Lake Geneva Environmental Agency

Big Foot Creek Water Quality Study

Phase 2 Final Report

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Executive Summary

Big Foot Creek Watershed on Lake Geneva has been a known source of water pollution since Geneva Lake's first Water Quality Management Plan was prepared during 1976-1977. Big Foot Creek continues to be a significant source of phosphorus to Geneva Lake and has also been the source of an iron discharge to Geneva Lake near Big Foot Creek State Park's swimming area. Several existing data was used to understand the watershed, its landuse changes, and the potential sources of contamination including surface water, groundwater, and geologic studies, existing monitoring wells near known contaminated landfill site, and lab test results of water sampling.

The deposition of phosphorus and dissolved and flocculant iron near groundwater seeps is a common phenomenon. Glacial events deposited iron rich rock from the Canadian shield and the depressions of inland lakes accumulate dead biomass, a significant source of phosphorus. Anaerobic conditions favor mobilization of reduced ferrous iron to oxidized iron precipitate as groundwater seeps to the ground surface. To complicate things, mobilized phosphorus can also precipitate with available calcium as the cation if the iron concentration is too low and the pH is alkaline, as it is in the Bigfoot Creek watershed.

Three stream sites were located on either Bigfoot Creek or its tributaries as surface water monitoring sites. Testing of iron and phosphorus constituents show that the average of all samples exceeded regulatory criteria for iron and phosphorus at each of the three sample sites. From average iron and phosphorus concentrations and regression equations developed for the site, 121,600 lb of iron inflow occurred during 2019 and 2020 and 7,250 lb of phosphorus inflow occurred during the same period at the Site A outlet.

The Addition of calcium (as limestone) to the treatment process will help achieve removal of both the iron and phosphate in the relatively alkaline waters of Bigfoot Creek. Such a system can be designed as a treatment wetland provided that backflows from the lake are prevented and the wetland area and volume of limestone is sufficient to maximize residence time and water-limestone contact. For sufficient iron removal, the wetland would require 1,100,000 lb of limestone per year (245 cy/yr) or 2450 cy for a 10-year design life. It is expected that within a 10-year period, all significant iron and phosphorus contributing to the present problem would be bound up in the wetland treatment system.

1.0 Introduction and Problem Statement

RES was retained in 2020 by the Geneva Lake Environmental Agency to assess, analyze and develop Best Management Practices for water quality issues stemming from the Big Foot Creek watershed.

The Big Foot Creek watershed is a 1,554-acre watershed at the east end of Geneva Lake in Walworth County, Wisconsin (see Appendix A). The watershed is situated roughly between South Lake Shore Drive to the west and Route 120 to the east. The watershed is drained by Big Foot Creek which is a small waterway with tributaries from the south, east and north. The tributaries flow toward the confluence of Big Foot Creek at the eastern end of Lake Geneva where the creek discharges into Buttons Bay.

Land uses consist primarily of agricultural and other passive land uses except for a small residential development on the north west and east ends of the watershed, and a cement plant along the east edge.

Big Foot Creek has been a known source of water quality pollution since Geneva Lake's first Water Quality Management Plan was prepared during 1976-1977. Additional sampling events and studies completed between 1976 and 2021 confirm that Big Foot Creek continues to be a significant source of phosphorus to Geneva Lake. Big Foot Creek has also been the source of a reddish discharge to Geneva Lake near Big Foot Creek State Park's swimming area.

This document is Phase II of a Big Foot Creek Water Quality Study that commenced in 2019 upon receipt of a Wisconsin Department of Natural Resources Small Scale Lake Planning Grant. The Phase I report (2020 Geneva Lake Environmental Agency (GLEA)) focuses on documenting the Creek's water quality and loading to Geneva Lake. This Phase II report focuses on assessing and analyzing data collected during Phase I, and recommending BMPs to address water quality issues, and in particular, phosphorus and the source of the reddish discharge.

Background information described in the Phase I report is not repeated or only briefly described in this Phase II report.

2.0 Review Existing Data

RES reviewed a variety of data to develop a better understanding and context of past land uses, studies, activities, and proposed sources and causes of water quality degradation. These studies include:

- GLEA, 2020. Big Foot Creek Watershed Study Phase 1.
- GLEA, 2010. Groundwater in the Geneva Lake Area, Walworth County, Wisconsin.
- Gotkowitz, Madeline and Jonathon Carter. 2009. Groundwater flow model for the Geneva Lake area, Walworth County, Wisconsin. Wisconsin Geological and Natural History Survey.
- Dale Robertson et al. 2002. Hydrology and water quality of Geneva Lake, Walworth County, Wisconsin. U.S. Geological Survey Water-Resources Investigations Report 02-4039.
- Ecology and Environment, Inc. 1986. Hydrogeologic investigation and site inspection report for Otto Jacobs Landfill Lake Geneva, Wisconsin.
- Applied Ecological Services, Inc. 1994. Proposal for the continued investigation of Big Foot Creek's degraded water quality and design of wetland management alternatives to mitigate the discharge.
- Lake Geneva Storm Sewer Layout Map.
- Contaminated Properties Database: Wisconsin Department of Natural Resources (WDNR) Bureau for Remediation and Redevelopment Tracking System (BRRTS) On the Web.
- Publicly Available GIS Data for Watershed Mapping (Topography, Wetlands, Parcels, and Landuse).

3.0 Existing Conditions

Geographic Information System (GIS) Mapping Review

The spatial area of the watershed was analyzed and described using available GIS data.

Watershed and sub-watershed boundaries were determined using ArcGIS and 1-foot topographic contour data, as well as storm sewer flows. The City of Lake Geneva provided data layers of the City- owned storm sewers, inlets, and manholes. These sub-watersheds are shown in Appendix B and described in Table 1 below.

Table 1 - Sub-watershed Area

SMU I.D.	SMU Area (acres)	Percent of Total Area
SMU 1	289.0	18.6%
SMU 2	374.9	24.1%
SMU 3	111.1	7.1%
SMU 4	476.3	30.6%
SMU 5	186.3	12.0%
SMU 6	116.8	7.5%
Total	**1,554.4**	**100%**

Landuse varied throughout the watershed and included industrial, commercial, residential, highway, and open space. Open space, consisting primarily of agricultural land, made up most of the area (79%) followed by residential, industrial, highway, and commercial, respectively (Table 2). The landuse summary map is shown in Appendix C and described in the table below.

Parcel and landowners were located and mapped in Appendix D. Big Foot Beach State Park makes up the largest tract of public property. The rest of the watershed is private except road rights-of-way.

The Wisconsin Wetlands Inventory and Walworth County Soil Survey was used to map hydric soils, wetlands, and restorable wetlands. The site lies in a wide valley depression, so large wetland areas were expected. Mapped wetlands and hydric soils are shown in Appendix E.

Table 2 - Landuse by Sub-watershed

Landuse	SMU 1	SMU 2	SMU 3	SMU 4	SMU 5	SMU 6	Total
Industrial	27.7	0	0	92.9	0	0	120.6
Commercial	0	0	0	14.3	0	2.6	16.9
Residential	0	0	7.7	119.1	10.8	0	137.5
Highway	2.3	7.1	0	41.0	4.8	0	55.2
Open Space	258.9	367.8	103.4	209.1	170.7	114.2	1224.1
Total	**289.0**	**374.9**	**111.1**	**476.3**	**186.3**	**116.8**	**1554.4**

Potential Contamination Sites

The Wisconsin Department of Natural Resources (WDNR) Bureau for Remediation and Redevelopment Tracking System (BRRTS) On the Web was used to determine potential contamination sites within the watershed. This is a comprehensive online database that provides information on contaminated properties and other cleanup and redevelopment activities in Wisconsin. A map of potential contamination sites is shown in Appendix F. While the BRRTS On the Web database includes historic water and soil sampling data taken during remediation, the data set did not include measurements of phosphorus, iron, or other potential contaminants that could be causing the red discoloration at the Big Foot Creek outlet.

Quantifying Surface Runoff

WinSLAMM was used to model and quantify the potential contribution of phosphorus from each sub-watershed. GIS topography, storm sewer, landuse, and soils mapping were used to create an existing conditions model. This exercise provided insight into the amount of phosphorus was flowing into the lower reaches of the watershed from surface runoff. A map of the sub-watersheds and WinSLAMM results in pounds of phosphorus is shown in Appendix G and Table 3 below.

Table 3 – Total Suspended Solids and Phosphorus Runoff Results

SMU I.D.	SMU Area (acres)	Total Suspended Solids Runoff (pounds)	Particulate Phosphorus Runoff (pounds)
SMU 1	289.0	31,179	42
SMU 2	374.9	19,720	51
SMU 3	111.1	17,912	57
SMU 4	476.3	96,779	228
SMU 5	186.3	11,894	28
SMU 6	116.8	7,006	15
Total	**1,554.4**	**184,490**	**421**

Background water quality chemistry

The deposition of high phosphorus with dissolved and flocculant iron where groundwater seeps to the surface is a common phenomenon. Most glacial tills and related sediments in Wisconsin were derived from glacial debris quarried from the iron rich rocks of the Canadian Shield around western Lake Superior then moved and deposited throughout Wisconsin. Inland lake coastal wetlands are usually basins or low areas on lake edges that accumulate dead biomass with substantial phosphorus and the glacial debris is the iron source. The buried parent materials of glacial origin and decomposing biomass in the wetlands demands free oxygen. The usual state of groundwater in these systems is anaerobic. This favors the mobilization of reduced ferrous iron (+2 valence) in groundwater followed by precipitates of oxidized iron (usually +3 valence) when discharged into surface waters. The soluble iron and phosphate ions typically oxidize to precipitate pollutants out of groundwater when it reaches the surface. This is the source of the familiar red precipitate in groundwater seeps on ditches and stream banks. Mobilized phosphorus can also precipitate with available calcium as the cation if the iron concentration is too low and the pH is alkaline as it is in the Bigfoot Creek watershed. Both the pH and competitive cations, especially calcium and ammonia, may complicate this situation depending on the concentrations of all the ions in the water and the total alkalinity that is typically largely owing to the presence of calcium ions and ammonia.

4.0 Water Quality Sampling Methodology and Sample Data

Sampling Methodology

Three stream sites were located on either Bigfoot Creek or its tributaries as monitoring sites. Additionally, a background groundwater site (well) at the Otto Jacobs plant was also sampled at each sampling time (#10051988, 5E). Sample sites included the discharge site of Big Foot Creek to Geneva Lake where three culverts discharge to Geneva Lake (Site # 10051986 1A). A second stream sample site was in Big Foot Beach State Park, east of the culverts under South Lake Shore Drive, just north of the entrance to Big Foot Beach State Park (10051989, 2B). A third stream site was located on the eastern portion of tax parcel IL 1200003A where the stream flows through a single culvert under a gravel access road (10051986, 3C). The location of the three Bigfoot Creek monitoring sites is shown in Appendix H.

Samples were collected once a month between May and October 2020 for six sample dates. All but the May samples were sent to the Wisconsin State Lab of Hygiene for analysis leaving only five samples for analysis of total dissolved solids, iron, total phosphorus, ammonia, and chemical oxygen demand.

Several bottles of sample were collected during each sampling event. One bottle was used for pH, conductivity, total dissolved solids (TDS) and alkalinity. A separate bottle was used to collect samples for dissolved oxygen analysis. These analyses were performed by the field crew within 24 hours of sampling.

An Orion model 230A pH meter with an Orion 9107BN probe was used for pH measurements.

The meter was calibrated with a 7 and 10 standards for each sampling. Conductivity and total dissolved solids were measured with a Hach model 44660 conductivity/TDS meter. A blank and standard of 0.7065 mS/ were used to calibrate the instrument prior to collection of each set of data. Turbidity was measured in NTUs using a LaMotte 2020we Turbidimeter that was zeroed with DI water and standardized with 1 NTU and 10 NTU standards. Alkalinity was measured using a Hach low level test kit. For 2020 samples, dissolved oxygen was measured using the YSI model 57 oxygen meter and a YSI 5739 prob. The meter was air calibrated for each sampling. For the 2019 samples, dissolved oxygen was measured using the Winkler titration method.

Three other bottles per site were also collected. These samples were shipped to the Wisconsin State Lab of Hygiene (WSLH) for analysis. One bottle was preserved with sulfuric acid and was used for nutrient analysis. One bottle was preserved with nitric acid and was analyzed for iron. A third bottle with no preservatives was used for total suspended solids and chemical oxygen demand. The WSLH samples were collected processed and shipped per WSLH guidelines.

After the water samples were collected at sites 10051985 1A, 10051989 2B, and 10051986 3C, a cross-sectional profile of the stream channel was measured to determine the cross-sectional channel area at each sample location. Flows at site B and C were measured in culverts. Flow at site A were measured at a section of the stream that had relatively unimpeded flow and was straight. Total width and depth were recorded for determination of area. Flows were measured using a Global Water Flow Probe FP111. Discharge (Q, cubic feet per second) was calculated by multiplying stream area (square feet) by flow velocity (feet per second).

The Wisconsin State Lab methods for laboratory analysis were:

Total Suspended Solids:	SM2540D
Iron:	EPA 200.7
Phosphorus:	EPA 365.1
Ammonia	EPA 350.1
COD high level	ASTM D1252-06B
Nitrate + Nitrite -N	EPA 353.2
Total Kyeldahl-N	EPA 351.2

Sample Data

Results for the water sampling are shown in Appendix I. Average values of flow and the sampled iron and phosphorus constituents show that the average of all samples exceeded regulatory criteria for iron and phosphorus at each of the three sample sites (See Table 4 below).

Table 4 – Average Water Sample Results

Sample Location	Average Iron Concentration* (mg/l)	Average Phosphorus Concentration* (mg/l)	Average Flow (cfs)	Average Hourly Iron Mass Discharge (lb/hr)	Average Hourly Phosphorus Mass Discharge (lb/hr)
Site A	10.9	0.65	4.24	7.38	0.45
Site B	12.1	0.69	1.44	2.60	0.15
Site C	11.7	0.69	2.88	5.92	0.36

**Regulatory Criteria –*

Iron = 1.0 mg/l per EPA 10/07/20 Current Criteria (Typ. 1986 Gold Book)

Phosphorus = 0.03 mg/l per State of Wisconsin Current Criteria

5.0 Water Quality Assessment Methodology and Results

Only a limited sample set of data was collected due to budgetary constraints. An initial assessment was done for the watershed using WinSLAM, but this model failed to account for the high concentrations of iron and phosphorus found in the limited water samples from the three sample sites. Review of the watershed showed that much of the historic wetland area in the watershed had been drained and that mobilization of iron and phosphorus resulting from these drained wetlands likely was elevating the amounts of iron and phosphorus being discharged to Bigfoot Creek. Thus, it was not feasible to use conventional water quality models. Therefore, the following assessment methodology was adopted for the project:

1. Use a regression analysis of 24-hour precipitation data (which had been collected during the sampling period by the client) vs the measured sample flows to define a precipitation vs flow equation for the sample sites.
2. Limit the analysis to the data collected at Site A since this sample site contained the composite of all flows discharging from Bigfoot Creek into Lake Geneva.
3. Average the sample iron and phosphorus concentrations for Site A and use these averages as a constant constituent concentration regardless of flow (a series of regression equations were developed to test for a relation between sample flow rate and constituent concentration with no significant correlation found).
4. Develop regression equations for 24-hour, 48-hour and 72-hour precipitation totals vs sampled flow rates at Site A for the days sampled and test for correlation. Lag these precipitation totals by 0, 24 and 48 hours to test for correlation accounting for groundwater and overland flow retardation.

Results

With these analyses completed, a design flow based on a regression equation was developed as a function of the measured sample flows vs. 48 hr precipitation. Amounts with 0 hr lag was found to provide the best correlation (See Appendix J for graphs of all regression equations and their coefficients of correlation). This equation is:

Site A flow (cfs) = (48 hr rainfall in inches) x 4.030 + 1.77 cfs

The equation uses 1.77 cfs as the continuous baseflow (likely either vadose zone groundwater due to waters held in the peaty soils and/or groundwater resulting from backwater heads from the lake due to lake level fluctuations).

