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Appendix L: Project 1007 Feasibility Study Process and Outline Sediment Remedial Evaluation

Project 1007 Feasibility Study
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Acronyms and Abbreviations

%	Percent
°C	Degrees Celsius
µg/kg	microgram per kilogram
ac	acre
AGWC	Anna's Grove Wetland Complex
AOC	Area of Concern
CAPEX	Capital Expenditure
cy	cubic yards
ENR	Engineering News-Record
EPA	United States Environmental Protection Agency
EPL	Eagle Point Lake
FS	Feasibility Study
ft	feet
GAC	Granular Activated Carbon
GRA	General Response Action
HFPO-DA	Hexafluoropropylene oxide-dimer acid (Gen-X)
MPCA	Minnesota Pollution Control Agency
ODS	Oakdale Disposal Site
OPEX	Operating Expenditure
PFAS	Per- and Polyfluoroalkyl Substances
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutanesulfonic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexanesulfonic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
RAO	Remedial Action Objectives
SDSV	Site-Specific Sediment Screening Value
URCWC	Upper Raleigh Creek Wetland Complex
WCL	Washington County Landfill

L1 Introduction

The Project-1007 (Site) Feasibility Study (FS) identified 13 areas of concern (AOCs) that are contaminated with per- and polyfluoroalkyl substances (PFAS), three of which are sediment AOCs. Section 9 of the FS and Appendix D (Remedial Technology and Action Screening: Detailed Descriptions and Analysis) screened potential remedial technologies for their applicability to the Site and retained several technologies for potential implementation. Several of the retained technologies scored poorly for effectiveness, implementability, and/or technology readiness, but were still retained because of the limited availability of technologies specific to sediment remediation. This appendix evaluates sediment response options and provides recommendations for interim next steps to begin to address sediment AOCs.

L1.1 Sediment AOC's and Applicable Remedial Alternatives

Of the 13 AOC's identified as part of this FS, three are sediment AOCs while the remainder are groundwater or surface water AOCs. Summarized in Table L.1, these three sediment AOCs are AOC 11: Upper Raleigh Creek Wetland Complex (URCWC), AOC 12: Anna's Grove Wetland Complex (AGWC), and AOC 13: Eagle Point Lake (EPL) Sediment. AOC 11 is further sub-divided into three wetland areas: URCWC-A, located north of the Menards on Hadley Ave. N. and 34th St. N., URCWC-B, located south of the LA Fitness on 34th St N. and Hemingway Ave N., and URCWC-C, located south of 32nd St. N. in Oakdale, MN. These sub-sections of AOC 11, as well as AOC 12 and AOC 13 are shown in Figure 161 (See Appendix A). Although AOCs 11 and 12 are close spatially, these were maintained as two separate AOCs because of the differing potential risk to the public. Homes border the AGWC and there are signs of people, including children, entering the wetland area. New apartment buildings have been constructed near URCWC-C and the potential for residents to enter the wetland should be considered, especially as the areas near the wetland continue to be developed. Other wetlands and natural areas along Raleigh Creek and the Project 1007 Conveyance system were not made into AOCs because at the time of developing AOCs, other areas were not above sediment standards.

Table L.1: Sediment AOCs and Locations.

AOC	Name/Sub-Location	Location Description
AOC 11	URCWC-A	Wetland located north of Menards and southeast of Kwik Trip, bordered by Interstate-694 to the east, Hadley Ave N. to the west, and 34th St. N. to the north
	URCWC-B	Wetland located south of LA Fitness on 34th St. N. and bordered by Interstate-694 to the west, Hemingway Ave. N. to the east,
	URCWC-C	Wetland located south of Pinz and east of Ideal Storage and bordered by 32nd St. N. to the north
AOC 12	AGWC-N & AGWC	Two wetland areas located within the Anna's Grove residential development west of Ideal Ave. N. and north of Stillwater Blvd.
AOC 13	Eagle Point Lake Sediment	Sediment in and around Eagle Point Lake in the Lake Elmo Park Reserve

Eight remedial alternatives addressing all thirteen AOCs were developed as part of this FS. Recommendations from this appendix are incorporated into Remedial Alternatives 2-8. No sediment response actions are considered for Alternative 1 as it is the no further action alternative. Details on remedial alternatives can be found in Section 11 of the FS.

For all remedial alternatives, including Remedial Alternative 1 (no further action), interim measures are still expected at the former Oakdale Disposal Site (ODS) to reduce migration of PFAS from ODS into these sediment AOCs. Remedial action is expected to include a re-route of Raleigh Creek to reduce mass flux of PFAS away from ODS. Other interim actions may be required to further address PFAS migration from ODS.

L1.2 Sediment Remedial Targets

As stated by the Remedial Action Objectives (RAOs) in Section 8 of the FS, the goals of treatment for each sediment AOC are to:

1. Prevent human exposure of PFAS-containing sediments at concentrations above the relevant sediment criteria for protection of human health.
2. Reduce downgradient migration into surface water and groundwater of PFAS currently adsorbed to the sediment. This can be measured through a decrease in sediment concentrations over time and through decreasing concentration statistical trends within surface water and groundwater downgradient of these AOCs.

This FS has been completed in accordance with Priority 1 of the 2018 Settlement between the State of Minnesota and 3M Company (3M) (Minnesota v. 3M, 2018) (the Settlement), which is to provide safe and sustainable drinking water resources for current and future generations in the PFAS-impacted communities. Preventing damage to ecological receptors was not explicitly identified as a goal for sediment treatment as a result of the focus on drinking water. Additional work, outside the scope of this FS, may be necessary to fully investigate ecological impacts and may impact the choice of remedial alternatives.

Table L.2 summarizes the Minnesota Pollution Control Agency (MPCA) Site-Specific Sediment Screening Values (SDSVs). The SDSVs were derived by MPCA in March 2024 using the United States Environmental Protection Agency's (EPA) Superfund methodology for soil and modified to reflect the sediment exposure pathway for those recreating in areas on the banks of waterbodies where sediments may be present that are only sometimes water covered. The 5-day SDSVs are applicable to AOC 12, and the 2-day SDSVs are applicable to AOCs 11 and 13.

Table L.2: Site-Specific Sediment Screening Values.

Compound	Abbreviation	MPCA SDSV - 5 Days/Week	MPCA SDSV - 2 Days/Week
	Applicable AOC	AOC 12	AOCs 11 & 13
Perfluorooctanoic acid	PFOA	0.40 µg/kg	0.99 µg/kg
Perfluorooctanesulfonic acid	PFOS	18 µg/kg	45 µg/kg
Perfluorohexanesulfonic acid	PFHxS	170 µg/kg	430 µg/kg
Perfluorobutanesulfonic acid	PFBS	1,500 µg/kg	3,700 µg/kg
Perfluorohexanoic acid	PFHxA	2,600 µg/kg	6,600 µg/kg
Perfluorobutanoic acid	PFBA	120,000 µg/kg	250,000 µg/kg
Hexafluoropropylene oxide-dimer acid (GenX)	HFPO-DA	160 µg/kg	390 µg/kg

Legend: µg/kg = microgram per kilogram.

The MPCA has also developed soil reference values (SRVs) for PFAS compounds in both residential/recreational and commercial/industrial settings, given in Table L.3. These values may also be applicable to the sediment AOCs, though additional work is needed to determine Site-specific cleanup values.

The 2021 baseline ecological risk assessment (BERA) found the potential for impacts for some aquatic life and mammalian wildlife communities due to PFAS impacts in these AOCs (AECOM, 2021). At this time receptor-specific endpoints have not been calculated based on the data gathered during the BERA. Determining these endpoint concentrations is a crucial component in determining the required remedial actions to be protective of ecological receptors.

Table L.3: MPCA Residential and Industrial Soil Reference Values.

Compound	Residential/Recreational SRVs (µg/kg)	Commercial/Industrial SRVs (µg/kg)
PFBS	1,100	14,000
PFBA	20,000	220,000
PFOS	1.3	18
PFOA	0.16	0.86
PFHxS	0.0054	0.072
PFHxA	1,900	24,000
PFDA	0.027	0.36
HFPO-DA	66	970

A detailed analysis of concentrations of detected PFAS species in sediment AOCs can be found in Section 5 of the FS and Appendix C (Project 1007 Remedial Investigation Report).

L1.3 Sediment Response Options

Section 9 of the FS and Appendix D (Remedial Technology and Action Screening: Detailed Descriptions and Analysis) screened potential remedial technologies for their applicability to the Site and retained several technologies for potential implementation. Several of the retained technologies scored poorly for effectiveness, implementability, and/or technology readiness, but were still retained because of the limited availability of technologies specific to sediment remediation. Of the General Response Actions (GRAs) considered in Section 9 of the FS, sediment access restrictions and ex-situ sediment treatment were retained to address sediment RAOs. In-situ sediment responses such as soil mixing/stabilization, thermal treatment, and soil washing were not retained over concerns of lack of effectiveness, potential for ecosystem destruction, and continued potential for PFAS to leach from sediment to groundwater.

Sediment access restrictions address part one of the sediment RAOs by preventing incidental exposure to impacted sediments. These can be accomplished by installing fencing and/or posting signage around each sediment AOC to restrict access and inform residents about exposure risks. Ex-situ sediment treatment extracts impacted sediment via excavation or dredging, treats or disposes of it, and backfills the excavated area with clean material. Potential disposal methods relevant to sediment AOCs are landfilling, incineration, and thermal desorption. Ex-situ sediment treatment has the potential to address both components of the RAOs, depending on the effectiveness of extraction. Potential sediment response options, including a long-term monitoring option, are described below:

L1.3.1 Sediment Response Option 1: Long-term monitoring

This response option is provided as a baseline comparison for the other sediment response options. Sediment and/or surface water samples would be collected at some interval (e.g., quarterly, semi-annually, or annually) to evaluate PFAS concentration in sediment over time. No removal of contaminated material would occur.

L1.3.2 Sediment Response Option 2: Fencing / Access Restrictions

Fencing, signage, or other access restrictions (e.g., resident notification letters) would be implemented to reduce incidental exposure of residents to PFAS. No removal of contaminated material would occur.

L1.3.3 Sediment Response Option 3: Sediment Removal and Landfilling

Sediment would be extracted via excavation or dredging to remove sediment exceeding the relevant sediment cleanup values within each AOC. The extracted sediment would then be landfilled. The AOC would be backfilled with clean material.

L1.3.4 Sediment Response Option 4: Sediment Removal and Incineration

Sediment would be extracted via excavation or dredging to remove sediment exceeding the relevant sediment cleanup values within each AOC. The extracted sediment would then be incinerated. The AOC would be backfilled with clean material.

An additional sediment response option was initially included in this analysis: ex-situ thermal desorption of PFAS. Using this method, sediment would have been extracted via excavation or dredging and then undergone thermal desorption to strip PFAS from the sediment. Thermal desorption heats impacted sediments to temperatures between 450°C to 650°C to desorb PFAS from sediments and volatilize it into an air stream (Clean Earth, 2019; Zhao, 2019; EA Engineering, 2020; Söregård, 2020). The offgas would have been treated by thermal incineration and the treated soil recycled. However, after initial consultation with a thermal desorption vendor, the vendor cautioned against use of thermal desorption at this Site due to uncertain performance metrics for organic-rich sediments (up to 30% organics in Site specific sediment have been observed in sampling). The observed organics concentrations onsite of up to 30 percent are significantly higher than the 7-10 percent range with which the vendor has observed success. This is consistent with available literature, with slow desorption reported at 10% organic matter (Navarro, 2022). Depending on the size of the organics, the material that becomes dried in the rotary kiln can become fuel in the secondary treatment unit. The remaining can become “charred” and behave like charcoal/carbon and bind or generate some contaminants. Reductions in treatment rates due to the high organics would be required to reduce treatment rates to control potential fuel loading to the secondary treatment unit.

Thermal desorption was thus screened out as a result of these vendor discussions and is not evaluated further in this appendix. This technology may be reconsidered if successful results are observed with organic-rich influent in the future.

Additional technologies such as in-situ thermal remediation and ex-situ soil washing are in development for treatment of PFAS-contaminated sediments beyond the treatment technologies considered in this appendix. However, as discussed in Section 9 of the FS, these additional technologies are not ready for full-scale use and thus not discussed here. As research and development into these emerging treatment alternatives for PFAS-contaminated sediment continues, additional treatment alternatives should be reconsidered in the future if further commercial backing and successful field demonstrations are achieved.

L1.4 Methods for Evaluation

The following criteria were used to evaluate sediment response options: effectiveness, implementability, cost, risk, and portion of PFAS destroyed by treatment. As the goal of this FS is to provide safe and sustainable drinking water resources for current and future generations in the PFAS-impacted communities as laid out by the Settlement, evaluation of these criteria focuses on human

health and does not broadly consider other ecological impacts. Further work is needed to address ecological impacts more adequately.

