Lake Ida, County Ditch 23 & Contributing Lakeshed Feasibility Study

Prepared for
Douglas Soil and Water Conservation District

December 2019

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Contents

List of Tables

List of Figures

List of Large Figures

List of Appendices

Key Terms

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including: aquatic life, aquatic recreation, and aquatic consumption.

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or pollutant source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Terrain Analysis: This term is used to describe the development of a hydrologically conditioned digital elevation model of the terrain in a watershed and its use to identify areas of greatest concern for erosion, based on secondary attributes such as stream power index threshold values that can be visualized in GIS mapping. The stream power index is a function of both slope and tributary flow accumulation values, which can be thought of as the volume of water flowing to a particular point on the ground.

Acronyms

BMP	Best management practice
BWSR	Board of Water and Soil Resources
DEM	digital elevation model
DO	Dissolved oxygen
GIS	geographic information system
HUC	Hydrologic unit code
kg	kilograms
LiDAR	Light detection and ranging
MDNR	Minnesota Department of Natural Resources
µg/L	micrograms per liter
MPCA	Minnesota Pollution Control Agency
NCHF	North Central Hardwood Forest
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
ppb	parts per billion
SPI	stream power index
SWCD	Soil and Water Conservation District
TMDL	Total maximum daily load
TP	Total phosphorus
TSS	Total suspended solids
WWTP	wastewater treatment plant

1 Executive Summary

Douglas Soil and Watershed Conservation District (SWCD) applied for and received an Accelerated Implementation Grant from Minnesota Board of Water and Soil Resources (BWSR) to fund the majority of this feasibility study for reducing phosphorus loadings to Lake Ida from its lakeshed with significant focus on the County Ditch 23 watershed, including the Minnesota Department of Natural Resources (MDNR) aquatic management area (AMA) wetland complex that County Ditch 23 passes through before discharging into the lake. Project funding, including cash from Douglas County and the Ida Lake Association as well as in-kind contributions from Douglas SWCD, provided for all of the technical assistance used to inform this study, including data gathering, monitoring, modeling, analysis and conceptual design of improvement options. Barr Engineering Company (Barr) teamed with Widseth Smith Nolting (WSN) to provide technical assistance for this study.

Longitudinal monitoring conducted during the 2018 growing season confirmed, similar to historical grab sampling, that the County Ditch 23 wetland sediment is releasing large amounts of phosphorus (approximately 590 pounds in 2018) that becomes entrained in the ditch flow that is carried immediately downstream to Lake Ida, which is nearly impaired for excess phosphorus.

Several improvement options that primarily involved upstream treatment or minimizing sediment phosphorus release were evaluated as a part of this study. The most promising improvement options were compared for feasibility, cost-effectiveness and permit considerations. The following options are specifically recommended for project implementation based on their cost-benefit and good potential to minimize long-term maintenance costs:

- Alternative A involves the retrofit of an off-line pond a short distance upstream of the AMA wetland. It is recommended for implementation because it restores a project that was previously implemented, but was not functioning due to a diversion weir that was in disrepair. This option has the added benefit of reducing peak flows in the County Ditch 23 system. It is expected that implementation of this option will reduce the downstream phosphorus load by 40 pounds, based on the 2018 monitoring conditions.
- Alternative D2 involves the construction of a new channel around the north and west edges of the wetland that is intended to minimize contact between most of the County Ditch 23 flow and the wetland sediments that are currently releasing phosphorus. This option has the added benefit of providing more assurance that the long-term channel integrity can be maintained, including maintenance access, while minimizing contact with ponded wetland water on both sides of the channel. It will also convey all of the flows and minimize the risk of settling that would otherwise happen with a channel cut through the middle of the wetland. It is expected that implementation of this option will reduce the phosphorus load to Lake Ida by approximately 230 pounds, based on the 2018 monitoring conditions.

In addition, a subwatershed assessment was completed for the Lake Ida HUC 12 (lakeshed) to identify areas of concentrated flow and potential erosion, which included ground truthing sites shown in terrain analysis mapping. The results of this analysis and feasibility study were used to identify implementation priorities and projects for future grant funding.

2 Introduction

2.1 Problem Statements

Based on a review of the total phosphorus data collected prior to 2018, upstream of the AMA at Site 2 and downstream at Site 1 (see Large Figure 1), several observations (provided as follows) could impact the study design and treatment strategy for County Ditch 23:

- Phosphorus concentrations appear seasonal at each site—lower concentration at the beginning of the summer and higher between late summer and early fall. This is typical for watersheds with wetlands and lakes that store phosphorus inputs from the spring and then release phosphorus when temperatures increase, sediment becomes anaerobic, and iron-bound phosphorus is released downstream. The AMA appears to be releasing phosphorus in late summer and therefore is a source of phosphorus to Lake Ida, which is nearly impaired for excess phosphorus, during the critical summer period.
- There are few monitoring points prior to June where the phosphorus and sediment loading that occurs in the spring is unknown. Consequently, the monitoring data collected prior to 2018 does not provide a complete understanding of annual phosphorus and sediment loads.
- Flow data was not available prior to 2018, so we did not know the flows and phosphorus or sediment loads. Hydrology data are also needed for BMP design since sizing and hydraulics are dependent upon the high and low flows and the associated loads.
- Monitoring has been conducted at only two monitoring locations prior to 2018. To understand flows and hence phosphorus and solids loads from the west of Lake Ida Way and to areas as far as Garfield, additional monitoring locations are needed to better understand loads from these sources.
- Greater monitoring frequency is needed during the year (every one to two weeks) to create a treatment approach that targets high or low flows or both.
- Additional chemistry monitoring parameters are needed to assist with source identification and BMP design. These parameters include ortho-phosphate (PO_4), volatile suspended solids, pH, dissolved oxygen, temperature, iron, aluminum, calcium, and magnesium.

2.2 Project Approach

Douglas SWCD applied for and received a BWSR Accelerated Implementation Grant to fund the majority of this feasibility study for reducing phosphorus loadings to Lake Ida from its lakeshed with significant focus on the County Ditch 23 watershed, including the MDNR AMA wetland complex that County Ditch 23 passes through before discharging into the lake.

An accurate H&H model of the County Ditch 23 watershed draining to and through the AMA is key to developing and implementing a plan to significantly reduce the phosphorus that is attributable to the AMA and its discharge to Lake Ida. The AMA and its hydraulics are extremely complex. Understanding how and where flows in County Ditch 23 jump its banks and then flow into and spread through the wetland and understanding how and where flows drain from the wetland and enter County Ditch 23 cannot be accomplished by the use of conventional one-dimensional H&H models. As a result, the two-dimensional PC-SWMM software was used on the AMA in the feasibility phase of the project. The modeling was calibrated to several measured events to develop the most accurate understanding of how flows currently move through the wetland and where structures might be placed to manipulate flows to achieve phosphorus release and phosphorus pass-through reduction.

In addition to preparing the H&H model calibration, the flow and water quality data collected by the SWCD was combined with the historical monitoring data and reviewed to correlate new flow, water quality, and wetland shallow sediment data to better understand when and under what conditions phosphorus is released in high concentrations. Developing this understanding would aid us in identifying how ditch and wetland flows and water levels should be manipulated to reduce the release of high concentrations of phosphorus.

Both a detailed H&H model and a good understanding of the dynamics of phosphorus release are necessary to develop improvement concepts and costs for flow manipulation in County Ditch 23 and the AMA wetland targeted at reducing phosphorus release. The modeling is intended for use in analyzing the hydraulics of possible flow-control and water-level control structures that might be employed in the ditch and wetland.

Terrain analysis performed for the entire Lake Ida watershed was completed to identify numerous erosion and phosphorus-loading hotspot areas in the lakeshed outside of the AMA wetland. This resulted in a prioritization process for identifying how and why those problem areas were chosen and represents a tool the SWCD can continue to refine and use to identify and prioritize future projects.

Project funding, including cash from Douglas County and the Ida Lake Association as well as in-kind contributions from Douglas SWCD, provided for all of the technical assistance used to inform this study. Barr teamed with WSN to provide technical assistance for this study. The development of the H&H model; the understanding of the phosphorus release dynamics; terrain analysis; and the results, conceptual design of improvement options, recommendations, and opinions of cost of system modifications and operation for the AMA wetland are included and further described in the remaining sections of this feasibility report.

3 Background

This section examines a range of background data and information that was consulted or incorporated as part of this study's water quality assessment and model calibration. This information includes (1) the location, land use, soils, and status of point sources of phosphorus in the study watershed, (2) a water quality primer that helps explain the interrelationships between wetland ecology and water quality monitoring, (3) documentation of bathymetry in the AMA wetland, and (4) some key results from past water quality monitoring.

3.1 Location and County Ditch 23 Drainage System

The County Ditch 23 watershed location extends from the city of Garfield to the AMA wetland. The AMA wetland has a contributing drainage area of approximately 4,786 acres before discharging to Lake Ida (Large Figure 1). Subwatersheds were delineated in ArcGIS using the digital elevation model (DEM) developed from MDNR's 2011 light detection and ranging (LiDAR) elevation dataset, as well as, bathymetric survey data of the AMA wetland and culverts surveyed by WSN in July 2018. Subwatersheds were delineated to every major depression, landlocked basin, or major road crossing. Subwatershed area was calculated in GIS. To more accurately model drainage, surveyed draintile information was also included in the model to connect subwatersheds that would otherwise appear landlocked.

3.2 Land Use and Land Cover

A detailed land use classification study was conducted as part of this modeling effort using NAIP 2017 aerial imagery. The impervious percentage for each subwatershed was defined as the total area of impervious surface and open water area derived from the land use classification study. An assumption of 100% directly connected was applied to the total impervious area.

3.3 Soils, Infiltration and Runoff Parameters

The Horton equation was used to approximate infiltration rates in the subwatersheds. The Horton infiltration parameters include hydraulic conductivity, initial infiltration rate, and decay rate. Table 3-1 summarizes the Horton infiltration parameters used for the initial uncalibrated model. The table includes Horton infiltration values for each hydrologic soil group. Composite infiltration values for each watershed were calculated by computing a weighted average based on the percentage of each soil type in the watershed.

Table 3-1 Horton Infiltration Parameters

Hydrologic Soil Group	Initial Infiltration Rate (in/hr)	Hydraulic Conductivity (in/hr)	Decay Constant (1/hr)
A	**5**	**0.38**	**4.14**
B	**3**	**0.23**	**4.14**
C	**2**	**0.10**	**4.14**
D	**1**	**0.03**	**4.14**

The values for impervious and pervious depression storage were initially set at 0.06 inches and 0.17 inches, respectively. Zero percent detention was set to 0% for all areas as the areas of open water were defined in the percent imperviousness for each subwatershed. The selected roughness coefficients for overland flow were initially 0.355 for pervious surfaces and 0.015 for impervious surfaces.

3.4 Subwatershed Width and Slope

In PCSWMM, surface runoff from subwatersheds is routed to the outlet of each subwatershed using the nonlinear reservoir method. During each time step, PCSWMM calculates the surface runoff from the subwatershed. The flow rate from a subwatershed is directly related to the subwatershed slope, overland flow surface roughness, depression storage, and width parameter. As the subwatershed width increases, the peak flow rate from the subwatershed also increases. With a higher runoff rate, less runoff is stored within the subwatershed and less infiltration occurs. This increases the runoff volume for a given rainfall event over pervious surfaces. However, as the watershed width decreases the opposite occurs; the peak flow rate from the subwatershed decreases, infiltration increases, and less runoff volume is generated.

The methodology used for the PCSWMM modeling involves estimating subwatershed width by dividing the subwatershed area by the longest flow path (James et. al., 2010).

Subwatershed slope was calculated as the mean slope of the 2013 USGS National Elevation Dataset (NED) within each subwatershed using ArcGIS (U.S. Geological Survey, 2013).

The majority of elevation-dependent parameters (e.g., subwatershed storage, overflow elevations, etc.) were calculated using LiDAR elevation data (1-meter cell resolution) (MDNR, 2011). However, when using the high-resolution LiDAR dataset, slope can be overestimated by irregularities in the surface in the form of large deep “holes” or “hills” where buildings were removed from the LiDAR data. Because the NED dataset is lower-resolution, large changes in elevation between adjacent cells are less common and more-reflective of the true land slope; therefore, the slope was calculated by using the lower resolution NED dataset (~10-meter grid cell size).

3.5 Groundwater, Soil Storage and Lateral Drainage

The groundwater module of PCSWMM was used to simulate the fate of water that fell as precipitation and then infiltrated into the soil. While soil-water is relatively unimportant for short-duration (e.g. 24-hour) design event simulations, during long-term simulations it can represent a significant proportion of the total water yield, particularly in watersheds with dense stream networks, or watersheds with extensive agricultural drainage ditches and draintile.

