MINNEHAHA CREEK
WATERSHED DISTRICT
QUALITY OF WATER, QUALITY OF LIFE

Meeting: Board of Managers
Meeting date: 3/14/2024
Agenda Item #: 12.1
Action type: Board Action

Title:	Ordering of the East Auburn Wetland Restoration Project and Authorization to Release a Request for Proposals for Design and Engineering Services
Resolution number:	24-015
Prepared by:	Name: Sophia Green Phone: 952-641-4523 sgreen@minnehahacreek.org
Reviewed by:	Name/Title: Michael Hayman, Project Planning Director; Chuck Holtman, Smith Partners
Recommended action:	The Board of Managers formally orders the East Auburn Wetland Restoration Project and authorizes the release of a request for proposals (RFP) for design and engineering services.
Schedule:	March 2024 – Release RFP for design and engineering services May 2024 – Award contract for design and engineering services Summer/Fall 2024 – Project design Fall/Winter 2024 – Bid solicitation and construction contracting
Budget considerations:	Fund name and code: East Auburn Wetland Restoration (3160) Fund budget : $550,000 Expenditures to date: $0 Requested amount of funding: Not applicable

Past Board action:	Res # 21-052	Authorization to Execute Contract for Assessment for the East Auburn Wetland Monitoring and Feasibility Support
	Res # 22-063	Authorization to release a Request for Proposals for the East Auburn Wetlands feasibility study.
	Res # 22-085	Authorization to Award Contract for East Auburn Wetlands Feasibility Study

Summary:
The 2017 Minnehaha Creek Watershed District (MCWD) Watershed Management Plan (WMP) identifies that impairments in East Auburn Lake are driven primarily by external wetland phosphorus export making its way into the lake. The WMP also identifies the wetland systems between Wassermann Lake and East Auburn Lake as a potential restoration opportunity to address nutrient export to East Auburn Lake.

Beginning in 2019, MCWD staff analyzed historical water quality data to determine the extent to which the wetland system between Wassermann Lake and East Auburn Lake exports phosphorus. That analysis revealed that the phosphorus was higher at the outlet of the wetland complex rather than the inlet, exporting an approximate 135 pounds of phosphorus per year to East Auburn Lake. In 2021, MCWD staff commenced a refined water quality sampling, hydrology, and vegetation analysis, in cooperation with Stantec, in the wetland system to identify if there is a specific area within the wetlands responsible for the majority of the phosphorus export. This analysis indicated that a relatively small portion of the wetland complex, the Cell 1 Wetland, is the primary driver of phosphorus export.

In September 2022, the board authorized the release of Request for Proposals (RFP) for feasibility to identify opportunities to address phosphorus export from the wetland. The feasibility study was contracted in 2023 with Moore Engineering and its subconsultants, Wetland Solutions, Inc., and Dr. Nathan Johnson from the University of Minnesota, with the primary objective of evaluating and recommending alternative strategies to manage phosphorus export from the wetland to East Auburn Lake. The study was completed in October 2023 and assessed seven alternative approaches to nutrient reduction and provided a final restoration project recommendation. The final report (attachment A) identified hydrologic restoration of the wetland through the installation of an outlet control structure as an opportunity to reduce nutrient export to East Auburn Lake by 50% while restoring the wetland to a more natural hydrologic condition. When compared to other approaches to nutrient reduction in wetland systems, hydrologic restoration is viewed as a cost-effective option with both lower regulatory obstacles, and total design and construction costs. The project estimate in the 2024 budget is $550,000, to be funded by means of the District ad valorem tax levy. The feasibility study estimates a total design and construction cost of approximately $300,000, signifying a project alternative with an opportunity to be delivered under the initial project budget.

At its January 25, 2024 meeting, the Board received an update from staff on the outcomes of the feasibility study and staff's recent coordination to initiate project design with the City of Victoria (City), which owns the land on which the project will occur. The Board was informed that the City supports the District's project goals and wishes to facilitate project development and implementation, and potentially integrate trail improvements with the proposed outlet control structure.

As such, on February 26, 2024, the Victoria City Council approved a resolution of support for the East Auburn Wetland Restoration Project (attachment B). Through the resolution, the City authorizes the District to access city land within the project area and to perform surveys and investigations for the purpose of project design. While the resolution does not serve as a legal contract for providing rights to access the land, the City Council authorizes city staff to work with MCWD to develop such project agreements, easements or other documents to allow the District to construct and maintain the project on city land, and to bring such documents forward for consideration by the Council.

Staff also shared the estimated project timeline and project budget with the Board at its January 25, 2024 meeting. Staff anticipates releasing the RFP for design and engineering services following the March 14, 2024 board meeting, with an anticipated contract award in May 2024. The project would then enter the project design phase through the summer and fall of 2024 to prepare for bidding and construction commencing early winter 2024. Construction of the project is expected to be complete in 2025.

In accordance with Minnesota Statutes §103B.251, MCWD staff have provided for notice of public hearing on March 14, 2024. The hearing will afford an opportunity for the public to address the Board on the ordering of the East Auburn Wetland Restoration Project. Absent comment that warrants further consideration, MCWD staff recommends that the Board formally order the East Auburn Wetland Restoration Project and advance the project into the design phase through release of an RFP for design and engineering services (attachment C).

Supporting documents (list attachments):

- East Auburn Wetland Restoration Feasibility Study
- Resolution of Support from the City of Victoria for the East Auburn Wetland Restoration Project
- Request for Proposals for Engineering for the East Auburn Wetland Restoration

MINNEHAHA CREEK
WATERSHED DISTRICT
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RESOLUTION

Resolution number: 24-015

Title: Ordering of the East Auburn Wetland Restoration Project and Authorization to Release a Request for Proposals for Design and Engineering Services

WHEREAS the Minnehaha Creek Watershed District (MCWD) has developed a plan for the Six Mile Creek-Halsted Bay Subwatershed (SMCHB) that identifies implementation strategies to achieve MCWD's goals of protecting and improving water quality, water quantity, ecological integrity, and thriving communities through land use and water integration;

WHEREAS the MCWD Watershed Management Plan (WMP) identifies the wetlands between Wassermann Lake and East Auburn Lake as the location of a capital investment to reduce watershed nutrient loading to improve water clarity and create a more abundant and diverse aquatic vegetation community in East Auburn Lake;

WHEREAS in 2021 and 2022, MCWD staff conducted a refined water quality sampling, hydrology, and vegetation analysis in the wetland system between Wassermann Lake and East Auburn Lake to identify specific areas within the wetland responsible for the majority of the phosphorus export;

WHEREAS the analysis indicated that the wetland cell (cell 1) at the outlet of Wasserman Lake is the primary driver of phosphorus export to East Auburn Lake, indicating total phosphorus concentration in groundwater is much greater than that in the stream channel and that the phosphorus in groundwater and wetland soil is mobilizing and exporting to downstream East Auburn Lake;

WHEREAS on December 15, 2022, the MCWD Board of Managers approved a contract with Moore Engineering to conduct a feasibility study for the East Auburn Wetland Restoration;

WHEREAS in October 2023, Moore Engineering delivered its final report to MCWD, assessing seven alternative approaches to nutrient reduction in the Cell 1 wetland, and identified hydrologic restoration of the wetland through the installation of an outlet control structure as the most feasible and cost effective opportunity to reduce nutrient export to East Auburn Lake;

WHEREAS on January 25, 2024, the Board of Managers reviewed the feasibility report and directed staff to continue partnership discussions with the City of Victoria to effectively advance the project;

WHEREAS Victoria supports MCWD's project goals and wishes to facilitate project development and implementation, and potentially to integrate city trail improvements with the proposed outlet control structure;

WHEREAS on February 26, 2024, the Victoria City Council adopted a resolution of support that expressed Victoria's support for the East Auburn Wetland Restoration project; authorized the MCWD to access city land within the project area to perform surveys and investigations for the purpose of project design; and authorized city staff to work with MCWD staff to develop project agreements, easements or other documents necessary for the District to construct and maintain the project on city land, and bring such documents forward for consideration by the Council;

WHEREAS in accordance with Minnesota Statutes § 103B.251, subdivision 3, the MCWD held a duly noticed public hearing on ordering of the East Auburn Wetland Restoration Project on March 14, 2024, at which time all interested parties had an opportunity to address the Board on the East Auburn Wetland Restoration Project;

WHEREAS the Board of Managers finds that the Project will be conducive to public health and promote the general welfare, and is in compliance with Minnesota Statutes §§103B.205 to 103B.255 and the WMP adopted pursuant to §103B.231;

NOW, THEREFORE, BE IT RESOLVED that pursuant to Minnesota Statutes § 103B.251 and the WMP, the Minnehaha Creek Watershed District Board of Managers orders the East Auburn Wetland Restoration Project;

BE IT FURTHER RESOLVED that the MCWD Board of Managers authorizes the District Administrator, on advice of counsel, to release the Request for Proposals for Engineering Design Services.

Resolution Number 24-015 was moved by Manager _____________, seconded by Manager ____________. Motion to adopt the resolution ___ ayes, ___ nays, ___abstentions. Date: March 14, 2024.

____ Date: ___________________________
Secretary

Attachment A

East Auburn Wetland Restoration Feasibility Study

October 2023
Moore Project No. 22924

moore engineering, inc.

PREPARED FOR

Minnehaha Creek Watershed District
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1. Introduction

In their 2017 Water Resources Management Plan (WRMP), the Minnehaha Creek Watershed District (MCWD) identified a goal to address nutrient export to East Auburn Lake (Minnehaha Creek Watershed District, 2017). Based on internal research and monitoring, MCWD identified Cell 1 in the wetland complex that feeds East Auburn Lake (referred to as the East Auburn Wetland) as the primary contributor of phosphorus to the lake. MCWD selected the Moore Engineering Team (Moore Engineering, Inc. [Moore], Wetland Solutions, Inc. [WSI], and Dr. Nathan Johnson) to develop a feasibility assessment for the Cell 1 Wetland to evaluate and recommend alternative strategies to manage phosphorus export from the wetland to East Auburn Lake.

1.1. Project Location

The Cell 1 Wetland site is in the City of Victoria, in Carver County, along Six Mile Creek between Wasserman Lake (upstream) and East Auburn Lake (downstream). Six Mile Creek is either an excavated or artificially incised creek that flows through a complex of four wetlands between the two lakes. Six Mile Creek flows into the Cell 1 Wetland at the outlet from Wasserman Lake where it passes through a 24-inch pipe under Church Lake Boulevard (County Road 43). The Cell 1 Wetland extends from below this culvert to a narrow cross-section where there is a pedestrian footpath at its north end. Below this footpath the creek continues through a series of additional wetland cells. The location of the Cell 1 Wetland and surrounding features is shown in Figure 1-1.

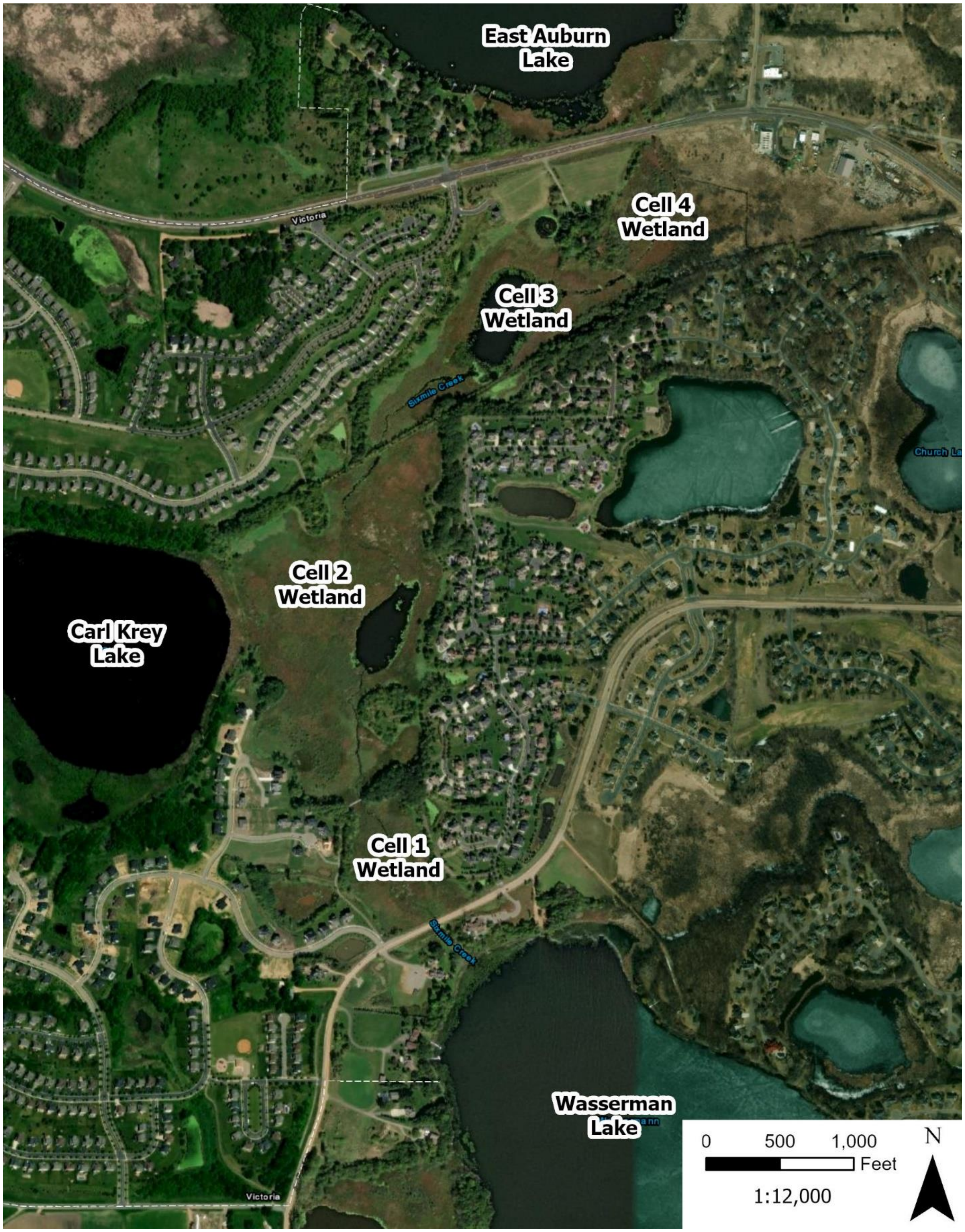

Figure 1-1. Cell 1 Wetland Location

1.2. Cell 1 Wetland History

The Cell 1 Wetland is not shown on the 1853 surveys of the area. However, Wasserman Lake and Lake Auburn are shown and Six Mile Creek is shown largely bypassing Lake Auburn to the west (Figure 1-2). In the 1905 United States Geological Survey (USGS) topographic map Six Mile Creek is shown connecting to the southeast corner of Lake Auburn as it exists today. This map also shows a road in place near the existing location of Church Lake Boulevard at the southern end of Cell 1, indicating that a culvert was already in place at the outlet of Wasserman Lake by 1905 (Figure 1-3). Review of more recent aerial photographs dating back to the 1940s demonstrates that the channel through the Cell 1 Wetland has been manipulated from its natural condition and straightened to improve drainage.

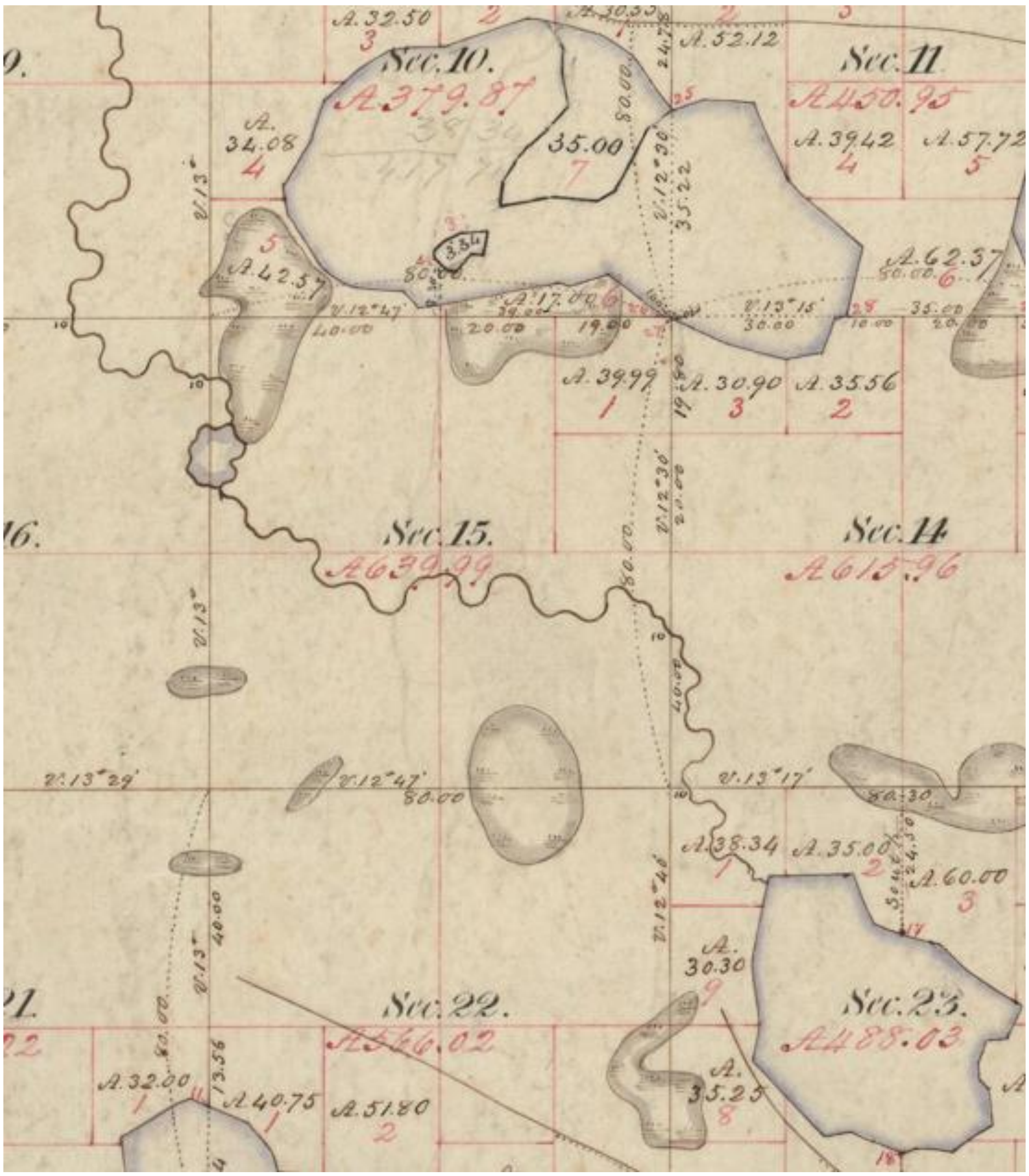

Figure 1-2. 1853 Survey of Wasserman Lake (Bottom Right) and Auburn Lake (Top Center)