Average iron inflow concentration of 10.90 mg/l is the sampled average. No correlation was found between measured flows and iron concentrations, nor between precipitation and iron concentrations, so the sample average was used as the best available value.

Average phosphorus concentration of 0.65 mg/l is the sampled average. No correlation was found between measured flows and phosphorus concentrations, nor between precipitation and phosphorus concentrations, so the sample average was used as the best available value.

From the flow equation and the iron and phosphorus average sample concentrations, 121,600 lb of iron inflow occurred during 2019 and 2020 and 7,250 lb of phosphorus inflow occurred during the same period at the Site A outlet.

6.0 BMP Analysis

Field observations during sampling provided important indicators of processes involved. First was the appearance of red precipitates on the stalks of emergent plants (probably Typha sp.). These deposits strongly suggest that photosynthetic periphyton algal species plus decomposer bacterial and fungal species growing in lipid films on these surfaces promoted the removal of some soluble iron and phosphate from waters in the wetlands where the streams combine to generate Big Foot Creek. Second was the wide variance in discharges from the wetlands that did not correlate to rainfall events. This variance suggests that groundwater baseflow plays an important role in the iron and phosphate transport.

Addition of calcium (as a limestone amendment) to the treatment process will help achieve removal of both the iron and phosphate in the relatively alkaline waters of Bigfoot Creek in an anaerobic wetland condition with precipitates including FeCO3, Ca3(PO4)2, Fe3(PO4)2 and complexes of calcium, carbonate, phosphate, and iron.

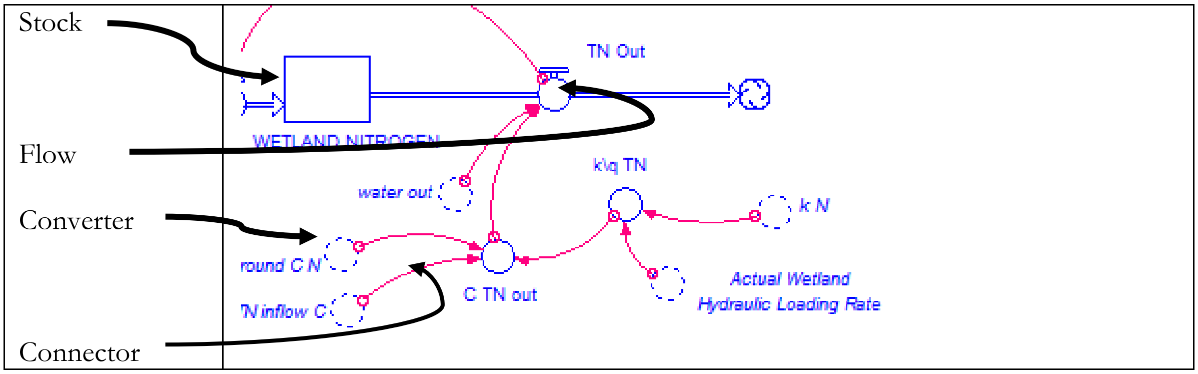
Such a system can be designed as a treatment wetland. Fundamental requirements of the wetland would include the following: 1.) Backflows from the lake into the treatment wetland must be prevented so that flows move only from the watersheds into the lake; 2.) Sizing the volume of the wetland to provide sufficient hold time to allow the iron and phosphate to precipitate into the sediments; 3.) Configuring the wetland with as long a flow path as possible so that concentrations of the pollutants are reduced along the entire flow path; 4.) Providing suitable surfaces for periphyton and decomposer organisms to attach and grow on; and 5) providing sufficient limestone to convert both iron and phosphate into a sparingly insoluble precipitates which can be retained in the wetland soils.

The results of the analysis of the existing conditions described in the previous section showed that the system for removing excessive iron and phosphorus from the Bigfoot Creek waters should be designed to treat 60,800 lb of iron per year and 3,625 lb of phosphorus per year to be fully effective. Requirements for sizing a treatment wetland for the iron and phosphorus removal from the Bigfoot Creek watershed were developed using the STELLA modeling software (see Appendix K) for a range of wetland sizes.

STELLA Model Software Description

STELLA is a commercial software package, published by ISEE Systems, Inc., that allows the user to model complex dynamic systems processes through mathematical relationships. The software has a graphical user interface that can accept variable user input and display model output via numerical readouts, tables, and graphs. Within the STELLA platform, variables are input as stocks, flows or converters. Interactions between these inputs are defined by connectors.

The model quantifies the accumulation of phosphorus and iron removed by the treatment elements in model stocks, the inflows of these constituents from watershed runoff and their outflows from the wetland as flows, and the equations defining the removal process as a series of converters with connectors (see figure below).



Model Description

The model is run for a specified period as an integrated simulation, with the model analyst defining the analysis period, the time unit (hours, days, weeks, or years) and the time step for which each integration calculation takes place (Dt). This model was prepared using a daily time step for a two-year period and a time step of 0.25 days (6 hours), combined with the Euler Equation for Integration.

The model uses the daily water runoff values calculated from the daily precipitation-based regression equations and averaged iron and phosphorus concentration values from the collected water samples.

Model Elements

The basic model parts include a treatment component which quantifies the removal of the inflow of iron and phosphorus, using wetland treatment elements as a total period removal and an average annual removal. Removal capacities for the wetland system were based on first order rate equations for removals:

Phosphorus – $(C_o-C^*)/(C_i-C^*) = (1+k/pq)^{-p}$

C_o = outflow concentration (mg/l)
C_i = inflow concentration (mg/l)
C^* = background concentration (0.002 mg/l)
k = rate constant 0.0274 m/day
P = number of wetland cells in system
q = hydraulic loading rate (m/day)

Iron – $(C_o)/(C_i) = \exp(-k/q)$

C_o = outflow concentration (mg/l)
C_i = inflow concentration (mg/l)
k = rate constant 0.29 m/day
q = hydraulic loading rate (m/day)

The limestone quantity was conservatively calculated as the amount needed to complex all iron and phosphorus removed for the design life of the wetland.

It should be strongly noted that the conceptual calculations are derived from a very limited data set and before advanced preliminary/design phases are started, additional sampling should be made of the Bigfoot Creek iron and phosphorus water concentrations.

Design Elements

Limestone ($CaCO_3$) is recommended as an amendment material to both remove iron as $FeCO_3$ and phosphorus as $Ca_3(PO_4)_2$ under aerobic conditions. The 60,800 lb of iron per year would require 1,100,000 lb of limestone per year (245 cy/yr) or 2,450 cy for a 10-year design life. The phosphorus would be able to share the limestone and be bound in a complex with the calcium and iron. It is expected that within a 10-year period, all significant iron and phosphorus contributing to the present problem would be bound up in the wetland treatment system.

The treatment wetland is designed as a linear flow wetland with a minimum length to width ratio of 6:1 and a recommended 12:1 ratio (the sizing model assumed a 6:1 ratio). The average hydraulic residence time is recommended to be 14 days and the recommended hydraulic loading rate is 0.03 meters per day. The recommended wetland water level bounce is 2 feet maximum to achieve the aerobic environment. The typical wetland design outflow rate is 2.5 cfs and the recommended wetland size is approximately 60 acres based on the STELLA based model developed for the project (see Table 5 below for summary of wetland size options vs. iron and phosphorus removals). A suggested limestone placement design would include 3 acres (14,700 sy) of limestone layer with a 6″ thickness within the 60-acre wetland. An initial sedimentation basin to collect the larger sediment particles is recommended also.

Table 5 - Wetland Size vs Removal Efficiency

Wetland Area (acres)	% Iron Removal*	% Phosphorus Removal Range*
80	90	53 -85
70	89	50-83
60	88	47-82
50	87	43-79
40	84	37-76
30	81	31-71
20	74	23-62
10	59	13-46
5	42	7-30
80	90	53 -85
70	89	50-83
60	88	47-82

**Removals are calculated based on a wetland with plug flow conditions and first order removal rate constants, with k (Fe) = 0.29 meters/day and k(P) = 0.0274 to 0.1644 meters/day. Maximum water depth in wetland used in the calculations was 0.6 meters. The lower value of k for P is likely conservative given the amount of iron available to assist with phosphorus removal reactions.*

7.0 Wetland Construction Concept Plan and Cost Estimate

A 5-acre pilot project is recommended to monitor the effectiveness of a limestone treatment wetland to remove iron and phosphorus. A concept plan and cost estimate of a 5-acre wetland was completed based on an ideal access and site locations. The cost estimate is below in Table 6, and the concept plan is shown in Appendix L.

Table 6 - Conceptual Cost Estimate for Pilot Treatment Wetland

Item	Quantity	Unit	Unit Cost	Extension	Notes
Mobilization	1	LS	$ 50,000.00	$ 50,000.00	Includes demobilization and cleanup
Erosion and Sediment Control	1	LS	$ 20,000.00	$ 20,000.00	Includes installation and maintenance throughout project
Restoration	1	LS	$ 50,000.00	$ 50,000.00	Includes seeding and vegetation establishment
Common Excavation	8,400	CY	$ 50.00	$ 420,000.00	Includes all work necessary for excavation to 1-foot depth throughout the entire wetland area using timber mats and disposing material.
Earthen Berm Deflector	170	CY	$ 50.00	$ 8,500.00	Existing soil used to construct berms. Includes all work necessary for excavation, placement, and compaction of berms as well as removing excess material form the site
3-inch Clear Crushed Limestone	3,110	TON	$ 25.00	$ 77,750.00	Includes all work necessary for placing limestone pads and limestone berms, as well as removing excess material form the site
Outlet Control Structure	1	LS	$ 10,000.00	$ 10,000.00	Includes all work necessary for excavation and placing outlet structure, as well as removing excess material form the site
			Subtotal	$ 636,250.00	
			Contingency (20%)	$ 127,250.00	
			Total	$ 763,500.00	

The iron and phosphorus removal in a 5-acre wetland may be inadequate to see improvements in water clarity at the lake, even with significant reductions in iron and phosphorus. If a larger wetland or wetlands are constructed, the proposed concept site can be expanded, or other locations could be utilized. Other potential sites were identified based on wetland extents, landowner parcels, and proximity to the stream outlet. The potential wetlands map is shown in Appendix M. To identify wetland sites more accurately throughout the watershed, detailed topographic surveys should be competed in areas chosen as likely candidates. Using a drone to capture topography after burning the cattail marsh would be a cost-effective method for collecting topographic data.

Permitting a Constructed Treatment Wetland

Permitting a project that involves wetland disturbance will trigger involvement from local, state, and federal agencies. Table 7 below shows the anticipated permits for constructing 5-acre or larger wetland. If the wetland area is less than 5-acres, the project is likely exempt from the environmental assessment requirement.

Table 7 - Anticipated Permits

Permit Description
County Shoreland Zoning
State Erosion Control and Stormwater Management
State Wetland Disturbance
State Environmental Assessment
Federal Wetland Disturbance

8.0 Conclusions and Next Steps

- Water quality sampling revealed very high levels of P and Fe higher than state and federal standards.
- Conventional surface water modeling using WinSLAMM indicated that surface water runoff does not account for excessive levels of P and Fe captured during sampling.
- The likely source of high P and Fe levels, as well as the orange discoloration, is likely the result of a chemical reaction caused by drained wetlands in muck soils.
- Constructing a limestone treatment wetland(s), depending on size, should ameliorate excessive P and Fe levels as well as address the orange plume in the lake.
- Additional water quality sampling to confirm and refine findings should be conducted prior to design.
- Additional topographic data should be collected to confirm the placement of limestone treatment wetland(s).
- A smaller (say five acre) treatment wetland should be constructed and monitored to demonstrate proof of concept before constructing additional treatment wetlands.
- GLEA should explore the potential of selling P credits in a water quality trade to fund proposed treatment wetland strategies.

Appendix A-M

Appendix A

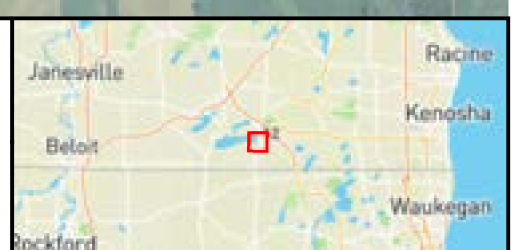
Site Map

BIGFOOT CREEK WATERSHED

Project Boundary

LEGEND

- Project Boundary
- Ownership Parcels
- Flowline (NHD)



AES Project #: 18-0861

Coordinate System:
NAD 83 WI State Plane South
Mapped by: tos
Filename: FIGX_18_0861_BigfootCreek_AOI

Appendix B

Sub-watershed Map

BIGFOOT CREEK WATERSHED
Figure X: SMU Detailed Topography
SMU 1
SMU 2
SMU 3
SMU 4
SMU 5
SMU 6
0
0.05
0.1
0.2 Miles
N
LEGEND
Project Boundary
SMU Definitions
Flowline (NHD)
Contour (1ft)
Storm_Structures
Storm_Mains
Stormwater_Ponds
Janesville
Racine
Kenosha
Beloit
Waukegan
Rockford
Marengo
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Coordinate System:
NAD 83 WI State Plane South
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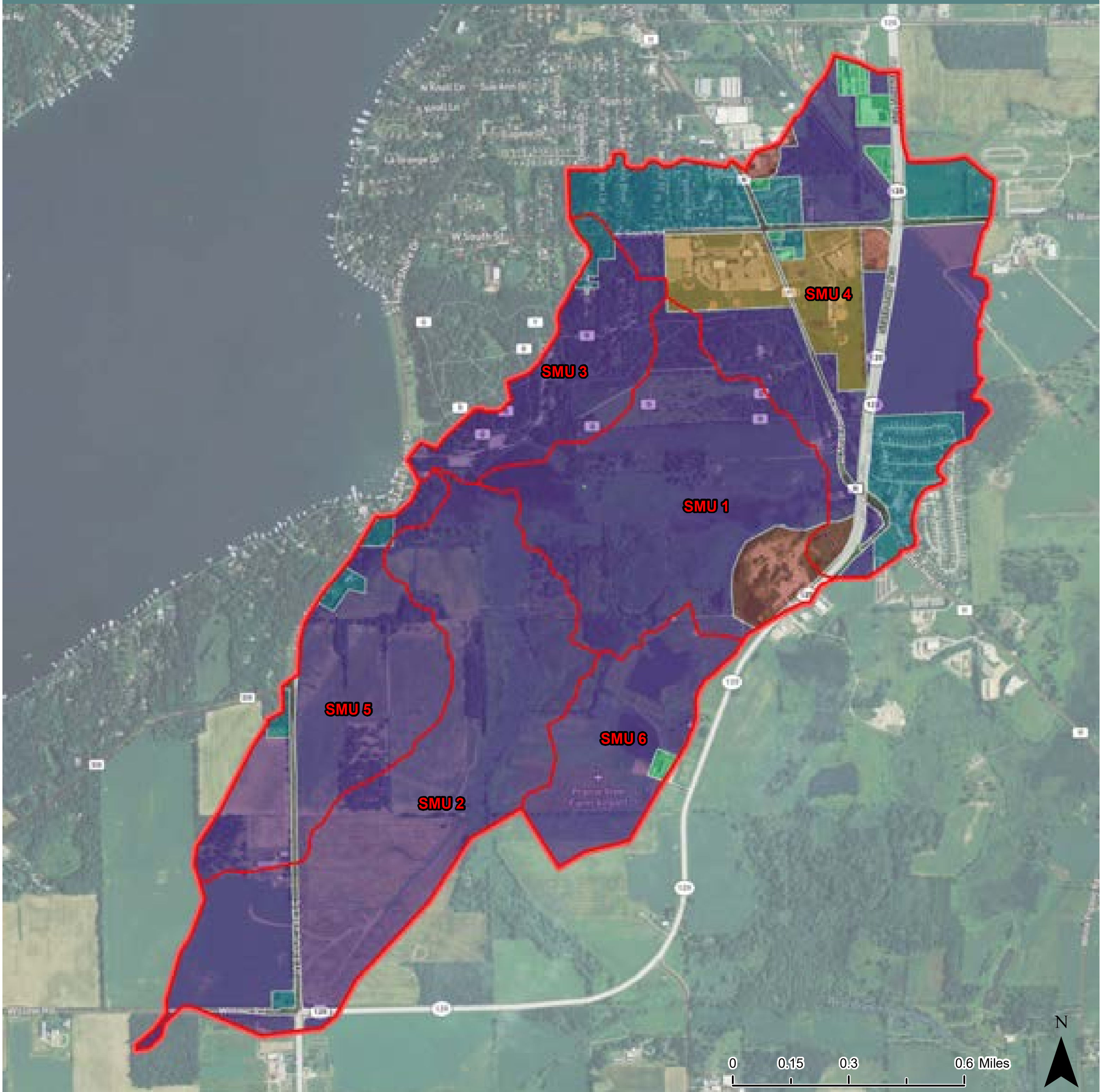
Appendix C