PCSWMM implements “aquifer” objects to simulate soil water storage within the runoff layer. These aquifer objects can be shared by multiple subwatersheds, or a separate aquifer object can be created for each subwatershed. Individual aquifer objects were created for each subwatershed where groundwater was modeled. Groundwater was modeled in all subwatersheds with the exception of a few landlocked watersheds. Water volume that infiltrates into the soil is passed to the aquifer object during each time step. Water deposited into the aquifer can have a variety of fates, including storage within the soil, lateral drainage to a PCSWMM hydraulic node, loss to deep percolation, and loss to evapotranspiration.

Characteristics used to simulate soil water storage in PCSWMM include porosity, wilting point, field capacity, saturated hydraulic conductivity, conductivity slope, and tension slope. Porosity is the total proportion of the soil volume that is porous and available for water storage. When the soil pores have been completely filled, the soil is termed to be "saturated". Water can drain from saturated soil vertically to groundwater aquifers, or laterally to lakes, streams, or ditches. Saturated soil can drain by gravity until it reaches its field capacity, defined as the proportion of the soil volume that can hold water against the pull of gravity. Water then can be removed through evaporation or evapotranspiration until the soil's wilting point is reached. The wilting point represents the proportion of the soil volume that can retain water through surface tension with the soil particles. This water cannot be removed under typical physical conditions.

Porosity, wilting point, field capacity, and saturated hydraulic conductivity were calculated as area weighted averages based on SSURGO soil textures, using typical values for each soil texture as presented by Rawls, et. al. (1982). PCSWMM defaults were used, including values of 10 (dimensionless) for conductivity slope, 15 (inches) for tension slope, 0.002 for Lower GW Loss Rate.

The soil lateral saturated hydraulic conductivity was calculated based on the subcatchment area-weighted vertical saturated hydraulic conductivity. The vertical conductivity was multiplied by a factor of 1.5 according to guidance from Sands (2014) as presented by others. The subcatchment flow length was calculated by manually digitizing a representative cross-section in ArcGIS, perpendicular to the main flow path of each subcatchment where groundwater was modeled. The cross-section length was used to represent the "Length" variable. The groundwater module requires values for the initial elevation of the saturated zone and the average surface elevation of the subcatchment, from which is derived the initial depth of the unsaturated zone, and the water content of the unsaturated zone. The elevation of the saturated zone was initially set equal to the receiving node invert, and thereafter increased as needed during calibration to match early-season discharge rates. The unsaturated zone water content was set equal to field capacity. The subcatchment surface elevation of the subcatchment was calculated as the average elevation of the representative subcatchment cross-section using ArcGIS.

3.6 Wastewater Discharges of Phosphorus to County Ditch 23 System

The City of Garfield has a pond treatment system that is permitted by MPCA for spring and fall discharges of treated wastewater to the County Ditch 23 drainage system. Figure 3-1 shows the recent history of annual phosphorus loadings contained in the Garfield wastewater treatment plant (WWTP) Discharge Monitoring Reports (DMRs) maintained by MPCA. Figure 3-1 indicates that 14 kg of phosphorus was discharged in 2018, which is comparable to TP loads from the past four years. Figure 3-1 also shows that past TP loads were higher, between 24 and 136 kg, from 2005 to 2011.

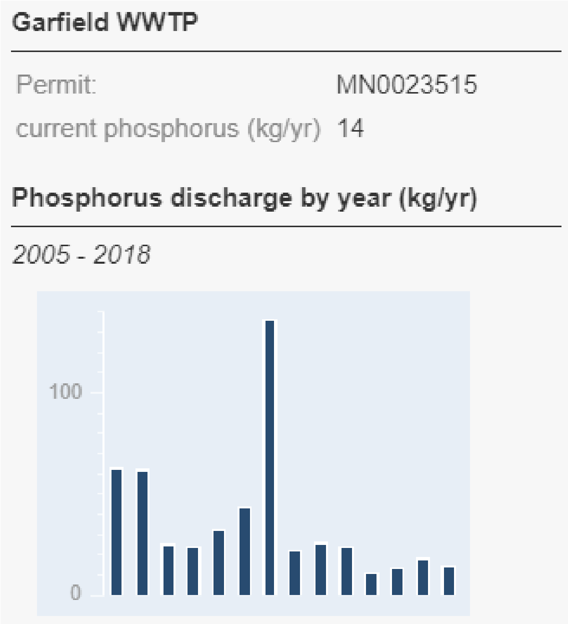

Figure 3-1 Recent history of annual phosphorus discharges from Garfield WWTP

3.7 AMA Wetland System

The AMA wetland system has historically received drainage and assimilated nutrients from the 4,786-acre County Ditch 23 watershed, which includes wastewater discharges from the Garfield WWTP. The following water quality primer helps to explain the interrelationships between wetland ecology and past/present water quality monitoring.

3.7.1 Dissolved Oxygen

Biological activity peaks during the spring and summer when photosynthetic activity is driven by high solar radiation (Water on the Web, 2004). Furthermore, during the summer most eutrophic water bodies in temperate climates are stratified. The combination of thermal stratification and biological activity causes characteristic patterns in water chemistry. During summer stratification, the conditions in each layer diverge. The surface water dissolved oxygen (DO) concentration remains high throughout the summer because of photosynthesis and diffusion from the atmosphere. However, oxygen conditions in the bottom water vary with trophic status. In eutrophic (more productive) systems, bottom-water DO declines during the summer because it is cut-off from all sources of oxygen, while organisms continue to respire and consume oxygen. The bottom layer of the wetland may eventually become anoxic, or totally devoid of oxygen.

As microorganisms continue to decompose material in the lower water column and in the sediments, they consume oxygen, and DO is depleted (Water on the Web, 2004). No oxygen input from the air occurs with ice cover, and, if snow covers the ice, it becomes too dark for photosynthesis. Low DO in the water overlying the sediments can exacerbate water quality deterioration; because when the DO level drops below 1 mg O_2/L chemical processes at the sediment-water interface frequently cause release of phosphorus from the sediments into the water. This new phosphorus and ammonium that has built up in the bottom water fuels increased algal growth in the wetland, as well as downstream water bodies.

3.7.2 Nutrients

Aquatic organisms influence (and are influenced by) the chemistry of the surrounding environment. For example, phytoplankton extract nutrients from the water and zooplankton feed on phytoplankton. Nutrients are redistributed from the upper waters to the bottom as the dead plankton gradually settles to lower depths and decompose (Water on the Web, 2004).

Essential nutrients such as the bioavailable forms of phosphorus and nitrogen typically increase in the spring from snowmelt runoff and from the mixing of accumulated nutrients from the bottom during spring turnover and decrease during summer stratification as nutrients are taken up by algae and eventually transported to the bottom water when algae die and settle out (Water on the Web, 2004). Any "new" input of nutrients into the surface water may trigger a "bloom" of algae. Such inputs may be from upstream tributaries after rainstorms, from die-offs of aquatic plants, or from pulses of stormwater or wastewater. In the absence of rain or snowmelt, an injection of nutrients may occur simply from high winds that mix a portion of the nutrient-enriched upper waters into the bottom waters.

Each water body has distinct zones of biological communities linked to its physical structure. The near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow. Like all other plants, algae require phosphorus to grow and reproduce. Phosphorus enters the water in two ways:

- Externally—from surface runoff entering the water or from groundwater. Humans can have profound influences on lake chemistry. Excessive landscape disturbance causes higher rates of leaching and erosion by removing vegetative cover, exposing soil, and increasing water runoff velocity, which in turn, may exacerbate downstream erosion from ravine and bluff sources. Lawn fertilizers, pet waste, leaf litter, grass clippings, wastewater and urban stormwater inputs all add micronutrients such as nitrogen and phosphorus to watershed runoff. Dry deposition (typically associated with wind erosion), and atmospheric deposition from direct precipitation on the lake surface both contribute additional nutrients.

- Internally—from the bottom sediments. Phosphorus already in the wetland naturally settles to the bottom and is periodically re-released from the sediments back into the water under certain conditions.

Even when external sources of phosphorus have been reduced or eliminated through best management practices, the internal recycling of phosphorus can still support explosive algal growth. Internal phosphorus loading is a large problem in waters with disturbed watersheds because of historic inputs of phosphorus from stormwater runoff. Phosphorus in runoff has concentrated in the sediments of wetlands as successive years of algal blooms have died and settled to the bottom. This phosphorus is recycled from the sediments into the overlying waters, primarily during summer periods, when it contributes to the growth of nuisance algal blooms. Figure 3-2 is a simple graphic explaining the relationship between phosphorus, algae, and DO (Water on the Web, 2004).

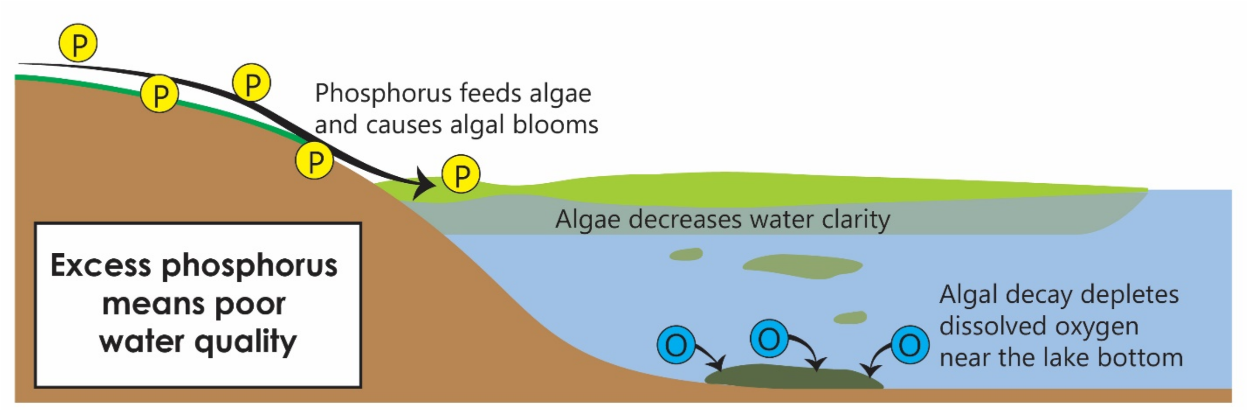

Figure 3-2 Relationship between Phosphorus, Algae, and Dissolved Oxygen

3.8 AMA Wetland Bathymetric Survey

Large Figure 2 includes wetland bathymetry (depth) data collected by WSN staff in 2018. The survey data shows that the AMA wetland is generally between one to two feet deep throughout.

Based on wetland bathymetry and other available data, sediment sampling locations were identified and sediment cores were collected from the locations shown in Large Figure 3 to analyze sediment phosphorus fractions, measure anoxic phosphorus release rates and phosphorus adsorption capacity under oxic conditions. The results of the sediment core testing and analysis are further discussed in Section 4.3.

3.9 Summary of Past Water Quality Monitoring

This section presents some key results from past water quality monitoring efforts. Figure 3-3 shows past total phosphorus monitoring results for grab samples collected upstream and downstream of the AMA wetland at respective locations consistent with Sites 2 and 1, as shown in Large Figure 1. Phosphorus concentrations appear seasonal at each site—lower concentration at the beginning of the summer and higher from late summer to early fall. This is typical for watersheds with wetlands and lakes that store phosphorus inputs from the spring and then release phosphorus when temperatures increase, sediment becomes anaerobic, and iron-bound phosphorus is released downstream. Figure 3-4 shows a closer window of the 2014 monitoring season, which confirms that the AMA wetland appears to be releasing phosphorus in late summer and therefore is a source of phosphorus during the critical summer period.