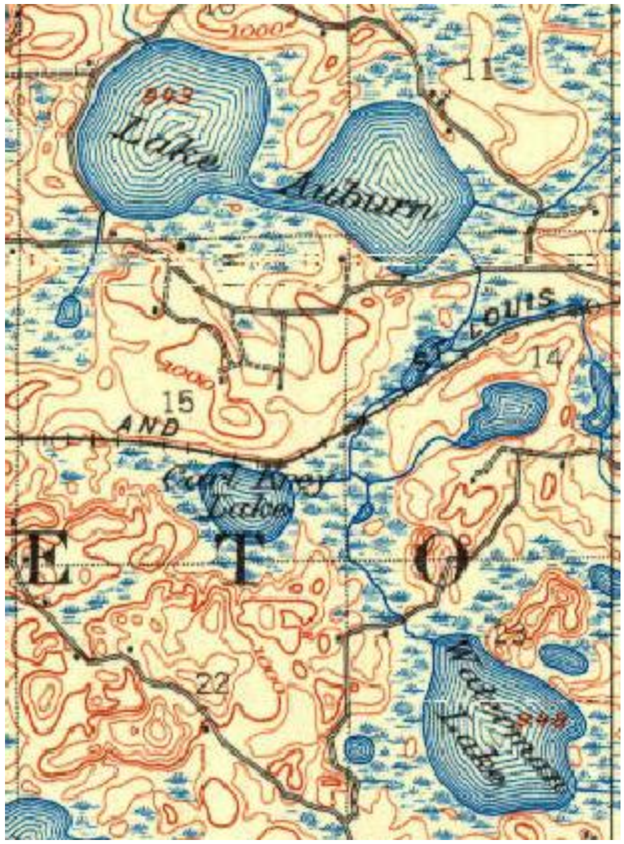

Figure 1-3. 1905 USGS Survey

1.3. Cell 1 Wetland Description

The Cell 1 Wetland is one of four wetland cells in the East Auburn Wetland between Wasserman Lake and Lake Auburn along Six Mile Creek. The Cell 1 Wetland is the most upstream wetland cell and is an emergent marsh with a channel that meanders through the cell and under the bridge at the downstream (northern) extent of the wetland. In this location the wetland narrows and the channel flows under the bridge before expanding into the next marsh (Cell 2) located to the north of the walkway. The Cell 2 downstream boundary is considered to be a trail where the wetland flows through a 36-inch culvert. After going under the trail, the wetland continues in Cell 3 before narrowing and entering Cell 4. Cell 4 continues until the wetland flows under Arboretum Boulevard (MN Highway 5) and into East Auburn Lake.

1.3.1. Wetland Vegetation Community

The wetland community in the East Auburn Wetland is dominated by emergent vegetation with a channel that meanders through all the wetland cells from Wasserman Lake to East Auburn Lake. In addition, there are some areas of shallow open water in the wetlands and Carl Krey Lake located west of the wetland. Based on an evaluation of Cells 3 and 4, the dominant plant communities in the marsh were invasives including narrow leaf cattail (*Typha angustifolia*), common reed (*Phragmites australis*), and reed canary grass (*Phalaris arundinacea*) (Wenck Associates, Inc., 2017). In addition to these communities there were some native species observed at lower densities.

1.3.2. Wetland Topography

Survey elevations were collected in select locations in the Cell 1 Wetland as part of a recent study by Stantec in 2021 and 2022. This topographic detail showed that the light detection and ranging (LiDAR) data previously collected for the site was not particularly accurate in the marsh, likely due to vegetation density, LiDAR point density, and potentially standing water. The field topographic survey showed that the wetland bottom in the marsh was approximately 943.5 to 945 feet (NAVD88). The elevations within the channel were about one foot lower and between 942.5 and 943.5 feet. The wetland survey points are shown in Figure 1-4. These survey points and the aerial photograph were used to develop estimated contours for the marsh that are shown in Figure 1-5.

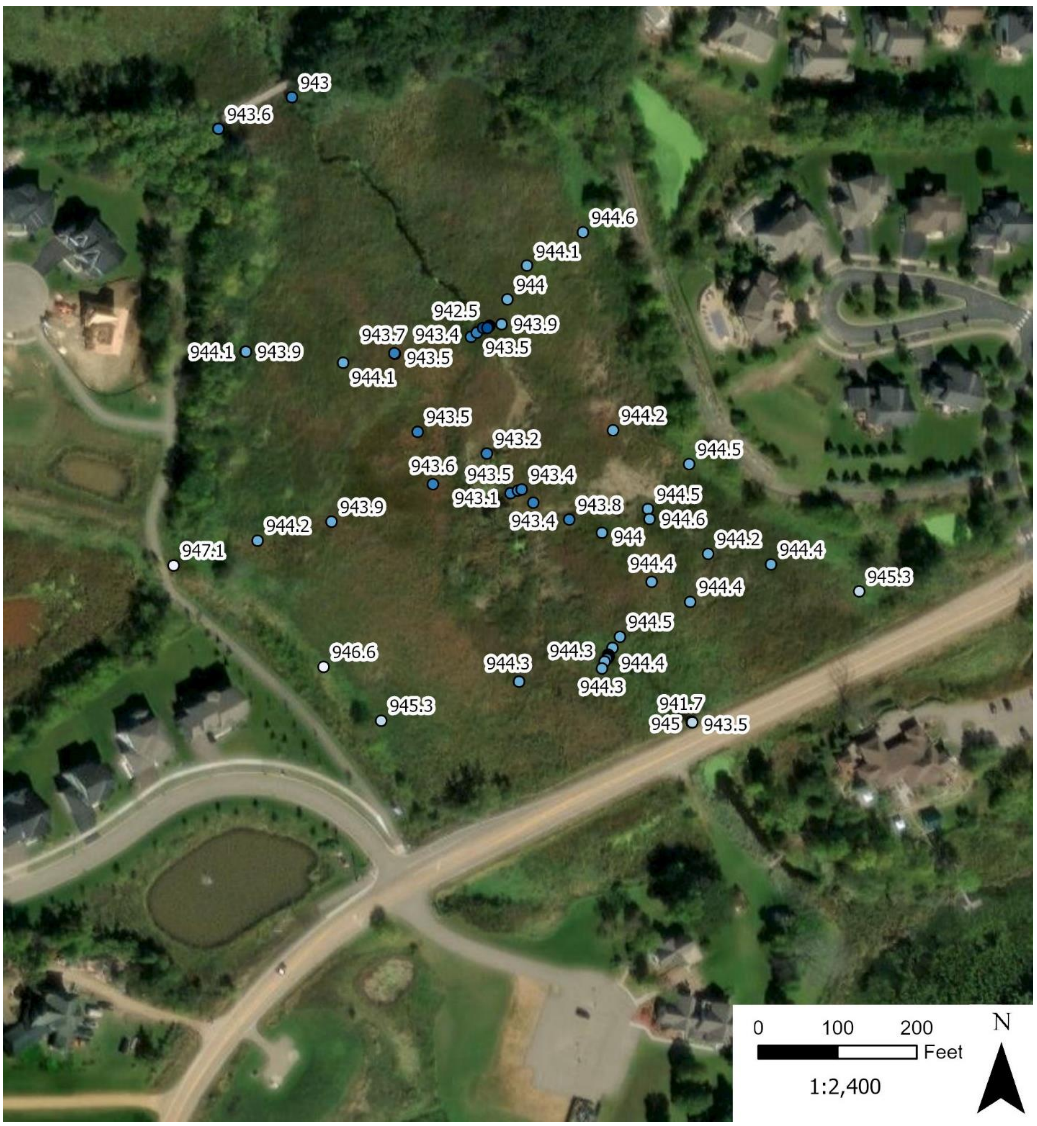

Figure 1-4. Cell 1 Wetland Survey (ft NAVD88)

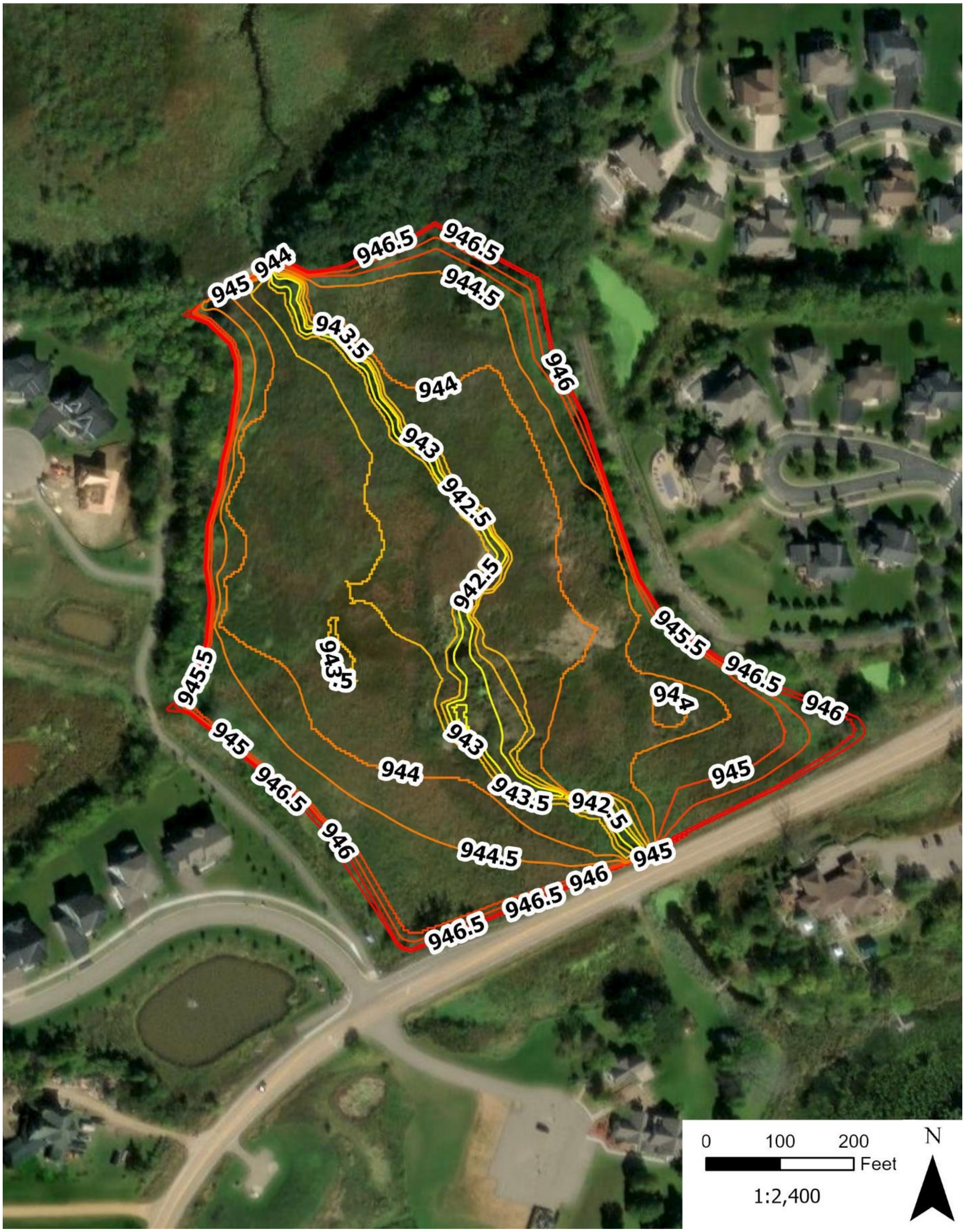

Figure 1-5. Cell 1 Wetland Elevation Contours (ft NAVD88)

2. Data Analysis

This feasibility assessment relied on data collected by others during previous studies. These data included surface water and groundwater quality, flows, sediment samples, water levels, and vegetation data. The collected data were used to evaluate the wetland and develop alternatives to reduce nutrient exports from the wetland. The following sections discuss the data that were evaluated and observations from this analysis.

2.1. Sampling Locations

The wetland complex has been sampled for water quality and hydrology at several stations during different time periods. The longest-term dataset is available for the wetland complex inlet and outlet with station CSI12 (upstream station) located at Church Lake Boulevard downstream of Wasserman Lake and CSI05 (downstream station) located upstream of East Auburn Lake at Arboretum Boulevard. In addition to these stations, data collection has occurred at the wetland midpoint, between Cell 2 and Cell 3, at CSI19. Finally, data collection also occurred between Cell 1 and Cell 2 at CSI22. These sampling locations are shown in Figure 2-1. The statistics and periods-of-record (PORs) for these stations are provided in the Appendices.

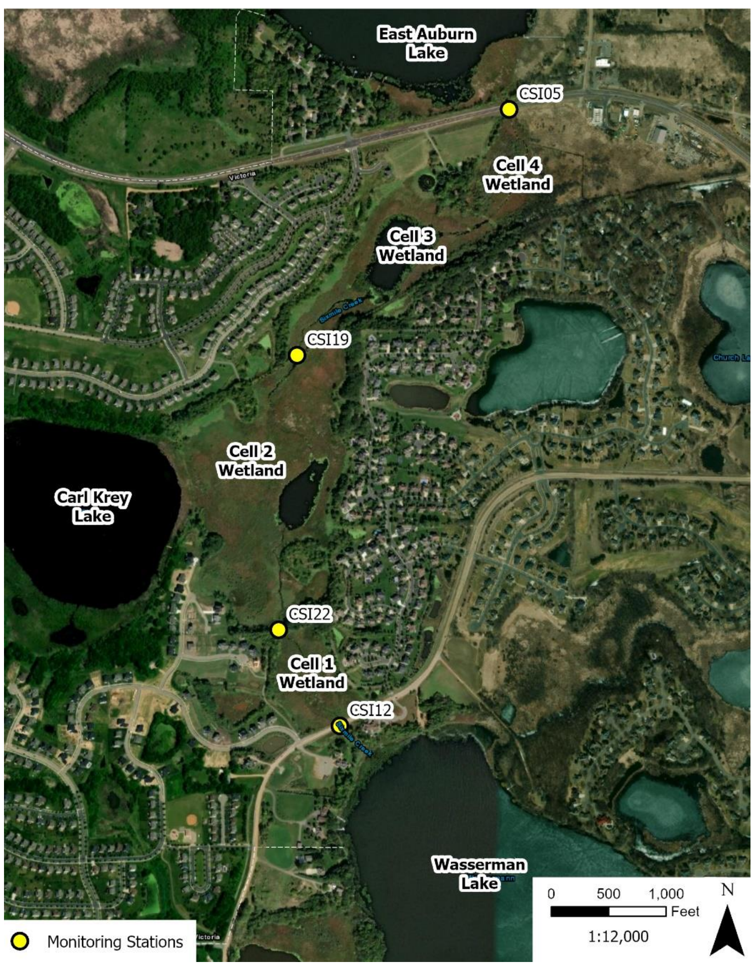

Figure 2-1. Sampling Stations on Six Mile Creek

In addition to these longer-term data, detailed data have been collected within the Cell 1 Wetland. This included data collection by MCWD in 2022 for water quality, water levels, and sediment characteristics. These data were collected at a series of locations within the channel, marsh, fringe, and adjacent uplands. These data were collected between May and September of 2022. These Cell 1 sampling stations are shown in Figure 2-2.

