the mouth of the Slip by water depth and sediment depth.

- No long lead items have been identified.
- Experienced contractors are regionally located, and dredging equipment is readily available.
- Post-dredge capping or ICs are not required as recontamination is not predicted. Natural sediment deposition is slow and not expected within the Slip.
- Potential for recontamination is uncertain.
- Potential for flux from groundwater sources is uncertain.
- Benthos recolonization will occur quickly.

Technical Feasibility

Hydraulic dredging is an effective alternative used for mitigating the RAOs of the C Street Slip as a standalone option as exposure to contaminated sediment would be eliminated in both the short- and long-term. In the short-term, dredging would simultaneously eliminate the contaminated source material as well as the existing benthos community. Hydraulic dredging is not an effective approach for dredging clay and/or other consolidated sediment layers and is not recommended if clay bounds the dredge prism. If vertical delineation is incomplete or it's unclear if the target COCs have contaminated the confining clay layer, confirmation sampling may be recommended prior to a polishing pass or additional dredging until "clean" sediment is reached.

Dredging equipment will need to be sized appropriately to accommodate the deep dredge depth in the entrance to the Slip. No long-lead items have been identified. Qualified contractors and equipment are located throughout the Great Lakes region. The construction window for the site is small and thus mobilization efficiency and SMA construction will be crucial to make the most of the time for dredging and sediment processing.

Restoration Time Frame

Sustainable restoration of the benthos community is expected in a reasonable time frame without additional engineering or ICs.

Economic Feasibility

Costs of hydraulic dredging and ex situ sediment management for C Street Slip are predicted to be high compared to other sediment removal alternatives due to the additional costs associated with ex situ sediment management, s/s and disposal. ICs will not be required but long-term monitoring may be required.

Additional Requirements

Hydraulic dredging is not capable of efficiently removing clay compared to mechanical dredging approaches. Based on treatability test results, mechanically excavated and stacked sediment will dewater and meet T&D requirements the same as or better than hydraulically dredged sediment. In addition, the volume of filtrate water would be significantly greater with hydraulic dredging than mechanical. Unless there is no suitable space available for sediment processing, mechanical dredging is a more efficient alternative.

A dual polymer program of ChemTreat coagulant P822L (208 ppm) followed by ChemTreat anionic flocculant 816E (177 ppm) was identified as the best performer for a 5% sediment slurry based on release of filtrate volume and clarity. Geotextile tube pillow tests dewatered C Street sediment slurries (5% solids) to greater than 59.9% solids in 7-d dewatering time with a filtrate total suspended solids (TSS) of 147 mg/L. Although the filter cake passed a PFT, 5% Calciment admixture was required to increase UCS to greater than 3,000 lb/ft^2 (96-h cure time). Filtrate collected from the geotextile tube did not have detectable concentrations of volatile organic compounds (VOCs) and mercury. Four semi-volatile organic compounds (SVOCs) were detected at concentrations less than 0.04 µg/L. Dry weight solids of these amended sediment samples increased from 59.9% to 94.1% and 90.9% for 5% Calciment™ and 10% Portland cement admixtures, respectively.

Hydraulic dredging can be implemented in C Street Slip with engineering controls and best management practices (e.g., turbidity curtains) to manage resuspension of contaminated sediments during dredging. A pre-design investigation will be required prior to a full design of the project including but not limited to a bathymetric survey, H&H modeling and/or sediment transport modeling.

Natural recovery processes and benthos recolonization of surficial sediment occur quickly if the new sediment surface is composed of fines. ICs would not be required. C Street Slip is an industrial waterway and this alternative does not eliminate the potential for recontamination of surficial sediment if contaminant sources were not identified and eliminated. Monitoring of the Slip is assumed to be required to track recovery and confirm that recontamination does not occur over time.

This alternative will be accepted by federal and state regulatory authorities as the remedial alternative for C Street Slip as hydraulic dredging would be relatively easy to implement and subsequently maintain for the design life of C Street Slip.

This alternative will be accepted by community stakeholders as hydraulic dredging of C Street Slip will remove targeted COCs greater than PRG values from the Slip.

Hydraulic Dredging is a long-term effective alternative, mitigating impacts to the fish and benthos communities (BUIs Nos. 1 and 4) in C Street Slip. As mechanical dredging and sediment processing of stacked sediment is more efficient and less expensive than hydraulic dredging, processing a slurry and treating 4-5 times the volume of filtrate, hydraulic dredging is eliminated from consideration.

6.2.6 Mechanical Dredging with an Amended Sediment Cap

This alternative consists of mechanical dredging of contaminated sediment hot spots, stacking and processing the dredge material in a designated onsite SMA (dewatering and/or stabilizing) and placing an amended sediment cap over the area of the Slip impacted by tPAH with a three-foot sand cap with 3% activated carbon or comparable reagent. Dredging and cap installation progress and productivity will be tracked and monitored real-time with GIS-based surveying technology (e.g., HyPack, DredgePack). Sediment with tPAH and mercury concentrations greater than PRGs is mechanically dredged with an environmental clam shell bucket and transferred into the SMA via trucks or hopper barges. Hopper barge(s) transport the sediment to the SMA if a suitable riverfront footprint is available for transloading barges. The sediment needs to be dewatered and stabilized to generate filter cake suitable for transportation and disposal. Although exposure to contaminated sediment by fish and benthos is eliminated by dredging, it is possible that residual contaminants are missed and remain in the target area. An amended sediment cap is used to isolate the impacted area and reduce the risk of future exposure.

By removing the contaminated sediments from C Street Slip that are greater than PRG values, the risk of contaminated sediment exposure to the fish and benthos community is eliminated. Amended sediment capping is subsequently used to cover the target area and further eliminate the potential for exposure to residual COCs missed during the investigation or subsequent dredging. An amended sediment cap may also mitigate contaminated groundwater that seeps and fluxes through the capped sediment, adsorbing VOCs, tPAH and mercury, if present. Additional design considerations will need to be evaluated with bench-scale column testing. The remedial activities include:

1. Pre-design Investigation
    a. Bathymetric survey of the sediment surface of the target area prior to cap placement.
    b. Dewatering and S/S treatability tests to identify sediment management strategies and associated efficacy to refine design assumptions.
    c. Measure sediment deposition rate and perform sediment transport modeling.
    d. Treatability tests to identify cap thickness.

2. Mechanical dredging of the contaminated sediment hot spots and conveyance to the SMA.
3. If necessary, transportation of mechanically dredged material to waterside offloading area via hopper barge. Transload dredged sediment from hopper barges to a lined SMA with gravity stacking.
4. Addition of a stabilization reagent to the sediment to enhance dewatering processes as well as improve the compaction potential and/or strength of the dewatered sediment prior to transportation and disposal in a commercial landfill.
5. Filtrate water is collected in a sump and pumped to the water treatment plant prior to discharge.
6. Mechanical or hydraulic placement of sand layer with 3% activated carbon or comparable sorption media delivered from a landside mix tank or hopper barge.
7. Confirmation sampling and surveying to verify cap thickness and coverage across the target area.
8. Stone armoring if required.
9. Long-term monitoring for cap and armor stone stability and integrity as well as benthos community recolonization.
10. ICs may be required for all or part of the Slip.

Assumptions

- The dredge prism is easily accessible.
- A nearby footprint with water access is available for construction of the SMA and transloading area.
- Debris removal is not required prior to dredging.
- All dredged sediment will be processed simultaneously, and sand separation and collection provide no advantages.
- No long lead items have been identified.
- Experienced contractors are regionally located, and dredging equipment is readily available.
- ICs are required post-cap installation.
- Recontamination from landside and groundwater sources is not expected.
- Potential for flux from groundwater sources is uncertain.
- Natural sediment deposition of fine sediment does not occur quickly in the Slip such that benthos recolonization occurs.
- Infrastructure and other debris will not interfere with cap placement and stability.
- Prop wash, scour and other Slip activities will not impact cap integrity.
- Materials for cap construction are locally available.

Technical Feasibility

Hot spot dredging followed by installation of an amended sediment cap over the target area is an effective alternative mitigating for the RAOs of C Street Slip as a standalone option as exposure of fish and benthos to contaminated sediment would be eliminated in both the short- and long-term. In the short-term, dredging would eliminate the contaminated source material as well as the existing benthos community. If residual contaminants remain after dredging, a sediment cap would eliminate the risk of potential exposure from these residual materials.

Implementability

No specialized equipment or long-lead items have been identified. Qualified contractors and equipment are located throughout the Great Lakes region. The construction window for the site is small and thus mobilization efficiency will be crucial to make the most of the time for dredging, sediment processing, and capping in one construction season.

Restoration Time Frame

Sustainable restoration of the benthos community is expected in a reasonable time frame without additional engineering or ICs.

Economic Feasibility

Costs of dredging, ex situ sediment management and amended sediment cap placement for C Street Slip are predicted to be lower than sediment removal alternatives due to the additional costs associated with ex situ sediment management and disposal of the entire volume. Costs associated with the cap design and placement may be reduced if the thickness of the cap can be reduced as the highest concentrations of COCs have been removed. ICs and long-term monitoring may be required.

Additional Requirements

Mechanical dredging followed by cap installation in the Head of Slip may be implemented in C Street Slip with engineering controls and best management practices (e.g., turbidity curtains) to manage resuspension of contaminated sediments during dredging and cap material placement. A pre-design investigation will be required prior to a full design of the project including but not limited to a bathymetric survey, H&H modeling, bench-scale column testing and/or sediment transport modeling.

Natural recovery processes and benthos recolonization of surficial sediment would occur quickly. ICs may be required to limit damage to the cap. C Street Slip is an industrial waterway and this alternative does not eliminate the potential for recontamination of surficial sediment or the cap material if contaminant sources were not identified and eliminated. Addition of activated carbon or another sorption reagent into the cap will help mitigate transfer of COCs through the cap to aquatic receptors. Monitoring of the Slip is assumed to be required to track recovery and confirm recontamination does not occur over time.

This alternative will be accepted by federal and state regulatory authorities as the remedial alternative for C Street Slip as mechanical dredging followed by a cap would be relatively easy to implement and subsequently maintained for the design life of C Street Slip.

This alternative will be accepted by community stakeholders as mechanical dredging followed by a cap of C Street Slip will remove targeted COCs greater than PRG values from the Slip as well as mitigate for groundwater COCs and other contaminant residuals missed during dredging.

Dredging followed by an amended sediment cap is a long-term effective alternative, mitigating impacts to the fish and benthos communities (BUIs Nos. 1 and 4) in C Street Slip. Removing the contaminated sediment followed by installation of a sediment cap removes and eliminates the potential for exposure of contaminants. Hot spot dredging followed by a sediment cap is the recommended remedial alternative over mechanical dredging alone if residual COCs from landside or groundwater sources are predicted to re-contaminate C Street Slip.

7. Definitive Evaluation and Recommendations

The remedial alternatives (listed below) retained from the screening-level alternatives analysis were evaluated and compared to one another in the definitive evaluation based on overall technical feasibility (long-term and short-term effectiveness), implementability, restoration time frame, economic feasibility and additional requirements. There are typically multiple process options within a remedial strategy that can be applied within the project area. The alternatives included in the definitive evaluation were subjected to a more thorough set of criteria. Cost estimation was then used for each alternative carried forward (Sections 6.2.1 to 6.2.6) to conceptually engineer and design a viable process option flow for mitigating impacted sediments in C Street Slip.

A scoring system was developed (Section 7.1.1) to compare alternatives for each evaluation criteria. In this assessment, all criteria are equally weighted, and a total score was used for identification of a recommended alternative.

- **No Action**
- **Sediment Cap (unamended and amended)**
- **Mechanical Dredging**
- **Hydraulic Dredging**
- **Mechanical "Hot-spot" Dredging followed by an Amended Sediment Cap**

A comparison of definitive remedial alternatives for mitigating sediment RAOs in C Street Slip contaminated with tPAHs and/or mercury is summarized in **Table 7-1**. Mechanical Dredging and Mechanical Dredging of Hot-spots followed by an Amended Sediment Cap were the remedial alternatives identified to have the highest probability of achieving the RAOs for sediments in C Street Slip and effectively addressing tPAH and mercury measured in sediment concentrations greater than PRGs for the design life of C Street Slip. A side-by-side summary of the remedial alternatives' comparison is provided in (**Table 7-2**).