Effectiveness: Effectiveness considers the ability of a sediment response option to meet current regulatory PFAS standards and to address sediment RAOs. As the focus of this FS is protection of drinking water resources for current and future generations in PFAS-impacted communities, the focus of this criterion is human health. At this time, Site-specific cleanup standards have not been developed; thus, for the purposes of this report, SDSVs and SRVs are both considered for use as remedial targets.

Implementability: This criterion evaluated the ability to employ a sediment response option. While all sediment response options are commercially available or have undergone field demonstrations and are thus considered technologically implementable, Site-specific conditions are evaluated here that may make implementing a technology that is commercially available unfeasible.

Cost: Capital expenditure (CAPEX) and annual or operating expenditure (OPEX) are both considered for this criterion. Evaluation was completed using initial CAPEX and OPEX estimates; these estimates and the assumptions made are detailed at the end of this document.

Risk: This criterion considers risk to nearby residents, risk to other communities, and ecological risk. Risk to residents near wetlands considers the risk of PFAS exposure to residents who live near an AOC, as well as other hazards associated with remedial operations. Risk to other communities is also considered, which evaluates the short-term risk to other communities posed by remedial operations and long-term risks from PFAS spread; for example, transport and disposal of soil contaminated with PFAS out of state transfers some risk from Minnesota communities to communities in other states, though the PFAS is better contained and able to be managed at disposal facilities intended for capture of PFAS-containing materials. Finally, ecological risk is also considered, which evaluates the risk a treatment option poses to the natural environment. While consideration of the risk to ecological receptors from PFAS surface water and sediment contamination was not a primary consideration in this FS, high level risks to the ecosystem from PFAS impacts were included in the ecological risk evaluation based on the BERA report (AECOM, 2021).

Portion of PFAS Destroyed: This criterion compares the relative mass of PFAS that is ultimately destroyed by a given treatment train. Destruction of PFAS is evaluated separately from “Effectiveness” and “Risk” because the lack of complete PFAS degradation pathways in the environment makes it uniquely persistent. Additionally, regulatory criteria are extremely low, so even diluted waste streams, such as landfill leachate sent to a wastewater treatment facility, can be problematic without targeted destruction technologies. Reduction of PFAS mobility achieved by disposal is evaluated as part of the ‘Risk’ criteria. Further details on PFAS destruction can be found in Section 9 of the FS and Appendix G (PFAS Destruction Technology Bench-Scale Study Summary and Analysis).

It is important to note these evaluation criteria assume source zone reduction occurs prior to implementation of remedial activities. Investigation as part of this FS has identified the source zones that continue to release PFAS to the environment: ODS and the Washington County Landfill (WCL). AOCs 11 and 12 continue to be impacted by PFAS released from ODS, and AOC 13 is impacted by PFAS released currently from ODS and historically was impacted by WCL. Control of these source zones must be prioritized over sediment response actions as continued PFAS release will continue to contaminate sediment. Thus, if sediment remedial actions were taken prior to control of source zones is achieved, recontamination of sediment would likely occur. For more information on Site investigations, see Section 5 of the FS and Appendix C.

L1.5 Response Option Descriptions

L1.5.1 Access Restrictions

Access restrictions can be encouraged with signage and residential communications or enforced with fencing. Signage and residential communications may be more appropriate for exposures posed by intermittent hazards such as fish consumption advisories to warn anglers about the hazards of consuming contaminated fish or warnings to residents to avoid intermittently occurring foam. Fencing may be more appropriate around areas with more continuous risks, such as wetlands with high exceedances of sediment cleanup values, near areas of easier access, or where frequent AOC access has been observed. Figure L.1, Figure L.2, and Figure L.3 illustrate potential fencing locations in each AOC; estimated fence lengths are given in Table L.4. URCWC-B does not require fencing at this time as the parking lot south of LA Fitness and along Hemingway Ave. N. are already fenced, however, should the land south of URCWC-B be developed, fencing would likely be needed to the south of the wetland. This is not included in this appendix as it is assumed to be the responsibility of the developer; an environmental covenant may be necessary to ensure any development south of URCWC-B requires a future developer to provide fencing and potentially signage and notification to residents to restrict access to the wetland.

Table L.4: Estimated Fence Length by AOC.

AOC	Name/Sub-Location	Fence Length (feet)
AOC 11	URCWC-A	1,300
	URCWC-B	N/A – already fenced
	URCWC-C	1,800
AOC 12	AGWC-N	1,600
	AGWC	2,600
AOC 13	Eagle Point Lake Sediment	15,200

L1.5.2 Sediment Removal

Contaminated sediment can be removed by excavation or dredging. Both methods of sediment removal would require site preparation activities such as vegetation clearing and installation of an access road to enable site access. Sediment handling and staging areas would also be required.

Excavation would involve removal of contaminated sediment by using heavy machinery with direct access to the entire area to be removed. Excavation could be achieved using a variety of machinery, from backhoes in smaller areas to larger excavators for larger areas. Excavation would require access roads to be built for both the machinery removing sediment as well as dump trucks to haul away contaminated sediment. Use of long-reach excavators could reduce access needs, however proper clearance from overhead power lines would be needed. Excavation is most applicable to dry sediments, though it can also be used in areas that are seasonally dry or areas that have been dewatered. Excavations of dry, seasonally dry, or dewatered AOCs are also likely to require installation of temporary stormwater diversion structures.

Where large surface water volumes render surface water body dewatering infeasible, dredging of submerged sediment may be the more appropriate technology. Mechanical dredging and hydraulic dredging are the two most common methods (ITRC, 2014). Mechanical dredging utilizes specialized, heavy equipment such as a crane or excavator fitted with a clamshell bucket to remove contaminated

sediment; sediment is then removed from site either using a barge (in larger areas where on-the-water removal occurs) or with a dump truck, when access from shore is possible.

Hydraulic dredging uses a pump to remove sediment using suction; sediment is fluidized and pumped to a discharge location for further handling (ITRC, 2014). Large volumes of water are needed to remove sediment and can be as high as 1,000-2,000 gallons per cubic yard (cy) of sediment (ITRC, 2014); thus, dewatering would be required prior to sediment disposal. Dewatering would require additional staging area and could include methods such as mechanical dewatering or dewatering tubes (Englis, 2007). Mechanical dewatering is assumed for the purposes of this appendix; a more specific analysis of dewatering technologies is outside the scope of this appendix. It is also assumed removed water can be discharged back into the water body from which it came, though it may require treatment prior to discharge. Treatment of removed water is not considered in this appendix and would therefore increase cost estimates if found to be required.

AOC sublocations and applicable sediment extraction method are summarized in Table L.5. Excavation could be used for all three wetland areas in AOC 11 during seasonally dry periods. AOC 11 proposed excavation areas are summarized in Figure L.4 (AOC 11, URCWC-A), Figure L.5 (AOC 11, URCWC-B), and Figure L.6 (AOC, URCWC-C). The two wetland areas that comprise AGWC in AOC 12 have been observed to have periods of seasonally low water levels but typically still have some water present; thus, dredging would likely be required. Proposed sediment removal areas are summarized in Figure L.7 (AOC 12, AGWC-N) and Figure L.8 (AOC 12, AGWC). If suitable access can be achieved in AGWC, mechanical dredging could be used, otherwise hydraulic dredging could potentially be required. Hydraulic dredging would likely be required for AOC 13 due to the size of Eagle Point Lake (120 acres [ac]) and relative shallowness of the lake (three feet mean depth, six feet maximum depth) (Met Council, 2021) which would make use of a barge and mechanical dredging impractical. Figure L.9 summarizes proposed sediment removal areas in AOC 13. Sediment volumes to be removed were estimated using ArcGIS for AOCs 11 and 12 and estimated using the approximate surface area of Eagle Point Lake for AOC 13 (Met Council, 2021).

Table L.5: Sediment Removal Volumes by AOC.

AOC	Name/Sub-Location	Sediment Extraction Method	Wetland Area (acre)	Area to be Excavated (ac)	Estimated Removed Sediment Volume (cubic yards)
AOC 11	URCWC-A	Excavation	14.6	4.3	7,000
	URCWC-B	Excavation	11.2	5.6	16,500
	URCWC-C	Excavation	9.9	3.1	11,200
AOC 12	AGWC-N	Mechanical Dredging	1.1	1.1	5,400
	AGWC	Mechanical Dredging	4.4	3.7	20,000
AOC 13	Eagle Point Lake Shoreline Sediment	Excavation	3.5	3.5	17,000
	Eagle Point Lake Sediment	Hydraulic Dredging	120	120	200,000

Figures L.4 – L.9 illustrate the known extent of sediment contamination in each AOC. In each figure, the highlighted blue regions delineate the extent of each wetland. Where sufficient data exists, contour lines were generated based on the location and depth of each PFAS sediment sample point. Raster files were then created based on these samples points which showed shaded depth reactions, and these regions were converted to contour lines to estimate the depth of excavation or dredging needed to

address PFAS impacts. For wetlands where there was insufficient data to delineate contours, sediment removal was assumed to be to a single depth across the wetland that would be sufficient to capture impacts exceeding the relevant SDSVs. Additional sampling would be recommended prior to commence of sediment removal to further delineate the sediment removal area.

L1.5.3 Sediment Disposal

Once removed, sediment must be properly disposed of to mitigate future risk of exposure. Two methods are considered in this appendix: landfilling and incineration. Landfilling would involve transportation of contaminated sediment to an appropriate facility that accepts PFAS-containing waste, such as a hazardous waste landfill. These facilities, which are sometimes also known as closed-loop landfills, have sufficient liners and leachate collection systems to prevent re-release of PFAS into the environment. Incineration would utilize a hazardous waste incinerator to destroy PFAS. Ash/incombustible sediment that remained behind after incineration would be landfilled at an appropriate hazardous waste landfill.

L1.6 Cost Estimates

Cost estimates were developed for sediment response options evaluated in this appendix. Unit cost estimates reflect the opinion of AECOM of probable construction costs utilizing information available at the time the document was prepared.

AECOM has no control over future costs of construction labor, materials, equipment, nor of contractors' methods of determining prices, nor of competitive construction industry market conditions. The accuracy of the estimates is not guaranteed, and they are not intended to predict the outcome of the construction bidding.

AECOM has based the unit costs on AACE Class V estimating guidance. This opinion of probable costs is based on conceptual design and the basis of estimate summarized in this report. All costs were developed in September 2024 dollars based on the Engineering News-Record (ENR) Building Cost Index for Minneapolis. All project descriptions and cost estimates in this report represent planning-level accuracy and opinions of costs (-50%, +100%).

The unit costs have been developed based on cost estimating resources including:

- Local vendor estimates for specialized materials and equipment;
- Construction and installation costs from similar AECOM projects;
- Historical data and prices for similar facilities designed and/or constructed by AECOM;
- Where applicable, pricing estimates from governmental agencies or technical groups;
- Where applicable, historic costs have been inflated based on Engineering News Record construction indices.

The estimated unit cost includes the sum of materials, labor, and equipment of reasonably identified features of a project. The estimated total project cost is the sum of construction costs with additional allowances for direct and indirect costs and contingencies.

The following additional indirect costs and contingencies were included while developing costs for Sediment Response Options 3 and 4:

Indirect:

- Contractor Overhead and Profit (10%)
- Engineering and Construction Contingencies (10%)

Mobilization and site setup was not included as a direct contingency for Sediment Response Options 3 and 4 as it was included in a vendor estimate. Indirect contingencies are lower than similar Class V estimates in this FS as high-end unit costs were selected, which builds in a level of contingency to cost estimates. Contingency is also included in Sediment Response Options 1 and 2, though to a lesser extent. These response options would not involve engineering design and would require less extensive planning. Thus, less contingency was assumed to be required.

Unit cost estimate assumptions for CAPEX items are summarized in Table L.6. While sediment removal estimates were calculated per cy, some unit costs are applied on a per ton basis. Bulk soil density was estimated using Web Soil Survey (USDA, 2019) data from each wetland except for Eagle Point Lake, which did not have sufficient data to estimate bulk soil density. Thus, an average of the other wetland bulk soil densities was used for Eagle Point Lake. Soil composition and density data is available in Table L.23. Estimates did not include costs for backfill under waterbodies, specifically under Eagle Point Lake, as it was assumed backfill would not be required. If clean backfill of Eagle Point Lake was required, this would result in an increase in the overall remedial cost.