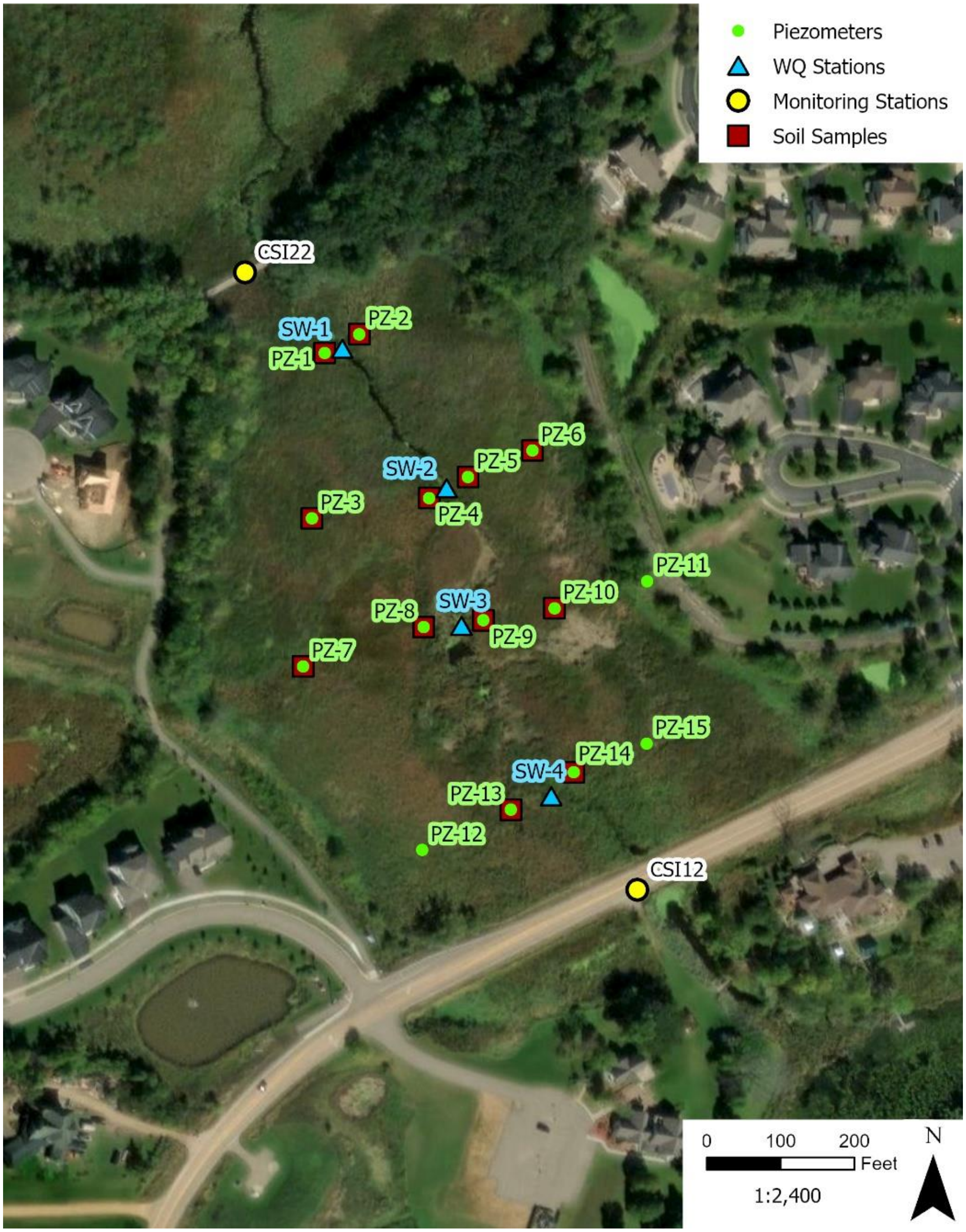

Figure 2-2. Cell 1 Wetland Sampling Stations

2.1. Flow Measurements

Flow measurements were collected at the inlet and outlet of the wetland complex beginning in 2009. These measurements showed a slight increase in flows through the wetland (Figure 2-3). This increase is expected due to direct rainfall on the wetland and runoff from the areas adjacent to the wetland that contribute stormwater. Median flows at the inlet and outlet were 2.30 cfs and 2.72 cfs, respectively with peak measured flows of 42.5 cfs at the inlet and 28.1 cfs at the outlet. This generally indicates that the existing culverts that control wetland inflows and outflows are sized appropriately to pass low storm events and baseflows without causing extensive ponding but do restrict discharge for higher events (as indicated between a minimal difference in median and low flows, and a significant difference in peak flows).

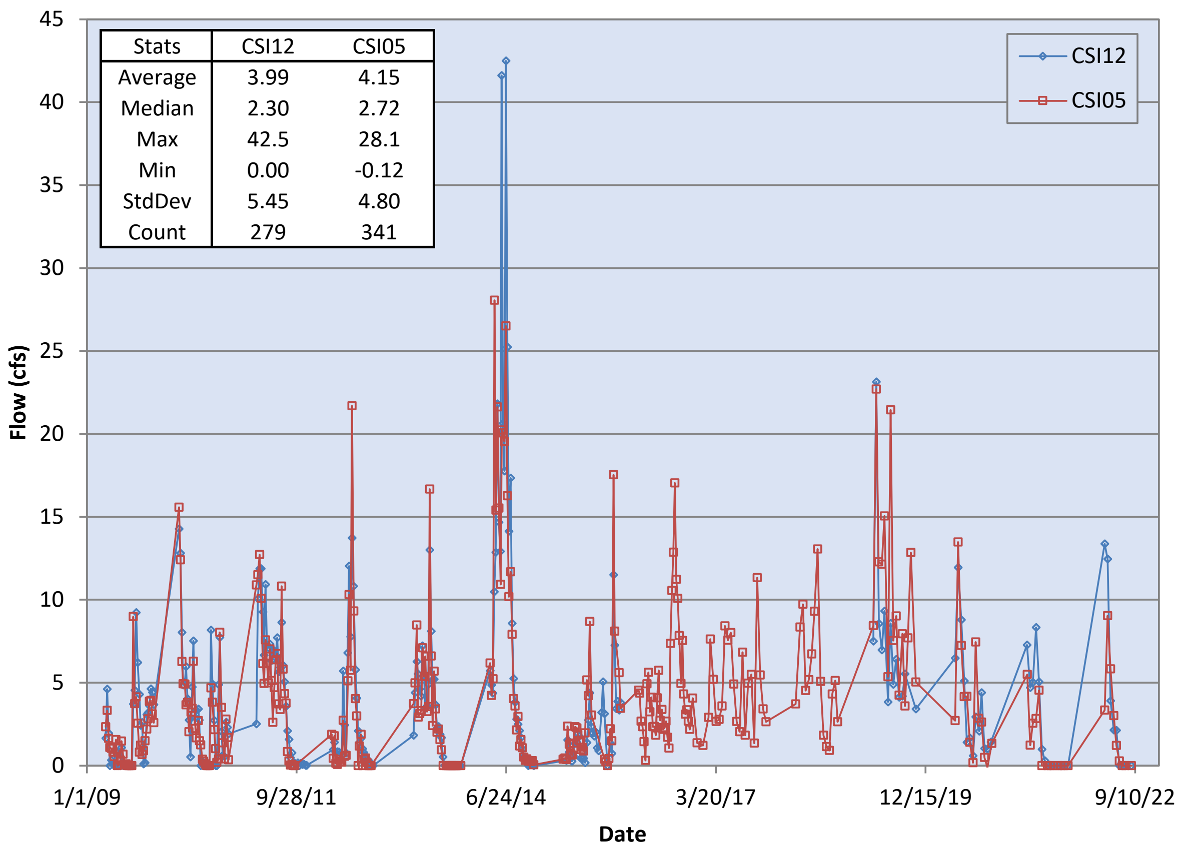

Figure 2-3. Flow Measurements at the Inlet and Outlet of the Wetland Complex

In addition to evaluating the time series, the annual pattern of flows was also considered to examine the magnitude of flows during different months. These data show that flows were highest in spring and early summer before tapering off in the late summer until increasing slightly in the fall in years with wetter than normal precipitation as shown in Figure 2-4. These seasonal changes in flow were particularly pronounced in the upstream areas of the wetland at CSI12.

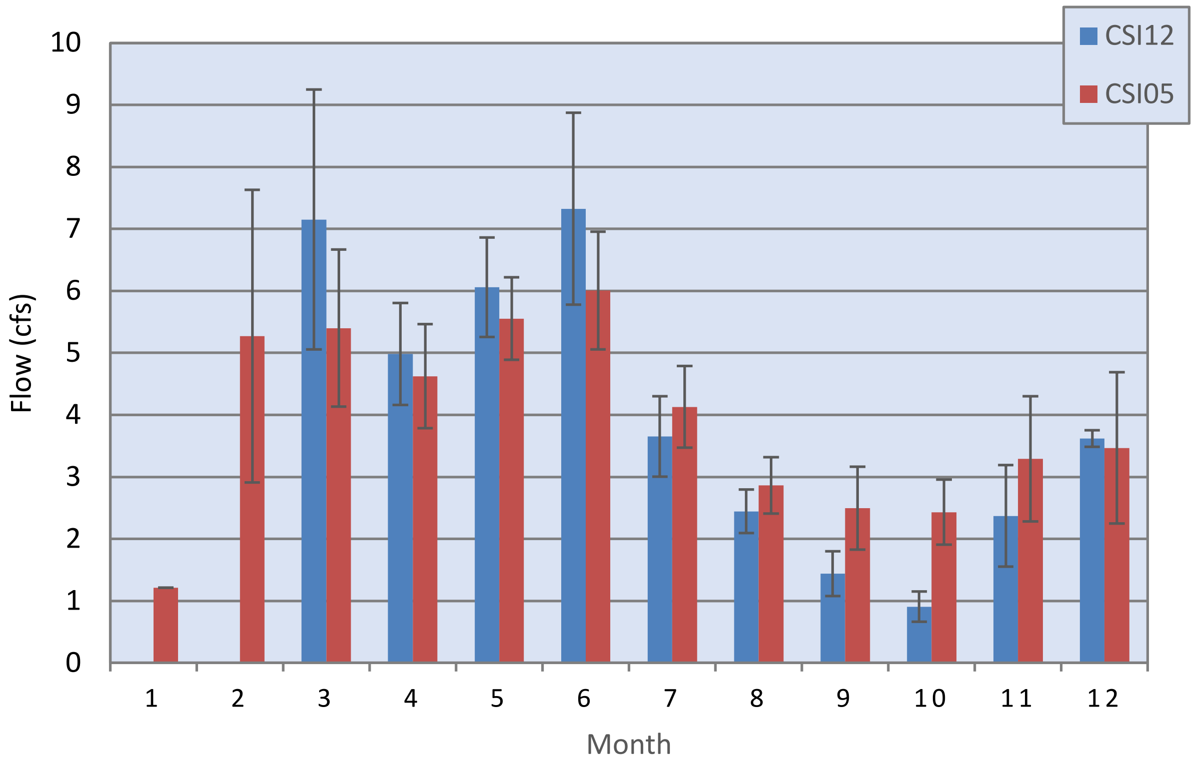

Figure 2-4. Average Monthly Flows at the Inlet and Outlet of the Wetland Complex

2.2. Water Quality

Water quality data have been collected from the previously described stations at varying frequencies and over variable PORs. The stations with the longest PORs are located immediately upstream of the Cell 1 Wetland (CSI12) and at the outlet of the wetland complex (CSI05). These stations have data extending back to 2009. At these stations the total phosphorus (TP) increased between the wetland inlet and outlet with higher average and median values at the downstream station (Figure 2-5). Additionally, the data showed a consistent seasonal trend with higher concentrations being released in the summer from the wetland complex (Figure 2-6).

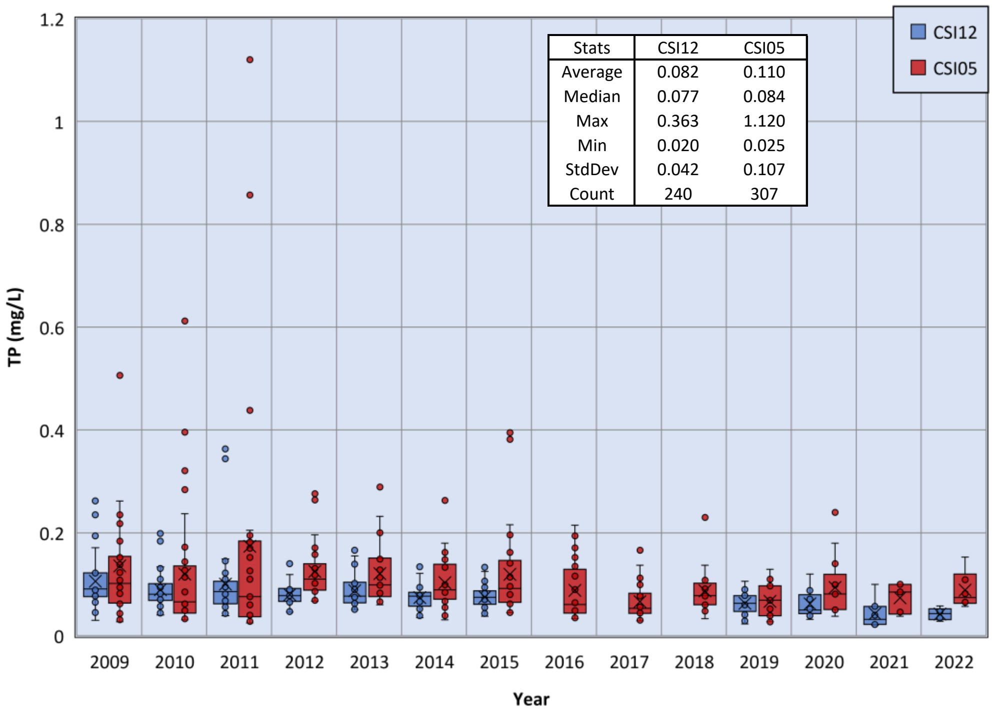

Figure 2-5. Total Phosphorus Concentration at the Inlet and Outlet of the Wetland Complex

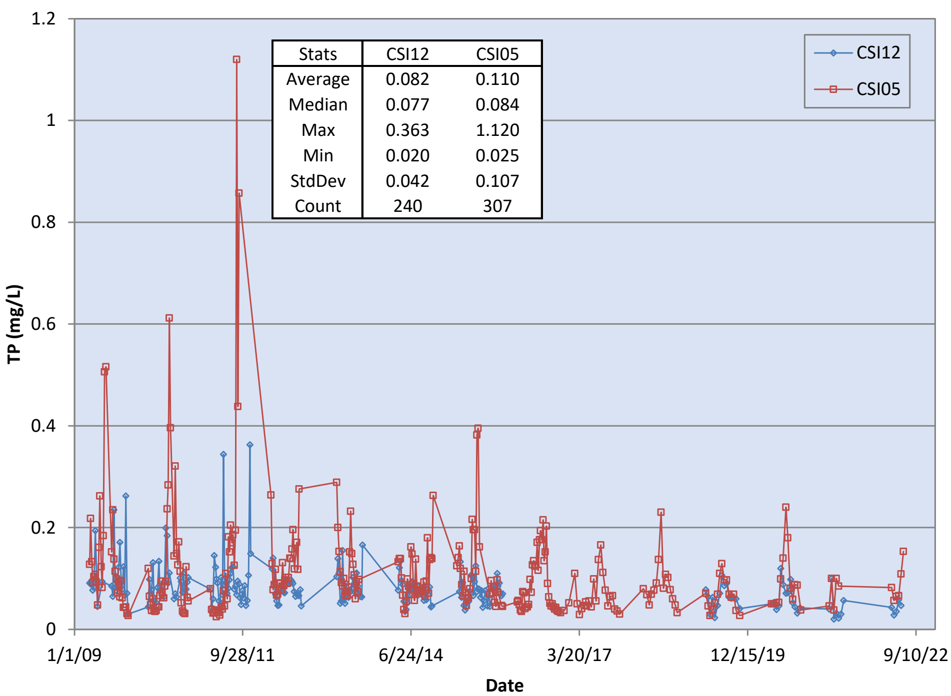

Figure 2-6. Total Phosphorus Concentration Time Series at the Inlet and Outlet of the Wetland Complex

Ortho-phosphorus (OP) at these same stations showed a more substantial increase between the wetland inlet and outlet (Figure 2-7). OP discharge increased in both total mass and the ratio of OP to TP through the wetland; at the wetland inlet approximately 10-percent of the TP was in the OP form while at the wetland outlet approximately 40-percent of the TP was in the OP form. These data also showed a seasonal pattern with increasing concentrations later in the year at the downstream station (Figure 2-8). Stormwater sampling statistics for all sampled stations are provided in Appendix A.

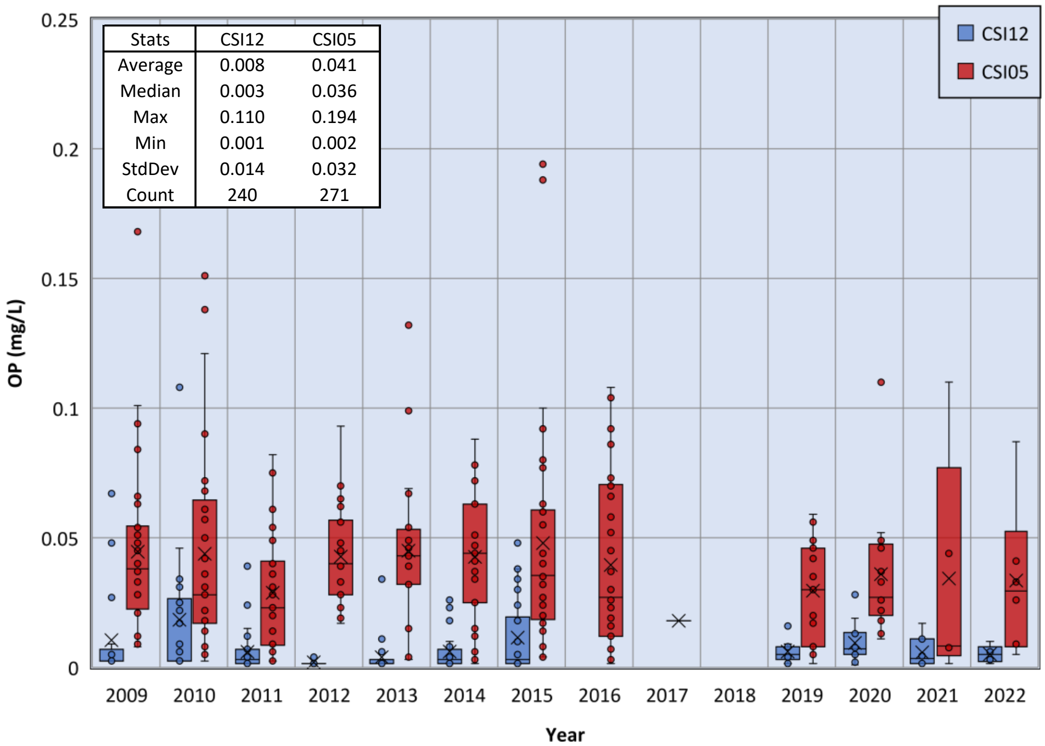

Figure 2-7. Ortho-Phosphorus Concentration at the Inlet and Outlet of the Wetland Complex