Landuse Map

BIGFOOT CREEK WATERSHED

Land Use

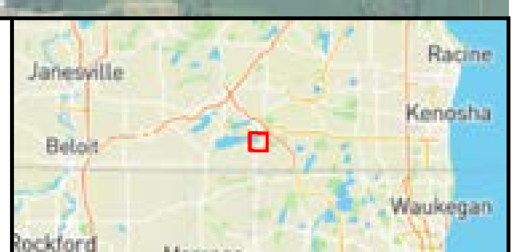


LEGEND

- Project Boundary
- SMU Definitions

Land Use (WinSLAMM)

- Commercial
- Freeway or Highway
- Industrial
- Institutional
- Open Space
- Residential



AES Project #: 18-0105

Coordinate System:
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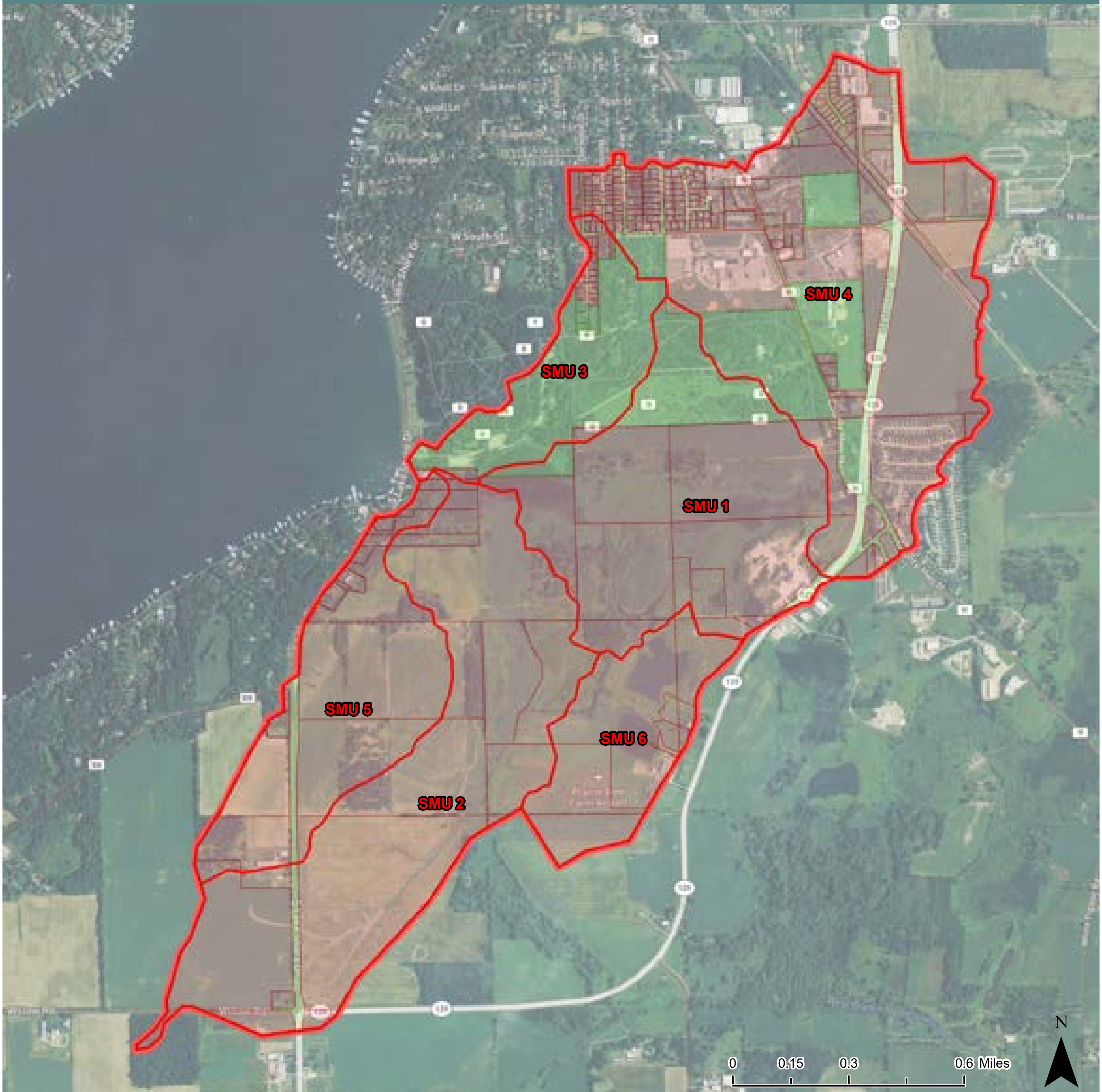
Appendix D

Parcel Map

BIGFOOT CREEK WATERSHED

Parcel Ownership

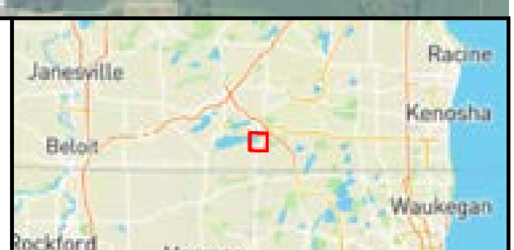


LEGEND

- Project Boundary
- SMU Definitions

Parcel Ownership

- Private
- Public



AES Project #: 18-0105

Coordinate System:
NAD 83 WI State Plane South
Mapped by: tos
Filename: FIGX_18_0861_BigfootCreek

Appendix E

Wisconsin Wetland Indicators and Hydric Soils Maps

BIGFOOT CREEK WATERSHED

SMU 1 Wisconsin Wetland Inventory

LEGEND

Project Boundary

SMU Definitions

Contour (1ft)

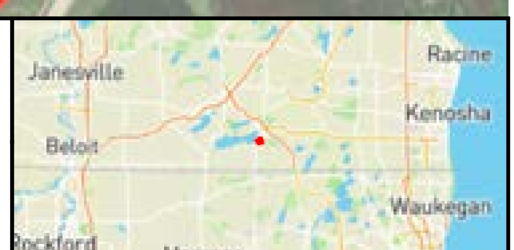
Wisconsin Wetland Inventory

Dammed/Filled or Excavated Pond

Wetland too small to delineate

Hydric Soils

Yes



AES Project #: 18-0861

Coordinate System:
NAD 83 WI State Plane South
Mapped by: tos
Filename: FIGX_18_0861_BigfootCreek_SMU_Detail

BIGFOOT CREEK WATERSHED

SMU 2 Wisconsin Wetland Inventory

LEGEND

Project Boundary

SMU Definitions

Contour (1ft)

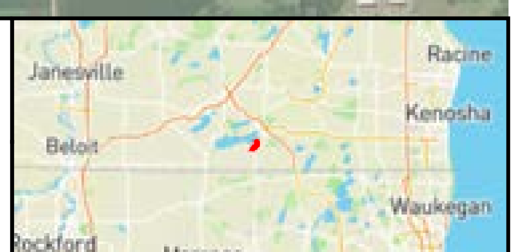
Wisconsin Wetland Inventory

Dammed/Filled or Excavated Pond

Wetland too small to delineate

Hydric Soils

Yes



AES Project #: 18-0861

Coordinate System:
NAD 83 WI State Plane South
Mapped by: tos
Filename: FIGX_18_0861_BigfootCreek_SMU_Detail

BIGFOOT CREEK WATERSHED

SMU 3 Wisconsin Wetland Inventory

LEGEND

Project Boundary

SMU Definitions

Contour (1ft)

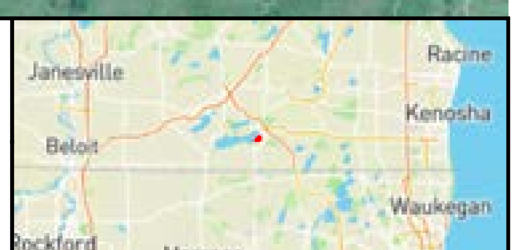
Wisconsin Wetland Inventory

Dammed/Filled or Excavated Pond

Wetland too small to delineate

Hydric Soils

Yes



AES Project #: 18-0861

Coordinate System:
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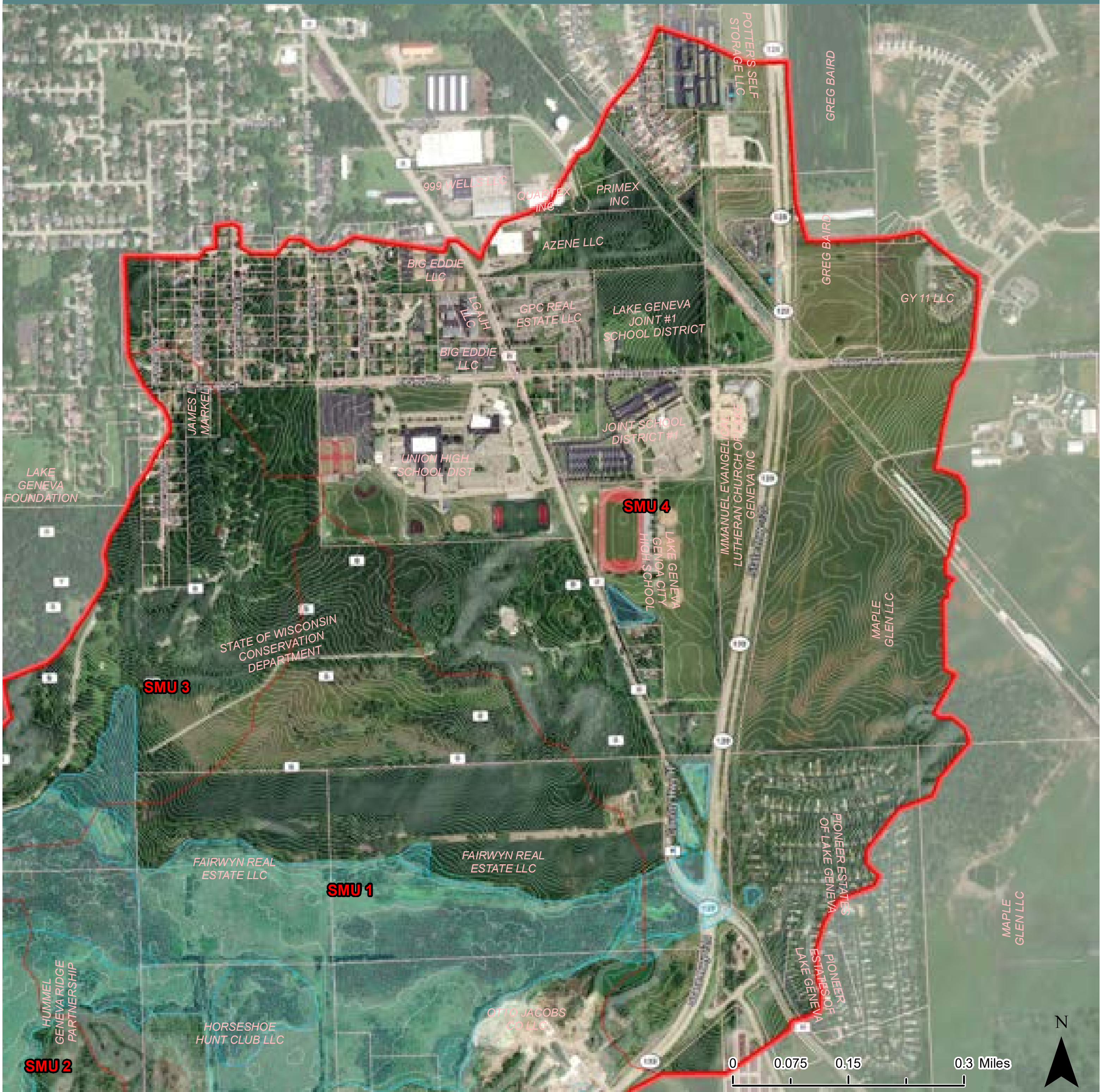
BIGFOOT CREEK WATERSHED

SMU 4 Wisconsin Wetland Inventory



LEGEND

Project Boundary

SMU Definitions

Contour (1ft)

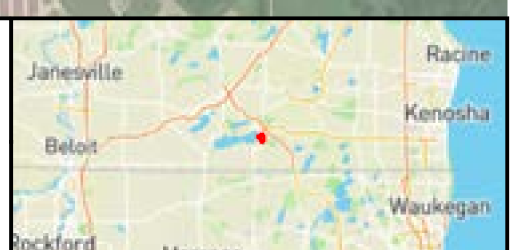
Wisconsin Wetland Inventory

Dammed/Filled or Excavated Pond

Wetland too small to delineate

Hydric Soils

Yes



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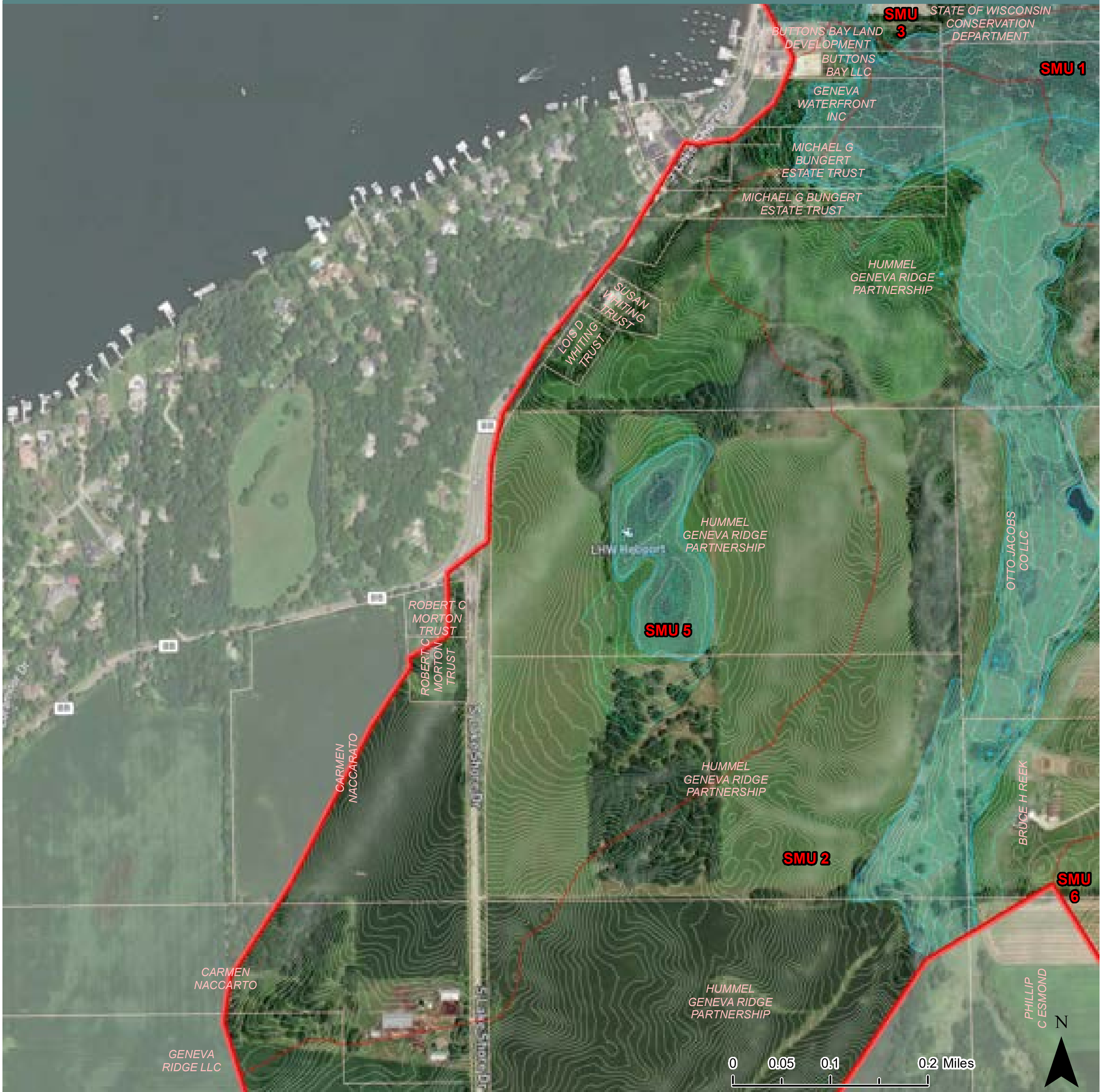
BIGFOOT CREEK WATERSHED