7.1.1 Scoring System to Compare Alternatives

Scoring each alternative was completed by assigning a value (1-20) to each criterion for each alternative. Values were summed and divided by the number of criteria to create a total average value for each alternative. Scoring was defined as follows to select an alternative with the highest probability of success:

16-20: Strongly recommended. Values within this range indicate that this alternative is an excellent option based on the criterion. Values within this range indicate that the alternative is constructable, uses a proven strategy for risk mitigation, has been applied to similar environments, has little uncertainty, is predictable and will stay on budget as designed and estimated. Land is available near the Slip that is suitable for equipment staging and/or sediment processing with no additional engineering support or additional costs. There is a low probability of project delay as materials and equipment for this alternative are readily available and there are no long lead items. Results of the remediation will mitigate the risk(s) associated with tPAH- and Mercury-contaminated sediment and address BUIs Nos 1 and 4. Recontamination potential is low and VOCs and other MGP-related constituents will not be encountered in the field during remedial construction.

11-15: Recommended. Values within this range indicate that this alternative is a recommended option based on the criterion. Values within this range indicate that the alternative is constructable, uses a proven strategy for risk mitigation, has been applied to similar environments, has minimal uncertainty, is predictable and has low probability of change orders. Land is available near the Slip that is suitable for equipment staging and/or sediment processing with some additional engineering support and costs. The cost of land acquisition and subsequent restoration is low. There is a low probability of project delay as materials and equipment for this alternative are readily available and there are no long lead items. Results of the remediation will mitigate the risk(s) associated with tPAH- and mercury-contaminated sediment and address BUIs Nos 1 and 4. Recontamination potential is low and VOCs and other MGP-related constituents will be managed with BMPs if encountered in the field during remedial construction.

6-10: **Acceptable but with several challenges.** Values within this range indicate that this alternative is acceptable but has several challenges that can be mitigated with engineering and BMPs. Values within this range indicate that moderate impacts to project costs are expected as well as a strong possibility for project delays and a need to use mitigation measures to resolve challenges. Values within this range indicate that the alternative is constructable, uses a blend of proven and innovative strategies for risk mitigation, has been applied to other project sites with success and has moderate uncertainty. Land is available near the Slip that is suitable for equipment staging and/or sediment processing with major engineering and design support and costs. The cost of land acquisition and subsequent restoration is high. Results of the remediation will mitigate the risk(s) associated with tPAH- and mercury-contaminated sediment and address BUIs Nos 1 and 4. There is a moderate probability of project delay as materials and equipment for this alternative are available and there are no long lead items. Recontamination potential is high and VOCs and other MGP-related constituents will be managed with BMPs if encountered in the field during remedial construction but delays to construction are expected.

1-5: Not recommended. Values within this range indicate that this alternative is acceptable but has several engineering and design challenges that can be mitigated with engineering and BMPs. Values within this range indicate that moderate impacts to project costs are expected as well as a strong possibility for project delays and a need to use mitigation measures to resolve challenges. Values within this range indicate that the alternative is constructable, uses a blend of proven and innovative strategies for risk mitigation, has been applied to a few project sites with success and has moderate uncertainty. Land is available but is not located adjacent to the Slip. The space is suitable for equipment staging and/or sediment processing with major engineering and design support and costs. The cost of land acquisition and subsequent restoration is moderate/high. Results of the remediation will mitigate the risk(s) associated with tPAH- and mercury-contaminated sediment and address BUIs Nos 1 and 4, but the restoration time is predicted to be years. There is a moderate probability of project delay as materials and equipment for this alternative are available and there are no long lead items. Recontamination potential is high and VOCs and other MGP-related constituents will be managed with BMPs if encountered in the field during remedial construction but delays to construction are expected.

7.1.2 Cost Estimates

Cost estimates were developed based on dredging of 40,000 CY in situ or installing a three-foot sediment cap (amended or unamended) over 150,500 ft^2. Amendment was estimated at 3% of the total but confirmation testing will be required prior to design and placement. In order to develop cost estimates for the Mechanical Dredging with Amended Sediment Cap, it was assumed that 20,000 CY of sediment would be dredged and 50,000 ft^2 of area would be covered with cap materials.

Assumptions, schedules and line-item estimates were developed from recent project construction costs (**Appendix B**). Cost estimates include minimal project management and project controls (1.5 hrs/d), full-time construction management (CM)/construction quality assurance (CQA) staff, water treatment system installation and operation for the life of the project, and commercial landfill disposal at $75/ton. In addition, all cost estimates include a 10% contingency. A summary of cost estimates for the five definitive alternatives are:

Unamended Sediment Cap	-	**$2.425,000**
Amended Sediment Cap	-	**$2,905,000**
Mechanical Dredging	-	**$10,353,000**
Hydraulic Dredging	-	**$10,229,000**
Mechanical Dredging with an Amended Sediment Cap	-	**$7,611,000**

7.1.3 Recommendations

Mechanical dredging with an environmental clam-shell bucket mounted on a crane derrick working off a spudded barge is the recommended alternative for excavating the sediment from C Street Slip with tPAH and mercury concentrations greater than PRG values. The crane boom can reach all parts of the dredge prism with little movement of the barge as the boom is long enough to position the bucket over the shallow areas within the head of Slip. The bucket size is typically 1-5 CY with less than a one-minute cycle time loading a nearby hopper barge or scow. This approach is dependent on transportation of the barge to a transloading site for offloading, dewatering and/or stabilization for subsequent transportation and disposal.

Mechanical dredging is an effective, easy to implement alternative that mitigates RAOs of C Street Slip as potential exposure pathway to fish (BUI No. 1) and benthos (BUI No. 4) would be eliminated in both the short- and long-term. Mechanical dredging is effective for dredging some clay and/or other consolidated sediment layers compared to hydraulic dredging methods. If vertical delineation is incomplete or it's unclear if the confining clay layer is contaminated with tPAH or Hg, confirmation sampling may be recommended prior to a polishing pass or additional dredging until "clean" sediment is reached.

Mechanical dredging is the most expensive remedial alternative as the estimated timeline for completing the dredging and overall project is the longest (37 weeks) compared to other alternatives. If the project is procured as a performance-based contract, the contractor will have several opportunities to save time and money and decrease costs including but not limited to:

- Minimize rehandling of sediment once excavated;
- Expedite the schedule by increasing number of dredges, barges, decreasing cycle time, barge transit time and dewatering time;
- Use less reagent or an alternate reagent to stabilize the dewatered sediment;
- Dispose of the sediment in a less expensive disposal unit;
- Discharge contact water to a publicly owned treatment works (POTW) in lieu of treating and discharging to the dredge prism;
- Reuse construction materials (e.g., road rock and geotextile) for beneficial restoration applications; and
- Live load dredged sediment from hopper barges (i.e., amend the sediment in the barges) directly to trucks for transportation and disposal without using a SMA for sediment processing.

8. References

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Tables

Table 7-1 Comparison of definitive remedial alternatives for mitigating sediment RAOs in C Street Slip contaminated with tPAHs and/or mercury.

Table 7-2 Definitive remedial alternatives were compared, retained and/or eliminated for recommendation based on effectiveness, restoration time frame, implementability, state and community acceptance, reduction in toxicity and cost.

Table 7-1. Comparison of definitive remedial alternatives for mitigating sediment RAOs in C Street Slip contaminated with tPAHs and/or mercury.

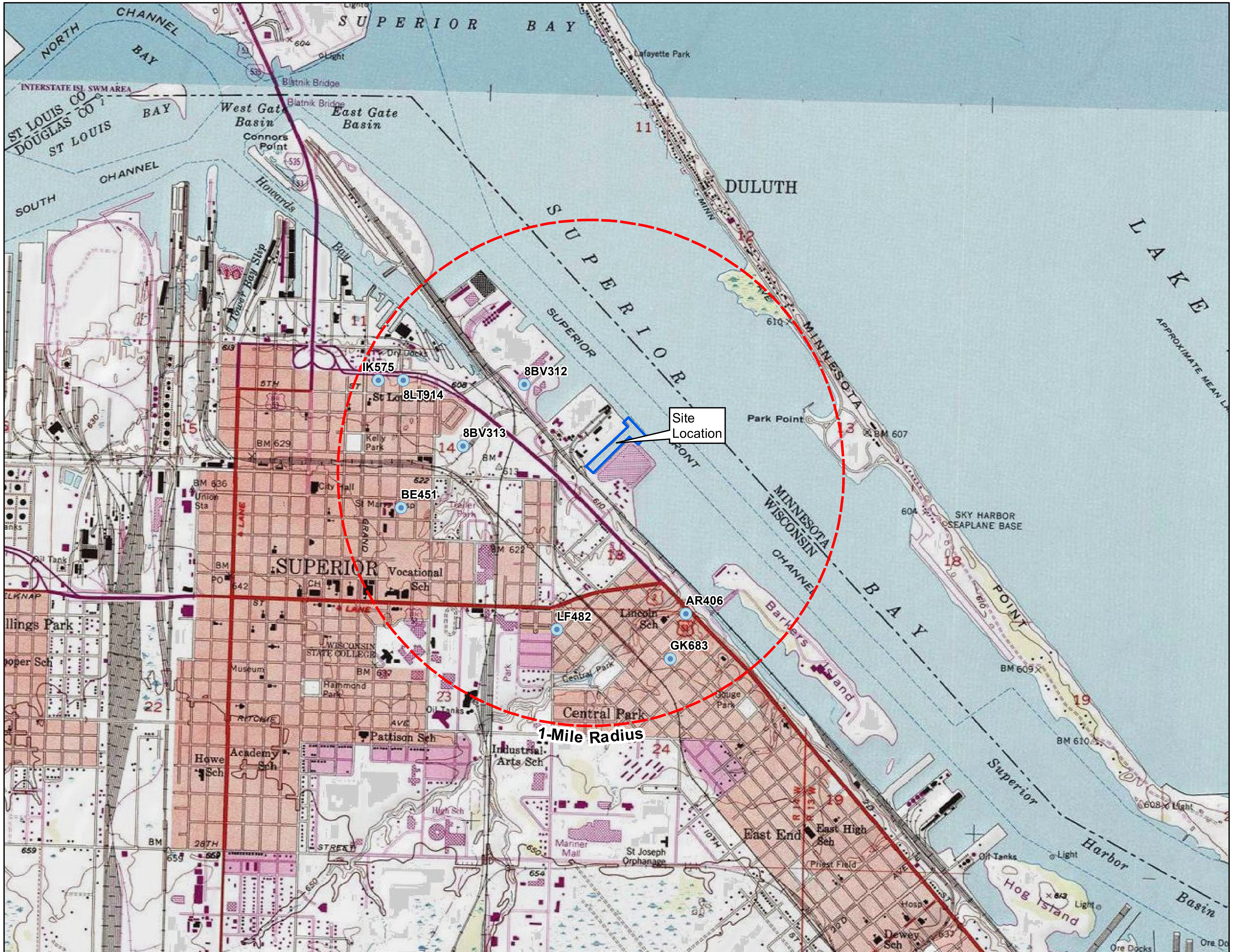
Evaluation Criteria	Alternative 1	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 9
	No Action	Unamended Sediment Cap	Amended Sediment Cap	Mechanical Dredge	Hydraulic Dredge	Dredge and Cap
Threshold Criteria						
Overall Protectiveness of Public Health and the Environment	X	✓	✓	✓	✓	✓
Compliance with Applicable, Relevant, and Appropriate Requirements (ARARs)	X	✓	✓	✓	✓	✓
Evaluation Criteria						
Long-term Effectiveness	1	6	12	18	16	15
Short-term Effectiveness	1	12	14	16	14	18
Implementability	1	14	14	17	14	16
Restoration Time Frame	1	9	10	17	17	16
Economic Feasibility	20	15	15	14	14	16
Additional Requirements	20	14	12	15	15	10
Total	44	70	77	97	90	91

Table 7-2. Definitive remedial alternatives were compared, retained and/or eliminated for recommendation based on effectiveness, implementability, restoration time frame, economic feasibility, and additional requirements.