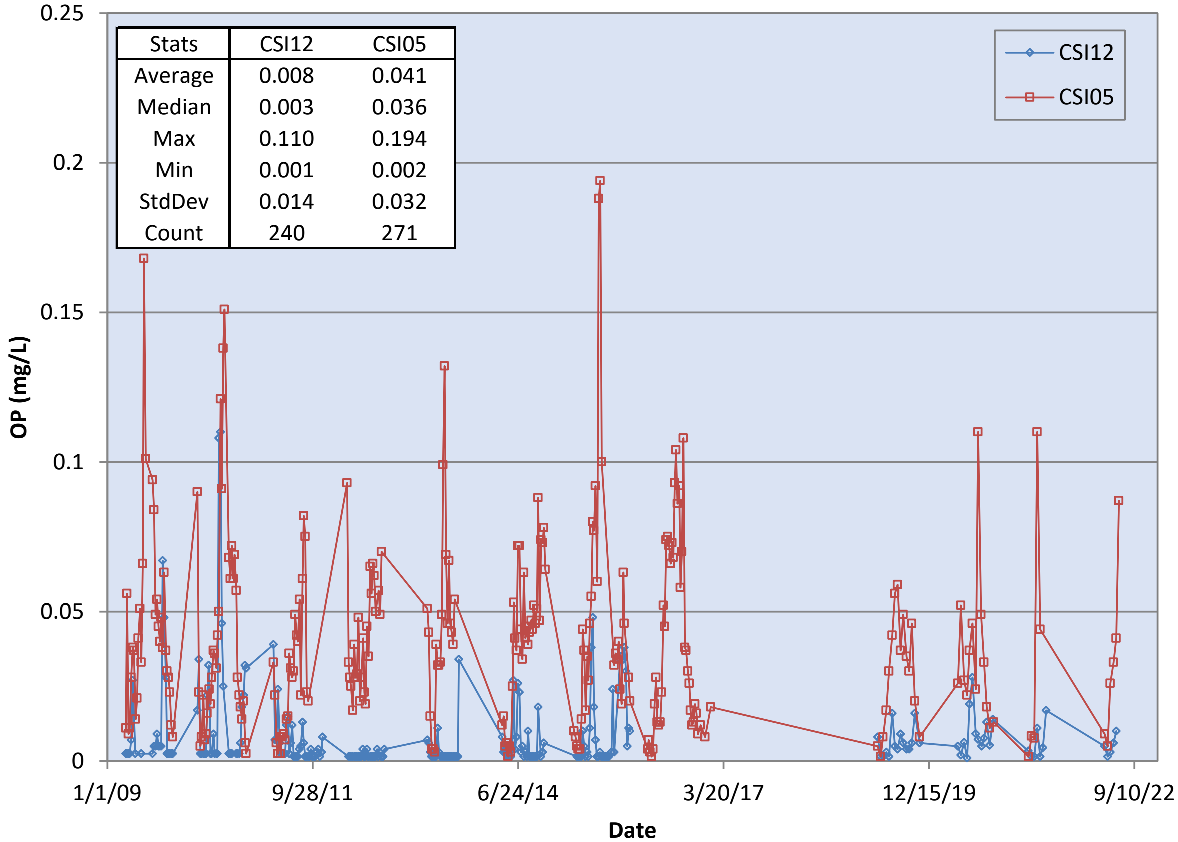

Figure 2-8. Ortho-Phosphorus Concentration Time Series at the Inlet and Outlet of the Wetland Complex

Concentrations of TP and OP were also evaluated monthly to examine trends in concentration during different months. For TP, this examination showed average outflow concentrations exceeding average inflow concentrations from March through September. (Figure 2-9). Increases in concentration were particularly apparent from June to September. OP showed the same increases in concentration through the wetland with a consistent release of OP in all months (Figure 2-10). This release was particularly pronounced from June through September.

Concentrations of TP and OP were paired with flows to evaluate the mass of phosphorus entering and leaving the wetland. These data showed a consistent export of TP except during infrequent occasions when the load entering exceeded the load leaving the wetland (Figure 2-11). OP showed a similar relationship with the load leaving the wetland exceeding the load entering the wetland (Figure 2-12).

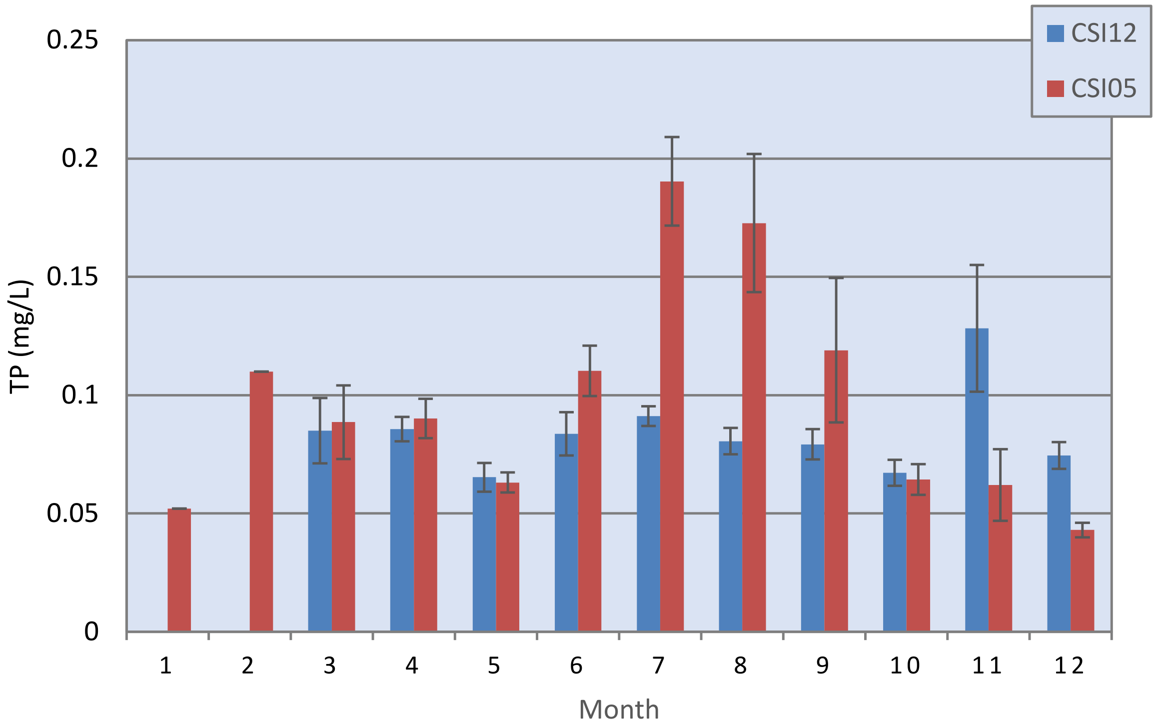

Figure 2-9. Average Monthly Total Phosphorus Concentrations at the Inlet and Outlet of the Wetland Complex

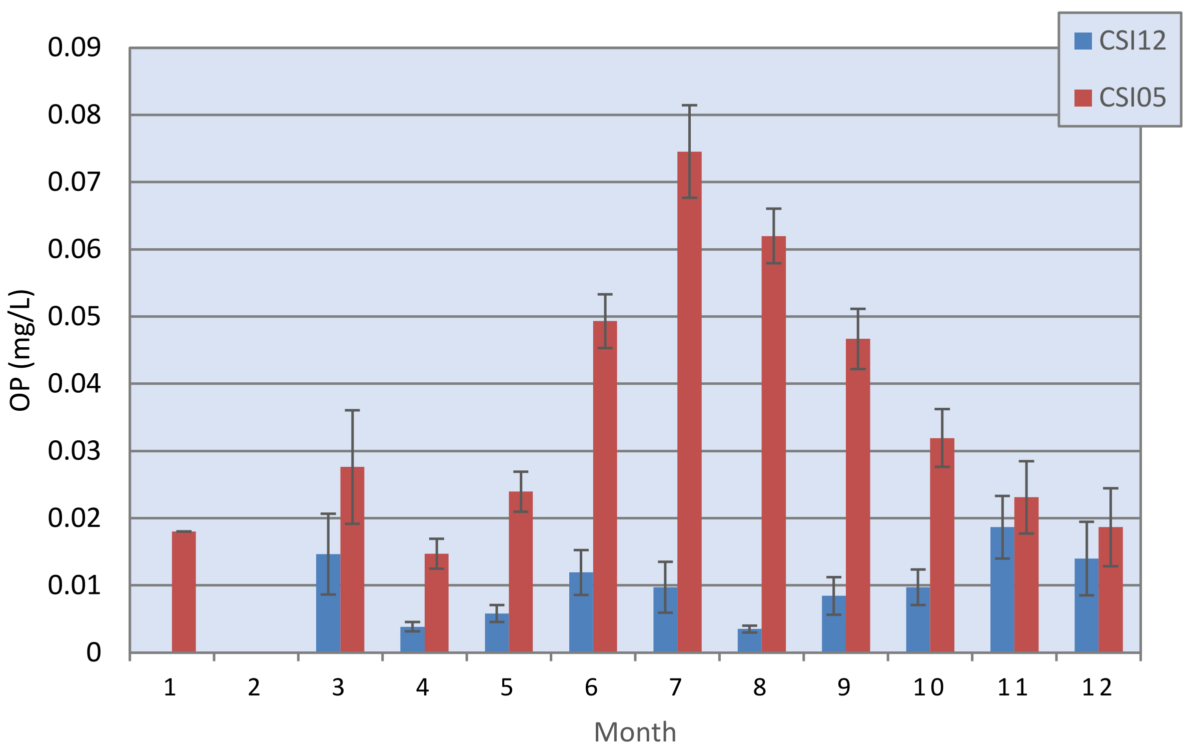

Figure 2-10. Average Monthly Ortho-Phosphorus Concentrations at the Inlet and Outlet of the Wetland Complex

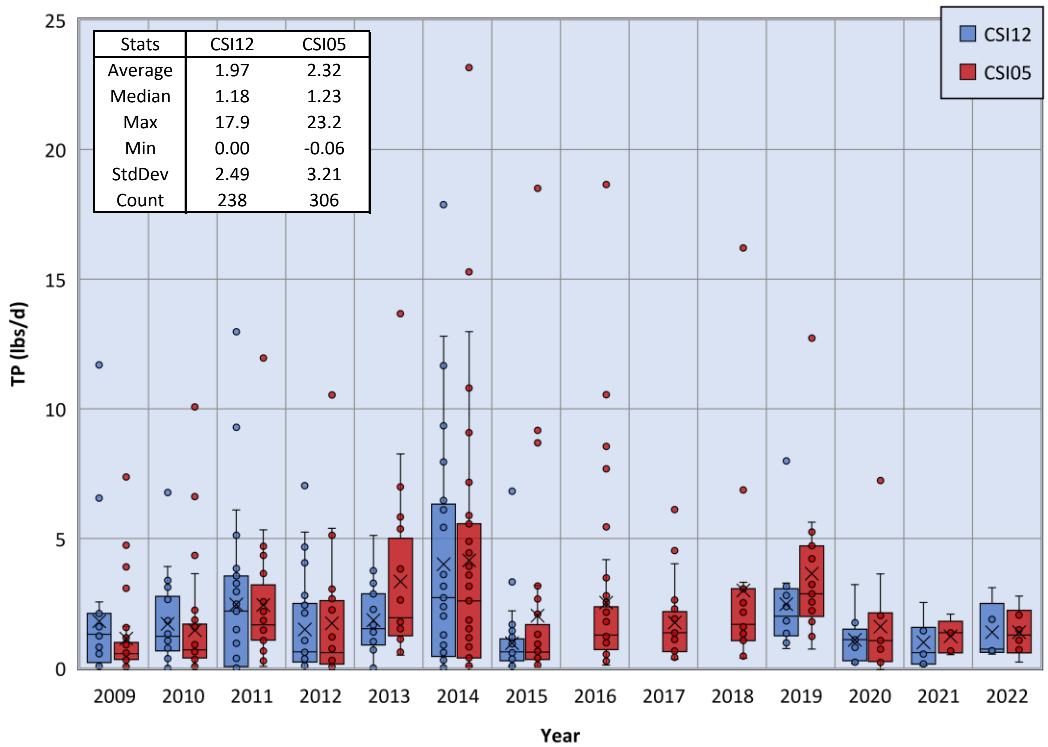

Figure 2-11. Total Phosphorus Load Entering and Leaving the Wetland Complex

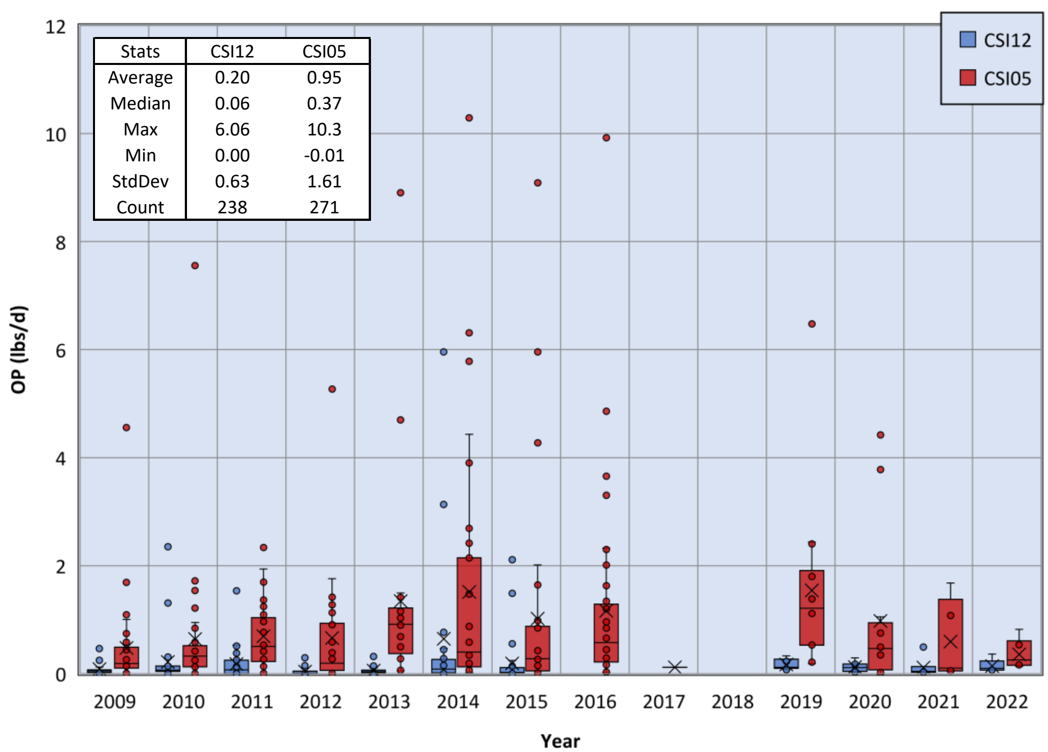

Figure 2-12. Ortho-Phosphorus Load Entering and Leaving the Wetland Complex

Monthly loading was also evaluated for TP and OP. These data show that, excluding January and February which had single samples, the months with consistent export were July through October, with October only having a minor export as shown in Figure 2-13. A similar loading pattern existed for OP except that export occurred in most months, and June through September had the largest increases in OP loading (Figure 2-14).

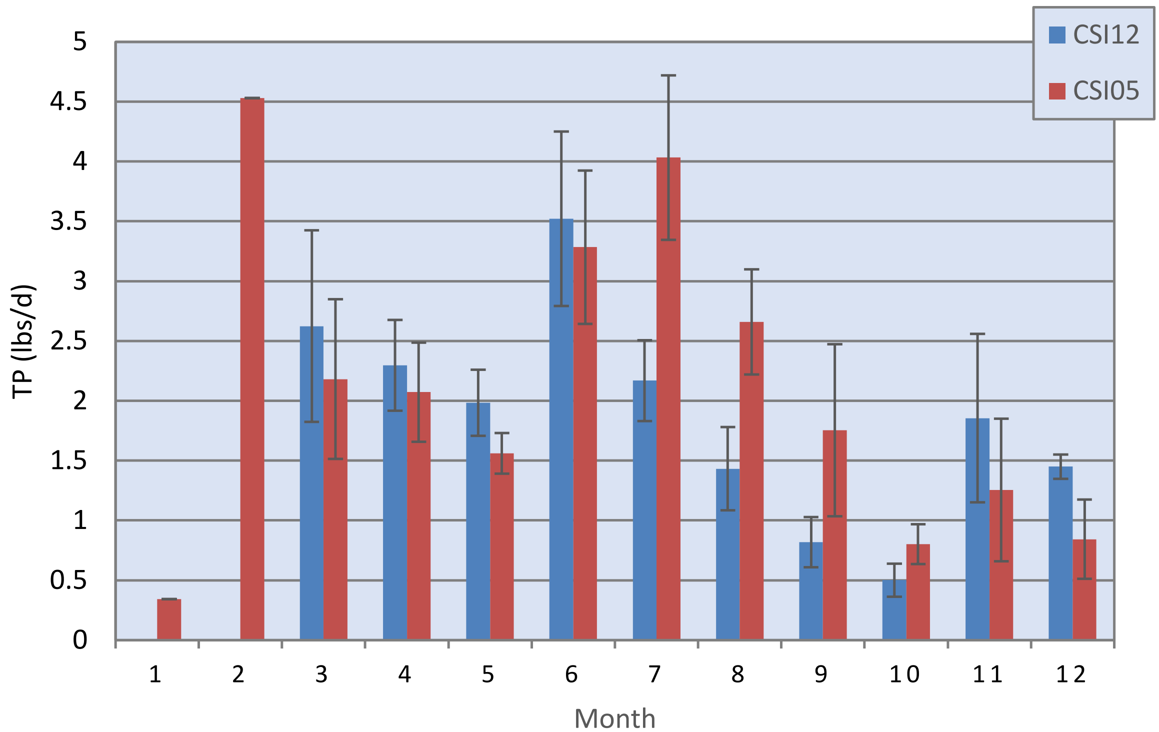

Figure 2-13. Average Monthly Total Phosphorus Loads at the Inlet and Outlet of the Wetland Complex