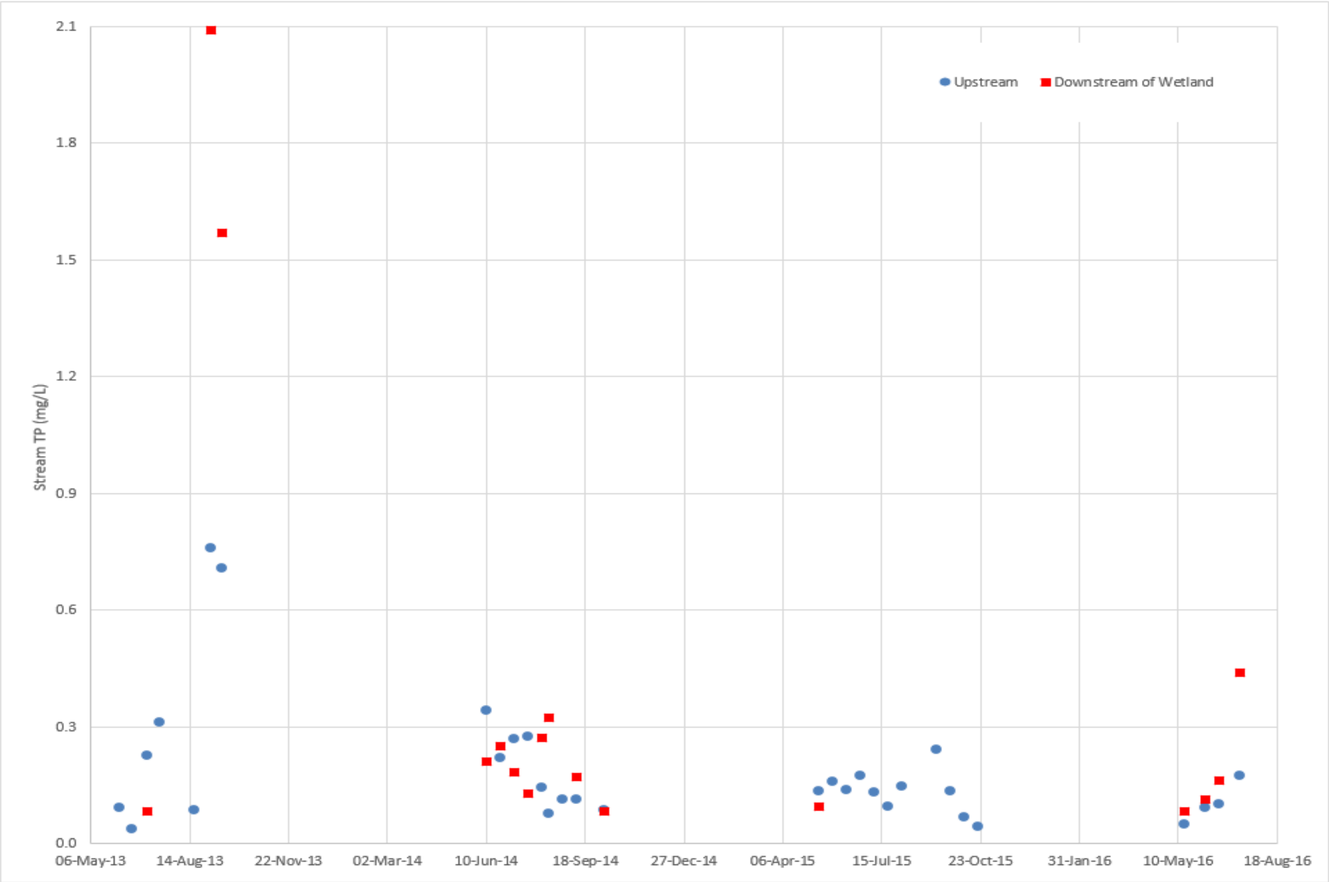

Figure 3-3 AMA Wetland Inflow and Outflow Total Phosphorus Monitoring, 2013-2016

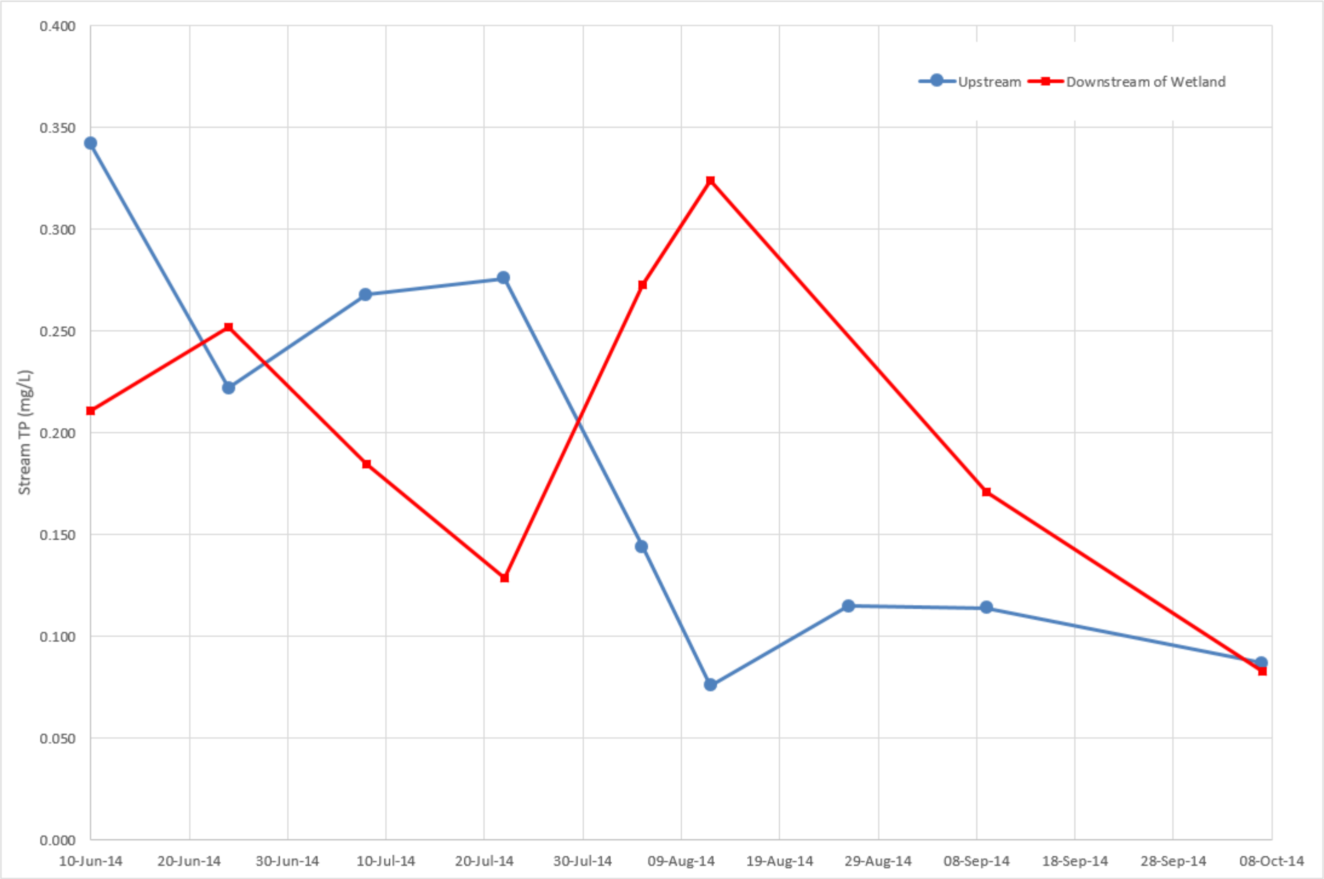

Figure 3-4 AMA Wetland Inflow and Outflow Total Phosphorus Monitoring from 2014

4 Results of 2018 Monitoring

To understand wetland and watershed conditions of the study watershed, we consulted available background information and data discussed in Section 3.0 In this section, we examine currently available wetland water quality and watershed monitoring data and the role this data plays in modeling and analysis. Modeling and the implications of the monitoring results are further discussed in Section 5.0.

4.1 Watershed Monitoring Methods

Large Figure 1 shows the three sites where watershed monitoring of flow and water quality conditions occurred during 2018. Barr installed and trained Douglas SWCD staff on the operation and maintenance of the monitoring equipment, as well as the standard operating procedure for grab sample collection and analysis by RMB Environmental Laboratories. Water quality grab sample parameters included total phosphorus, total dissolved phosphorus, ortho-phosphate (PO_4), total and volatile suspended solids, biochemical oxygen demand, chloride, nitrate/nitrite, total nitrogen, total Kjeldahl nitrogen, pH, dissolved oxygen, temperature, conductivity, silica, iron, aluminum, calcium, sodium and magnesium.

Based on the subwatershed layout and the direction of water flow, a comparison of monitoring results from Sites 1 and 2 allows for an evaluation of the seasonal wetland phosphorus release or uptake, while a comparison of the results between Sites 2 and 3 differentiates the seasonal phosphorus contributions between the northern and southern halves of the County Ditch 23 watershed. The monitored flow tributary to Site 3 includes discharges from the Garfield WWTP.

4.2 Water Quality Monitoring Results

Longitudinal monitoring conducted during the 2018 growing season (shown in Figure 4-1) confirmed, similar to historical grab sampling, that the AMA wetland sediment is releasing phosphorus during the summer months that becomes entrained in the County Ditch 23 flow that is carried immediately downstream to Lake Ida. Figure 4-1 shows that there was only one summer event where the outflow TP concentration was lower than the inflow concentration, while the AMA wetland was removing some of the inflow TP load during three separate spring sampling events. Figure 4-1 also shows that the highest phosphorus levels entering the AMA wetland occurred in the fall, which corresponds with the timing of the Garfield WWTP discharges.

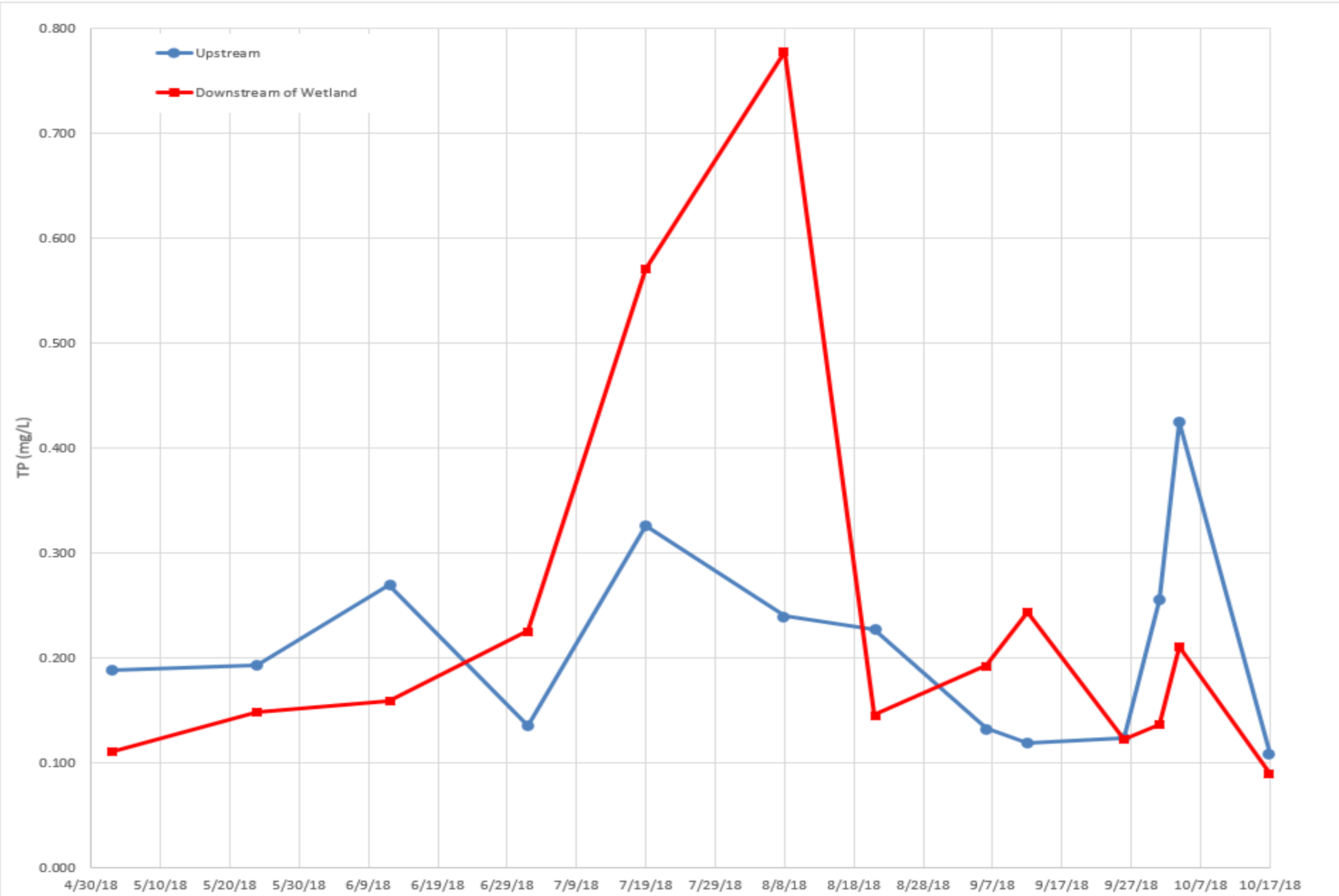

Figure 4-1 2018 AMA Wetland Inflow and Outflow Total Phosphorus Monitoring

As previously discussed, microorganisms consume oxygen as they decompose material in the lower water column and sediments. Low DO in the water overlying the sediments leads to water quality deterioration; because when the DO level drops below 1 mg O_2/L chemical processes at the sediment-water interface frequently cause release of phosphorus from the sediments into the overlying water. Figure 4-2 shows that flow entering the AMA wetland is well-oxygenated, but the high oxygen demand of the wetland sediments causes a significant drop in the DO concentrations throughout the year, but significantly lower outflow DO concentrations occur during the summer months, which correspond with the periods of sediment phosphorus release documented in Figure 4-1.