Some sediment response options would require on-going maintenance or yearly expenses, which would result in OPEX. Restoration of wetlands was assumed to require 10 years, with years 1-5 focused on management of invasive species and flora establishment while monitoring only would occur during years 6-10. Based on recent AECOM project costs and cost estimates, maintenance during years 1-2 are estimated to cost \$25,000 per acre, years 3-5 estimated to cost \$8,100 per acre, and years 6-10 estimated to cost \$2,000 per acre. PFAS samples for long-term monitoring were assumed to cost \$400 per sample. Labor to collect samples and analyze data was not included as long-term monitoring is proposed for additional AOCs beyond the scope of this appendix. Sediment samples would be collected at the same time as samples from other AOCs, reducing labor costs. Fencing OPEX costs were estimated to be 1% of fence CAPEX.

Table L.6: Sediment Response Option Unit Cost Estimates.

Remedial Activity	Sub-Activity	Cost per Unit	Cost Description	Source
Fencing	-	\$125 per foot installed	Fencing and installation costs	AECOM previous project
Excavation	Excavation	\$16 per cy	Excavation & Loading	Vendor Cost Estimate
	Excavation (with dewatering)	\$27 per cy	Excavation, addition of drying agent, loading	Vendor Cost Estimate
	Backfill & Restoration	\$27 per cy	Clean fill, basic site restoration	Vendor Cost Estimate
Dredging	Hydraulic Dredging	\$24 per cy	Includes piping to dewatering area	Anchor QEA, 2020
	Mechanical Dewatering	\$36 per cy	Includes piping to discharge water	Anchor QEA, 2020
	Restoration of dewatering area	\$5 per cy	-	Anchor QEA, 2020
Disposal	Landfill	\$308 per ton	Includes transportation cost	Vendor Cost Estimate
	Incineration	\$941 per ton	Includes transportation cost	Vendor Cost Estimate
Restoration	Wetland Restoration	\$60 per square yard	-	MPCA, 2022

L2 Individual Analysis of Sediment Response Options

Sediment response options considered for sediment remediation are described in the following section. Additional information on specific technologies can be found in Section 9 of the FS and Appendix D. A summary of individual treatment train rankings is given in Table L.7.

Table L.7: Sediment Response Options Individual Rankings.

Sediment Response Option	Effectiveness	Implementability	Cost	Risk	Portion of PFAS Destroyed
Option 1: Long-Term Monitoring	Low	High	CAPEX: Low	Moderate	Low
			OPEX: Low		
Option 2: Fencing/ Access Restrictions	Moderate	Moderate	CAPEX: Moderate	Low	Low
			OPEX: Low		
Option 3: Sediment Removal & Landfilling	High	Low	CAPEX: High	Moderate	Low
			OPEX: Moderate		
Option 4: Sediment Removal & Incineration	High	Low	CAPEX: High	Moderate	High
			OPEX: Moderate		

L2.1 Sediment Response Option 1: Long-term monitoring

Sediment Response Option 1 is long-term monitoring. This response option would utilize the collection and analysis of sediment samples to monitor PFAS concentrations in sediment over time. Natural leaching of PFAS from sediment could result in decreases of PFAS sediment concentrations over time, which could result in lower sediment PFAS concentrations in wetlands. As previously discussed, reduction of sediment concentrations is dependent on source zone control and reduction of PFAS loading through surface water to wetland sediments.

L2.1.1 Effectiveness

Effectiveness to meet RAOs is expected to be low. Long-term monitoring would not directly reduce the risk of incidental human contact with PFAS contaminated sediments, nor would it decrease downgradient movement of PFAS. However, long-term monitoring would provide data to determine if mass reduction efforts at source zones have been effective.

L2.1.2 Implementability

Implementability for long-term monitoring is high and is summarized by AOC in Table L.8.

Table L.8: Sediment Response Option 1 Implementability Scoring.

AOC	Wetland	Scoring
AOC 11	URCWC-A	High. Sediment sampling previously conducted and requires no additional infrastructure to be installed.
	URCWC-B	
	URCWC-C	
AOC 12	AGWC-N	High. Sediment sampling previously conducted and requires no additional infrastructure to be installed.
	AGWC	
AOC 13	EPL	High. Sediment sampling previously conducted and requires no additional infrastructure to be installed.

L2.1.3 Cost

Costs would be low for long-term monitoring. There would be no CAPEX costs associated with this sediment response option, as long-term monitoring would not require installation of any specific equipment. Yearly cost of PFAS samples by AOC are given in Table L.9. Cost to collect samples and analyze data are not included as Site-wide long-term monitoring is proposed and collection/data analysis of these samples would be incorporated into Site-wide long-term monitoring costs. Note that this only includes costs to sample sediment; cost estimates do not include costs to sample surface water or groundwater. While surface water and groundwater samples are necessary to evaluate the reduction in downgradient migration of PFAS into surface water and groundwater, long-term monitoring is proposed as a remedial approach across the Site. Surface water and groundwater costs are not listed here as these samples are already included in the relevant surface water and groundwater samples included in the proposed long-term monitoring. Overall long-term monitoring costs can be found in Section 12 of the FS.

Table L.9: Sediment Response Option 1 OPEX Sediment Sampling Cost Estimate.

Wetland	Samples per Year: Sediment		Sample Cost per Year	
	Low ⁽¹⁾	High ⁽²⁾	Low	High
URCWC-A	1	6	\$400	\$2,400
URCWC-B	1	6	\$400	\$2,400
URCWC-C	1	6	\$400	\$2,400
Anna's Grove N	1	6	\$400	\$2,400
Anna's Grove	1	6	\$400	\$2,400
EPL	1	6	\$400	\$2,400
Totals:	6	36	\$2,400	\$14,400

(1) Assumes 1 sediment sample per wetland, once per year.

(2) Assumes 3 sediment samples per wetland, twice per year.

L2.1.4 Risk

Risk to nearby residents is moderate as no measures would be taken to reduce residents' potential exposure to contaminated sediment. Risk to other communities would be moderate as contaminated sediment could leach PFAS to downgradient communities, though PFAS leaching from AOCs 11, 12 and 13 is expected to contribute less than the current levels of PFAS moving downgradient from ODS and WCL. Ecological risk of the remedial action (collection of PFAS samples) is low as sampling would not

substantively impact the wetland. However, the PFAS concentrations are elevated in the surface water and sediment and are predicted to have negative impacts on wildlife receptors (AECOM, 2021). Specifically, food web modeling showed impacts to spotted sandpiper, great blue heron, little brown bat, muskrat, tree swallow, and mink (AECOM, 2021). Thus, there would still be moderate risk to ecological receptors as a result of PFAS impacts remaining in the sediment. Overall risk for this sediment response option is moderate.

L2.1.5 Portion of PFAS Destroyed

No PFAS would be destroyed with this sediment response option, thus the portion of PFAS destroyed would be low. PFAS would remain in the sediment and potentially desorb to surface and groundwater over time.

L2.2 Sediment Response Option 2: Fencing / Access Restrictions

Sediment Response Option 2 would utilize fencing and access restrictions to reduce incidental exposure of residents to PFAS contaminated sediments. Cost estimates were developed for wetlands in all AOCs, with individual analysis of each AOC. Under this response option, signage and notifications would also be utilized to inform residents of the presence of contaminated sediment and to provide information on avoiding exposure. While this response option would include both fencing and signage/notifications, analysis is focused on fencing as signage and notifications are easily implementable, low cost, and have previously been used as an interim response measure.

L2.2.1 Effectiveness

Fencing and access restrictions are expected to have moderate effectiveness when evaluated against the sediment RAOs. Fencing would decrease the risk of human exposure to PFAS-containing sediments by increasing difficulty of access. Signage and notifications to residents would help increase resident awareness of contaminated sediments. However, effectiveness might be lower in AOC 13 as Eagle Point Lake would be expected to remain open for use by non-motorized watercraft. Additionally, there would be no reduction in downgradient migration of PFAS to downgradient surface water and groundwater from desorption of PFAS currently bound to sediment. Thus, overall effectiveness would be moderate as only one of the two RAOs would be addressed by this sediment response option.

L2.2.2 Implementability

Implementability is summarized by AOC in Table L.10. Implementability varies by AOC but is expected to be moderate when all AOCs are considered.

Table L.10: Sediment Response Option 2 Implementability Scoring.

AOC	Wetland	Scoring
AOC 11	URCWC-A	Moderate. Fencing would be installed along Hadley Ave. N., which would facilitate access and decrease site preparation needs. Installation in the vicinity of the Kwik Trip car wash would likely require coordination with the business but could likely be done without impeding Kwik Trip traffic. Most of this land is owned by Menards, which would require cooperation with the company to install fencing. Deed restrictions may also be required to ensure fencing remains in place, potentially decreasing implementability.
	URCWC-B	Not Applicable, fencing already installed to the north and east; however, as in other wetlands, deed restrictions may be required to ensure fencing remains in place.
	URCWC-C	High. Fencing would be installed along 32 nd St. N. which would facilitate access and decrease site preparation needs. Sidewalk would likely be impeded during installation, but temporary jersey barriers could be installed to provide a safe walkway for pedestrians. Most of this property is owned by the City of Oakdale; minimal issues with installation of fencing are expected, though deed restrictions may also be required to ensure fencing remains in place.
AOC 12	AGWC-N	Moderate. Areas to be fenced do not have easy access and may require access agreements with residents along with restoration of residents' yards. Deed restrictions may also be required to ensure fencing remains in place.
	AGWC	Moderate. Areas to be fenced do not have easy access and may require access agreements with residents along with restoration of residents' yards. Deed restrictions may also be required to ensure fencing remains in place.
AOC 13	EPL	Low. Installation of fencing would require significant disruption around Eagle Point Lake and is likely to cause habitat disruption. Community members are unlikely to support fence installation. Permits may be difficult to obtain depending on the regulatory agency. However, if only signage is used, implementability would be high. Coordination with park officials could help to determine the most effective places to install signage.

L2.2.3 Cost

Estimated costs for fencing are given in Table L.11 and access restrictions (signage and resident notifications) are detailed in

Table L.12. Fencing and access restrictions are expected to be low to moderate in cost, depending on the AOC in which they are implemented. Fencing costs for AOC 11 (URCWC-A and URCWC-C) and AOC 12 (AGWC-N and AGWC) would be significantly lower than fencing costs for AOC 13, given the relative size of Eagle Point Lake to the other AOCs. No fencing is considered for URCWC-B at this time as there is already fencing to the north and east of the wetland, though an environmental covenant may be necessary to guarantee that fencing is kept in place. The need for fencing in URCWC-B should be reevaluated in the future if the area south of the wetland is further developed; as previously discussed, an environmental covenant may be necessary to require fencing additional fencing around URCWC-B should there be additional development in the area.

Table L.11: Sediment Response Option 2 Fencing CAPEX and OPEX Cost Estimates by AOC.

AOC	AOC 11 ⁽¹⁾		AOC 12		AOC 13
Wetland	URCWC-A	URCWC-C	AGWC-N	AGWC	EPL
Fence Length (ft)	1,300	1,800	1,600	2,600	15,200
Fence Cost	\$170,000	\$230,000	\$220,000	\$330,000	\$1,910,000
Site Preparation	\$50,000	\$50,000	\$50,000	\$75,000	\$500,000
<i>Contingency</i>	<i>\$50,000</i>	<i>\$50,000</i>	<i>\$50,000</i>	<i>\$75,000</i>	<i>\$250,000</i>
CAPEX Total	\$270,000	\$330,000	\$320,000	\$480,000	\$2,660,000
Yearly OPEX ⁽²⁾	\$2,700	\$3,300	\$3,200	\$4,800	\$26,600

(1) URCWC-B is already fenced to the north and to the east of the wetland; additional fencing is not considered in this appendix.

(2) Fencing OPEX estimated at 1% of project CAPEX cost.

Table L.12: Sediment Response Option 2 Signage and Notification CAPEX and OPEX Cost Estimates by AOC.

AOC	Category	AOC 11	AOC 12	AOC 13
Signage & Notifications	CAPEX	\$5,000	\$10,000	\$25,000
Yearly Notifications	OPEX	\$20,000		

L2.2.4 Risk

Risk to nearby residents is low as fencing and access restrictions would reduce residents' potential exposure to contaminated soil. Risk to other communities would be moderate as contaminated sediment could leach PFAS to downgradient communities, though PFAS leaching from AOCs 11, 12 and 13 is expected to contribute less than the current levels of PFAS moving downgradient from ODS and WCL. Ecological risk is low to moderate; fencing is unlikely to impact wetlands in AOCs 11 and 12 while fencing in AOC 13 could impact wildlife around Eagle Point Lake. As stated previously, wetland species are at risk as a result of the elevated PFAS concentrations in the sediment and surface water (AECOM, 2021). Overall risk for this sediment response option is low, though it must be noted the risk for AOC 13 is expected to be higher than AOCs 11 and 12 due to increased ecological risk around Eagle Point Lake.

