40th Avenue West
Remediation-To-Restoration Project
Focused Feasibility Study Report

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On behalf of the St. Louis River Area of Concern

FOCUSED FEASIBILITY STUDY REPORT
FOR
40TH AVENUE WEST REMEDIATION-TO-RESTORATION PROJECT AREA
IN THE ST. LOUIS RIVER AREA OF CONCERN

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LIST OF ACRONYMS AND ABBREVIATIONS

AIS	Aquatic Invasive Species
AOC	Area of Concern
APE	Area of Potential Effects
ASTM	American Society for Testing and Materials
BARR	Barr Engineering Company
BMP	Best Management Practice
BUI	Beneficial Use Impairment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	Chain of Custody
DQO	Data Quality Objective
DTM	Digital Terrain Model
FdL	Fond du Lac Band of Lake Superior Chippewa
FFS	St. Louis River 40th Avenue West Focused Feasibility Study
FLV	Floating Leaf Vegetation
GIS	Geographical Information System
GLNPO	Great Lakes National Program Office
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Act
GIS	Geographic Information System
GPS	Geographic Positioning System
IGLD	International Great Lakes Datum of 1985
IGLD 85	International Great Lakes Datum of 1985
Jewell	Jewell Associates Engineers (USFWS Contractor)
LWD	Low Water Datum
MDL	Method Detection Limit
MEP	Maximum Extent Practicable
MERLA	Minnesota Environmental Response and Liability Act
MNDNR	Minnesota Department of Natural Resources
MNDOT	Minnesota Department of Transportation

MPCA	Minnesota Pollution Control Agency
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NAD	North American Datum
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NRRI	Natural Resources Research Institute
NWS	National Weather Service
OHWM	Ordinary High Water Mark
ROW	Right of Way
QA	Quality Assurance
QAM	Quality Assurance Manual
QAPP	Quality Assurance Project Plan
QAPrP	Quality Assurance Program Plan
QC	Quality Control
R2R	Remediation to Restoration
RAP	Remedial Action Plan (2013)
RCRA	Resource Conservation and Recovery Act
RL	Reporting Limit
RPD	Relative Percent Difference
SAV	Submerged Aquatic Vegetation
SE	Sorting Efficiency
SHPO	State Historical Preservation Office
SLRA	St. Louis River Alliance
SLRAOC	Saint Louis River Area of Concern
SLRCAC	St. Louis River Citizen Action Committee
SOP	Standard Operating Procedure
Stantec	Stantec Consulting Services (USFWS Contractor)
SQT	Sediment Quality Target
TES	Threatened, Endangered or Special Concern Species
USACE	United States Army Corps of Engineers
USEPA/EPA	United States Environmental Protection Agency

USFWS	United States Fish and Wildlife Service
USGS	United States Geographical Survey
USH	United States Highway
UTM	Universal Transverse Mercator
VIC	Voluntary Investigation & Cleanup (MN non-petroleum brownfields cleanup program)
WDNR	Wisconsin Department of Natural Resources

GLOSSARY

Area of Potential Effects (APE) – The maximum area that may be affected by a project for the purpose of determining direct and indirect effects to historic resources.

Bathymetry - The study of underwater depth of lake or ocean floors. For this study it refers to the topography of the floor of the St. Louis River.

BMP – Best Management Practices – A term used to describe accepted activities, prohibitions of practices, maintenance procedures, and or other management practices to prevent or reduce pollution of stormwater runoff.

Lidar – Light Detection and Ranging remote sensing method that uses a pulsed laser to measure ranges to the Earth. Lidar data is generally collected from equipment mounted on airplanes. The pulsed laser measurements, combined with other data recorded by the airborne system, generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

Maximum Extent Practicable (MEP) – A regulatory term, in the case of this Focused Feasibility Study referring to stormwater control and treatment, describing the point where the limitation of technology, project cost, and/or site constraints make full achievement of a regulatory requirement impracticable. Often the defining characteristics of MEP is left up to interpretation by the designer and the reviewer of each project. This can result in different definitions and standards for individual projects.

Nonpoint Source Pollution – In the context of this report nonpoint source pollution (NPS) refers to surface water pollution washed off parking lots, roads and highways, and lawns (often containing fertilizers and pesticides).

Ordinary High Water Mark - The Ordinary High Water Mark is used to determine the extent of public water. Land disturbance activities below or near the OHWM often requires State or Federal permitting. Minnesota Statutes 103G.005 Subd. 14. states "Ordinary high water level. 'Ordinary high water level' means the boundary of water basins, watercourses, public waters, and public waters wetlands, and: 1.the ordinary high water level is an elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial; 2.for watercourses, the ordinary high water level is the elevation of the top of the bank of the channel; and 3.for reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool." For the purpose of interpreting Section 404 of the Clean Water Act, The Army Corps defines the term as follows: "The term ordinary high water mark means that line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas." The State of Minnesota and Federal OHWA can vary which has legal, regulatory and real estate/property rights implications.

Riprap - Stone, rock or rubble used to armor shorelines, streambeds, abutments, pilings and other shoreline or streambank structures against scour and wind, ice or water erosion.

Shoal –A submerged landform or bar of accumulated or placed riverbed substrate over which the body of water is shallow. The formation normally lies just below the water surface, but may be exposed during low water conditions.

Shoreline Softening – Use of ecological principles and practices to achieve stabilization of shorelines previously lined with riprap, concrete, seawalls or other hardscapes, while enhancing habitat, and improving aesthetics.

Watershed - An extent of land within which water flows down into a specified body, such as a river or lake.

EXECUTIVE SUMMARY

Through the Great Lakes Restoration Initiative (GLRI), the U.S. Fish and Wildlife Service (USFWS) has supported the development of the feasibility stage of the Remediation-to-Restoration process for the 40th Avenue West Complex. The 40th Avenue West Complex (Project Area) is an approximately 330-acre segment of the St. Louis River estuary, located at the southern portion of Lake Superior within the City of Duluth. The river is the largest U.S. Lake Superior tributary and forms the border between Minnesota and Wisconsin. The estuary is one of the most biologically productive regions for aquatic, terrestrial, and avian use in the southern portion of Lake Superior.

The lower 39 miles of the St. Louis River and surrounding watershed, inclusive of the Project Area, was designated an AOC in 1987 due to historic chemical contamination and poor water quality resulting in reduced fish and wildlife populations. The remedial action planning process for the St. Louis River began in 1989 as a combined effort between the Minnesota Pollution Control Agency (MPCA) and the Wisconsin Department of Natural Resources (WDNR). In 1992, a Remedial Action Plan (RAP) Stage 1 document was completed for the AOC followed by the Lower St. Louis River Habitat Plan (Habitat Plan) in 2002. The Habitat Plan identified the 40th Avenue West complex as a location to restore productive fish and wildlife habitat. The 2013 St. Louis River RAP Update further identified the 40th Avenue West complex as an area that would benefit the Degraded Fish and Wildlife Populations, Degradation of Benthos, and Loss of Fish and Wildlife Habitat BUIs.

This Focused Feasibility Study (FFS) report presents concepts for improving the 40th Avenue West Complex that would benefit the Degraded Fish and Wildlife Populations, Degradation of Benthos, and Loss of Fish and Wildlife Habitat BUIs by adding shoreline habitat, increasing floating leaf vegetation (FLV) and submerged aquatic vegetation (SAV) habitat, creating islands or shoals and associated habitat, dredging deepwater overwintering fish habitat, and addressing the risks posed by hazardous substances to fish and wildlife. The concepts were developed and refined based on a wealth of previous and current studies of the Project Area including: proposed and existing bathymetry; watershed impacts; historic resources; fish, wildlife and benthic surveys and studies; vegetation surveys and predictive modeling; and sediment characterization including locations of contamination. Summaries of past and present Project Area data is presented in this report. The report also includes a summary of public and landowner outreach efforts.

There are two concepts under consideration for restoration of the Project Area, constructing islands and constructing shoals instead of islands. Estimates of quantities and opinions of probable costs are presented for the preferred concepts. The cost of these suggested improvements range from $7.9 to $14.5 million depending on the features constructed and alternatives considered. Addressing contaminated sediments and anthropogenic materials (wood waste) may cost an additional $25 million when fully implemented.

Implementation of the 40th Avenue West Complex Remediation-to-Restoration Project will greatly contribute to the removal of beneficial use impairments (BUIs) within this AOC. While all the suggested actions and design elements contained within this report may not be necessary to achieve AOC delisting, this FFS Report provides the basis for further restoration efforts within the 40th Avenue West Complex with the overall goal of removing the risks to fish and wildlife resources while restoring high quality habitat.

SECTION 1 – INTRODUCTION

1.1. BACKGROUND

The St. Louis River, located on the western edge of Lake Superior, is the lake's largest U.S. tributary. The river runs 192 miles through Minnesota and forms the border between Minnesota and Wisconsin. Of the 192 miles, the lower 21 miles are within the St. Louis River Estuary. The estuary remains one of the most biologically productive regions in the western portion of Lake Superior despite over a century of anthropogenic impact. The estuary provides a wide variety of habitat types for aquatic, terrestrial and avian wildlife.

The lower 39 miles of the St. Louis River and surrounding watershed was designated an AOC in 1987, one of seven located on Lake Superior due to the presence of chemical contaminants, poor water quality, reduced fish and wildlife populations, and habitat loss. Nine Beneficial Use Impairments (BUIs) were identified in the AOC; including: Degraded Fish and Wildlife Populations, Fish Tumors and Other Deformities, Degradation of Benthos, Restrictions on Dredging, and Loss of Fish and Wildlife Habitat. The remedial action planning process for the St. Louis River began in 1989 as a combined effort between the Minnesota Pollution Control Agency (MPCA) and the Wisconsin Department of Natural Resources (WDNR). At that time, the agencies created a citizens advisory committee, the St. Louis River Citizen Action Committee (SLRCAC), the precursor to today's St. Louis River Alliance (SLRA). In 1992, a Remedial Action Plan (RAP) Stage 1 document was completed for the AOC. In 1995, the Stage II Remedial Action Plan (RAP) was developed. Following the recommendations of the 1995 Stage II RAP, and through the support of the SLRCAC and other partners, the Lower St. Louis River Habitat Plan (Habitat Plan) was developed in 2002. The Habitat Plan provided "an estuary-wide guide for resource management and conservation that would lead to adequate representation, function, and protection of ecological systems in the St. Louis River, so as to sustain biological productivity, native biodiversity, and ecological integrity." In 2008 the SLRA facilitated the development of "Delisting Targets" for each BUI in the St. Louis River AOC. In 2011 and 2012, a Stage II RAP update was published by the Wisconsin Department of Natural Resources and in 2013, a Stage II RAP update was published by all the AOC partners, titled "St. Louis River Area of Concern Implementation Framework: Roadmap to Delisting" (2013 RAP Update), to be used to further guide the removal of BUIs and delist the AOC. In August 2014, the first BUI was removed, Degradation of Aesthetics.

Utilizing the Habitat Plan, St. Louis River AOC stakeholders chose to begin implementation of a Remediation-to-Restoration project at the 40th Avenue West Complex (Project Area), an approximate 330-acre segment of the St. Louis River estuary located in the City of Duluth. The Project Area is characterized as highly industrialized including abandoned and existing infrastructure currently being utilized. Active industrial uses within the Project Area include the New Page water intake pipe and slip, Minnesota Power Hibbing power plant water intake and outfall pipes, and Erie Pier slip with service to an active Confined Disposal Facility operated by the City of Duluth and the USACE.

The goals of Remediation-to-Restoration projects are to address multiple identified issues concurrently to maximize the ability to meet objectives, such as removing risks to fish and wildlife resources in a way that will help meet the ecological goals of the Project Area. Stakeholders have continued to identify the 40th Avenue West Complex as a priority area through the 2013 RAP Update, in which the complex was identified as an area where contaminated sediment remediation and habitat restoration would be needed to remove the Loss of Fish and Wildlife Habitat BUI.

Through the Great Lakes Restoration Initiative (GLRI) the U.S. Fish and Wildlife Service (USFWS) was able to support a preliminary assessment of the Project Area and the development of an ecological design for the AOC. The full results of the preliminary assessment can be found in the document, *An Ecological Design for the 40th Avenue West Remediation-to-Restoration Project* (Ecological Design Report), prepared by the Natural Resources Research Institute (NRRI 2012). Together with additional GLRI funding and continued stakeholder involvement, the USFWS was able to further support the next stage of the Remediation-to-Restoration process, the development of this Focused Feasibility Study (FFS).

The purpose of the FFS is to evaluate the alternatives to address limiting factors in the Project Area (including contaminated sediments and degraded fish and wildlife habitats), as well as evaluate those construction actions necessary to achieve the Preferred Ecological Design objectives and stakeholder goals for the Project Area. As part of the FFS, a Preferred Ecological Design was developed with goals and objectives to address several BUI's with a focus on improving aquatic habitat. In the development of the FFS, additional information needs were identified and addressed that were critical to evaluate a suite of remediation and restoration alternatives and estimated construction costs. Information gained from this study, and provided in this report, will be used in the next stage of the Remediation-to-Restoration process, the Design Phase.

Implementation of the 40th Avenue West Complex Remediation-to-Restoration Project will greatly contribute to the removal of several BUIs, including Degraded Fish and Wildlife Populations, Degradation of Benthos, and Loss of Fish and Wildlife Habitat. While not all the suggested actions and design elements contained within this report may be necessary to achieve AOC delisting, this FFS Report will ensure that work completed to achieve AOC goals will lay the appropriate groundwork for further restoration efforts within the 40th Avenue West Complex above and beyond BUI removal with the overall goal of removing the risks to fish and wildlife resources while restoring high quality habitat.

1.2. 40th AVENUE RESTORATION SITE TEAM

The 40th Avenue Restoration Site Team (Site Team) consists of members from Federal, State, and Local agencies that each has a role in the management of the St. Louis River and its shoreline. The Site Team guided the development of the report, and provided guidance to ensure the FFS will meet the needs of the St. Louis River AOC.

40th Avenue West Restoration Site Team

Name	Title	Affiliation
Diane Desotelle	St. Louis River AOC Coordinator and Restoration Site Team Leader	Minnesota Pollution Control Agency
Zachary Jorgenson	Ecological Services Biologist	US Fish and Wildlife Service
Al Mozol	Engineering Technician	US Army Corps of Engineers Duluth Area Office
Rick Gitar	Water Regulatory Specialist	Fond du Lac Environmental Program
Cliff Bentley	Ecological and Water Resources Area Hydrologist	Minnesota Department of Natural Resources
Matt Steiger	St. Louis River Area of Concern Coordinator	Wisconsin Department of Natural Resources
Martha Minchak	MN DNR Habitat Restoration Project Manager	Minnesota Department of Natural Resources
Ross Lovely	Business Developer Business and Economic Development Department	City of Duluth
Jim Sharrow	Facilities Manager	Duluth Seaway Port Authority
Deborah DeLuca	Government & Environmental Affairs Director	Duluth Seaway Port Authority

1.3. EXISTING DATA

There is a wealth of data previously collected in the Estuary that contributed to the development of this FFS. Where applicable, the source of this data is referenced throughout this report and its appendices. Of particular use in the further development of the restoration design concepts was the Ecological Design Report prepared by NRRI and the bathymetric surveys of the Project Area performed by Barr Engineering Company.

1.3.1. MPCA SEDIMENT QUALITY DATABASE

As part of the Remedial Action Plan process, stakeholders identified the need to compile sediment quality data collected from the lower St. Louis River in a database formatted for mapping and evaluation purposes. The Minnesota Pollution Control Agency (MPCA) and its collaborators developed the database which contains tools to assemble several types of sediment quality data and to plot features of this data on maps. The database assists with the data analysis and assessment of the Estuary for ecological risk and ongoing monitoring. The following sediment quality parameters are included in the database: sediment chemistry, sediment toxicity, benthic invertebrate community structure; tissue residue chemistry data from fish tissues, invertebrates, and plants; and physical data (e.g., particle size). Updates to the database have been made through several phases and will continue to include additional data types as well as future data as it is collected.

The database served as a screening tool from which priority areas of the AOC, including the Project Area, were identified based on sediment quality and benthos concerns. For the purpose of this FFS the database was an additional resource for the evaluation of past sediment quality and benthos data and was used as the basis for the Sampling and Analysis Plan (SAP) developed for this project and approved by MPCA. For example, the Phase IV GIS-Based Sediment Quality Database for the St. Louis River Area of Concern—Wisconsin Focus summarizing sediment PEC-Q prior to 2005 showed the area around the Erie Pier Confined Disposal Facility (Erie Pier) was generally above the Level I SQT screening thresholds. As part of the FFS, sediment samples were targeted by Erie Pier to determine current concentrations of dioxin/furans, PAHs and select metals. Utilization of the databases indicated that contaminated sediments that may affect habitat quality exist throughout the Project Area. Further discussion on sediment quality and ecological risk assessment can be found in Section 2.10.

1.3.2. ECOLOGICAL DESIGN REPORT

A preliminary assessment of the Project Area was completed in 2012 and is summarized in the Ecological Design Report (NRRI 2012). This report provides baseline data and goals for restoration efforts including information on sediment contamination, ecotoxicology, vegetation, sediment types, benthic macroinvertebrates, fish assemblage and bird usage of the area. Vegetation, macroinvertebrates and sediment characterization were also completed for five reference areas selected by project cooperators as areas representing target habitat types for the Project Area. The biological and substrate data available for the Project Area from the Ecological

Design Report is summarized below. The data indicated that probable limiting factors to habitat quality within the Project Area included turbidity and wind fetch both of which limit light penetration needed to establish macrophytes and increase shoreline erosion. This data, along with other environmental variables such as bathymetry, were then used in predictive vegetation models created by NRRI to evaluate the existing conditions of the Project Area as well as evaluate five habitat restoration scenarios. The Ecological Design Report also contained summaries of property owner and public outreach efforts, as well as recommended areas where additional data or research was required.

Aquatic Plant Communities

Aquatic plant communities were sampled up to 40 feet in depth, but few aquatic plants were found at depths exceeding 8.2 feet. Of the combined data set of 856 records, there were 67 records (7.82%) in the emergent marsh class, 145 (16.94%) in the floating leaf aquatic bed, and 312 (36.45%) as submerged aquatic bed class. The remaining 332 points (38.79%) had no vegetation present. The purpose of the sampling was to both determine the extent of the vegetation in the Project Area and to calibrate a model used to predict vegetative establishment based on design scenarios. The sampling also suggested a significant lack of aquatic vegetation in a large portion of the Project Area.

The emergent marsh (EM) class was the most diverse of the three plant communities, including a mix of emergent, floating-leaf and submerged aquatic plants with 22 taxa occurring in at least 5% of the sample points in the estuary. The most frequent taxa in this community were of algae, arrowheads (*Saittaria* spp.), water marigold (*Megalodonta beckii*), northern milfoil (*Myriophyllum sibiricum*), and bulrushes (*Schoenoplectus spp*). Floating-leaf aquatic bed (FL), consisted of a mix of submerged, floating-leaf and free-floating aquatic plants, with the submerged aquatic plants often dominant in this type. This was the second most diverse of the three aquatic plant communities. This community had 12 plant taxa occurring in at least 5% of the sample points in the estuary. The most frequent were water celery (*Vallisneria americana*), algae, water meal (*Wolffia spp*.), clasping-leaf pondweed (*Potamogeton richardsonii*), Canada waterweed (*Elodea canadensis*), and bushy pondweed (*Najas flexilis*). Submerged aquatic bed (SAV) contained the least diverse of the three aquatic plant encountered communities and was mainly submerged aquatic plants mixed with occasional free-floating plants. Only 6 plant taxa occurred in at least 5% of the sample points in the estuary. The most frequent plant taxa for this group were water celery (*Vallisneria americana*) and Canada waterweed (*Elodea canadensis*).

Benthic Macroinvertebrates

The benthic macroinvertebrate community was sampled and relationships were tested with habitat variables such as aquatic plant community, percent vegetative cover, water depth, substrate type, fetch distance and depth exposure. Unfortunately, a shortage of data points and insufficient variability in the benthos data did not allow for testing of all those relationships. The report discussed a possible correlation of taxa richness increasing as westerly fetch distance increases; however, the relationship is largely based on three area reference points rather than sample points from the Project Area itself. A wide range of species were found in many of the habitat types with no statistical difference in species richness based on the habitat type. The abundance of taxa was found to increase in shallow depths with low exposure and decrease at deeper depths with high exposure.

Hexagenia, commonly used as indicators of improved habitat quality, was collected in the St. Louis River estuary, with samples showing a preference of silt or silty mud to sandier conditions and larger amounts of organic matter with not much regard to various depths. Hexagenia was generally found at 75% vegetative cover, though it was found more abundant at lower vegetative cover. There was a strong correlation showing increasing abundance at greater depth and exposure, especially in the intermediate to deep water categories.

Avian Communities

The status of the avian community was based on weekly surveys of the Project Area during the fall migration season (August - November 2010), breeding season (June 2010), and spring migration season (March - May 2011). Over 13,500 individual bird observations were made. The observations showed a clear association between habitat features such as islands, the shallow areas west of Erie Pier and nearshore areas to the different groups of birds. Species associated with land, such as songbirds, raptors and corvids used both coastlines and existing islands in the Project Area. The majority of shorebirds were found to prefer shallow habitats with 63% of the observations occurring in high energy habitats and 25% of observations occurring in low energy habitats, while 13% of shorebird occurrences were spotted on land. Waterbirds were found to prefer shallow habitat as well with 46% of observations occurring in high energy habitats and 22% of observations in low energy habitats, while waterfowl had 35% of observations occurring in high energy habitats and 27% of observations occurring in low energy habitats.

Fish Assemblage

The fish assemblage comprises 27 fish species based on available trawl net, fyke net, electro-fishing, and fixed fill net catch data. Section 2.4 describes the findings of the report, along with additional recent information, in greater detail.

Ecotoxicology Results

Sediments

Sediment samples were taken at six locations in the Project Area in 2011 and showed elevated levels of select chemicals. Numerous chemical concentrations exceeded the Level II SQTs, while a majority of the chemicals exceeded Level I SQTs. Polycyclic aromatic hydrocarbons (PAHs) were frequently encountered at elevated levels and were the only chemicals seen above Level II SQT values. PAHs were found at concentrations that impact sediment-dwelling organisms at all six of the sample sites. Concentrations varied by the type of PAHs and location. The PAH 2-methylnapthalene exceeded Level II SQTs at all six of the sample locations, implying an anticipated harmful effect on sediment-dwelling organisms. Acenaphthalene, benzo(a)anthracene, naphtalene, phenanthrene, and pyrene all had measured concentrations above Level II SQTs at five of the six locations. In addition, Total PCBs, Total DDTs, O, p'DDD, dieldrin, zinc, mercury, nickel, and lead were measured at concentrations between Level I and Level II SQTs. Of the six sample locations, Site 1 (immediately south of the Minnesota Power Hibbard plant always had one of the elevated concentrations, with certain chemical concentrations far exceeding Level II SQTs. For example, both concentrations of 2-methylnapthalene and acenaphthalene were four times greater than Level II SQTs while benzo(a)pyrene and fluorene were over twice as high. For the remaining sites concentrations varied by chemical.

Fish Tissue

Chemical analyses of fish tissues were similar to those of sediment chemical concentrations. To evaluate PAH concentrations, white suckers were sampled from the Project Area and compared to white suckers from Stryker Bay in 2001 and 2002 (a Superfund Site prior to remediation). In addition, white suckers sampled from the Project Area were compared to the 50th and 90th percentile levels of Biomonitoring of Environmental Status and Trends Program (BEST). The Best program was a study conducted in 1995 that analyzed certain chemicals in 1378 fish from 22 species along 47 sample locations in the Mississippi River and one reference location in North Bay. Average total PAH concentrations in the white suckers in the Project Area were slightly less than those of the white suckers collected in Stryker Bay, but elevated compared to fish from the reference location at North Bay. The results of the white suckers sampling in the Project Area indicate that PAHs are readily available for uptake and/or bioaccumulation. In addition, the average of total PCBs was around the 50th percentile of the BEST program, though four of the white suckers in the Project Area had concentrations near the 90th percentile while one fish measured at a concentration that exceeded the 90th percentile. Arsenic, copper, mercury and nickel concentrations measured near or above the 90th percentile in individual fish, though most chemicals averaged the 50th percentile concentration. The Ecological Design Report determined that the analysis of PAHs and other chemicals in fish tissues supported the results from sediment sampling, leaving reason to believe that these same toxins were present in other key parts of the food chain, including macroinvertebrates and birds.

Ecological Design Report Ecotoxicology Study Conclusions

Given the results of the preliminary ecotoxicological evaluation, the primary contaminants of ecological concern identified within the Project Area were PAHs, although PCBs, mercury and nickel were also thought to be affecting ecological resources. The report recommended that the lateral and vertical extent of sediment contamination in the Project Area should be addressed as well as bioaccumulation and food chain effects of PAHs, PCBs, mercury and nickel.

Habitat Restoration Scenarios

The intent of the habitat restoration scenarios contained within Ecological Design Report was to provide some guidance toward understanding how plant and animal communities would react to changes in wind fetch, substrates and bathymetry. The report showed the most pronounced effects were predicted to come from scenarios that increased the amounts of low energy environments in both shallow and intermediate depths. The low energy environment scenarios projected increases in habitat for macroinvertebrates, fish and birds. Increasing deep habitat predicted increases in Hexagenia as well as walleye and other fish that use deeper waters as refugia. The scenarios provided examples of restoration techniques for the 40th Avenue West Complex. Elements of these scenarios were incorporated into the conceptual designs for this FFS and presented to the Site Team.

1.3.3. REFINING THE HABITAT RESTORATION SCENERIOS

Between the publication of the Ecological Design Report and the FFS an initial "Preferred Scenario Concept Plan" took shape (Figure 1). Developed by members of both the Ecological Design Report and Site Team, the design incorporated two large islands in the southern bay of the Project Area, as well as areas of both shoreline softening and increased depth. This concept plan was the starting point for the concepts developed in the FFS.

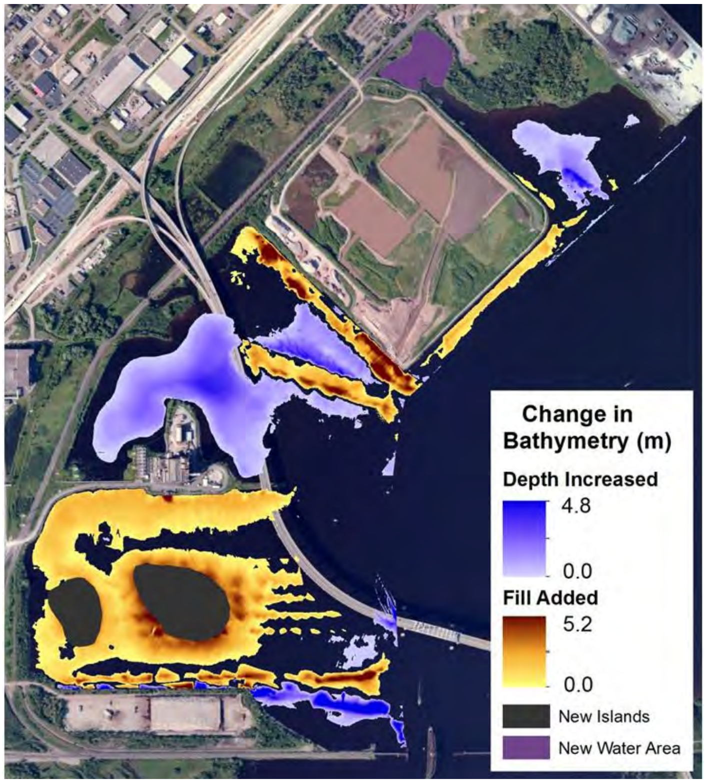

Figure 1. 40th Avenue West Preferred Scenario Concept Plan
(Source: NRRI-unpublished)

1.3.4. BATHYMETRIC SURVEYING AND MAPPING

Barr Engineering Company was contracted by MPCA in 2013 to conduct a bathymetric survey of five locations within the SLRAOC, including the Project Area. Barr also completed what was referred to as a "pre-engineering" evaluation of the sites based on concept designs at the time of the survey. The purpose of this work was to estimate preliminary dredging volumetric data for MPCA to submit to the USACE. Bathymetric data was collected via boat mounted sonar at 50 foot intervals. The survey datum was; Horizontal: MN State Plane North NAD83 US Feet; Vertical: NAVD88 US Feet.

Barr imported their bathymetric survey data into GIS software to create mapping and volume data for their initial analysis. Jewell used the original point data from the bathymetric survey to create an Autodesk Civil 3D-based digital terrain model (DTM) for the Project Area. This was done to eliminate potential errors in conversion of GIS based DTMs to ones based in engineering design software. Jewell then created colored bathymetry mapping (Figure 2) from their DTM. This mapping was compared to previous bathymetric mapping as an additional quality check. The colored bathymetry mapping proved critical to the refinement of the design concepts for the Project Area.

One issue of note was discovered concerning the bathymetric data. The Barr survey was conducted using the NAVD88 datum. Knowing this, Jewell conducted its work in the same datum. The USACE has been using the International Great Lakes Datum of 1985 (IGLD 85). There is a 2.11 inch (0.176 foot) difference in the two datums at 40th Avenue with NAVD88 being the higher of the two datum (IGLD Elevation 601.1= NAVD88 Elevation 601.28). The Site Team deemed this difference negligible for the preliminary design and modeling; however, this issue should be addressed as the various design elements utilizing the Barr survey move toward final design both in the Project Area and throughout the AOC.