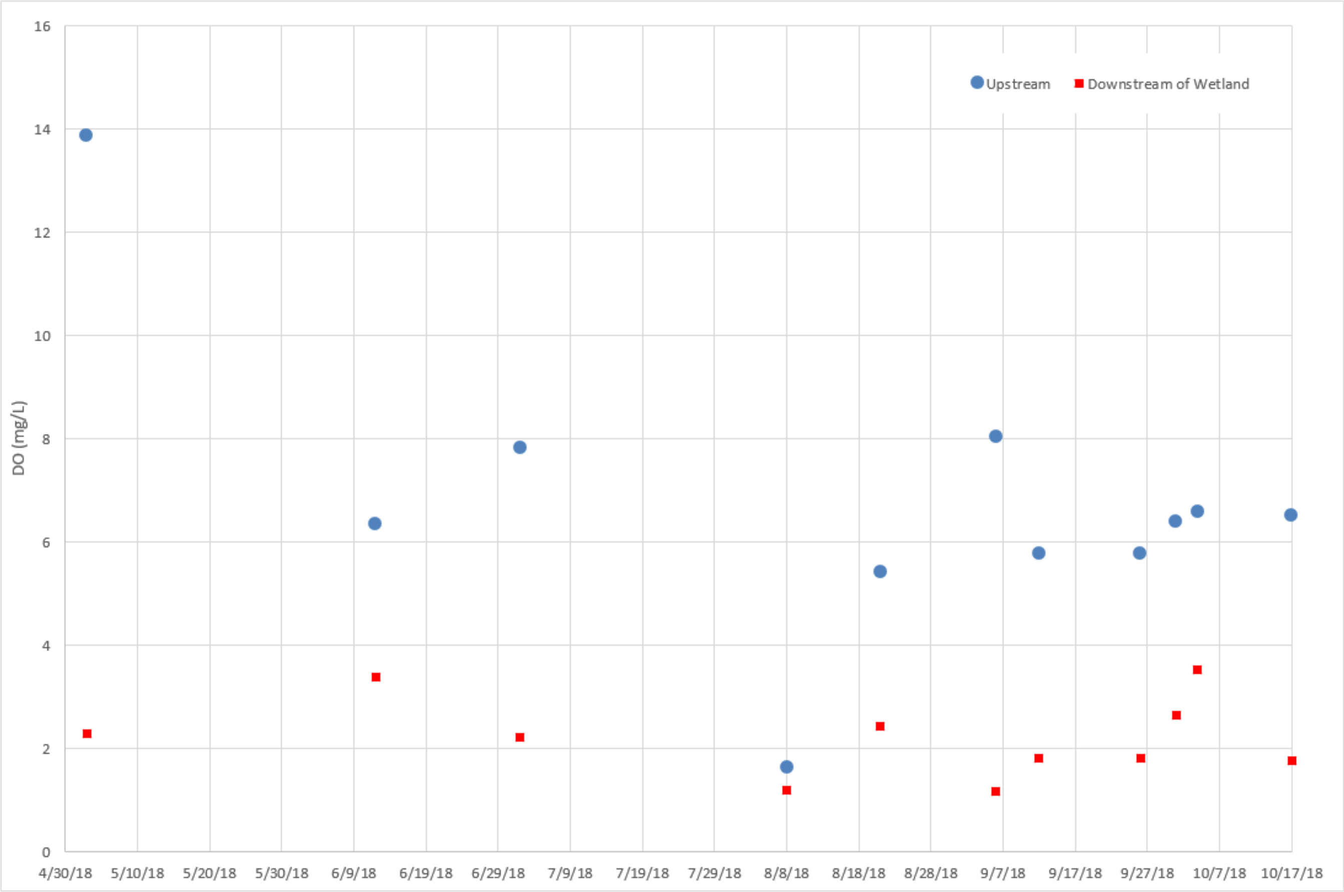

Figure 4-2 2018 AMA Wetland Inflow and Outflow Dissolved Oxygen Monitoring

Longitudinal water quality monitoring results from 2018, similar to the TP data shown in Figure 4-1, were combined with the flow estimates to generate TP loadings for each of the respective monitoring sites. The resulting TP load estimates are shown (in kilograms) in Figure 4-3 for each site, based on the 2018 monitoring period. As previously discussed, a comparison of monitoring results from Sites 1 and 2 indicates that seasonal wetland phosphorus release resulted in a net increased TP load of 269 kg (i.e., approximately 592 pounds of additional TP becomes entrained in the AMA wetland outflow), which is about 35% of the TP load delivered to Lake Ida during the 2018 monitoring (see Figures 4-3 and 4-4).

A comparison of the results between Sites 2 and 3 (from Figure 4-3) shows that the nonpoint source phosphorus contribution from the northern half of the County Ditch 23 watershed is significantly higher than the south half (see Figures 4-3 and 4-4). The monitored flow tributary to Site 3 includes discharges from the Garfield WWTP, which represented approximately 2 percent of the monitored TP load to Lake Ida from the County Ditch 23 watershed. In past years, the Garfield WWTP may have represented as much as 18% of the 2018 TP load from the County Ditch 23 watershed, which could be as high as 30 to 40 percent of the TP load during a year with lower flow.

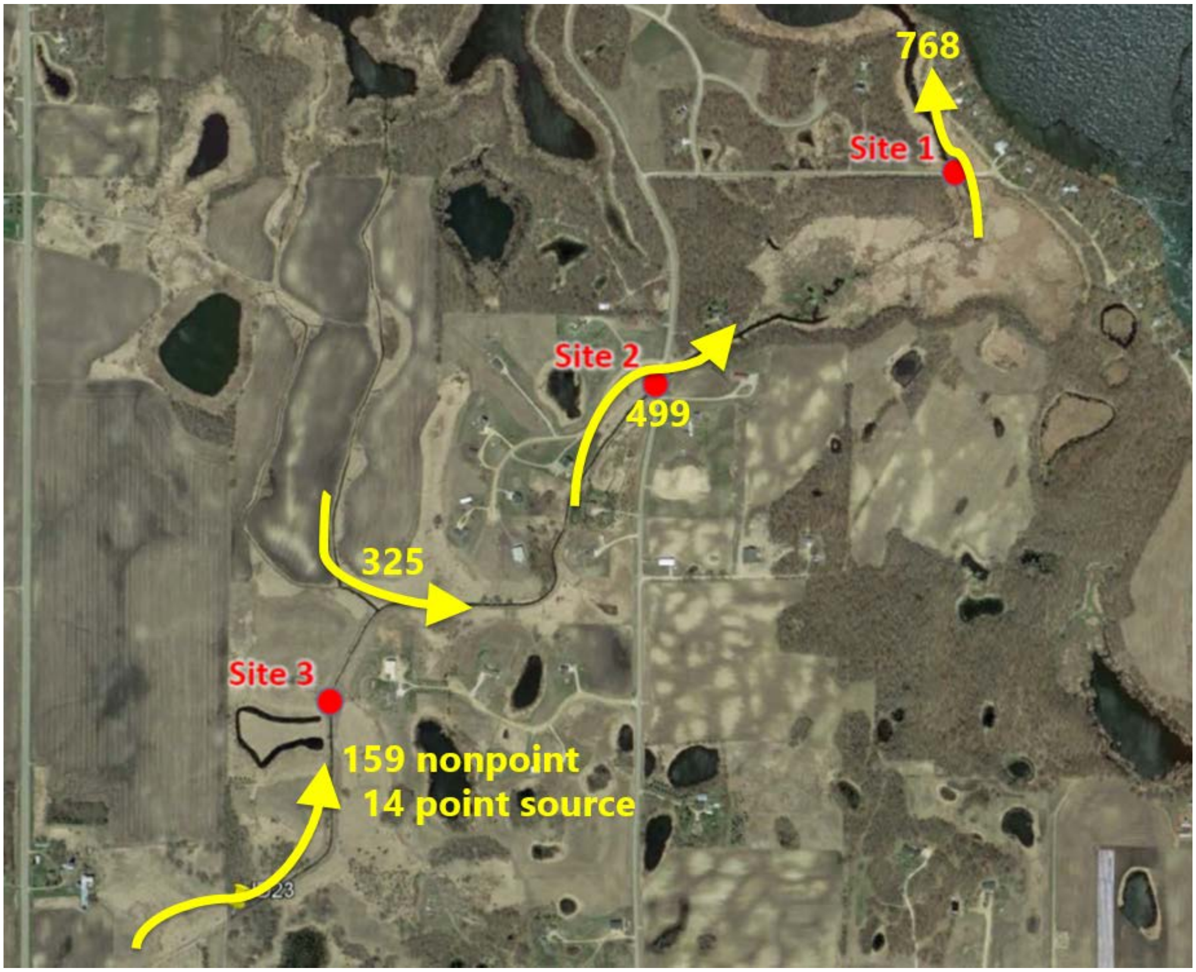

Figure 4-3 2018 Monitored Total Phosphorus Load Estimates (kg)

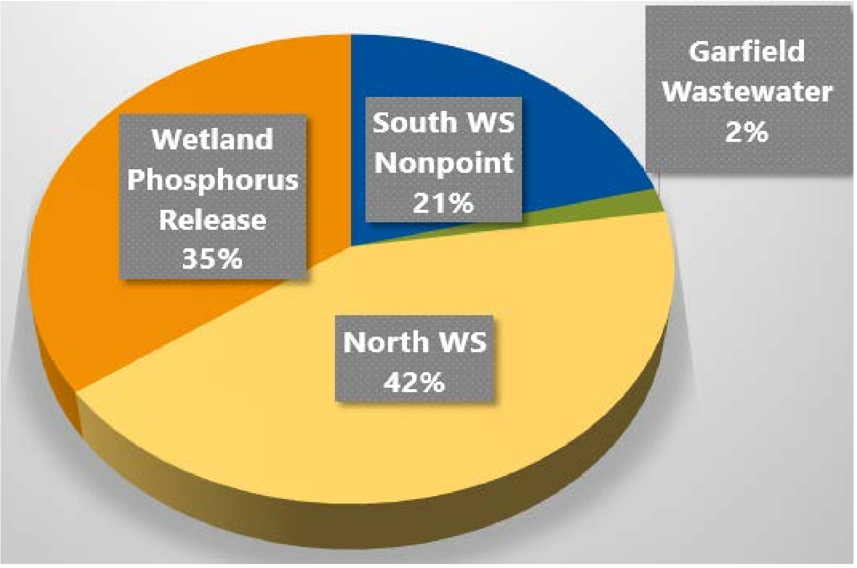

Figure 4-4 2018 Monitored Total Phosphorus Load Delivered to Lake Ida from County Ditch 23 Sources (%)

4.3 Sediment Phosphorus Monitoring and Management Implications

As previously discussed, sediment sampling locations were identified and sediment cores were collected from the locations shown in Large Figure 3 to analyze sediment phosphorus fractions, measure anoxic phosphorus release rates and phosphorus adsorption capacity under oxic conditions. The laboratory experiments confirmed that phosphorus adsorption capacity still exists for the wetland sediments under oxic conditions, but the sediment phosphorus fraction analysis confirmed that much of the sediment phosphorus throughout the wetland is present in mobile (loosely-bound) or organic fractions, which are more readily released to the overlying water under anoxic conditions or with biological decomposition, respectively.

Figure 4-5 and Table 4-1 summarize the results of the data collected to provide estimates for anoxic sediment phosphorus release from the wetland sediment core samples. This lab experiment subjects each sediment core to anoxic conditions, then measures (and plots) the buildup of phosphorus in the overlying water throughout time. Figure 4-5 shows that the rate of sediment phosphorus release was generally linear throughout the 18-day experiment with the roughly similar amounts of phosphorus buildup over time. Table 4-1 shows how the lab testing results were used to calculate phosphorus release rates, based on two separate timeframes (8 and 18 days). With the exception of Core 2, the average of the remaining anoxic sediment phosphorus release rates was 24 mg/m^2/day, which is very high compared to similar experiments and would account for more than the net increased TP load of 269 kg (592 pounds), previously attributed to wetland phosphorus release in 2018 if sediment anoxia lasts more than 80 days.