SMU 5 Wisconsin Wetland Inventory



LEGEND

Project Boundary

SMU Definitions

Contour (1ft)

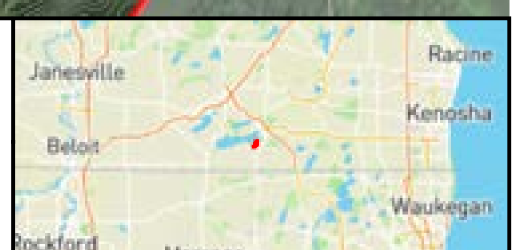
Wisconsin Wetland Inventory

Dammed/Filled or Excavated Pond

Wetland too small to delineate

Hydric Soils

Yes



AES Project #: 18-0861

Coordinate System:
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Mapped by: tos
Filename: FIGX_18_0861_BigfootCreek_SMU_Detail

BIGFOOT CREEK WATERSHED

SMU 6 Wisconsin Wetland Inventory

LEGEND

Project Boundary

SMU Definitions

Contour (1ft)

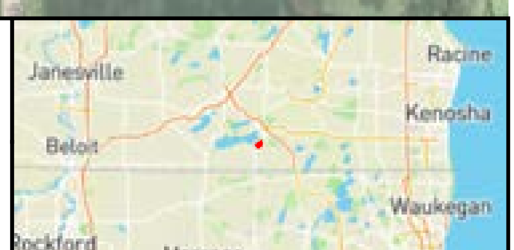
Wisconsin Wetland Inventory

Dammed/Filled or Excavated Pond

Wetland too small to delineate

Hydric Soils

Yes



AES Project #: 18-0861

Coordinate System:
NAD 83 WI State Plane South
Mapped by: tos
Filename: FIGX_18_0861_BigfootCreek_SMU_Detail

BIGFOOT CREEK WATERSHED

Hydric Soils

LEGEND

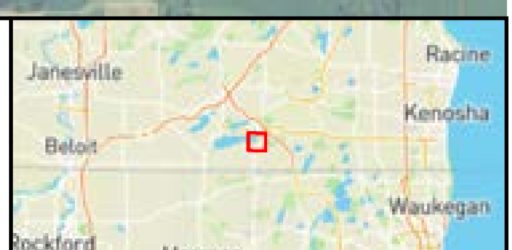
Project Boundary

SMU Definitions

Hydric Soils (SSURGO)

Hydric

Hydric Inclusions



AES Project #: 18-0105

Coordinate System:
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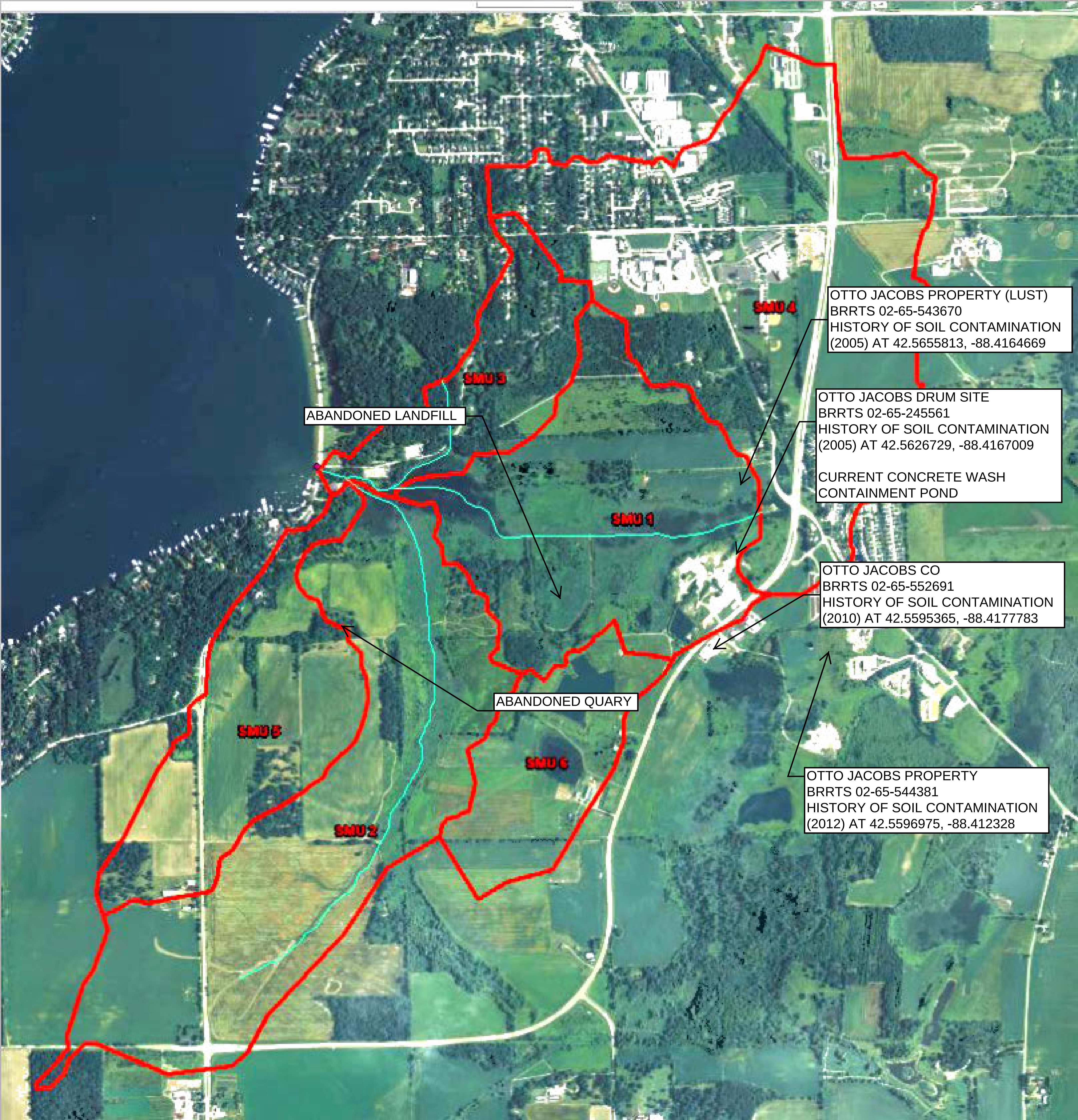
Mapped by: tos
Filename: FIGX_18_0861_BigfootCreek

Appendix F

Contaminated Sites Map



OTTO JACOBS PROPERTY (LUST)
BRRTS 02-65-543670
HISTORY OF SOIL CONTAMINATION
(2005) AT 42.5655813, -88.4164669
SMU 4
SMU 3
OTTO JACOBS DRUM SITE
BRRTS 02-65-245561
HISTORY OF SOIL CONTAMINATION
(2005) AT 42.5626729, -88.4167009
CURRENT CONCRETE WASH
CONTAINMENT POND
ABANDONED LANDFILL
SMU 1
OTTO JACOBS CO
BRRTS 02-65-552691
HISTORY OF SOIL CONTAMINATION
(2010) AT 42.5595365, -88.4177783
ABANDONED QUARY
SMU 5
SMU 6
OTTO JACOBS PROPERTY
BRRTS 02-65-544381
HISTORY OF SOIL CONTAMINATION
(2012) AT 42.5596975, -88.412328
SMU 2

Appendix G

WinSLAMM Map

Particulate Phosphorus Contribution

Appendix H

Monitoring Sites Map

Surface Water Data Viewer Map

Legend

- Station Points with Historic Data
- Station Points with Recent Data (10 years)
- Station Points without Data (Active, Usable)
- Station Points without Data (New Station, Pending)
- Station Lines with Historic Data
- Station Lines with Recent Data (10 years)
- Station Lines without Data (Active, Usable)
- Station Lines without Data (New Station, Pending)
- Municipality
- State Boundaries
- County Boundaries
- Major Roads
  - Interstate Highway
  - State Highway
  - US Highway
- County and Local Roads
  - County HWY
  - Local Road
- Railroads
- Tribal Lands
- Index to EN_Image_Basemap_Leaf_Off

Notes

0.1 0 0.06 0.1 Miles

NAD_1983_HARN_Wisconsin_TM

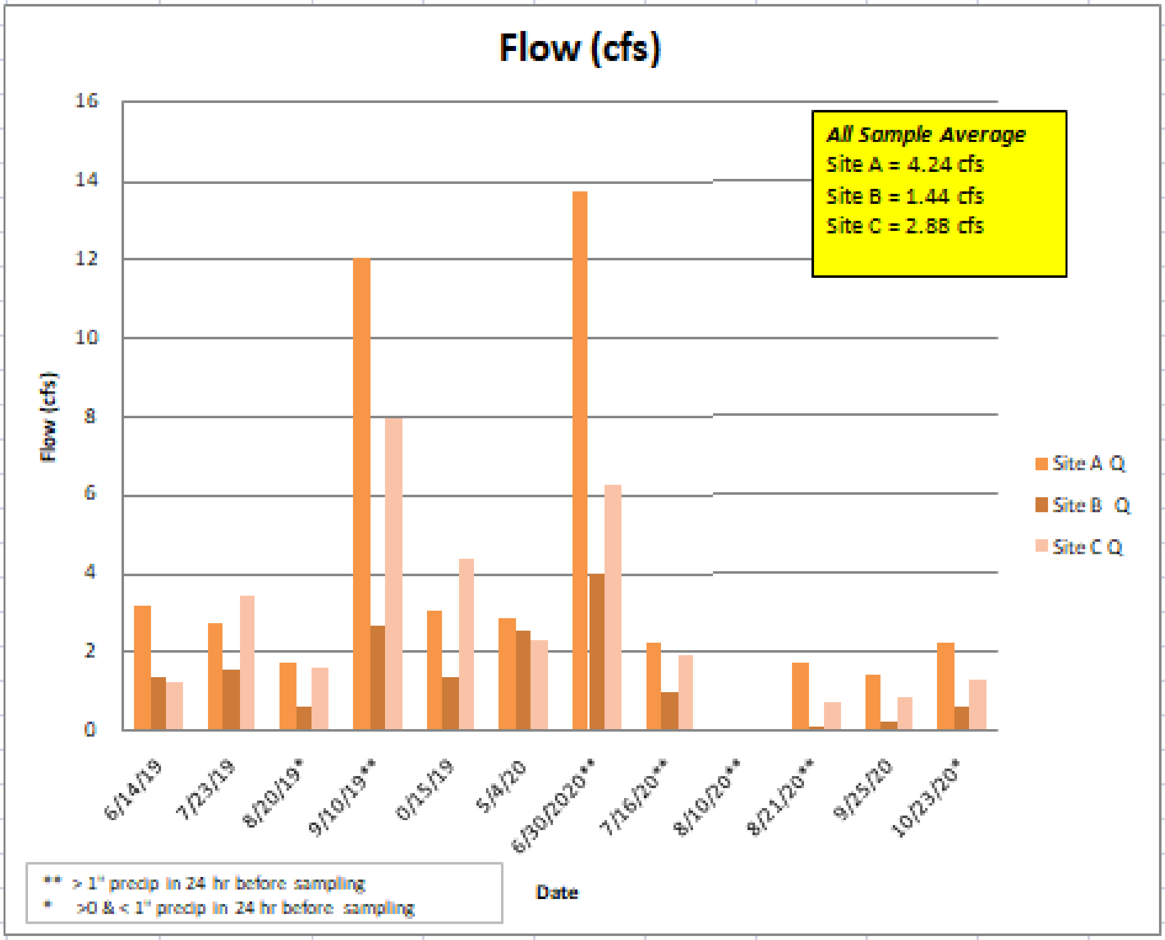
1: 3,960

Appendix I

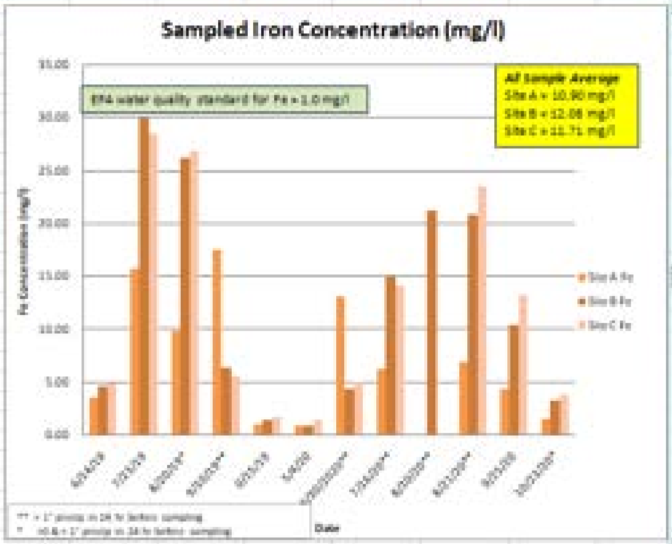
Water Sampling Data and Regulatory Criteria

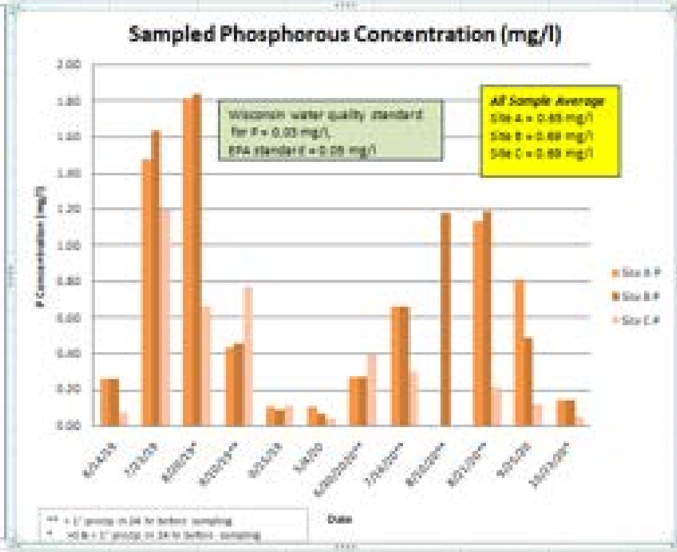
			6/14/19	7/23/19	8/20/19*	9/10/19**	0/15/19	5/4/20	6/30/2020**	7/16/20**	8/10/20**	8/21/20**	9/25/20	10/23/20*		
sample date		5/14/2019	6/14/2019	7/23/2019	8/20/2019	9/10/2019	10/15/2019	5/4/2020	6/30/2020	7/16/2020	8/10/2020	8/21/2020	9/25/2020	10/23/2020		average
Site A																
Site A Fe	mg/l		5.04	26.10	25.90	6.48	1.52	1.54	4.25	12.90		18.40	14.40	3.35		10.90
Site A P	mg/l		0.26	1.48	1.82	0.43	0.10	0.10	0.27	0.66		1.13	0.81	0.14		0.65
Site A Q	cfs	1.82	3.16	2.69	1.70	12.05	3.05	2.86	13.69	2.19		1.68	1.38	2.21		4.24
Site A Fe	g/hr		1624	7157	4488	7960	473	449	5931	2880		3151	2026	755		3354
Site A P	g/hr		84	406	315	528	31	29	377	147		194	114	32		205
Site A Fe	lb/hr		3.57	15.75	9.87	17.51	1.04	0.99	13.05	6.34		6.93	4.46	1.66		7.38
Site A P	lb/hr		0.18	0.89	0.69	1.16	0.07	0.06	0.83	0.32		0.43	0.25	0.07		0.45
Site B																
Site B Fe	mg/l		4.74	29.9	26.2	6.45	1.46	0.87	4.37	15	21.3	20.9	10.4	3.37		12.08
Site B P	mg/l		0.26	1.64	1.84	0.46	0.09	0.06	0.27	0.66	1.18	1.19	0.49	0.14		0.69
Site B Q	cfs	1.19	1.35	1.54	0.59	2.68	1.3	2.53	4.01	0.98		0.09	0.21	0.57		1.44
Site B Fe	g/hr		652	4694	1576	1762	193	224	1786	1499		192	223	196		1181.56
Site B P	g/hr		36	257	111	126	12	15	110	66		11	10	8		69.35
Site B Fe	lb/hr		1.44	10.33	3.47	3.88	0.43	0.49	3.93	3.30		0.42	0.49	0.43		2.60
Site B P	lb/hr		0.08	0.57	0.24	0.28	0.03	0.03	0.24	0.15		0.02	0.02	0.02		0.15
Site C																
Site C Fe	mg/l		4.98	28.5	26.9	5.59	1.7	1.42	5.09	14.1		23.5	13.2	3.87		11.71
Site C P	mg/l		0.25	1.56	1.9	0.43	0.11	0.08	0.28	0.7		1.4	0.68	0.16		0.69