L2.2.5 Portion of PFAS Destroyed

No PFAS would be destroyed with this sediment response option, thus portion of PFAS destroyed would be low. PFAS would remain in the sediment and potentially desorb to surface water to be transported downstream or into groundwater over time.

L2.3 Sediment Response Option 3: Sediment Removal and Landfilling

Sediment Response Option 3 would use excavation or dredging to remove contaminated sediment from AOCs. Sediment would then be transported to a hazardous waste landfill that accepts PFAS-containing wastes for final disposal.

L2.3.1 Effectiveness

Removal of sediment and landfilling is expected to have high effectiveness when evaluated against the sediment RAOs. Removal of contaminated sediment would prevent human exposure to PFAS-containing sediments. It would also reduce downgradient migration of PFAS to downgradient surface water and groundwater that can occur from desorption of PFAS currently bound to sediment. Effectiveness is dependent on sufficient removal of contaminated sediment; should excavation or dredging not remove all contaminated material above the relevant sediment cleanup values, effectiveness would only be moderate.

L2.3.2 Implementability

Implementability is summarized by AOC in Table L.13. Implementability does vary with AOC, but overall implementability is expected to be low. An additional consideration, which is not fully explored in this appendix, is the likelihood of obtaining permits. Excavation of the permanently or semi-permanently flooded portion of Type 3 (shallow marshes with six or more inches of water), Type 4 (deep marshes with six inches to three feet of water), or Type 5 (shallow open water under six feet deep) wetlands or excavation which converts any type of wetland to a non-wetland is regulated by the Wetland Conservation Act (WCA) (BWSR, 2020). Each of the sediment AOCs contains regions as assigned by the National Wetland Inventory (NWI) which qualify them as regulated by the WCA (Kloiber, 2019). It may be challenging to obtain permits to excavate the wetlands without significantly more study on the expected recovery time and reduction of PFAS impacts to ecological receptors.

Table L.13: Sediment Response Option 3 Implementability Scoring.

AOC	Wetland	Ranking
AOC 11	URCWC-A	Moderate. Wetlands are located away from residential homes and off roadways. Traffic on roads would likely be impeded during some phases of excavation but could be managed with standard safe work practices. With proper access agreements, staging could take place off roads in all AOCs with minimal site disturbance.
	URCWC-B	
	URCWC-C	
AOC 12	AGWC-N	Low. Wetlands are located behind residents' homes. Access would likely require significant disturbance to residents' property. Staging would be difficult due to limited space available near wetlands.
	AGWC	
AOC 13	EPL	Low. Significant site preparation would be needed to remove sediment from EPL and from around the EPL lake shore. Community support is expected to be low and may pose challenges. Significant permitting is likely required, and legal challenges could occur.

L2.3.3 Cost

CAPEX cost estimates for Sediment Response Option 3 are given in Table L.14 (AOC 11), Table L.15 (AOC 12), and Table L.16 (AOC 13). Estimated OPEX costs are given in Table L.17. OPEX cost estimates assume 10 years of work is needed to rehabilitate wetlands, with the initial two years of active restoration expected to cost \$25,000 per acre to establish new species, years three through five expected to cost \$8,100 per acre to remove invasive species and maintain restoration areas, and the final five years being monitor only at \$2,000 per acre. Costs are based on previous AECOM project experience. For the purposes of this analysis, a present worth is not conducted on estimated OPEX costs; instead, a simple sum for the 10 years of OPEX is given in Table L.17. Costs are expected to be high.

Table L.14: Sediment Response Option 3 CAPEX Estimates for AOC 11.

AOC	AOC 11		
Parameter	URCWC-A	URCWC-B	URCWC-C
Area of Sediment Removal (ac)	4.3	5.6	3.1
Depth of Sediment Removed (ft)	1 to 2	1 to 3	1 to 3
Volume of Sediment Removed (cy)	7,000	16,500	11,200
Mass of Sediment Removed (tons)	7,875	18,563	12,600
Additional Site Investigation	\$25,000	\$25,000	\$25,000
Mobilization/Demobilization	\$25,300	\$25,300	\$25,300
Clearing & Site Setup	\$25,000	\$40,000	\$25,000
Excavation & Loading	\$112,000	\$264,000	\$180,000
Transportation & Landfilling	\$2,035,000	\$5,998,000	\$4,177,000
Wetland Restoration	\$1,250,000	\$3,240,000	\$2,860,000
Subtotal	<u>\$3,480,000</u>	<u>\$9,600,000</u>	<u>\$7,300,000</u>
<i>Contractor Overhead & Profit (10%)</i>	<i>\$350,000</i>	<i>\$960,000</i>	<i>\$730,000</i>
<i>Engineering and Construction Contingencies (10%)</i>	<i>\$350,000</i>	<i>\$960,000</i>	<i>\$730,000</i>
Total	\$4,180,000	\$11,520,000	\$8,760,000

Table L.15: Sediment Response Option 3 CAPEX Estimates for AOC 12.

AOC	AOC 12	
Parameter	AGWC-N	AGWC
Area of Sediment Removal (ac)	1.1	3.7
Depth of Sediment Removed (ft)	3	1 to 3
Volume of Sediment Removed (cy)	5,400	20,000
Mass of Sediment Removed (tons)	6,075	22,500
Additional Site Investigation	\$25,000	\$25,000
Mobilization/Demobilization	\$25,300	\$25,300
Clearing & Site Setup	\$25,000	\$40,000
Excavation & Loading	\$145,000	\$536,000
Transportation & Landfilling	\$1,935,000	\$7,911,000
Wetland Restoration	\$333,000	\$1,260,000
Subtotal	<u>\$2,490,000</u>	<u>\$9,800,000</u>
<i>Contractor Overhead & Profit (10%)</i>	<i>\$250,000</i>	<i>\$980,000</i>
<i>Engineering and Construction Contingencies (10%)</i>	<i>\$250,000</i>	<i>\$980,000</i>
Total	\$2,990,000	\$11,760,000

Table L.16: Sediment Response Option 3 CAPEX Estimates for AOC 13.

AOC	AOC 13	
Parameter	EPL - Shoreline	EPL - Lake Sediment
Area of Sediment Removal (ac)	3.5	120
Depth of Sediment Removed (ft)	3	1
Volume of Sediment Removed (cy)	17,000	200,000
Mass of Sediment Removed (tons)	19,125	225,000
Additional Site Investigation	\$50,000	\$50,000
Mobilization/Demobilization	\$51,000	\$350,000
Clearing & Site Setup	\$130,000	-
Excavation & Loading	\$272,000	-
Transportation & Landfilling	\$6,056,000	\$71,243,000
Wetland Restoration	\$1,010,000	-
Hydraulic Dredging		\$4,800,000
Mechanical Dewatering		\$7,200,000
Restoration of Dewatering Area		\$1,000,000
Subtotal	\$7,570,000	\$84,650,000
<i>Contractor Overhead & Profit (10%)</i>	<i>\$760,000</i>	<i>\$8,470,000</i>
<i>Engineering and Construction Contingencies (10%)</i>	<i>\$760,000</i>	<i>\$8,470,000</i>
Total	\$9,090,000	\$101,590,000

Table L.17: Sediment Response Option 3 Yearly OPEX Estimates.

AOC	AOC 11			AOC 12		AOC 13
Year	URCWC-A	URCWC-B	URCWC-C	AGWC-N	AGWC	EPL Shoreline
Years 1-2	\$109,000	\$141,000	\$79,000	\$28,000	\$94,000	\$88,000
Years 3-5	\$36,000	\$46,000	\$26,000	\$10,000	\$31,000	\$29,000
Years 6-10	\$9,000	\$12,000	\$7,000	\$3,000	\$8,000	\$7,000
10-Year Cost	\$366,000	\$474,000	\$265,000	\$95,000	\$315,000	\$295,000

L2.3.4 Risk

Risk to nearby residents long-term is low as excavation/dredging would remove contaminated soil and thus remove the risk of residents' potential exposure to contaminated soil. There would be some short-term risk associated with construction, though this could be mitigated with safe work practices. There would be some risk to other communities as transport of contaminated sediment to a hazardous waste landfill would shift some of the long-term risk to another community. However, the risk of exposure from disposal of PFAS in hazardous waste landfills would be significantly lower than the risk of exposure to residents from uncontrolled contaminated sediments in accessible areas. Thus, risk to other communities is low. Dredging can result in re-suspension of sediment, potentially impacting downgradient communities if contaminated sediment is resuspended and transported downgradient as a result of remedial actions; however, mitigation efforts would help to reduce the transport of sediment downgradient as a result of dredging activities. Short-term ecological risk is high as excavation/dredging

would substantively impact the wetland. Long-term ecological risk would be low as PFAS impacts to wildlife receptors would be mitigated. Overall risk for this sediment response option is moderate due to the ecological damage that is expected to occur from construction activities.

L2.3.5 Portion of PFAS Destroyed

Contaminated sediment, and thus PFAS sorbed to the contaminated sediment, would be sequestered in a hazardous waste landfill. This would not result in any direct destruction of PFAS. It is possible that leachate collection from the hazardous waste landfill could result in the destruction of some PFAS depending on the treatment methods utilized by the specific landfill. However, this is not a common practice currently. Sediment would also require dewatering prior to landfilling; treatment of removed water with granular activated carbon (GAC) to remove any PFAS would be recommended. PFAS removed by the GAC would be destroyed upon GAC reactivation. However, this is likely an insignificant mass compared to the overall mass of PFAS sorbed to the sediment and is not expected to change the relative scoring.

L2.4 Sediment Response Option 4: Sediment Removal and Incineration

Sediment Response Option 4 would use excavation or dredging to remove contaminated sediment from AOCs. Sediment would then be transported to an incinerator that accepts PFAS-containing wastes to incinerate soil. Any material that remained after incineration (e.g., ash, silicates) would be landfilled in a hazardous waste landfill.

L2.4.1 Effectiveness

Removal of sediment and landfilling is expected to have high effectiveness when evaluated against the sediment RAOs. Removal of contaminated sediment would prevent human exposure to PFAS-containing sediments. It would also reduce downgradient migration of PFAS to downgradient surface water and groundwater that can occur from desorption of PFAS currently bound to sediment. Effectiveness is dependent on sufficient removal of contaminated sediment; should excavation or dredging not remove all contaminated material above the relevant sediment cleanup values, effectiveness would only be moderate.

L2.4.2 Implementability

Implementability is summarized by AOC in Table L.18. Implementability does vary with AOC, but overall implementability is expected to be low. An additional consideration, which is not fully explored in this appendix, is the likelihood of obtaining permits. Excavation of the permanently or semi-permanently flooded portion of Type 3, 4, or 5 wetlands or excavation which converts any type of wetland to a non-wetland is regulated by the WCA (BWSR, 2020). Each of the sediment AOCs contains regions as assigned by the NWI which qualify them as regulated by the WCA (Kloiber, 2019). It may be challenging to obtain permits to excavate the wetlands without significantly more study on the expected recovery time and reduction of PFAS impacts to ecological receptors.

Table L.18: Sediment Response Option 4 Implementability Scoring.

AOC	Wetland	Ranking
AOC 11	URCWC-A	Moderate. Wetlands are located away from residential homes and off roadways. Traffic on roads would likely be impeded during some phases of excavation but could be managed with standard safe work practices. With proper access agreements, staging could take place off roads in all AOCs with minimal site disturbance.
	URCWC-B	
	URCWC-C	
AOC 12	AGWC-N	Low. Wetlands are located behind residents' homes. Access would likely require significant disturbance to residents' property. Staging would be difficult due to limited space available near wetlands.
	AGWC	
AOC 13	EPL	Low. Significant site preparation would be needed to remove sediment from EPL and from around the EPL lake shore. Community support is expected to be low and may pose challenges. Significant permitting is likely required, and legal challenges could occur.

L2.4.3 Cost

CAPEX cost estimates for Sediment Response Option 4 are given in

Table L.19 (AOC 11), Table L.20 (AOC 12), and Table L.21 (AOC 13). Estimated OPEX costs are given in Table L.17; due to the similarities between Sediment Response Option 3 and 4, expected OPEX costs for restoration are expected to be the same. OPEX cost estimates assume 10 years of work is needed to rehabilitate wetlands with the initial two years of active restoration expected to cost \$25,000 per acre to establish new species, years three through five expected to cost \$8,100 per acre to remove invasive species and maintain restoration areas, and the final five years being monitor only at \$2,000 per acre. Costs are based on previous AECOM project experience. For the purposes of this analysis, a present worth is not conducted on estimated OPEX costs; instead, a simple sum for the 10 years of OPEX is given in Table L.17.