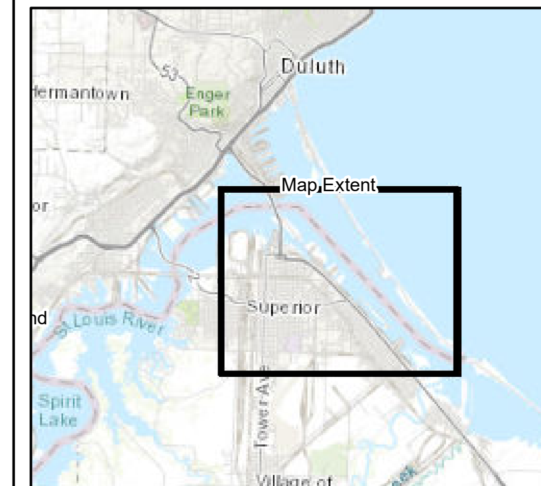
Process Options	Effectiveness	Implementability	Restoration Time Frame	Economic Feasibility	Additional Requirements
No Action (Alternative 1)	Does not meet the RAOs for this project.	N/A	N/A	$0	None
Unamended Sediment Capping (Alternative 4)	Meets the RAOs for this project. Effective in the short-term, but loses effectiveness over time without O&M.	Engineering controls and BMPs required to manage resuspension. Assumes cap materials are locally available.	Exposure pathways initially eliminated in short-term; Recolonization in years; Contamination remains in place	$2,425,000	ICs would be required in perpetuity to eliminate dredging, construction, prop wash and scour to limit damage to the capped area.
Amended Sediment Capping (Alternative 5)	Meets the RAOs for this project. Effective in the short-term, but loses effectiveness over time without O&M.	Engineering controls and BMPs required to manage resuspension. Assumes cap materials are locally available.	Exposure pathways initially eliminated in short-term; Recolonization in years; Contamination remains in place but mitigated with sorption media	$2,905,000	ICs would be required in perpetuity to eliminate dredging, construction, prop wash and scour to limit damage to the capped area.
Mechanical Dredging (Alternative 6)	Meets the RAOs for this project. Removal of the sediment contaminated with tPAH and Hg concentrations greater than PRGs will eliminate risk in short- and long-term. Dredging does not protect from recontamination due to landside, surface water and/or groundwater sources.	Contractors and equipment for this project are regionally available. The project is dependent on nearby, suitable land available for both sediment processing and receipt of barges for transloading.	Sustainable restoration is expected in a season or two	$10,353,000	Pre-design investigation will be required prior to a full design of the project. Monitoring of the Slip is assumed to be required to track recovery and confirm recontamination does not occur over time.
Hydraulic Dredging (Alternative 7)	Meets the RAOs for this project. Removal of the sediment contaminated with tPAH and Hg concentrations greater than PRGs will eliminate risk in short- and long-term. Dredging does not protect from recontamination due to landside, surface water and/or groundwater sources.	Contractors and equipment for this project are regionally available. The project is dependent on nearby, suitable land available for sediment management and a WTP. A large volume of contact water will require treatment	Sustainable restoration is expected in a season or two	$10,229,000	Pre-design investigation will be required prior to a full design of the project. Monitoring of the Slip is assumed to be required to track recovery and confirm recontamination does not occur over time.
Mechanical "Hot-spot" Dredging and Amended Capping (Alternative 9)	Meets the RAOs for this project. Removal of tPAH and Hg hot-spots will eliminate risk in short- and long-term. Dredging alone does not protect from recontamination due to landside, surface water and/or groundwater sources. Additional use of an amended cap will decrease future exposure and mitigate risk due to residuals and/or recontamination.	Contractors and equipment for this project are regionally available. The project is dependent on nearby, suitable land available for dredge sediment processing and receipt of barges for transloading.	Sustainable restoration is expected in a season or two	$7,611,000	Pre-design investigation will be required prior to a full design of the project. Monitoring of the Slip is assumed to be required to track recovery and confirm recontamination does not occur over time. ICs may be required to limit damage to the cap.

Figures

Figure 1-1 Site Location
Figure 4-1 Mercury, Surface and Subsurface Analytical Summary, C Street
Figure 4-2 Total PAHs, Surface and Subsurface Analytical Summary, C Street Slip
Figure 4-3 Dredge Prism Design; Plan View (Plumes)
Figure 4-4 Dredge Prism Design; Plan View (Dredge Prisms)
Figure 4-5 Dredge Prism Design; Plan View (Volume Surface)
Figure 4-6 Dredge Prism Design; Profiles
Figure 4-7 Dredge Prism Design; Cross Sections (01)
Figure 4-8 Dredge Prism Design; Cross Sections (02)



VICINITY MAP



Legend

- Water Supply Well
- C-Street Slip
- 1-Mile Radius

Source:
USGS 7-5 Minute Topographica Map
Superior and Duluth Quadrangles

Wisconsin Department of Natural Resources -
Bureau of Drinking Water and Groundater

N

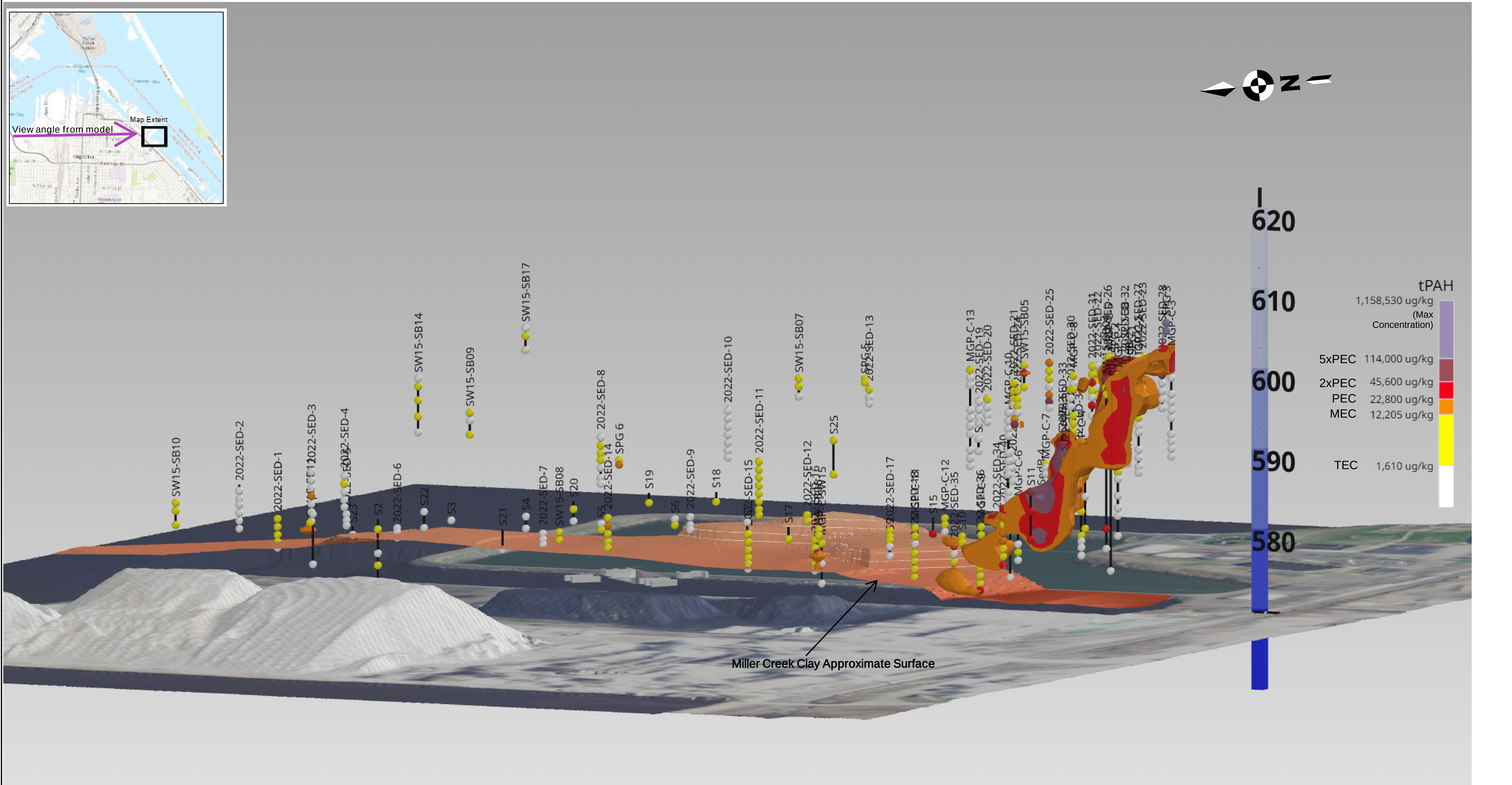
0 1,000 2,000 4,000
Feet

AECOM

Title:	**Site Location C-Street Slip**
Project:	Remedial Alternatives Report Superior, Wisconsin
Client:	Wisconsin DNR
File Name:	Site Map C Street.mxd

Project No.:	Date:	Figure:
60685299	4/22/2023	1-1

Path: L:\DCS\GIS\Projects\Superior\MXD\C Street\Site Map C Street.mxd



Aerial image is displaced downward for spatial reference.

TITLE

TOTAL PAHs, SURFACE AND SUBSURFACE ANALYTICAL SUMMARY, C STREET

AECOM

AECOM TECHNICAL SERVICES, INC.
SOUTHFIELD, MI., 248-204-5900

FOR INFORMATIONAL PURPOSES ONLY

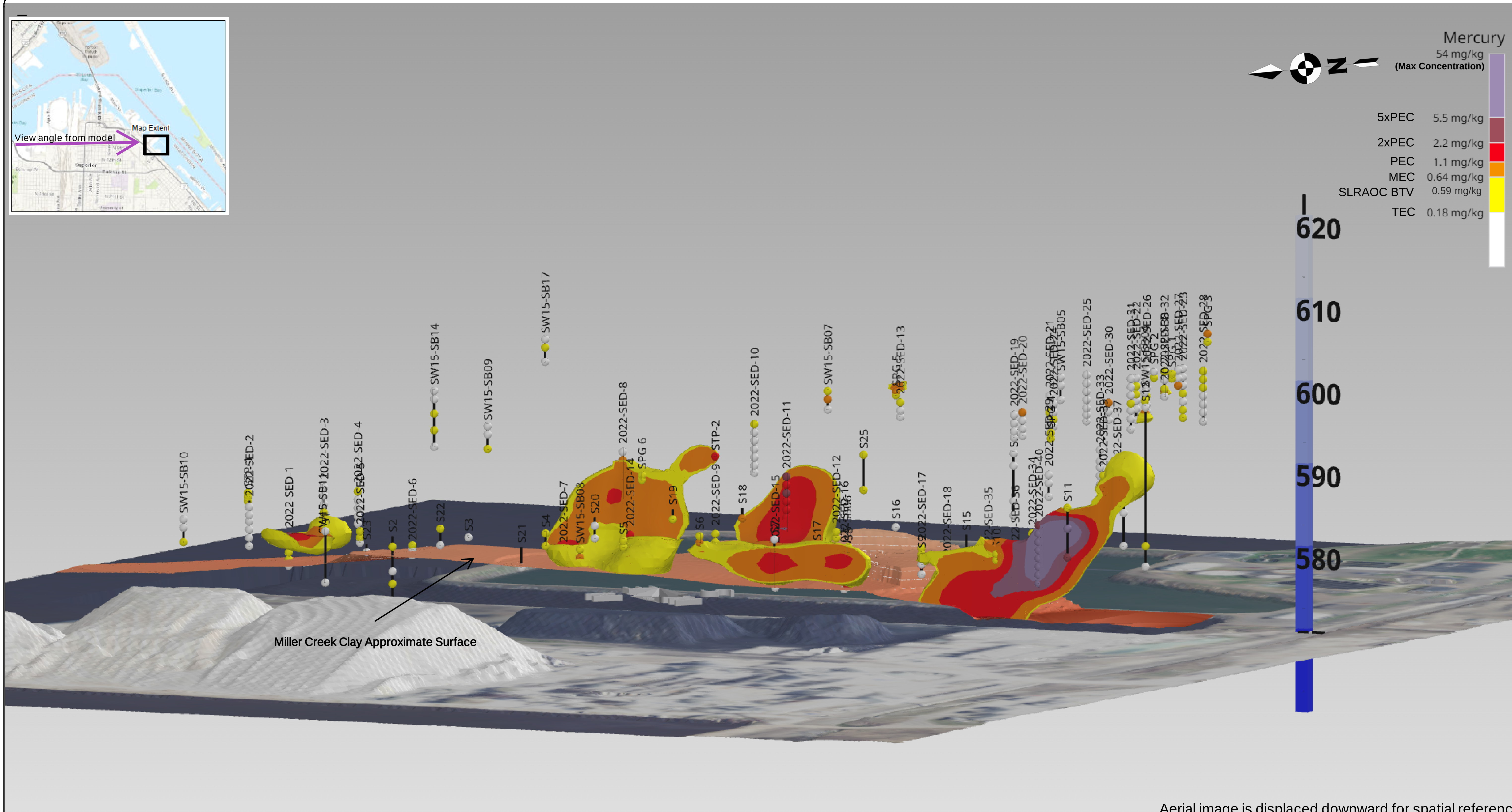
NOTE: THE PLUME REPRESENTS CONTAMINATION ABOVE 12,205 µg/kg (1 X MEC)