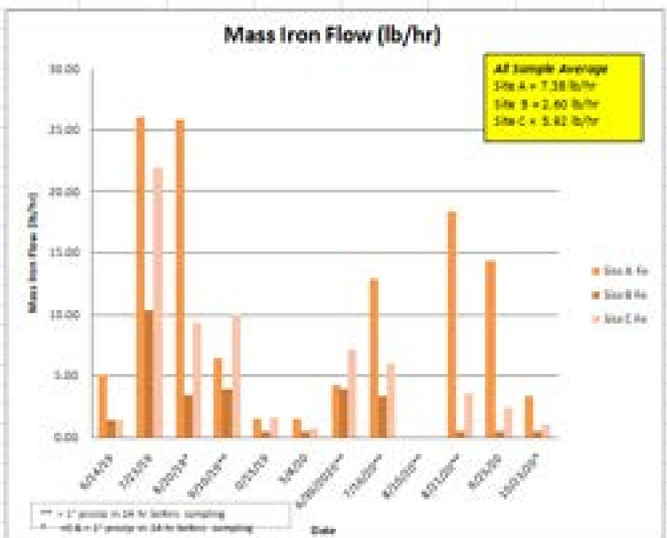
			6/14/19	7/23/19	8/20/19*	9/10/19**	0/15/19	5/4/20	6/30/2020**	7/16/20**	8/10/20**	8/21/20**	9/25/20	10/23/20*		
sample date		5/14/2019	6/14/2019	7/23/2019	8/20/2019	9/10/2019	10/15/2019	5/4/2020	6/30/2020	7/16/2020	8/10/2020	8/21/2020	9/25/2020	10/23/2020		average
Site C																
Site C Fe	mg/l		4.98	28.5	26.9	5.59	1.7	1.42	5.09	14.1		23.5	13.2	3.87		11.71
Site C P	mg/l		0.25	1.56	1.9	0.43	0.11	0.08	0.28	0.7		1.4	0.68	0.16		0.69
Site C Q	cfs	0.98	1.2	3.43	1.55	7.97	4.37	2.27	6.25	1.89		0.67	0.8	1.25		2.88
Site C Fe	g/hr		609	9965	4250	4542	757	329	3243	2717		1605	1076	493		2690
Site C P	g/hr		31	545	300	349	49	19	178	135		96	55	20		162
Site C Fe	lb/hr		1.34	21.92	9.35	9.99	1.67	0.72	7.13	5.98		3.53	2.37	1.08		5.92
Site C P	lb/hr		0.07	1.20	0.66	0.77	0.11	0.04	0.39	0.30		0.21	0.12	0.04		0.36

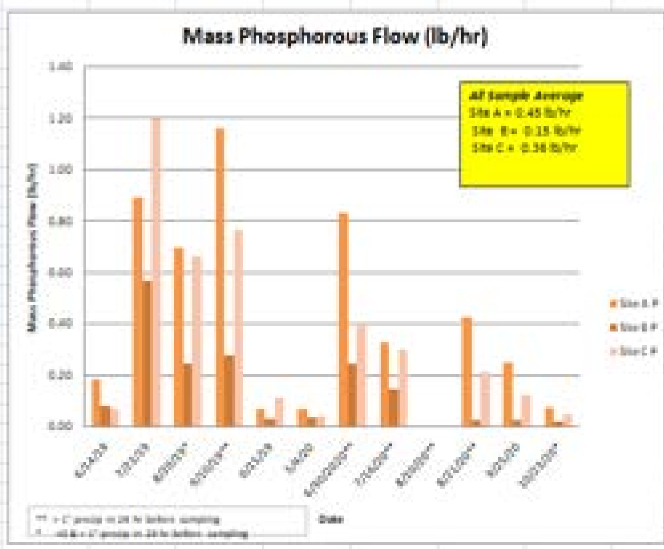


Flow (cfs)
All Sample Average
Site A = 4.24 cfs
Site B = 1.44 cfs
Site C = 2.88 cfs
Flow (cfs)
16
14
12
10
8
6
4
2
0
6/14/19
7/23/19
8/20/19*
9/10/19**
0/15/19
5/4/20
6/30/2020**
7/16/20**
8/10/20**
8/21/20**
9/25/20
10/23/20*
Site A Q
Site B Q
Site C Q
** > 1" precip in 24 hr before sampling
* >0 & < 1" precip in 24 hr before sampling
Date


Sampled Iron Concentration (mg/l)
All Sample Average
Site A = 10.90 mg/l
Site B = 12.08 mg/l
Site C = 11.71 mg/l
Date


Sampled Phosphorous Concentration (mg/l)
All Sample Average
Date


Mass Iron Flow (lb/hr)
All Sample Average
Date

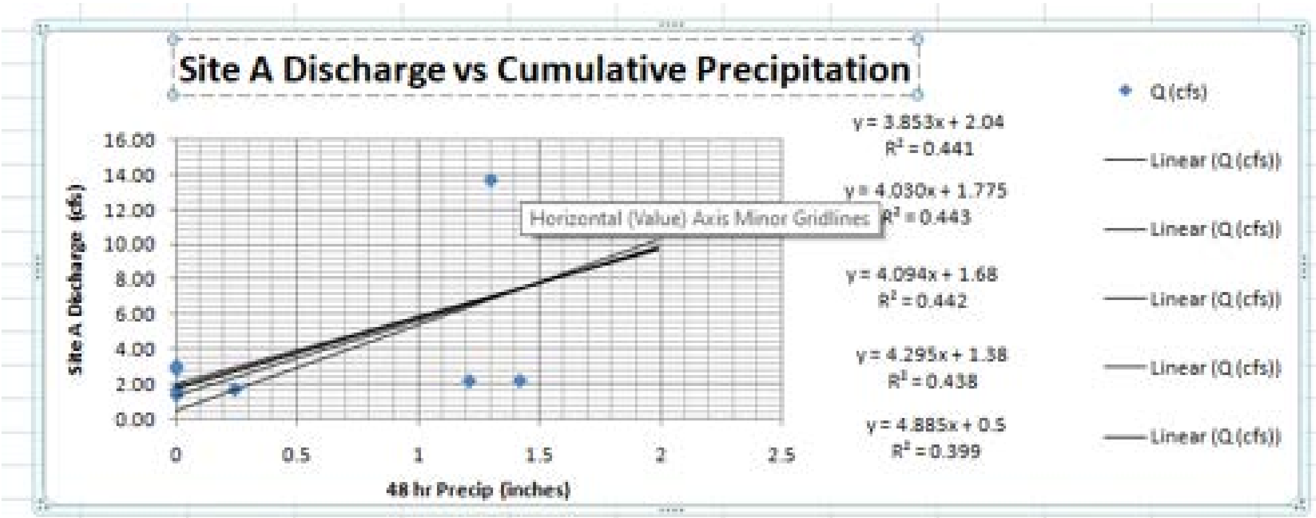

Mass Phosphorous Flow (lb/hr)
All Sample Average
Date

REGULATORY CRITERIA

		WI	EPA 10/7/20 Current Criteria (Typ. 1986 Gold Book)	EPA 25th Percentile Ecoregion VII
TSS	mg/l	none	none	na
Fe	mg/l	none	1	na
P	mg/l	0.03	0.05	0.033
NH_3	mg/l	none	1.9	na
NO_2/NO_3	mg/l	none	10	0.3
TKN	mg/l	none	none	0.24
COD	mg/l	none	none	na
pH		6-9	none	na
Turb	NTU	none	none	1.7
Conductivity	mSm/cm	none	none	na
DO	mg/l	5	none	na
Alkalinity	mg/l	none	20	na

Appendix J

Graphs of Regression Equations and Coefficients

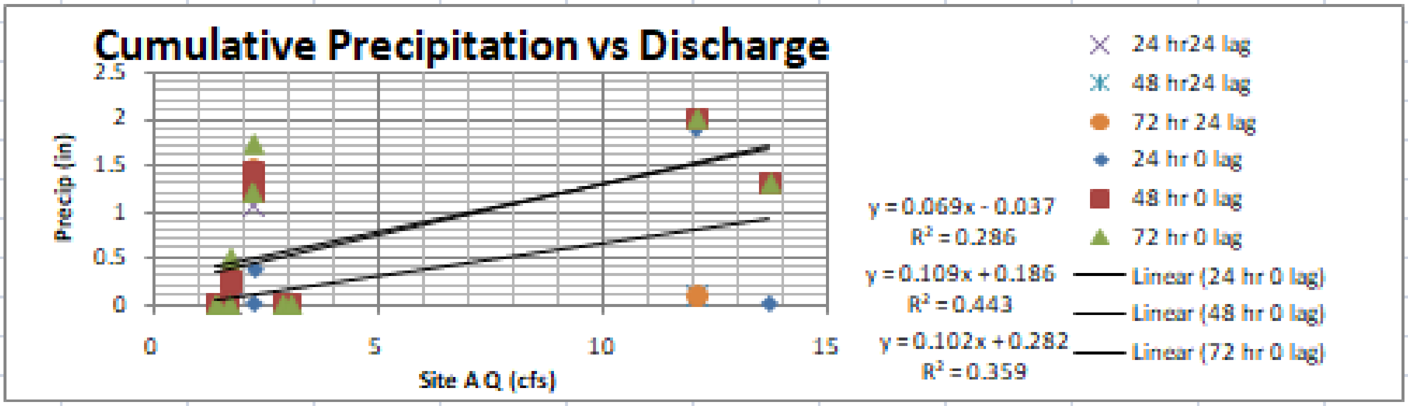


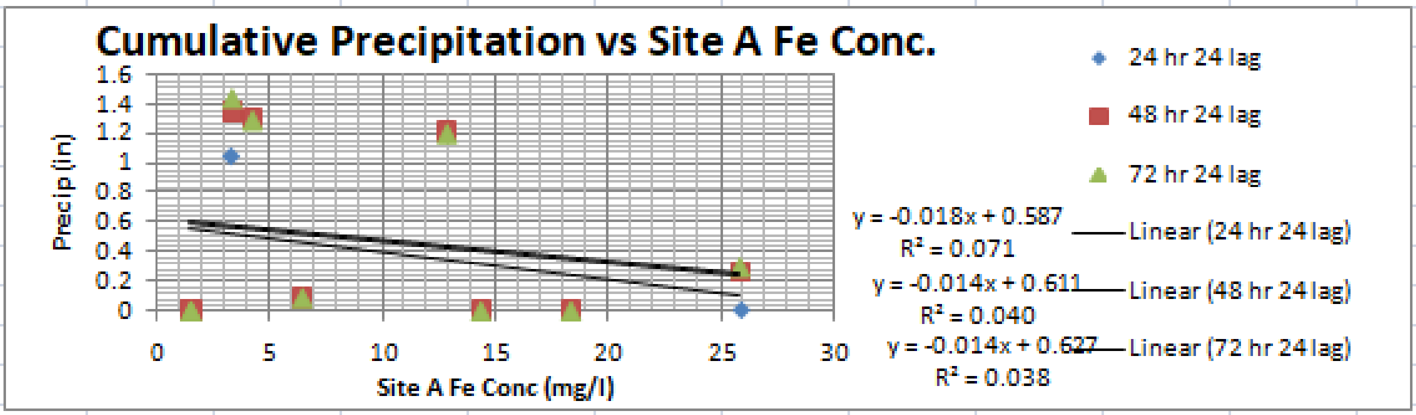
Q (cfs) = 48 hr. precipitation (inches) + 1.77 cfs

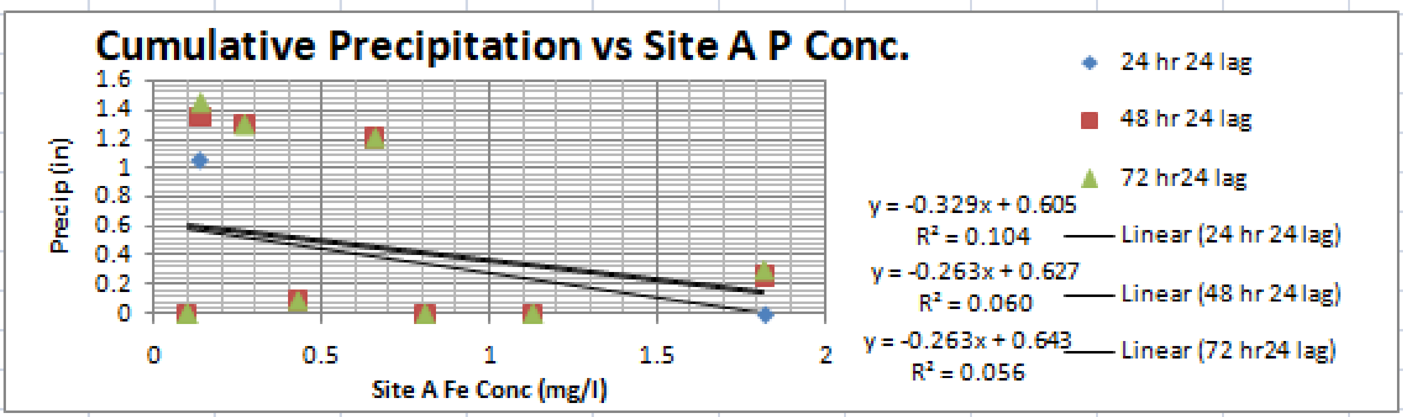
R^2 = 0.443

0 Hours Lag

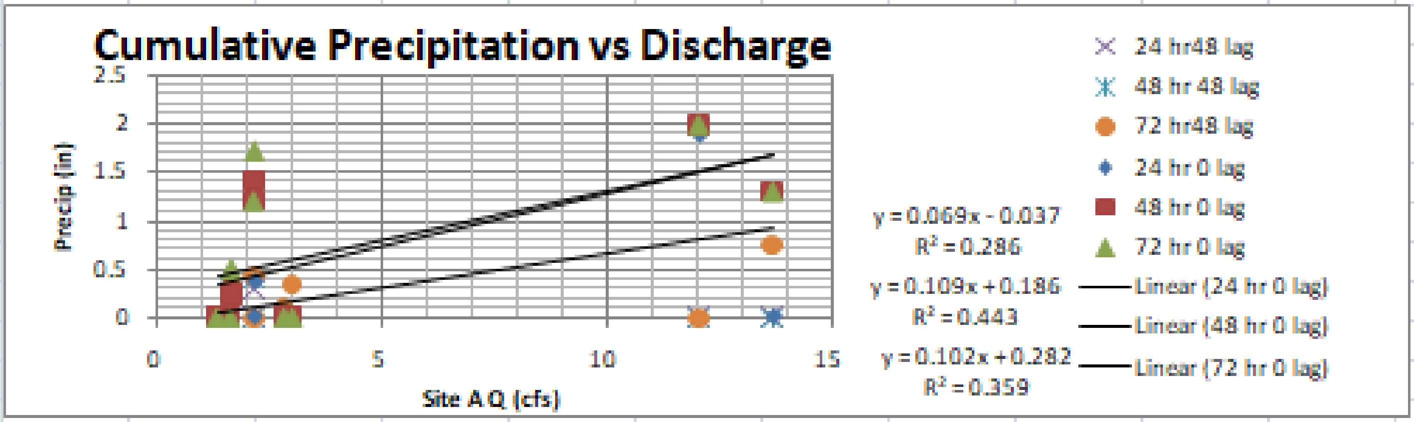
24, 48, and 72, Hour Cumulative Rainfall – 24 Hour Lag