Table L.19: Sediment Response Option 4 CAPEX Estimates for AOC 11.

AOC	AOC 11		
Parameter	URCWC-A	URCWC-B	URCWC-C
Area of Sediment Removal (ac)	4.3	5.6	3.1
Depth of Sediment Removed (ft)	1 to 2	1 to 3	1 to 3
Volume of Sediment Removed (cy)	7,000	16,500	11,200
Mass of Sediment Removed (tons)	7,875	18,563	12,600
Additional Site Investigation	\$25,000	\$25,000	\$25,000
Mobilization/Demobilization	\$25,300	\$25,300	\$25,300
Clearing & Site Setup	\$25,000	\$40,000	\$25,000
Excavation & Loading	\$112,000	\$264,000	\$180,000
Transportation & Incineration	\$6,216,000	\$18,324,000	\$12,759,000
Wetland Restoration	\$1,250,000	\$3,240,000	\$2,860,000
Subtotal	\$7,630,000	\$21,900,000	\$15,850,000
<i>Contractor Overhead & Profit (10%)</i>	<i>\$770,000</i>	<i>\$2,190,000</i>	<i>\$1,590,000</i>
<i>Engineering and Construction Contingencies (10%)</i>	<i>\$770,000</i>	<i>\$2,190,000</i>	<i>\$1,590,000</i>
Total	\$9,170,000	\$26,280,000	\$19,030,000

Table L.20: Sediment Response Option 4 CAPEX Estimates for AOC 12.

AOC	AOC 12	
Parameter	AGWC-N	AGWC
Area of Sediment Removal (ac)	1.1	3.7
Depth of Sediment Removed (ft)	3	1 to 3
Volume of Sediment Removed (cy)	5,400	20,000
Mass of Sediment Removed (tons)	6,075	22,500
Additional Site Investigation	\$25,000	\$25,000
Mobilization/Demobilization	\$25,300	\$25,300
Clearing & Site Setup	\$25,000	\$40,000
Excavation & Loading	\$145,000	\$536,000
Transportation & Incineration	\$6,350,000	\$23,520,000
Wetland Restoration	\$333,000	\$1,260,000
<u>Subtotal</u>	<u>\$6,440,000</u>	<u>\$26,030,000</u>
<i>Contractor Overhead & Profit (10%)</i>	<i>\$650,000</i>	<i>\$2,610,000</i>
<i>Engineering and Construction Contingencies (10%)</i>	<i>\$650,000</i>	<i>\$2,610,000</i>
Total	\$7,740,000	\$31,250,000

Table L.21: Sediment Response Option 4 CAPEX Estimates for AOC 13.

AOC	AOC 13	
Parameter	EPL - Shoreline	EPL - Lake Sediment
Area of Sediment Removal (ac)	3.5	120
Depth of Sediment Removed (ft)	3	1
Volume of Sediment Removed (cy)	17,000	200,000
Mass of Sediment Removed (tons)	19,125	225,000
Additional Site Investigation	\$50,000	\$50,000
Mobilization/Demobilization	\$51,000	\$350,000
Clearing & Site Setup	\$130,000	-
Excavation & Loading	\$272,000	-
Transportation & Incineration	\$18,499,000	\$217,636,000
Wetland Restoration	\$1,010,000	-
Hydraulic Dredging		\$4,800,000
Mechanical Dewatering		\$7,200,000
Restoration of Dewatering Area		\$1,000,000
<u>Subtotal</u>	<u>\$19,970,000</u>	<u>\$230,990,000</u>
<i>Contractor Overhead & Profit (10%)</i>	<i>\$2,000,000</i>	<i>\$23,100,000</i>
<i>Engineering and Construction Contingencies (10%)</i>	<i>\$2,000,000</i>	<i>\$23,100,000</i>
Total	\$23,970,000	\$277,190,000

L2.4.4 Risk

Risk to nearby residents long-term is low as excavation/dredging would remove contaminated soil and thus remove the risk of residents' potential exposure to contaminated soil. There would be some short-term risk associated with construction, though this could be mitigated with safe work practices. There would be some risk to other communities, as transport of contaminated sediment to a hazardous waste incinerator and incineration itself would result in greenhouse gas emissions and potentially release partially degraded PFAS compounds through incinerator air emissions. However, the risk of exposure from the incineration of PFAS would be reduced through proper operation and pollution controls of a hazardous waste incinerator. Additionally, the risks of air emissions from a hazardous waste incinerator are expected to be significantly lower than the risk of exposure to residents from uncontrolled contaminated sediments in accessible areas. Thus, the risk to other communities is low. Additionally, dredging can result in re-suspension of sediment, potentially impacting downgradient communities if contaminated sediment is resuspended and transported downgradient as a result of remedial actions, though mitigation efforts would help to reduce the transport of sediment downgradient as a result of dredging activities. Short-term ecological risk is high as excavation/dredging would substantively impact the wetland. Long-term ecological risk would be low as PFAS impacts to wildlife receptors would be mitigated. Overall risk for this sediment response option is moderate due to the ecological damage that is expected to occur from construction activities.

L2.4.5 Portion of PFAS Destroyed

All removed sediment would be incinerated, thus much of the PFAS bound to sediment would be destroyed, thus the portion of PFAS expected to be destroyed is high. Sediment would likely require dewatering prior to incineration; treatment of removed water with GAC to remove any PFAS would be recommended. The majority of PFAS removed by the GAC is expected to be destroyed upon GAC reactivation. This is likely to be an insignificant mass of PFAS compared to the mass sorbed to sediment but would represent best practice and provide the most complete PFAS destruction. Thus, the overall portion of PFAS destroyed is expected to be high.

L3 Comparative Analysis of Sediment Response Options

In the comparative analysis of sediment response options, each of the four response options are compared against one another with respect to the five criteria selected for analysis of the individual response options. Rankings are summarized in Table L.22.

Table L.22: Comparative Rankings of Sediment Response Options.

Criteria	Sediment Response Option Rankings
Effectiveness	Least able to meet sediment RAOs to most able 1 < 2 < 3 = 4
Implementability	Least implementable to most implementable 4 < 3 < 2 < 1
Cost	Lowest expected CAPEX to highest expected CAPEX 1 < 2 < 3 < 4 Lowest expected OPEX to highest expected OPEX 1 < 2 < 3 = 4
Risk	Least risk to most risk 2 < 1 = 3 = 4
Portion of PFAS Destroyed vs. Landfilled	Lowest percentage of PFAS destroyed to highest percentage of PFAS destroyed 1 = 2 < 3 < 4

Legend: ' = ' = equal to; ' > ' = greater than; ' < ' = less than.

L3.1 Effectiveness

Effectiveness scoring is based on a sediment response option's ability to achieve Site sediment RAOs, namely, to prevent human exposure of PFAS-containing sediments above sediment cleanup values and to reduce downgradient migration of PFAS into surface water and groundwater. Sediment Response Options 3 and 4 are most likely to be able to achieve these RAOs as they would result in the removal of contaminated sediment from the affected wetlands. As both response options only differ in how soil is disposed of as opposed to removed, no difference in effectiveness is expected. Sediment Response Option 2 would be the next most effective, with fencing and access restrictions helping to reduce incidental exposure to PFAS but not reducing downgradient migration. Finally, Sediment Response Option 1 would be the least effective, as long-term monitoring would not achieve either sediment RAO.

L3.2 Implementability

Implementability considers the potential challenges and actual feasibility of utilizing a particular sediment response option. Sediment Response Option 1 would be the most implementable as sediment samples have already been collected as part of this FS and long-term monitoring is a common tool used in remediations projects. Sediment Response Option 2 would be the next most implementable. Access restrictions and resident notifications are easily implementable, and similar to long-term monitoring, have already been implemented in parts of the Project 1007 Site. Fencing is more easily implementable in some wetlands than others (e.g., fencing near URCWC-A or URCWC-C would be easier to install than fencing around AGWC-N/AGWC or Eagle Point Lake), lowering the overall implementability of this response option. Finally, Sediment Response Options 3 and 4 are the least implementable due to concerns over permitting related to ecological impact and restoration, and technology application.

L3.3 Cost

Both CAPEX and OPEX costs were estimated for all sediment response options. Sediment Response Option 1 would have the lowest CAPEX cost, as no CAPEX is needed to implement long-term monitoring. Sediment Response Option 2 would have the next lowest CAPEX cost, though cost will vary by wetland. Sediment Response Options 3 and 4 would have the highest CAPEX costs, with Sediment Response Option 4 being the most expensive to implement. The price to dispose of or incinerate the sediment is the primary driver of cost for Sediment Response Options 3 and 4.

OPEX costs over the initial five years are expected to rank similar, with Sediment Response Option 1 < 2 < 3 = 4. While wetland restoration is expected to require 10 years, the final five years are expected to be monitor-only, which is a significantly lower expense than the active restoration anticipated during the initial five years of restoration activities. Thus, an initial five-year period is used to compare costs to account for the higher costs during the first five years of wetland restoration. Additionally, it must be noted that no labor is included when considering long-term monitoring, as long-term monitoring is expected to take place Site-wide and include other sampling efforts including monitoring of the drinking water aquifers. Thus, the additional hours required to collect sediment samples are expected to be negligible compared to the total number of hours required to complete Site-wide sampling.

L3.4 Risk

The risk criterion considers the risk to nearby residents, risk to other communities, and ecological risk. Sediment response options are ranked here by cumulative scoring, which consider all three risk criteria for one overall score. Sediment Response Option 2 is considered to have the lowest overall risk, as risk to nearby residents would be decreased and ecological risk as a result of habitat disruption would be minimized by use of fencing as opposed to more aggressive interventions. Ecological risks associated with PFAS impacted sediment would not be addressed. Sediment Response Options 1, 3, and 4 are all

expected to have moderate risk. Sediment Response Option 1 would not decrease risk to nearby residents nor ecological receptors, but it would not result in short-term risk due to construction activities. Alternatively, Sediment Response Options 3 and 4 would reduce the risk to nearby residents and the long-term risk to ecological receptors but would result in short-term risk to ecological receptors due to the construction activities.

L3.5 Portion of PFAS Destroyed

Portion of PFAS destroyed evaluated the relative amount of PFAS that are ultimately destroyed by a sediment response. This is opposed to remaining in place or being sequestered in a landfill. Sediment Response Option 4 includes incineration of removed sediment, thus it would have the highest portion of PFAS destroyed, as incineration can destroy PFAS molecules. Sediment Response Option 3 would landfill removed sediment, which would not directly result in the destruction of any PFAS. As discussed, some PFAS could ultimately be destroyed by treatment of landfill leachate or through treatment of removed water during dewatering by GAC, but the overall destruction of PFAS is expected to be minimal. Finally, Sediment Response Options 1 and 2 would result in no portion of PFAS being destroyed, as long-term monitoring and fencing/access restrictions would not result in any PFAS destruction.

L4 Recommendations

Sediment Response Options 1 and 2 are recommended for implementation in overall FS remedial alternatives as interim measures to address sediment impacts. Specifically, Sediment Response Option 1 (long-term monitoring) is recommended for all three sediment AOCs to monitor PFAS concentrations in sediment to quantify if sediment concentrations decrease over time as source zone controls are implemented. Long-term monitoring of sediment impacts over the next five to ten years will help to determine if other interim measures such as the Raleigh Creek re-route are reducing PFAS concentrations in sediment AOCs. Sediment Response Option 2 (fencing, signage, notification to residents) is recommended in AOC 11 to prevent access to URCWC-C and in AOC 12. These are the only areas where fencing is recommended as there are homes in AOC 12 that back up to AGWC and a new apartment complex was recently built across from URCWC-C. Though access to URCWC-A is possible, fencing is not recommended near URCWC-A as there is no residential housing near this area and the pedestrian sidewalk is located on the opposite side of Hadley Ave N, reducing the risk to residents. Nor is additional fencing recommended near URCWC-B as fencing exists along the north and east of the wetland which blocks the primary access points. Should development to the south of URCWC-B occur, fencing should be evaluated at that time. Fencing is also not recommended around Eagle Point Lake as it would be disruptive to the ecosystem and have minimal impact as the lake would remain open for non-motorized watercraft. Signage is recommended for each of the wetland areas, especially at Eagle Point Lake.

Sediment Response Options 3 and 4 are not recommended at this time. Raleigh Creek remains a source of PFAS to sediment AOCs, meaning any remediation of sediment AOCs prior to improved source zone control would be likely to result in re-contamination of the sediment AOCs. Additionally, removal of sediment would be disruptive to the wetlands within each of the sediment AOCs and the severity of destruction to the wetland habitats has not been fully quantified in this appendix. Anticipated costs of wetland restoration and, more critically, landfilling or incineration are very high. Pursuit of sediment removal at this time, when it is not yet understood how other remedial actions across the Site will impact sediment AOCs, is premature when Site objectives may be able to be met without sediment removal. At this time, the cost per mass of PFAS removed is expected to be much higher for sediment excavation than remedial actions at other AOCs across the Site. Additionally, while technologically implementable, wetland excavation could require several years of effort to obtain permits to pursue the

work. However, sediment excavation may need to be reconsidered in the future should other remedial actions not be sufficient to achieve RAOs in sediment AOCs.