Constituent	PRG = 1x MEC	
	µg/kg	yd^3
Total PAHs	12,205	3,212

NOT A PROFESSIONAL SURVEY
ALL LOCATIONS/DIMENSIONS ARE APPROXIMATE

DATE	JOB NO
06/01/23	60685299
DR KD	SKETCH NO.
CK JS	FIG. 4-1

Y:\Projects\WDNR\SaintLouisBaySlips\MXDs\C Street Total PAH.mxd



TITLE	MERCURY SURFACE AND SUBSURFACE ANALYTICAL SUMMARY, C STREET
AECOM	AECOM TECHNICAL SERVICES, INC. SOUTHFIELD, MI., 248-204-5900 — FOR INFORMATIONAL PURPOSES ONLY

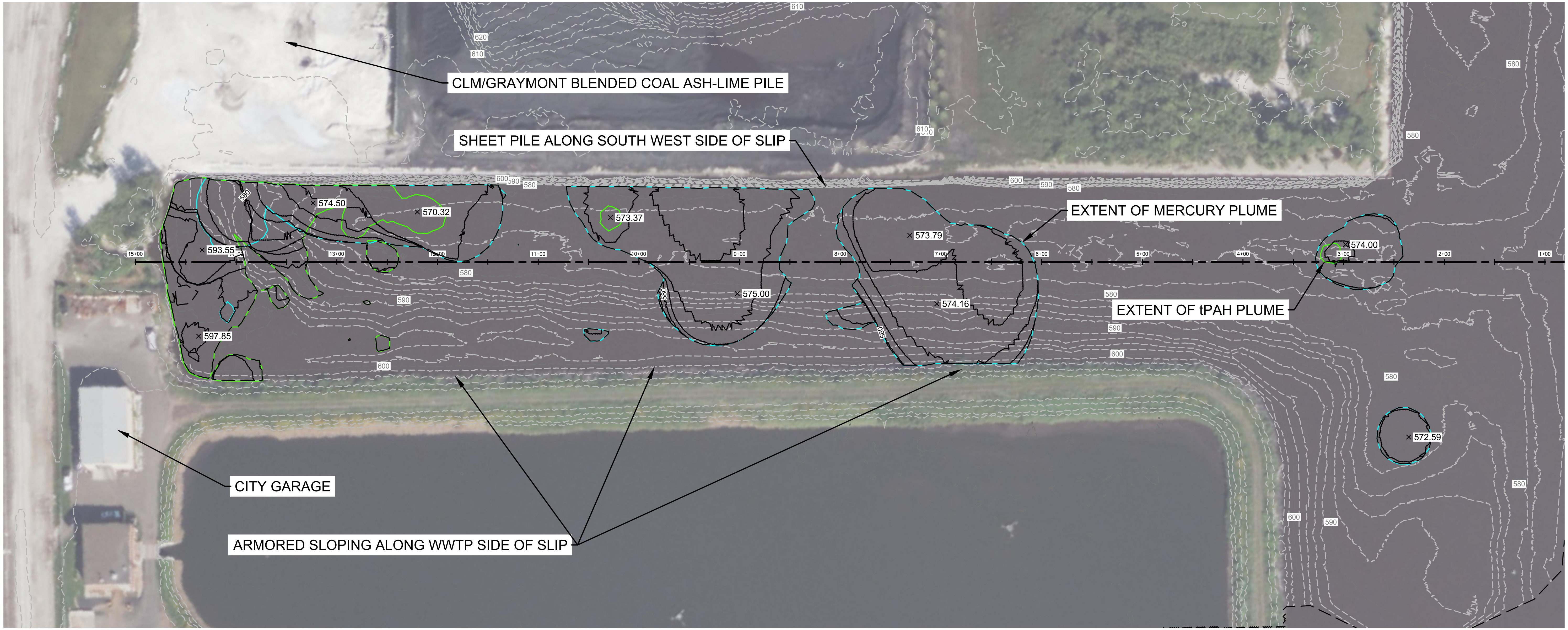
NOTE: THE PLUME REPRESENTS CONTAMINATION ABOVE THE PRG OF 0.59 mg/kg (SLRAOC BACKGROUND BTV)

Constituent	PRG = SLRAOC mg/kg	yd^3
Mercury (Hg)	0.59	12,548

NOT A PROFESSIONAL SURVEY
ALL LOCATIONS/DIMENSIONS ARE APPROXIMATE

DATE	JOB NO
06/01/23	60685299
DR KD	SKETCH NO.
CK JS	FIG. 4-2

Y:\Projects\WDNR\SaintLouisBaySlips\MXDs\C Street Mercury.mxd



NOTES:

1. TWO BATHYMETRIC SURVEY FILES TITLED "20221205_ReProcessed_Depth1.xyz" AND "20220721Superior_CSlip_SoundingPole_IGLD85.xyz" WERE PROVIDED BY AFFILIATED RESEARCHERS INC. ON 12/06/2022 FOLLOWING ADJUSTMENTS MADE DUE TO CONFLICTING ELEVATION DATA.
2. PLUME SURFACES SHOWN ARE FROM AN EARTH VOLUME SYSTEM (EVS) SOFTWARE MODEL. HORIZONTAL AND VERTICAL MOST DATA WERE EXPORTED USING EVS AND USED AS A GUIDE FOR DESIGNING THE DREDGE PRISMS SHOWN ON C-02.
3. CITY OF SUPERIORS WASTEWATER TREATMENT PLANT (WWTP) HOLDING POND LIES TO THE SOUTH-EAST OF THE C-STREET SLIP. THE SLOPING ALONG THE WWTP IS OBSERVED TO BE RIP-RAP ARMORED AND IS ASSUMED TO EXTEND TO THE TOE OF THE SLOPE INTO THE SLIP.

50 0 100
GRAPHIC SCALE IN FEET

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1	JLL	06/09/23	REVISIONS				
0	JLL	02/24/23	DRAFT				

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WISCONSIN DNR
SUPERIOR, WISCONSIN

PROJ. NUMBER: 60685299
DATE: 06/09/2023

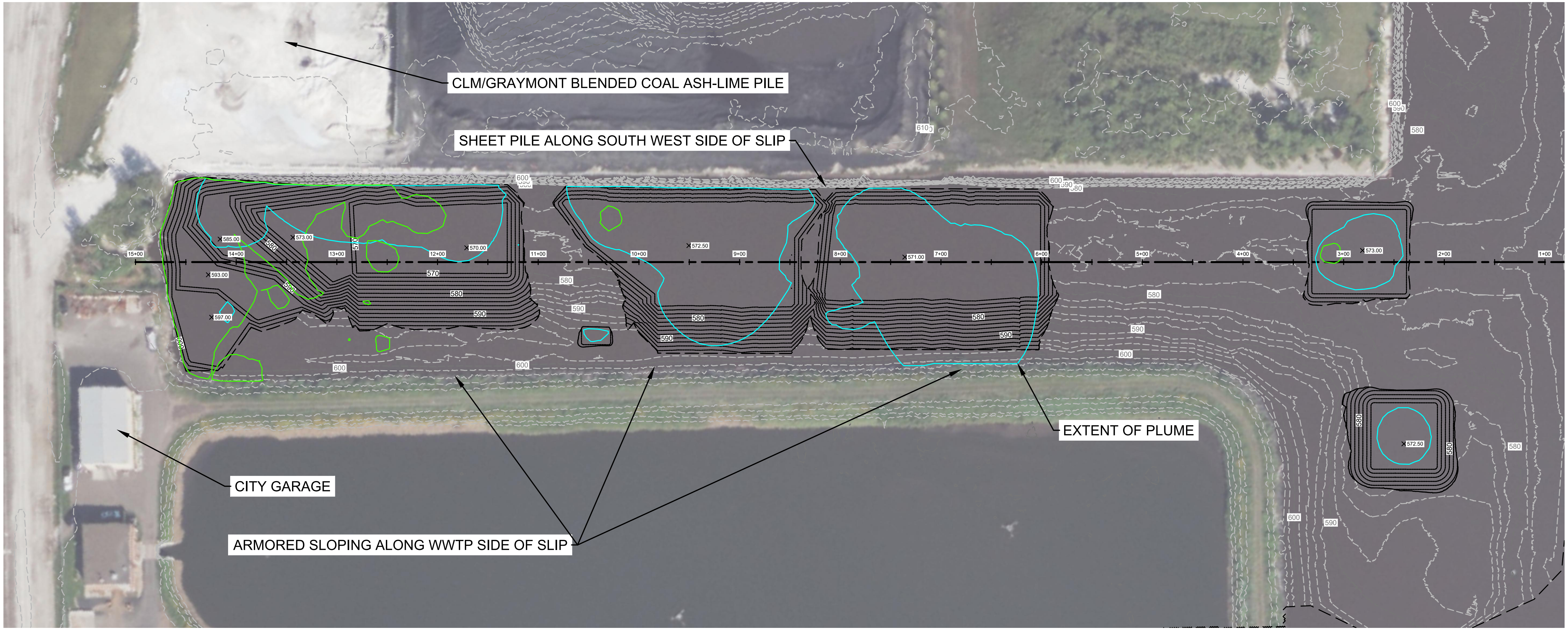
C-STREET SLIP DREDGE PRISM DESIGN PLAN VIEW (PLUMES)

SUPERIOR SLIPS DREDGING

DRAWING NUMBER: 4-3

SHEET NUMBER: 1 of 6

REVISION 1



NOTES:

1. DREDGE PRISM WERE DESIGN WITH 2(H):1(V) SIDE SLOPES.
2. A CLAY SURFACE WAS ENCOUNTERED DURING FIELD INVESTIGATIONS AND IS TO BE USED AS THE "BASE OF EXCAVATION" WHERE APPLICABLE. DURING DREDGING, IF THE CONTRACTOR ENCOUNTERS THE CLAY LAYER PRIOR TO THE DREDGE PRISM BASE DEPTH SHOWN, DREDGING IS TO BE TERMINATED.
3. A 6 INCH OVER DREDGE WAS DESIGNED IN AREAS WHERE THE CLAY LAYER IS NOT THE BASE. NO OVER DREDGING INTO THE CLAY LAYER.
4. DREDGE PRISMS ARE DESIGNED TO BE AS CONSTRUCTIBLE AS POSSIBLE.
5. SHEET PILE ALONG FORMER MGP SIDE OF THE SLIP.
6. RIP RAP ARMORED SLOPE ALONG WWTP SIDE OF SLIP.
7. WATER SURFACE ELEVATION AT APPROXIMATELY 602.5 FEET.