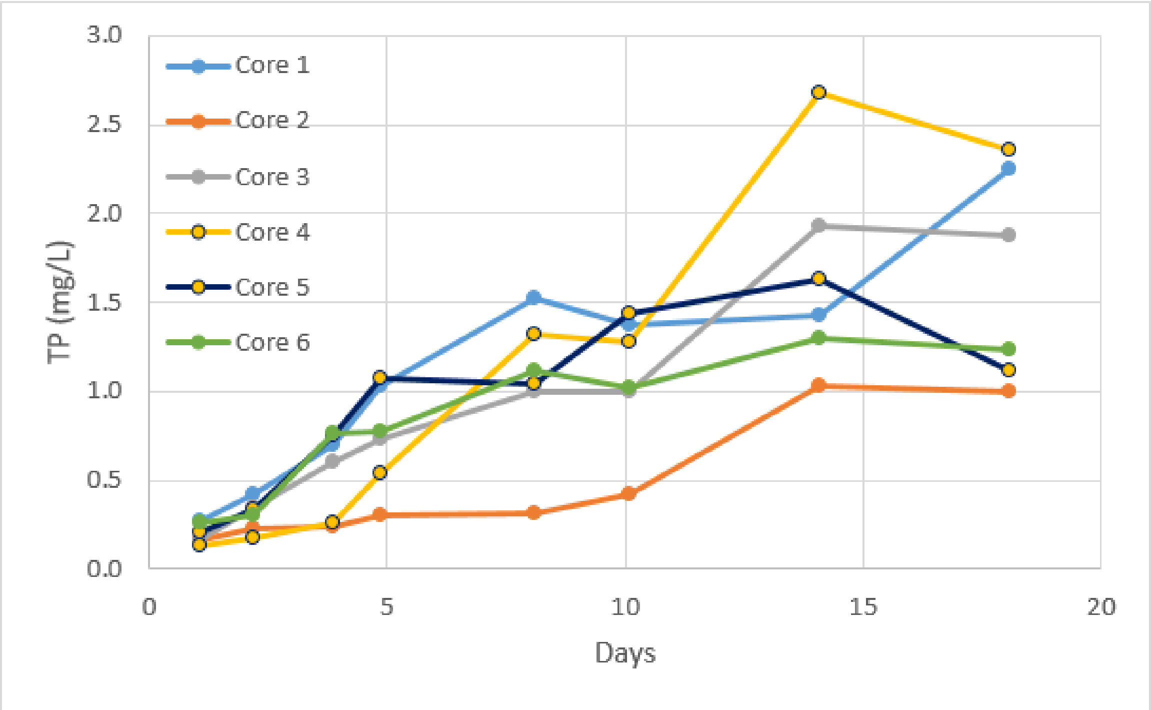

Figure 4-5 Measured Total Phosphorus Release from Anoxic Sediment Core Samples

Table 4-1 Calculated Total Phosphorus Release from Anoxic Sediment Core Samples

Lake Ida wetland TP Release Rates							
Days		Core 1	Core 2	Core 3	Core 4	Core 5	Core 6
8.1	TP (mg/L)	1.52	0.31	1.00	1.32	1.05	1.12
	Δ TP (mg/L)	1.37	0.18	0.87	1.19	0.93	1.00
	Δ TP (mg)	1.12	0.15	0.71	0.98	0.76	0.82
	release rate mg/m2/day	36	5	23	31	24	26
18.1	TP (mg/L)	2.25	1.00	1.88	2.36	1.12	1.23
	Δ TP (mg/L)	2.10	0.87	1.75	2.23	1.00	1.12
	Δ TP (mg)	1.74	0.72	1.45	1.85	0.83	0.93
	release rate mg/m2/day	25	10	21	27	12	13

5 Watershed Modeling and Terrain Analysis

Both a detailed H&H model and a good understanding of the dynamics of phosphorus release are necessary to develop improvement options for flow manipulation in County Ditch 23 and the AMA wetland, targeted at reducing phosphorus release. Watershed modeling was created for drainage areas tributary to County Ditch 23 with the intent of using it to analyze the hydraulics of possible flow-control and water-level control structures that might be employed in the ditch and wetland. In addition, a subwatershed assessment was completed for the Lake Ida HUC 12 (lakeshed) to identify areas of concentrated flow and potential erosion, which included ground truthing sites shown in terrain analysis mapping. The results of this modeling and analysis can be used to identify implementation priorities and projects for future grant funding.

5.1 Watershed Modeling

As discussed in Section 4.3, an anoxic sediment phosphorus release rate of 24 $mg/m^2/day$ applied to the wetland area of 34 acres for approximately 80 days would account for more than the net increased TP load of 269 kg, that the monitoring data was used to attribute to wetland phosphorus release in 2018 (see Section 4.2).

Since the AMA wetland and its hydraulics are extremely complex, understanding how and where flows in County Ditch 23 jump its banks and then flow into and spread through the wetland required the use of the two-dimensional PC-SWMM software. The modeling was calibrated to several measured events to develop the most accurate understanding of how flows currently move through the wetland and where structures might be placed to manipulate flows to minimize contact time and/or area of inundated wetland soils to achieve reductions in sediment phosphorus release.

Table 5-1 shows how the results of the two-dimensional modeling, calibrated to the existing condition, compared with three other improvement concepts for a 1-year runoff design event. Alternative A involves the retrofit or restoration of an off-line pond immediately upstream of Site 3 to provide upstream storage, while Alternatives C and D involved two separate methods to bypass flow that would otherwise come in contact with more anoxic wetland sediment area and/or with a longer residence time in the wetland.

Table 5-1 Modeled AMA Wetland Inundation and Residence Time for Improvement Alternatives

1YR Model Results

Scenario	Description	Inundated Area (ac)	Time Through Wetland (hrs)
Existing Conditions	Existing Conditions	34.4	15
Alternative A	Raised dam at Site 3 and decreased culvert size (to 12-inches) in Site 3 off-line sedimentation basin	32.7	14
Alternative C	Alternative A + a low-flow pipe bypassing the wetland	25.4	21
Alternative D	Alternative A + 50-foot-wide CD#23 channel through wetland	28.6	11

Section 6 provides more detailed discussion of various improvement alternatives, including implementation costs, but the modeling results in Table 5-1 provide for direct comparison of the product of wetland inundation area and residence time, which is expected to directly correspond with the potential for sediment phosphorus release when compared to the existing condition for the respective flow volumes through the wetland. In the case of Alternative C, the flow through the wetland consists of the simulated flow rates that exceed the hydraulic capacity of the bypass pipe. With Alternative C, it is expected that lower flow through the wetland will be offset by the higher residence time, resulting in water quality benefit that is similar to Alternative D. Based on the results in Table 5-1, it is expected that Alternative D will reduce the sediment phosphorus release by approximately 230 pounds, based on the relative reduction of the product of wetland inundation area and residence time.

5.2 Lakeshed Terrain Analysis

Terrain analysis performed for the entire Lake Ida watershed was completed to identify numerous erosion and phosphorus-loading hotspot areas in the lakeshed outside of the AMA wetland. The methodology for this analysis was primarily taken from the Zumbro River Watershed Restoration Prioritization & Sedimentation Reduction Project's Digital Terrain Analysis Manual (Barr, 2014), which is predominantly based on completing the following steps:

- Use results of the culvert survey to pre-process or "burn in" culvert locations and elevations in the Douglas County LiDAR digital elevation model (DEM) such that it is hydrologically conditioned and available for use throughout the Lake Ida lakeshed.
- Use the hydrologically conditioned DEM to calculate primary and secondary terrain attributes in GIS that will be used to determine mapping thresholds and visuals of the terrain analysis output; which in this case, involved identification of areas with the 95th and 99th percentiles in the computed Stream Power Index (SPI) and Compound Topographic Index values.

The SPI is a function of both slope and tributary flow accumulation values, which can be thought of as the volume of water flowing to a particular point on the ground. The SPI represents the ability of intermittent overland flow to create erosion, but the SPI values are not differentiated based on soil types or land cover effects on runoff volume or erosion potential. The top one percent of SPI values are displayed in the large-scale figure shown in Appendix A, developed for the terrain analysis of the entire Lake Ida lakeshed. Figure 5-1 shows a zoomed-in portion of the large-scale figure that includes the culvert locations (shown in red). Consistent with the Appendix A figure, the pixels shown in Figure 5-1 range from the green, which represent the 99th percentile SPI values, to the red which represent the highest SPI values calculated for this terrain analysis. The red arrows in Figure 5-1 are intended to draw attention to pourpoints that warrant field verification for erosion, based on the presence of the highest SPI values, which are a byproduct of conveyances with higher slope at the downstream confluence of larger flow accumulation values.

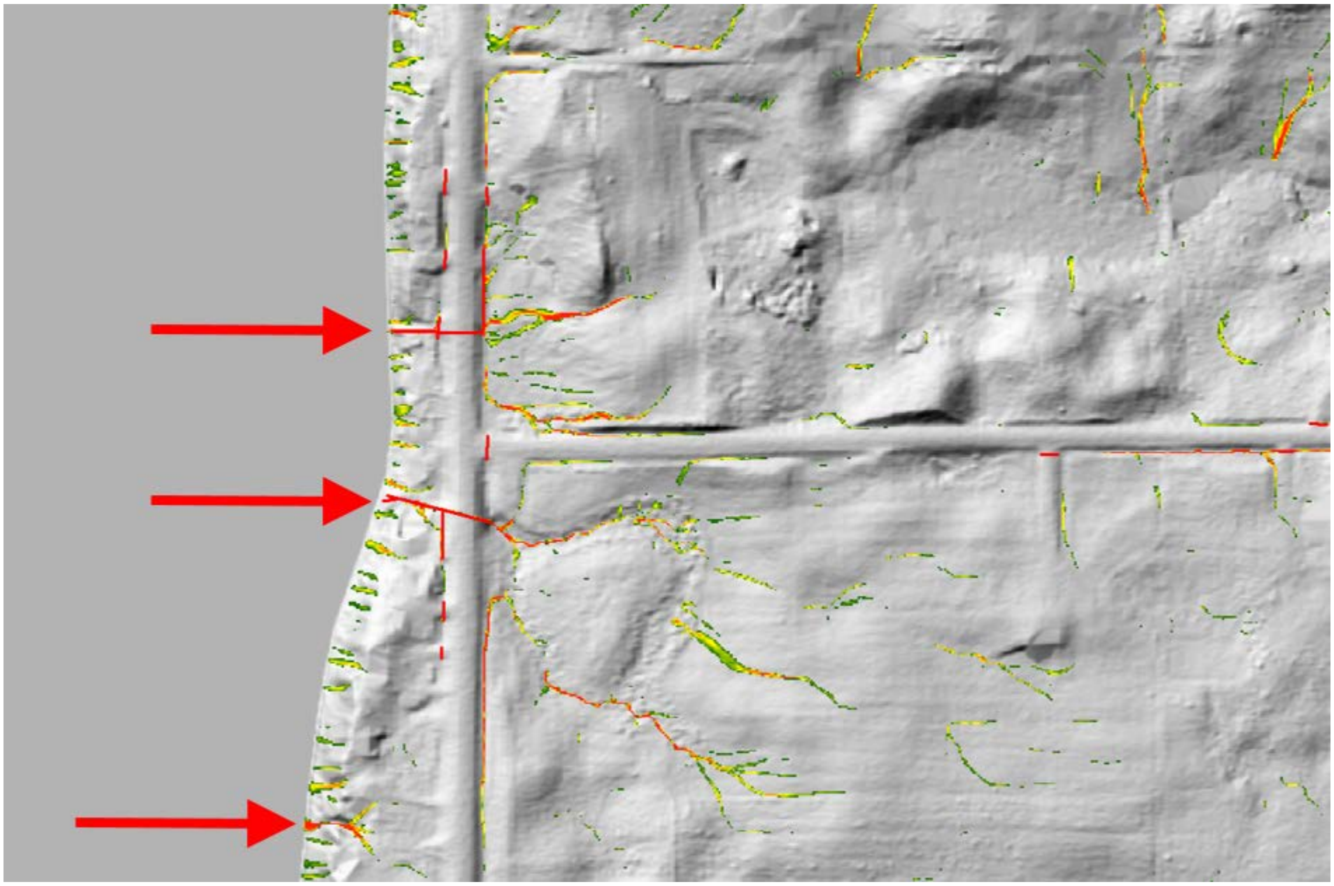

Figure 5-1 Example Area for Interpretation of Terrain Analysis Mapping

6 Feasibility Analysis

6.1 Potential Improvement Options

To remove phosphorus from the runoff from a mixed-use agricultural watershed with point source inputs and some impervious area runoff, there are several basic approaches that are typically employed:

- settle solids to which phosphorus is bound (particulate phosphorus) so that solids removal results in the removal of phosphorus
- remove dissolved phosphorus with a filtration media that binds and inactivates phosphorus or implement mechanical treatment such as an inflow alum treatment system
- promote the biological uptake and removal of phosphorus in the wetland

Potential improvement options that were discussed, but removed from further consideration for various reasons, are described as follows:

- dredging—expected high costs with limited benefit and issues with disposal of dredge spoils
- water level manipulations—potential to exacerbate sediment phosphorus release; does not
- creating new upstream storage area—watershed modeling of distributed upstream storage was completed and showed limited hydrologic benefits, and associated water quality treatment potential, because tile drainage causes much of the upstream watershed flow to bypass surface storage areas
- chemical treatment system or media filter downstream of wetland—high capital and O&M costs; limited treatment capacity at high flows; and treatment system likely infeasible as floc pond would be required for chemical precipitation
- re-aeration—high capital and O&M costs; limited feasibility and treatment capacity given wetland scale and potential for resuspension
- cattail harvesting—unproven; would likely require much longer time horizon for potential water quality improvement

Improvement options that primarily involved restoration of upstream pond treatment or minimizing sediment phosphorus release were evaluated in more detail as a part of this study. The following subsections compare the feasibility, cost-effectiveness and permit implications for the improvement options that warranted further consideration.