As discussed, sediment remediation should also not be completed until surface water impacts are greatly decreased. This requires additional remedial action at PFAS source areas. As source zone remedial measures lead to surface water with lower PFAS impacts flowing through the wetland areas, leaching of PFAS from the sediments is expected. The potential of PFAS to leach from contaminated soil is evaluated in Appendix I (Leachability Study for PFAS-Impacted Sediments for Project 1007 Bench-Scale Report). Capture of the PFAS that leaches from sediment is important to reduce PFAS loading to downgradient receptors, and treatment of Site surface water may be less expensive and less disruptive than sediment remediation. In-stream permeable adsorptive barriers are proposed as an interim remedial measure to capture a portion of the PFAS that is expected to leach from sediment once upgradient surface water concentrations decrease. See Appendix M (Project 1007 Surface Water Treatment Evaluation) for an evaluation of Site surface water treatment for additional discussion on permeable adsorptive barriers.

Significant efforts are underway to develop new remedial technologies for PFAS. If new in-situ remediation technologies are developed that can remediate PFAS with less damage to natural ecosystems, those technologies should be considered in the future. However, at this time, no sediment PFAS remedial technology can be recommended, particularly given the ongoing concerns over PFAS loading from source areas. Thus, for sediment AOCs, long-term monitoring and access restrictions/signage/notifications are recommended as the most appropriate responses to address drinking water impacts at this time.

Finally, additional evaluation is required to better understand the risk to ecological receptors. This FS has been completed in accordance with Priority 1 of the 2018 Settlement, which is to provide safe and sustainable drinking water resources for current and future generations in the PFAS-impacted communities. Preventing damage to ecological receptors was not explicitly identified as a goal for sediment treatment as a result of the focus on drinking water. Further evaluation of the risk to ecological receptors is needed, and after that additional evaluation, further remedial actions may be identified that are necessary to protect ecological receptors.

L5 References

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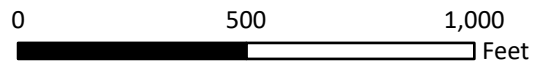
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L6 Figures



Figure L.1: AOC 11 - Proposed Fence Line
Project 1007 Feasibility Study



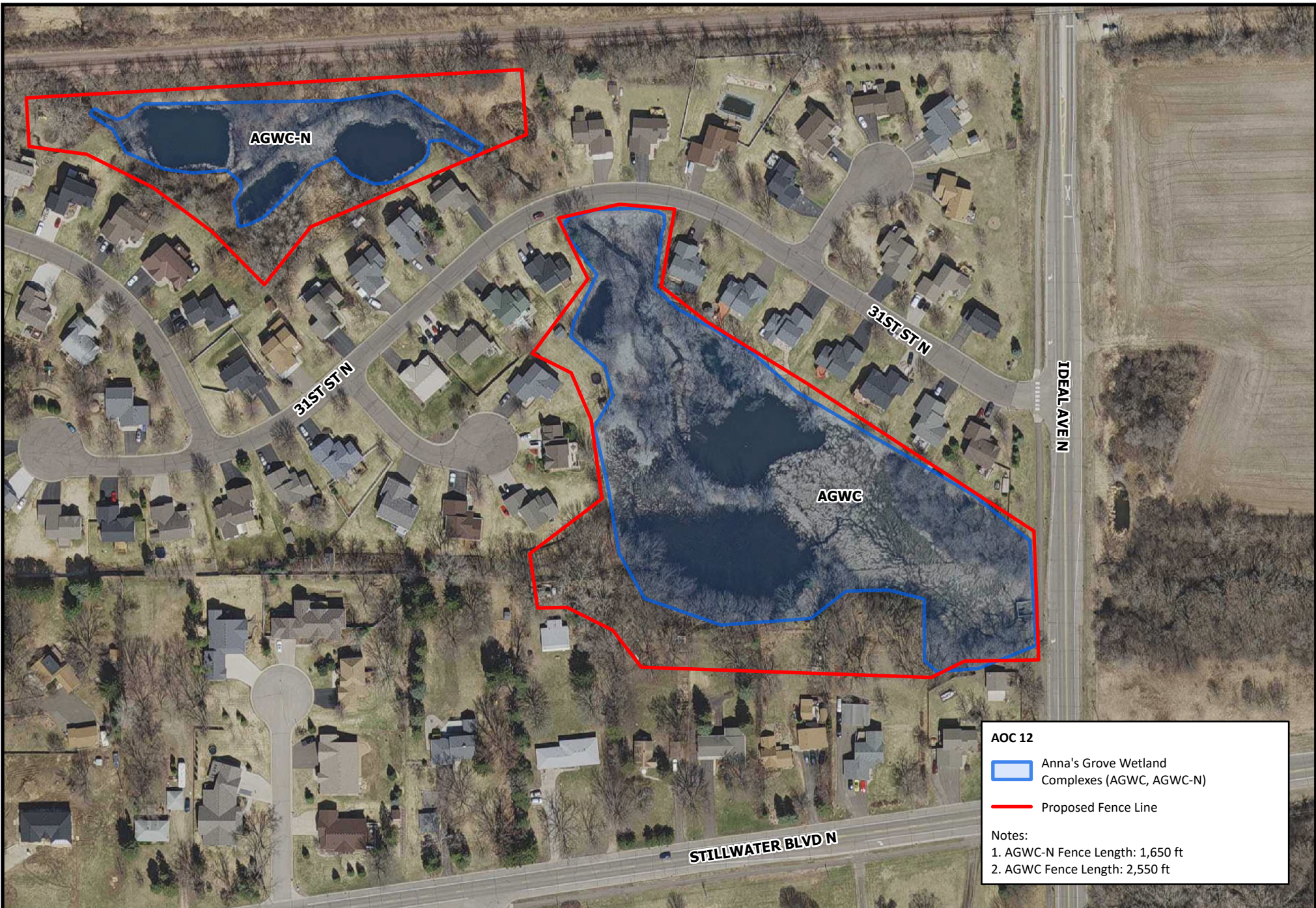
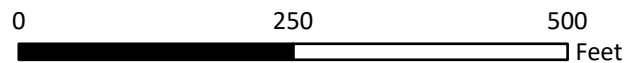


Figure L.2: AOC 12 - Proposed Fence Line
Project 1007 Feasibility Study



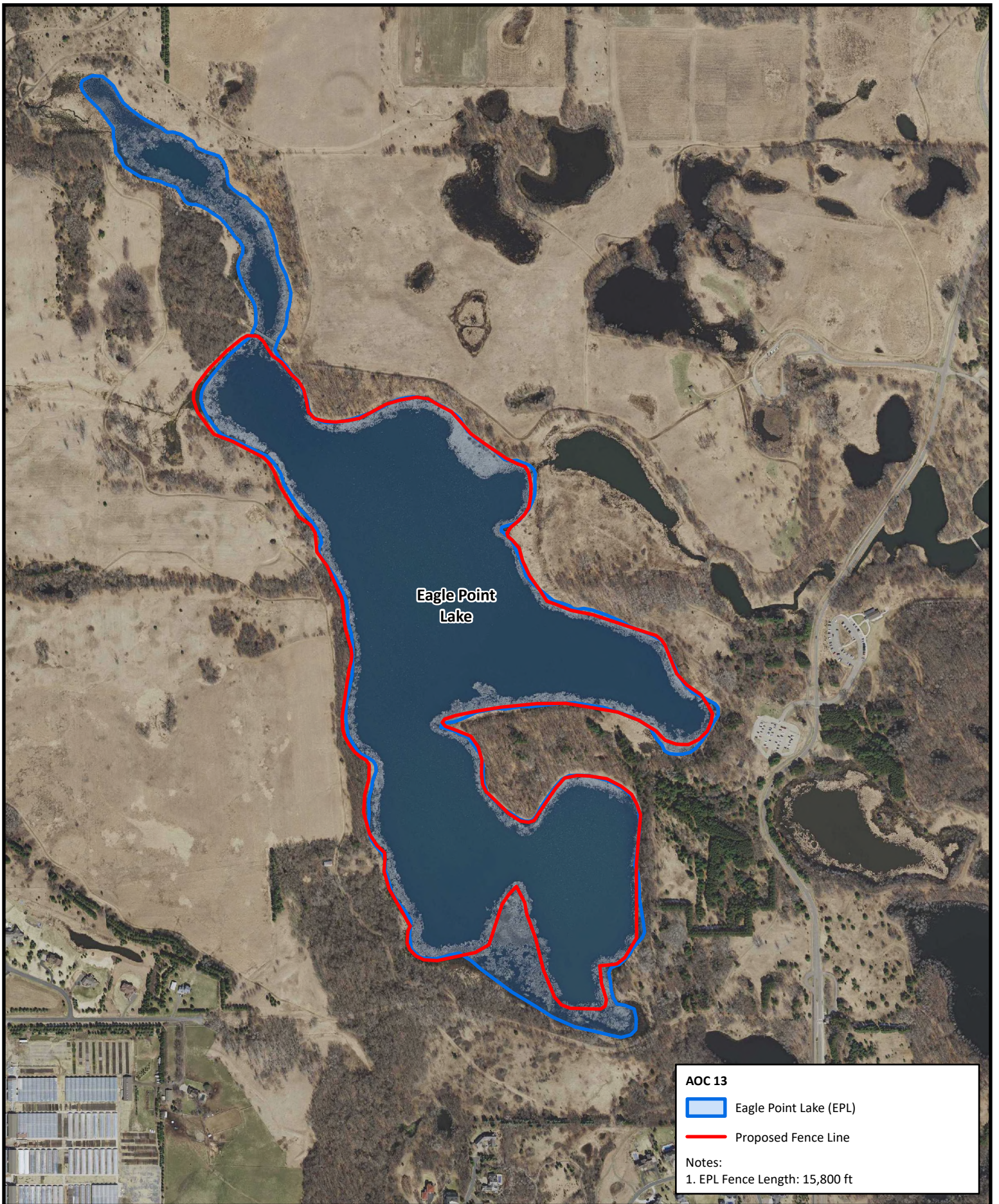
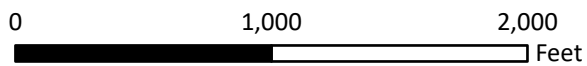


Figure L.3: AOC 13 - Proposed Fence Line
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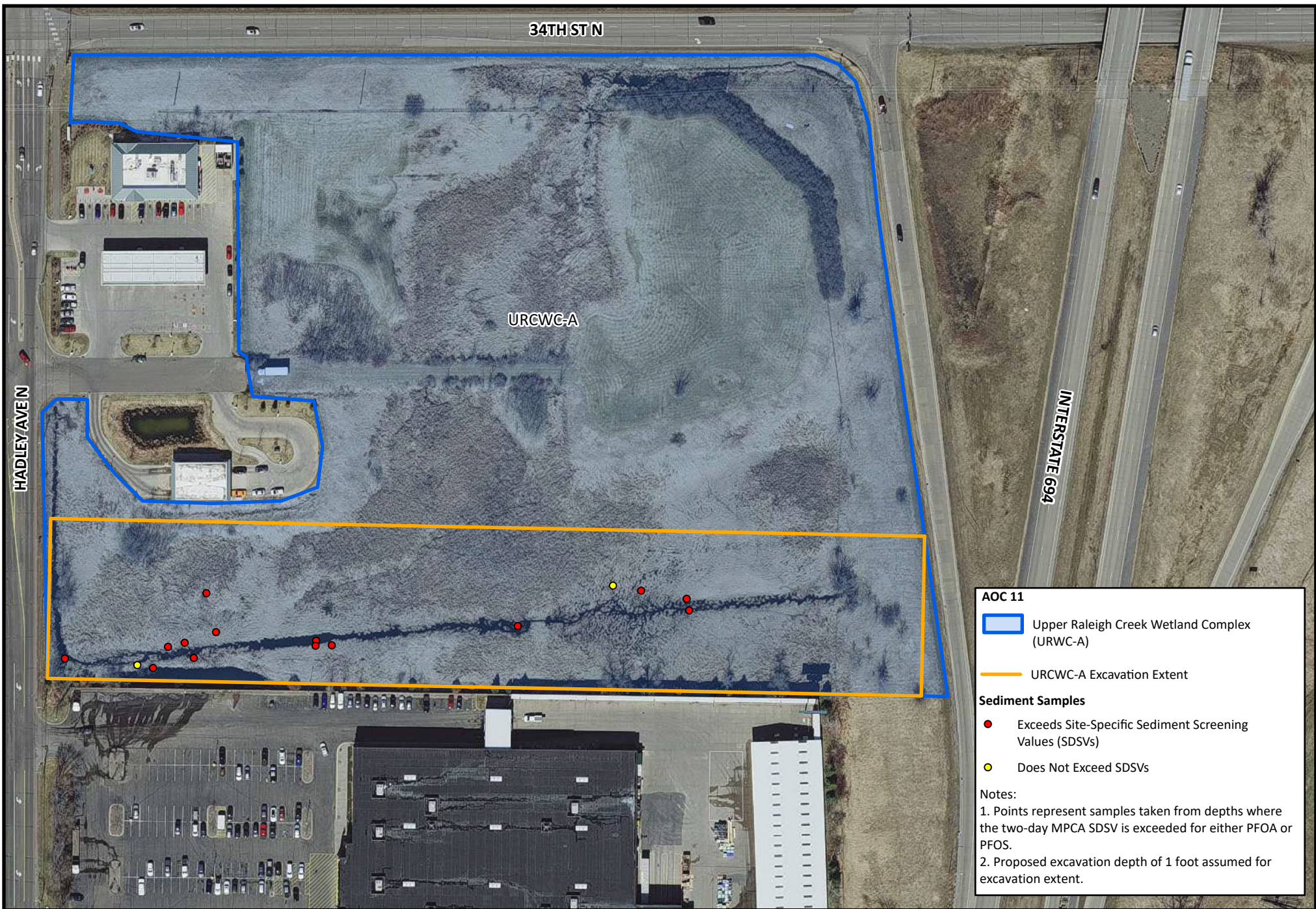
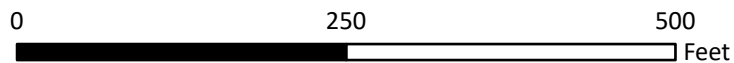