50 0 100

GRAPHIC SCALE IN FEET

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1	JLL	06/09/23	REVISIONS				
0	JLL	02/24/23	DRAFT				

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DATE: 06/09/2023

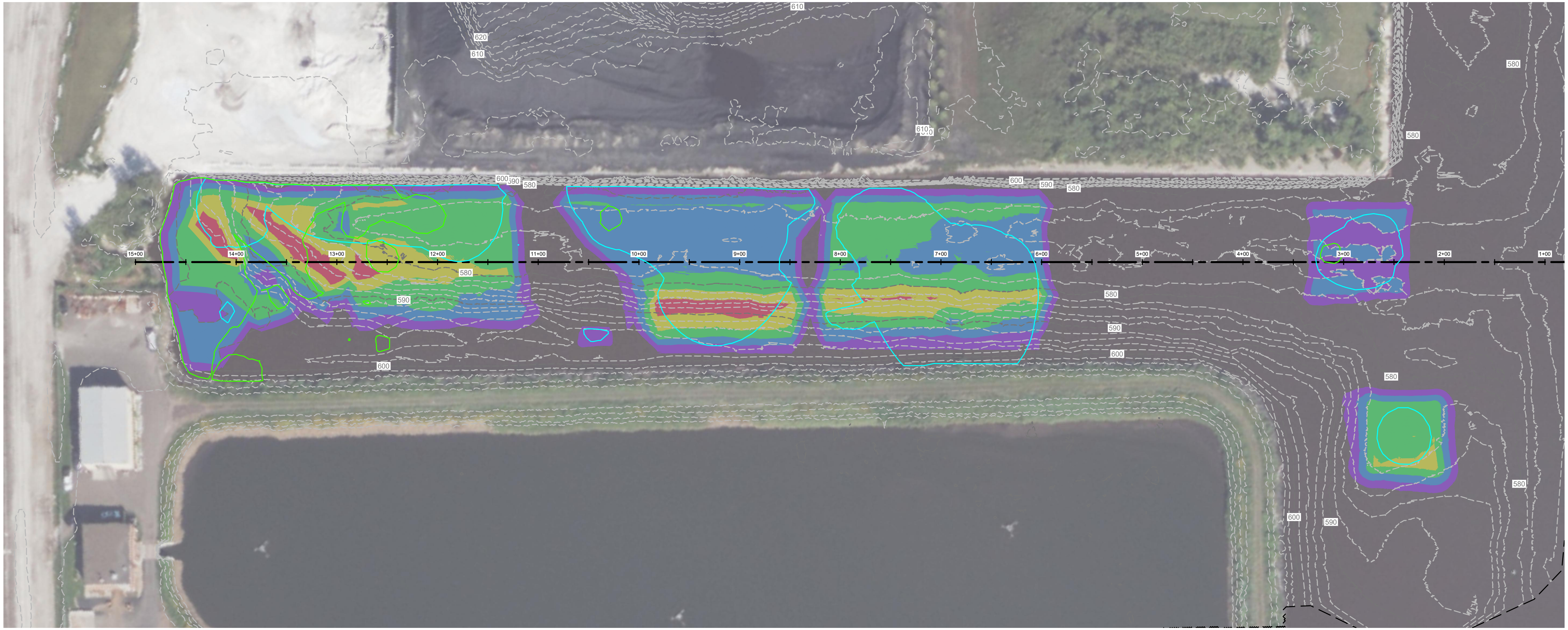
DREDGE PRISM DESIGN
PLAN VIEW (DREDGE PRISM)

SUPERIOR SLIPS DREDGING

DRAWING NUMBER: 4-4

SHEET NUMBER: 2 of 6

REVISION 1



50 0 100
GRAPHIC SCALE IN FEET

Elevations Table				
Number	Minimum Elevation	Maximum Elevation	Area	Color
1	-15.00	-12.00	4858.94	
2	-12.00	-9.00	17964.83	
3	-9.00	-6.00	43269.79	
4	-6.00	-3.00	48016.60	
5	-3.00	0.00	29568.27	

Cut/Fill Summary

Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
DREDGE PRISM	1.000	0.000	144131.84 Sq. Ft.	31020.94 Cu. Yd.	0.00 Cu. Yd.	31020.94 Cu. Yd.<Cut>
Totals			144131.84 Sq. Ft.	31020.94 Cu. Yd.	0.00 Cu. Yd.	31020.94 Cu. Yd.<Cut>

NO	DRWN	DATE	REVISION	CHKD	DATE	APPVD	DATE
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1	JLL	06/09/23	REVISIONS				
0	JLL	02/24/23	DRAFT				

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PROJ. NUMBER: 60685299

DATE: 06/09/2023

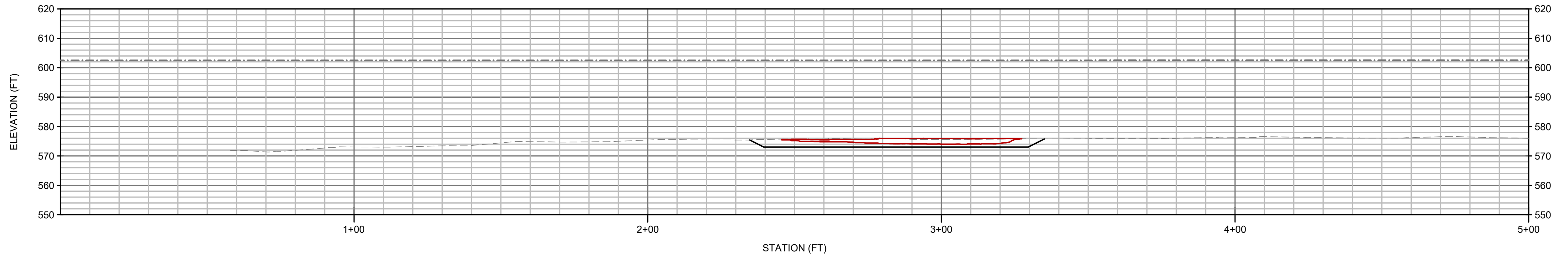
C-STREET SLIP DREDGE PRISM DESIGN PLAN VIEW (VOLUME SURFACE)

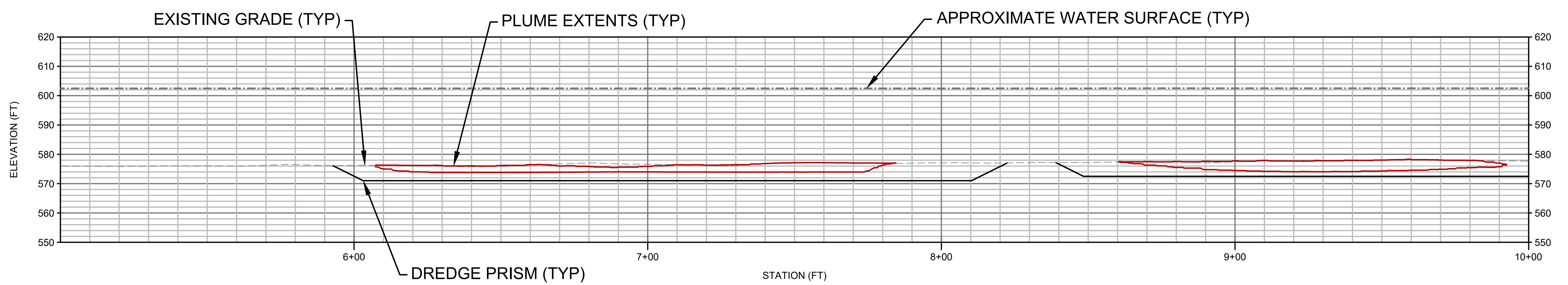
SUPERIOR SLIPS DREDGING

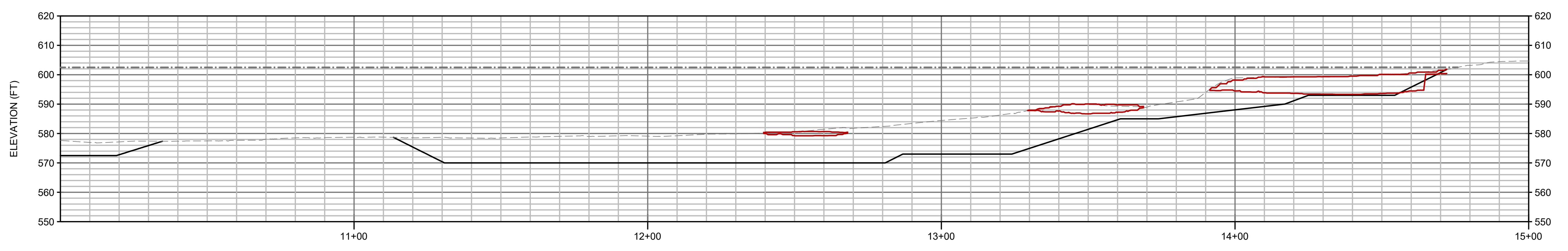
DRAWING NUMBER: 4-5

SHEET NUMBER: 3 of 6

REVISION 1







NOTES:

1. PROFILE VIEWS C-STREET SLIP FROM SLIP HEAD TO INNER SLIP, LEFT TO RIGHT.
2. SEE SHEETS C-01 THROUGH C-03 FOR PROFILE STATIONING.
3. WATER SURFACE ELEVATION AT APPROXIMATELY 602.5 FEET.

NO	DRWN	DATE	REVISION	CHKD	DATE	APPVD	DATE
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1	JLL	06/09/23	REVISIONS				
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PROJ. NUMBER: 60685299 DATE: 06/09/2023

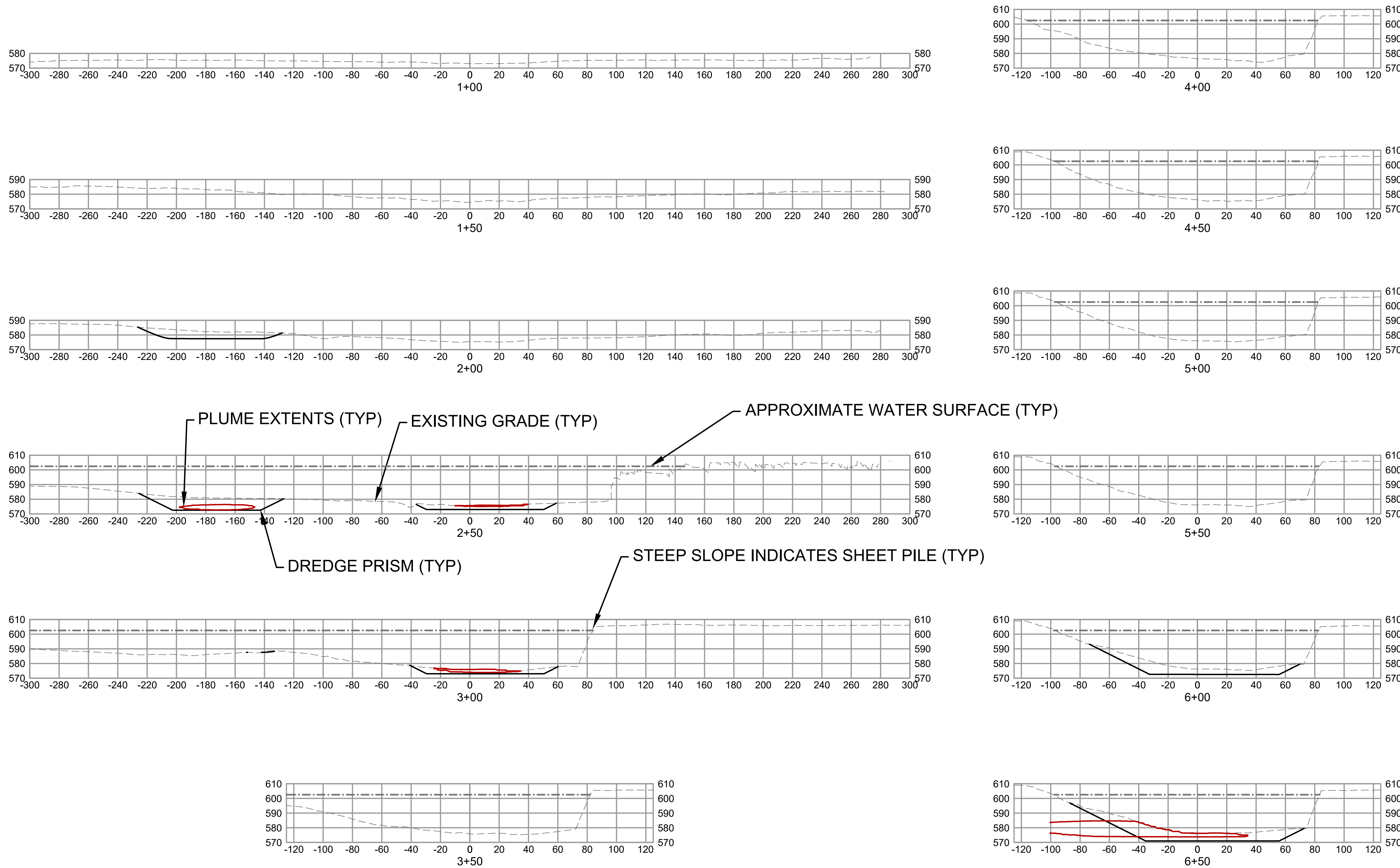
DREDGE PRISM DESIGN PROFILES

SUPERIOR SLIPS DREDGING

DRAWING NUMBER: 4-6

SHEET NUMBER: 4 of 6

REVISION 1



NOTES:

1. CROSS SECTIONS VIEW C-STREET SLIP FROM SLIP HEAD TO INNER SLIP, LOOKING INTO THE SLIP.
2. SEE SHEETS C-01 THROUGH C-03 FOR SECTION STATIONING.
3. WWTP IS VIEWED ON THE LEFT SIDE AND THE SHEET PILE ALONG THE FORMER MGP SIDE IS VIEWED ON THE RIGHT.