6.1.1 Alternative A—Retrofit Stormwater Treatment Pond

Upstream of monitoring location Site 3 is an off-line sedimentation pond constructed in 2002 in order to improve water quality of County Ditch 23 flow to Lake Ida. The off-line pond was designed with a connection to County Ditch 23 with two 24-inch CMP culverts as shown in Figure 6-1. County Ditch 23 receives the drainage from all the tiled watersheds (approximately 2,000 acres) upstream of Site 3 and daylights about 1,700 feet upstream of Site 3. A concrete weir in the center of County Ditch 23 was designed to force low flows to travel through the upstream 24-inch culvert into the off-line basin for the purpose of settling sediment and phosphorus in the pond. The existing concrete weir was not present in the ditch during a 2018 site inspection.

Alternative A involves the replacement of the missing concrete weir that, along with a newly installed berm, would be raised to an elevation of 1371 feet. In addition, a new outlet control structure would be installed and the off-line sedimentation basin outlet culvert would be decreased from a 24-inch CMP to a 12-inch CMP pipe. It is estimated that 25% of the annual flow and associated TP load can be diverted through the treatment pond. Based on the monitored TP load shown in Figure 4-3 and an assumed removal of 50 percent of the diverted flow, it is expected that this option will result in a TP load reduction of approximately 40 pounds. Implementation of this alternative should not entail any permit obstacles as it primarily involves the correction of a project that we previously permitted and implemented on behalf of the ditch authority.

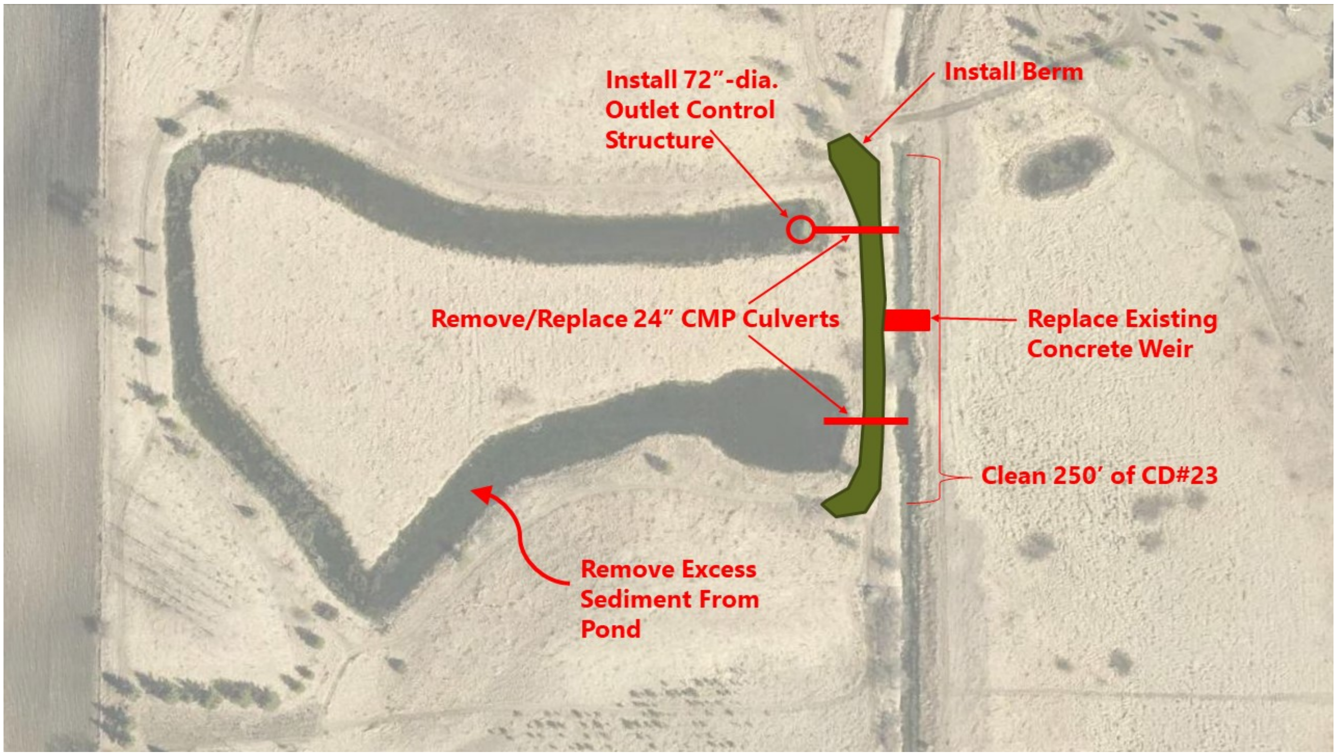

Figure 6-1 Proposed Conceptual Design for Alternative A—Retrofit Stormwater Treatment Pond

6.1.2 Options for Bypassing AMA Wetland

As discussed in Section 5.1, Alternatives C and D involved two separate methods to bypass flow that would otherwise come in contact with more anoxic wetland sediment area and/or with a longer residence time in the wetland. Alternative C involves the installation of a low-flow pipe to bypass the AMA wetland and daylight to the downstream end of the culverts at Site 1 as shown in Figure 6-2. Because the wetland area is relatively flat, there is only a few feet of fall between the upstream and downstream ends of the low-flow pipe. The proposed pipe will have a shallow slope with little head on the upstream end; therefore, in order to convey the 1-year peak flow (approximately 10 cfs), a 27-inch low-flow pipe was assumed for design purposes.

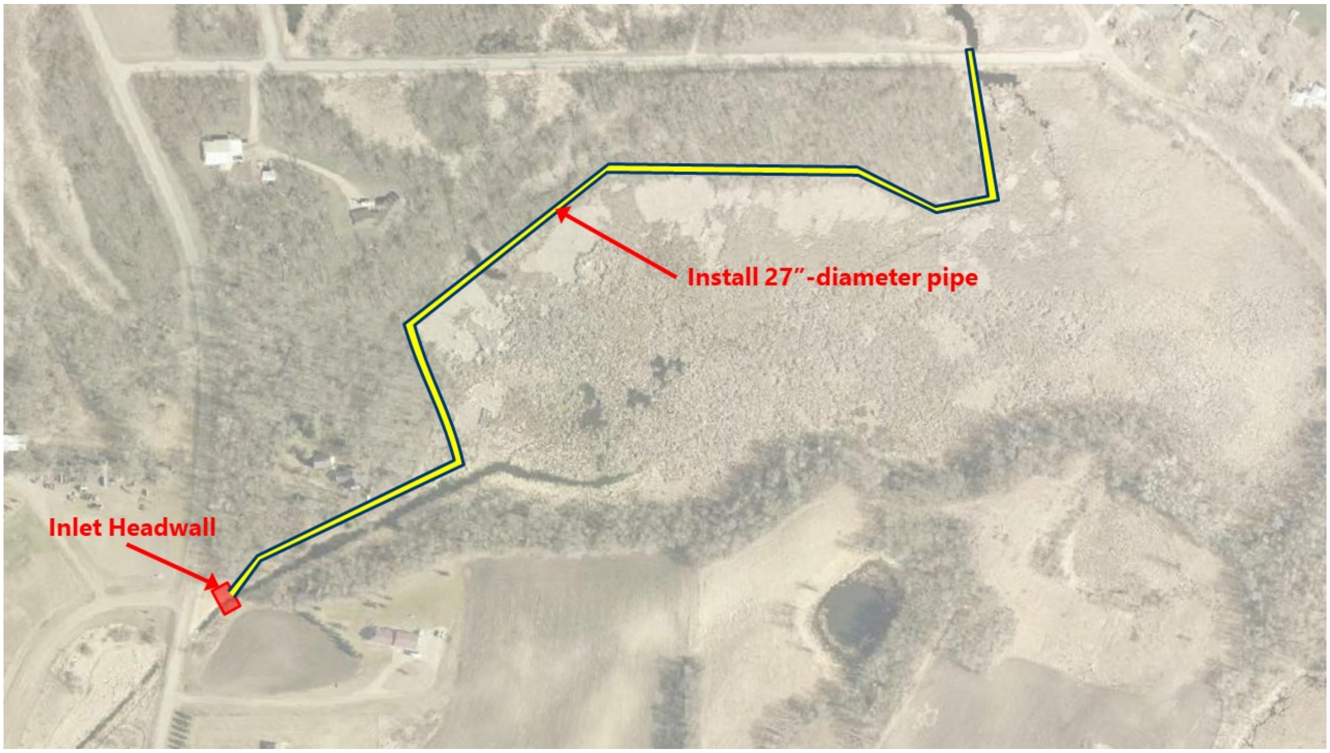

Figure 6-2 Proposed Conceptual Design for Alternative C—Low Flow Bypass Pipe of AMA Wetland

For the purposes of further evaluating detailed design options, two separate channel alignments were considered for Alternative D. Alternative D1 would involve the installation of a 50-foot-wide channel that would take the most direct route through the middle of the wetland as shown in Figure 6-3, while Alternative D2 would have the same 50-foot-wide channel follow the north edge of the wetland as shown in Figure 6-4.

Implementation of any of these three alternatives for bypassing the AMA wetland should not entail significant land ownership or permit obstacles as the wetland is not a public water, so this work would not require a Public Water Work Permit; there are no concerns with WCA rules; and the ditch authority is amenable to the bypass options. MNDNR owns the AMA, so a Special Use Permit would be required along with notification of proposed repair or improvement to County Ditch 23. It is expected that all three alternatives require a Corps permit, but it can be argued that current condition has led to significant degradation of the AMA wetland, Alternatives D1 and D2 will maintain wetland hydrology while Alternative D2 can be implemented at the wetland fringe to minimize disturbance.

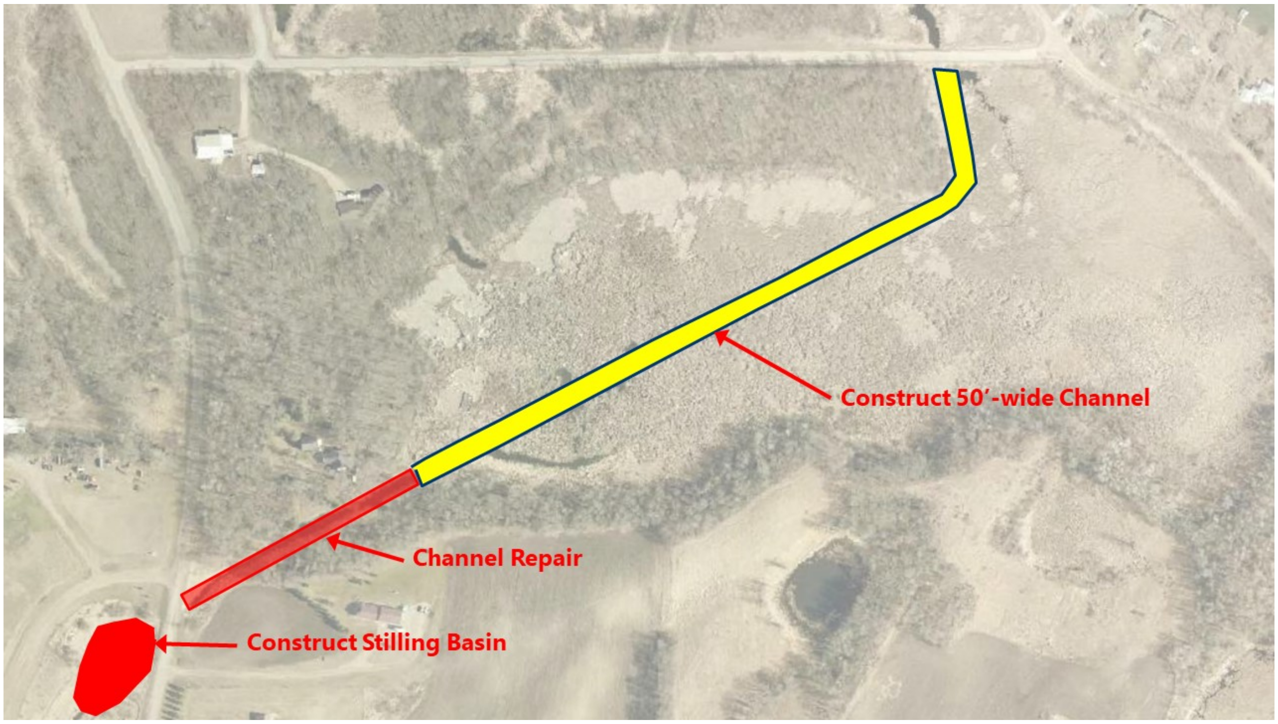

Figure 6-3 Proposed Conceptual Design for Alternative D1—Channel Bypass Through AMA Wetland