The bathymetry of the site varies due to existing dredge channels associated with pre-1900 era docks that have been removed. South of the Hibbard power plant, the water depth is typically 5-6 feet deep based on the design Low Water Datum elevation of 601.1 (NAVD88). The dredge channels in the center of the bay range from 9-11 feet deep. Along the south side of the Project Area, at the New Page utilized MN Power dock (Berwind Dock), depths range from 17-21 feet deep in that slip. North of the Hibbard power plant extending to Erie Pier, the water ranges between 1.5 and 3.5 feet deep. There is a deep former slip and active slip along Erie Pier. North of Erie Pier depth average 1.5 to 2.5 feet deep.

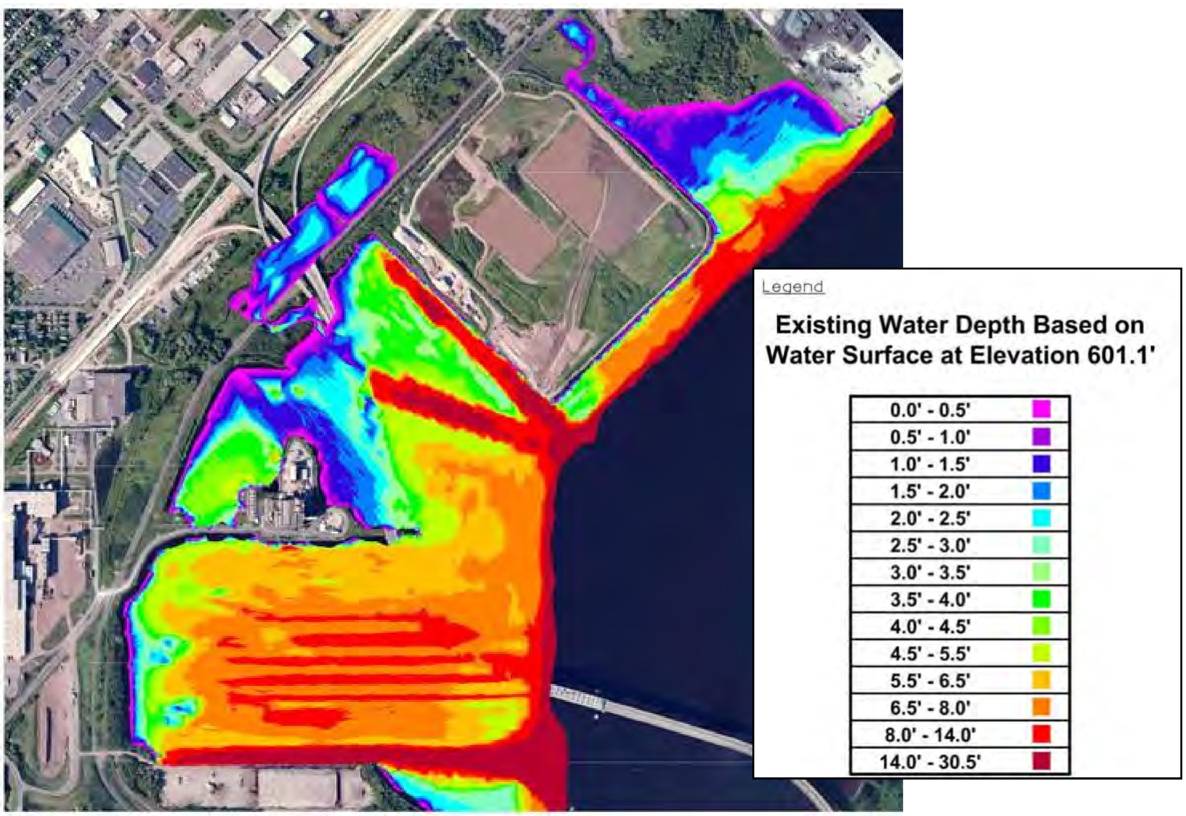

Figure 2. 40th Avenue West Existing Bathymetry

1.4. VISION AND GOALS

To begin refining a Preferred Design for the Project Area, the Site Team identified a Vision and Goals, the first step in site planning as described by the St. Louis River AOC Remediation-to-Restoration template. Once the ecological endpoints were described, construction alternatives for remediation, restoration, and end use planning were able to be identified and evaluated. The vision for the 40th Avenue West Complex, as established by the Site Team, is "Restoring multiple ecological and physical estuary functions and maintaining industrial uses."

The following are the goals, in no specific order, for the 40th Avenue West Complex:

1. Remove fish and wildlife exposure to hazardous substances
2. Remove anthropogenic substrates to improve benthic invertebrate habitat
3. Reduce turbidity from wind fetch and wave action
4. Increase bathymetric variability to improve habitat and reduce wave action
5. Increase aquatic vegetation (emergent, floating, submerged)
6. No loss of aquatic habitat
7. Enhance shoreline habitat
8. Improve habitat for:
    a. Benthic invertebrates
    b. Walleye, perch, bluegill, northern pike
    c. Stopover habitat for migrant waterfowl, shorebirds, and songbirds
    d. Turtles
9. Improve eco-recreation use
10. Protect cultural resources
11. Improve overwinter fish habitat
12. Evaluate watershed influences to protect restored habitat
13. Incorporate stakeholder needs
14. Maintain industrial uses
    a. New Page water intake pipe and slip (wood storage area)
    b. Minnesota Power water intake and outfall pipes (Hibbard power plant)
    c. Erie Pier slip (active Confined Disposal Facility)
15. Complete actions that will help contribute towards the removal of the Beneficial Use Impairments:
    a. Degraded Fish and Wildlife Populations (BUI #2)
    b. Degradation of Benthos (BUI #4)
    c. Loss of Fish and Wildlife Habitat (BUI #9)

Not all the stated goals may be necessary to achieve AOC delisting. Further restoration efforts within the 40th Avenue West Complex above and beyond BUI removal may be required to remove the risks to fish and wildlife resources and fully restore high quality habitat.

SECTION 2 - DATA GATHERING AND ANALYSIS

The need for additional Project Area data and analysis was identified during the development of the Ecological Design Report, during the initial scoping of the FFS, and as existing data was further evaluated during the FFS. This section describes those efforts.

2.1. SHORELINE TOPOGRAPHIC SURVEY

A topographic survey of the Project Area was performed over several days in June and September of 2014. The data was utilized in the analysis of shoreline softening and naturalization design, to establish the limits of vegetation and shoreline types, and to record the location of landowner equipment and infrastructure.

The survey was conducted using survey grade GPS equipment and the same datum as the bathymentric survey, NAVD 88. A GPS base station was referenced to known MNDOT monumentation and a rod mounted GPS "rover" was used by survey personnel to collect data. On average, 50 feet of the shoreline width was surveyed from the swing bridge at the south project limits to the Hallet Dock property at the north. The extent of shoreline types were surveyed and representative photographs taken (Appendix A and Appendix B). The shoreline topographic survey was combined with the bathymetric surface data during the creating of surface models. Since the bathymetric survey was conducted by boat there were some areas of limited data in the shallow areas along the shoreline. Where water depth allowed, the shoreline was waded and the river bottom surveyed to create a more accurate representation of the shoreline conditions. In addition to the 50 feet of shoreline, the pond areas under the Bong Bridge was surveyed and this data was combined with the bathymetry of the pond bottoms.

Lidar data was downloaded from MNDOT to "fill the gaps" in areas not covered by the bathymetric or topographric surveys. While the lidar data was seldom used in design areas, it did allow for additional characterization of the Project Area, including drainage patterns and topography of inaccessible areas.

2.2. RIPARIAN SHORELINE SURVEY

The riparian shoreline was cataloged during the shoreline topographic surveys and during vegetation surveys (see page 15). To complete and confirm the GPS survey of the shoreline composition limits, shoreline composition was sketched on aerial imagery and later digitized in GIS. A map of the combined data is shown in Figure 3 and Appendix A. Representative shoreline photographs are provided in Appendix B.

The Project Area includes approximately 25,674 linear feet, or 4.9 miles of shoreline. Approximately half of the shoreline habitat consists of rock, riprap, and rubble (approximately

12,165 linear feet). A majority of the rock, riprap, and rubble is located on the shorelines of the Hibbard power plant and Erie Pier. Portions of the Hibbard power plant shoreline fringe consists of alder thicket growing within the riprap reinforced banks. A concrete wall/dock exists along the south shore of the bay (dock owned by Minnesota Power) and portions of Erie Pier.

Table 1. Riparian Shoreline Habitat Types

Shoreline Habitat	Linear Feet
Rock, Riprap, and Rubble	12,165
Alder Thicket, Sparse Trees	4,619
Shallow Marsh: Typha X glauca	4,083
Concrete Wall or Dock	2,204
Wet Meadow/Sand-Gravel	867
Wet Meadow/Rocky	719
Sand	632
Common Reed (Phragmites)	184
Sand with Heavy Driftwood	97
Wood Trestle	53
Power Plant Intake	51
Total	**25,674**

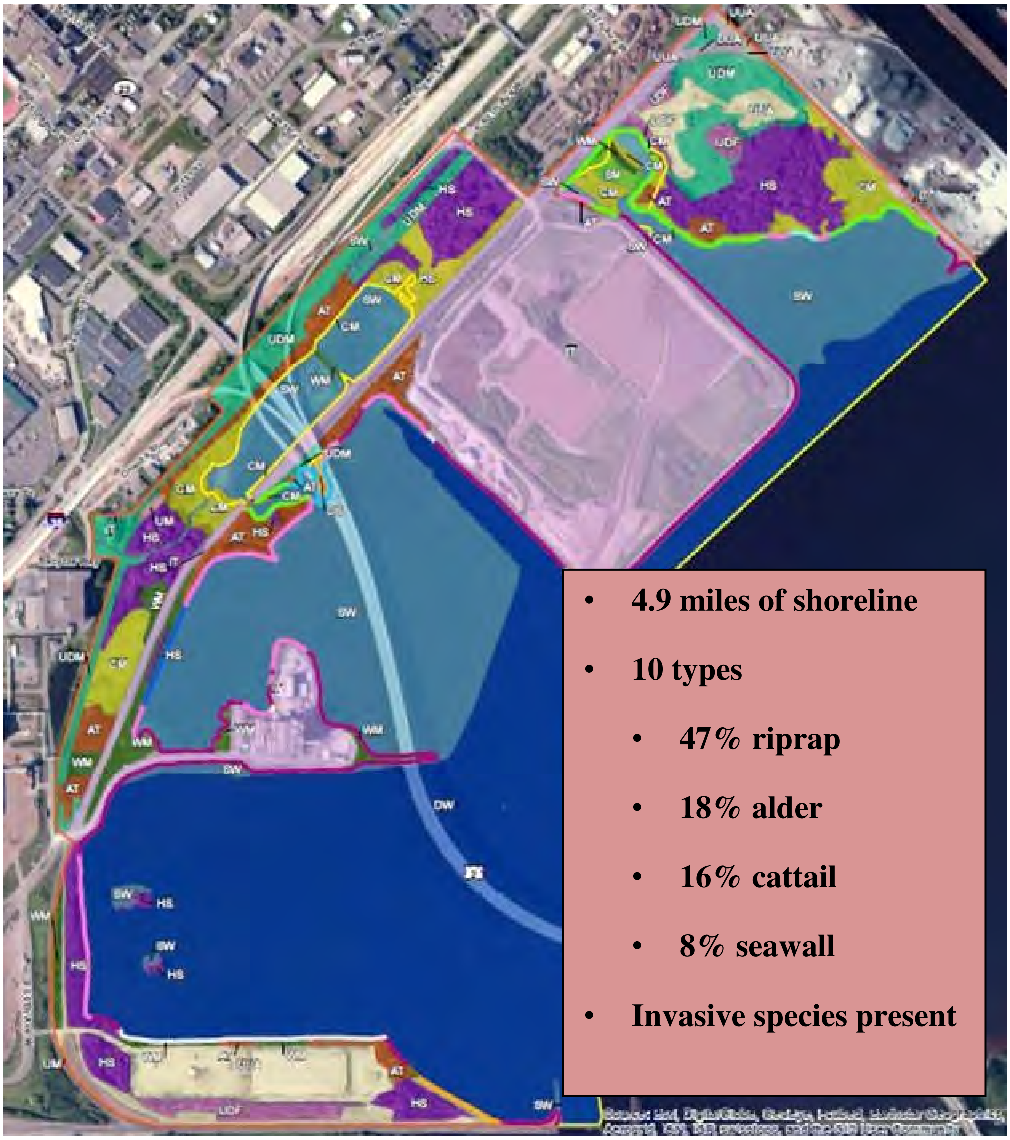

Figure 3. Botanical Communities and Shoreline Habitat
(Full size map with legend provided in Appendix A)

2.3. VEGETATION SURVEY

A vegetation survey was completed on September 30 and October 1, 2014. The vegetation survey summarizes the vegetation, terrestrial and aquatic habitat conditions, and the potential for restoration within the Project Area, including surrounding buffer areas. Among the topics evaluated and discussed are; floristic diversity, plant communities, rare plants, and invasive species. The survey is based on data collected during the 2014 field assessment and on a review of existing data. The 2014 site evaluation is intended to complement previous investigations of aquatic habitats within the Project Area and to support the planning process for aquatic and shoreline habitat restoration.

Meander surveys were utilized to investigate the plant communities within the Project Area. Buffer areas contiguous with the Project Area were evaluated for habitat potential based on field reconnaissance, comparison to similar habitat types evaluated onsite, and analysis of aerial imagery. Additional information was obtained from an existing shoreline survey completed during the FFS; terrestrial and benthic topographic data collected during the FFS; and a biological survey conducted by the NRRI in 2010.

A total of 13 upland, wetland and aquatic plant communities were identified and mapped (Figure 3 and Appendix A) within the Project Area and buffer. Plant communities, dominant species and acreages within the Project Area and buffer are provided below in Table 2. Results from the vegetation surveys are described in the Stantec Technical Memo *St. Louis River Vegetation Survey* dated April 2, 2015.

Table 2. Summary of Shoreline Plant Communities

	Community	Total Acres	Dominant Species
Aquatic	Deep Water	194.9	Not Surveyed
	Shallow Water	125.89	water lily (*Nymphaea odorata*), duckweed (*Lemna minor*), Canada waterweed (*Elodea canadensis*), naiad (*Najas flexilis*)
Wetland	Alder Thicket	15.05	bluejoint grass, red-osier dogwood (*Cornus sericea*), crested fern (*Dryopteris cristata*), sensitive fern (*Onoclea sensibilis*)
	Cattail Marsh	21.52	hybrid cattail (*Typha X glauca*), reed canary grass (*Phalaris arundinacea*), bluejoint grass (*Calamagrostis canadensis)*, common reed (Phragmites, australis)
	Disturbed Shoreline	0.87	cocklebur (*Xanthium strumarium*), common barley (*Hordeum jubatum*), narrow leaved cattail (*Typha angustifolia*), alkali rayless aster (*Symphyotrichum ciliatum*)
	Hardwood Swamp	34.61	willow (*Salix spp.*), balsam poplar (*Populus balsamifera*), green ash (*Fraxinus pennsylvanica*), alders (*Alnus spp*.), red-osier dogwood
	Wet Meadow	9.75	reed canary grass, fowl bluegrass (*Poa palustris*), Grass-leaved goldenrod (*Euthamia graminifolia*), northern bugleweed (*Lycopus uniflours*), sandbar willow (*Salix interior*), balsm poplar (*Populus balsaminifera*)
	Sedge Meadow	1.15	tussock sedge (*Carex stricta*), bluejoint grass (*Calamagrostis canadensis*), woolgrass (*Scirpus cyperinus*), marsh cinquefoil (*Comarum palustre*), water dock (R*umex orbiculatus*)
Upland	Industrial/Transportation	122.54	Little to no vegetation
	Upland Degraded Forest	5.88	paper birch (*Betula papyrifera*), balsam poplar (*Populus balsmaifera*) green ash (*Fraxinus pennsylvanica*), Scotch pine (*Pinus sylvestris*), glossy buckthorn (*Frangula alnus*), tatarian honeysuckle (*Lonicera tatarica*)
	Upland Degraded Meadow	25.18	Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pretense*), red clover (*Trifolium pratense*), Maximilian's sunflower (*Helianthus maximilianii*), Canada goldenrod (*Solidago canadensis*)
	Upland Meadow	1.87	big bluestem (*Andropogon gerardi*)
	Upland Unvegetated Area	25.46	Little to no vegetation
	TOTAL	584.67	

Rare Species

There were no Federally listed or Minnesota listed threatened, endangered or special concern (TES) species identified within the Project Area. A full site evaluation for TES species and rare plant communities, including a review of Natural Heritage Information System data and additional targeted surveys of the Project Area, may be required during future design and construction phases.

Invasive Species

Invasive species are widespread within the Project Area and are characterized as aggressive non-native plants that reduce habitat diversity and restrict growth of native plant species common to this ecotype. Invasive species with significant populations include hybrid cat-tail (*Typha X glauca*), narrow-leaved cat-tail (*T. angustifolia*), reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), glossy buckthorn (*Frangula alnus*), common buckthorn (*Rhamnus cathartica*) and bush honeysuckle (*Lonicera tatarica*). Hybrid cat-tail is dominant in marshy areas and shorelines of ponds, channels, and the St. Louis River. Reed canary grass is fairly common in wet meadow, cat-tail marsh, and alder thicket communities along shorelines throughout the Project Area. Populations of the other invasive species identified are more limited in extent. Narrow leaved cat-tail was uncommon within the Project Area, found at scattered locations in cat-tail marsh, and occurring locally in disturbed shoreline affected by stormwater. Purple loosestrife is occasional and scattered within the wet meadow and shoreline areas. Glossy and common buckthorn and bush honeysuckle were widely scattered within the Project Area on drier positions within the alder thicket and wet meadow. These woody species were more widespread and occurred locally at higher densities within the Buffer in hardwood swamp, upland degraded forest, and upland degraded meadow. Giant Daisy (*Leucanthemella serotina*) is an introduced perennial forb that occurs in a population of approximately 100 stems in the sedge meadow. This species has been observed to be spreading in northern Wisconsin, and is potentially invasive (Steve Garski, pers. comm.).

While not a dominant invasive, several stands of Phragmites (*Phragmites australis*) were observed in the Project Area. The stands are small and easily controllable and it is highly advised to coordinate the spraying of the invasive as soon as practical. It may also prove useful to coordinate the mapping of these locations with the GIS - database of invasive plants maintained by the Great Lakes Indian Fish and Wildlife Commission (GLIFWC).

2.4. FISH COMMUNITIES

Additional fish community studies were not completed as part of this Focused Feasibility Study, but additional information collected since the completion of the Ecological Design Report were included. NRRI assembled fish community data from existing surveys completed by MNDNR, USEPA, and USFWS as part of *An Ecological Design for the 40th Avenue West Remediation-to-Restoration Project* report, dated August 2012 (revised October 2012).

Based on available catch data from existing surveys conducted by MNDNR, USEPA, and USFWS, the fish assemblage comprises a total 27 fish species (J. Hoffman, J. Lindgren pers. comm.). Fish assemblage catch data from the joint USEPA and USFWS aquatic invasive species early detection surveys from the sampling years 2006, 2008, and 2009 were combined following Peterson et al. (2011). In those three years, 11 sampling events within the Project Area or adjacent shipping channel were conducted. Additionally, catch data from the MNDNR annual gillnet survey data for the same years (2006, 2008, and 2009; two gillnets per year) were combined. The MNDNR reported a fair to good fish community rating. Native species were observed throughout the estuary including in the deepwater habitats associated with dredged slips which provided suitable habitat for native fish species. Eurasian ruffe (*Gymnocephalus cernuus*) is the most prevalent non-native fish species observed which could threaten native walleye and perch populations. Table 3 summarizes combined catch data of most common species from three years (2006, 2008, and 2009) combined following Peterson et al. (2011) and other aforementioned available catch data.

Table 3. Combined Data of Most Common Fish Species

	Species
Combined Catch Data USEPA & USFWS (2006, 2008, and 2009), and Peterson et al. (2011)	spottail shiner (*Notropis hudsonius*)
	bluegill (*Lepomis macrochirus)*
	pumpkin seed (*Lepomis gibbosus)*
	mimic shiner (*Notropis volucellus*)
	troutperch (*Percopsis omiscomaycus*)
	northern pike (*Esox lucius*)
	yellow perch (*Perca flavescens*)
	smallmouth bass (*Micropterus dolomieu)*
	channel catfish (*Ictalurus punctatus)*

	walleye (*Sander vitreus*)
	non-native species (most abundant, Eurasian ruffe (*Gymnocephalus cernuus*)
Combined Catch Data (J. Hoffman, J. Lindgren pers. com.)	spottail shiner (*Notropis hudsonius*)
	rock bass (*Ambloplites rupestris*)
	white sucker (*Catostomus commersonii*)
	walleye (*Sander vitreus*)
	yellow perch (*Perca flavescens*)
Combined Catch Data MNDNR (2006, 2008, and 2009)	rock bass (*Ambloplites rupestris*)
	shorthead redhorse (*Moxostoma macrolepidotum)*
	Eurasian ruffe (*Gymnocephalus cernuus*)
	walleye (*Sander vitreus*)
	yellow perch (*Perca flavescens*)

[1] most common fish comprised 75% of the total assemblage by abundance
[2] compared to the joint USEPA and USFWS data

2.5. SUBMERGED AQUATIC AND FLOATING LEAF VEGETATION

Habitats containing both floating leaved vegetation (FLV) and submerged aquatic vegetation (SAV) species provides high biological productivity throughout the estuary and is characterized by water less than 6 feet in depth. A floating aquatic vegetation survey was conducted as part of the 2014 vegetation survey effort. Approximately 2.2 acres of FLV was identified in the Project Area through a field assessment and aerial mapping.

SAV and FLV plant communities dominated the lower St. Louis River prior to industrialization, but have been substantially altered as a result of dredging, siltation, increased turbidity and wave action. A severe rain event on June 19-20, 2012 resulted in a flush of debris and sediment into the system from streams, and may have resulted in a subsequent decrease in aquatic vegetation cover (C. Reschke, pers. comm.). Aerial imagery from August 2010 shows a greater extent of FLV in the Project Area than was observed in 2014, which may be due to a combination of factors, including siltation and recent high Lake Superior water levels. Water clarity observed in October 2014 varied from clear and brown-stained to highly turbid. Common aquatic plant species identified included white water lily (*Nymphaea odorata*), duckweed (*Lemna minor*), Canada waterweed (*Elodea canadensis*), and naiad (*Najas flexilis*). Results from the vegetation surveys are described in the Stantec Technical Memo *St. Louis River Vegetation Survey* dated April 2, 2015 (Appendix A).

In addition, USEPA sampled SAV in 2011 (Angradi, T.R., M.S. Pearson, D.W. Bolgrien, B.J. Bellinger, M.A. Starry, and C. Reschke. 2013). Data was collected using hydroacoustic survey methods to create predictive models for SAV in the SLRE of western Lake Superior.

The establishment of SAV and FLV based on predictive models analyzing conceptual designs for the Project Area is discussed in Section 3.2.2.

2.6. WATERSHED EVALUATION

A watershed evaluation was conducted to determine possible contamination and hydrological influences on the Project Area. The full results of this evaluation, including recommendations for improving stormwater quality, can be found in a report titled *40th Avenue West Watershed Evaluation* (Appendix C). The recommendations within the report include Best Management Practices (BMP) that can be employed within the Project Area and others that apply to the watershed as a whole. While the Site Team will focus on BMPs that can be employed within the Project Area, the additional recommendations may be useful to the City of Duluth or local watershed groups. Any improvements to stormwater management will ultimately improve water quality in the Project Area.

As part of the evaluation, field surveys were performed to identify sources of potential surface water discharges and to map storm sewer and culvert outfalls, streams, and drainage channels within the Project Area. Field data was compared to online sources as well as GIS mapping provided by the City of Duluth.

The contributing watershed basin of the Project Area is a developed urban area with a mix of commercial, industrial, and residential land use. The watershed boundary is shown in Figure 4. The total land area of the watershed is approximately 1702 acres (2.66 square miles). An approximate breakdown of the land uses of the watershed is shown Table 4.

Table 4. Land Use Areas

Land Use	Area (Acres)	Percentage of Total Area
Open Space	640	37.6
Residential	454	26.7
Commercial/Light Industrial/Warehousing	282	16.5
Industrial	230	13.5
Erie Pier Placement & Reuse Facility	96	5.6
Total	**1702**	**100**

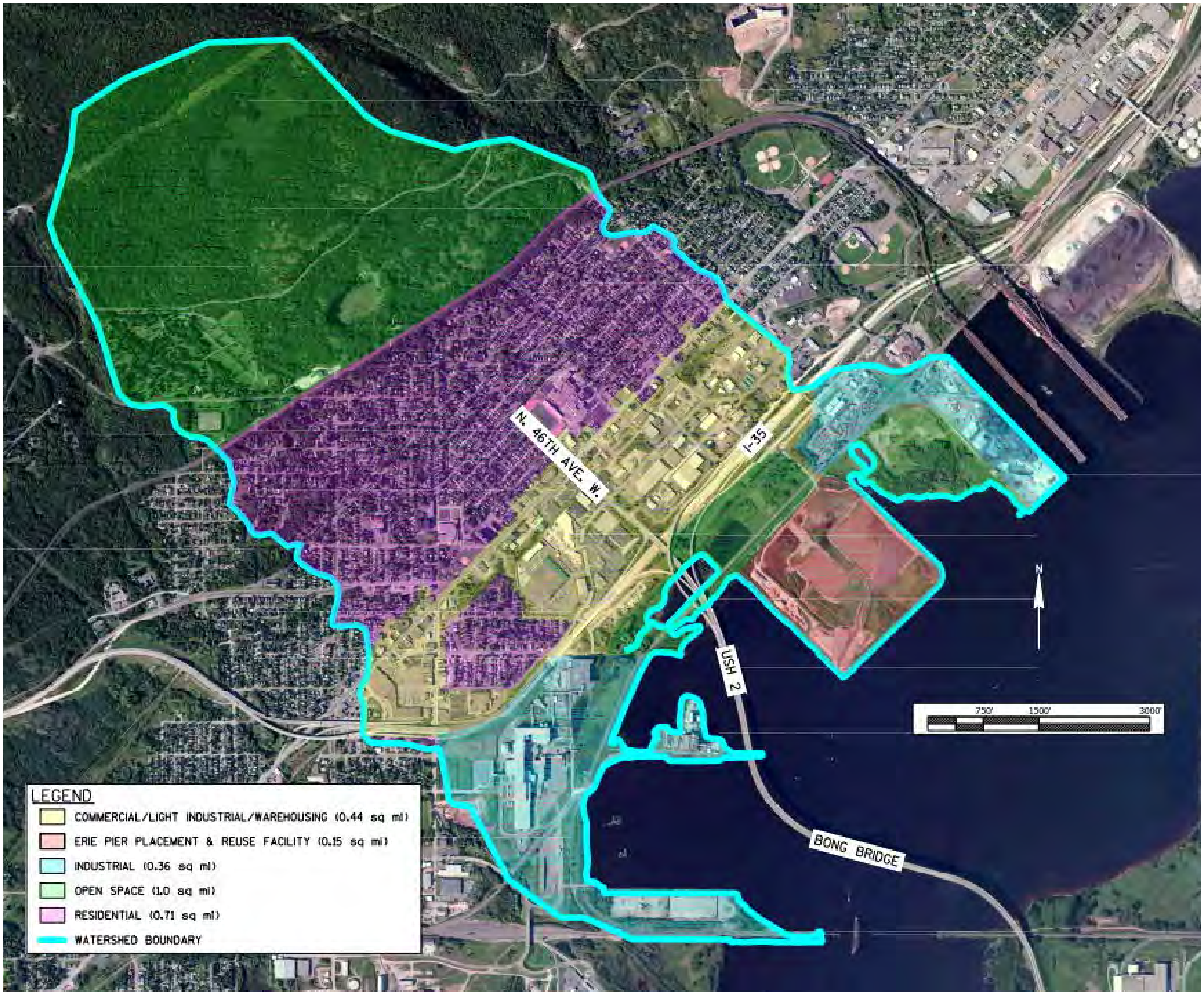

Figure 4. 40th Avenue West Watershed Boundary and Land Use Map

This evaluation determined that potential sources of pollution to the Project Area, although conveyed via storm sewers, are largely nonpoint source originating from the urbanized environment. The watershed report in Appendix C identifies potential sources of nonpoint source pollution within the watershed such as runoff from parking lots and other impervious surfaces. Identifying and mitigating these sources will likely result in the most cost effective means of improving water quality. The watershed report also contains preliminary designs and opinions of probable cost for "end of pipe" stormwater treatment options. These include concepts for the modification of existing ponds behind Erie Pier and construction of a sediment trap for a large city storm sewer near the northwest side of these ponds. Modification of the ponds behind Erie

Pier was identified by the Site Team as being beneficial for the overall improvement of the Project Area. These treatment concepts were not designed to achieve a particular water quality or quantity goal, but rather Best Management Practices (BMPs) were integrated into the designs with the goal of achieving water quality improvements to the Maximum Extent Practicable (MEP) based on site constraints. Opinions of probable cost for the pond modifications ranged from $758,900 to $1,597,400. The estimate for the sediment trap at the stormsewer outfall is estimated at $167,700. These opinions of probable cost do not include the cost of land acquisition or environmental remediation costs for contaminated sediments. Modeling of these BMPs predicted a significant improvement to water quality resulting from their construction. Modeling was conducted utilizing WinSlamm software v10.0. Winslamm is specifically identified as an approved stormwater model in Wisconsin, Minnesota, and other States, and Canadian Provinces. Appendix C and Table 5 show how the modification of the ponds behind Erie Pier can contribute significantly to the reduction of pollutants from the watershed.