NO	DRWN	DATE	REVISION	CHKD	DATE	APPVD	DATE
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1	JLL	06/09/23	REVISIONS				
0	JLL	02/24/23	DRAFT				

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PROJ. NUMBER: 60685299

DATE: 06/09/2023

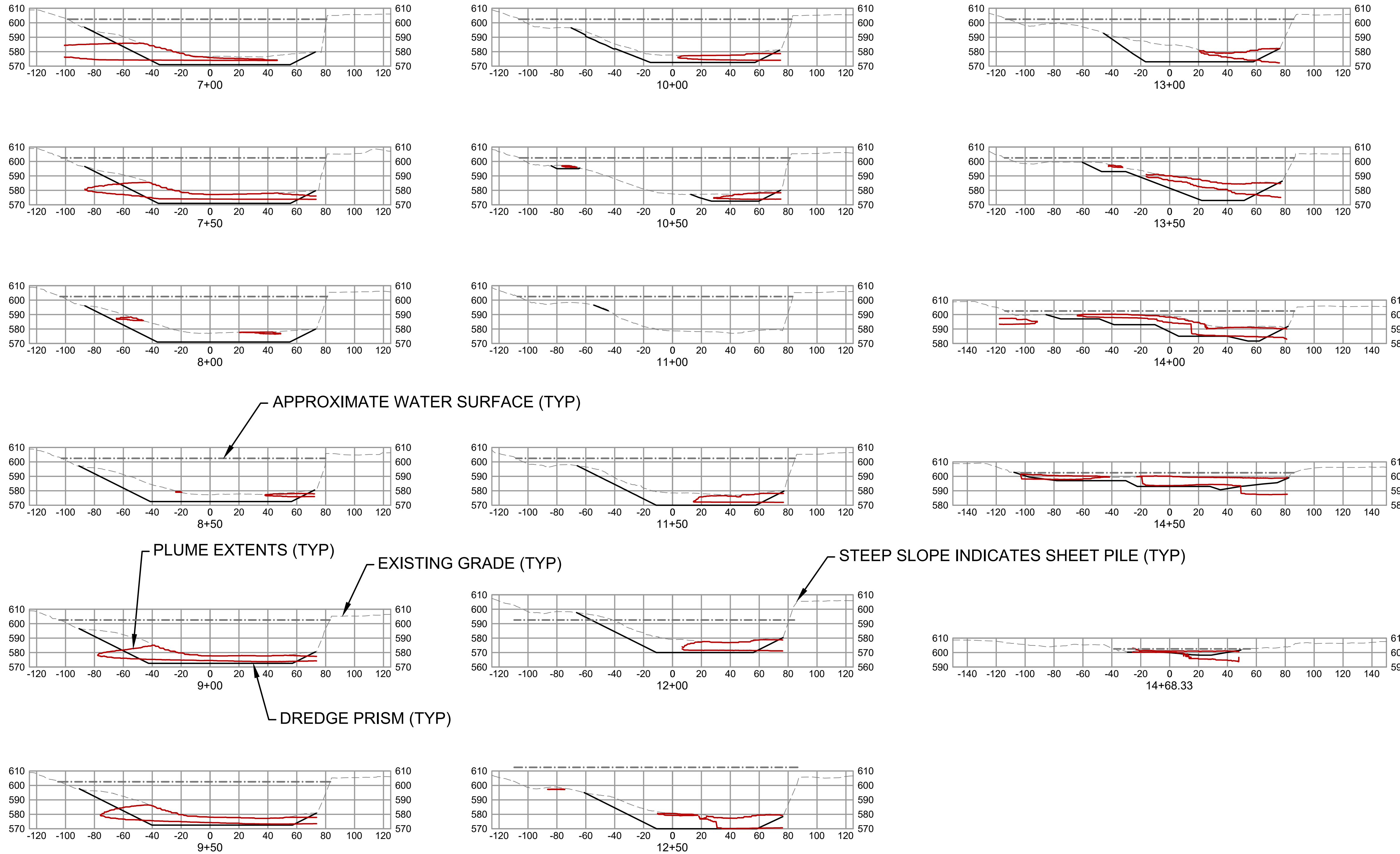
DREDGE PRISM DESIGN
CROSS SECTIONS

SUPERIOR SLIPS DREDGING

DRAWING NUMBER: 4-7

SHEET NUMBER: 5 of 6

REVISION 1



NOTES:

1. CROSS SECTIONS VIEW C-STREET SLIP FROM SLIP HEAD TO INNER SLIP, LOOKING INTO THE SLIP.
2. SEE SHEETS C-01 THROUGH C-03 FOR SECTION STATIONING.
3. WWTP IS VIEWED ON THE LEFT SIDE AND THE SHEET PILE ALONG THE FORMER MGP SIDE IS VIEWED ON THE RIGHT.

NO	DRWN	DATE	REVISION	CHKD	DATE	APPVD	DATE
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1	JLL	06/09/23	REVISIONS				
0	JLL	02/24/23	DRAFT				

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PROJ. NUMBER: 60685299 DATE: 06/09/2023

DREDGE PRISM DESIGN CROSS SECTIONS

SUPERIOR SLIPS DREDGING

DRAWING NUMBER: 4-8

SHEET NUMBER: 6 of 6

REVISION 1

Appendix A C Street Slip Sediments with Mercury or tPAH Concentrations Greater than PRG Values Based on EVS Model Interpolation

Appendix A – C Street Slip Sediments with Mercury or tPAH Concentrations Greater than PRG Values Based on EVS Model Interpolation

Constituents of concern (COCs) for C Street, mercury (Hg) and total polynuclear aromatic hydrocarbons (tPAH), were evaluated with EVS (Earth Volumetric Studio version 2022.10.2), geographic information system (GIS) software ArcGIS (Esri, version 10.8.1), and ArcPro (Esri, version 3.0).

EVS is a Windows program developed by C Tech Development Corporation that provides 3D modeling and advanced interpolation techniques, including 3-D Kriging and geologic indicator kriging (GIK), volumetric calculations, geostatistical analysis, and advanced visualization tools for environmental science disciplines using a graphical icon-driven environment of modules (component programs) that combine to create customized EVS applications, and provides automation using Python 3 (Python programming) scripts. The contamination results (referred to in EVS terminology as "3D Fields" and colloquially as "plumes") represent a 3D model of the analytical field data.

Data Sources

The C Street model was generated from 103 parent sample locations collected between 1994 and 2022, with chemical data obtained from mercury samples (1994-2022) and tPAH (2000-2022). The data utilized in the model originated from the EQuIS database and exported for EVS use. The average sample interval length spans from 0.20 feet to 8.0 feet, averaging approximately 1 foot. In the EVS model, the vertical sample locations were generated from the midpoint of each interval. A total of 42 lithologic samples that were collected during the 2022 field investigation were modeled independently from the chemical data in order to provide the limits of the low-plasticity clay layer necessary for planning the excavation prism. A bathymetric surface developed from three bathymetric survey datasets collected on July 18, 2022 by Affiliated Researchers was generated in ArcGIS as a raster with a 3-foot cell size that is the maximum point spacing of the surveys. The resulting surface was used in to confine the results to below the bathymetric surface.

Modeling Approach

The 3D plumes were generated with an interpolation process called Kriging, which employs a statistical expression called a semi-variogram. The semi-variogram models the spatial correlation of field sample data with distance and is typically conveyed in graphical form as points (Figures 1 and 2). This statistical expression can also be portrayed as a change in spatial variance with distance and is where the term "semi-variogram" originated. Because the modeling process is data-driven, it cannot address COC distribution based on historical knowledge in localized areas, but is useful for understanding the contamination in a general context.

For natural phenomena, the spatial correlation between samples is typically higher at smaller sample distances and decreases with increasing sample distances, i.e. concentrations are more similar when closer together than further apart. In graphical form, a higher degree of spatial correlation is reflected by points that are comparatively close in distance and are visibly aligned with each other, rather than points that are farther apart, which typically have decaying spatial correlation and high variance. This is shown in Figure 1 for mercury, where the spatial correlation points on the x-axis are aligned on an ascending curve below approximately 245 feet.

To model the correlations, a best-fit curve was adapted to the semi-variogram graph by adjusting the parameters "range," "sill," "vertical and horizontal anisotropy," and "nugget" to a semi-variogram model type that establishes the shape of the curve. This is related to regression analysis curve-fitting where a curve function is fitted to sample points. These parameters are defined below.

The range parameter is the distance beyond which sample values are not spatially correlated and is reflected in the semi-variogram where the point alignment decays, and the fitted curve becomes flat (Figures 1 and 2). The range value is the distance where sample values express a continuous unit (such as a connected plume). Beyond the range value, the samples are not correlated, have a high variance, and correspond to the dissolution or dissociation of a plume at its outer boundary. The “vertical anisotropy” value influences the horizontal spread of the modeled values, where increasing the values will stretch the model laterally. Both parameters have a significant influence on the resulting plume shape, where the vertical anisotropy value is guided by consideration of the history of the deposition and hydrodynamics in the slip. Mercury and tPAH contamination at the C Street Slip has occurred over a prolonged period of industrial activity and bathymetric changes. As a result, the contamination plume shapes in the model are assumed to be spatially broad because of persistent mixing dynamics, and a vertical anisotropy ratio was selected to provide connectivity in the output model between the sample data. Using a low anisotropy value will render “bull’s eyes” where the output model is locally limited to around each sample value.

The vertical anisotropic ratio section of 15 was established by increasing the value iteratively for mercury until sufficient connectivity was generated between the sample points at the midpoint effect concentration (MEC) value of 640 µg/kg. The same vertical anisotropic ratio was used for tPAH since it is assumed that the value represents similar hydrologic sedimentation processes that affect the horizontal connectivity of all analytes.

The “sill” is an expression of the total variance of the data and is where the semi-variogram curve flattens.

The “nugget” value is an expression of the small-scale variability of the data or noise. It is declared as zero in this modeling scheme to reduce the subjectively defined parameters and to simplify the modeling process.

The semi-variogram range value of 250 ft for mercury in comparison to 150 feet for tPAH, indicates that the tPAH plume’s shape is generally smaller compared to mercury. Variations in the Kriging model parameters of the range and the horizontal to vertical anisotropy have a significant effect on the output plume’s geometries.