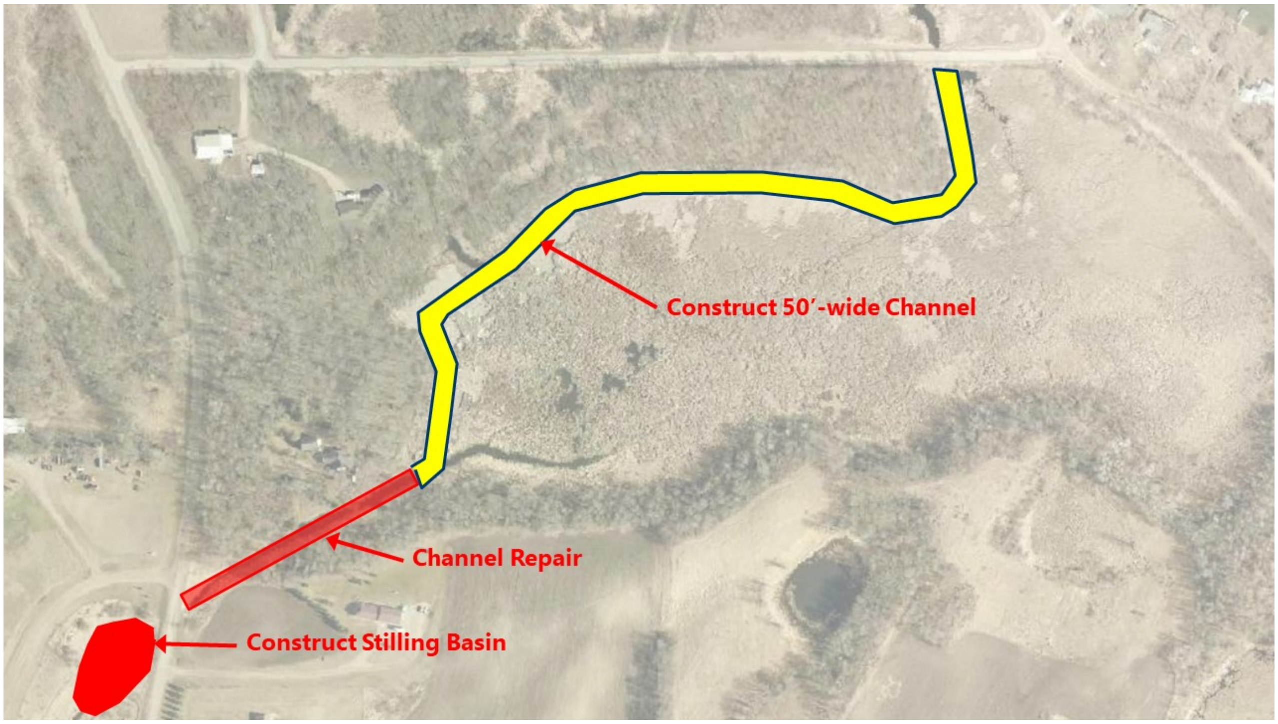

Figure 6-4 Proposed Conceptual Design for Alternative D2—Channel Bypass Along AMA Wetland Edge

6.2 BMP Cost-Benefit Analysis

Table 6-1 provides opinions of capital construction costs for the respective watershed BMPs at the respective BMP locations. The annual load reductions expected for the watershed practices were estimated based on expected treatment efficiency and/or monitoring/modeling data (further discussed in Sections 4 and 5). The cost-effectiveness values in the table should be comparable as it is expected that these options will experience similar lifespans and/or timeframes for significant levels of operation and maintenance.

Table 6-1 Summary of Structural Water Quality Improvement Options

Water Quality Improvement Option	Estimated Annual TP Reduction (lbs/yr)	Opinion of Capital Costs	Annual Cost per Pound TP Removed ($/lb)
Alternative A	40	$240,000	$6,000
Alternative C	230	$450,000	$1,960
Alternative D1	230	$430,000	$1,870
Alternative D2	230	$540,000	$2,350

6.3 Recommendations for BMP Implementation

The following options are specifically recommended for project implementation based on their cost-benefit and good potential to minimize long-term maintenance costs:

- Alternative A involves the retrofit of an off-line pond a short distance upstream of the AMA wetland. It is recommended for implementation because it restores a project that was previously implemented, but was not functioning due to a diversion weir that was in disrepair. This option has the added benefit of reducing peak flows in the County Ditch 23 system. It is expected that implementation of this option will reduce the downstream phosphorus load by 40 pounds, based on the 2018 monitoring conditions.
- Alternative D2 involves the construction of a new channel around the north and west edges of the wetland that is intended to minimize contact between most of the County Ditch 23 flow and the wetland sediments that are currently releasing phosphorus. This option has the added benefit of providing more assurance that the long-term channel integrity can be maintained, including maintenance access, while minimizing contact with ponded wetland water on both sides of the channel. It will also convey all of the flows and minimize the risk of settling that would otherwise happen with a channel cut through the middle of the wetland. It is expected that implementation of this option will reduce the phosphorus load to Lake Ida by approximately 230 pounds, based on the 2018 monitoring conditions.

It is also recommended that project partners pursue final design and permitting for manual addition of a phosphorus-binding element (such as alum granules) to the wetland soils each winter to gradually reduce the potential for phosphorus release in the summer and fall. Treating wetland sediments with alum has two expected mechanisms to control phosphorus release: (1) aluminum binds with iron-bound phosphorus in the sediment, thereby forming aluminum-bound phosphorus, and (2) a residual amount of unbound aluminum remains in the sediment and is available to bind phosphorus that is released from the decay of organic phosphorus. In addition, enhanced treatment of point source discharge from the city of Garfield is recommended to remove dissolved phosphorus that would otherwise flow to Lake Ida and/or contribute to the saturation of phosphorus in the AMA wetland soils. It is envisioned that enhanced treatment could take one of two forms: (1) participation in an MPCA pilot project intended to optimize biological treatment of stabilization ponds, or (2) an aerial application of alum to the pond in advance of each discharge event. It is expected that each of these suggestions for long-term implementation will result in at least 20 pounds of annual TP load reduction and a gradual, lasting reset of lower steady-state TP concentrations entering the County Ditch flow to Lake Ida.

As described in Section 5.2, a subwatershed assessment was completed for the Lake Ida HUC 12 (lakeshed) to identify areas of concentrated flow and potential erosion, which included ground truthing sites shown in terrain analysis mapping. The results of this analysis were used to identify lakeshed implementation priorities and projects for future grant funding.

7 References

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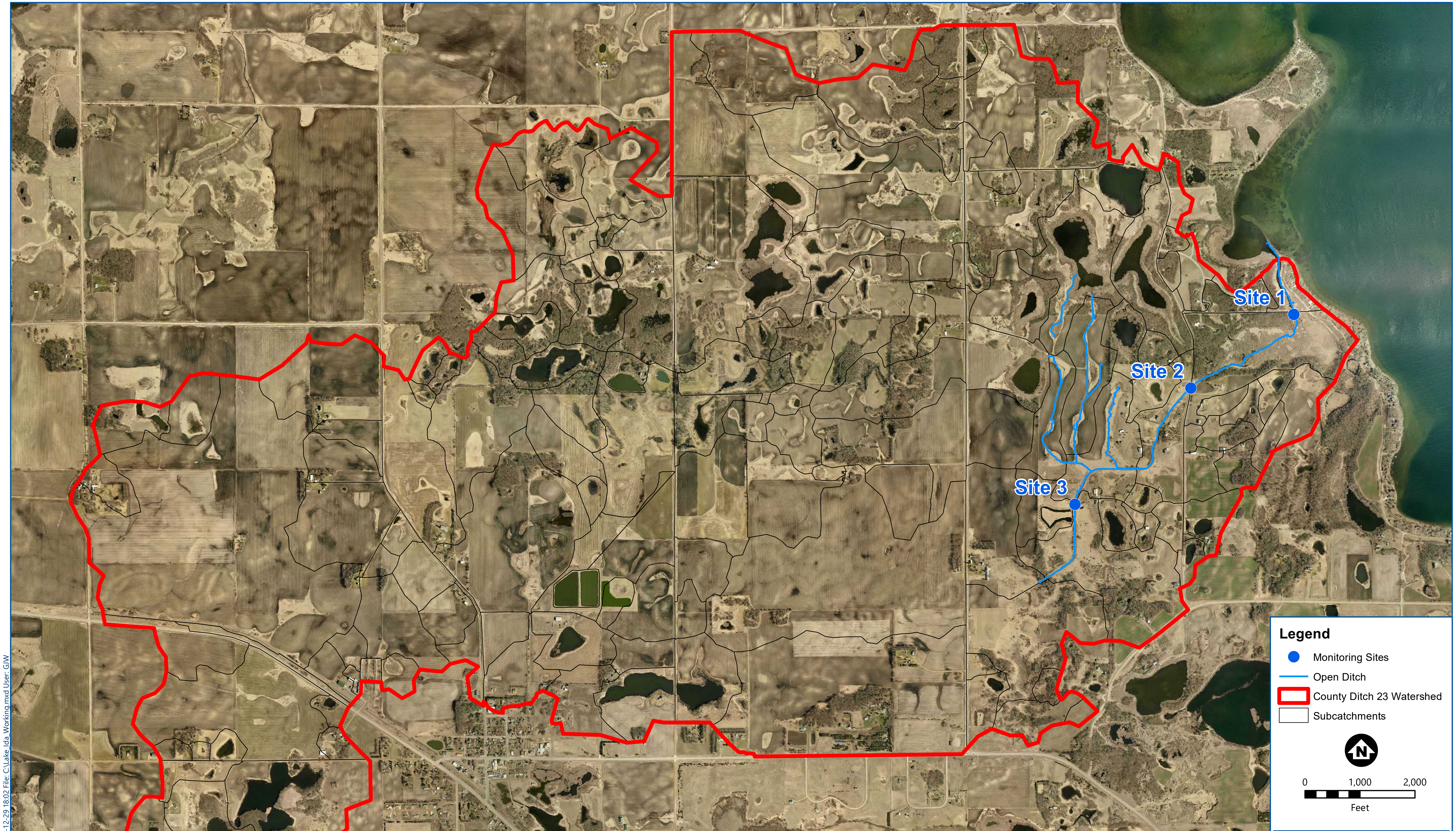
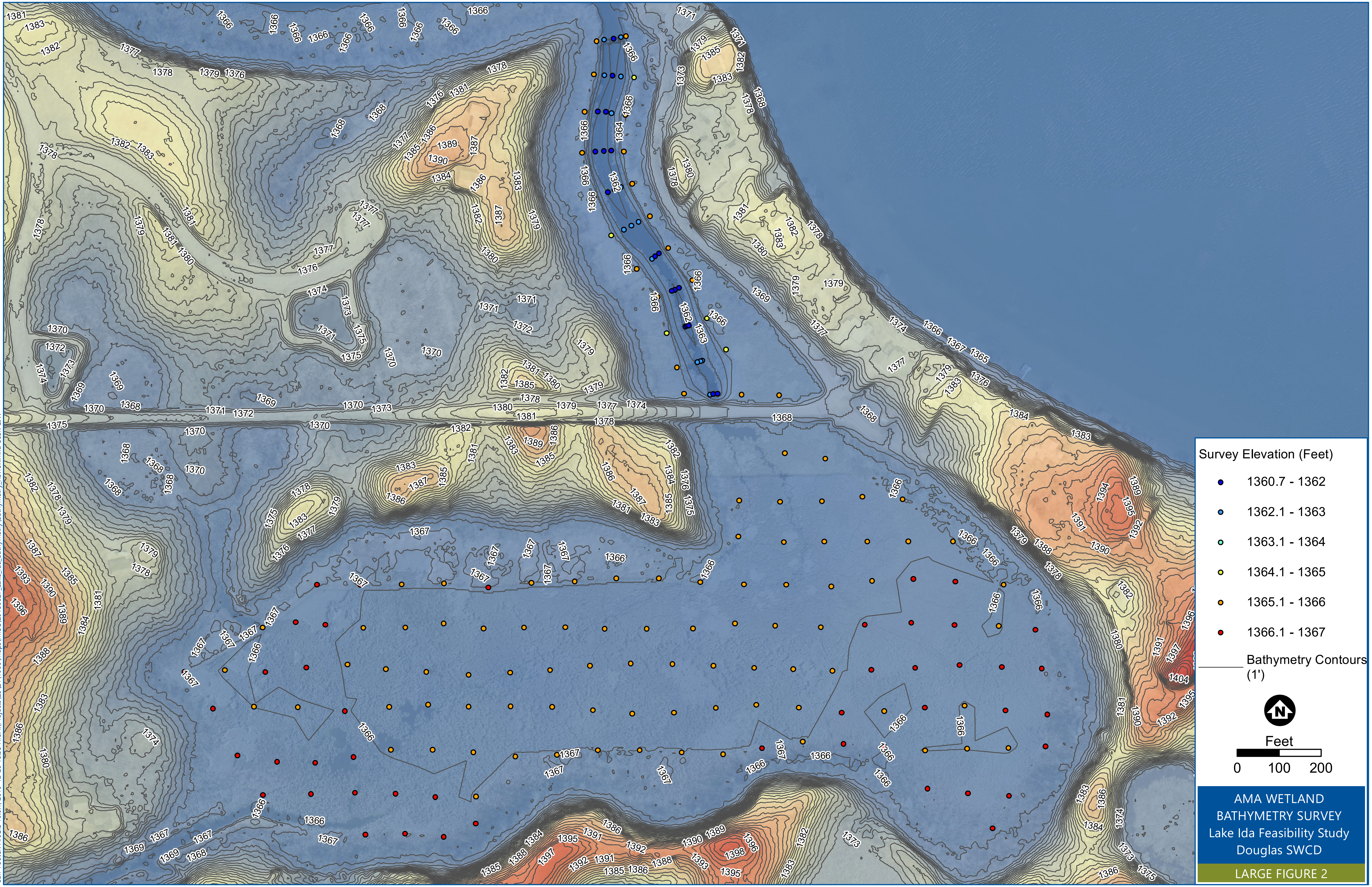
Large Figures