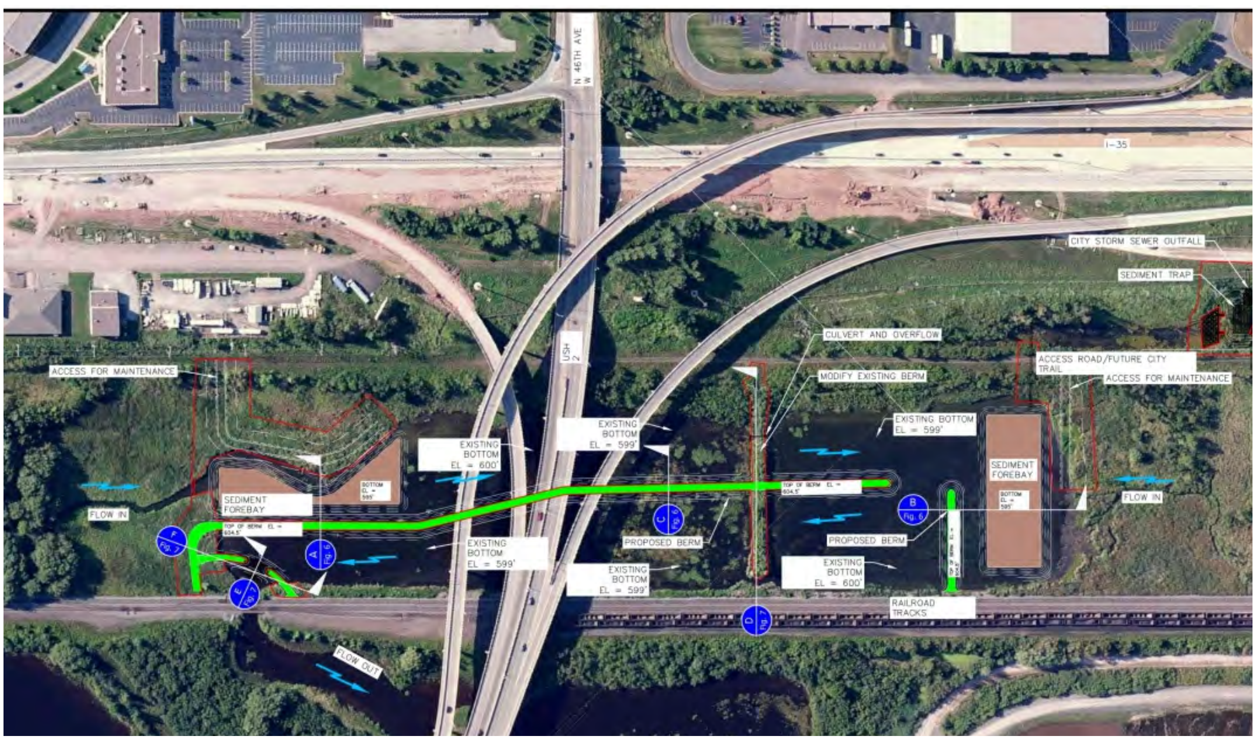

Figure 5. Proposed Erie Pier Ponds Modification

Table 5. Pollutant Reduction Resulting from Modification of the Ponds Behind Erie Pier-Option 1

Pollutant	Pollutant Yield No Controls (lbs.)	Pollutant Yield With Controls (lbs.)	Percent Reduction
Total Suspended Solids (TSS)	1.987×10^6	542,132	72.72%
Total Phosphorus	4,706	2,361	49.83%
Total Kjeldahl Nitrogen (TKN)	17,915	10,883	39.25%
Total Chemical Oxygen Demand (COD)	985,229	525,913	46.62%
Total Copper	486.6	272.4	44.03%
Total Lead	590.5	194.9	67.00%
Total Zinc	1,667	950.8	42.96%

From: Jewell Associates Engineers.2015. 40th Avenue West Watershed Evaluation. Prepared for U.S. Fish and Wildlife Service, Region 3. May 2015

2.7. ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Archaeological and historic property studies are underway for the Project Area. An initial literature search was conducted by USACE Detroit District and identified several expected historic sites within the Project Area of Potential Effects (APE). Two types of historic properties are expected within the APE (Walker and Hall 1976, Ward and McCarthy 1996). Sawmill operations in the late 1800s and early 1900s were located on docks extending from the land over the water; remnants of sawmill and dock structures as well as wood waste debris may be in the APE. In addition, at least one shipwreck has been identified to have sunk in the aquatic part of the APE. Specific locations are still being evaluated and due to concerns for protection of these resources, the potential locations of these resources are not mapped or identified in this FFS.

A phase I survey of the Project Area and other sites in the AOC and a phase II survey of selected sites within the St. Louis River are scheduled for 2015 and will be completed by the USACE Detroit District. It is important the results of the phase 1 and phase 2 work be evaluated against the proposed Preferred Ecological Design as final plans for the site are developed. Adjustments of potential dredge removal and placement areas and shoreline softening areas may necessary.

2.8. GEOTECHNICAL INVESTIGATION AND ANALYSIS

2.8.1. GEOTECHNICAL INVESTIGATION

GEI Consultants, Inc (GEI) and Strata Earth Services conducted a geotechnical investigation at the 40th Avenue West Project Area in September 2014 under a contract with USACE. Sub-samples from each geotechnical boring were provided to Stantec for environmental analyses. A summary of the geotechnical investigation is described below and in the GEI Subsurface Investigation Report – FY14 St. Louis River AOC Geotechnical Investigation – 40th Avenue West, dated January 26, 2015. Boring logs and mapping from the geotechnical investigation report is included in Appendix D. Figure 6 and Figure 7 show the location of the geotechnical and environmental sampling.

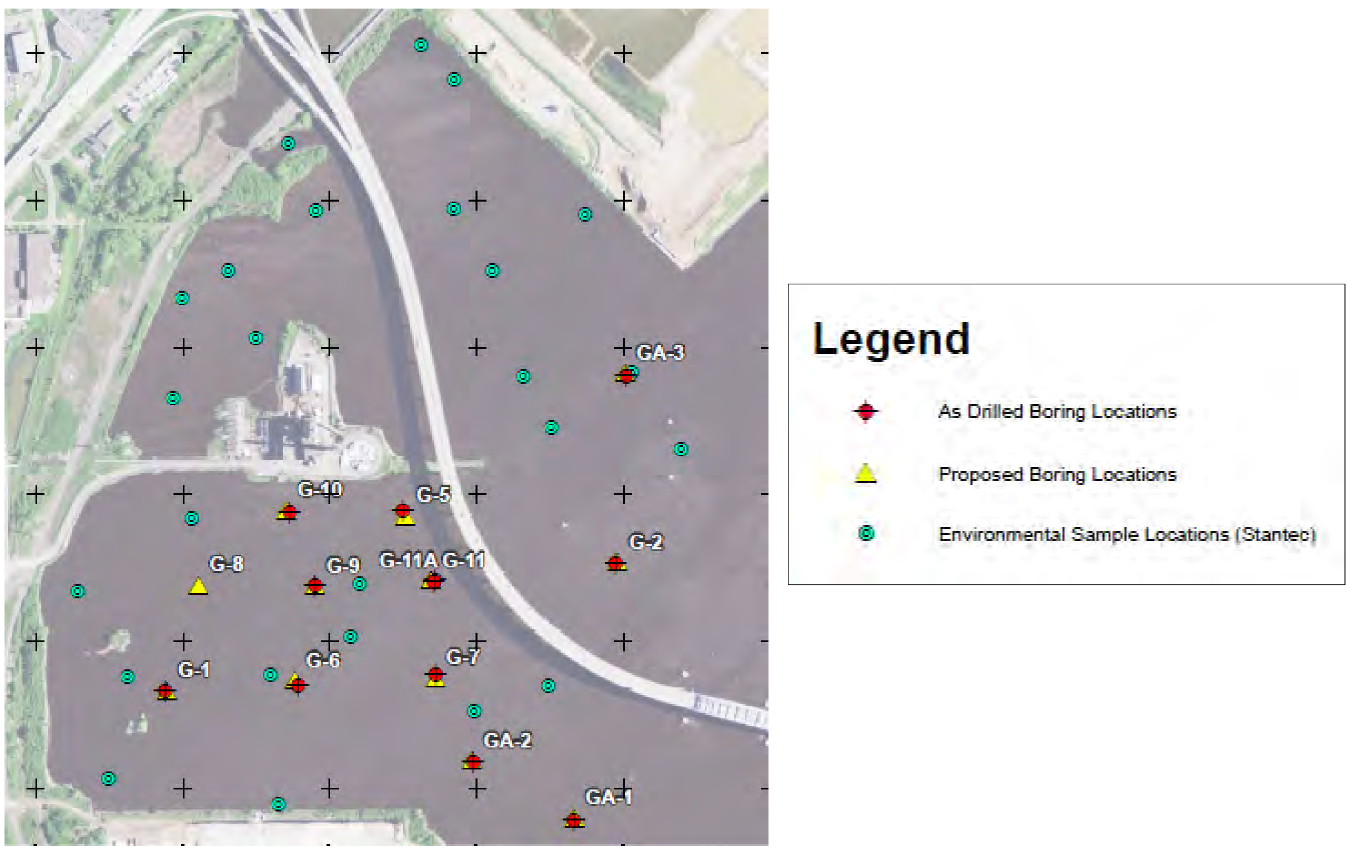

Figure 6. Southern Sediment Investigation Locations
(Source: GEI 2015)

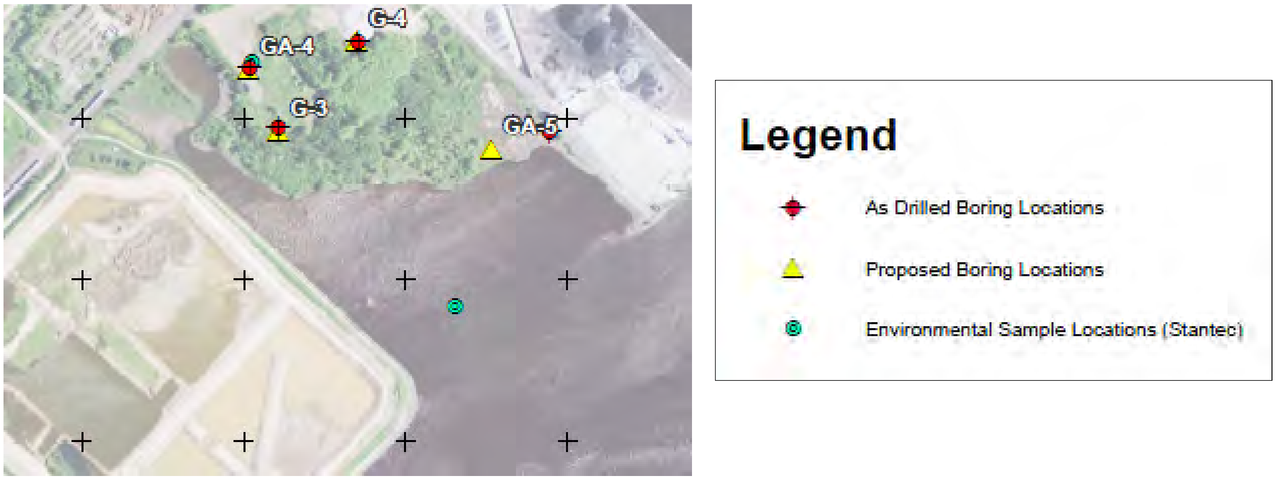

Figure 7. Northern Sediment Investigation Locations
(Source: GEI 2015)

The results of the subsurface conditions were separated into two areas due to the separation distance of 0.75 miles. A total of sixteen (16) borings were completed during the survey. Twelve borings were completed in the southern portion of the investigation area and an additional four borings were completed in the northern portion. The southern investigation area is predominately south of Erie Pier while the samples in the northern portion were on the Hallet Dock property.

The southern investigation area was completed at water depths ranging between approximately 8 and 18 feet in depth. This area generally consists of a variety of interlayed silts, clays and granular material. The total boring depth ranged from 25.2 feet to 83.7 feet from the water surface. Sediments consist of very loose to loose organic silt, silt, and some peat in the western corner of the site. Additional peat is present at depths between 10 and 12 feet (below water surface) in the eastern portion of the site. Beneath the peat, interlayered silt, silty sand, and sand are present. The granular material consists of sand and silty sand, in layers as much as 9 feet thick. High plasticity clay is present at depths greater than approximately 28 feet (below water surface) across the site. There has been some discussion as to whether the material classified as peat is naturally occurring peat or anthropogenic wood waste. Further discussion on anthropogenic substrates is found in Section 2.9.3.

Borings completed in the northern investigation area were drilled on land. These borings ranged from 25.0 feet to 31.5 feet in depth. Fill material, as much as 11.5 feet thick, consisting of silty sand, sand with gravel, sand with wood fragments, sand with silt and crushed limestone was encountered at these boring locations. Sand and stiff to hard clay soils were encountered underlying the fill. Underlying the sand and clay layers, a layer of wood chips and peat up to 7 feet thick is present. The fill and wood/peat is underlain by silt, silty sand, and clay.

Soil samples were delivered to the GEI geotechnical laboratory in Woburn, Massachusetts for testing of a variety of engineering properties including; visual classification, moisture content, hand penetrometer, Atterberg limits, sieve and hydrometer (combined) analysis, direct shear, U-U (Q) test, one dimensional consolidation, and percent organic (loss on ignition). Results of the soil sampling testing are summarized in the referenced GEI Subsurface Investigation Report.

2.8.2. GEOTECHNICAL ANALYSIS

A preliminary settlement analysis of the substrates was conducted for the purpose of analyzing the effects of fill placement associated with barrier island or shoal construction (Appendix D). The analysis was conducted by the USACE Detroit District at the request of the Site Team. The analysis was performed for the location with the subgrade most prone to settlement near boring G-7. A proposed island or shoal at this location is estimated to settle between 1 and 4 feet. It is estimated most of this consolidation (1to 3 feet) will occur in the first two years of placement. Up to an addition foot of settling may continue beyond five years of placement. The analysis recommends that “based on the potential for subgrade settlement and consolidation, additional placements (beyond the initial island creation placement) of dredge material on the created islands to maintain target elevations may be required.”

This analysis was preliminary in nature and was completed to a level appropriate for a feasibility study. Further analysis will be required as the Project Area moves towards the final restoration design.

It is important to note the analysis assumed material placement of similar consistency to maintenance dredging materials, which is a mix of silts and sand. Construction of islands or shoals with the soils dredged from the Project Area may create additional challenges including significant settlement. Silts and sands are available at depth in portions of the Project Area so careful evaluation of available materials is recommended.

Settlement of nearshore placement of dredged materials was not analyzed. Upon conferring with the USACE Detroit District, for the purposes of this FFS, 1 foot of settlement was assumed for nearshore dredge placement.

2.9. SUBSTRATE ANALYSIS AND MAPPING

2.9.1. SUBSTRATE DATA

The substrate data analyzed and mapped for the FFS was gathered from multiple sources. Initial review of substrate was presented in the NRRI Ecological Design Report. Mapping by NRRI was based on hydroacoustic echosounder data collected in April and May of 2010 by the Fond du Lac Resource Management Department. The original Fond du Lac data was separated into 13 classifications. NRRI reclassified substrates into sand, clay, and muck. A map of this data is presented in Figure 8.

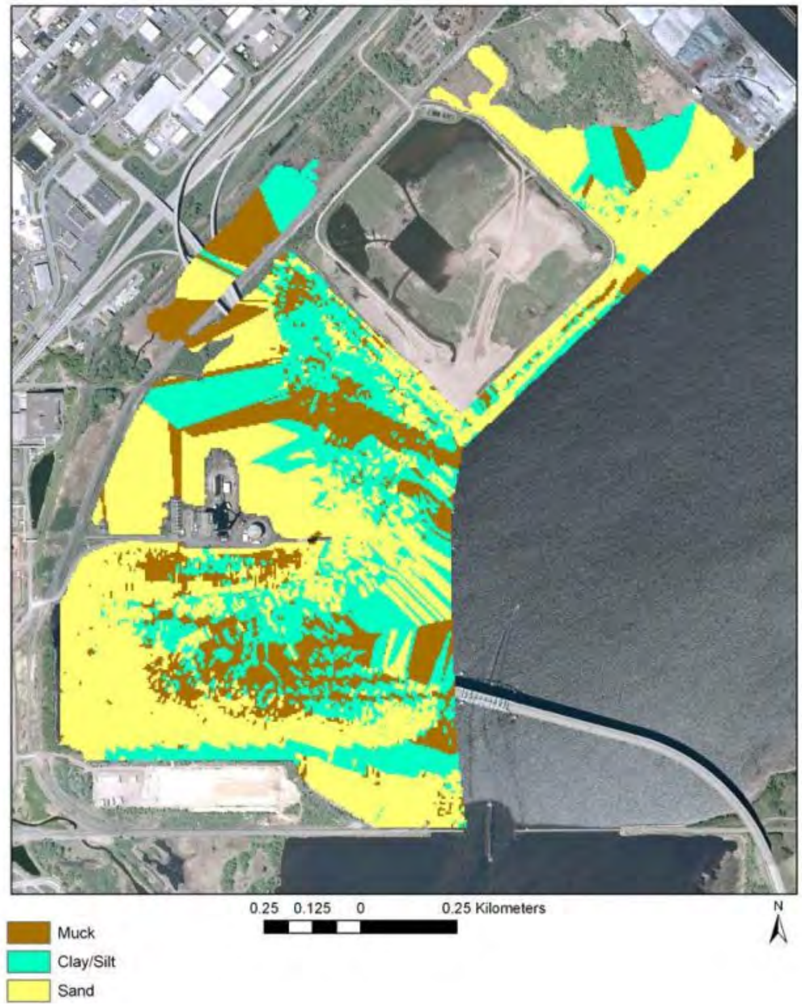

Figure 8. Substrate Classification, Interpolated from Fond Du Lac and NRRI Point Sample Data. (Source: NRRI 2012)

The NRRI mapping provided a characterization of the in situ sediments at the surface of the estuary substrate. One substrate that appears overestimated in the mapping is the area of surficial sands, especially south of the Minnesota Power Hibbard power plant. Not as much sand was encountered during the sediment sampling and geotechnical analysis conducted for this FFS (Figure 9 and Appendix F). There are a couple possible reasons for the difference in results. Wood wastes may have been interpreted as sand or gravel during the ecosounding. In addition Table 1 in the NRRI Ecological Design Report shows that the Fond du Lac classification for “sand/coffee ground mix”, rock, cobbles, and sand were reclassified as sand for mapping purposes.

To expand upon this early mapping, data from several additional sources was analyzed. In addition to the 2014 geotechnical borings by GEI, Jewell used boring logs from the 2014 Stantec analytical sampling and 2010 USEPA analytical sampling to further define the 40th Avenue West substrates. One issue with the multiple sets of boring logs is that different textural classifications were employed. The GEI data was presented in the USCS (Unified Soil Classification System) format. The Stantec and USEPA data used USDA soil texture classifications based on field observations. Jewell reclassified all the boring data to USCS format. For future work in the AOC, a standard classification for substrates should be established.

A total of 60 borings were used to create computerized models of the substrates for the purpose of mapping and determining substrate type volumes in dredge areas. All the GEI borings and Stantec borings south of Erie Pier were utilized to create the model (Figure 6). The USEPA borings were used to fill data gaps within the limits of the model. No substrate texture modeling was conducted north of Erie Pier as no work is proposed for that area with the 40th Avenue West Project. The borings were used to create the model and resultant mapping employing the Autodesk Civil 3D 2014 geotechnical software module. The geotechnical software employed allowed for ease of coordination with existing and proposed bathymetric models as well provides a greater likelihood the models may be compatible with the work of future designers.

2.9.2. NATIVE SUBSTRATES

Using the 2014 geotechnical and environmental borings as well as 2010 USEAP boring data, maps of substrates at various depths were created that show locations of sands, peat, clay, silts and organic silt (muck). The maps are found in Appendix F. Figure 9 shows a map of the substrates on the surface of the estuary bed south of Erie Pier. Wood waste was found throughout the project limits. It is believed much of the peat may be the result of decomposed wood waste. Although both materials are soft and unconsolidated, the peat encountered differs from the organic silt in that it has a much higher organic content. Further discussion on wood wastes is found in the section on anthropogenic substrates starting on page 30.

The substrates vary throughout the Project Area. South of the Minnesota Power Hibbard power plant, the substrates in the first 3 to 5 feet of the surface are primarily silts, peat and organic silt (muck). The peat will be discussed in greater detail in the discussion on anthropogenic materials in Section 2.9.3. In the northwest corner of the bay closer to the Hibbard power plant, there are pockets of silty sand. Throughout the bay, sands and clays are present at greater depth; however, most of these material lie below the intended depth of excavation and are below the potential bioactive zones.

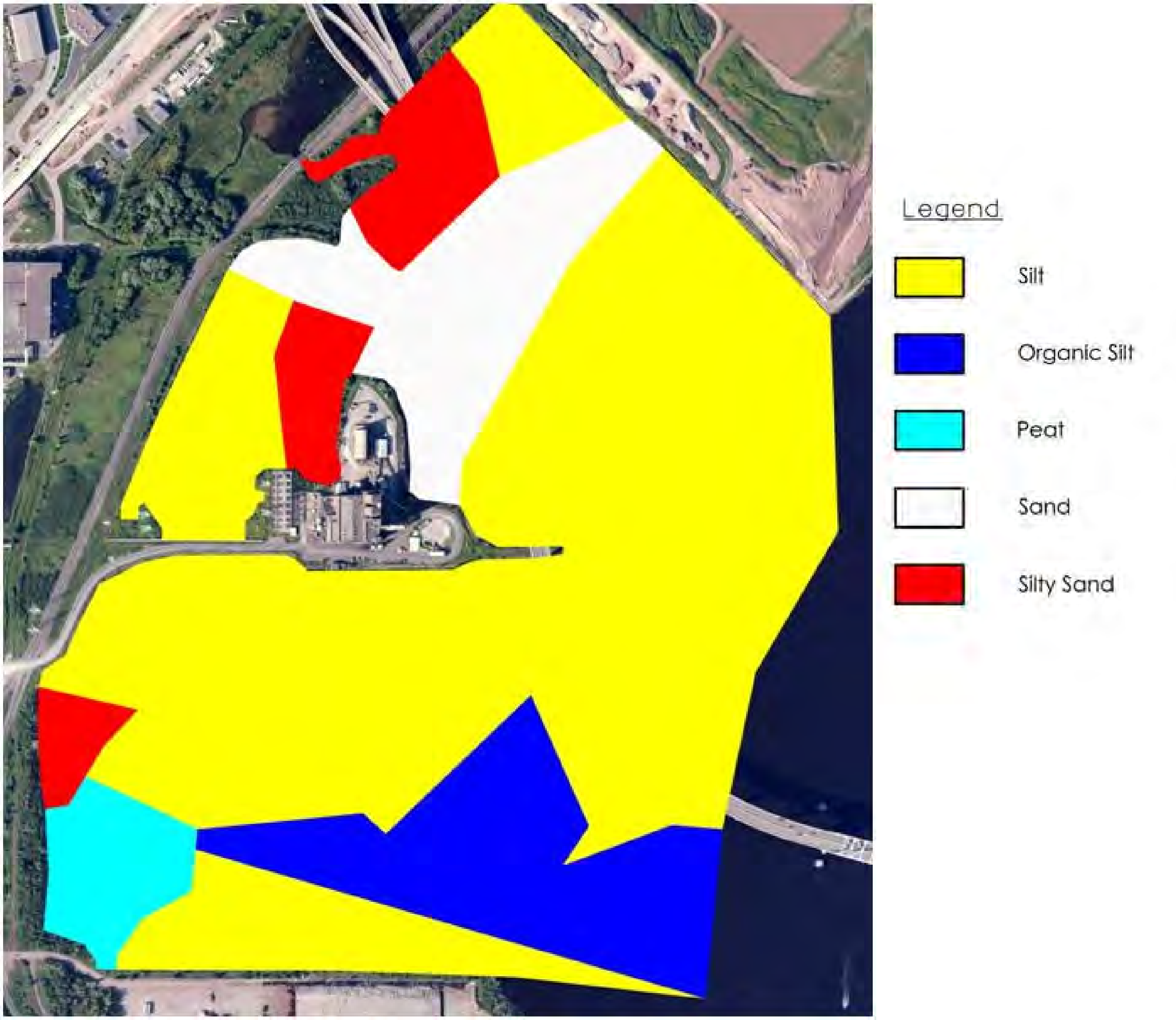

Figure 9. 40th Avenue West Surficial Substrates (0 to 0.5 feet)

North of the Minnesota Power Hibbard power plant to Erie Pier, significantly more sand and silts and significantly less peat and organic silt was observed. Sands mainly were located closer to the north side of the Hibbard power plant, while silt is present along Erie Pier and east of the Hibbard power plant. As discussed in the *40th Avenue West, Duluth, MN Sediment Chemistry, Bioassay, Tissue Bioaccumulation, and Benthic Community Assessment Report* prepared as part of this FFS (Appendix G), chemical contamination more readily binds to silty substrates and less to sandy substrates. This may explain why the substrates in the sandy channel leaving the ponds behind Erie Pier show little sign of contamination while the silts north of this location have higher levels of contamination. This finding is discussed in further detail in the referenced report.

2.9.3. ANTHROPOGENIC SUBSTRATES

Sediment sampling was conducted in the fall of 2014 to further define the extent of anthropogenic substrates present in the Project Area. There are two primary forms of anthropogenic substrates in this area of the estuary, contaminated sediments and wood wastes. Contaminated sediment consists of chemically impacted substrates and is discussed in greater detail in Section 2.10 and the companion report entitled *40th Avenue West, Duluth, MN Sediment Chemistry, Bioassay, Tissue Bioaccumulation, and Benthic Community Assessment Report* found in Appendix G . Wood waste is another significant contributor to anthropogenic substrates in the 40th Avenue West Project Area resulting from historic sawmills and lumber docks located in this area dating back to at least the early 1900's. The Sandborn Fire Insurance map shown in Figure 10 and Appendix E shows lumber docks and a sawmill in the bay south of the Minnesota Power Hibbard power plant. Multiple sources of sediment data indicate a high level of wood waste in this area, which is often referred to as "Coffee Grounds Flats."

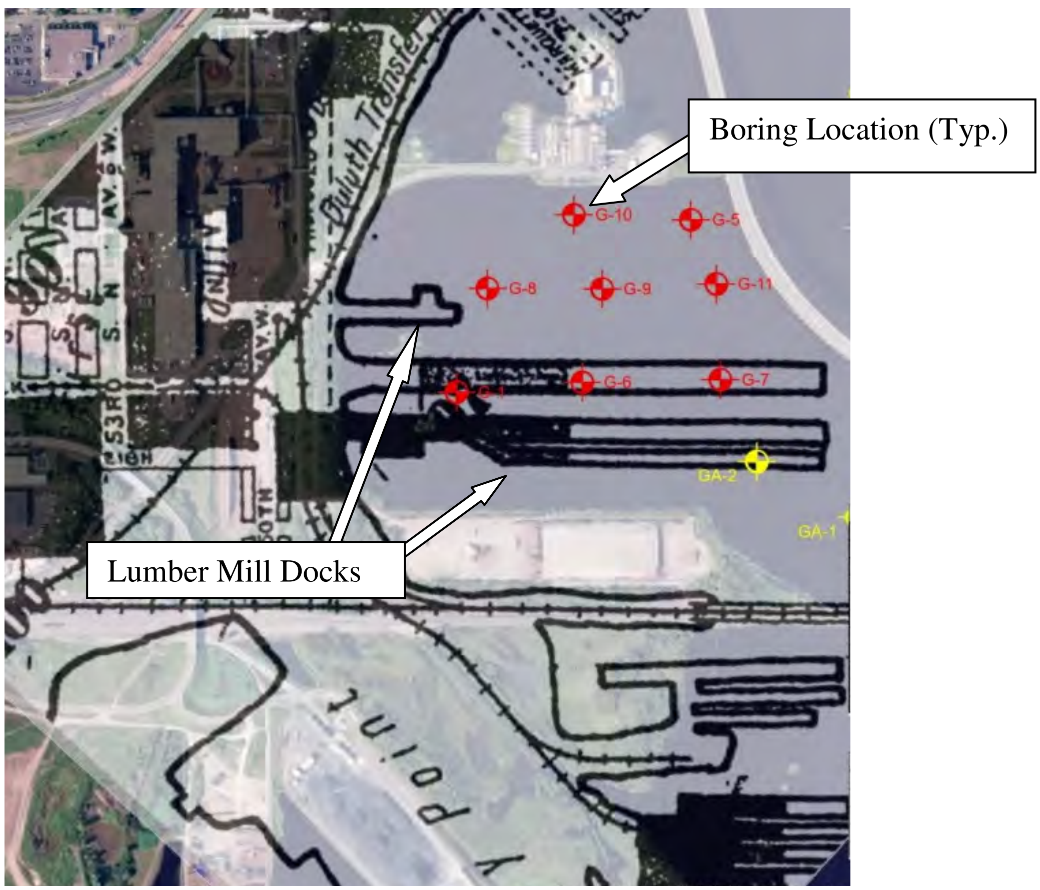

Figure 10. Project Area 1905 Sandborn Map Overlaid on Geotechnical Boring Map
(Source: USACE utilizing Sandborn Company mapping overlay-unpublished)

Multiple sources of data were analyzed to determine the extent of wood wastes, including the 2014 geotechnical borings by GEI, 2014 Stantec analytical sampling, and 2010 USEPA analytical sampling. The material is segregated into three categories based on the size and consistency of wood. Wood pieces are described as wood chunks, trace wood (fine wood fragments), and wood pulp (fine decomposed wood particles). The results indicate wood waste ranges from the surface to 6.6 ft (200 cm) in depth. Figure 11 contains sediment sample locations, wood waste descriptions, and depths at which wood waste was found from the sediment surveys (See also Appendix F).