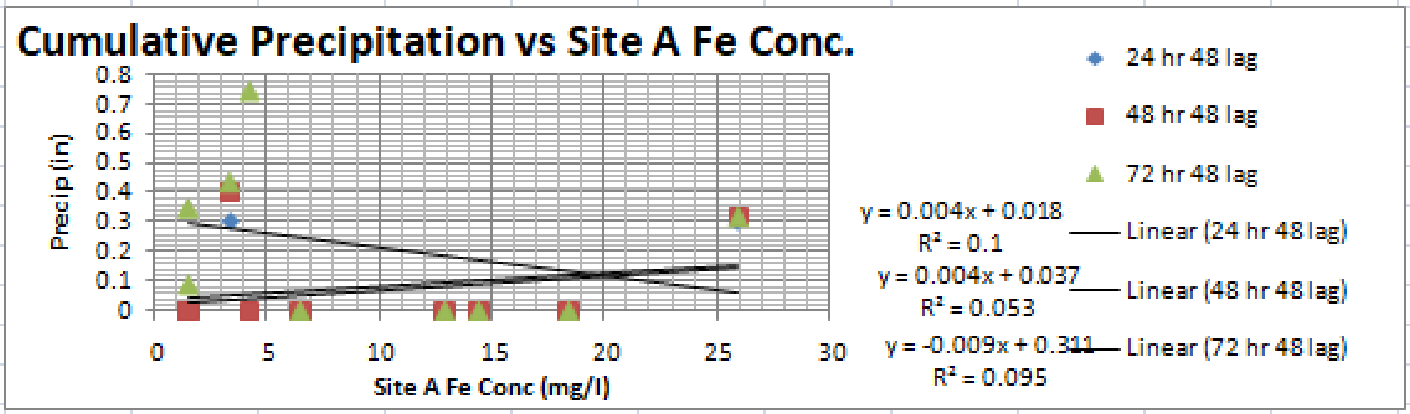


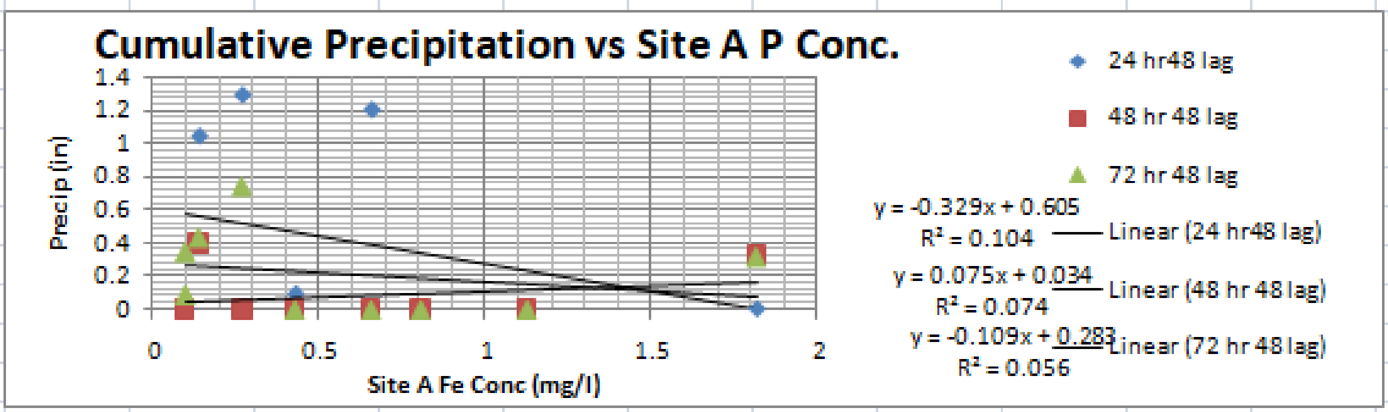




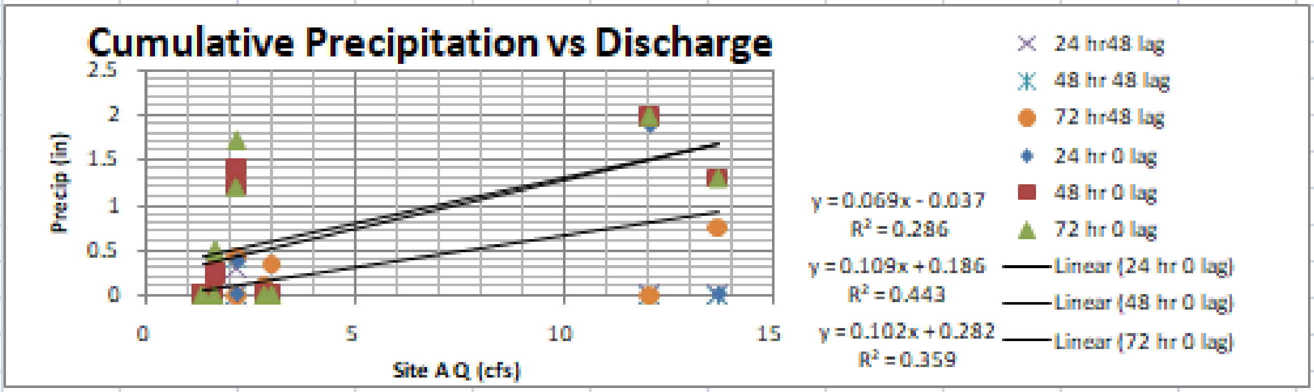
24, 48 and 72, Hour Cumulative Rainfall – 48 Hour Lag