Figure L.4: AOC 11 - URCWC-A Sediment Excavation Area
Project 1007 Feasibility Study



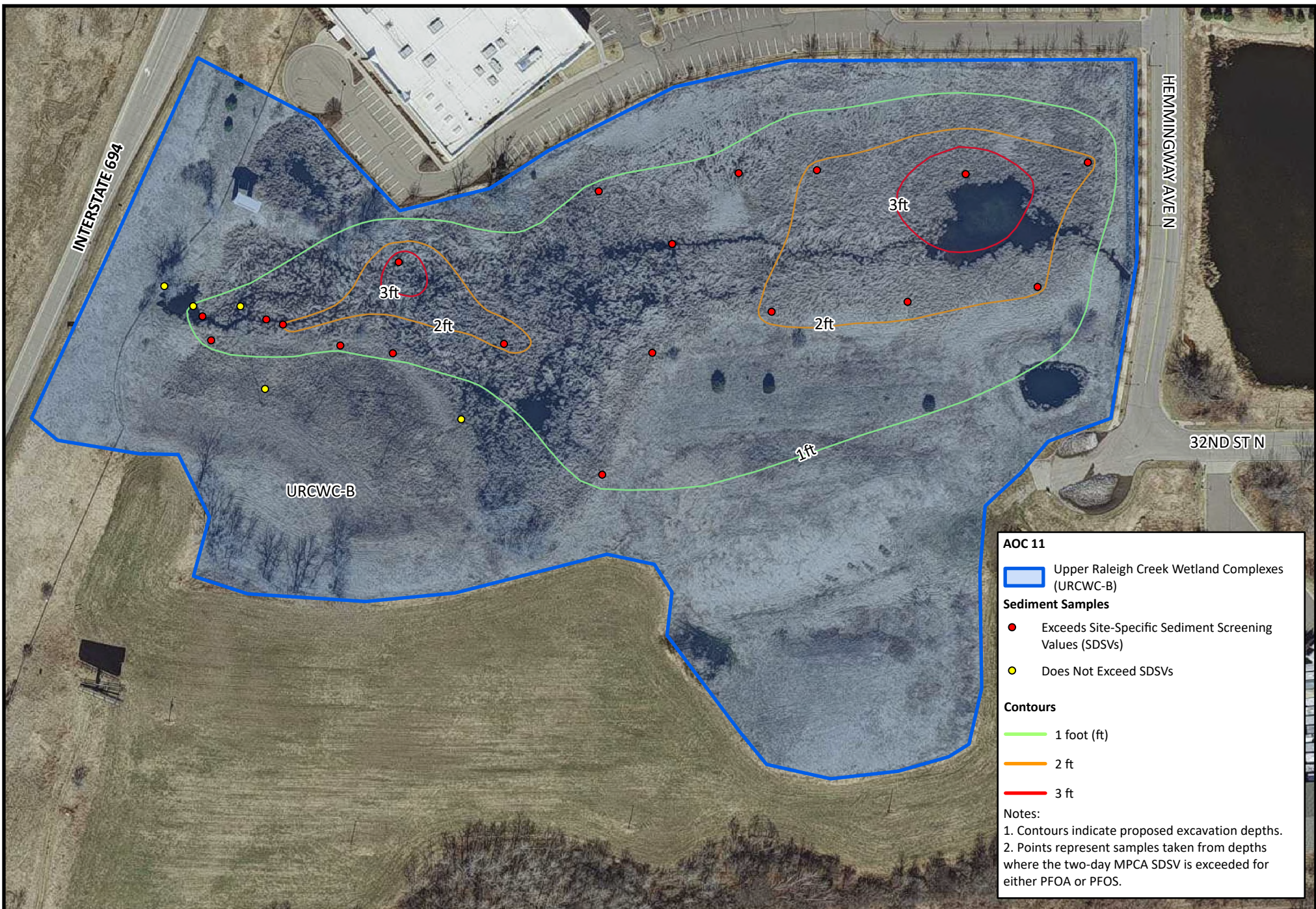
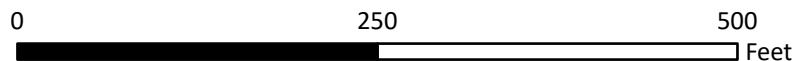


Figure L.5: AOC 11 - URCWC-B Sediment Excavation Area
Project 1007 Feasibility Study



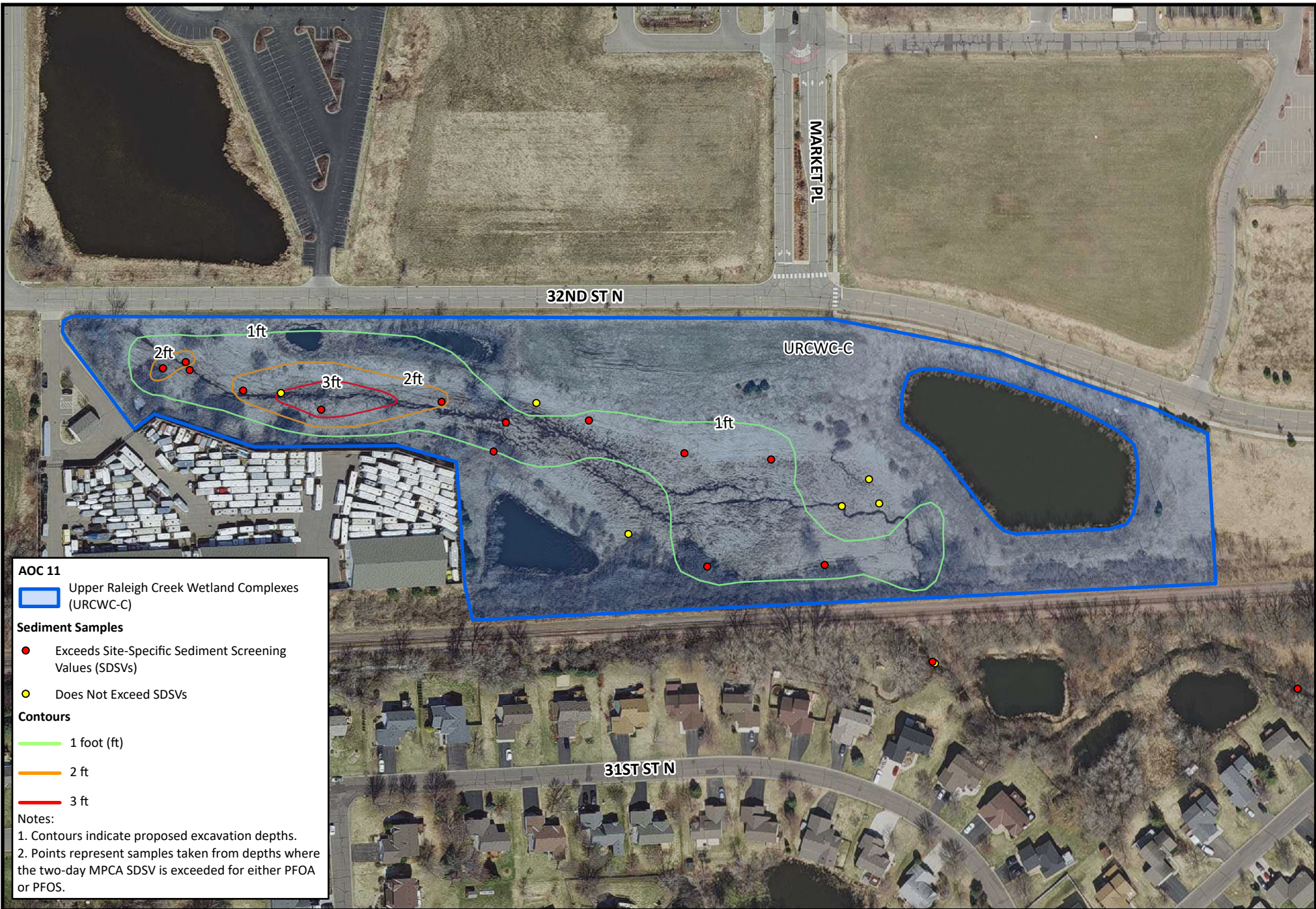
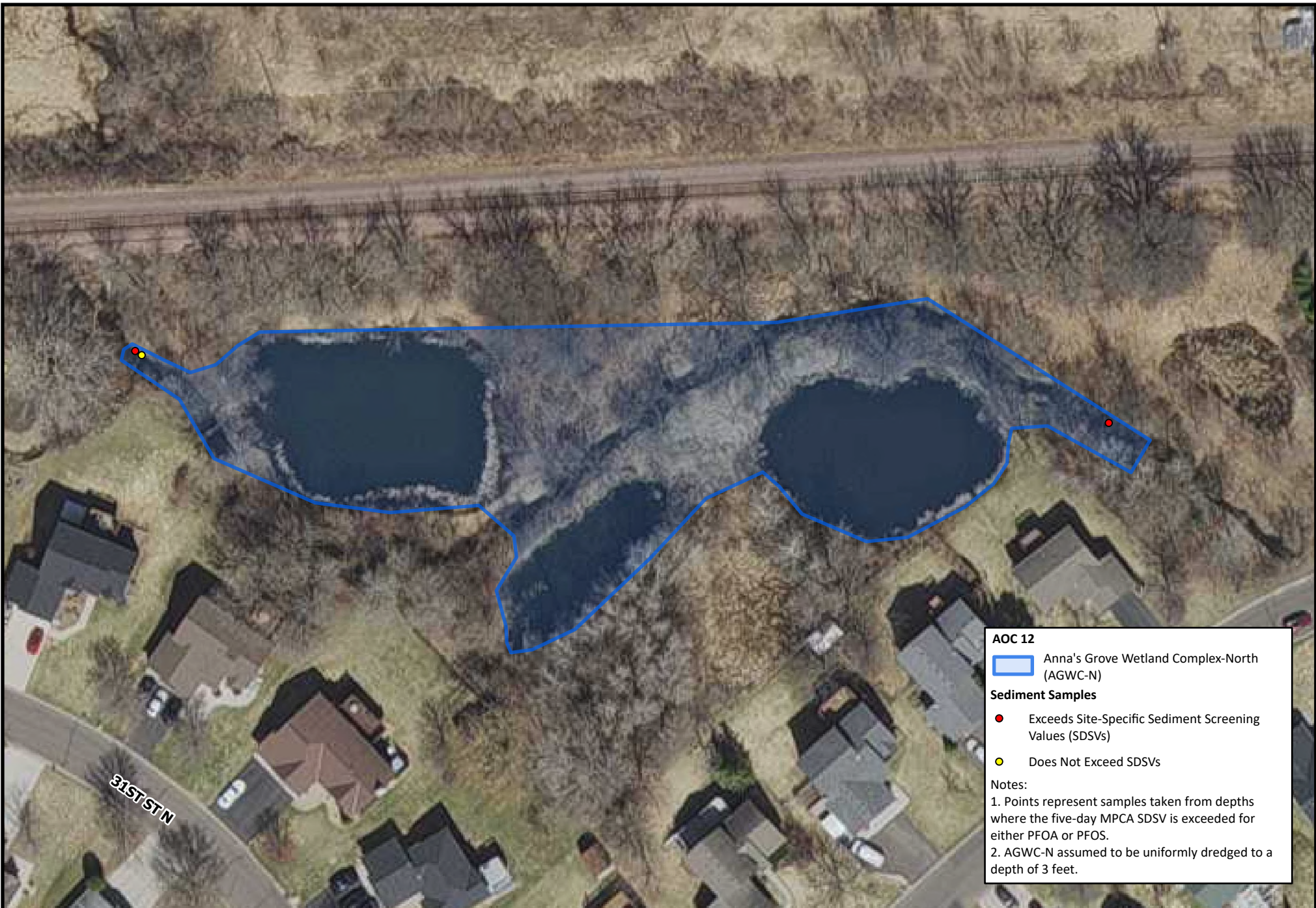