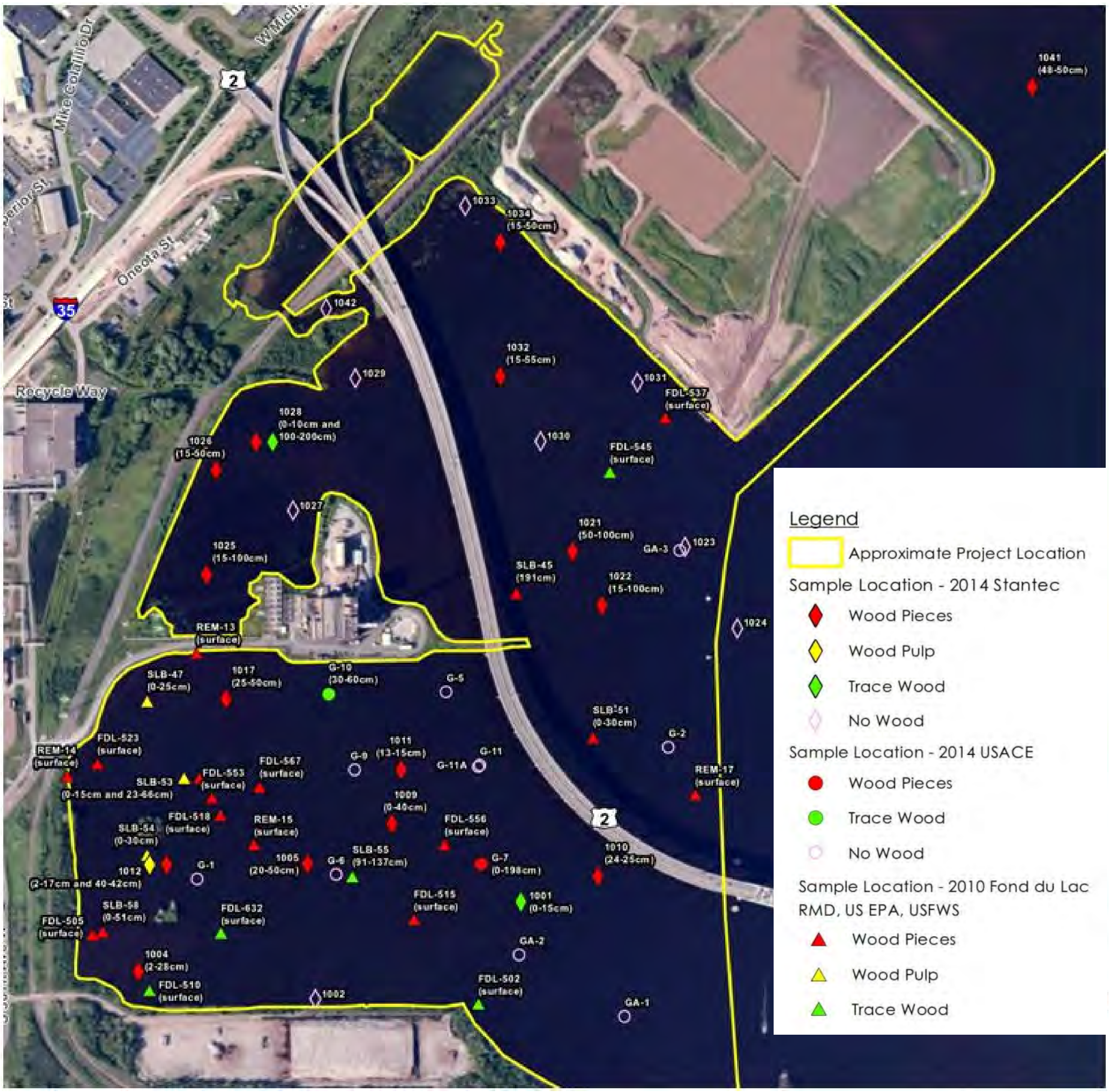

Figure 11. Wood Waste Locations

In addition to the wood waste, a significant amount of the in situ substrate was classified as peat by both GEI and Stantec during the 2014 sampling. This material often contained fibrous materials and was similar in appearance to natural peat. Through discussions with the USACE Detroit District and GEI, it was determined the peat material was likely the result of anthropogenic wood waste. Figure 12 and Figure 13 show examples of wood waste and peat encountered during sediment sampling.

Figure 12. Peat from Boring G-1 Sample 2
(Source: March 20, 2015 GEI Organic Material Photo Log, FY14 St. Louis River Area of Concern Geotechnical Investigation – 40th Avenue West)

Figure 13. Sample 1004 "Wood Waste"

The GEI Report presented the percentage of organic material in 5 select peat samples using ASTM D7348-13, "*Standard Test Methods for Loss on Ignition (LOI) of Solid Combustion Residues*." Table 6 shows organic content within samples containing peat.

Table 6. Organic Content Test Results – ASTM D7348-13

Geotech Boring Number	Sample ID	Depth (ft)	Organic Content %
G-1	2	1.5-3.0	59.9
G-2	4B	8.0-8.5	27.1
G-3	7	15.0-16.5	46.3
GA-2	3A	5.0-6.0	75.9
GA-3	3	5.0-6.0	40.7

Source: GEI Consultants Inc. 2015. Subsurface Investigation Report FY14 St. Louis River Area of Concern Geotechnical Investigation - 40th Avenue West W912P6-14-D-0002, Delivery Order DC01. Prepared for U.S. USACE, Detroit District. January 26, 2015. Depth value was recalculated to reflect depth from surface of substrate.

Based on the sediment samples, there is a significant volume of wood material present within the Project Area, which may be posing a risk to the establishment of vegetation and benthic invertebrate communities. To determine the risk to benthic macroinvertabrates, it was determined that the health of the benthos would be evaluated from the 2014 sediment and bioassay sampling conducted as part of this FFS. Benthos findings are discussed in Section 2.10.2 of this report and the *40th Avenue West, Duluth, MN Sediment Chemistry, Bioassay, Tissue Bioaccumulation, and Benthic Community Assessment Report* (Appendix G).

2.10. ECOLOGICAL RISK ASSESSMENT

Existing ecological risk information, as described in Sections 1.3.1 and 1.3.2, indicated areas of limited sediment contamination within the Project Area. However, recent chemical composition was unknown prior to the FFS. Chemical, toxicological and biological sampling occurred as part of the study, in coordination with the geotechnical investigation, to assess the current risks to fish and wildlife resources that may be present in the Project Area.

In September 2014, sediment samples were collected from twenty-eight (28) locations throughout the Project Area, with twenty-six (26) locations being in-water and two (2) locations being upland. As described in the Sampling Analysis Plan (SAP) (Stantec, 2014), sediment samples were collected at up to four different depths (0-15 cm, 16-50 cm, 51-100 cm, and 101-200 cm) and sent to Pace Analytical Laboratories for chemical analysis. Additionally, surficial sediments (0-15 cm) were also collected and shipped to the appropriate laboratories for whole sediment toxicity tests, bioaccumulation exposure studies, and benthic macroinvertebrate analysis. Water samples were also collected at four (4) locations for total ammonia and sulfide analyses. Sample locations are show in Figure 14. The primary objective of the evaluation was to collect and evaluate environmental chemistry, aquatic toxicity, and benthic community samples in sediment and environmental chemistry samples in near surface water. The data was used, applying a weight of evidence approach, to evaluate the risk and potential toxicity to fish and wildlife resources and to identify potential areas requiring remedial activities to achieve ecological goals.

The following sections provide a summary of results from this investigation. Additional information is provided in Appendix G titled “40th Avenue West, Duluth, MN Sediment Chemistry, Bioassay, Tissue Bioaccumulation, and Benthic Community Assessment Report” prepared as part of this FFS.

2.10.1. CHEMICAL ANALYSIS

2.10.1.1. SURFACE WATER

Water samples were collected and analyzed for pH, dissolved oxygen, temperature, specific conductivity, oxidation reduction potential, and turbidity at all sample locations using a calibrated YSI multiparameter flow-through sonde. An additional set of water samples were collected and analyzed for nitrogen (as ammonia) and sulfides at four of the locations. Collection of these parameters was to assist with determining overall water quality in the Project Area and with determining if wood waste is affecting water quality and posing a risk to fish and wildlife resources. Water quality parameters were generally consistent between the different locations and near background levels within the AOC. Sulfides were below detection limits at all four additional sampling locations, and total nitrogen concentrations were measured between 0.098

mg/L and 0.19 mg/L. Total ammonia thresholds, as identified by the USEPA, are 3.48 mg/L at a pH of 6.5, and 0.25 mg/L at a pH of 9.0. No concentrations were measured above 0.25 mg/L for total ammonia, indicating that total ammonia is not a risk to fish and wildlife resources.

2.10.1.2. SEDIMENT

Sediment samples were collected at twenty-eight locations (Figure 14) and tested for the concentrations of chemicals, including: polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs, calculated as congener sums), polychlorinated dibenzodioxins and furans (Dioxin/Furan, PCDD/F), and a suite of heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc). Samples were collected at up to four different depth horizons (0-15 cm, 16-50 cm, 51-100 cm, and 101-200 cm). Chemical concentrations were compared to two sediment quality targets (SQT's) established by the MPCA and its collaborators (Crane et al. 2000) as preliminary screening values to be used in the weight of evidence approach. The two levels and definitions are:

- Level I SQT: Intended to identify contaminant concentrations below which harmful effects on sediment dwelling organisms are unlikely to be observed.
- Level II SQT: Intended to identify contaminant concentrations above which harmful effects on sediment dwelling organisms are likely to be observed.

For a better understanding as to the overall chemical toxicity of the sediment, Mean Probable Effect Concentration Quotients (PEC-Q) were calculated following methodology in Crane and Hennes (2007). Mean PEC-Q's were calculated for metals (without mercury), PCBs and PAHs. Mean PEC-Qs provide a sediment assessment tool that distills data from a mixture of contaminants into one unitless index. The mean PEC-Q provides a way to compare sediment quality over time and space (Long *et al.* 2006). For toxicity tests, incidence of toxicity tends to increase as the mean PEC-Q ranges increase. High PEC-Q values tend to suggest sediment that is affected by higher concentrations of chemical constituents. The PEC-Q provides a reliable basis for predicting if sediments are likely toxic or not toxic in the St. Louis River AOC (Crane *et al.* 2000, 2002). Because PCBs were largely below detection limits, three PEC-Q calculations were made to best assess potential toxicity of the sediment samples being evaluated:1) using zero as a value for non-detected PCB data, 2), using half the detection value of PCBs, and 3) eliminating PCBs entirely from the quotient.

Dioxin/Furan results were calculated to toxic equivalent (TEQ) values following methodologies in Crane and Hennes (2007) and compared to Level I and Level II SQTs values. These values were calculated for fish toxic equivalency factors (TEFs) based on Van den Berg et al. (1998), as has been done in previous years for studies in the 40th Avenue project site. By calculating TEQs, it provides further weights of evidence to determine if chemical contamination is posing a risk to fish and wildlife resources.

Figure 14. Project Area Analytical Sample Map

Dioxins/Furans were the most commonly detected chemical at levels exceeding the Level II SQT threshold. There were 11 sampling locations in the Project Area in which Dioxin/Furan TEQs were above the Level II SQT thresholds in at least one horizon and were all located in the Project Area south of Erie Pier (Figure 15). Multiple sample locations had TEQs above the Level I SQT threshold at all sampled horizons, including sites; 1001, 1002, 1010, 1017, 1021, 1023, 1024, 1025, 1027, 1030, 1031, 1032, 1033, and 1034. Sampling locations north of Erie Pier had no detections above the Level II SQT threshold.

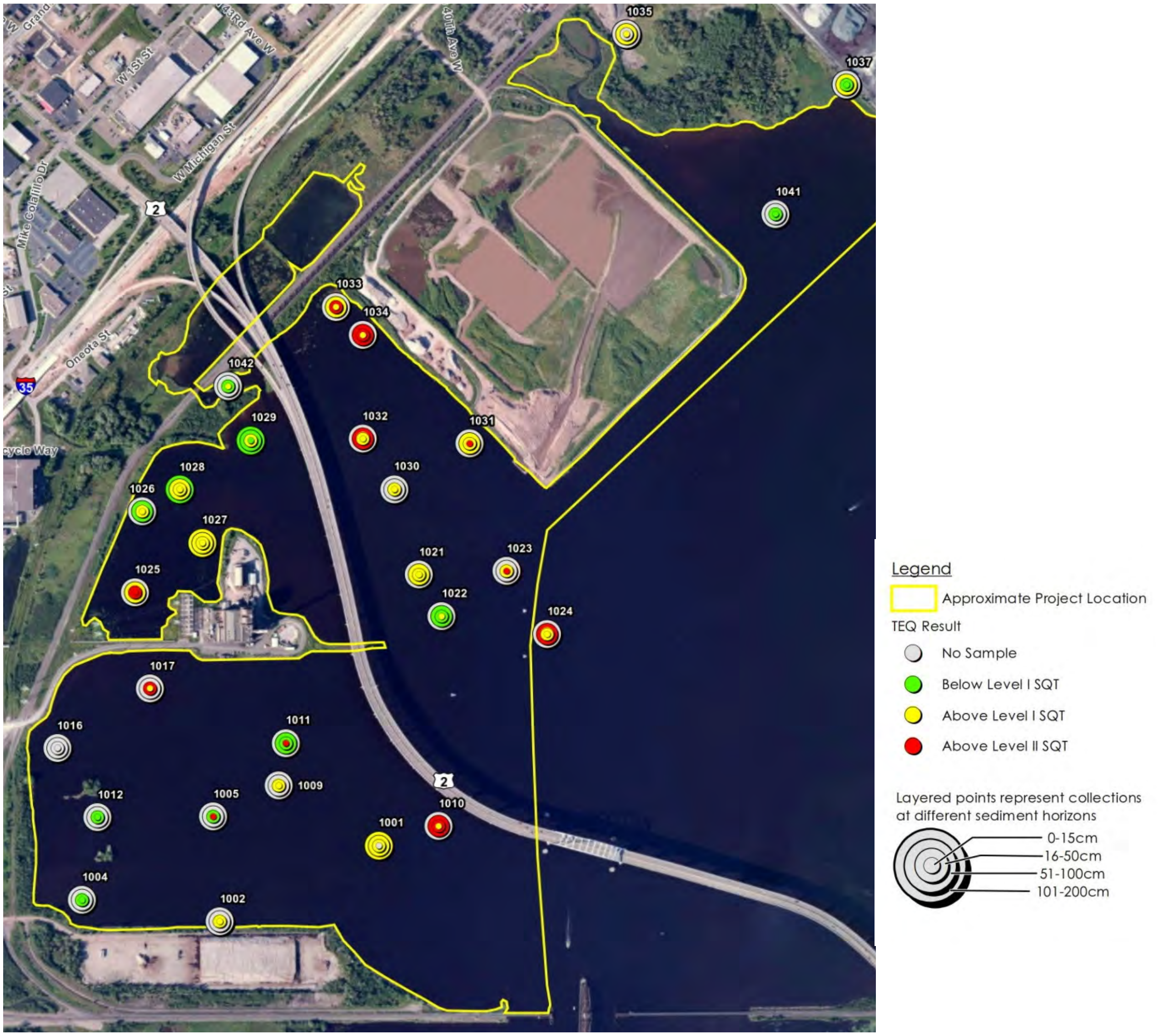

Figure 15. Dioxin/Furan TEQ Results

Metals concentrations in the Project Area were measured at levels above the Level I SQT at multiple sample sites, but had no Level II SQT exceedances. Metals that were detected above the Level I SQT threshold in at least one horizon include: arsenic (5 locations), cadmium (4 locations), lead (6 locations), mercury (14 locations), and nickel (6 locations). Sample locations that had multiple metals detected above the Level I SQT in at least one horizon include; 1025, 1026, 1027, 1032, 1033 and 1034. While no Level II SQT exceedances for metals were noted, it is believed elevated metals may impact the elevated PEC-Q results.

Total PAH concentrations (Figure 16) were also detected above the Level I SQT threshold at multiple sample locations in multiple horizons. There was one station (1026) in which the total PAH concentration was above the Level II SQT threshold, in the 16-50cm horizon. PCB concentrations were largely below the detection limit for the samples collected for all congeners tested. There were concentrations above the Level I SQT threshold at sample locations 1026, 1033, 1034, and 1042. PCBs were not detected above the Level II SQT threshold at any sample location.

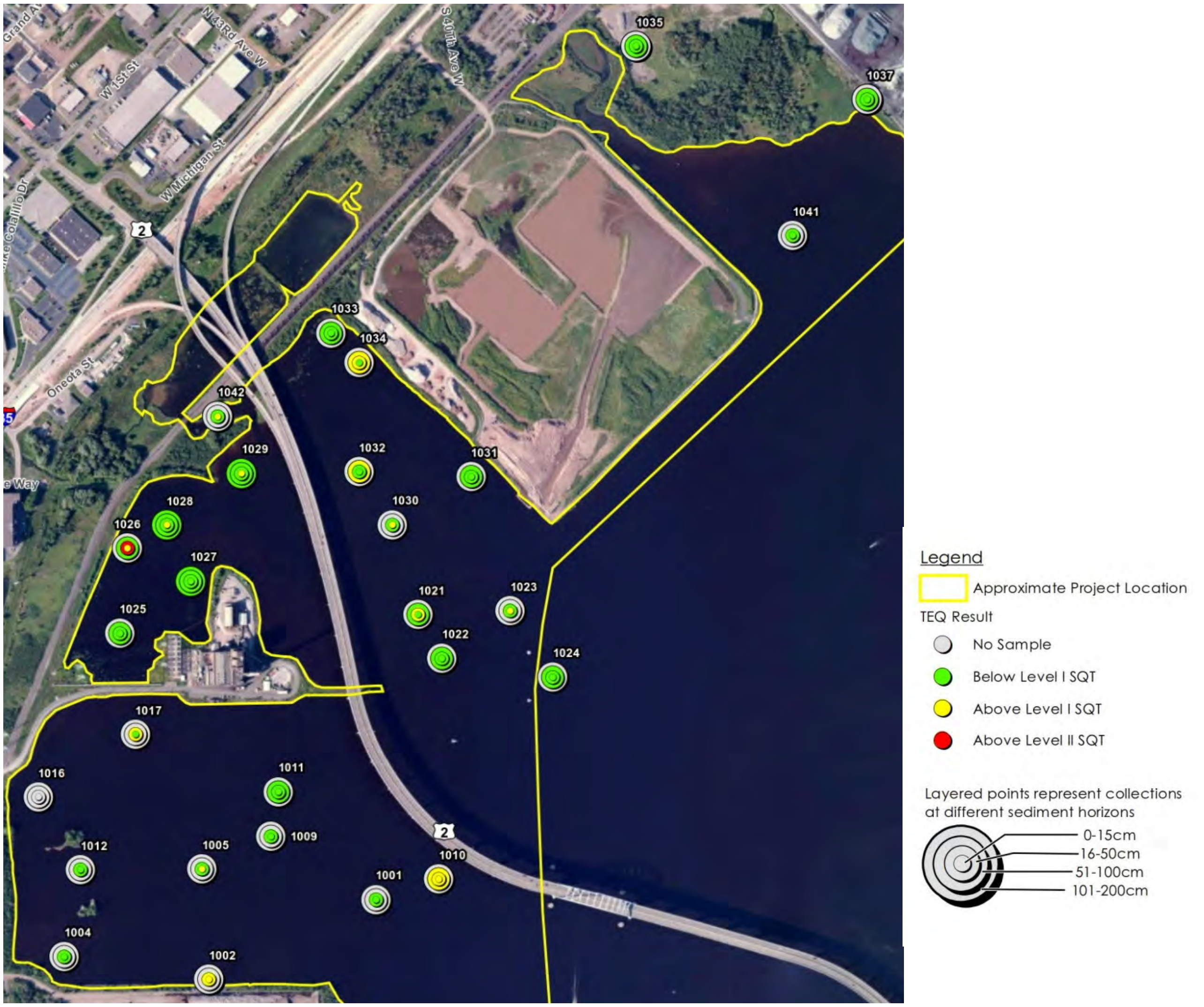

Figure 16. Total PAHs Results

Mean PEC-Q values were calculated only using total PAH and metals because PCBs were largely absent, and the inclusion of PCBs into the mean PEC-Q calculation may under represent the risk to fish and wildlife resources. When mean PEC-Q values (metals and total PAH, Figure 17) were screened against SQT thresholds, nineteen of the sample locations had Level I SQT exceedances in at least one horizon, with eighteen of the sample locations having exceedances in the surficial (0-15 cm) horizon. At one location (1026), the mean PEC-Q was above the Level II SQT threshold in the 16-50 cm horizon. When PCBs were included in the mean PEC-Q calculation, eleven sample locations had Level I SQT exceedances in at least one horizon, with eight sample locations having exceedances in the surficial horizon.. These exceedances should be attributed to total PAH and metal concentrations in samples, not PCB concentrations. There were no Level II SQT exceedances when PCBs were included in the mean PEC-Q calculations. While the mean PEC-Q value provides a sediment assessment tool that distills data from a mixture of contaminants into one unitless index, it is important to remember that the mean PEC-Q does not take into account dioxins/furans nor mercury, which also appear to be constituents of concern.

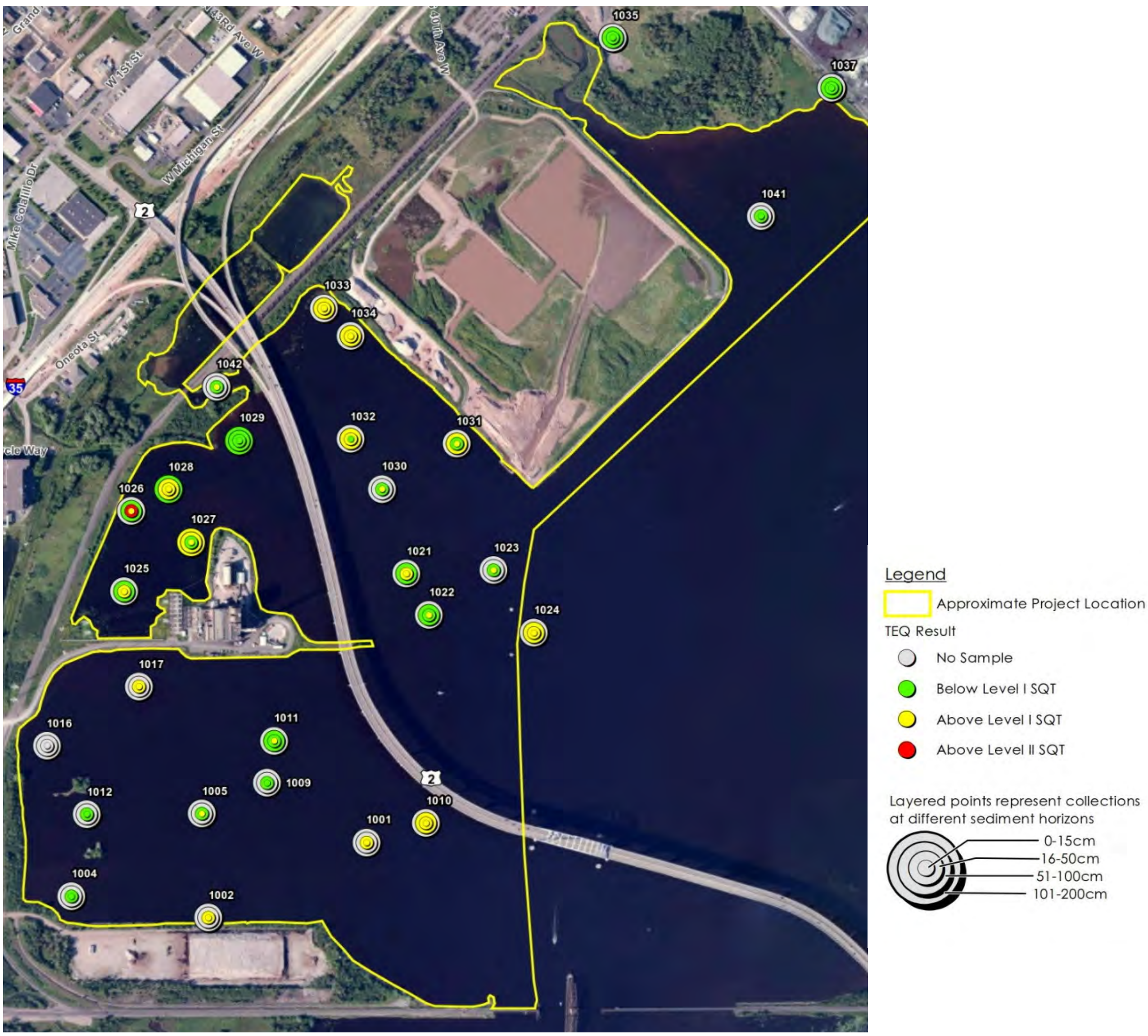

Figure 17. Mean PEC-Q (Metals and PAH)

2.10.1.3. PHYSICAL SEDIMENT CHARACTERIZATION

Sediment samples were evaluated for grain size and sediment composition was described. The distribution of grain size varied among the locations, with sample locations 1028, 1029, and 1042 being comprised of 75% or greater sand, while the remaining locations were comprised of 50% or greater silt. Clay was a minor constituent of the overall sediment texture at all sample locations. Wood particles and chips were identified within different horizons of samples throughout the Project Area. Some woody particle material was related to natural peat in the sediment while other particles were from anthropogenic influences. In particular, the area known as "Coffee Ground Flats" had a high incidence of wood chips in sediment samples.

2.10.1.4. WHOLE SEDIMENT TOXICITY TESTS

Surficial sediment (0-15 cm), collected concurrently with sediment chemistry and benthic community samples, were used for whole sediment toxicity tests. Toxicity tests included the *Chrionomus dilutes* 10-day exposure (Table 7) and the *Hyallela azteca* 28-day exposure (Table 8). Survival, growth, and biomass were recorded during both exposures, and site sample results were compared to a laboratory control and an in-site control (location 1041). The in-site control was chosen prior to sampling because it was expected to have sediment characteristics similar to the rest of the Project Area, but have no chemical contamination. These assumptions were confirmed by pre-assessments (see above). The laboratory control and in-site reference had between 95% and 100 % survival in both toxicity tests.

Survival for the Project Area samples were generally over 80% in both toxicity tests, except locations 1001 (73.8%) and 1005 (78.8%) for *C. dilutes* tests and 1042 (50%) for *H. azteca* tests. However, eighteen of the twenty-one locations showed a significant decrease in survival as compared to the laboratory control for the *C. dilutes* tests, and nine of the twenty-one locations showed a significant decrease compared to the in-site reference location. For the *H. azteca* test, eleven of the twenty-one locations had significantly lower survival compared to the laboratory control, and three of the twenty-one locations were significantly lower than the in-site reference. Growth and biomass were significantly reduced for all locations compared to the laboratory control for the *C. dilutes* test, but there were no differences between the in-site reference and sample locations. For the *H. azteca* test, growth and biomass were also significantly reduced as compared to the laboratory control, with nine of the twenty-one locations significantly lower than the in-site reference for growth, and eleven of the twenty-one locations significantly lower than the in-site reference for biomass. These results indicate that while survival may be relatively high (> 80%), growth and biomass of organisms may be being impacted at multiple sites in the Project Area in the surficial (0-15 cm) sediments.

Table 7. 10-day *Chironomus dilutus* Survival and Growth

Sample I.D.	GLEC No.	Percent Survival (%)	Growth (average mg)	Biomass (average mg)
GLEC Lab Control*	Lab Control 124	100	1.3275	1.3275
SS-1041-AT site ref^	10254	96.3	0.8089*	0.7743*
Water Only	Secondary Control	92.5	0.9085	0.8434
SS-1022-AT	10207	83.8*^	0.7972*	0.6646*
SS-1024AT	10208	87.5*^	0.9486*	0.8255*
SS-1031-AT	10222	92.5	0.9225*	0.8489*
SS-1032-AT	10209	96.3*	0.7603*	0.7326*
SS-1021-AT	10210	90.0*	0.8720*	0.7809*
SS-1026-AT	10212	98.8	0.9343*	0.9222*
SS-1028-AT	10213	92.5*	1.0318*	0.9515*
SS-1025-AT	10214	93.8*	0.8855*	0.8300*
SS-1010-AT	10215	85.0*^	0.9554*	0.8103*
SS-1029-AT	10216	96.3*	0.8938*	0.8599*
SS-1001-AT	10217	73.8*^	1.0638*	0.7621*
SS-1042-AT	10218	92.5*	1.0645*	0.9788*
SS-1009-AT	10219	86.3*	1.0784*	0.9120*
SS-1017-AT	10220	95.0*	0.9687*	0.9184*
SS-1011-AT	10221	86.3*^	0.9029*	0.7740*
SS-1033-AT	10223	91.3*	1.0127*	0.9158*
SS-1034-AT	10224	88.8*^	0.9064*	0.8024*
SS-1002-AT	10225	87.5*^	0.9279*	0.7986*
SS-1005-AT	10226	78.8*^	0.8728*	0.6894*
SS-1012-AT	10256	82.5*^	0.9732*	0.8134*

*Statistical difference for investigative sediment sample when compared to GLEC Lab Control.