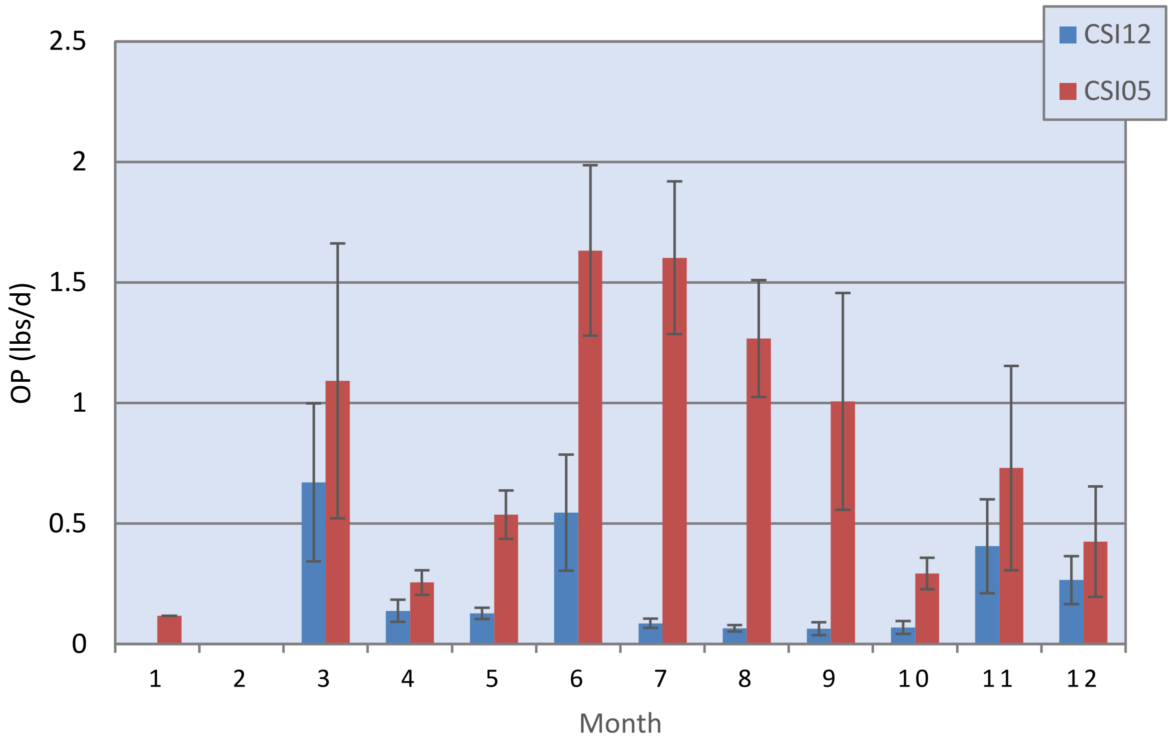

Figure 2-14. Average Monthly Ortho-Phosphorus Loads at the Inlet and Outlet of the Wetland Complex

2.2.1. Cell 1 Wetland Surface Water Quality Sampling

Limited surface water quality samples have been collected at station CSI22 at the outlet from Cell 1 to Cell 2. These data were collected between mid-2020 through mid-2022. At CSI22, TP concentrations were elevated when compared to samples collected at CSI12, the inflow from Wasserman Lake to Cell 1 (Figure 2-15). Similar but more pronounced increases were observed for OP in the Cell 1 Wetland as shown in Figure 2-16. Figure 2-17 shows a positive, increasing relationship between TP and total iron (TFe) concentrations in the Cell 1 wetland surface water samples. This occurs during reducing conditions when iron-bound phosphorus can be released from the sediments to the overlying water. As shown in the sediment results (Section 2.4), the estimated mass of iron-bound phosphorus is relatively small, but the potential release may still be an important contribution seasonally.

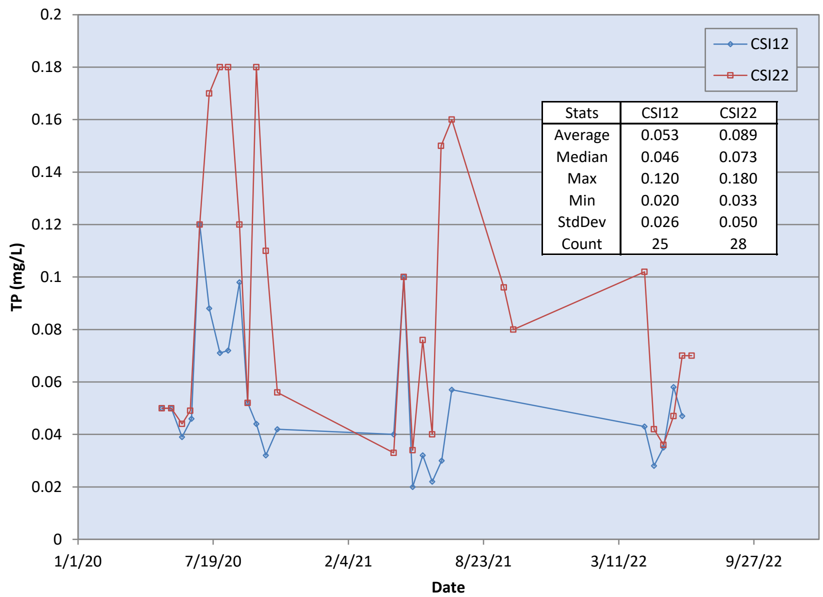

Figure 2-15. Total Phosphorus Concentrations for the Cell 1 Wetland Inflow and Outflow

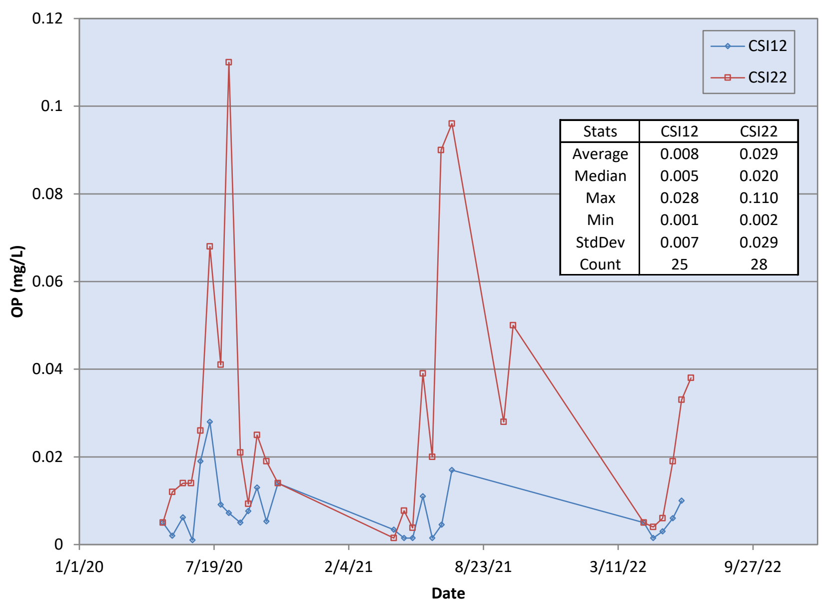

Figure 2-16. Ortho-Phosphorus Concentrations for the Cell 1 Wetland Inflow and Outflow

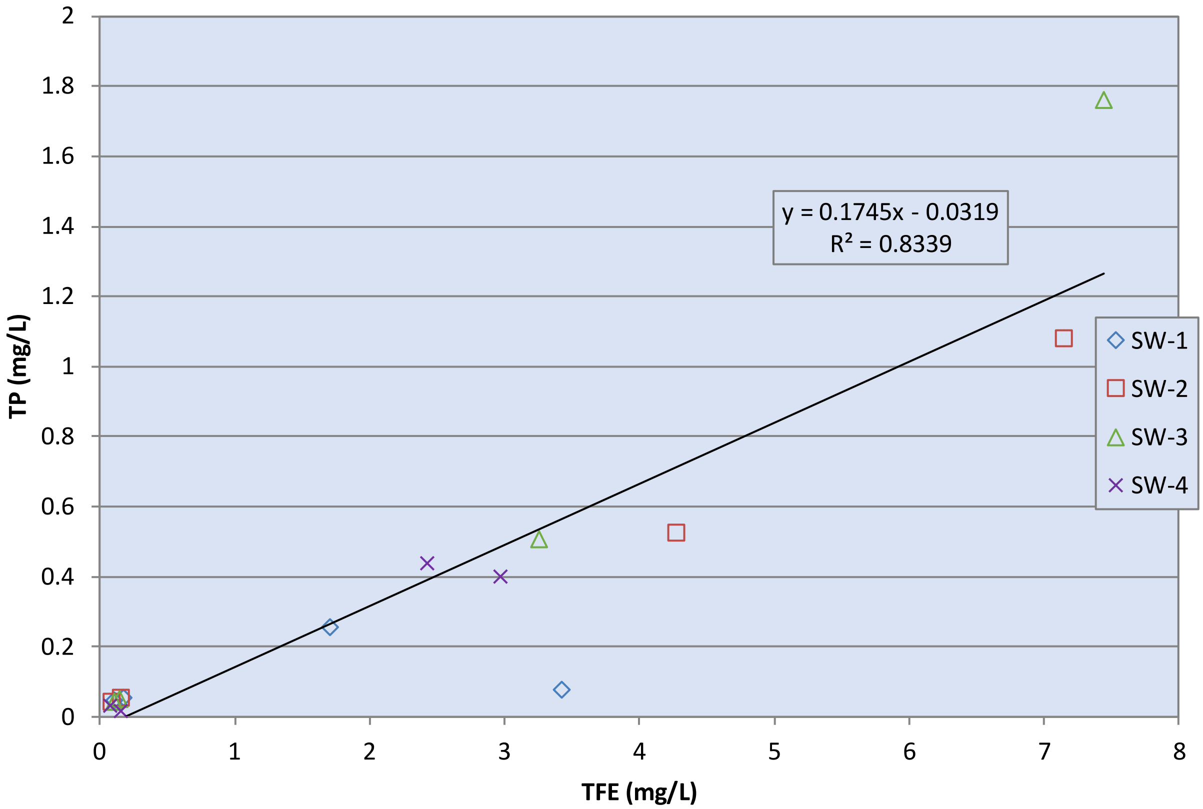

Figure 2-17. Relationship Between TP and Total Iron in Cell 1 Surface Water

2.3. Water Levels

Water level data were collected at shallow monitoring wells installed in the Cell 1 Wetland as part of the detailed study completed by Stantec in 2022 (Stantec, 2022). Within Cell 1, water levels were collected at five locations (1 channel, 3 in the wetland, and 1 upland), shown in Figure 2-2. At the wetland monitoring well locations, water levels were collected at three depths, surface, shallow, and deep. The water levels were plotted and are shown in Figure 2-18. These data show that most of the marsh dried out by mid-June and that water was primarily contained in the channel (elevations less than 943.5 feet) by early-July. Review of water levels demonstrates the sub-surface drainage of water to the channel with a gradual drop in levels during the summer months before re-hydration of the entire marsh during August and early-September following precipitation events. The complete details for each sampling location including all three collected water levels are shown in Appendix B.

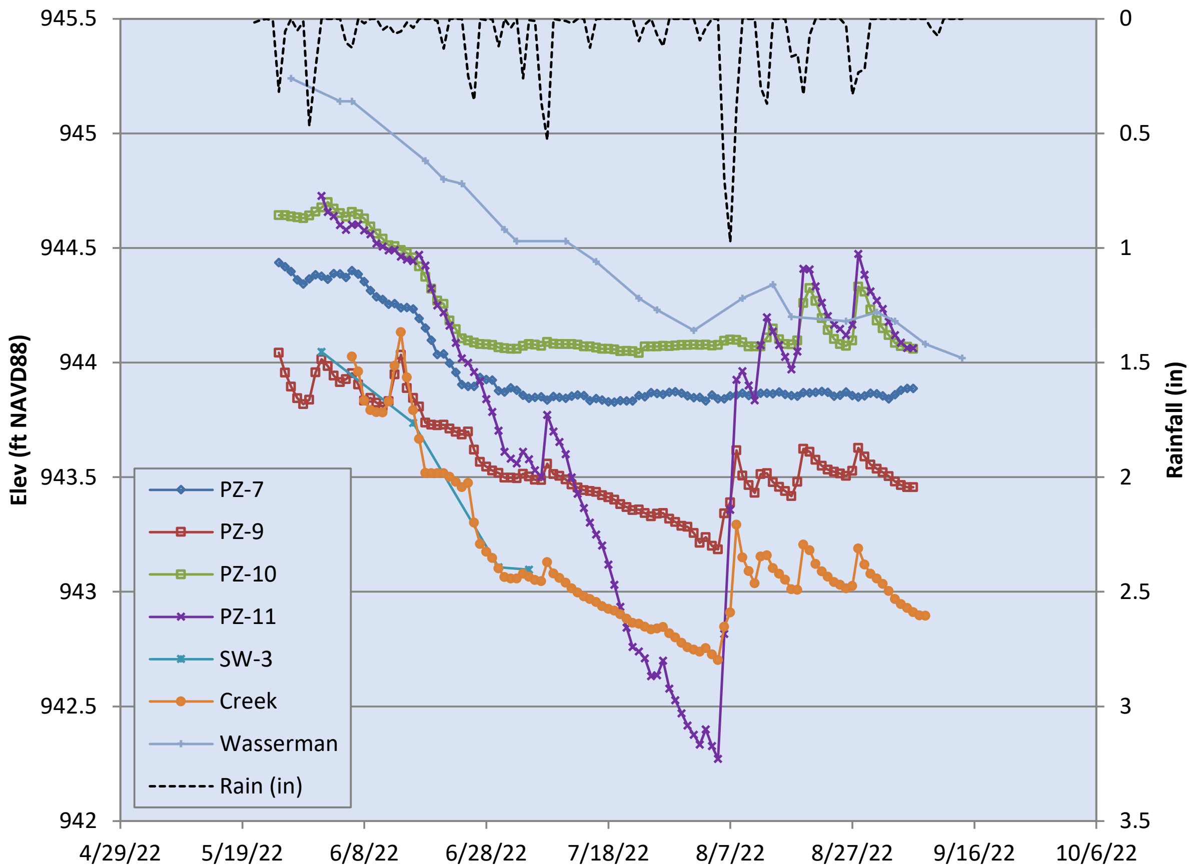

Figure 2-18. Cell 1 Wetland Water Levels and Rainfall

2.4. Soil Sampling

Soil sampling was completed as part of the detailed study of the Cell 1 Wetland by Stantec (Stantec, 2022). This included collection of samples at each of the piezometer locations at three depths: surface (0-1 feet), shallow (1-2 feet), and deep (4-5 feet) and in the stream. At each of these depths/locations the soil TP fractionation was measured and reported. Forms of soil phosphorus (P) that were measured and reported included: loosely-bound P, iron-bound P, labile organic P, aluminum-bound P, calcium-bound P, and refractory organic P. This order also generally corresponds to the bioavailability of these sources with the loosely-bound P, iron-bound P, and labile organic P being mobile and the aluminum-bound P, calcium-bound P, and refractory organic P being non-mobile under normal conditions. The average soil fractionation for the depths/locations are shown in Figure 2-19. These samples show that there is more mobile P in the stream and surface stations than in the shallow and deep samples. For these same samples average non-mobile P was similar amongst the depths/locations. The sediment data sampling results for all of the locations and depths are provided in Appendix C.

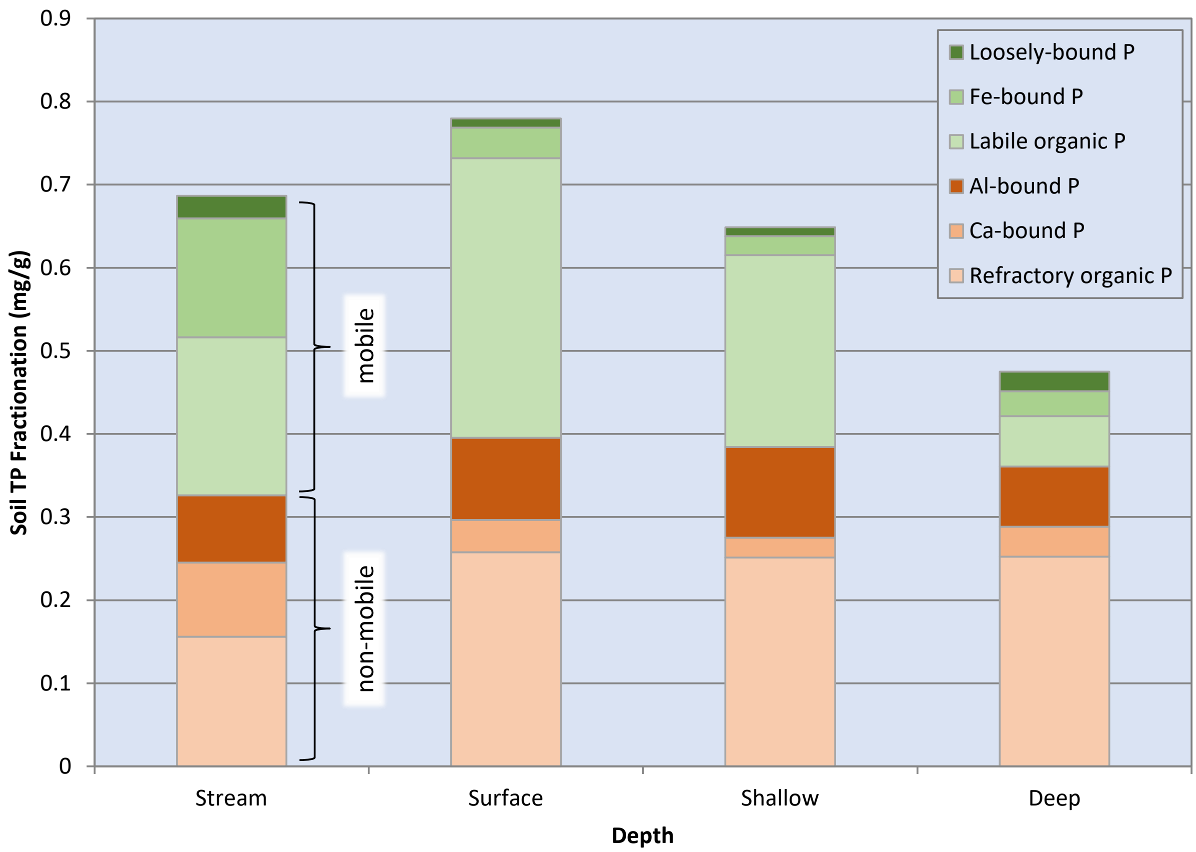

Figure 2-19. Sediment Total Phosphorus Fractionation Averages by Depth/Location

Concentrations of these components are shown for the surface samples in Figure 2-20. In the surface samples, TP varied between 0.55 and 1.23 mg/g. Some variability in concentrations were observed across the wetland with PZ-10 having the highest TP of the samples.