Figure L.6: AOC 11 - URCWC-C Sediment Excavation Area
Project 1007 Feasibility Study



0 250 500
 Feet



AOC 12

 Anna's Grove Wetland Complex-North (AGWC-N)

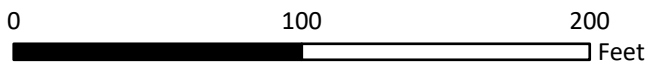
Sediment Samples

-  Exceeds Site-Specific Sediment Screening Values (SDSVs)
-  Does Not Exceed SDSVs

Notes:

1. Points represent samples taken from depths where the five-day MPCA SDSV is exceeded for either PFOA or PFOS.
2. AGWC-N assumed to be uniformly dredged to a depth of 3 feet.

Figure L.7: AOC 12 - AGWC-N Sediment Dredging Area
Project 1007 Feasibility Study



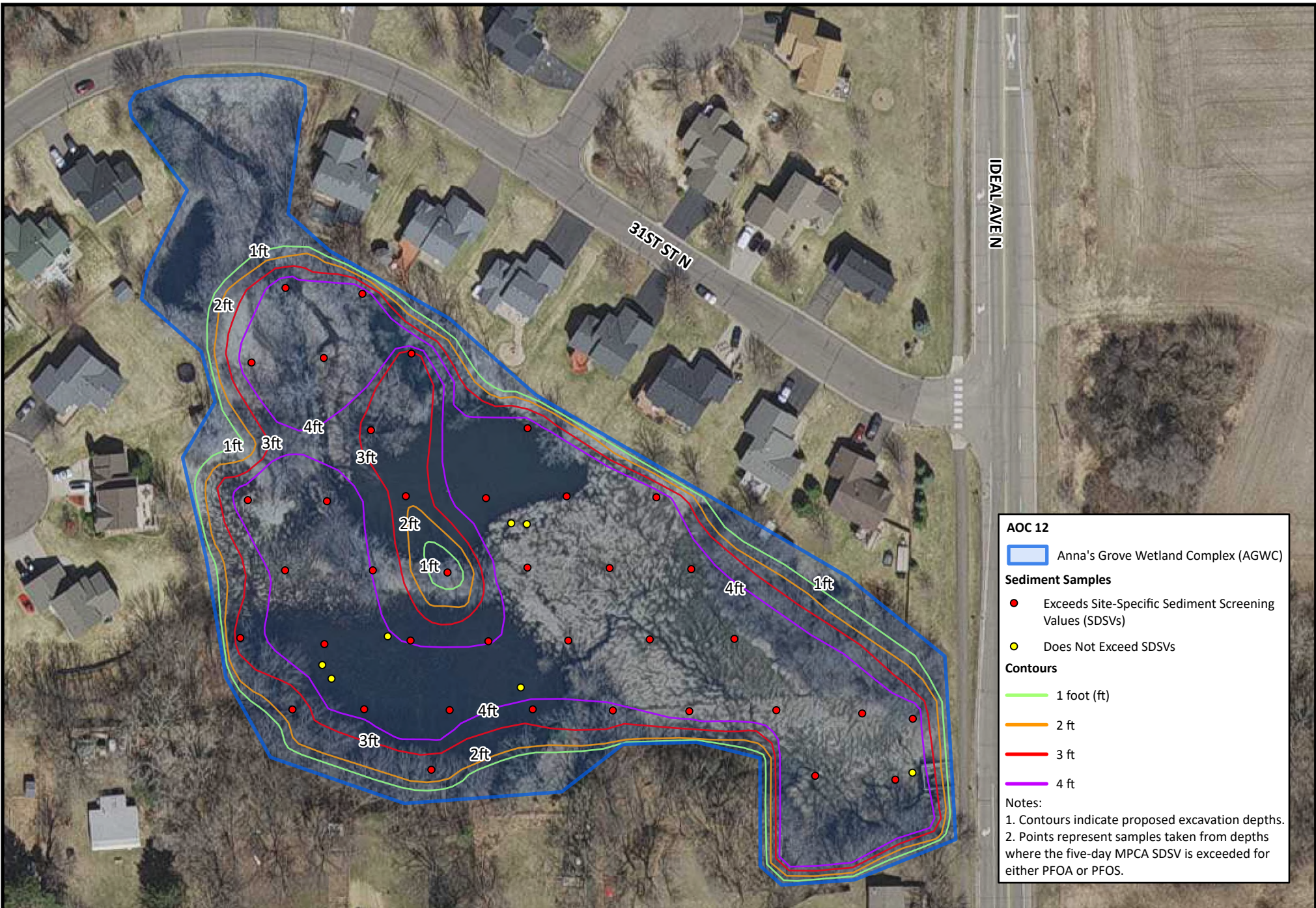
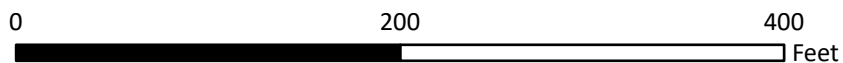


Figure L.8: AOC 12 - AGWC Sediment Dredging Area
Project 1007 Feasibility Study



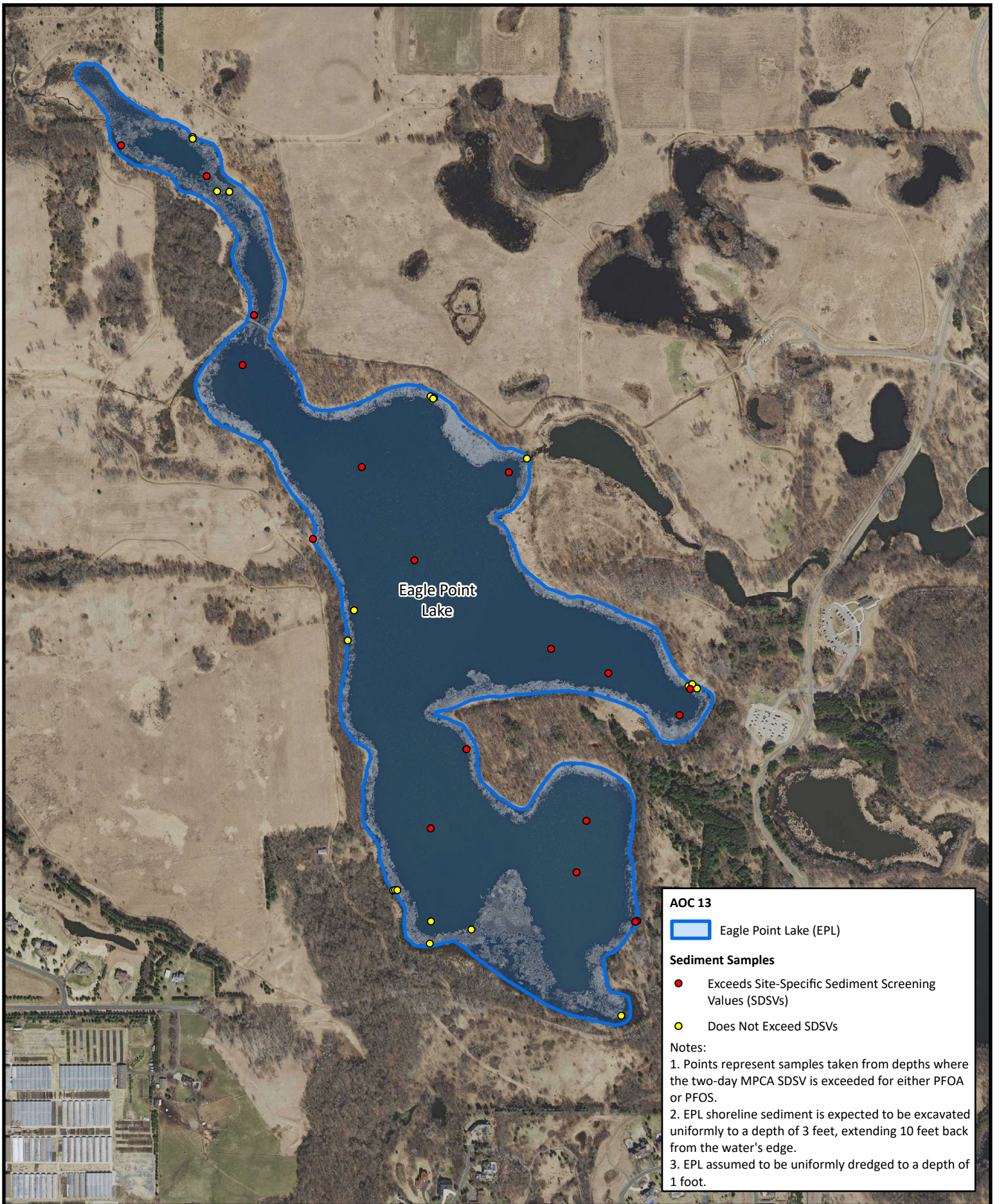
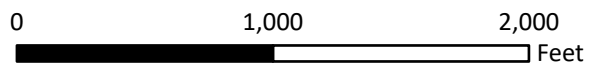


Figure L.9: AOC 13 - Eagle Point Lake Shoreline Sediment Excavation and Sediment Dredging Area Project 1007 Feasibility Study



L7 Additional Tables

Table L.23: Wetland Soil Types and Bulk Density.

Wetland	Soil Type ⁽¹⁾	Bulk Density (g/cm ³) ⁽¹⁾	Percentage Composition ⁽¹⁾
AOC 11			
URCWC-A	Freer Silt Loam	1.47	0.8%
	Markey Muck	0.30	22.0%
	Barronett Silt Loam, Sandy Substratum	1.35	77.2%
	Aggregate Bulk Density	1.12 g/cm ³ (1,888 lb/cy)	
URCWC-B	Antigo Silt Loam	1.52	0.8%
	Brill Silt Loam	1.51	10.8%
	Kingsley Sandy Loam	1.33	1.0%
	Poskin Silt Loam	1.52	9.8%
	Barronett Silt Loam, Sandy Substratum	1.37	77.6%
	Aggregate Bulk Density	1.40 g/cm ³ (2,361 lb/cy)	
URCWC-C	Santiago Silt Loam	1.48	29.7%
	Kingsley Sandy Loam	1.66	0.3%
	DeMontreville Loamy Fine Sand	1.65	11.6%
	Poskin Silt Loam	1.52	0.5%
	Barronett Silt Loam, Sandy Substratum	1.37	57.9%
	Aggregate Bulk Density	1.44 g/cm ³ (2,422 lb/cy)	
AOC 12			
AGWC-N	Santiago Silt Loam	1.48	9.7%
	Barronett Silt Loam, Sandy Substratum	1.37	90.3%
	Aggregate Bulk Density	1.38 g/cm ³ (2,327 lb/cy)	
AGWC	Antigo Silt Loam	1.51	2.0%
	Brill Silt Loam	1.51	1.9%
	Auburndale Silt Loam	1.51	69.9%
	Kingsley Sandy Loam	1.64	11.3%
	Barronett Silt Loam, Sandy Substratum	1.37	1.8%
	Water	N/A	13.1%
	Aggregate Bulk Density	1.52 g/cm ³ (2,569 lb/cy)	
AOC 13			
EPL	Aggregate Bulk Density ⁽²⁾	1.37 g/cm ³ (2,313 lb/cy)	

Legend: g/cm³ = grams per cubic centimeter; lb/cy = pounds per cubic yard.

(1) Data from Web Soil Survey.

(2) Due to incomplete data around Eagle Point Lake, bulk density is assumed to be an average of bulk densities from the other wetlands.