^ Statistical difference for investigative sediment when compared to Site Reference.

Table 8. 28-day *Hyallela azteca* Survival and Growth

Sample I.D.	GLEC No.	Percent Survival (%)	Growth (average mg)	Biomass (average mg)
GLEC Lab Control*	Lab Control 124	98.8	0.4036	0.3977
SS-1041-AT-sitef ref^	10254	95.0	0.1917*	0.1820*
Water Only	Secondary Control	90.0	0.2420	0.2201
SS-1022-AT	10207	92.5*	0.1169*^	0.1083*^
SS-1024-AT	10208	93.8*	0.1606*^	0.1503*^
SS-1031-AT	10222	93.8	0.1603*	0.1492*
SS-1032-AT	10209	90.0*	0.1538*	0.1384*^
SS-1021-AT	10210	87.5*	0.1301*^	0.1132*^
SS-1026-AT	10212	88.8*	0.1911*	0.1700*
SS-1028-AT	10213	87.5*^	0.1961*	0.1747*
SS-1025-AT	10214	87.5*	0.1667*	0.1457*
SS-1010-AT	10215	96.3	0.1308*^	0.1252*^
SS-1029-AT	10216	95.0	0.1825*	0.1726*
SS-1001-AT	10217	96.3	0.1573*^	0.1513*^
SS-1042-AT	10218	50.0*^	0.4101	0.1865*
SS-1009-AT	10219	87.5*	0.1620*	0.1401*^
SS-1017-AT	10220	92.5	0.1581*^	0.1450*^
SS-1011-AT	10221	83.8*^	0.1568*^	0.1304*^
SS-1033-AT	10223	92.5	0.1752*	0.1621*
SS-1034-AT	10224	95.0	0.2382*	0.2243*
SS-1002-AT	10225	93.8	0.1837*	0.1730*
SS-1005-AT	10226	90.0*	0.1553*^	0.1386*^
SS-1012-AT	10256	95.0	0.1373*^	0.1309*^

*Statistical difference for investigative sediment sample when compared to GLEC Lab Control.
^Statistical difference for investigative sediment when compared to Site Reference.

2.10.1.5. TISSUE BIOACCUMULATION

Lumbriculus variegatus 28-day bioaccumulation tests were conducted using surficial sediment collected at the same locations as the toxicity tests. Following exposure, the surviving *L. variegatus* were depurated for 24 hours in overlying water to purge gut contents, weighed and tissues were analyzed for chemical concentrations. Tissues were tested for the same suite of chemicals as the sediment samples.

Metals in *L. variegatus* tissues (Arsenic, Barium, Cadmium, Chromium, Copper, Lead, Mercury, and Nickel) indicated low levels of uptake of these contaminants. Similarly, PCB tissue concentrations indicated low uptake and sediment results for the majority of congeners were non-detectable. Tissue concentrations of PAHs were low and often below laboratory reporting detection limits. However, dioxin and furan congeners showed a range of uptake, and all tissues contained concentrations of dioxin and furan congeners. The presence of these contaminants in the tissues of *L. variegatus* presents a pathway of exposure for fish and wildlife resources.

Bioaccumulation was calculated for the *L. variegatus* tissues by dividing the worm tissue concentrations by sediment concentrations. Following USEPA Biota-Sediment Accumulation Factor protocols, tissues tested were lipid normalized. Results show that for dioxins/furans and total PAHs, this species had inconsistent uptake of the chemicals as the sediment chemical concentrations increased. However, several of the individual dioxin and furan congeners showed positive correlations of uptake in the tissue as compared to the sediment, and several of the stations that showed increased uptake of individual dioxin and furan congeners were from locations where sediment concentrations exceeded Level I or Level II SQT thresholds.

2.10.1.6. SOIL SAMPLES

Soil samples were collected for total ammonia and sulfides analysis at two locations. Collection of these samples was to assist with determining if decomposing wood waste was affecting the property north of Erie Pier. Sulfides were undetectable and total nitrogen concentrations were low. It has since been determined no work will occur on or near this property as part of the habitat restoration efforts in the Project Area.

2.10.2. BENTHIC COMMUNITIES

Macroinvertebrate sediment samples were co-located with samples collected for chemistry and toxicity analyses. Macroinvertebrate samples were evaluated to determine current benthic community structure. Samples were sorted, enumerated, and morphological taxonomic identification was performed. . Univariate and multivariate taxonomic metrics were calculated to determine similarity in diversity, composition, and species tolerance to sediment contamination levels between and among stations sampled within the Project area Additionally, data collected as part of the USEPA 2010 St. Louis River Estuary study and described in the Ecological Design Report, including upstream reference locations were also analyzed separately and combined with the 40th Avenue project site macroinvertebrate community data. By using the 2010 Reference locations, this provided a baseline (threshold) for which 40th Avenue community metrics were compared to determine if the status of the Project location is equivalent to or below anticipated biodiversity metrics. Example metrics calculated included abundance, species richness, Ephemeroptera/Plecoptera/Tricoptera (EP1) index, and Shannon-Weiner diversity. An average for each metric was calculated, along with a standard deviation, and site sediment communities were compared to the lower 95% confidence limit of the reference location mean. This method allowed for us to determine how closely the macroinvertebrate metrics from the 2014 site data were to reference locations. Furthermore, it gives a threshold that can be used as an achievement goal with regard to assessing success of future remediation efforts. Macroinvertebrate screening thresholds are shown as a solid line on graphs with the macroinvertebrate metrics.

Macroinvertebrate abundance (number of organisms/m^2) and species richness from the 2014 sampling were similar to the 2010 samples collected within the Project Area, but were lower than the 2010 reference locations (Figure 18 and Figure 19). The same pattern was observed using other metrics for evaluation including; taxa richness, Shannon-Weiner diversity, and EPA index. Dominant macroinvertebrate groups included oligochaetes and chironomids, both considered opportunistic taxa with the ability to tolerate anthropogenically affected sediments. A comparison of 2014 macroinvertebrate communities to the SLROC 2010 study suggest that the macroinvertebrate communities are stable and showed no change toward improvement or decline.

All reference stations had abundance and species richness metrics above their associated thresholds. For the 2010 40th Avenue results for these two metrics only two stations, REM 08c and REM02, had species richness at or above the threshold of 20 taxa and one station (REM08c) approached the threshold. In 2014, only one station (1029) was above the threshold with three stations (1042, 1025 and 1026) approaching 20. These minor differences in species richness are not significantly different when the two years are compared considering the 95% confidence intervals. For abundance of individual macroinvertebrate organisms the threshold value was calculated to be 387 individuals. In 2010, eleven of the twenty (55%) were above this threshold at the Project location. In 2014, nine of the twenty-one locations were above the threshold determined for abundance with two stations near this limit (52%) suggesting there was no significant difference when 2010 benthic macroinvertebrate communities were compared to 2014 benthic communities at the 40th Avenue Project location.

Using the combined benthic metrics, ordinary kriging was performed using data from the 2014 and 2010 sampling locations in the Project Area compared to the lower 95% confidence interval of the average of the benthic metrics from the 2010 reference locations to evaluate the spatial distribution of the metrics across the Project Area. The results show lower macroinvertebrate community habitat quality at multiple locations throughout the Project Area (Figure 20). Areas where these lower quality macroinvertebrate communities were located include the area around "Coffee Ground Flats" (sample sites 1012 and 1017), the area in the southwestern corner of Erie Pier (sample sites 1033 and 1034), and along the eastern edge of the Project Area (sample sites 1024 and 1041). Results are consistent with what was observed in the Progress Report that compared benthic conditions in the Project Area to conditions in "Least Disturbed" areas in the AOC (USEPA 2014a). Sandier sediments were characterized in the area of the pocket marsh system behind Minnesota Power where higher benthic habitat quality was observed. This type of sediment texture not only supports more diverse benthic communities but also has less affinity to bind contaminants when compared to silt or clay particles as was found in the majority of the Project area.

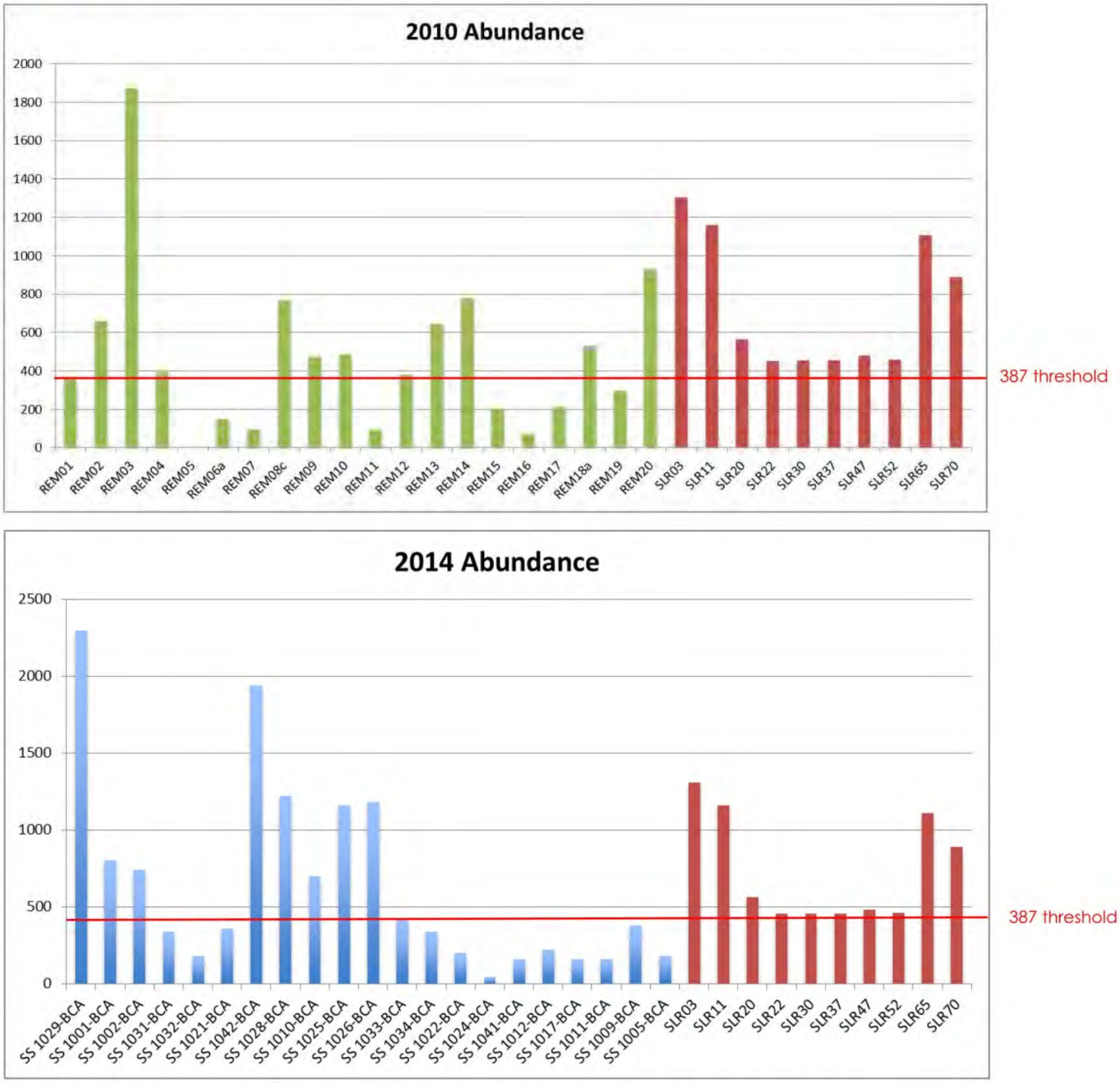

Figure 18. Comparison of Macroinvertebrate Abundance (2010 with SLR Reference Stations and 2014)

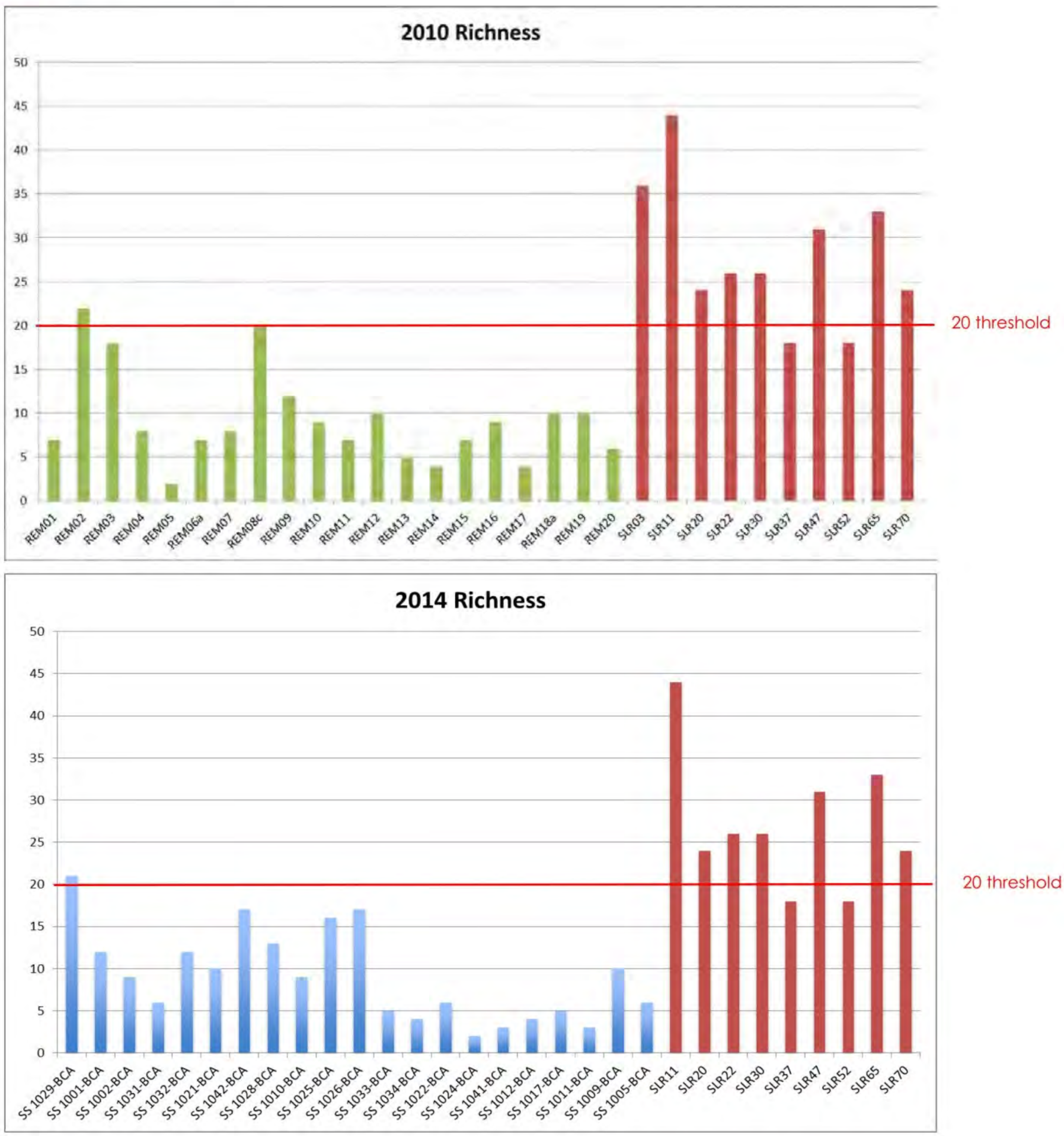

Figure 19. Comparison of Macroinvertebrate Abundance (2010 with SLR Reference Stations and 2014)

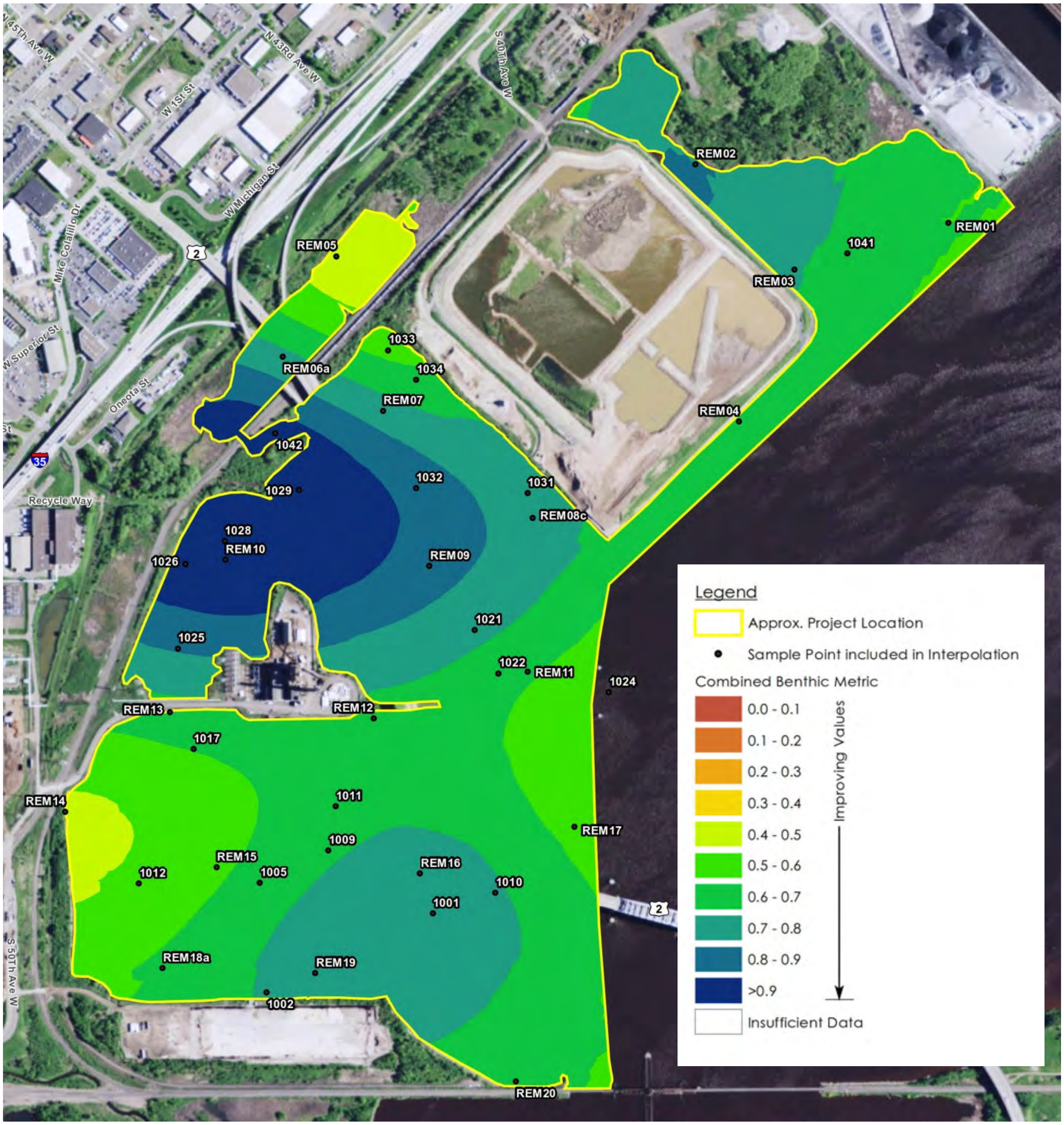

Figure 20. Benthic Kriging Results Combined 2010 and 2014 Data

2.10.3. SUMMARY OF ECOLOGICAL RISK ANALYSIS

The Project Area includes a gradient of sediment chemistry concentrations, which includes locations that have low chemical concentrations presenting a low risk to aquatic organisms to locations with higher levels of contamination presenting a high risk to organisms utilizing this habitat. The Project Area contains a variety of sediment textures and compositions, including high incidences of wood waste, sand and/or silt. Sediment chemistry is correlated to sediment texture across the site because areas with fine silts and clays have a higher affinity to bind contaminants than sediments with sand and coarser grain size particles. The area known as "Coffee Ground Flats", located southwest of Minnesota Power Plant, has a high prevalence of wood wastes with lower levels of chemical concentrations. The area in the southwestern corner of Erie Pier has a high prevalence of silt with higher concentrations of multiple chemicals. Along the western edge of the project site is a system of two ponds in which previous sediment chemistry data indicated elevated chemical concentrations, and has been identified as a "Remediation Site" by the AOC. The two pond system has a narrow opening directly into the southwest corner of Erie Pier in the Project Area. It is hypothesized that the elevated chemical concentrations in the southwest corner of Erie Pier is from the water and sediments that are released from the two pond system.

Throughout the Project Area, dioxins/furans, total PAHs and select metals had variable concentrations with spatial heterogeneity, including several elevated concentrations. The PCB congeners tested showed no detection for the majority of locations sampled. When mean PEC-Q for metals and total PAH are calculated, results indicate that the combination of these contaminants is at levels that may be posing a risk to resources. Although concentrations of some contaminants at certain areas show a reduction when compared to prior sampling years (Phase IV database), the continued elevation of these classes of contaminants indicate that these chemicals should be considered constituents of concern.

Whole sediment toxicity tests indicate that areas within the Project Area are presenting a risk to the benthic community. While survival was often above 80% for sample locations, statistical analyses indicated that there is a significant difference between the in-site reference area and some locations, indicating a risk of detrimental impact to benthic communities. Additionally, multiple sampling locations showed significantly decreased growth and biomass compared to the in-site reference, further indicating risks to benthic communities.

The results of the whole sediment toxicity tests were further supported by the results of the benthic community assessments. When compared to reference locations, results from the 2010 and 2014 sampling events indicate that there are degraded communities in multiple locations of the Project Area. This observation is consistent with what was observed in the Progress Report that compared benthic conditions in the Project Area from multiple sampling events to conditions in "Least Disturbed" areas in the AOC (USEPA 2014a). Sampling locations where benthic communities are lower than the reference locations are also areas where significant differences in survival, growth, and/or biomass were observed. These sites include the "Coffee Ground Flats" area, the area southwest of Erie Pier, and the areas along the western edge of the Project Area.

Bioaccumulation in L. variegatus tissues were more strongly correlated to individual furan congener concentrations than to the overall TEQ or individual dioxin congener concentrations. There was high variability in dioxin tissue concentrations which would explain the low correlation values when comparing tissue concentrations to sediment concentrations. At some locations, including those where sediment concentrations were measured above the SQT I and SQT II thresholds, there was evidence of increased uptake in the tissues. The detection of multiple constituents of concern in L. variegatus tissues indicate that the chemicals are bioavailable and are able to get into the food web from the sediment, although multiple locations indicated low bioaccumulation of the constituents.

2.10.4. AREAS OF ECOLOGICAL CONCERN

Utilizing historic and recent analytical data, a comprehensive and multiple line-of-evidence approach was used to evaluate ecological risks to fish and wildlife resources within the Project Area. Based on this approach five areas of ecological concern have been identified (see map presented in Appendix G). The five ecological concern areas, as described below, identify the elements that indicate a risk to resources and specific management actions to address the risk while meeting the ecological goals for the Project Area.

The five areas of ecological concern are as follows:

1. Coffee Ground Flats (Management Units (MU's) 1 and 3 – see map in Appendix G and Figure 33 on page 75) – Sediment in this MU is primarily anthropogenic wood waste and is providing poor quality habitat for benthic macroinvertebrate communities. Sediment contamination is limited to Station 1002 that is posing a risk to resources, as observed through a decrease in survivability in *Chironomous dilutus*. Recommended management actions include dredging of anthropogenic substrates then filling with sediment suitable to encourage aquatic vegetation growth to create high quality habitat and meet the Preferred Design.

2. The area south of the Minnesota Power Hibbard power plant (MU's 2, 4, 5, & 7) showed low benthic habitat quality, impacts to survival, growth, and biomass, and had exceedances of SQT thresholds for PAHs, some metals, mean PEC-Q and dioxin/furan TEQs at multiple depths. Recommended management actions for this area include remediating via dredging and then placement of clean sediment suitable to encourage aquatic vegetation growth to create high quality habitat and meet the Preferred Design. Sediment should be placed to depths identified in the Preferred Design and include a minimum of 1.0 meter potential

bioactive zone for water depths up to 8 feet, and 0.5 meter potential bioactive zone in areas identified to be below 8 feet in water depth to reduce risk to ecological resources.

3. The area north of Minnesota Power Hibbard power plant and adjacent to the Pond system behind Erie Pier (MU 11) showed exceedances of SQT thresholds for PAHs, some metals, mean PEC-Q, and dioxin/furan TEQs at multiple depths, as well as a decrease in survival at Station 1028 in *Hyallela azteca* as compared to the in-site reference. This area should be addressed through a combination of dredging and filling to meet design goals and ensure a minimum of 1.0 meter potential bioactive in areas identified by the design to be up to 8 feet in water depth, and 0.5 meter potential bioactive zone in areas identified to be below 8 feet in water depth. However, this work should be completed following the remediation of the two pond system.

4. The southwestern corner of Erie Pier (MU 13) had SQT threshold exceedances of total PAH, dioxin/furan TEQ, some metals, and mean PEC-Q. This area also had a decrease in benthic community, and a decrease in survival and biomass as compared to the in-site reference. It is hypothesized that stream flow from the two ponds system behind Erie Pier is being concentrated into this corner. It is advised to address the two ponds system prior to undertaking the suggested management actions for this area. Upon remediation of the two ponds, this area should be remediated via dredging and refilled with substrate suitable for vegetation growth and benthic macroinvertebrate establishment to meet the design goals. The depth of clean material should be consistent with St. Louis River Estuary standards (see above bioactive zone recommendations).

5. The southeastern corner of Erie Pier (MU's 9, 14, and 15) showed dioxin/furan TEQ, total PAH, some metals, and mean PEC-Q exceedances of Level I and Level II SQT thresholds. A reduction in benthic community, survival, growth and biomass were also observed in this area. Management actions recommended for this area include remediation by strategic dredging and the creation of an island consistent with design goals that would provide additional surface area and three-dimensional structure for vegetation establishment, which will help attract macroinvertebrates and subsequently fish, birds, reptiles, and amphibians. The depth of clean material should be consistent with St. Louis River Estuary standards (see above bioactive zone recommendations).

2.11. LAND OWNER OUTREACH EFFORTS

The project goals for a successful restoration of the Project Area included incorporating stakeholder needs and maintaining industrial uses. To facilitate these goals landowner outreach was incorporated into the FFS efforts. Stakeholders with landholdings (see Appendix I) were routinely invited to project meetings and included in substantial correspondence regarding the 40th Avenue West project. Many of these landowners were also engaged during the development of the NRRI Ecological Design Report (EDR) for the 40th Avenue West Remediation-to-Restoration project. During development of the EDR, major corporate property owners (New Page Corporation, Duluth; Hallett Dock Company, Allete/Minnesota Power, CN Railroad, and BNSF Railroad) were contacted by letter and met with in person. A separate public ownership and small business joint stakeholder meeting was held as well. As a result of those interactions, several questions or concerns were discussed and warrant repeating as background for this project. Those interactions can be found in Appendix I.

Representatives of the Minnesota Department of Transportation and Hallet Dock Company participated in some project meetings and presentations throughout development of the FFS. Railroad Companies and the City of Duluth did not respond to invitations to participate or scheduling conflicts arose. One specific attempt to provide additional landowner input during the development of the FFS was a landowner meeting at the MPCA offices in Duluth on June 3, 2015. The purpose of the meeting was to present the progress of the work in the Project Area and to solicit questions and comments from these stakeholders. Representatives of area landowners including; Verso/Newpage, Minnesota Power, Minnesota DOT, Hallett Dock, BNSF Railroad, Canadian National Railroad and the City of Duluth were invited to the meeting. Representatives of Minnesota Power/Allete and Verso/New Page attended the meeting and their comments and concerns were incorporated into Appendix I. Some of the significant comments include:

- New Page has a water intake along Berwind slip used to make snow to pile on logs. Restoration designs should ensure adequate intake capacity for this operation.
- New Page offered that they would like to maintain the option of using the deep-water slip along the pier where they now store logs. This pier, the Berwind Dock, is owned by Minnesota Power and leased to New Page.
- MN Power has concerns regarding potential impacts to intake and outfall water-cooling system. Restoration design alternatives need to provide enough water depth and flow for the cooling system to operate. Two thermal monitors located along this area need to remain mid-stream and mid-depth in accordance with the facility NPDES permit.