The shallow sediment samples showed a range of TP concentrations from 0.44 to 1.00 mg/g. As with the surface samples some variability was observed between sampling stations with PZ-1 having the highest concentrations of TP. The TP fractionation for all of the shallow samples is shown in Figure 2-21.

The deep sediment samples had the lowest TP concentrations on average of the sampling depths. The range of concentrations were from 0.30 to 0.64 mg/g. These samples also showed the most consistent concentrations and the lowest mobile P fraction. The TP fractionation for the deep samples is shown in Figure 2-22.

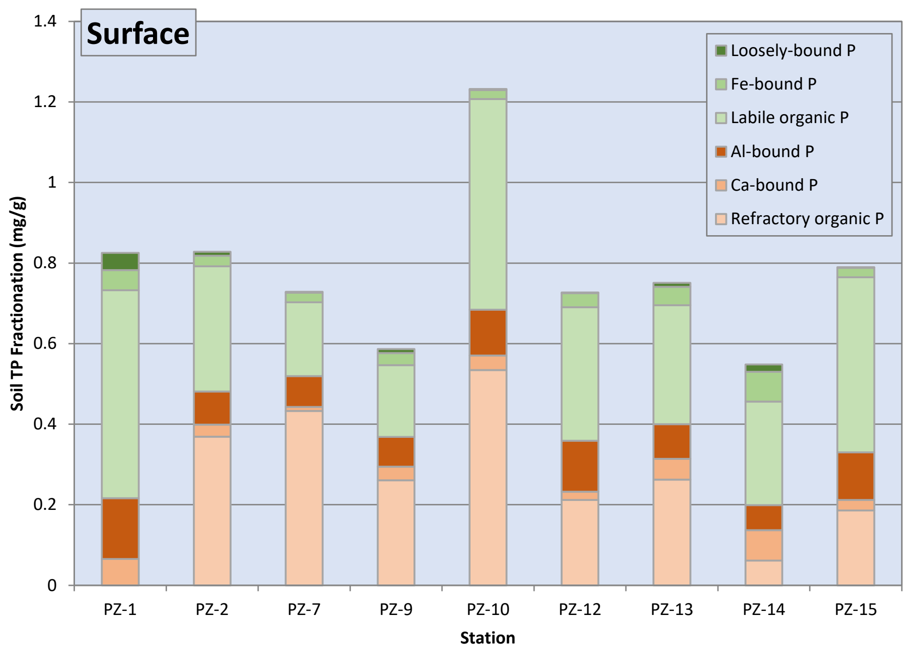

Figure 2-20. Sediment Total Phosphorus Fractionation for Surface Samples

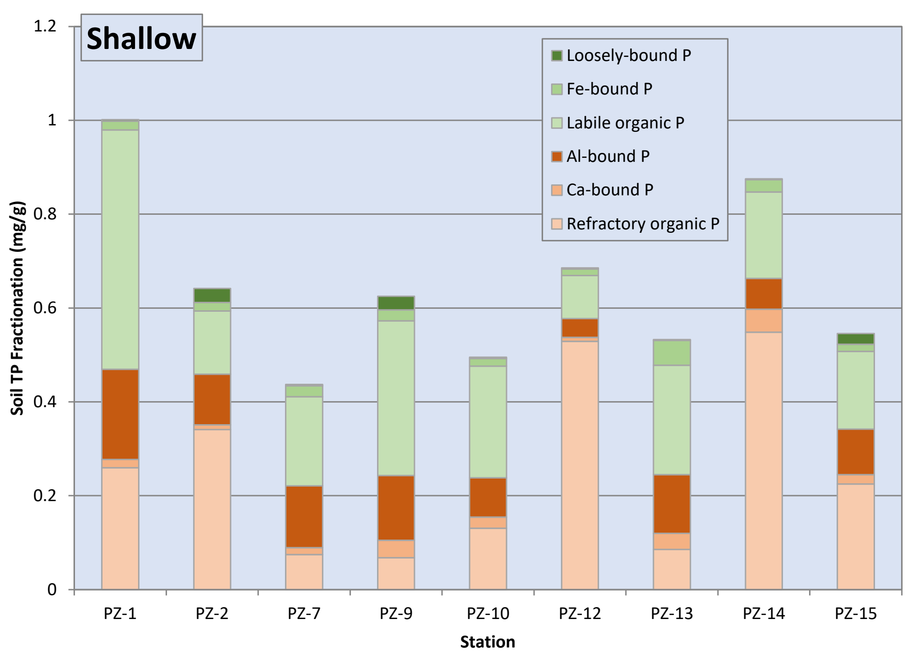

Figure 2-21. Sediment Total Phosphorus Fractionation for Shallow Samples

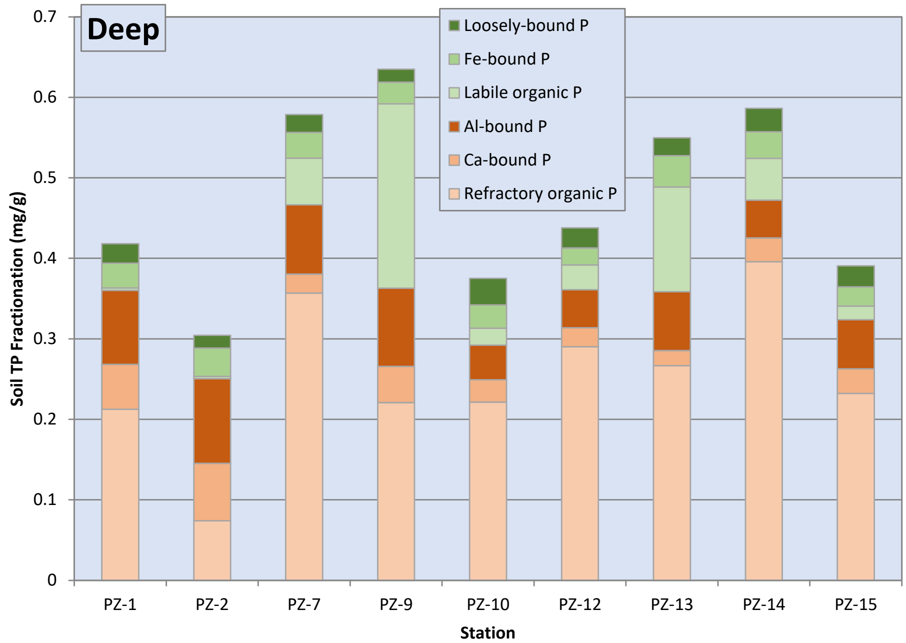

Figure 2-22. Sediment Total Phosphorus Fractionation for Deep Samples

2.5. Groundwater Sampling

Groundwater quality samples were collected in conjunction with installation of the piezometers and sediment sampling described in Sections 2.3 and 2.4. Samples were collected from the same subsurface depth zones as the sediments (0-1 feet, 1-2 feet, and 4-5 feet below surface) and the results represent pore water quality. Samples were collected at varying frequencies between May and August 2022 (Stantec, 2022). Surface pore water TP averaged 0.417 mg/L and ranged from 0.064 to 0.886 mg/L across the site. Surface OP concentrations were lower averaging 0.172 mg/L and ranging from 0.023 to 0.379 mg/L. Figure 2-23 shows the spatial variability in near-surface pore water average TP and OP concentrations. Figure 2-24 shows the groundwater TP and OP concentrations for the shallow pore water interval and Figure 2-25 for the deep pore water interval. Pore water TP and OP concentrations generally increased with depth below the wetland surface. TP averaged 0.244 mg/L for the shallow samples and 0.372 mg/L for the deep samples. OP averaged 0.124 mg/L for the shallow samples and 0.178 mg/L for the deep samples. Figure 2-26 shows the fractions of total particulate phosphorus (TPP) and ortho (soluble) phosphorus in the groundwater. Detailed results are provided in Appendix D.

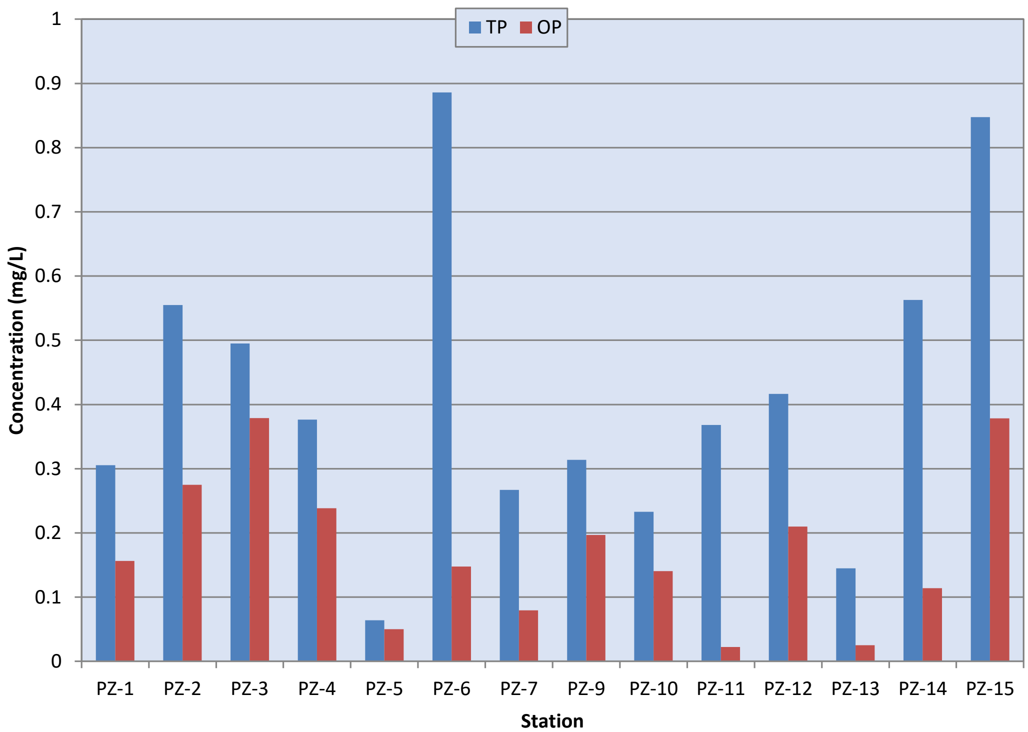

Figure 2-23. Surface (0-1 feet) Groundwater Phosphorus Concentrations

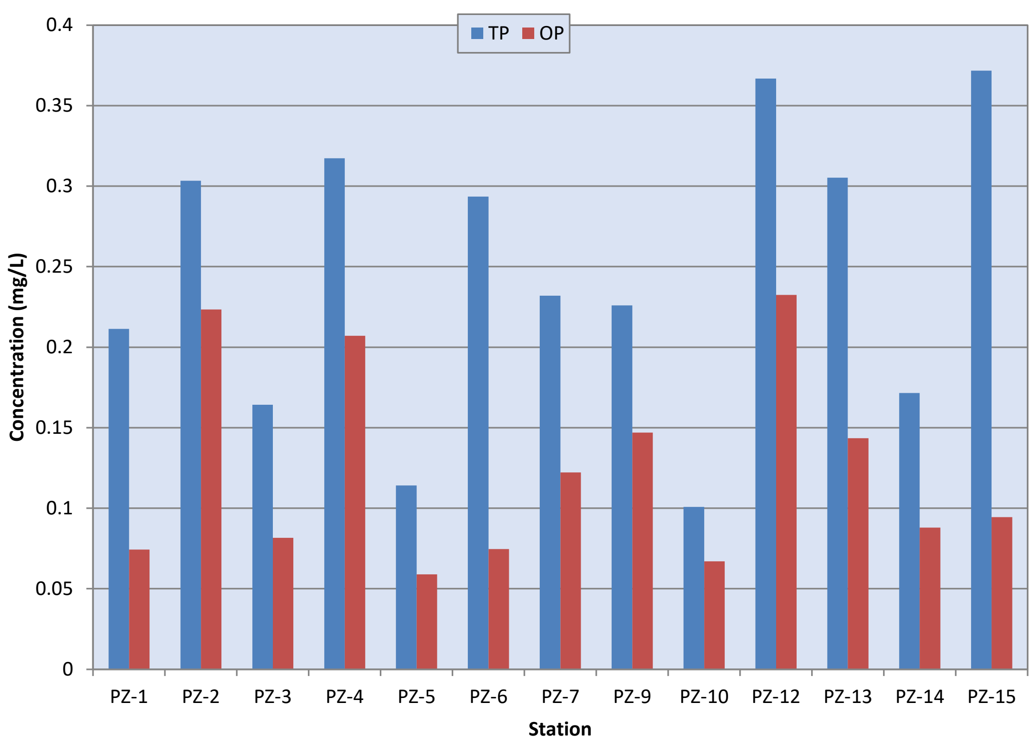

Figure 2-24. Shallow (1-2 feet) Groundwater Phosphorus Concentrations

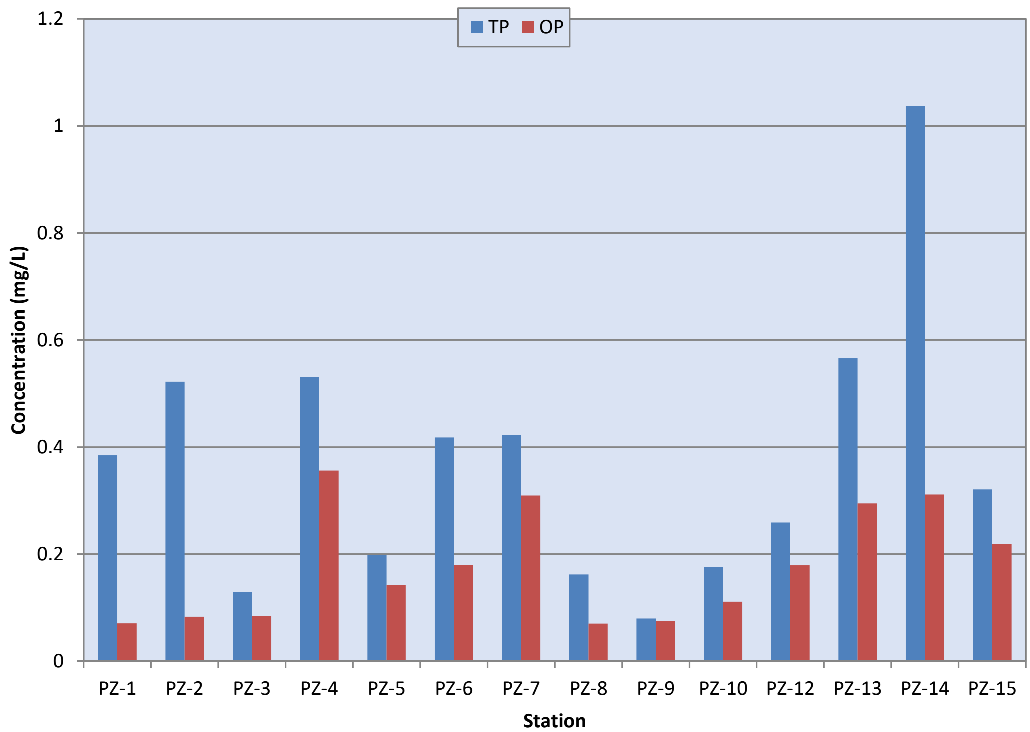

Figure 2-25. Deep (4-5 feet) Groundwater Phosphorus Concentrations

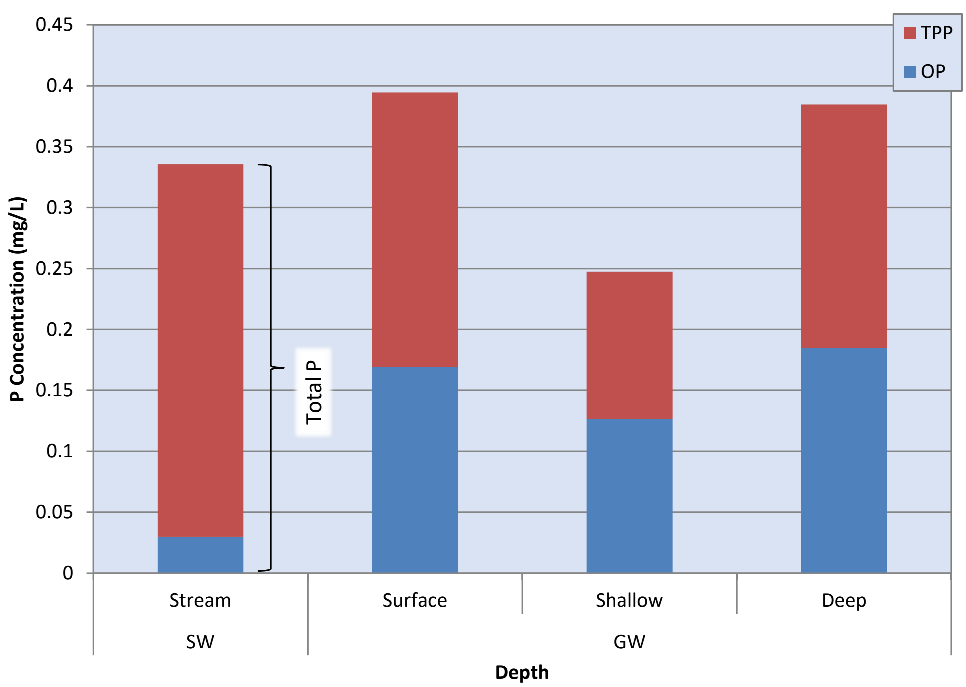

Figure 2-26. Particulate (TPP) and Ortho Phosphorus Surface Water and Groundwater Concentrations

2.6. Summary of Cell 1 Wetland Impairments

The East Auburn Wetland has been identified as a source of phosphorus loading to East Auburn Lake. This finding was documented in the *East Auburn Wetland Phosphorus Analysis* (Beck, 2019). In this analysis MCWD evaluated phosphorus concentrations into and out of the East Auburn Wetland. The analysis found that TP was higher at the outlet than at the inlet. It also showed that TP was relatively constant through the wetland while OP increased, and that these changes were most pronounced during summer (warmer months). This analysis also considered mass loading and found that the Auburn Wetland exported 135 pounds per year of OP on average.