STUDY AREA
WATERSHED
Lake Ida Feasibility Study
Douglas SWCD

LARGE FIGURE 1



Survey Elevation (Feet)
1360.7 - 1362
1362.1 - 1363
1363.1 - 1364
1364.1 - 1365
1365.1 - 1366
1366.1 - 1367
Bathymetry Contours (1')
N
Feet
0 100 200
AMA WETLAND
BATHYMETRY SURVEY
Lake Ida Feasibility Study
Douglas SWCD
LARGE FIGURE 2


Core1
Core2
Core3
Core4
Core5
Core6
Sediment Coring Locations
Feet
0
95
190
SEDIMENT SAMPLING
CORING LOCATIONS
Lake Ida Feasibility Study
Douglas SWCD
LARGE FIGURE 3

Appendix A

Terrain Analysis Mapping


SPI Value
(~99th Percentile Shown)
High : 10.0495
Low : 2.58843
0
3,500
Feet
LAKE IDA
TERRAIN ANLYSIS
BARR

Appendix B

Cost Estimates for Structural Improvement Options Considered

Preliminary Engineer's Opinion of Cost:
Alternate "A" Site 3 Berm and Culverts

ITEM DESCRIPTION	UNIT	AMOUNT	UNIT COST	TOTAL COST
MOBLIZATION	EACH	1	6000.00	6000.00
SILT FENCE	LN FT	1150	3.50	4025.00
SILTATION LOG	LN FT	350	5.50	1925.00
EROSION CONTROL BLANKET	SQ YD	1760	1.75	3080.00
TEMPORARY MULCH	SQ YD	13600	0.69	9384.00
MISC. EROSION CONTROL BMP's	LS	1	2500.00	2500.00
ACCESS ROUTE TO SITE	LS	1	3000.00	3000.00
CLEAR AND GRUB	LS	1	2500.00	2500.00
CONTROL OF WATER	LS	1	2600.00	2600.00
CLEAN COUNTY DITCH 23	CU YD	260	4.50	1170.00
REMOVAL OF EXCAVATED CHANNEL MATERIAL (TYPE 1) TO SPOIL AREA	CU YD	260	3.50	910.00
CONSTRUCT BERM WITH AGGREGATE SOILS	CU YD	1584	15.00	23760.00
EXCAVATION OF EXCESS SEDIMENT FROM POND	CU YD	2376	4.50	10692.00
PLACE EXCAVATED MATERIAL FROM SEDIMENT POND IN SPOIL PLACEMENT AREA	CU YD	2376	3.50	8316.00
REMOVE 24" CMP	LN FT	120	2.50	300.00
72" DIA. SEDIMENT POND OUTLET CONTROL STRUCTURE	LS	1	18000.00	18000.00
CONE GRATE TRASHRACK FOR 72" DIA. CONTROL STRUCTURE	EACH	1	3912.00	3912.00
24" CMP	LN FT	120	48.34	5800.80
24" CMP FRLARED END SECTION	EACH	3	193.00	579.00
STEEL SHEET PILE WEIR	LS	1	12000.00	12000.00
CLASS III RIPRAP	TON	50	75.00	3750.00
NATIVE SEEDING	LS	1	4500.00	4500.00
SITE RESTORATION	LS	1	3000.00	3000.00
			SUBTOTAL =	$ 131,703.80
ENGINEERING AND PERMITTING 30%				$ 39,511.14
CONSTRUCTION OBSERVATION				$ 30,000.00
CONTINGENCY 30% **				$ 39,511.14
			TOTAL =	$ 240,730.00

PROBABLE RANGE -15% to + 30% **($ 204,600) to ($ 312,900)**

*DOES NOT INCLUDE CONSTRUCTION STAKING

** "PRICE DOES NOT INCLUDE SOIL CORRECTION OR A PIPE SUPPORT SYSTEM DUE TO POOR SOILS. THERE IS A 30% CONTINGENCY IN THE EVENT DEEP, POOR FOUNDATION SOILS IDENTIFIED DURING THE PROJECT DESIGN".

Preliminary Engineer's Opinion of Cost:
Alternate "C" Low Flow Bypass Pipe

ITEM DESCRIPTION	UNIT	AMOUNT	UNIT COST	TOTAL COST
MOBLIZATION	EACH	1	15000.00	15000.00
SILT FENCE	LN FT	350	3.50	1225.00
SILTATION LOG	LN FT	350	5.50	1925.00
STREET SWEEPING	LS	1	1200.00	1200.00
MISC. EROSION CONTROL BMP's	LS	1	3500.00	3500.00
CLEAR AND GRUB	LS	1	10000.00	10000.00
CONTROL OF WATER	LS	1	5000.00	5000.00
SAW CUT BITUMINOUS PAVEMENT	LN FT	160	7.50	1200.00
REMOVE BITUMINOUS PAVEMENT	SQ YD	374	6.50	2431.00
AGGREGATE, PIPE BEDDING MATERIAL	CU YD	648	19.00	12312.00
GEOTEXTILE FABRIC	SQ YD	5000	1.75	8750.00
REMOVAL OF EXCESS TRENCH MATERIALS, TYPE 1	CU YD	1128	5.50	6204.00
30" CPEP SMOOTH INTERIOR	LN FT	2500	52.77	131925.00
30" CPEP FLARED END SECTION AND TRASH RACK	EACH	2	2606.00	5212.00
INLET HEADWALL AND DIVERSION CONTROL STRUCTURE	EACH	1	25000.00	25000.00
OUTLET CONTROL STRUCTURE	EACH	1	15000.00	15000.00
CLASS III RIPRAP	TON	40	75.00	3000.00
CLASS 5 AGGREGATE BASE	CU YD	83	35.00	2905.00
REPLACE BITUMINOUS PAVEMENT	TON	63	72.00	4536.00
NATIVE SEEDING	LS	1	2500.00	2500.00
SITE RESTORATION	LS	1	4000.00	4000.00
			SUBTOTAL =	$ 262,825.00
ENGINEERING AND PERMITTING 30%				$ 78,847.50
CONSTRUCTION OBSERVATION				$ 30,000.00
CONTINGENCY 30%**				$ 78,847.50
			TOTAL =	$ 450,520.00

PROBABLE RANGE -15% to + 30% **($ 382,900) to ($ 585,700)**

*DOES NOT INCLUDE CONSTRUCTION STAKING

** "PRICE DOES NOT INCLUDE SOIL CORRECTION OR A PIPE SUPPORT SYSTEM DUE TO POOR SOILS. THERE IS A 30% CONTINGENCY IN THE EVENT DEEP, POOR FOUNDATION SOILS IDENTIFIED DURING THE PROJECT DESIGN".

Preliminary Engineer's Opinion of Cost:
Alternate "D1" Channel Through Wetland

ITEM DESCRIPTION	UNIT	AMOUNT	UNIT COST	TOTAL COST
MOBLIZATION	EACH	1	12000.00	12000.00
SILT FENCE	LN FT	250	3.50	875.00
SILTATION LOG	LN FT	450	5.50	2475.00
STREET SWEEPING	LS	1	1200.00	1200.00
MISC. EROSION CONTROL BMP's	LS	1	4500.00	4500.00
CLEAR AND GRUB THROUGH WETLAND	LS	1	2000.00	2000.00
CLEAR AND GRUB THROUGH WOODED AREA	LS	1	8000.00	8000.00
CONTROL OF WATER	LS	1	10000.00	10000.00
MUD MATS	LN FT	1555	3.00	4665.00
CHANNEL EXCAVATION THROUGH WETLAND	CU YD	10885	6.50	70752.50
CHANNEL EXCAVATION THROUGH WOODED AREA	CU YD	1200	5.50	6600.00
REMOVAL OF EXCAVATED CHANNEL THROUGH WETLAND MATERIAL (TYPE 1)	CU YD	10885	4.50	48982.50
REMOVAL OF EXCAVATED CHANNEL THROUGH WOODED AREA MATERIAL (TYPE 1)	CU YD	1200	4.50	5400.00
GEOTEXTILE FABRIC	SQ YD	9330	1.75	16327.50
SAND CHANNEL LINING	CU YD	4323	11.00	47553.00
CLASS III RIPRAP	TON	32	75.00	2400.00
EXCAVATION OF STILLING BASIN UPSTREAM OF LAKE IDA WAY	CU YD	1500	5.50	8250.00
REMOVAL AND DISPOSAL OF STILLING BASIN EXCAVATED MATERIAL (YYPE 1)	CU YD	1500	4.50	6750.00
NATIVE SEEDING	LS	1	5000.00	5000.00
SITE RESTORATION	LS	1	4000.00	4000.00
			SUBTOTAL =	$ 267,730.50
ENGINEERING AND PERMITTING 30%				$ 80,319.15
CONSTRUCTION OBSERVATION				$ 30,000.00
CONTINGENCY 20%				$ 53,546.10
			TOTAL =	$ 431,600.00

PROBABLE RANGE -15% to + 30% ($ 366,900) to ($ 561,100)

*DOES NOT INCLUDE CONSTRUCTION STAKING

Preliminary Engineer's Opinion of Cost:
Alternate "D2" Channel Along Wetland Edge With Bench

ITEM DESCRIPTION	UNIT	AMOUNT	UNIT COST	TOTAL COST
MOBLIZATION	EACH	1	15000.00	15000.00
SILT FENCE	LN FT	400	3.50	1400.00
SILTATION LOG	LN FT	650	5.50	3575.00
STREET SWEEPING	LS	1	1200.00	1200.00
MISC. EROSION CONTROL BMP's	LS	1	3500.00	3500.00
CLEAR AND GRUB ALONG WETLAND	LS	1	25000.00	25000.00
CLEAR AND GRUB THROUGH WOODED AREA	LS	1	8000.00	8000.00
CONTROL OF WATER	LS	1	10000.00	10000.00
MUD MATS	LN FT	1899	3.00	5697.00
CHANNEL EXCAVATION THROUGH WETLAND	CU YD	13293	6.50	86404.50
CHANNEL EXCAVATION THROUGH WOODED AREA	CU YD	1185	5.50	6517.50
BACKFILL OF EXCAVATED CHANNEL THROUGH WETLAND MATERIAL (TYPE 1) FOR BENCH	CU YD	13293	3.00	39879.00
REMOVAL OF EXCAVATED CHANNEL THROUGH WOODED AREA MATERIAL (TYPE 1)	CU YD	1185	4.50	5332.50
GEOGRID REINFORCEMENT	SQ YD	2532	9.50	24054.00
GEOTEXTILE FABRIC	SQ YD	11394	1.75	19939.50
SAND CHANNEL LINING	CU YD	5317	11.00	58487.00
CLASS III RIPRAP	TON	32	75.00	2400.00
EXCAVATION OF STILLING BASIN UPSTREAM OF LAKE IDA WAY	CU YD	1500	5.50	8250.00
REMOVAL AND DISPOSAL OF STILLING BASIN EXCAVATED MATERIAL (YYPE 1)	CU YD	1500	4.50	6750.00
NATIVE SEEDING	LS	1	6000.00	6000.00
SITE RESTORATION	LS	1	4000.00	4000.00
			SUBTOTAL =	$ 341,386.00
ENGINEERING AND PERMITTING 30%				$ 102,415.80
CONSTRUCTION OBSERVATION				$ 30,000.00
CONTINGENCY 20%				$ 68,277.20
			TOTAL =	$ 542,080.00

PROBABLE RANGE -15% to + 30% **($ 460,800) to ($ 704,700)**

*DOES NOT INCLUDE CONSTRUCTION STAKING