2.12. PUBLIC OUTREACH

To date, public involvement has primarily focused on adjacent landowners. General public engagement has largely been through materials distributed through 40th Avenue West project team websites and AOC related presentations and postings. The FFS was presented in a Poster Presentation at the 2015 St. Louis River Summit held on the University of Wisconsin-Superior Campus from March 31, 2015 through April 1, 2015. A copy of the poster is presented below in Figure 21.

Figure 21. St. Louis River Summit Focused Feasibility Study Poster Presentation

In addition to the poster presentation at the Summit, Zachary Jorgenson of the USFWS presented a powerpoint titled "St. Louis River 40th Avenue Complex Remediation-to-Restoration" and Diane Desotelle, Deepa de Alwis, and Dan Breneman of MPCA presented an overview of AOC efforts, titled "St. Louis River Area of Concern Quality Assurance Program Plan for Minnesota Based Projects."

On June 3, 2015, Diane Desotelle of MPCA, Zachary Jorgenson of USFWS, and Matt Steiger of WDNR presented an AOC update to the Duluth Harbor Technical Advisory Committee (HTAC).

Desotelle and Steiger gave overviews of multiple projects within the AOC and their respective statuses. Jorgenson gave a presentation of the work in the 40th Avenue West Project Area. Several questions and comments were received and are included in Appendix K.

Additional public outreach is planned as the project develops, including additional presentations to the HTAC and other community listening sessions.

SECTION 3 - RESTORATION DESIGN

3.1 PLAN DEVELOPMENT

The restoration plan discussed in this section was developed based on previous studies (i.e. Ecological Design Report), ongoing studies by project partners (i.e. USACE geotechnical investigation; USEPA vegetation modeling; and USACE hydraulic modeling), and stakeholder involvement. The plan includes a conceptual design for the entire 40th Avenue Project Area. It is anticipated that this plan may be implemented in phases based upon available funding and which project elements are required to address the needs of the AOC and to meet BUI removal requirements and which elements may be implemented with future projects. Recommendations for construction phasing are found in Section 3.6. Final design and permitting is required prior to construction and adjustments may be necessary based on further stakeholder input.

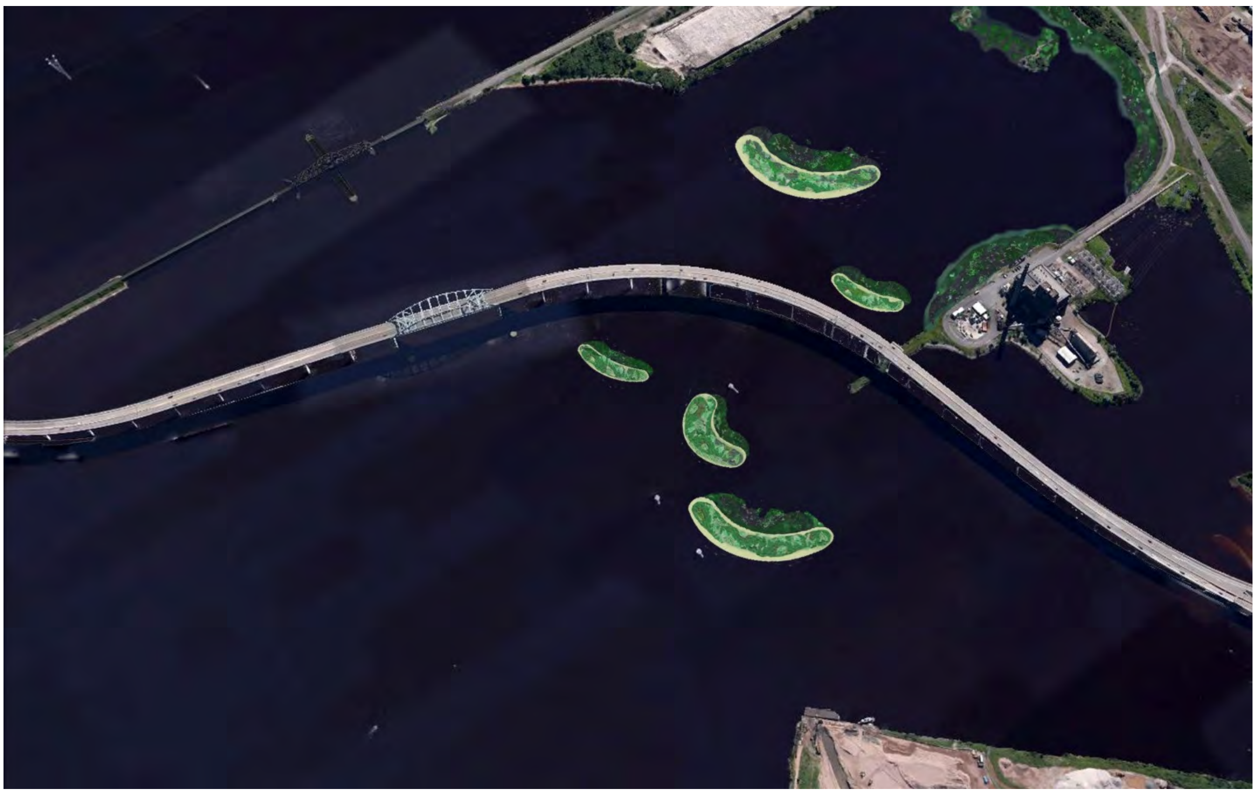

Figure 22. Aerial Rendering of Island Concept Facing Southwest

3.1.1. DESIGN CRITERIA

The restoration plan was developed to achieve the goals and objectives discussed in Section 1.4. The following ecological based design criteria were developed to improve habitat within the Project Area:

1. Remove fish and wildlife exposure to hazardous substances by addressing contaminated sediments
2. Remove anthropogenic substrates to improve benthic invertebrate habitat
3. Create open water habitat
4. Restore with natural substrate (sand or gravel)
5. Create island or shoal habitat to diversify estuary habitat, manage wind fetch, reduce turbidity and improve FLV/SAV habitat
    - Islands up to 3 feet above normal water level with sand substrate
    - Shoals 1 foot to 5 feet below normal water level with sand substrate
    - Emergent habitat 0 foot to 1.5 foot water depths
    - FLV habitat 0.5 foot to 5 foot water depths
    - SAV habitat 4 foot to 8 foot water depths
    - Locate islands 400 feet from shoreline to decrease predation
    - Vary island elevation to promote vegetation diversity
    - Vary island vane length and angle to promote sediment deposition
    - Incorporate woody material to improve nearshore aquatic habitat
6. Create overwinter deepwater fish habitat
    - >8 foot water depths
    - Connect deepwater habitat to adjacent deepwater areas to improve fish movements
    - Locate deepwater habitat near power plant outfall to attract fish during winter
7. Soften shoreline to increase nearshore emergent and FLV
    - Emergent habitat 0 foot to 1.5 foot water depths
    - FLV habitat 0.5 foot to 5 foot water depths
    - Incorporate woody material to improve nearshore aquatic habitat for fish, macroinvertebrates, reptiles and amphibians
    - Establish native emergent vegetation
8. Shoreline naturalization
    - Naturalize existing hardened shorelines
    - Establish native emergent and fruiting scrub-shrub vegetation
9. Implement actions to reduce watershed inputs into the Project Area to protect restored habitat.
    - Remove contaminated sediments from the 2 ponds behind Erie Pier
    - Redevelop the ponds to provide better reduction of watershed influences

3.1.2. INITIAL CONCEPT DESIGN DEVELOPMENT

As previously discussed in Section 1.3.3, the concepts developed for the Project Area are based on previous studies (i.e. Ecological Design Report), ongoing studies by project partners (i.e. USACE geotechnical investigation; USEPA vegetation modeling; and USACE hydraulic modeling), and stakeholder involvement. The initial concept (Figure 23), although not directly presented in the report, originated from the work on the Ecological Design Report.

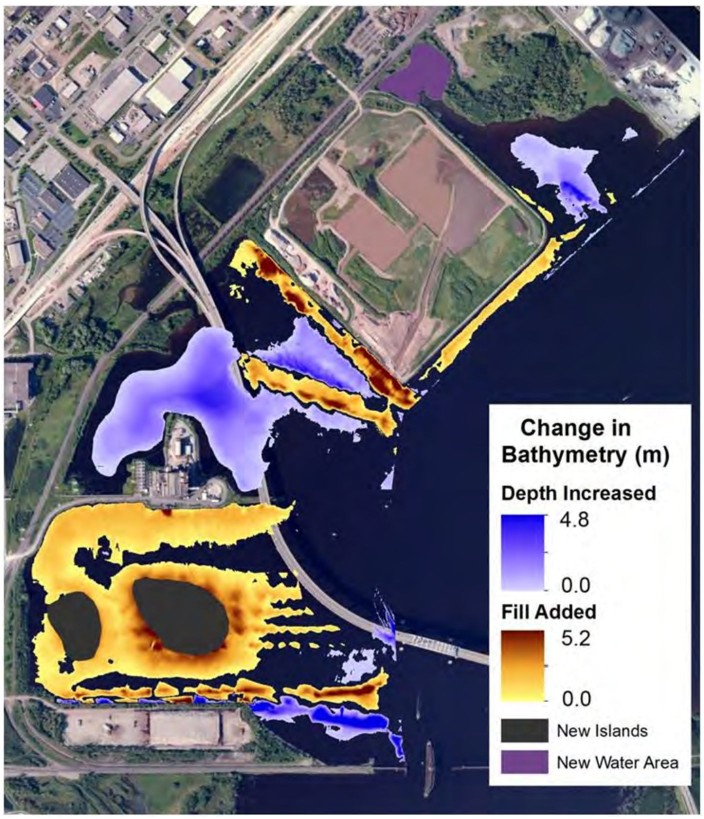

Figure 23. 40th Avenue West Preferred Scenario Concept Plan
(Source: NRRI - Unpublished)

Utilizing those initial designs and continued stakeholder input, the FFS team furthered the initial concept by adding features such as boundary islands to break up fetch (Figure 24), and adding additional fish overwintering and passage areas. Other features such as filling along Erie Pier and creating open water areas on the north side of the pier were removed for future consideration. The proposed bathymetry for the FFS concept is shown in Figure 25. In addition a schematic map of dredging and dredge placement areas for the initial FFS island placement concept is shown in Figure 26.

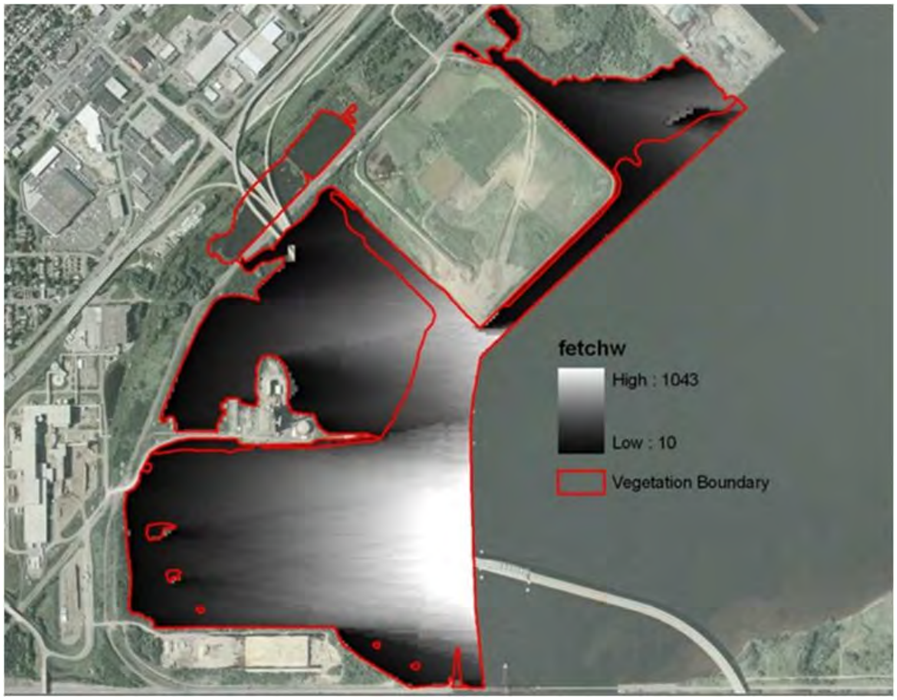

Figure 24. 40th Avenue West Wind Fetch Analysis
(Source: NRRI 2012)

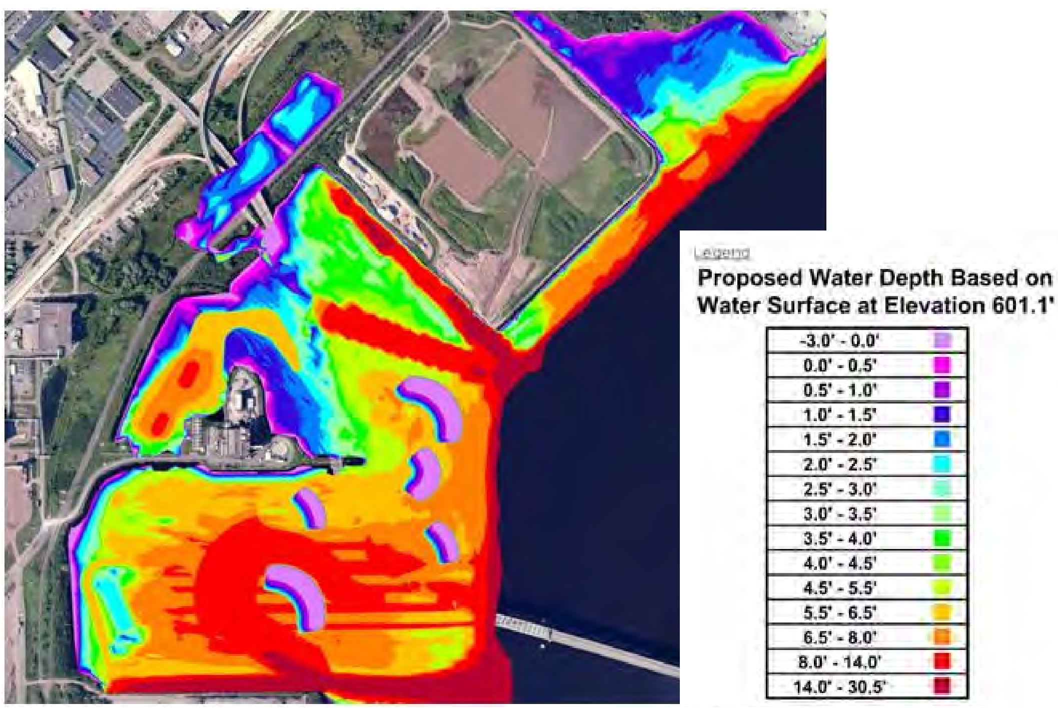

Figure 25. 40th Avenue West Proposed Bathymetry (Island Concept)

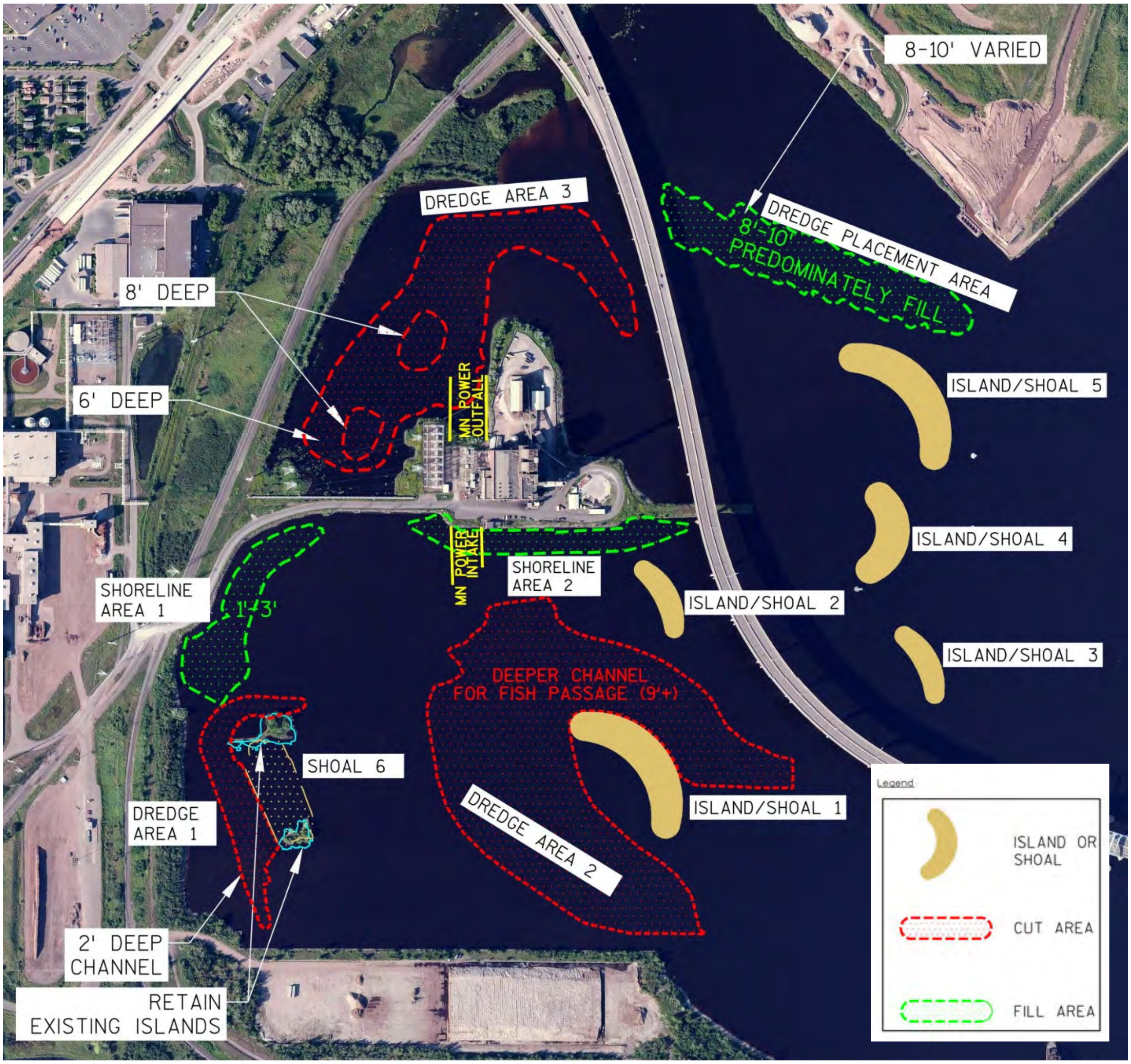

Figure 26. 40th Avenue Preferred Ecological Design Dredging/Dredge Placement Areas

Figure 26 represents a schematic of the conceptual design consisting of 5 islands and 1 shoal (Island Concept) or 6 shoals (Shoal Concept) along with dredging and dredge placement areas. The “island versus shoal” concepts are discussed in further detail in Section 3.4.

3.1.3. DESIGN ELEMENTS

The design elements developed for this Project Area include increasing deepwater habitat, creating barrier islands and shoals, and softening shorelines. The following sections provide descriptions of these elements and the benefits to fish and wildlife.

3.1.3.1. ISLANDS

There are both natural and constructed islands already within the St. Louis River (SLR) Estuary which provide valuable fish and wildlife habitat described further in this section. Constructed islands are not a new concept. They have been incorporated into riverine and lake systems to improve habitat across the Midwest, including Interstate Island in the SLR Estuary. Islands are constructed to reduce the adverse effects of wave action (scour, shoreline erosion and ice shoves), reduce near-shore sediment resuspension and to provide additional habitat for a variety of aquatic and terrestrial species.

Depending on the selected alternative, this project may incorporate five crescent shaped barrier islands constructed in the open water areas of the Project Area. General design considerations are based on previous projects implemented by the USACE and USFWS, including the Upper Mississippi River. Pilot projects in the SLRAOC and elsewhere will help refine the island construction.

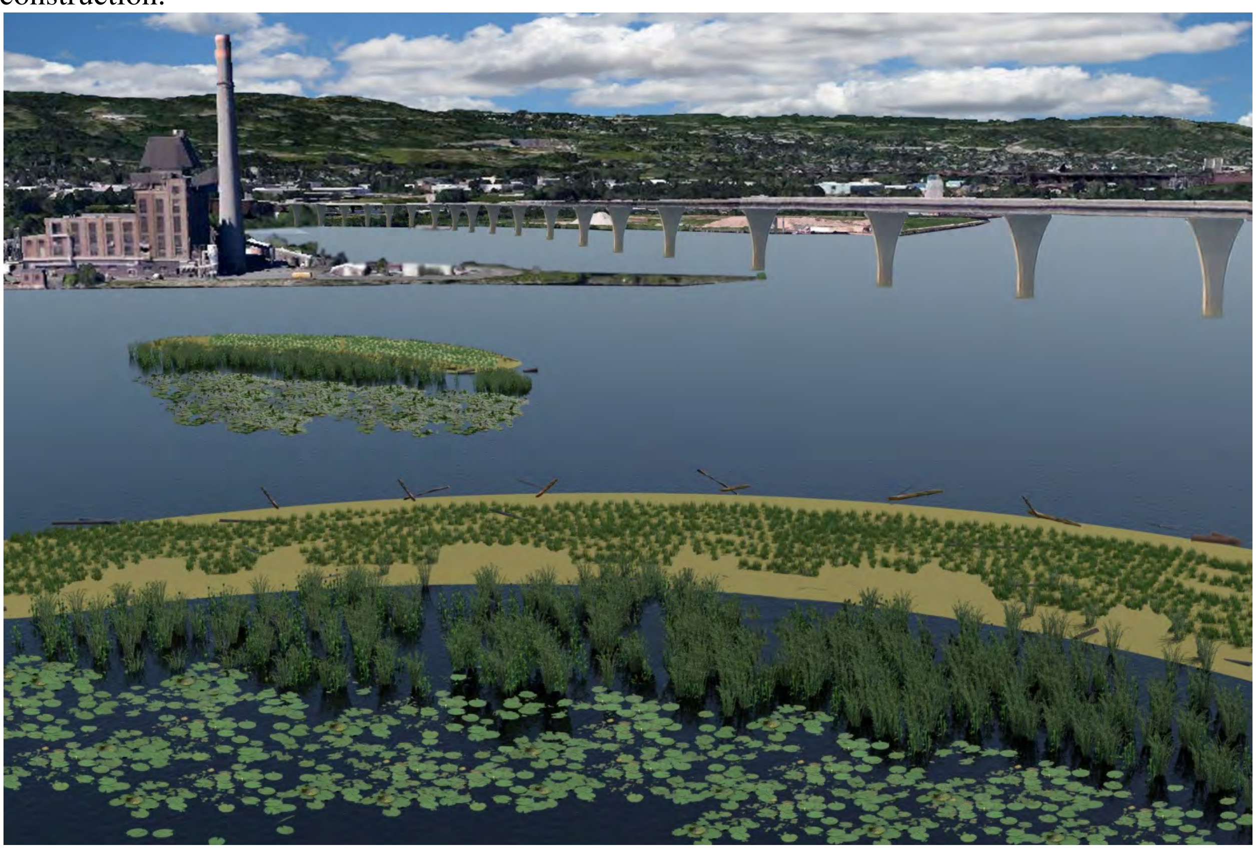

Figure 27. Rendering of Island Concept

The islands may be constructed by beneficial reuse of dredge material and utilizing a mixture of riprap (possibly reused materials from existing shorelines and demolished concrete walls on site), and topsoil. Bioengineering approaches to slope stabilization such as root wads and toe wood may also be incorporated into the final design. This FFS will discuss slope stabilization and the advantages and disadvantages of each approach.

The islands are proposed in water depths ranging from 3 to 10 feet. As proposed, the exposed surface of the islands will generally extend vertically to 3 feet above the design Low Water Datum elevation of 601.1 (NAVD88). The island surface may incorporate varying habitat types including limited upland grassland, wetlands and scrub-shrub. The leeward side of the islands can be extended to increase the near-shore littoral zone and create emergent and FLV habitat types. To increase habitat types on the interior of the islands, woody debris (tree stumps, cross logs, etc.) and rocky shoals are proposed. Limited native vegetation is proposed to revegetate the islands. The amount and type of substrates and other features included will need to be developed as part of the Design process as target species are finalized.

The biological benefits of the constructed islands include an increase of available habitat for aquatic and terrestrial organisms. Benefits to the local fishery include increased spawning areas along on the leeward side of the island, diverse near-shore feeding areas, and an increase in habitat heterogeneity adjacent to deeper, open water areas. The periphery of the islands will create current seams adjacent to slack water areas during high wind conditions that may concentrate forage fish and other organisms necessary for larger game fish species and birds. Feeding areas for waterfowl and shorebirds will also be created along all emergent and FLV areas. Terrestrial benefits include habitat and nesting locations for shorebirds and waterfowl. The amount and types of features included will be dependent upon target species, and will be finalized as part of the Design process.

Water quality benefits will also be realized through the construction of the islands. The placement of the islands in the off-shore open water areas will decrease wind fetch, wave action and resuspension of bottom substrates. The islands will also become a location of sediment deposition during high flow events in the St. Louis River. The differences in wave action and accompanying currents, in conjunction with the slack water areas behind the islands, will provide differing water temperature patterns in the surrounding shallow and deepwater areas. These water temperature differences are important to the increase in primary production, temperature sensitive species and nutrient cycling through the system. Reducing of fetch and accompanying wave action will also reduce the frequency of ice shoves in the winter months and resulting shoreline damage.

3.1.3.2. SHOALS

Shoals include shallow water habitat areas ranging from 1 to 5 foot depths and include submerged/exposed sand, emergent, and FLV habitats. These habitats provide similar benefits as described for the barrier island nearshore littoral zones. The primary objective of the shoals is to increase emergent and FLV habitats, and reduce the adverse effects of wave action and ice movement on the shoreline. Other benefits include increased near-shore habitat for aquatic species.

This project may incorporate one near-shore shoal between the two small existing islands south of the Minnesota Power Hibbard power plant. The stakeholders have also discussed converting some or all of the proposed barrier islands to shoals. The "island versus shoal" concepts are discussed in further detail in Section 3.4.

Near-shore shoals are proposed with varying configurations and dimensions to provide habitat variability and an aesthetically pleasing feature. Shoals will be constructed utilizing dredge material. The top of the shoal may have partially exposed and submerged portions dependent on water levels. Varying water depths will facilitate development of adjacent SAV and FLV habitats. To provide additional habitat types, woody debris and constructed wood habitat structures can be installed in the shoal area.

3.1.3.3. DEEPWATER HABITAT

Dredging within the Project Area historically was completed to increase water depth for shipping. The bathymetric survey mapping shows these dredged areas ranging in depth from 9 feet to more than 20 feet. Dredging is proposed within the Project Area to provide additional deepwater habitat for fish, improve fish movement, and to generate material for reuse within other habitat enhancement designs including constructed islands, shoals and softened shorelines. Proposed deepwater areas (Dredge Areas 2 and 3 on Figure 26) will create over winter habitat for fish and allow fish passage and connectivity between deepwater areas. The deepwater area proposed north of the Minnesota Power Hibbard power plant outfall is intended to provide overwinter habitat enhanced by the thermal impacts of the power plant discharge. The Ecological Design Report suggested that increasing deep habitat can result in increases in Hexagenia as well as walleye and other fish that use deeper waters as refugia.

The proposed deepwater areas will add additional overwinter habitat and provide better fish movement within the Project Area. The proposed dredging will create up to 25 acres of additional deepwater habitat. This area may lessen if adjustments for the needs of Minnesota Power are made as discussed in Appendix I.

3.1.3.4. SEDIMENT REMOVAL AND DREDGE PLACEMENT AREAS

Sediment samples within the Project Area show anthropogenic substrates (wood waste) present at varying depths and locations. The area south of the Minnesota Power Hibbard power plant has been identified for removal of wood waste and replacement with dredge material. As identified in the Preferred Design, the final depths will be similar to depths prior to wood waste removal.

An abandoned slip with water depths greater than 20 feet south of Erie Pier is proposed as a dredge placement area. Although this slip currently provides deepwater habitat, it terminates and does not connect with other deepwater habitats, limiting ingress/egress fish movements. This area is proposed for placement of dredge material to raise the bottom elevation to depths ranging from 8 to 12 feet deep in order to provide variability similar to adjacent deepwater habitats. This action will result in a net zero change in deepwater habitat within the Project Area and was identified as a low priority among the Site Team.

3.1.3.5. SHORELINE SOFTENING

Shoreline softening includes establishing transitional areas between the shoreline and deepwater aquatic habitats to create emergent, FLV and SAV habitats. Shoreline softening is expected to reduce wave action and ice damage within the littoral zone, enhance aquatic vegetation, and enhance fish and wildlife habitat for many species including amphibians, reptiles, shorebirds and waterfowl. The biological benefits are similar to those anticipated for the off-shore construction including additional fish spawning habitat and nursery area for a variety of fish species, increased habitat for a more diverse macroinvertebrate community, and the potential to establish a more diverse aquatic macrophyte community. Shoreline softening also increases the aesthetics of an area.

Incorporation of the woody debris, cross logs and tree stump/woody snag structures within these areas will also provide shallow water fish habitat, basking habitat for turtles and perches for birds. Reuse of riprap to create near-shore rock reefs may also be implemented along the shoreline to reduce wave action and create calm water areas for establishment of emergent vegetation.

Shoreline softening is proposed in several locations within the Project Area, including south of the Minnesota Power Hibbard power plant, and is intended to compliment shoreline naturalization areas.