To further isolate where changes in water quality took place, samples were collected at the wetland midpoint, downstream of Cell 2. These supplemental data showed that the first half of the wetland had higher phosphorus release than the second half, which showed very little additional increase. The increase in phosphorus was attributed to historic phosphorus loading from Wasserman Lake due to historically poor water quality in the lake. Cell 1 was implicated as the most likely source of phosphorus release because of the higher loading that would have occurred from the lake to this wetland cell. The analysis of sediment samples discussed in Section 2.4 support this theory with elevated TP concentrations observed in the stream and surface sediments, with lower concentrations of TP in the shallow and deep sediment samples.

This study used available data to further examine the phosphorus dynamics of the system and found that, as shown in the MCWD study, phosphorus increased through the Cell 1 Wetland and that the most significant mass loads occurred during the June through August timeframe. This study further considered the potential root causes of the phosphorus releases and developed a hypothesis based on the following data:

- Sediment phosphorus data indicate that the labile organic fraction is the dominant mobile TP fraction.
- The increase in TP through the wetland is dominated by exports in June, July, and August (Figure 2-11).
- Water levels in the wetland collected in 2022 show the system drying out in mid-June with water only present in the channel and levels slowly dropping as the channel drains the marsh.

Based on these observations in the data, it is hypothesized that phosphorus increases in the Cell 1 Wetland are being driven by a wet-dry cycling and release of TP primarily from the labile organic P fraction in the wetland sediments. This labile organic P, the most prevalent mobile fraction in the wetland, is potentially related to the export and settling of particulate phosphorus from Wasserman Lake during periods of poorer lake water quality and increased algae. In the current hydrologic condition, the wet-dry cycling is occurring because of the channel that cuts through the wetland that allows the marsh to completely dry out during the summer months when snowmelt has ended and runoff and rainfall is less frequent and driven by larger events.

This hydrologic regime allows the wetland to dry out, which both releases TP during oxidation of organic matter and allows subsurface flow from the marsh through the organic soils, transporting TP in the pore water, to the channel where it flows downstream. During subsequent rainfall events, flows and levels increase, flushing the water with higher concentrations of TP out of the wetland and downstream before the cycle repeats.

3. Alternatives Development

This study focused on identifying existing issues in the Cell 1 Wetland that are contributing to the release and export of phosphorus to the downstream wetlands and East Auburn Lake. After identifying the existing issues, the range of potential alternatives that might be used to address these releases were developed.

The alternatives developed for this project fell into one or more of three general categories: hydrologic modification, topographic modification, and chemical treatment. A total of seven alternatives were identified that might be implemented to address the release of phosphorus to varying extents. The estimated effectiveness of these alternatives was considered based on the assumption that the hypothesized cause of the phosphorus release was correct. These estimates of effectiveness were developed based on professional judgment and the mechanisms of release and export that were being addressed by the alternative.

Costs were estimated for each alternative based on the rough concepts the project developed. These cost estimates included a design and construction engineering estimate of 15-percent of the construction cost and a 30-percent construction contingency assuming potential work in wet conditions. Costs were prepared at the Class 4 level (Concept Study) as defined by the Association for the Advancement of Cost Engineering International (AACEI) for *Engineering, Procurement, and Construction for the Building and General Construction Industries* with a lower bound of -20 percent and an upper bound of +30 percent.

3.1. Hydrologic Restoration

This alternative involves the installation of a water level control structure at the downstream end of the Cell 1 Wetland. This control structure would be designed to allow water to be held in the marsh at or above the wetland bottom. The anticipated structure for this alternative is a sheet pile weir installed at the bridge between the Cell 1 and Cell 2 Wetlands. The rationale for this alternative is to prevent the complete dehydration of the marsh with associated oxidation of organic material and phosphorus release during re-hydration. This alternative would also keep water within the channelized portion of the wetland which would reduce the subsurface drainage of water through the marsh bottom to the channel. This is expected to reduce the transport of pore-water phosphorus to the channel that then flows downstream between events when the marsh is flooded. Depending on the level of inundation, this alternative may also increase the residence time of water in the wetland which may increase phosphorus removal in the marsh through plant uptake and particulate settling. Potential disadvantages of this alternative include making the marsh more anaerobic which could release iron-bound phosphorus and result in potential stage increases during storms.

Estimated costs for this alternative were $299,000 for the installation of a sheet pile weir across the marsh between Cell 1 and Cell 2 of the East Auburn Wetland. The conceptual cost estimate for Alternative 1 is shown in Table 3-1.

Table 3-1. Alternative 1 – Sheet Pile Weir Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 15,000	$ 15,000
2	CLEARING AND GRUBBING	AC	0.5	$ 15,000	$ 7,500
3	SHEETPILE (70'Lx15'D AND 50'Lx10'D)	SF	1,550	$ 75	$ 116,250
4	COMMON EXCAVATION	CY	40	$ 20	$ 800
5	RIPRAP	CY	40	$ 150	$ 6,000
6	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
7	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
8	VEGETATION ESTABLISHMENT	LS	1	$ 5,000	$ 5,000
				CONSTRUCTION SUBTOTAL	$ 170,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 34,000
				PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 26,000
				CONTINGENCY (30% ASSUMED)	$ 69,000
				TOTAL	**$ 299,000**
				LOW ESTIMATE (-20%)	$ 240,000
				HIGH ESTIMATE (+30%)	$ 390,000

3.2. Channel Elimination

This alternative involves backfilling the channel through the marsh to increase levels in the marsh, provide additional residence time, and reduce the pore-water flow subsurface through the marsh bottom into and downstream in the channel. This alternative is expected to reduce phosphorus by increasing residence time from spreading flow throughout the wetland rather than it being concentrated in the channel. This increases effective use of the marsh area for treatment and reduces pore water phosphorus transport in the channel between inundation events. Potential disadvantages include stage increases due to reduced conveyance capacity through the marsh and complexity with permitting that would be required to get approval to place fill in the wetland.

Estimated costs for this alternative were $211,000 and dominated by the cost to fill, assuming material would need to be brought in from offsite. This alternative also assumed the installation of three rip-rap ditch blocks to reduce the potential for water to erode the placed fill. The cost estimate is shown in Table 3-2.

Table 3-2. Alternative 2 – Backfilling Channel Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 11,000	$ 11,000
2	COMMON EXCAVATION (1200'Lx10'Wx3'D)	CY	1,500	$ 40	$ 60,000
3	RIPRAP (3X 10'Lx10'Wx3'D)	CY	33	$ 150	$ 5,000
4	IMPORT TOPSOIL	CY	300	$ 50	$ 15,000
5	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
6	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
7	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
				CONSTRUCTION SUBTOTAL	$ 120,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 24,000
				PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 18,000
				CONTINGENCY (30% ASSUMED)	$ 49,000
				TOTAL	**$ 211,000**
				LOW ESTIMATE (-20%)	$ 170,000
				HIGH ESTIMATE (+30%)	$ 280,000

3.3. Channel Elimination with In-Channel Treatment

This alternative is a modification of the previous alternative that would have the channel backfilled with an adsorptive material (*e.g.,* water treatment plant residuals). This alternative is expected to have the same benefits as the previous alternative, but with additional removal associated with adsorption on the channel fill. This also reduces the risk of continued pore-water drainage and preferential flow of water through the channel fill. Potential disadvantages are the same as those described for the previous alternative.

Estimated costs for this alternative were $370,000 with costs dominated by the cost to import fill with adsorptive capacity (e.g., water treatment plant residuals). The cost estimate is provided in Table 3-3.

Table 3-3. Alternative 3 – Backfilling Channel with Adsorptive Media Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 19,000	$ 19,000
2	MEDIA	CY	1,500	$ 100	$ 150,000
3	RIPRAP (3X 10'Lx10'Wx3'D)	CY	33	$ 150	$ 5,000
4	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
5	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
6	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
CONSTRUCTION SUBTOTAL					$ 210,000
DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)					$ 42,000
PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)					$ 32,000
CONTINGENCY (30% ASSUMED)					$ 86,000
TOTAL					$ 370,000
LOW ESTIMATE (-20%)					$ 300,000
HIGH ESTIMATE (+30%)					$ 490,000

3.4. Wetland Regrading

This alternative involves the re-grading of the entire Cell 1 Wetland. This would allow for improved hydraulics through the wetland, increased residence time, reduced phosphorus export and mobilization, and an expected increase in removal efficiency for water flowing through the system. This would also have the added benefit of allowing for a more desirable wetland plant community to be established. The primary removal associated with this alternative is increased treatment due to residence time and hydraulic efficiency and the reduction of pore-water phosphorus release by removal of the channel. Primary disadvantages of this alternative are anticipated capital cost, challenges of working in unstable soils in wet conditions, wetland disturbance, and permitting complexity required for altering the wetland. Improving the hydraulic efficiency and removal efficiency, however, may be masked by the effects of sediment phosphorus release and porewater export described in Section 2.

The estimated cost for this alternative was $1,226,000. The primary driver of this cost was the estimated cost to re-contour the wetland as shown in Table 3-4.

Table 3-4. Alternative 4 – Wetland Regrading Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 54,000	$ 54,000
2	DEWATERING	LS	1	$ 150,000	$ 150,000
3	CLEARING AND GRUBBING	AC	11.5	$ 10,000	$ 115,000
4	COMMON EXCAVATION (1.5'Dx11.5AC)	CY	27,830	$ 15	$ 417,450
5	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
6	WETLAND PLANTING	SY	55,660	$ 1	$ 55,660
CONSTRUCTION SUBTOTAL					$ 820,000
DESIGN AND CONSTRUCTION ENGINEERING (10% OF CONSTRUCTION COSTS ASSUMED)					$ 82,000
PERMITTING (5% OF CONSTRUCTION COSTS ASSUMED)					$ 41,000
CONTINGENCY (30% ASSUMED)					$ 283,000
TOTAL					**$ 1,226,000**
LOW ESTIMATE (-20%)					$ 990,000
HIGH ESTIMATE (+30%)					$ 1,600,000

3.5. Wetland Modification with Deep Zones

This alternative has similar goals to the previous alternative and involves back-filling the channel and excavating deep zones in the marsh. This would increase residence time and hydraulic efficiency which is expected to increase treatment and reduce pore water phosphorus release. Primary disadvantages include permitting complexity, capital cost, and degree of wetland disturbance.

The estimated costs for this alternative were $683,000. The cost estimate is provided in Table 3-5.

Table 3-5. Alternative 5 – Wetland Deep Zones Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 38,000	$ 38,000
2	DEWATERING	LS	1	$ 100,000	$ 100,000
3	CLEARING AND GRUBBING	AC	1.5	$ 15,000	$ 22,500
4	COMMON EXCAVATION	CY	5,000	$ 40	$ 200,000
5	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
6	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
7	VEGETATION ESTABLISHMENT	LS	1	$ 20,000	$ 20,000
CONSTRUCTION SUBTOTAL					$ 420,000
DESIGN AND CONSTRUCTION ENGINEERING (15% OF CONSTRUCTION COSTS ASSUMED)					$ 63,000
PERMITTING (10% OF CONSTRUCTION COSTS ASSUMED)					$ 42,000
CONTINGENCY (30% ASSUMED)					$ 158,000
TOTAL					**$ 683,000**
LOW ESTIMATE (-20%)					$ 550,000
HIGH ESTIMATE (+30%)					$ 890,000

3.6. Sediment Treatment

This alternative involves the treatment of the wetland area with an adsorptive amendment such as alum solution. This alternative could include treatment across the entire marsh, or just within and adjacent to the channel. This alternative would provide treatment by binding phosphorus that is released from sediments and to a lesser degree binding phosphorus in water that flows through the marsh near the sediment interface. The primary challenge of this alternative is an application method that would ensure that the amendment reached the sediment given the density of the vegetation in the marsh. Disadvantages of this alternative are potential impacts to the benthic community and capital cost depending on application rate and wetland preparation for treatment (burning, mowing, etc.).

The following assumptions were used to develop the estimated alum requirement:

- Average mobile phosphorus concentration in 0-30 cm sediment layer = 0.385 mg/g
- Dry density of 0-30 cm sediment layer = 0.381 g/cm^3
- Effective sediment treatment depth = 10 cm
- Molar alum dose (moles Al:P) = 10:1
- %Al in bulk alum solution = 4.4%
- Bulk alum solution density = 11.1 lb/gal

Two cost estimates were developed for this alternative. The first assumed wetland wide sediment treatment with mowing of the wetland in advance of application. This cost was estimated to be $592,000 as shown in Table 3-6.

Table 3-6. Alternative 6a – Sediment Treatment Whole Wetland Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 17,000	$ 17,000
2	WETLAND MOWING	AC	11.5	$ 5,000	$ 57,500
3	ALUM TREATMENT	GAL	36,600	$ 6	$ 219,600
4	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
5	VEGETATION ESTABLISHMENT	LS	1	$ 25,000	$ 25,000
CONSTRUCTION SUBTOTAL					$ 350,000
DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)					$ 70,000
PERMITTING (10% OF CONSTRUCTION COSTS ASSUMED)					$ 35,000
CONTINGENCY (30% ASSUMED)					$ 137,000
TOTAL					$ 592,000
LOW ESTIMATE (-20%)					$ 480,000
HIGH ESTIMATE (+30%)					$ 770,000

The second scenario was treatment of just the channel and assumed the channel area comprised 10% of the total area. The estimated cost for this scenario was $71,000. The cost estimate for this scenario is provided in Table 3-7.

Table 3-7. Alternative 6b – Sediment Treatment Channel Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 4,000	$ 4,000
2	ALUM TREATMENT	GAL	3,660	$ 6	$ 21,960
3	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
4	VEGETATION ESTABLISHMENT	LS	1	$ 10,000	$ 10,000
				CONSTRUCTION SUBTOTAL	$ 40,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 8,000
				PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 6,000
				CONTINGENCY (30% ASSUMED)	$ 17,000
				TOTAL	**$ 71,000**
				LOW ESTIMATE (-20%)	$ 60,000
				HIGH ESTIMATE (+30%)	$ 100,000

3.7. Inflow or Outflow Alum Treatment

This alternative would use an alum feed system to provide continuous treatment of flows coming into or out of the wetland. This would reduce concentrations of phosphorus in the water column. This would provide treatment for both phosphorus in the water and potential sediment release. The primary disadvantage of this alternative is a feed system that adequately mixes the alum in the water to be treated and the operation and maintenance associated with an alum feed system. There is also the potential for generation of floc that may accumulate downstream in the wetland and require maintenance.

The estimated cost for this alternative was $1,016,000. Costs evaluated for the alum treatment system were based on the average cost for alum treatment systems (Harper & Herr, 1998) with price escalated from 1998 to 2023 using the Consumer Price Index. These systems are highly site dependent and can have significant variations in price based on the level of infrastructure needed to measure flows, supply power, inject the alum, ensure adequate mixing, and capture floc for removal. The estimated costs are shown in Table 3-8.

Table 3-8. Alternative 7 – Alum Treatment System Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 54,000	$ 54,000
2	CIVIL SITE IMPROVEMENTS	LS	1	$ 50,000	$ 50,000
3	ALUM TREATMENT SYSTEM	LS	1	$ 500,000	$ 500,000
4	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
5	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
				CONSTRUCTION SUBTOTAL	$ 650,000
				DESIGN AND CONSTRUCTION ENGINEERING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 98,000
				PERMITTING (5% OF CONSTRUCTION COSTS ASSUMED)	$ 33,000
				CONTINGENCY (30% ASSUMED)	$ 235,000
				TOTAL	**$ 1,016,000**
				LOW ESTIMATE (-20%)	$ 820,000
				HIGH ESTIMATE (+30%)	$ 1,330,000

4. Alternatives Analysis

4.1. Ranking Criteria

Following development of the available alternatives, each alternative was scored for each of 10 criteria that address the project and permitting complexity, project impacts, expected degree of success, costs, and risk. Each of the evaluated criteria are briefly discussed in the following sections. Regardless of specific criterion evaluation methodology, a higher quantitative score corresponds to a qualitatively better outcome, or easier practice to implement.

4.1.1. Wetland Impacts

Each of these alternatives is expected to have some degree of impact on the existing Cell 1 Wetland. This criterion considered a smaller degree of impact more favorable with a higher score equating to less impact. Alternatives that were expected to have substantial impacts on vegetation and modification of the wetland surface from excavation or fill were scored a one, while those with impacts affecting only a small area (<0.1 acres) or no area scored a three, and alternatives between these scored a two.

4.1.2. Permitting Complexity

Since the proposed project is in a wetland that is designated as a Minnesota Department of Natural Resources Public Water and regulated by multiple local, state, and federal agencies, it is expected that the alternatives that were developed will require some level of permitting approval to implement. It is also assumed that alternatives would generally need to maintain or improve the function of the wetland in order to not be determined as an impact to wetland that could potentially require mitigation. This criterion evaluates the expected degree of permitting that will be required and the anticipated difficulty of the associated permitting with a higher score equating to easier permitting. Alternatives that were expected to have challenging permitting were scored a one, alternatives with little expected permitting were scored a three, and others were scored a two.