Figure 1 – C Street Mercury semi-variogram

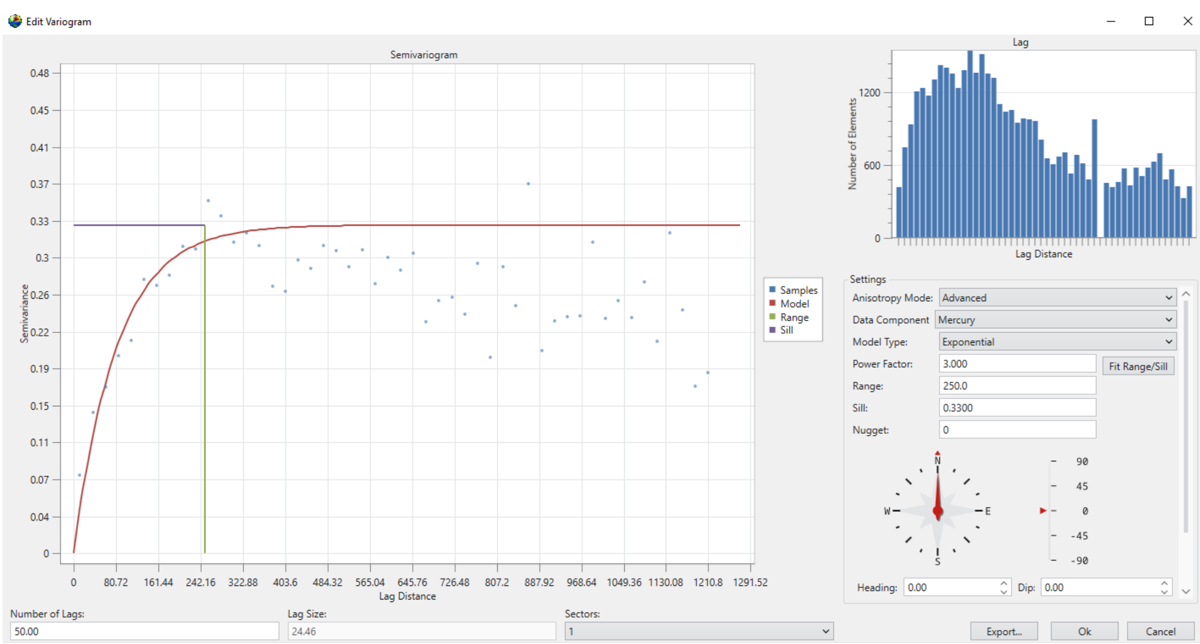
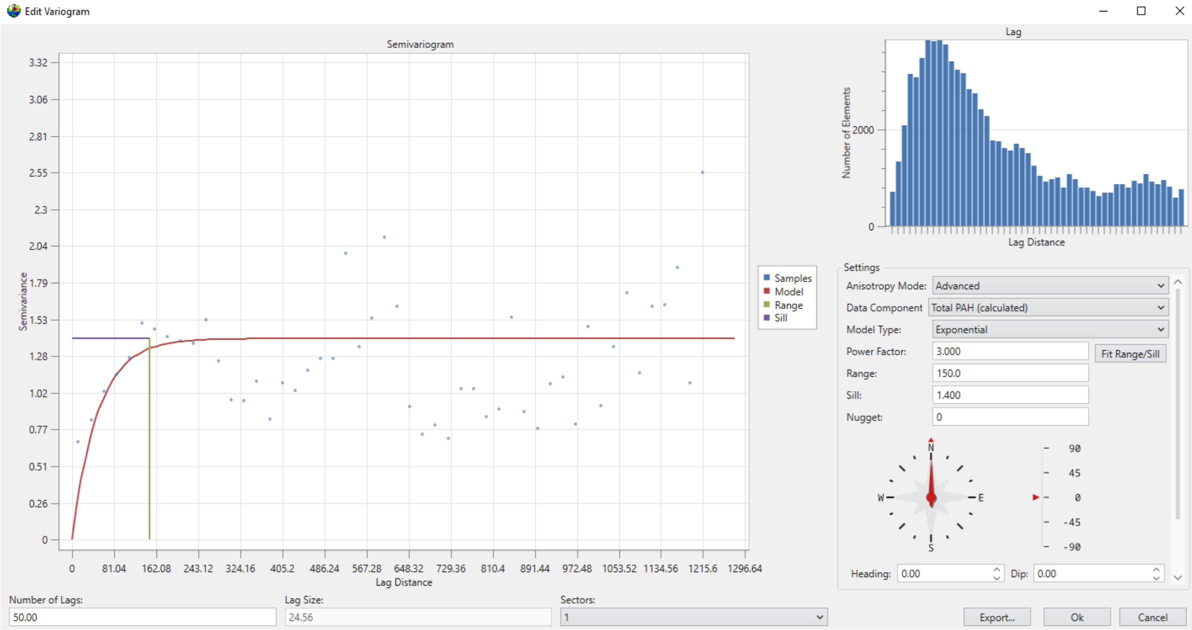


Figure 2 C Street tPAH semi-variogram 1



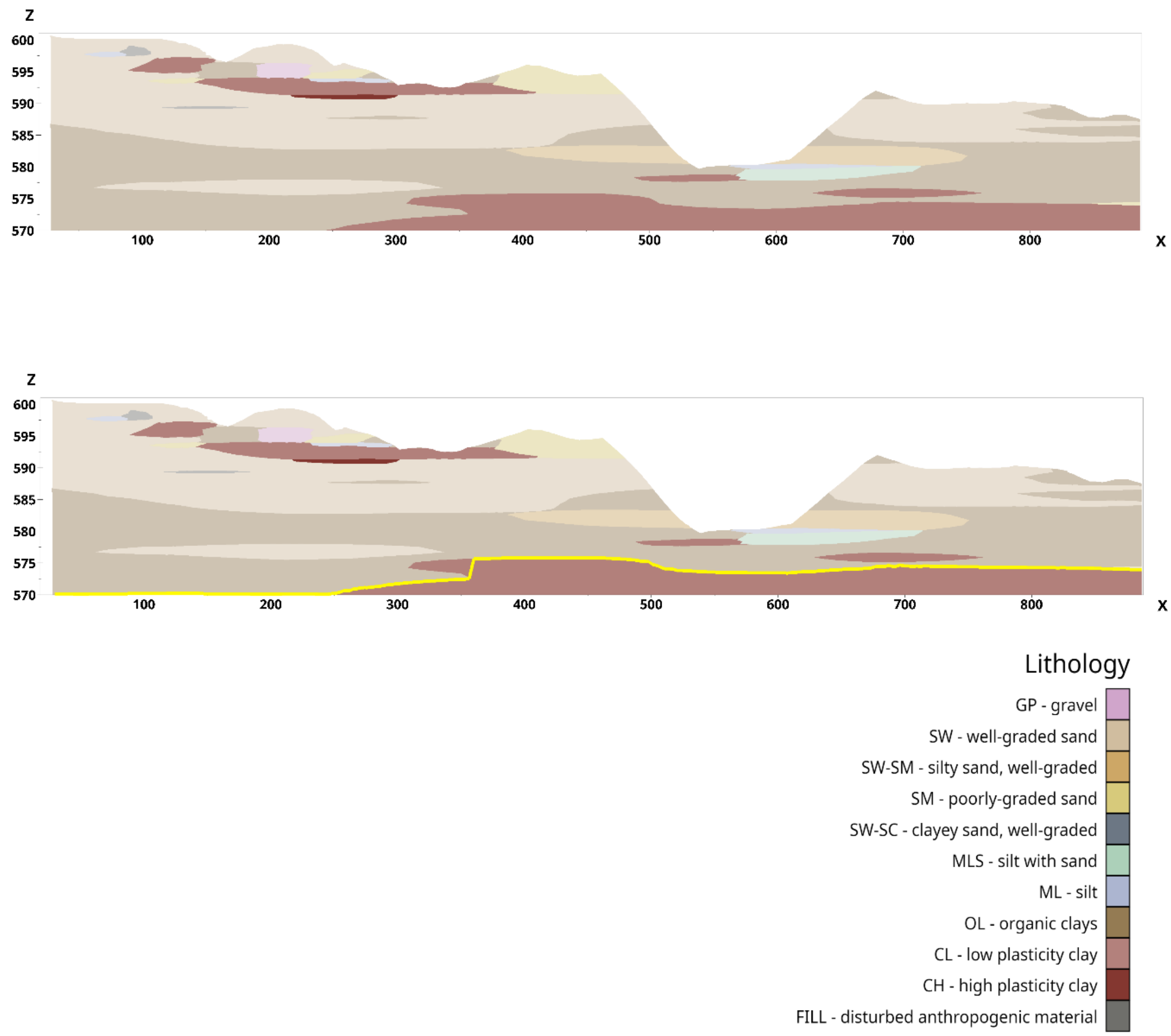
Since tidal patterns and industrial activity may elongate the plumes parallel to the long axis of the slip, the horizontal anisotropy parameter could potentially be used to generate that effect in the model. However, this parameter was not used because it is difficult to establish using the field data and is not appropriate to use a uniform value over a dynamically changing sedimentary environment with locally varying conditions.

The model has been reviewed by technical staff. Independent modeling by Foth, Inc., has developed kriging parameters that are very similar to AECOM's.

Lithology

An additional lithology model was generated in EVS from field samples using a form of Kriging called GIK (Geologic Indicator Kriging), that uses a variation of the Kriging algorithm specialized for discontinuous data such as geologic or lithologic boundaries.

Figure 3 - Derivation of Clay Surface



The lithologic model was used to assess the top elevation of the deepest low-plasticity clay layer to determine the maximum depth for dredging. This is because dredging below the low-plasticity clay deposits is not feasible. The generated surfaces were exported from EVS into ArcGIS and post-processed to calculate the lowest non-overhanging top of clay horizon and is represented by the yellow line in Figure 3. The GIS post-processing also included extrapolating the top of clay surface to the head of the slip (Figures 4 and 5).The mercury, and tPAH plumes were cut to above the clay surface using EVS tools. The result was used in EVS volumetric tools to provide the soil contamination volume in cubic yards.

Figure 4 – Example of Clay Surface Gap Coverage

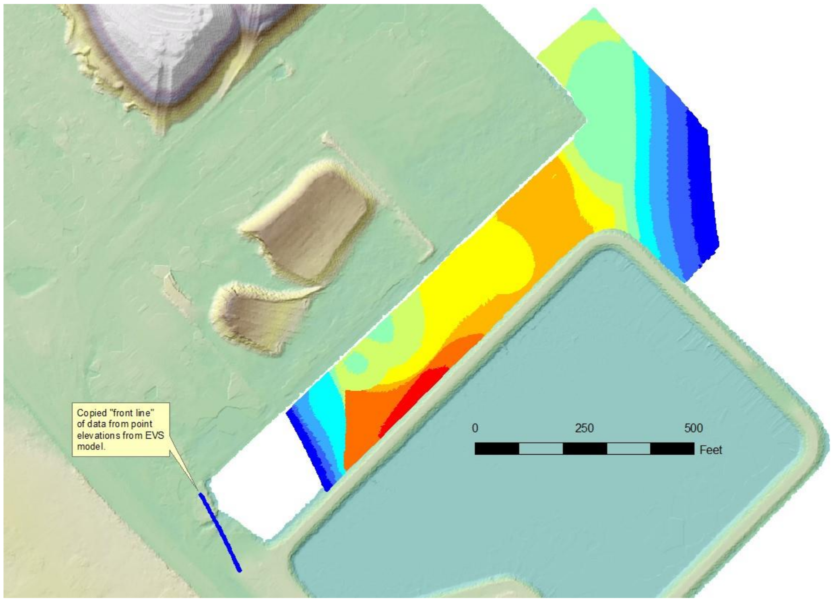
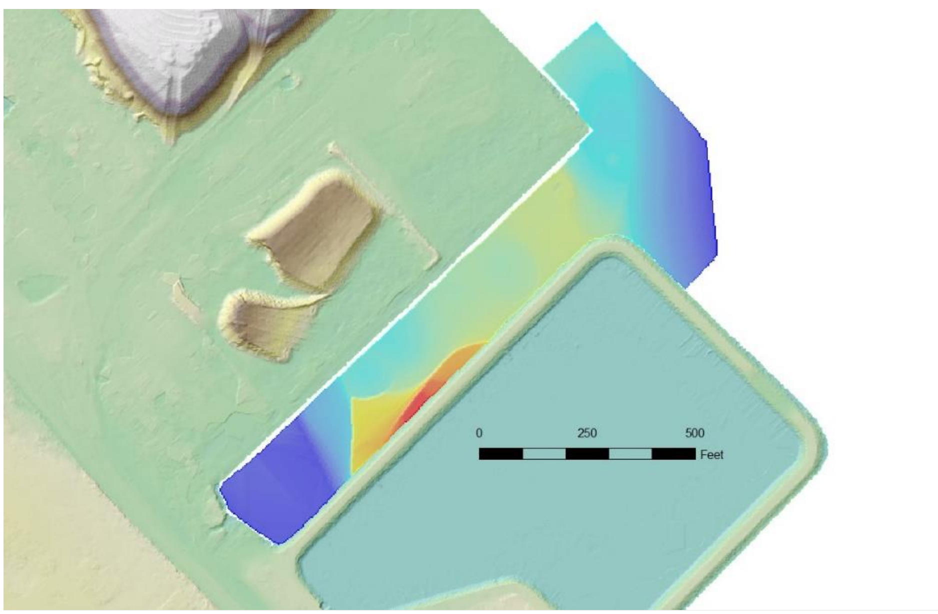


Figure 5 – Example of Resulting Clay Surface with Extrapolated Gap



Model Validation and Data Uncertainty

The major data uncertainties associated with 3D modeling center around the input data, parameter assumptions made by the modeler, and model validation to real-world conditions. Chemical and lithological data utilized in the model has been previously validated upon their imports into EQuIS. Data uncertainties previously discussed in the C Street Slip Remedial Investigation Report (AECOM, 2023) are appliable to the data. Modeling requires parameter assumptions about the behavior, properties, or interactions of the data being modeled. As mentioned above, the model is data driven and can aid to understanding the contamination in a general context. Validation of the model for C Street Slip was completed by reviewing any previous modeling produced by previous consultants and evaluating the model's accuracy in practical settings via a geologist's review of the stratigraphy and plume characterization.