Shoreline softening will increase emergent, FLV and SAV habitat with the Project Area and the SLRAOC. The areas proposed for softening will create 4.8 acres of SAV habitat and 0.5 acres of FLV habitat.

3.1.4. ADDITIONAL ENHANCEMENTS

Additional design elements were suggested or discussed with members of the Site Team to further enhance the project area. Two of these elements include naturalizing shorelines and increasing structure. The following sections provide descriptions of these elements and the fish and wildlife benefits. It is yet to be determined if these additional elements are required to address the needs of the Area of Concern and to meet BUI removal requirements. That said the concepts may be implemented with future projects. Further information, including construction details, for these enhancements is found Appendix M.

3.1.4.1. SHORELINE NATURALIZATION

Historically, large segments of the lower portion of the St. Louis River shorelines were stabilized and hardened with riprap, concrete and/or steel to provide flooding and erosion protection. Shoreline softening uses bioengineering and ecological principles to reduce erosion, enhance habitat, improve aesthetics and save money, while stabilizing and providing safety along the shorelines. Jewell conducted a shoreline composition survey to inventory shoreline habitat within the Project Area. Approximately 2.7 miles of the 4.9 miles of shoreline within the Project Area is considered hardened (See Table 1) and currently provides limited habitat value for fish and wildlife.

Shoreline softening may be achieved by removing portions of existing concrete walls and riprap and replacing with a combination of topsoil, vegetation and woody materials to soften the land-water interface. Shoreline softening techniques would be integrated into the existing hardened shoreline to maintain shoreline stability, minimize disturbance and reduce costs. Materials removed from the shoreline would be beneficially re-used in other habitat enhancement structures within the Project Area.

The simplest and most cost effective shoreline naturalization technique is the use of live stakes and post plantings. In general, the riprap along the shoreline cannot be thicker than 36 inches. If the riprap exceeds this threshold, it must be removed or reduced to accommodate the use of live stakes or post plantings. Live stakes are generally 2 to 4 feet in length and 2 to 6 inches in diameter. The pole plantings are slightly larger, requiring lengths of 4 to 6 feet and 2 to 6 inches in diameter. Typical species used in this application include willow or dogwood species. In many cases, these livestakes and pole plantings can be harvested from species within the Project Area.

In conjunction with the live staking, woody material would be incorporated into the shoreline where possible. Woody material including 12 to 16 foot logs with diameters ranging from 12 to 24 inches (with or without root balls) would be embedded into the existing riprap shoreline. The logs would be anchored to the shoreline through the use of wooden posts (8 to 12 feet in length) driven into the substrate under the riprap and fastened to the logs. The logs would be installed above and below the normal water level and protrude into the water of the riprap shoreline.

Placement of logs along the shoreline would also reduce wave action and create micro habitats along the shoreline.

Naturalizing vertical concrete walls is proposed to remove approximately 4 to 5 feet of concrete below the water surface. The material generated from cutting the concrete wall can be used in other habitat enhancement structures with the Project Area. The remainder of the wall below the water surface would provide an adequate footer for the toe wood. A 12 to 24 inch diameter log including the root ball, would be placed on the wall such that only the root ball protrudes past the wall face. These logs should be installed at varying depths below the water surface (either partially or completely submerged). The log is anchored to the shoreline material behind the wall with wood posts. The area above and behind the log is then backfilled with riprap and soil to a maximum slope at the water's edge of 2:1. The backfilling would commence until the existing shoreline surface elevation is met. A top dressing of topsoil would be added to a minimum depth of 6 inches. The topsoil would then be stabilized with a combination of a native seed mixture and live stakes.

Two additional habitat structures include the cross log wood structure and tree stump/woody snag structure. Both of these structures are typically utilized within existing emergent and FLV habitats with minimal impacts from wave action. These structures utilize large logs with root balls (typically 20 to 30 feet long and up to 24 inches in diameter). The cross log structure is built by crisscrossing up to 5 logs to create a "pile". Anchor logs or posts are driven into the substrate adjacent to the cross logs and fastened using rebar or wood dowels. Approximately half of the cross log structure is submerged with the remainder protruding above the water surface. Posts or logs are driven into the substrate and anchored to the structure. Detail drawings for these habitat structures as well as the others mentioned in this section can be found in Appendix M.

3.1.4.2. DEEPWATER HABITAT STRUCTURES

Deepwater habitat enhancements include timber habitat structures, submerged woody debris and rock feeding reefs. These structures would enhance the deepwater habitat by providing cover for forage fish and habitat for macroinvertebrates and game fish. These structures would also be suitable for the growth of algae and other phytoplankton. This algae growth provides a good food source for a variety of fish species that would reside near or within the structure.

Submerged log habitat structures consist of hardwood logs typically 15 to 18 feet in length and 12 to 15 inches in diameter secured with steel rods. Large ballast rocks or concrete anchor and hold the structures to the lake bottom. These structures are typically constructed and transported to the installation location or constructed on site during ice cover. These structures are typically installed in water at least 12 feet deep to allow navigational clearance.

The current substrate within the Project Area consists mainly of fine grained material with some sand and wood chips. Artificial rock reefs may be constructed utilizing riprap re-used from the Project Area. Reefs are proposed utilizing a mixture of three different sizes of rock and/or riprap; 60 percent of 4 to 8 inch diameter rock, 30 percent of 8 to 14 inch diameter rock and 10 percent of 16 inch diameter and larger material. If desired, a "top dressing" of fine rock material (2 inch to 4 inch) can be placed on the reef to further vary substrate size. The reefs are proposed in water at least 8 feet in depth to allow navigational clearance. The reef dimensions may be irregular and vary generally from 25 to 40 feet wide and can extend up to 700 feet long.

3.2. CONCEPT ANALYSIS

The Preferred Design concepts were further analyzed for hydraulic stability and vegetative establishment by project partners. Both the island concept and shoal concept were analyzed. The USACE evaluated the stability of the proposed islands and shoals using surface models of the proposed designs provided by Jewell. Vegetation establishment was modeled by Ted Angradi of USEPA employing the same Preferred Design concept surface models. Sections 3.2.1 and 3.2.2 further describe these efforts.

3.2.1. HYDRAULIC MODELING

The USACE Engineer Research and Development Center (ERDC) evaluated the stability of the proposed islands and shoals and native sediments in the Project Area. The model simulation included historical weather data from a period of four months which included two large storms and two high flow events in the St. Louis River. The USACE used two surface models created by Jewell depicting two proposed alternatives, one for the Island Concept and one for the Shoal Concept.

The USACE used the Geophysical Scale Transport Modeling System (GSMB) to determine if the dredged material and the surrounding native sediments would be transported away by water currents and wave action. The GSMB model framework includes wave, hydrodynamic, sediment and water quality transport models.

The conclusion presented by the USACE indicates there would be minimal erosion of the proposed islands, shoals and the surrounding native sediments. The erosion that was predicted was limited to the tops of some shoals and along the shorelines of some of the islands. The model of the Island Concept indicated the maximum erosion depth in proximity to the islands was approximately 25 cm (0.82 ft). The model of the Shoal Concept indicated a maximum net erosion depth of approximately 24 cm (0.8 ft). The USACE did not recommend modifying the island/shoal placement as a result of the modeling.

The USACE hydraulic model conclusions are as follows:

- "…the short period wind waves that are generated inside the harbor do not affect the calculated bed shear stresses unless the water depths are fairly shallow. This reduces the areas where erosion occurs.

- The 40th Ave embayment is off the main channel/river, so the flows in this area, that are the result of wind generated circulation as well as circulation resulting from flow separation off the point of land immediately to the south of this embayment, are low accept [*sic*] during large storm events. These low flows also contribute to the relatively small amount of net erosion that occurs."

A full description of the modeling efforts and results are presented in the USACE ERDC Letter Report, version April 30, 2015 (Appendix N). Further evaluation of sediment stability for AOC projects using climate change projections is planned to occur during the final design process. The climate change modeling of the 21st Avenue West Complex will be conducted first and based on those results this Project Area may be modeled as well. Refinements to the islands and shoals, such as slope protection, may be incorporated in the final designs based on the modeling results. The specific parameters for that event are being established and will be presented independently of this document.

3.2.2. SUBMERGED AQUATIC AND FLOATING LEAF VEGETATION MODELING

One of the stated project goals was to "*increase aquatic vegetation (emergent, floating, submerged)*". To gauge the effectiveness of the concept design, the United States Environmental Protection Agency (USEPA), Mid-Continent Ecology Division (MED) in Duluth, modeled the predictive establishment of submerged aquatic vegetation (SAV) and floating leaf vegetation (FLV) resulting from the proposed habitat restoration. The modeling was based on previous studies conducted by USEPA-MED. In the summer of 2014, MPCA asked USEPA-MED to develop a predictive model for FLV in the entire St. Louis River Estuary (USEPA 2014b). It was believed that existing models over-predicted FLV establishment. USEPA-MED found FLV present in the estuary at depths from 0.2 to 1.3 meter. Their work and resulting model has shown FLV has the highest probability of establishment in depths from 0.7 to 0.8 meters. The predicted depth limit for FLV occurrence was approximately 0.9 meters. A progress report describing the establishment of the FLV model is found in Appendix O (USEPA 2014b). Similarly, a model established by USEPA-MED and others in 2013 was used to predict SAV in the St. Louis River Estuary. Development of the model is described in detail in the article *Predicting submerged aquatic vegetation cover and occurrence in a Lake Superior estuary* (Angradi et al, 2013) found in Appendix O. USEPA-MED's work, as reflected in the model, suggests if the depth is generally less than 1 meter, SAV will establish if turbidity conditions are similar to the 2011 conditions on which the model is based. Turbidity has a significant influence on vegetation and is likely the reason vegetation establishment has been limited in the lower estuary. Flooding in 2012 has also likely impacted existing SAV and FLV establishment in the Project Area.

USEPA-MED used surface models created by Jewell depicting two proposed alternatives; one for the Island Concept and one for the Shoals Concept to run the vegetation models. These same vegetation models have been used to model sites throughout the AOC for consistency. The results of the model runs are presented in Table 9. Figure 28 shows the predicted SAV and FLV establishment in the Project Area for the "Island Concept". A similar map for the Shoal Concept can be found in Appendix O.

Table 9. Predicted SAV and FLV Establishment for 40th Avenue West Design Concept

Site Condition	Predicted FLV (Acres)	Percent Increase	Predicted SAV (Acres)	Percent Increase
Existing Conditions	11.7	-	51.87	-
Island Concept	14.85	27%	72.50	40%
Shoal Concept	11.8	0.1%	86.87	68%

The island and shoal concepts increase the predicted FLV and SAV in comparison to the existing condition because the proposed dredge placement creates additional shallow water habitat for vegetation to establish. SAV establishment for shoals is higher primarily because the entire structure is submerged as opposed to the islands where 7 or more acres will extend above the water's surface. FLV establishment is slightly higher for the island concept creating a more diverse assemblage of plant communities. This may be the result of the changes in the site's Relative Exposure Index (REI), a predictor in the probability of FLV and SAV establishment, of which wind direction and fetch are a factor. The islands are situated to reduce the impact of fetch and create a shallow near-shore habitat for vegetation. The sheltering effect of the islands in particular appears to benefit FLV.

The modeling predicted that the proposed designs will increase aquatic vegetation in the Project Area, which may aid in addressing *Degraded Fish and Wildlife Populations* (BUI #2) and *Loss of Fish and Wildlife Habitat* (BUI #9).

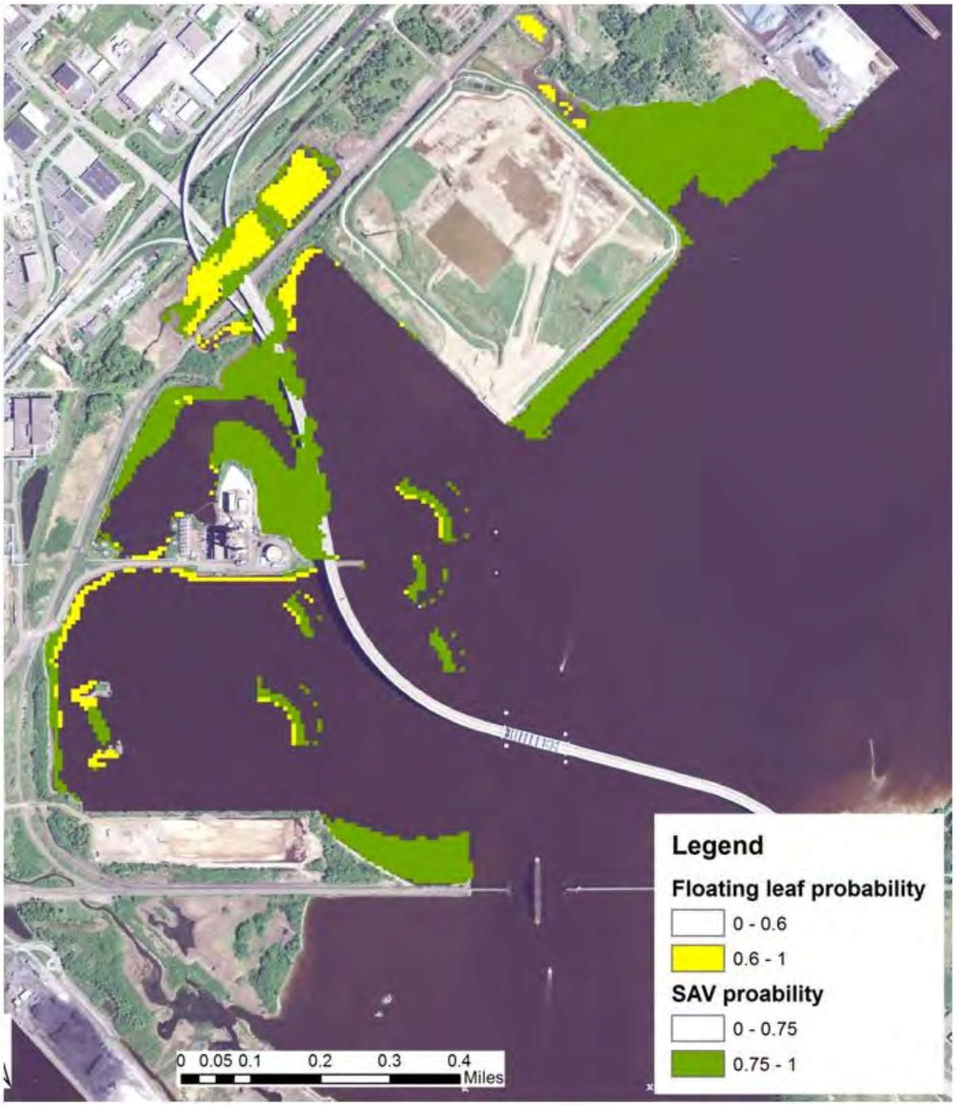

Figure 28. Predicted SAV and FLV Mapping for the 40th Avenue West Island Concept
(Source: USEPA-MED)

3.3. <u>ISLAND AND SHOAL DESIGN ELEMENTS</u>

Constructability and design enhancements for the Island and Shoal Concepts were explored. The following sections describe some of the suggested island/shoal design features.

3.3.1. ISLAND AND SHOAL CROSS SECTION

The concept developed for the islands and shoals is to provide a steeper, protected slope, on the eastern fetch side of the feature. On the leeward side submerged shelves would be constructed for the establishment of vegetation. The height of the islands averages 2 feet above the design Low Water Datum elevation of 601.1 (NAVD88) tapering to a 3 to 4 foot crest at the center. The leeward side would have a flat 6-inch deep shelf extending from the shore for 20 feet and then transition to a 60 foot shelf constructed at a 3% slope. Habitat features such as root wads and basking logs could be added at the time of construction or later as the island settles and vegetation establishes. Additional construction details can be found in Appendix L. Shoal construction is essentially the same however the feature would remain a minimum of 1 foot below the design Low Water Datum elevation of 601.1.

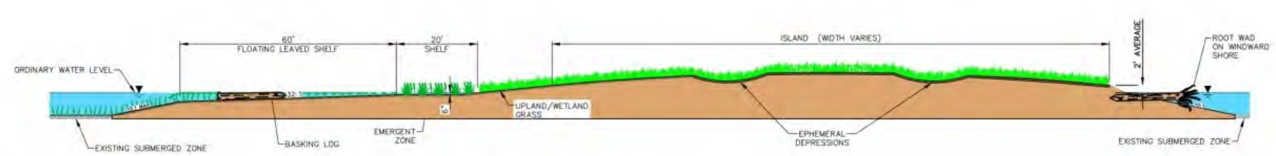

Figure 29. Section View of Island Construction

3.3.2. ISLAND AND SHOAL SLOPE STABILITY

The initial designs for the island and shoals assumed 25% maximum sideslopes (4 foot horizontal (H) to 1 foot vertical (V)), which was established from preliminary hydraulic modeling conducted by the USACE. While these slopes proved stable in the modeling, constructability may present a challenge because of slope failures. In further conversations with the geotechnical engineer with the USACE Detroit District, it was identified that other pilot projects in the Estuary have been using 4% maximum slopes (25H:1V). It was felt that the maximum stable slope for construction purposes was 10% (10H:1V). Based on this opinion, Jewell created an alternative design using 10% maximum island and shoal slopes. Table 11 and Table 12 provide dredging and dredge placement volumes for the Island and Shoal Concepts assuming 10:1 slopes. For all alternatives, it was assumed that 25% slopes would be stable for dredge removal areas as many of the other dredge channels in the Project Area exceed this slope and the material is largely consolidated. Continued evaluation of island and shoal slope stability is warranted as final designs are prepared. The evaluation should be based on further geotechnical analysis and experience with the 21st Avenue and other pilot projects in the Estuary and elsewhere.

Figure 30. Recommend Unprotected Island Sideslope

3.3.3. ISLAND AND SHOAL SLOPE PROTECTION

Several different means of protecting the fetch sides of the islands were explored. Options included different manners of riprap placement as well as bioengineered measures. An exhibit showing multiple alternatives for slope protection with corresponding pros and cons is found in Appendix L. They are summarized as follows.

Natural Shoreline

According to the USACE, a natural shoreline (Figure 30) would be stable at slopes up to 25%. However as discussed previously, 10% is the maximum recommended island slope for constructability purposes. While this does afford a more natural condition in comparison to other options, much more dredge material placement would be required and there would be little protection from erosion due to extreme weather events. For the purposes of this FFS 10% maximum slopes are the assumed design for the purpose of presenting volume and cost data. Appendix P and Appendix Q present volume and cost data for 25% slopes assuming riprap or other slope protection measures will be employed.

Toe Wood

Toe wood slope protection (Figure 31) has been supported by MNDNR staff and has been successful at other locations upstream on the river. It offers a more natural approach to bank protection over riprap but offers few constructability advantages. Slopes would need to be constructed at the 10% maximum similar to the natural shoreline with the toe wood placed post island formation. It would however, offer addition slope protection and would offer habitat variation that would be beneficial for multiple fish and wildlife species.

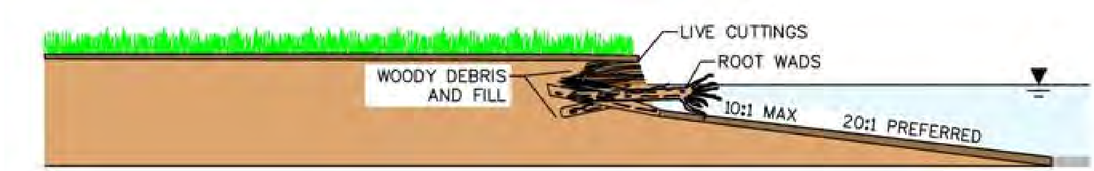

Figure 31. Toe Wood Slope Protection

Riprap

Slope protection with riprap (Figure 32) is a proven means of slope stabilization however it is the least natural in appearance, offers less beneficial habitat variation when compared to toe wood and can be costly to install. Cost savings could be realized by reusing riprap removed for naturalizing shorelines in the Project Area but an analysis of the available material would be required once the limits of shoreline work are established. Traditional riprap slope protection involves placing the material following the construction of slopes from dredge material. If the previously discussed 10% maximum slopes are employed, there would be no savings in dredge material required for this option. Alternately, a cofferdam could be constructed on the windward side of the islands to contain placed materials. If aesthetics are a concern, the cofferdam could be submerged to protect the toe of the island slope while providing a more natural appearance at the water's edge.

Table 17 and Table 18 in Section 3.8.1 contains cost data for traditional and cofferdam riprap placement for each island.

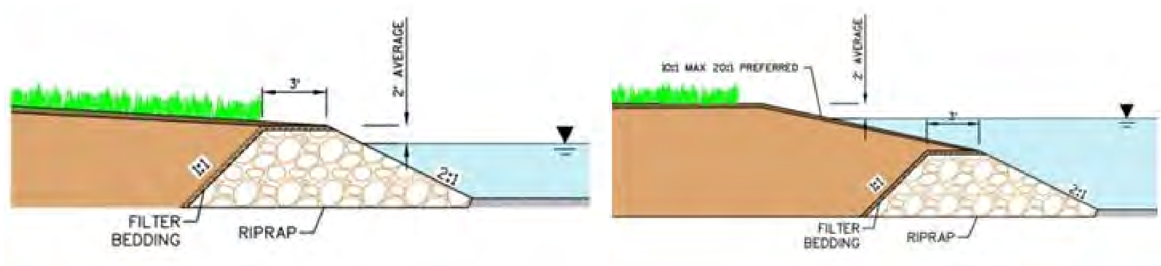

Figure 32. Riprap Slope Protection

3.4 ISLANDS VERSUS SHOALS

As previously stated, the concept for the Project Area consists of two main alternatives, an Island Concept and a Shoal Concept (Figure 26). The Concept shown in Figure 26 is a schematic of the conceptual design consisting either of 5 islands and 1 shoal along with dredge and dredge placement areas or constructing the 5 islands as shoals.

Habitat Creation

The habitat benefits of islands and shoals are discussed in Sections 3.1.3.1 and 3.1.3.2 respectively. Both offer the opportunity to increase SAV and FLV habitat although vegetative modeling suggests FLV may not establish with shoals. The biological benefits of both concepts include an increase of available habitat for aquatic organisms. Benefits to the local fishery include increased spawning areas along on the leeward side of the structures, diverse near-shore feeding areas, and an increase in habitat heterogeneity adjacent to deeper, open water areas. The shoals, however, lack some of the added benefits of islands including breaking up fetch, increased habitat diversity, and feeding and nesting areas for waterfowl and shorebirds. The amount and types of features included will be dependent upon target species, and will be finalized as part of the design process. Table 10 shows the anticipated benefits of the Island and Shoal Concepts.

Table 10. Summary of Habitat Area Improvements for Island and Shoal Concept Designs

Concept Type	Proposed Features	Net Benefit From Features 1-5	Net Benefit From Shoal 6
Islands	5 islands 1 shoal	7 acres of additional island habitat 5900 linear feet of shoreline habitat 3.9 acres of SAV habitat 0.9 acres of FLV habitat	0.5 acres of FLV habitat -0.11 acres of SAV habitat (converted)
Shoals	6 shoals	10.9 acres SAV habitat	0.5 acres of FLV habitat -0.11 acres of SAV habitat (converted)

Ownership

Ownership and maintenance of the islands was an initial concern of the Site Team. Islands potentially required an owner whereas shoals do not. MDNR has subsequently stated a willingness to take ownership of the islands created in the AOC.

Permitting

Permitting of islands was initially thought to be more difficult than shoals. As the concepts developed, MNDNR was more receptive to permitting islands. MNDNR staff indicated the islands are permittable, but the Site Team needs to show the necessity for the islands to be built.

Volumetrics

During the development of the concept design, Jewell modeled the various features of the Project Area using Autodesk AutoCAD Civil 3D software. Island and shoal fill areas, shoreline softening fill areas, and dredging/cut areas were modeled from the design concepts to determine material volumes and for use by others in further analyses. The concept designs were then compared to the existing bathymetry and material volumes of the features were calculated. Table 10 and Table 11 show the unadjusted volumes for the dredging and dredge placement areas as well as volumes of the islands and shoals after adjustment for consolidation. The Island Concept is estimated to require up to 91,000 CY of additional material, the cost of which needs to be weighed against the additional habitat gains. Please note that the figures and the resulting cost estimates reflect the worst case scenario for the estimated preliminary settlement analysis discussed in Section 2.8.2.

Table 11. Island Dredge/Dredge Placement Volumes for Concept Design with 10:1 Maximum Sideslopes

Feature	Dredge Volume (CY)	Dredge Placement Volume (CY)	Dredge Placement Volume (CY)Adjusted for Consolidation
I1 - Island 1	0	71,140	105,017
I2 - Island 2	0	20,400	34,614
I3 - Island 3	0	23,800	38,718
I4 - Island 4	0	31,070	50,539
I5 - Island 5	0	52,740	83,540
S6 - Shoal 6	0	7,020	10,370
D1 - Dredge Area 1 near Shoal 6	7,030	0	0
D2- Dredge Area 2 for Fish Passage East of Island 1	101,160	0	0
D-3 Dredge Area 3 North of MN Power Plant	67,080	0	0
F1- Shoreline 1 Placement Area Southwest of MN Power	0	7,010	12,035
F2 - Shoreline 2 Placement Area South of MN Power Plant	0	9,390	13,400
F3 - Dredge Placement Area Between Erie Pier and Bong Bridge	0	37,240	37,240
Total	**175,270**	**259,810**	**385,473**

Table 12. Shoal Concept Dredge/Dredge Placement Volumes for 10:1 Maximum Slopes

Feature	Dredge Volume (CY)	Dredge Placement Volume (CY)	Dredge Placement Volume (CY)Adjusted for Consolidation
S1 - Shoal 1	0	43,240	77,118
S2 - Shoal 2	0	9,800	24,014
S3 - Shoal 3	0	12,600	27,518
S4 - Shoal 4	0	14,850	34,319
S5 - Shoal 5	0	27,280	58,080
S6 - Shoal 6	0	7,020	10,370
D1 - Dredge Area 1 near Shoal 6	7,030	0	0
D2- Dredge Area 2 for Fish Passage East of Island 1	101,160	0	0
D-3 Dredge Area 3 North of MN Power Plant	67,080	0	0
F1- Shoreline 1 Placement Area Southwest of MN Power	0	7,010	12,035
F2 - Shoreline 2 Placement Area South of MN Power Plant	0	9,390	13,400
F3 - Dredge Placement Area Between Erie Pier and Bong Bridge	0	37,240	37,240
Total	**175,270**	**168,430**	**294,094**

Cost

All other factors being equal the cost difference between the Island and Shoal Concepts is primarily based on the additional 91,000 CY of required material placement. This results in an estimated reduced cost for the Shoal Concept of up to $1.7 Million. The actual reduction will be less as island and shoal consolidation estimates are finalized. There may also be cost reductions related to island vegetation establishment and slope stabilization. Project costs are discussed in further detail in Section 3.8.

Site Team and Stakeholder Input

Various site team and technical staff meetings were held throughout the development of the FFS. Aside from the concerns with permitting and ownership, the Island Concept was well supported by the group with shoals offering an alternative to addressing various logistical concerns. Going back to the development of the Ecological Design Report, islands were evaluated under several of the modeled habitat scenarios and ultimately a two island alternative was the initial concept recommended to the FFS team. Costs aside many members of the Site and technical teams supported the Island Concept .

3.5. ESTABLISHMENT OF MANAGEMENT UNITS

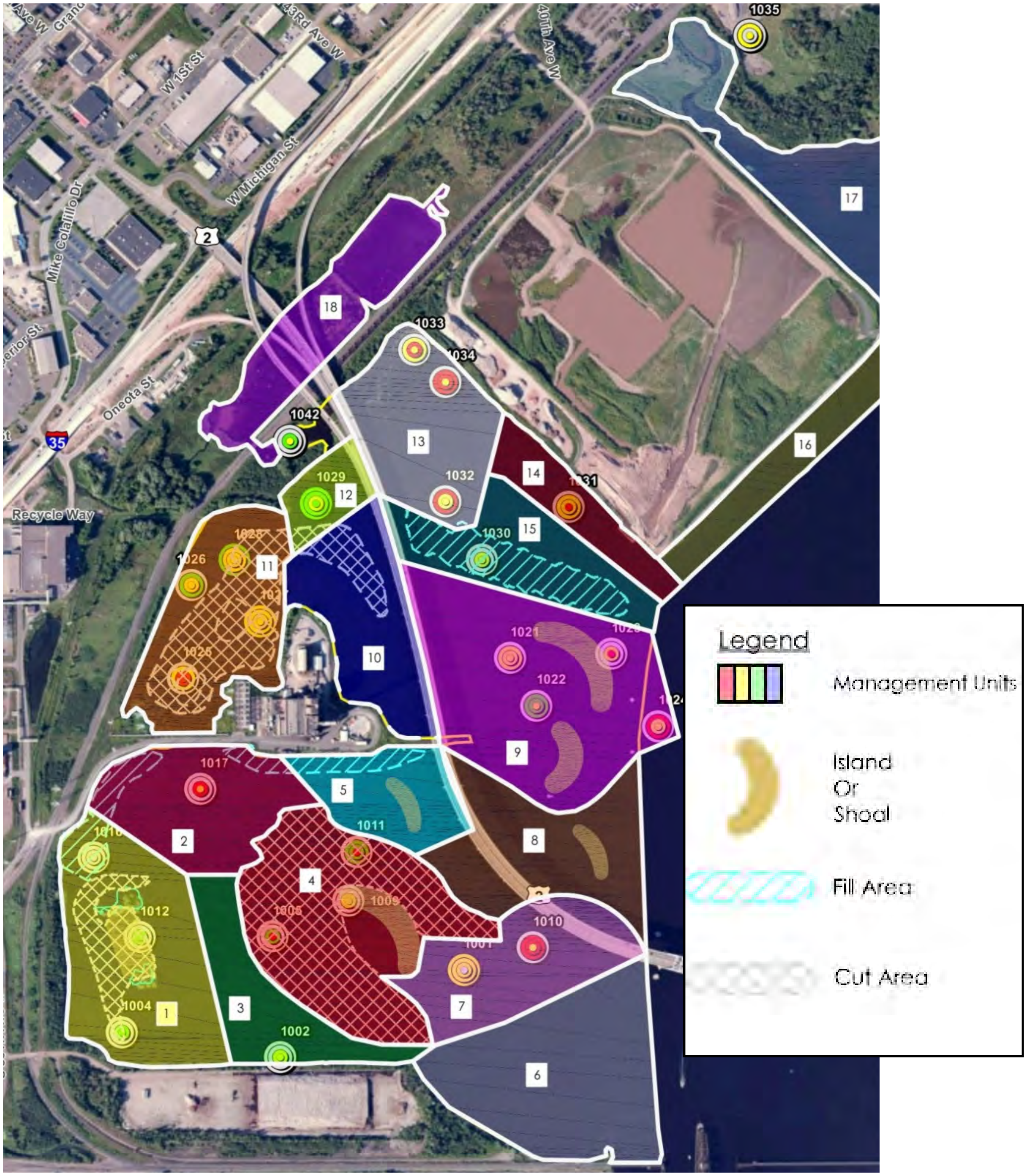

Figure 33. 40th Avenue West Management Unit Map
(see full map in Appendix H)

Management units for the site were established based on a combination of proposed conceptual habitat restoration areas, areas of sediment quality concern and areas of benthic quality concern. The management units (MU's) are not intended to suggest priority or construction phasing, but were established to allow for suggested actions such as sediment removal or additional testing.