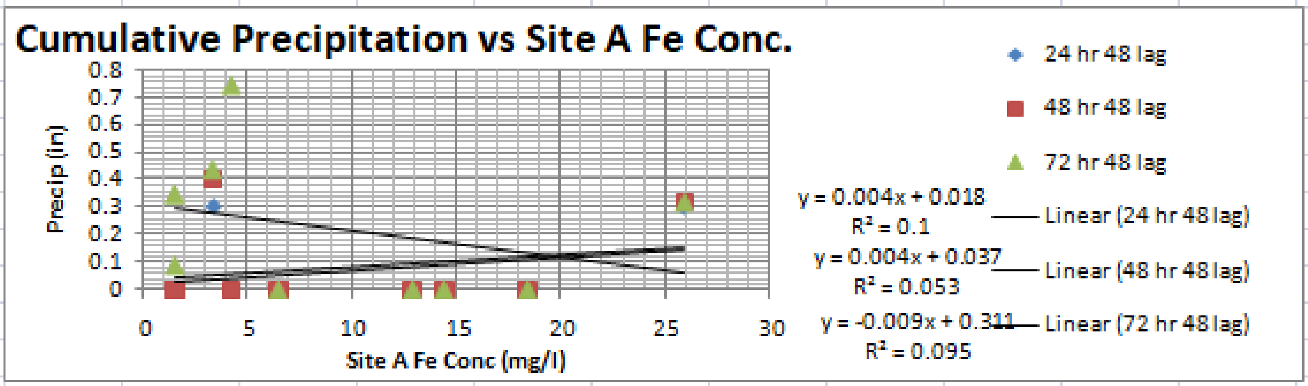


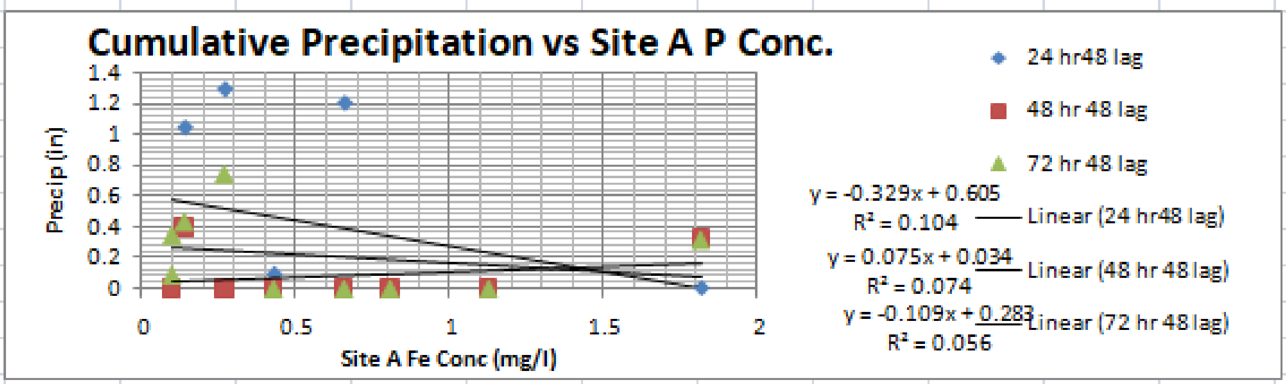




24 , 48 and 72 Hour Cumulative Rainfall – 48 Hour Lag



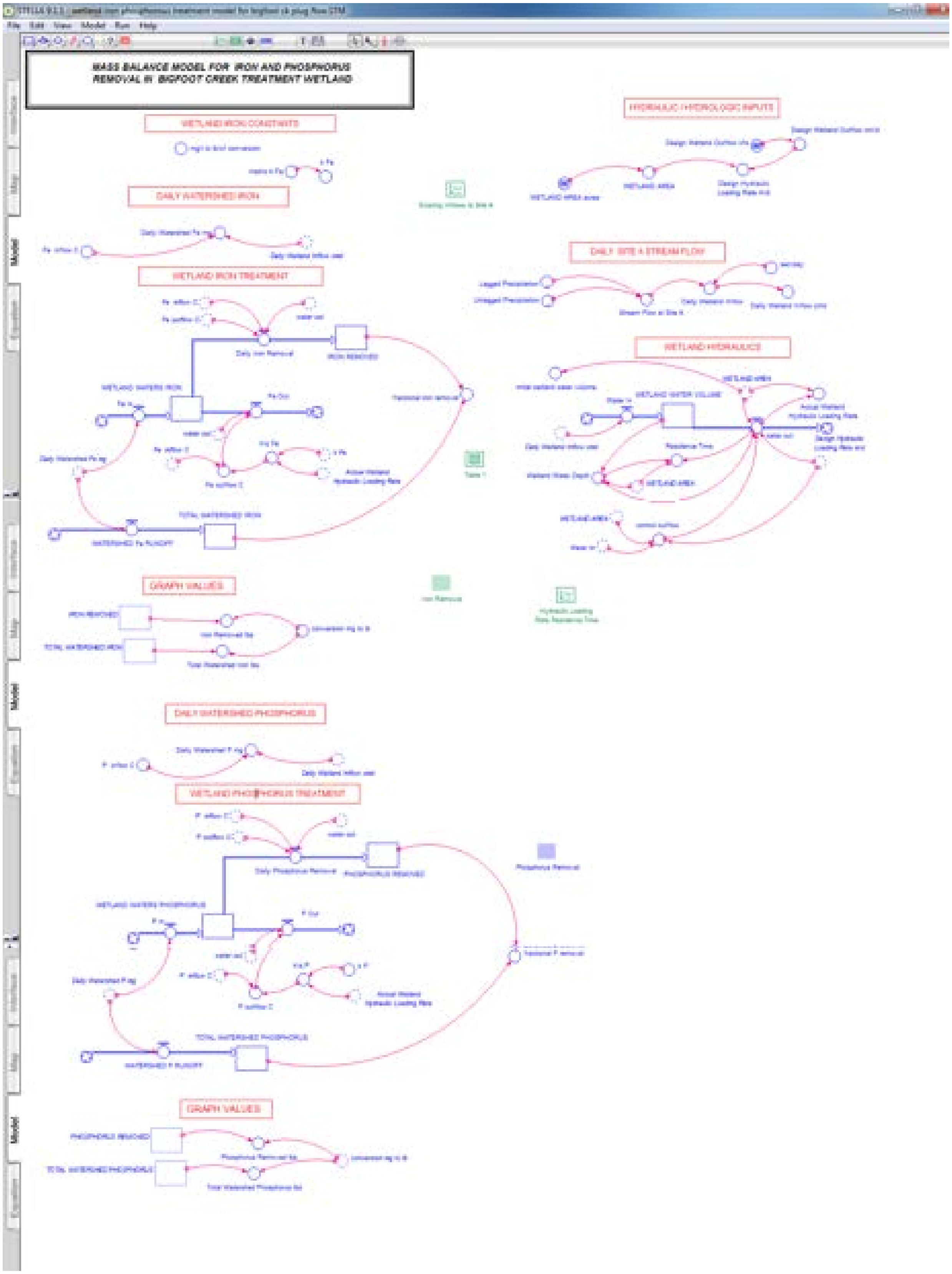




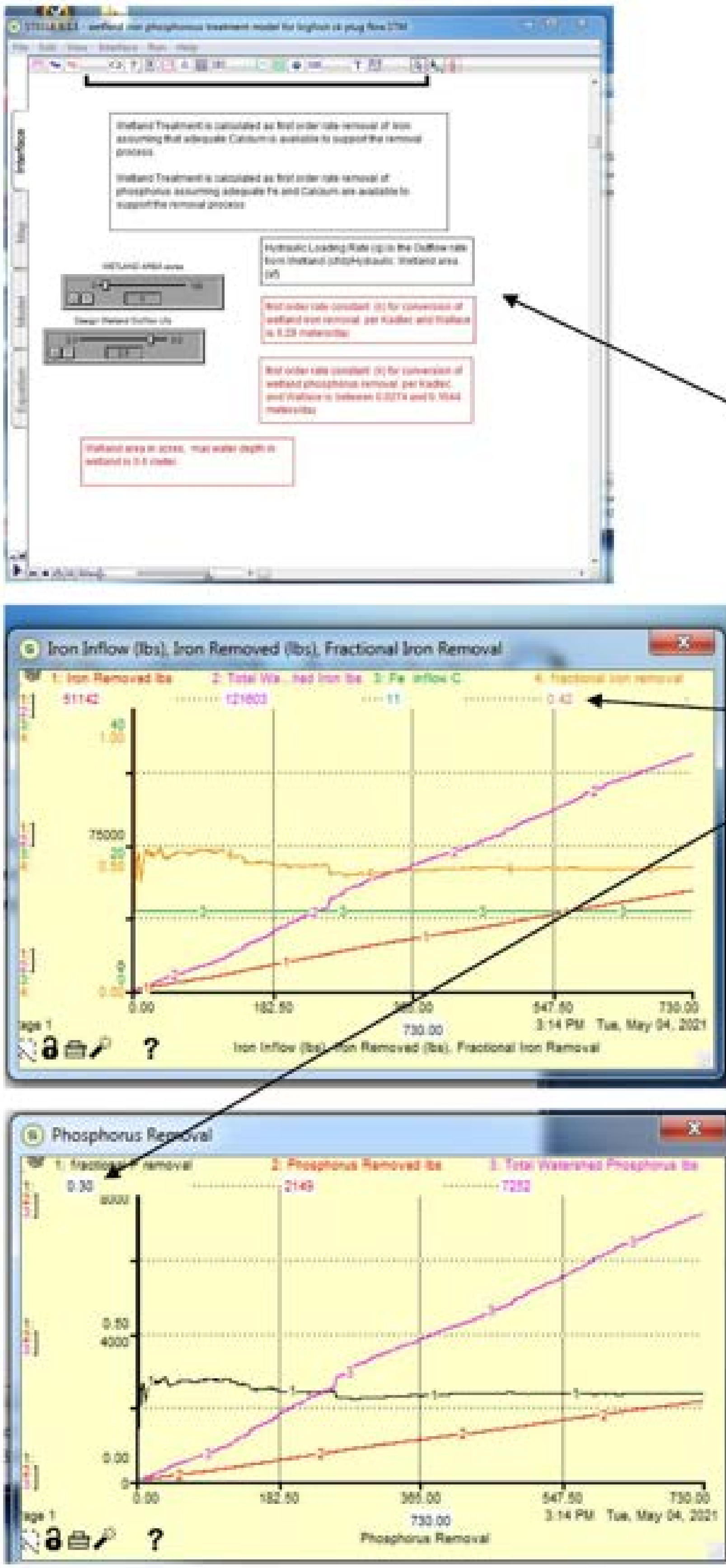
Appendix K

Stella Modeling Software Wetland Size Results

STELLA MODEL FLOWCHART



Modeled Wetland Treatment Effectiveness



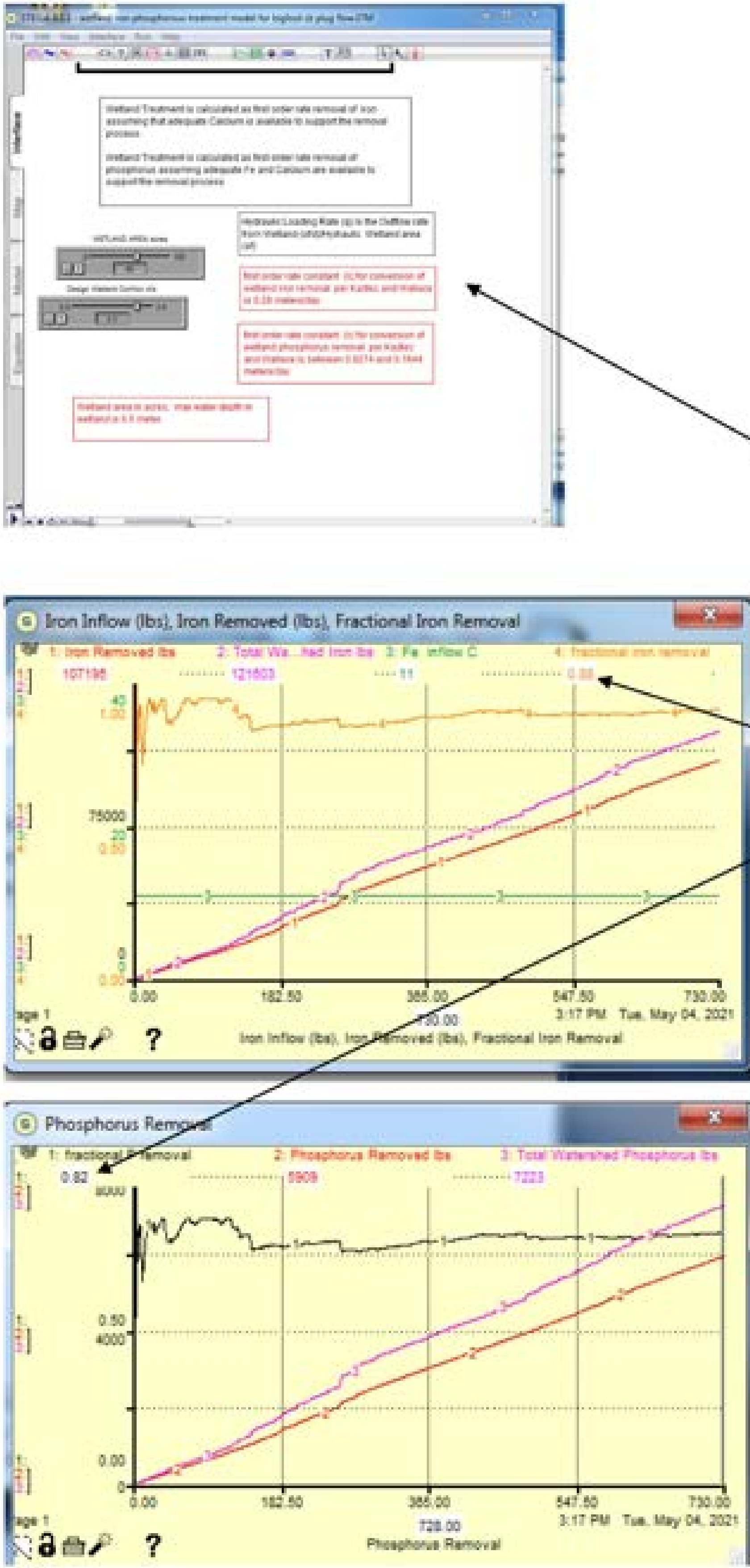
STELLA model results for 5 Acre Treatment Wetland Alternative

- 42% iron removal
- 30% phosphorus removal

Two year cumulative analysis period for 24 hr daily rainfall data and average sampled existing iron and phosphorus concentrations.

5 Acre wetland is the minimum wetland size that can be fitted within the lower reach of the Bigfoot Creek watershed and could be used as a demonstration of concept

Modeled Wetland Treatment Effectiveness



STELLA model results for 60 Acre Treatment Wetland Alternative

- 88% iron removal
- 82% phosphorus removal

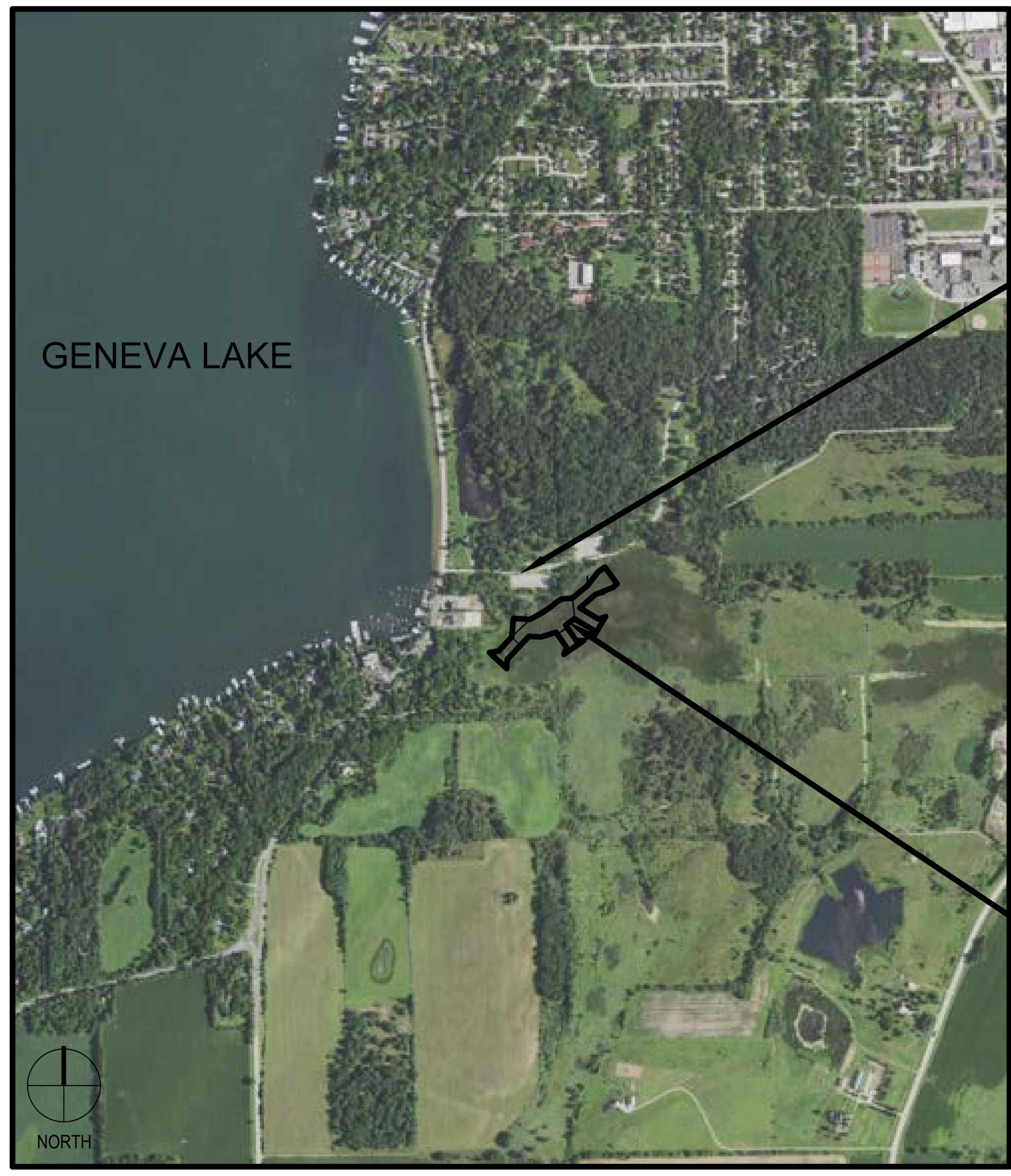
Two year cumulative analysis period for 24 hr daily rainfall data and average sampled existing iron and phosphorus concentrations.

A 60 acre area of treatment wetland within the Bigfoot Creek watershed would provide for optimal removal of iron and phosphorus. Several individual wetlands totaling 60 acres in area would be required

Appendix L

Concept Treatment Wetland Plans

LOCATION MAP



CONCEPTUAL PLANS FOR

BIG FOOT CREEK WATER QUALITY STUDY

LAKE GENEVA, WI

MARCH 2021

DRAWING INDEX

APPLIED ECOLOGICAL SERVICES
17921 W Smith Road
Brodhead, WI 53520
Office 608-897-8641
www.appliedeco.com
Email: info@appliedeco.com

BIG FOOT CREEK WATER QUALITY STUDY

WALWORTH COUNTY, WI

GENEVA LAKE ENVIRONMENTAL AGENCY
350 CONSTANCE ROAD, WILLIAMS BAY, WI 53191

AES Proj. #:	18-0861
Designed By:	DE/JAM
Drawn By:	JAM
Checked By:	
Coordinate System:	WI SP SOUTH-US SURVEY FT
Design Firm License:	_

ISSUED FOR

Date	Description	Revision
04/20/2021	CONCEPT DESIGN	1
05/26/2021	FINAL CONCEPT DESIGN	1

NOT FOR CONSTRUCTION

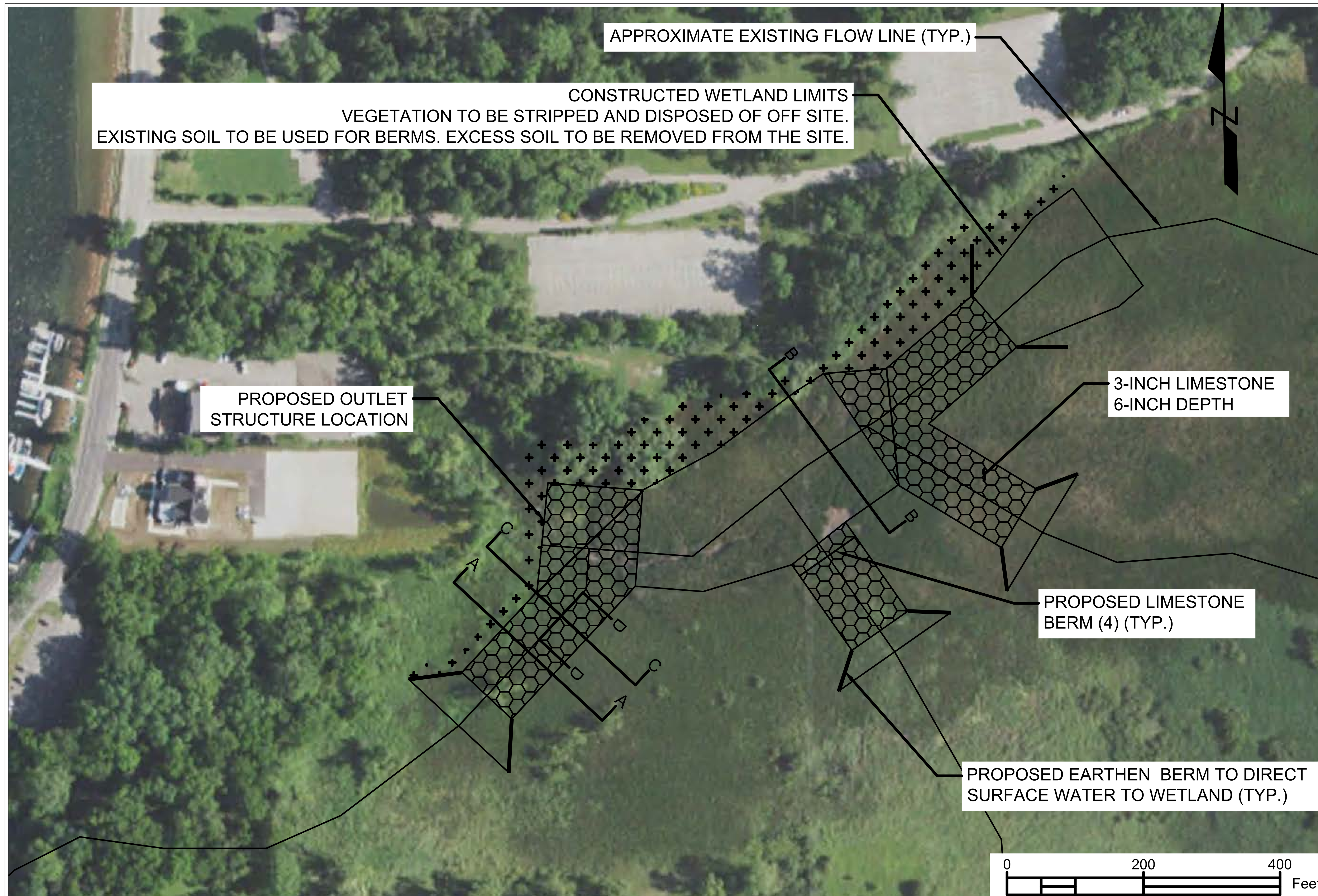
DATED:

SHEET TITLE

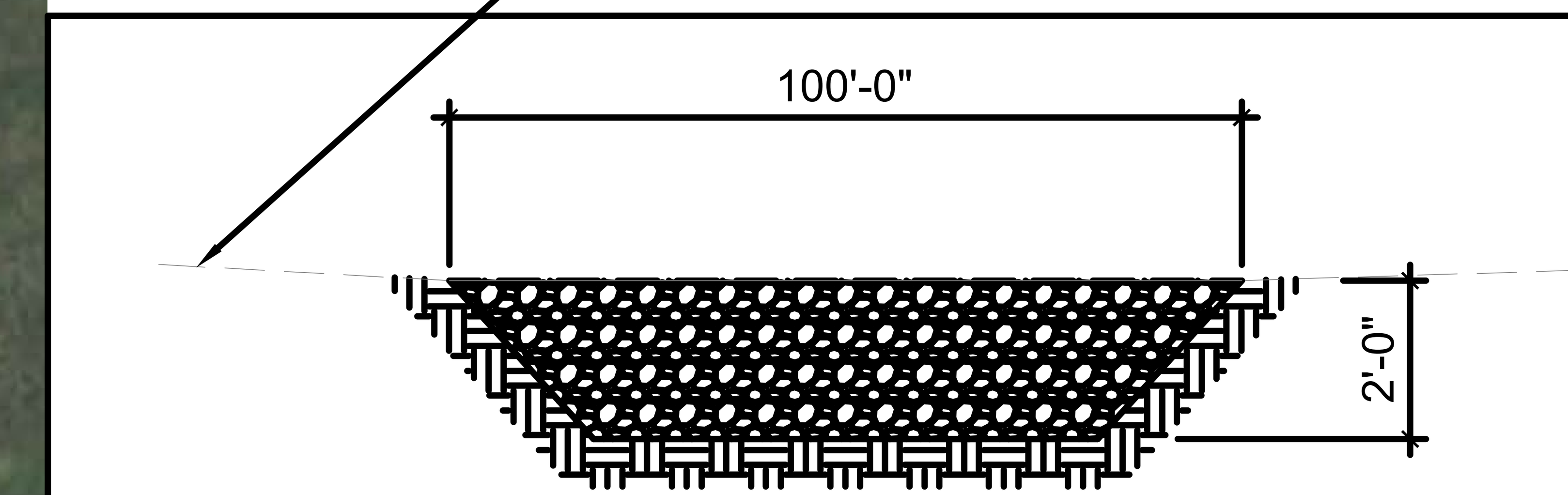
COVER

SHEET NUMBER

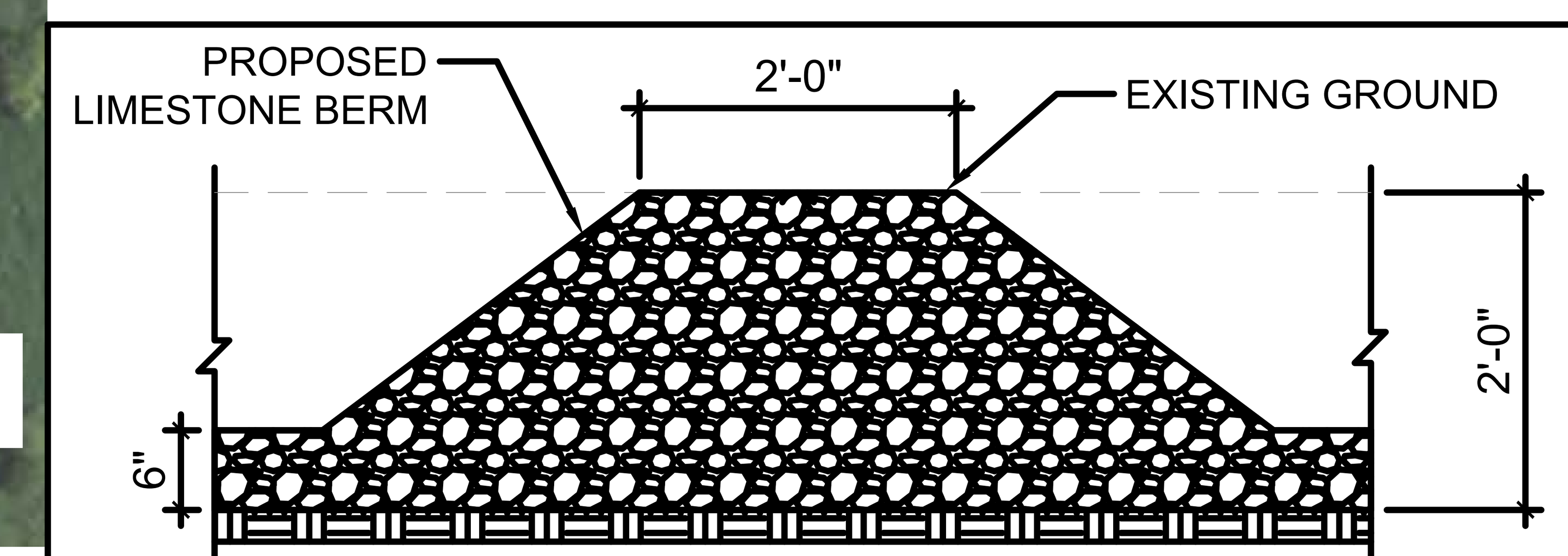
01



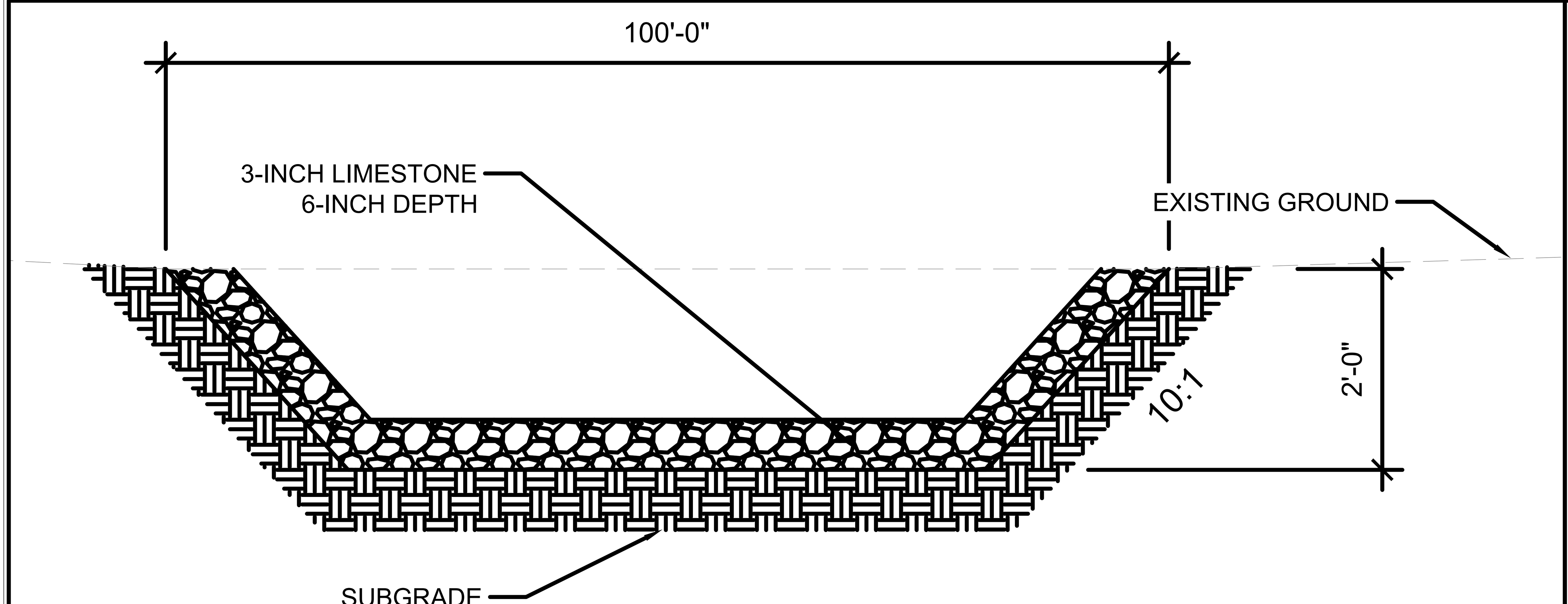
Wetland Disturbance Description	Area (acres)	Volume (CY)
Limestone Fill (Permanent)	2.4	2090
Earthen Berm Fill (Permanent)	0.12	167
Emergent Wetland Enhnancement (Permanent) (Area Outside of Limestone and Earthen Berm Fill)	2.8	N/A
Temporary Wetland Disturbance (access with timber mats and erosion control)	1.5	N/A



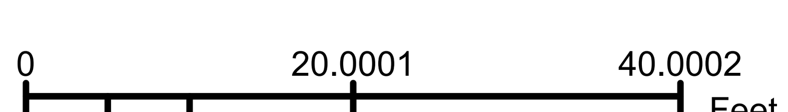
SECTION C-C - PROPOSED LIMESTONE BERM SECTION (NOT TO SCALE)

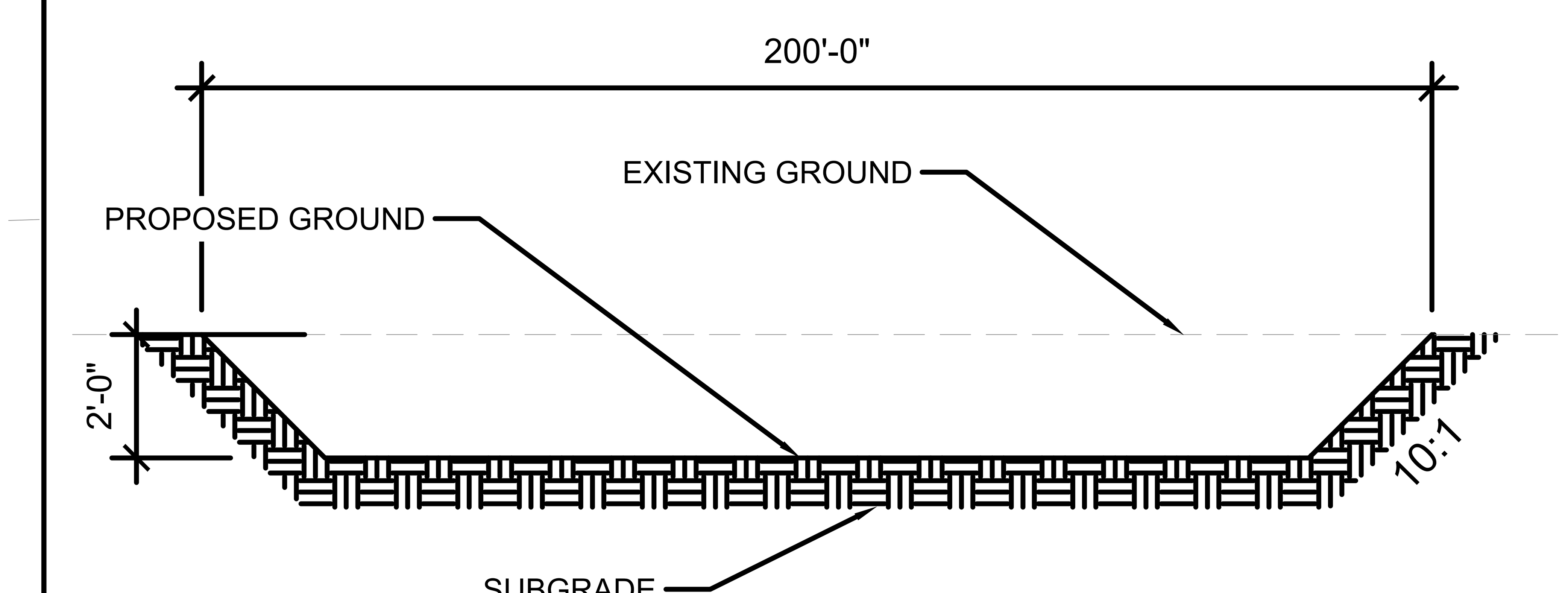


SECTION D-D - PROPOSED LIMESTONE BERM PROFILE (NOT TO SCALE)

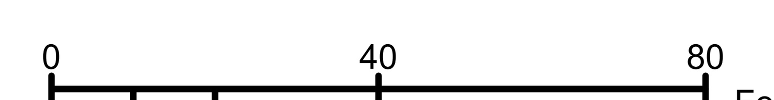


SECTION A-A - LIMESTONE WETLAND FILL





SECTION B-B - PROPOSED WETLAND



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BIG FOOT CREEK WATER QUALITY STUDY

WALWORTH COUNTY, WI

GENEVA LAKE ENVIRONMENTAL AGENCY
350 CONSTANCE ROAD, WILLIAMS BAY, WI 53191

AES Proj. #:	18-0861
Designed By:	DE/JAM
Drawn By:	JAM
Checked By:	
Coordinate System:	WI SP SOUTH-US SURVEY FT
Design Firm License:	_

ISSUED FOR

Date	Description	Revision
04/20/2021	CONCEPT DESIGN	1
05/26/2021	FINAL CONCEPT DESIGN	1

NOT FOR CONSTRUCTION

DATED:

SHEET TITLE

CONCEPT PLAN

SHEET NUMBER

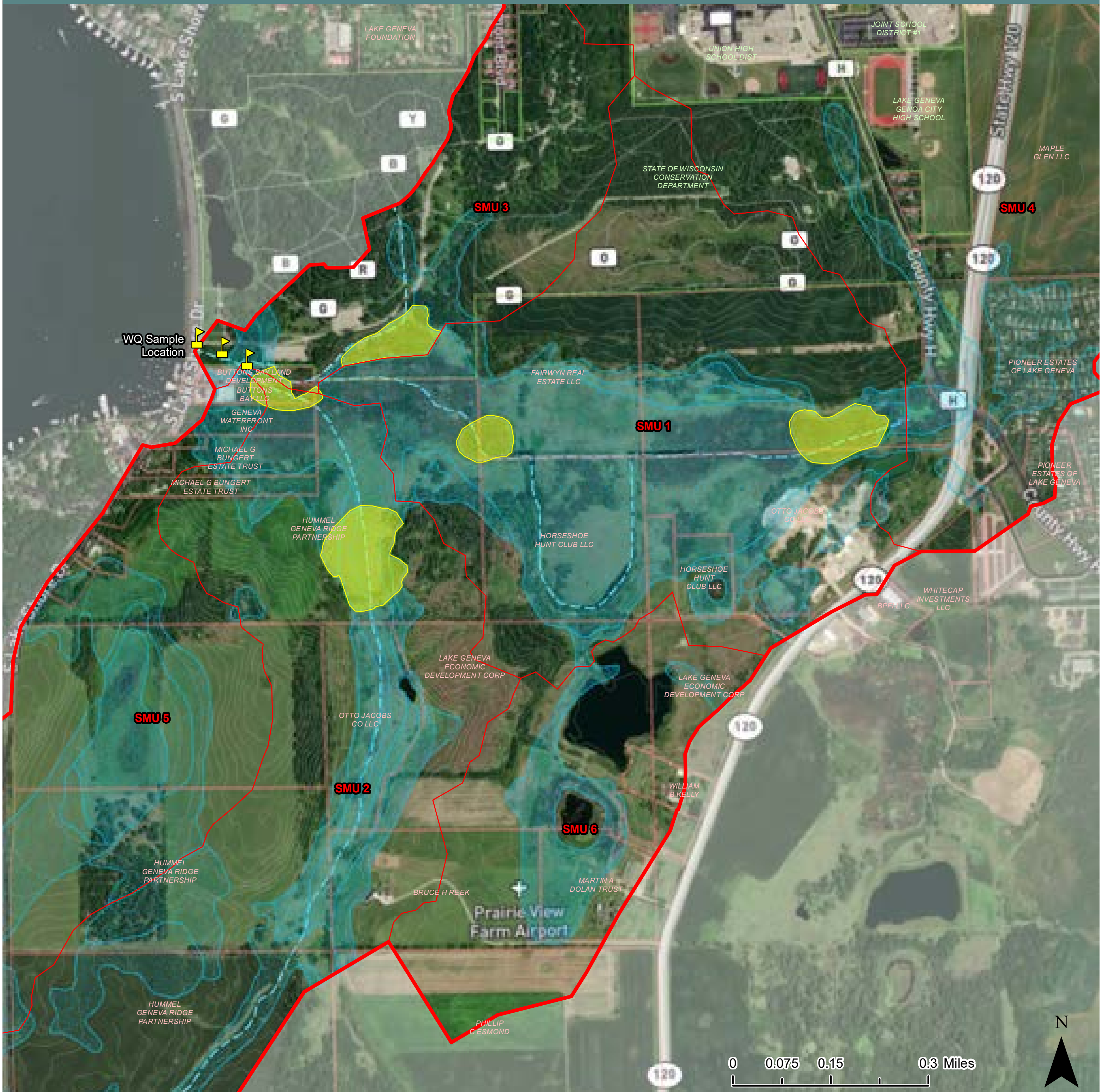
02

Appendix M

Potential Treatment Wetland Sites

BIGFOOT CREEK WATERSHED

Potential Treatment Wetland Sites



LEGEND

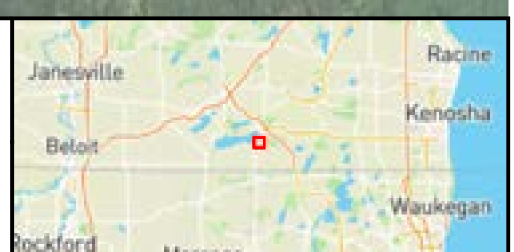
- Water Quality Sampling Sites
- Potential Treatment Wetland Locations
- Project Boundary
- SMU Definitions
- Contour (5ft)
- Flowline (NHD)

Parcel Ownership

- Private
- Public

Soils

- Hydric & Hydric Inclusions



AES Project #: 18-0861

Coordinate System:
NAD 83 WI State Plane South
Mapped by: tos
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