Appendix B Definitive Remedial Alternatives Cost Estimates

C Street Slip Remediation
Mechanical Dredging

In situ volume	**40,000**	**CY**
Disposal volume	**36,659**	**tons**
Cycle time	**60**	**CY/hr**
Uptime per day	**8**	**hr**
CY/day	**480**	**CY**
6 d/week	**2,880**	**CY**
Mobilization	**6**	**weeks**
Operations	**14**	**weeks**
T&D	**12**	**weeks**
Demobilization	**3**	**weeks**
Restoration	**2**	**weeks**
Total	**37**	**weeks**

Project management and controls	$54,390.00	1 h/d x 228 d for PM (offsite) and 0.5 h/d x 228 d for project controls (offsite)
Implementation Plan and Design		Performed prior to mobilization (4-6 months)
Permitting		Performed prior to mobilization (6 months)
Mobilization/Demobilization and SMA Construction		
Construction	$945,000.00	Survey, site prep, grading, access roads, fence, E&SC, sump, liner and WTP mob/demob (9 weeks)
Rock	$35,000.00	
Transloading dock	$50,000.00	Scow dewatering and Sennebogen offloading
Liner/Geogrid/Nonwoven	$37,500.00	> 20-miL HDPE or PE liner; 1" nonwoven below liner
Generators (x2)	$45,600.00	$100/d each
Mechanical Dredge Contractor		
mobilization/demobilization	$175,000.00	Mobilization - 6 weeks including dredge, spud barge and scows; construction temp facilities, transloading area and SMA
daily rate (6 days - 10 h/d)	$2,016,000.00	$24,000/d (equipment, personnel, fuel) for 84 days
Fuel	$144,300.00	$650/d
Filtrate Discharge and Sumps	$85,000.00	Sump pumps and discharge hose to WTP
Water treatment system (filtration and GAC sorption)	$675,000.00	$65,000/month (2,000 gpm); including operations
S/S and Loadout	$746,000.00	500 tons/d (12 weeks); 1,750 tons Calciment™
Transportation	$806,498.00	$22/ton
Disposal	$2,749,425.00	$75/ton
Additional solid waste	$45,000.00	liner
Restoration	$25,000.00	Grading and seeding
CM/CQA/OE	$666,000.00	CM/CQA/OE
	$111,000.00	$250/d (228 days)
Total	$9,411,713.00	
contingency	**$10,352,884.30**	10%

C Street Slip Remediation
Hydraulic Dredging

In situ volume	**40,000**	**CY**
Disposal volume	**31,322**	**tons**
Productivity	**85**	**CY/hr**
Uptime per day	**8**	**hr**
CY/day	**680**	**CY**
6 d/week	**4,080**	**CY**
Mobilization	**6**	**weeks**
Operations	**10**	**weeks**
T&D	**10**	**weeks**
Demobilization	**3**	**weeks**
Restoration	**2**	**weeks**
Total	**31**	**weeks**

Project management and controls	$45,570.00	1 h/d x 186 d for PM (offsite) and 0.5 h/d x 186 d for project controls (offsite)
Implementation Plan and Design		Performed prior to mobilization (4-6 months)
Permitting		Performed prior to mobilization (6 months)
Mobilization/Demobilization and SMA Construction		
Construction	$945,000.00	Survey, site prep, grading, access roads, fence, E&SC, sump, liner and WTP mob/demob (9 weeks)
Rock	$35,000.00	
Liner/Geogrid/Nonwoven	$37,500.00	> 20-miL HDPE or PE liner; 1" nonwoven below liner
Generators (x2)	$37,200.00	$100/d each
Hydraulic Dredge Contractor		
mobilization/demobilization	$175,000.00	Mobilization - 6 weeks including dredge; construction temp facilities and SMA
daily rate (6 days - 10 h/d)	$1,920,000.00	$32,000/d (equipment, personnel, fuel) for 60 days
Fuel	$120,900.00	$650/d
Geotextile tubes		
60' circ x 200' long	$182,000.00	28 tubes delivered to site from GSI
manifold/stingers/valves	$22,000.00	to be specified by AECOM; constructed and delivered by contractor; 1 stinger and 1 gate valve per tube
Booster pump and pipeline	$45,000.00	
Polymer (dual system)		
make-down unit and LMI pumps	$65,000.00	Velodyne makedown unit for flocculent
polymer (160,000 lb)	$400,000.00	$2.50/lb delivered (coagulant and flocculant)
high pressure water feed pump	$120,000.00	high pressure high head water feed pump (150 gal/min) for make-down water
Filtrate Discharge and Sumps	$85,000.00	Sump pumps and discharge hose to WTP
Water treatment system	$675,000.00	$65,000/month (2,000 gpm); including operations
(filtration and GAC sorption)		
S/S and Loadout	$630,000.00	500 tons/d (10 weeks); 1,500 tons Calciment™
Transportation	$689,084.00	$22/ton
Disposal	$2,349,150.00	$75/ton
Additional solid waste	$45,000.00	liner and tubes
Restoration	$25,000.00	Grading and seeding
CM/CQA/OE		
staff (2 people x 180 d)	$558,000.00	CM/CQA/OE
per diem ($250/d)	$93,000.00	$250/d (228 days)
Total	$9,299,404.00	
contingency	**$10,229,344.40**	10%

C Street Slip Remediation
Unamended Sediment Cap

Surface Area	**150,500**	**ft2**
Sand Volume	**16,722**	**CY**
Productivity	**85**	**CY/hr**
Uptime per day	**8**	**hr**
CY/day	**680**	**CY**
6 d/week	**4,080**	**CY**
Mobilization	**4**	**weeks**
Operations	**4**	**weeks**
T&D		**weeks**
Demobilization	**3**	**weeks**
Restoration	**2**	**weeks**
Total	**13**	**weeks**

Project management and controls	$19,110.00	1 h/d x 186 d for PM (offsite) and 0.5 h/d x 186 d for project controls (offsite)
Implementation Plan and Design		Performed prior to mobilization (4-6 months)
Permitting		Performed prior to mobilization (6 months)
Mobilization/Demobilization and SMA Construction		
Construction	$315,000.00	Survey, site prep, grading, access roads, fence, E&SC, sump, liner and WTP mob/demob (7 weeks)
Rock/Sand	$536,666.67	$300 sand/10 CY truck delivered
Liner/Geogrid/Nonwoven	$7,500.00	> 20-miL HDPE or PE liner; 1" nonwoven below liner
Generators (x1)	$7,800.00	$100/d each
Dredge Contractor		
mobilization/demobilization	$175,000.00	Mobilization - 4 weeks including dredge; construction temp facilities
daily rate (6 days - 10 h/d)	$720,000.00	$24,000/d (equipment, personnel, fuel) for 24 days; 6 days post confirmation
Fuel	$50,700.00	$650/d
High pressure water feed pump/tanks	$60,000.00	high pressure high head water feed pump (150 gal/min) for make-down water
Additional solid waste	$25,000.00	liner
Restoration	$15,000.00	Grading and seeding
CM/CQA/OE		
staff (2 people x 78 d)	$234,000.00	CM/CQA/OE
per diem ($250/d)	$39,000.00	$250/d (228 days)
Total	$2,204,776.67	
contingency	**$2,425,254.33**	10%

C Street Slip Remediation
Unamended Sediment Cap

Surface Area	**150,500**	**ft2**
Sand Volume	**16,722**	**CY**
Amendment	**502**	**CY**
Productivity	**85**	**CY/hr**
Uptime per day	**8**	**hr**
CY/day	**680**	**CY**
6 d/week	**4,080**	**CY**
Mobilization	**4**	**weeks**
Operations	**4**	**weeks**
T&D		**weeks**
Demobilization	**3**	**weeks**
Restoration	**2**	**weeks**
Total	**13**	**weeks**

Project management and controls		$20,580.00	1 h/d x 186 d for PM (offsite) and 0.5 h/d x 186 d for project controls (offsite)
Implementation Plan and Design			Performed prior to mobilization (4-6 months)
Permitting			Performed prior to mobilization (6 months)
Mobilization/Demobilization and SMA Construction			
Construction		$315,000.00	Survey, site prep, grading, access roads, fence, E&SC, sump, liner and WTP mob/demob (7 weeks)
Rock/Sand		$536,666.67	3,549
Amendment		$250,833	Activated carbon
Liner/Geogrid/Nonwoven		$7,500.00	> 20-miL HDPE or PE liner; 1" nonwoven below liner
Generators (x1)		$7,800.00	$100/d each
Dredge Contractor			
mobilization/demobilization		$175,000.00	Mobilization - 4 weeks including dredge; construction temp facilities
daily rate (6 days - 10 h/d)		$864,000.00	$24,000/d (equipment, personnel, fuel) for 30 days; 6 days post confirmation
Fuel		$54,600.00	$650/d
High pressure water feed pump/tanks		$75,000.00	high pressure high head water feed pump (150 gal/min) for make-down water
Additional solid waste		$25,000.00	liner
Restoration		$15,000.00	Grading and seeding
CM/CQA/OE			
staff (2 people x 84 d)		$252,000.00	CM/CQA/OE
per diem ($250/d)		$42,000.00	$250/d (228 days)
	Total	$2,640,980.00	
	contingency	**$2,905,078.00**	10%

C Street Slip Remediation
Mechanical Dredging with Amended Cap

In situ volume	**20,000**	**CY**
Disposal volume	**18,330**	**tons**
Cycle time	**60**	**CY/hr**
Uptime per day	**8**	**hr**
CY/day	**480**	**CY**
6 d/week	**2,880**	**CY**
Sand Volume	**5,574**	**CY**
Amendment	**167.22**	**CY**
Mobilization	**6**	**weeks**
Operations	**8**	**weeks**
T&D	**6**	**weeks**
Demobilization	**3**	**weeks**
Restoration	**2**	**weeks**
Total	**25**	**weeks**

Project management and controls	$41,160.00	1 h/d x 228 d for PM (offsite) and 0.5 h/d x 228 d for project controls (offsite)
Implementation Plan and Design		Performed prior to mobilization (4-6 months)
Permitting		Performed prior to mobilization (6 months)
Mobilization/Demobilization and SMA Construction		
Construction	$945,000.00	Survey, site prep, grading, access roads, fence, E&SC, sump, liner and WTP mob/demob (9 weeks)
Rock/Sand/Amendment	$285,830.00	sand - $300/10 CY truck delivered; activated carbon - $500/CY delivered
Transloading dock	$50,000.00	Scow dewatering and Sennebogen offloading
Liner/Geogrid/Nonwoven	$27,500.00	> 20-miL HDPE or PE liner; 1" nonwoven below liner
Generators (x2)	$33,600.00	$100/d each
Mechanical Dredge Contractor		
mobilization/demobilization	$175,000.00	Mobilization - 6 weeks including dredge, spud barge and scows; construction temp facilities, transloading area and SMA
daily rate (6 days - 10 h/d)	$1,584,000.00	$24,000/d (equipment, personnel, fuel) for 66 days
Fuel	$107,900.00	$650/d
Sand		
Filtrate Discharge and Sumps	$85,000.00	Sump pumps and discharge hose to WTP
Water treatment system (filtration and GAC sorption)	$600,000.00	$65,000/month (2,000 gpm); including operations
S/S and Loadout	$548,000.00	500 tons/d (6 weeks); 1,750 tons Calciment™
Transportation	$403,260.00	$22/ton
Disposal	$1,374,750.00	$75/ton
Additional solid waste	$45,000.00	liner
Restoration	$25,000.00	Grading and seeding
CM/CQA/OE	$504,000.00	CM/CQA/OE
	$84,000.00	$250/d (168 days)
Total	$6,919,000.00	
contingency	**$7,610,900.00**	10%

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