As discussed in Section 2.10.4, there are five areas of ecological concern consisting of multiple MU's for which recommended management actions are indicated. Other MU's involve habitat restoration work, areas for which no work is planned and areas requiring further consideration. Many of the areas recommended for further consideration were not investigated with the 2014 environmental sampling. Several of these areas had previously been evaluated as part of the 2010 USEPA sampling effort and did not warrant additional exploration or cause for concern. However, after the 2014 supplement samples were collected, some of the 2010 data was called into question. The questionable 2010 data was therefore not used for purposes of the FFS and left data gaps in the evaluation of the site. The 2010 locations were retested in 2015, but the results were not available during the preparation of this report. It is suggested the recommended areas be given a final review when the 2015 sample results are available.

Appendix H contains a map of the suggested management units along with the recommended actions for each. Associated cost data can be found in Appendix Q and Section 3.8.

3.6. SUMMARY OF HABITAT BENEFITS

The proposed improvements will create, restore, or enhance habitat and improve fish and wildlife populations within the Project Area and the SLRAOC. Implementation of these improvements is intended to address three of the nine BUIs including "Loss of Fish and Wildlife Habitat", "Degradation of Benthos" and "Degradation of Fish and Wildlife Populations". The following table provides a summary of habitat improvements anticipated by implementing this restoration plan.

Table 13. Summary of Habitat Area Improvements

Habitat Type	Existing	Proposed	Net Benefit
Islands	None present	5 islands	7 acres of additional island habitat 5900 linear feet of shoreline habitat 3.9 acres of SAV habitat 0.9 acres of FLV habitat
OR			
Shoals 1-5	None present	5 shoals	10.9 acres SAV habitat
Improvements for Both Island or Shoal Concept			
Shoal 6	None present	1 shoal (shoal 6)	0.5 acres of FLV habitat -0.11 acres of SAV habitat (converted)
Anthropogenic Sediment Removal	NA	167 acres	167 acres of degraded benthos habitat improved
Dredge Placement (former slip)	NA	6.25 acres	0 acres of deepwater habitat improved
Shoreline Naturalization	2.2 miles	2.4 miles (+1000 ft)	0.19 miles of shoreline naturalized
Shoreline Softening	NA	5.6 acres	4.8 acres of SAV habitat 0.5 acres of FLV habitat
Deepwater Habitat	>20 acres	Up to >25 acres additional	Up to 25 acres of additional deepwater habitat
Deepwater Structures	NA	10 structures	10 deepwater structures installed

3.7. CONSTRUCTION PHASING

Construction phasing in the Project Area is heavily dependent on the quality of available dredge materials for use in constructing the desired habitat. Based on geotechnical evaluations discussed in Section 2.8 , there is a limited quantity of silty sand within the Project Area from which to construct islands. Also, some of the material generated may pose an ecological risk and should not be reused for habitat creation. Table 14 shows the estimated volumes of materials generated from dredging within the Project Area.

Table 14. Dredge Material Volumes for Concept Design

Feature	Total Dredge Volume (CY)	Silt (ML) (CY)	Peat (Pt) (CY)	Silty Sand (SM) (CY)	Organic Silt (OL) (CY)	Sand (SP) (CY)	Wood (CY)
Dredge Area 1 near Shoal 6	7,030	3,135	1,567	2,328	0	0	0
Dredge Area 2 for Fish Passage East of Island 1	101,160	36,885	23,866	18,415	18,020	0	3,974
Dredge Area 3 North of MN Power Plant	67,080	22,836	0	21,733	21,682	829	0
Total Dredge Volume	175,270	62,856	25,433	42,476	39,702	829	3,974

The following phasing recommendations are based on the implementation of all design elements and addressing all ecological risks to meet the ecological goals for the 40th Avenue West Project Area. Staging may be re-evaluated based upon which project elements are required to address the needs of the Area of Concern and to meet BUI removal requirements and which elements may be implemented with future projects. For design area descriptions reference Figure 26 and Figure 33. Complete sediment removal recommendations can be found in Section 2.10.4 .

<u>**Phase I - Coffee Ground Flats**</u>

This stage includes work in the bay south of the Minnesota Power Hibbard power plant. The suggested work staging includes:

- **Sediment Removal for MU's 1, 2, 3, 4, 5 and 7**

  Based on the recommendations described in Section 2.10.4, remove wood waste and contaminated sediments. Dewatering of wood wastes (peat) may make it a viable material for landfill daily cover or possibly fuel for the Hibbard power plant. Capping of this material within the islands or shoals was discussed but additional geotechnical analysis would be required. Dispose of dredged contaminated sediment at an appropriate landfill.

- **Dredge Areas 1 and 2**

  Dredge Areas 1 and 2 to design grades. Remove wood wastes and peat for disposal, fuel use, island/shoal placement or place in dredge placement area south of Erie Pier. Beneficially reuse clean Dredge Area 2 sediments to restore sediment removal areas in MU's 1, 2, 3, 4, 5 & 7 and bring to Shoreline Area 1 and 2 to design grade.

- **Restore Shoreline Area 1 and Shoreline Area 2 to Design Grade**
  Dredging Areas 1 and 2 will not generate sufficient volumes of material to restore contaminated dredge areas and proposed shoreline softening areas. Shoreline softening areas will require beneficial reuse of dredging materials from navigational channel maintenance or offloading of materials from the Erie Pier Confined Disposal Facility or another clean source.

- **Create Islands/Shoals 1 and 2**
  Beneficially reuse navigational dredge material to construct Islands/Shoals 1 and 2 with navigational channel dredging materials or offloading materials from Erie Pier or another clean source.

Phase II – Ponds Behind Erie Pier (AOC Remediation Site)

This phase includes remediation and restoration of the ponds behind Erie Pier (lead by MPCA) prior to implementing work north of the Minnesota Power Hibbard power plant. Potential release of contaminants from the pond to any newly restored habitats in the Project Area is a concern. At a minimum, the work in MU 13 should be delayed until the ponds are addressed.

Phase III – Area between Minnesota Power Hibbard Power Plant and Erie Pier

This stage includes the work north of the Hibbard plant and southeast and southwest of Erie Pier.

- **Sediment Removal for MU's 9, 11, 13, 14 and 15**
  Based on the recommendations described in Section 2.10.4, remove contaminated sediments. Dispose of dredged contaminated sediment at an appropriate landfill.

- **Dredge Area 3**
  Dredge Area 3 to design grade. Beneficially reuse uncontaminated Dredge Area 3 sediments to restore sediment removal area in MU 13 followed by using remaining Dredge Area 3 material to begin restoration of MU areas 14 and 15 or 9.

Phase IV –Restore MU's 9, 14 and 15 to Original Grade

This phase includes restoring contaminate dredge areas southeast of Erie Pier. However, MU areas 14 and 15 may not need to be returned to original grade. These areas are near the offloading point for Erie Pier and additional depth may aid navigation.

- **Restore MU Areas 9, 14 and 15 to Original Grade**
  Beneficially reuse navigational dredge material to return MU Areas 9, 14 and 15 to original grade.

Phase V – Construct Islands/Shoals 3, 4 and 5

This phase includes construction of islands/shoals south of Erie Pier. Island/shoal construction can be with routine maintenance dredging materials when available.

- **Islands 4 and 5**
  Beneficially reuse navigational dredge material to construct islands 4 and 5.

- **Island 3**
  Beneficially reuse navigational dredge material to construct island 3.

3.8. OPINIONS OF PROBABLE COST

Opinions of Probable Cost are presented for the both the Island Concept and Shoal Concept in this Section. There are, however, various options and enhancements that can be incorporated into the final design as the stakeholders identify the elements that need to be implemented to meet the needs for AOC delisting and what elements may be addressed with future projects or other sources of funding. For this reason, multiple cost estimates are presented in Appendix Q. These estimates are presented so that they can be used in combination as various options are explored.

3.8.1. CONCEPT DESIGN COSTS

Two estimates for the concept design are presented below. Table 15 shows the concept design assuming that 10:1 maximum slopes are used around the islands for constructability. Table 16 contains an estimate for the Shoal Concept using the same 10:1 maximum slope. For both estimates, the use of turbidity barriers is the assumed turbidity reduction strategy. Turbidity Barriers, also known in the industry as turbidity curtains, silt screens, silt barriers, or silt curtains, are floating barriers designed specifically to contain and control the dispersion of floating turbidity or silt in a water body. The turbidity barrier quantities were calculated assuming barrier placement along the shoreline softening south of the Minnesota Power Hibbard Plant, around island placement areas, for the fill area south of Erie Pier and across the mouth of the bay north of the Hibbard plant. A 15% engineering cost and 15% contingency is added to each estimate. The 15% engineering cost assumes design and construction management costs to date and through project completion. No cost adjustments were made for beneficial reuse of dredge materials from maintenance dredging or offloading from Erie Pier. If these materials are made available to the project, there will still be an associated cost for collection and transport of the materials.

Table 15. Opinion of Probable Construction Costs – 10:1 Sideslope Islands

Item No.	Description	Quantity	Unit	Unit Price	Total Cost
1	Mobilization & Demobilization	1	LS	$250,000	$250,000
2	On Site Dredge Removal/Placement[1]	175,270	CY	$15	$2,629,050
3	Maintenance Dredging Placement[2]	276,764	CY	$15	$4,151,460
4	Turbidity Barriers	5,100	SY	$27	$137,700
5	Wood Waste Disposal	29,407	CY	$10	$294,070
6	Undistributed Quantity of Turbidity Barriers	500	SY	$27	$13,500
	Subtotal				$7,475,780
	Engineering (15%)				$1,121,367
	Contingency (15%)				$1,121,367
	Total				**$9,718,514**

Notes: *1. This volume contains a quantity of contaminated sediments. Adjustments to the sediment removal costs in Section 3.8.3 were made so that the cost of dredging this material was not estimated twice.*
2. Adjusted for beneficial reuse of onsite dredge material

Table 16. Opinion of Probable Construction Costs – 10:1 Sideslopes - Shoals

Item No.	Description	Quantity	Unit	Unit Price	Total Cost
1	Mobilization & Demobilization	1	LS	$250,000	$250,000
2	On Site Dredge Removal/Placement[1]	175,270	CY	$15	$2,629,050
3	Maintenance Dredging Placement[2]	185,385	CY	$15	$2,780,775
4	Turbidity Barriers	5,100	SY	$27	$137,700
5	Wood Waste Disposal	29,407	CY	$10	$294,070
6	Undistributed Quantity of Turbidity Barriers	500	SY	$27	$13,500
	Subtotal				$6,105,095
	Engineering (15%)				$915,764
	Contingency (15%)				$915,764
	Total				**$7,936,624**

Notes: *1. This volume contains a quantity of contaminated sediments. Adjustments to the sediment removal costs in Section 3.8.3 were made so that the cost of dredging this material was not estimated twice.*
2. Adjusted for beneficial reuse of onsite dredge material

Section 3.3.3 described slope protection measures for island and shoal construction. The most expensive but most stable alternative is to armor the fetch side of the structures with riprap. Table 17 shows the cost associated with placement of riprap. These costs assume virgin material is brought to the site and riprap is not beneficially reused from shoreline softening measures. The table shows both the quantities and costs associated with cofferdam construction methods used for the islands and placement of riprap after island construction.

Table 17. Riprap Island Sideslope Protection Quantities and Costs

Feature	Riprap for Cofferdam Construction (CY)	Riprap for Cofferdam Construction Cost	Riprap for Slope Protection (CY)	Riprap for Slope Protection Construction Cost
I1 - Island 1	9,000	$450,000	1,350	$81,000
I2 - Island 2	2,700	$135,000	575	$34,500
I3 - Island 3	3,000	$150,000	600	$36,000
I4 - Island 4	3,900	$195,000	800	$48,000
I5 - Island 5	5,200	$260,000	1,075	$64,500
Totals	**23,800**	**$1,190,000**	**4,400**	**$264,000**

Table 18. Riprap Shoal Sideslope Protection Quantities and Costs.

Feature	Riprap for Cofferdam Construction (CY)	Riprap for Cofferdam Construction Cost	Riprap for Slope Protection (CY)	Riprap for Slope Protection Construction Cost
S1 - Shoal 1	4,000	$200,000	825	$49,500
S2 - Shoal 2	925	$46,250	250	$15,000
S3 - Shoal 3	1,125	$56,250	300	$18,000
S4 - Shoal 4	1,300	$65,000	350	$21,000
S5 - Shoal 5	1,800	$90,000	450	$27,000
Totals	**9,150**	**$457,500**	**$2,175**	**$130,500**

Although the above tables show the costs associated with installing riprap, cost savings of up to $65,000 for the Island Concept and $372,000 for the Shoal Concept may be realized in the reduction of material placement for habitat creation. The lower costs are the result of reduced dredge placement from steepening island and shoal maximum sideslopes from 10:1 to 4:1 and constructing and protecting the steeper banks with riprap cofferdams. Final consolidation estimates will allow for a clearer indication of the potential reduced costs.

3.8.2. SHORELINE NATURALIZATION/HABITAT FEATURE COSTS

Shoreline naturalization costs range based on the practice employed. High end pricing can range from $300/LF for working from shore to $500/LF when working from the water. Approximately 1000 LF of shoreline naturalization was assumed for this study, with costs ranging from $300,000 to $500,000.

Less costly measures such as utilizing live staking instead of container shrubs reduce this cost. For $15,000, 1000 LF of live stakes can be installed 15 feet wide at 3 foot spacing.

It was assumed that the costs of shoreline naturalization, island enhancements and other habitat enhancements were reflected in the 15% contingency assigned to each concept cost estimate.

3.8.3. SEDIMENT REMOVAL COSTS

Cost estimates for anthropogenic and contaminated sediment removal are described in detail and shown in tables in Appendix Q. The estimates reflect the five areas of ecological concern found in Section 2.10.4. The assumptions made for each estimate accompany a table with the projected costs. For a description of the concerns and recommended measures for each area, see Section 2.10.4. As was done in the concept estimates, no cost adjustments were made for placement of dredge materials from maintenance dredging or offloading from Erie Pier. If these materials are made available to the project, there will still be an associated cost for collection and transport of the materials. Dredge placement volumes are estimated to refill the excavated material back to the original grade. The placement volumes include a 10% quantity increase to account for consolidation. For most areas it was assumed the underlying material was adequate to provide the recommended bioactive zone from Section 2.10.4 or that placed material from the concept designs will provide this substrate. Additional dredge placement volumes for shoreline softening and islands are contained within the concept estimates in Section 3.8.1. The total cost to address the contaminated sediment in all five areas of ecological concern may reach $25.5 million.

3.8.4. SUMMARY OF PROBABLE COSTS

The following table summarizes the anticipated project costs for the Island and Shoal Concepts presented in this section. This summary does not consider the alternative of riprap placement for sideslope protection or the other alternative costs presented in Appendix Q. The data in Appendix Q is intended to assist the Site Team should revisions or enhancements to the concepts be considered.

Table 19. Island and Shoal Cost Summary.

Concept Type	Proposed Features	Concept Design Construction Cost	Contaminated and Anthropogenic Sediment Removal Costs	Totals
Islands	5 islands 1 shoal	$9,718,514	$25,535,683	$35,254,197
Shoals	6 shoals	$7,936,624	$25,535,683	$33,472,307

3.9. DESIGN REFINEMENTS

Based on the findings of the environmental analysis, vegetation modeling, and stakeholder comments, a revised concept was explored for the Project Area. These concepts were developed without the input of the entire Site Team and represent efforts by the FFS authors to explore additional alternatives for improving habitat development in the Project Area. These additional refinements are described in Appendix R.

3.10. OTHER CONSIDERATIONS

3.10.1. ADDITIONAL GEOTECHNICAL ANALYSIS

Additional geotechnical analysis for slope stability, slope constructability and sediment consolidation is needed to better define the final design and associated construction costs. Sediment consolidation was assumed based on the worst case scenario for settlement near Islands 4 and 5. Slopes, while stable in hydraulic modeling, may not prove stable during dredge placement. Experience with the 21st Avenue and other pilot projects in the Estuary and elsewhere will help further define the final design for the Project Area features.

3.10.2. FURTHER ANALYTICAL ANALYSIS AND TESTING

The management unit map in Appendix H and described in Section 3.5 suggests areas that may require further consideration based on the 2015 resampling of previous USEPA data. Additional sampling may be required to better define the limits of the suggested sediment removal areas in Section 2.10.4. Further coordination between the stakeholders will better define the need for this additional study.

3.10.3. LANDOWNER AGREEMENTS

Landowner easements, land purchases and temporary construction easements may be necessary to facilitate this project. Public access to the Project Area is primarily limited to Erie Pier. Staging construction operations from that point may disrupt normal operation of the facility. Temporary easements for construction access and staging may be necessary, especially for areas south of the Minnesota Power Hibbard power plant.

3.10.4. DESIGN REVISIONS

Should the electronic drawings created for this FFS be employed for final designs, revisions near the Minnesota Power Hibbard power plant are required. Appendix I shows the correct location for the plant intake and outfalls but this was only recently determined. Design surface models need to be revised. In addition, Minnesota Power expressed some concerns regarding Dredge Area 3 that may need to be resolved.

3.10.5. PERMITTING

The project stakeholders are familiar with State and Federal permit requirements from projects within the estuary. For this Project Area, additional permitting and coordination will be required for work around the Bong Bridge and within MNDOT right of way. The permitting of islands has also been discussed at length in stakeholder meetings. MNDNR staff have indicated the islands are permittable but the applicant needs to show the necessity for the islands in terms of BUI removal in the AOC.

SECTION 4 - CONCLUSION

The vision for the 40th Avenue West Remediation-to-Restoration Project is to remove and immobilize any remaining pollutants currently located in the Project Area that are posing a risk to fish and wildlife resources and restore to more natural site conditions that enhance productivity for fish and wildlife. This vision was developed from fish and wildlife and habitat impacts identified from previous work in the Project Area, most recently reflected in the 2013 St. Louis River RAP Update. The 2013 RAP Update identified the 40th Avenue West complex as a project that would benefit the Degraded Fish and Wildlife Populations, Degradation of Benthos, and Loss of Fish and Wildlife Habitat BUIs. From this vision, past work in the Project Area and input from the Site Team, a restoration plan was developed that included ecological based design criteria developed to improve habitat within the 40th Avenue West Complex, including removal of anthropogenic substrates and residual sediment contamination, creation of wave break barriers and sand shoals, shoreline softening, promotion of submerged aquatic vegetation, and improvement of native wildlife habitat.

The Ecological Design Report was relied upon during the development of this FFS to further define the vision and goals for the restoration of the Project Area. The Ecological Design Report provided baseline data and goals for restoration efforts including information on sediment contamination, ecotoxicology, vegetation, sediment types, benthic macroinvertebrates, fish assemblage and bird usage of the area. Vegetation, macroinvertebrates and sediment characterization were also completed for five reference areas selected by project cooperators as areas representing target habitat types for the Project Area. The report identified several issues in the Project Area including:

- Probable limiting factors to habitat quality within the Project Area included turbidity and wind fetch, both of which limit light penetration needed to establish macrophytes and increase shoreline erosion.
- A lack of vegetation in a large portion of the Project Area.
- The abundance of benthic taxa was found to increase in shallow depths with low exposure and decrease at deeper depths with high exposure.
- Sediment sampling found some chemical concentrations exceeding the Level II SQTs, while a majority of the chemicals exceeded Level I SQTs. Polycyclic aromatic hydrocarbons (PAHs) were frequently encountered at elevated levels and found above Level II SQT values. PAHs were found at concentrations that impact sediment-dwelling organisms at all six of the sample sites.
- The analysis of PAH and other chemicals in fish tissues supported the results from sediment sampling, leaving reason to believe that these same toxins were present in other key parts of the food chain, including macroinvertebrates and birds.
- The most pronounced habitat restoration effects were predicted to come from scenarios that increased the amounts of low energy environments in both shallow and intermediate

depths. The low energy environment scenarios projected increases in habitat for macroinvertebrates, fish and birds. Increasing deep habitat predicted increases in Hexagenia as well as walleye and other fish that use deeper waters as refugia.

From the Ecological Design Report an initial concept for the Project Area was developed. The concept design was further refined during the development of the FFS with input from the Site Team. The current restoration plan includes two concepts based on island or shoal construction The Island Concept consists of 5 islands and 1 shoal along with dredge and dredge placement areas. A second Shoal Concept was considered which is to construct all five island features as shoals.

The concepts were modeled to predict vegetative establishment. One of the stated project goals was to "*increase aquatic vegetation (emergent, floating, submerged")*. To gauge the effectiveness of the concept design, the United States Environmental Protection Agency (USEPA), Mid-Continent Ecology Division (MED) in Duluth, modeled the predictive establishment of submerged aquatic vegetation (SAV) and floating leaf vegetation (FLV) resulting from the proposed habitat restoration. The modeling predicted significant increases in FLV and SAV establishment for both the Island and Shoal Concepts. The Island Concept saw SAV increase 40% and FLV increase 27%. The Shoal Concept resulted in a 0.1% increase in FLV and 68% increase in SAV. The larger increase in SAV for the shoals was largely due to the establishment of the SAV on the 7 acres of submerged surface that extends above the water surface for the Island Concept. Conversely, the sheltering effect of the islands in particular appears to benefit FLV providing a more diverse vegetation assemblage in the Project Area.

Hydraulic modeling for both concepts was conducted by the USACE. The USACE used the Geophysical Scale Transport Modeling System (GSMB) to determine if the dredged material and the surrounding native sediments would be transported away by water currents and wave action. The GSMB model framework includes wave, hydrodynamic, sediment and water quality transport models. The conclusion presented by the USACE indicated there will be minimal erosion of the proposed islands, shoals and the surrounding native sediments. The erosion that was predicted was limited to the tops of some shoals and along the shorelines of some of the islands.

Once it was determined the designs would result in habitat benefit and the islands and shoals in the concept designs would be stable, the designs were further analyzed to determine estimated quantities and opinions of probable cost. In addition, anthropogenic substrates and sediment contamination, impacting both project design and costs, were also evaluated.

Chemical, toxicological and biological sampling occurred as part of the study, in coordination with a geotechnical investigation, to determine the current risks to fish and wildlife resources that may be present in the Project Area. Sediment samples were collected at twenty-eight locations in the Project Area.

Dioxins/Furans were the most commonly detected chemical at levels exceeding the Level II SQT threshold. There were 11 of 28 sampling locations in the Project Area in which Dioxin/Furan TEQs were above the Level II SQT thresholds in at least one horizon and were all located in the Project Area south of Erie Pier. Multiple sample locations had TEQs above the Level I SQT threshold at all sampled horizons. Sampling locations north of Erie Pier has no detections above the Level II SQT threshold.

Metals concentrations in the Project Area were measured at levels above the Level I SQT at some sample sites, but had no Level II SQT exceedances. Metals that were detected above the Level I SQT threshold in at least one horizon include: arsenic (5 locations), cadmium (4 locations), lead (6 locations), mercury (14 locations), and nickel (6 locations).

Total PAH concentrations were also detected above the Level I SQT threshold at multiple sample locations in multiple horizons. There was one station in which the total PAH concentration was above the Level II SQT threshold. PCB concentrations were largely below the detection limit for the samples collected for all congeners tested. PCBs were not detected above the Level II SQT threshold at any sample location.

Mean PEC-Q values were calculated only using total PAH and metals because PCBs were largely absent, and the inclusion of PCBs into the mean PEC-Q calculation may under represent the risk to fish and wildlife resources. When mean PEC-Q values were screened against SQT thresholds, nineteen of the sample locations had Level I SQT exceedances in at least one horizon, with eighteen of the sample locations having exceedances in the surficial (0-15 cm) horizon. While the mean PEC-Q value provides a sediment assessment tool that distills data from a mixture of contaminants into one unitless index, it is important to remember that the mean PEC-Q does not take into account dioxins/furans nor mercury, which also appear to be constituents of concern.

Surficial sediment was collected concurrently with chemistry and benthic community samples to be used for whole sediment toxicity tests. Toxicity tests included the *Chrionomus dilutes* 10-day and the *Hyallela azteca* 28-day exposures. Survival, growth, and biomass were recorded during exposures, and site sample results were compared to a laboratory control and an in-site control. Survival for the Project Area samples were generally over 80% in both toxicity tests, except locations 1001 (73.8%) and 1005 (78.8%) for *C. dilutes* tests and 1042 (50%) for *H. azteca* tests. However, eighteen of the twenty-one locations showed a significant decrease in survival as compared to the laboratory control for the *C. dilutes* tests, and nine of the twenty-one locations showed a significant decrease compared to the in-site reference location for *H. azteca*. While survival may be relatively high, in comparisons to the in-site control, growth and biomass of organisms may be being impacted at multiple sites in the Project Area in the surficial (0-15 cm) sediments.

Tissue bioaccumulation tests yielded similar concerns regarding the impacts of chemical concentrations in the sediments. *Lumbriculus variegatus* 28-day bioaccumulation tests were conducted using surficial sediment collected at the same locations as the toxicity tests. Metals in *L. variegatus* tissues indicated low levels of uptake of these contaminants. Similarly, PCB and PAH's tissue concentrations indicated low uptake. However, dioxin and furan congeners showed a range of uptake, and all tissues contained concentrations of dioxin and furan congeners. The presence of these contaminants in the tissues of *L. variegatus* presents a pathway of exposure for fish and wildlife resources.

Sediment samples, collected concurrently with samples for chemistry analysis and toxicity tests, were evaluated for to determine current macroinvertebrate community metrics. Dominant macroinvertebrate groups included oligochaetes and chironomids, both considered opportunistic taxa with the ability to tolerate anthropogenically affected sediments. A comparison of 2014 macroinvertebrate communities to the SLROC 2010 study suggest that the macroinvertebrate communities are stable and showed no change toward improvement or decline. While the communities appear to be stable, all but two sample locations in 2010 and one in 2014 exceeded the thresholds established by the reference locations.

Based on the results of the chemical, toxicological and biological sampling, five areas of ecological concern were identified where the benthic community and associated habitat appear degraded or are posing a risk to fish and wildlife resources. These five areas include locations of anthropogenic wood waste that appear to be impacting benthic macroinvertebrate communities by providing poor quality habitat and may not be impacted by chemical contamination. Concepts for addressing the removal of anthropogenic substrates and sediment contamination from these areas of ecological concern are presented with costs exceeding $25 million.

This FFS presented concepts for improving the 40th Avenue West Complex that would benefit the Degraded Fish and Wildlife Populations, Degradation of Benthos, and Loss of Fish and Wildlife Habitat BUIs by adding 5900 linear feet of shoreline habitat for the Island Concept, and increasing FLV habitat (27% Island Concept/0.1% Shoal Concept), and SAV habitat (40% Island Concept/68% Shoal Concept). In addition, 7 acres of island habitat will be created employing the Island Concept and up to 25 acres of deepwater overwintering fish habitat will be created. The cost of these suggested improvements range from $7.9 to $14.5 million depending on the features constructed and alternatives considered.

The suggested improvements are intended to create additional habitat to promote fish and wildlife propagation and reduce the risk to fish and wildlife resources, meeting the Goals identified in Section 1.4, although not all the suggested improvements may be necessary to achieve AOC delisting. It will be the task of the project stakeholders to determine what measures are necessary to address BUI's and move to delist the AOC while not impeding or compromising the ultimate ecological vision. In conclusion, this FFS contains the framework for future habitat work for the 40th Complex that could help further enhance the health of the Estuary.

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CONTRIBUTORS

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