4.1.3. Engineering Complexity

This criterion considers the expected degree of engineering complexity associated with project implementation. A high score for this criterion is associated with projects that are expected to be less complex to develop. As with permitting, alternatives that required significant engineering complexity were scored a one, those with little required engineering were scored a three, and others scored a two.

4.1.4. Phosphorus Export Reduction

The developed alternatives are expected to have a range of effectiveness for phosphorus retention and/or removal. Based on the data analysis completed it appears that a majority of the phosphorus being exported from this system is internally generated and released during periods when the wetland experiences intermittent inundation. This criterion considers the expected degree of phosphorus export reduction with high reductions having a high score. Alternatives that were estimated to reduce export by 50% or more were scored a three, those with expected reductions of 20-50% were scored a two, and others were scored a one.

4.1.5. Capital Costs

Each of the presented alternatives will have a capital cost associated with its development. This criterion considers the expected cost associated with construction of the proposed alternative with a high score equating to a lower capital cost. Alternatives with an estimated cost greater than $800,000 received a one, between $400,000-$800,000 received a two, and less than $400,000 received a three.

4.1.6. Operations and Maintenance Costs

Once constructed, each of the proposed alternatives is expected to have varying degrees of operations and maintenance costs. This criterion considers the expected degree of ongoing costs associated with the project with a higher score for projects with expected lower costs.

4.1.7. Reduction Time Scale

Not all of the evaluated alternatives will provide a reduction on the same time scale. This criterion evaluates the expected duration before phosphorus reductions would be expected with a higher score equating to a quicker expected reduction. Alternatives with an expected two year or greater lag received a one, one to two years received a two, and a less than one year lag received a three.

4.1.8. Risk

There are unknowns associated with the alternatives that could result in different than expected outcomes. This criterion describes the expected risk associated with the alternatives. Alternatives with a high degree of uncertainty received a one, those with a moderate degree of uncertainty received a two, and those that would be expected to perform well regardless of the cause of the export received a three.

4.1.9. Ability to Mitigate Risk

Some of the evaluated alternatives have the potential to mitigate risks associated with their implementation (e.g., making weir plates removable so levels in the marsh can be adjusted if too high or too low). This criterion considers the ability to modify the alternative once implemented to reduce potential adverse outcomes. Alternatives with limited potential for mitigation received a one, those with some degree of ability to mitigate received a two, and those with one or more options for mitigation received a three.

4.2. Alternatives Matrix

For each of the considered alternatives the evaluated criteria were ranked on the three-point scale with a higher score signifying the desirable outcome (i.e. lower risk, lower complexity, lower cost, etc.). Scores on each criterion were then summed to yield a total score for each alternative. These scores were then used to rank the projects from best to worst with the highest scoring project receiving the highest score. The alternatives matrix is shown in Table 4-1, ranked in order of score from high to low. In addition to the alternatives matrix, estimated TP export reductions were developed for each alternative. These values were estimated based on professional judgement and the mechanisms of export being addressed by each alternative. The estimated export reductions for each alternative are shown in Table 4-2. Estimated reductions ranged from 20-80% for the evaluated alternatives.

Based on the scoring criteria and ranking, manipulating hydrology through installation of sheet pile was the highest-ranked option. The next highest-ranked alternative was sediment treatment with alum. The highest estimated export reduction was for alum treatment of inflow water, followed by sediment treatment, with manipulating hydrology in third.

Though this methodology provides an absolute ranking, it should be considered that the differences in the first ranked option (sheet pile weir) and the fourth ranked option (alum treatment system) is only three ranking points. However, the difference between the first ranked option and the seventh ranked option (regrading entire wetland) is 12 ranking points. Based on this method and detail of analysis, it can be said with high confidence that the sheet pile alternative is a better alternative than regrading the entire wetland. However, it is less clear whether the sheet pile is absolutely the better alternative than treating the channel or entire wetland with an adsorptive material (second ranked alternatives). Rather, it can be concluded that the top four alternatives likely would be better than the bottom three alternatives.

MCWD can use this ranking matrix to consider which alternative to pursue, based on MCWD specific parameters. The current ranking methodology weights each criterion equally. For example, if the initial capital costs are not a concern, and the highest degree of TP treatment is desired, this shifts alum treatment of the water ahead of the sheet pile or sediment treatment alternatives. Finally, combinations of alternatives were not considered in the ranking, but the MCWD could choose to implement multiple alternatives to address the same or different mechanisms and increase the likelihood of successfully reducing phosphorus export from the wetland.

Table 4-1. Alternatives Ranking Matrix

No.	Alternative	Description	Wetland Impacts	Permitting Complexity	Engineering Complexity	TP Export Reduction	Capital Costs	O&M Costs	Reduction Time Scale	Risk	Ability to Mitigate Risk	Total Score	Rank
1	Manipulate Hydrology	Outlet water level control structure	3	2	3	2	3	3	2	2	3	23	1
6	Sediment Treatment	Adsorptive treatment of sediments	2	2	3	3	2	3	3	2	2	22	2
3	Channel Treatment	Fill channel with adsorptive media	2	1	3	2	3	3	3	3	1	21	3
7	Inflow/Outflow Alum Treatment	Alum treatment of water	3	2	1	3	1	1	3	3	3	20	4
2	Channel Elimination	Fill channel	2	1	3	1	3	3	2	2	1	18	5
5	Topographic Modification	Deep zones and fill channel	1	1	2	1	2	3	1	2	1	14	6
4	Topographic Modification	Regrade wetland	1	1	1	1	1	3	1	1	1	11	7

Table 4-2. Estimated Export Reduction for Evaluated Alternatives

No.	Alternative	Description	Est. Export Reduction
1	Manipulate Hydrology	Outlet water level control structure	50%
2	Channel Elimination	Fill channel	20%
3	Channel Treatment	Fill channel with adsorptive media	35%
4	Topographic Modification	Regrade wetland	30%
5	Topographic Modification	Deep zones and fill channel	25%
6	Sediment Treatment	Adsorptive treatment of sediments	70%
7	Inflow/Outflow Alum Treatment	Alum treatment of water	80%

5. Hydraulic Evaluation

To evaluate the potential implications of manipulating hydrology the project team requested a copy of the District's XPSWMM stormwater model to better understand the wetland's hydraulic behavior under existing and proposed conditions. The project team truncated the District's model, updated it based on previously collected survey information, and subdivided the wetland into its four cells, as the provided model considered the entire wetland complex as a single cell. New, cell-specific storage curves were developed using a combination of previously collected survey data and LiDAR. Hydraulic connections from one cell to another were input based on survey information. Overflows between the cells were modeled based on LiDAR, where survey information was unavailable. Hydrologic inputs were updated to reflect the smaller, cell-specific drainage area. However, area was the only input parameter that was changed for the hydrologic components; watershed percent impervious, widths, and soils information were not altered.

The model was executed for the 100-year event to understand high water levels in the wetland, and adjacent waterbodies. The project team then developed a series of conceptual proposed conditions to determine what effect manipulating the runout elevation of the wetland would have on the wetland and adjacent waterbodies, assuming a sheet pile weir structure would be constructed to modify the wetland's runout elevation. Sheet pile widths varied from 10-feet wide to 500-feet wide, and elevations varied from 943.0 to 944.5. The intent of developing a series of models across this range of values is not to suggest that a 500-foot-wide sheet pile weir should be constructed. Rather, this is to provide a data point beyond what is a reasonable project, such that it can be understood how the system functions, and direct discussions such as: "if the objective is to raise the wetland's normal water level as high as possible, how wide of a weir is necessary such that the floodplain is unaltered?".

The extent of the area evaluated included Wasserman Lake to the south, Carl Krey Lake to the west, and Lake Auburn to the north. Table 5-1 summarizes existing high-water levels, and the assumed design constraints for the points of analysis.

Table 5-1: Assumed High Water Level Constraints

Comment	Existing 100-yr HWL	Assumed Maximum Elevation	Constraint Comment
Wasserman Lake	946.60	946.60	No-rise is required; in Zone A
Carl Krey Lake	945.99	945.99	No-rise is required; in Zone A
Lake Auburn	942.51	942.51	No-rise is required; in Zone A
Cell 1	945.23	950.00	No floodplain; cannot flood residents
Cell 2	945.23	946.00	No floodplain; cannot flood residents
Cell 3	944.66	944.66	No floodplain; existing HWL on private property; default to no-rise
Cell 4	944.66	944.66	No floodplain; existing HWL on private property; default to no-rise

Under existing conditions, the wetland (Cell 1) overflows at an elevation of 942.25. Based on the conceptual sheet pile model runs, this runout elevation could be raised to approximately 944.0 and still achieve the design criteria listed above. To achieve no-rise conditions on Wasserman Lake and maintain a runout elevation of 944.0, a sheet pile weir of between 25- to 50-feet would be required. A shorter length of sheet pile would be feasible if the proposed runout elevation is less than 944.0. These finer details would be addressed depending on the exact elevation and configuration desired, as part of a final design.

6. Conclusions and Recommendations

The Cell 1 Wetland located at the upstream end of the East Auburn Wetland Complex has been identified as the likely source of elevated total phosphorus (TP) loads to East Auburn Lake. This study collected and evaluated available water quality, flow, level, and sediment data for the Cell 1 Wetland and wetland complex with the goal of identifying the likely source of this TP loading.

Based on that evaluation, the dominant mechanisms that appear to contribute to the export of TP are decreased water levels in early summer that result in the wetland drying out. These dry outs result in subsurface drainage of the marsh to the channel which transports TP, primarily as ortho-phosphorus (OP), to the channel where it flows out or is flushed out during summer storm events. This dehydration of the wetland also results in mobilization of labile organic phosphorus in the sediments which is flushed out during these same rainfall and flow events.

To develop recommendations, this study considered seven potential alternative management strategies. These alternatives were ranked based on nine criteria and estimated TP export reductions were developed. Each of these alternatives had estimated capital costs developed to implement the projects. From the alternatives ranking and reduction estimates there were two alternatives that tied for the highest rank and had similar reduction estimates and capital costs. The recommended alternative is restoration of hydrology through installation of a sheet pile weir between the Cell 1 and Cell 2 Wetlands.

This weir would be constructed to reduce the short-circuiting and drainage of water with higher phosphorus concentrations through the channel in the marsh during the summer months when this system dries out. It is recommended that this weir include weir plates that can be removed in the event that elevated phosphorus concentrations occur due to the release of iron-bound phosphorus and anaerobic conditions.

To further reduce the potential for release, a second alternative could be applied in concert with hydrologic restoration. This recommended alternative is either sediment treatment with alum solution across the wetland or application of sediment treatment media within the channel. Either would reduce the export of phosphorus from subsurface drainage to the channel and would reduce the likelihood of sediment release associated with increasing the wetland hydroperiod and anaerobic conditions.

To provide additional information that can be used to advance a final design this study would recommend collection of continuous flow and level data at the inlet to the Cell 1 Wetland and continued collection of water quality samples at CSI12, CSI05, and CSI22. Additionally, it is recommended that drone-based LiDAR topography, supplemented with ground-based survey be collected to improve the understanding of the wetland bathymetry to guide design of a sheet pile weir. The optimal timing of this data collection would be during mid- to late-summer when the wetland water levels are very low.

7. References

Beck, B. (2019). *East Auburn Wetland Phosphorus Analysis* (p. 6) [Technical Memorandum]. Minnehaha Creek Watershed District.

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Appendix A

Stormwater Sampling Statistics

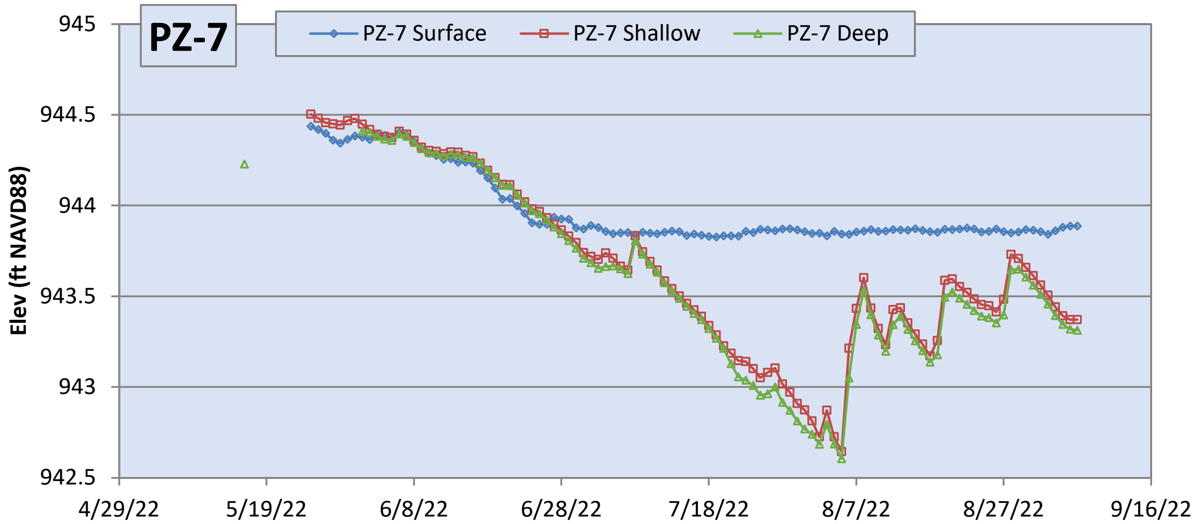
Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
Temp	C	CSI05	15.2	-0.06	28.8	7.60	508	Apr-09	Jun-22
		CSI12	16.9	0.00	30.2	7.81	451	Apr-09	Jun-22
		CSI19	15.7	0.00	27.2	8.86	27	May-20	Oct-21
		CSI22	14.4	0.00	27.1	8.82	33	May-20	Jun-22
		SW-1	23.4	21.9	25.5	1.51	4	Jun-22	Jul-22
		SW-2	23.4	22.1	24.5	1.08	4	Jun-22	Jul-22
		SW-3	20.4	19.0	20.9	0.93	4	Jun-22	Jul-22
		SW-4	21.1	20.3	22.2	0.84	4	Jun-22	Jul-22
DO	%	SW-1	4.16	0.14	8.52	3.93	4	Jun-22	Jul-22
		SW-2	4.39	0.16	8.51	4.15	4	Jun-22	Jul-22
		SW-3	4.03	0.33	8.60	4.09	4	Jun-22	Jul-22
		SW-4	3.71	0.52	8.33	3.69	4	Jun-22	Jul-22
	mg/L	CSI05	4.00	0.00	20.9	3.39	508	Apr-09	Jun-22
		CSI12	6.83	0.00	27.3	4.55	451	Apr-09	Jun-22
		CSI19	3.72	0.00	10.8	3.20	34	Jul-19	Oct-21
		CSI22	5.66	0.00	49.4	8.74	33	May-20	Jun-22
pH	SU	CSI05	7.34	4.25	9.10	0.42	487	Apr-09	Jun-22
		CSI12	7.98	6.68	17.1	0.79	435	Apr-09	Jun-22
		CSI19	7.54	7.28	7.99	0.21	23	May-20	Oct-21
		CSI22	7.56	6.92	8.49	0.43	27	May-20	Jun-22
		SW-1	7.39	6.76	7.98	0.65	4	Jun-22	Jul-22
		SW-2	7.43	6.68	8.18	0.83	4	Jun-22	Jul-22
		SW-3	6.61	6.44	6.76	0.16	3	Jun-22	Jul-22
		SW-4	7.54	7.15	8.25	0.61	3	Jun-22	Jul-22
Cond	uS/cm	CSI05	404	244	745	57.3	500	Apr-09	Jun-22
		CSI12	356	233	621	35.2	444	Apr-09	Jun-22
		CSI19	392	314	487	45.6	23	May-20	Oct-21
		CSI22	420	292	755	98.0	28	May-20	Jun-22
		SW-1	461	352	610	129	4	Jun-22	Jul-22
		SW-2	445	338	557	119	4	Jun-22	Jul-22
		SW-3	495	352	598	111	4	Jun-22	Jul-22
		SW-4	488	345	705	174	4	Jun-22	Jul-22
ORP	mV	SW-1	-38.3	-136	34.7	75.3	4	Jun-22	Jul-22
		SW-2	-4.83	-37.6	13.3	22.6	4	Jun-22	Jul-22
		SW-3	-30.8	-132	86.3	110	3	Jun-22	Jul-22
		SW-4	-39.4	-78.0	-6.50	36.1	3	Jun-22	Jul-22
TSS	mg/L	CSI05	7.31	0.50	268	27.6	100	Apr-09	Dec-15
		CSI12	8.80	0.50	104	11.7	100	Apr-09	Dec-15
Chloride	mg/L	CSI05	36.1	19.8	104	14.8	50	Apr-09	Nov-15
		CSI12	26.9	21.0	39.3	2.99	52	Apr-09	Dec-15

Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
TFE	mg/L	SW-1	1.35	0.11	3.42	1.56	4	Jun-22	Jul-22
		SW-2	2.92	0.09	7.15	3.43	4	Jun-22	Jul-22
		SW-3	2.74	0.11	7.44	3.46	4	Jun-22	Jul-22
		SW-4	1.41	0.08	2.97	1.51	4	Jun-22	Jul-22
TP	mg/L	CSI05	0.12	0.03	1.12	0.12	500	Apr-09	Jun-22
		CSI12	0.08	0.02	0.36	0.04	440	Apr-09	Jun-22
		CSI19	0.10	0.03	0.51	0.09	31	Jul-19	Oct-21
		CSI22	0.09	0.03	0.18	0.05	28	May-20	Jun-22
		SW-1	0.11	0.05	0.26	0.10	4	Jun-22	Jul-22
		SW-2	0.43	0.04	1.08	0.49	4	Jun-22	Jul-22
		SW-3	0.59	0.04	1.76	0.81	4	Jun-22	Jul-22
		SW-4	0.22	0.01	0.44	0.23	4	Jun-22	Jul-22
OP	mg/L	CSI05	0.04	0.00	0.19	0.03	460	Apr-09	Jun-22
		CSI12	0.01	0.00	0.11	0.01	440	Apr-09	Jun-22
		CSI19	0.04	0.00	0.23	0.04	31	Jul-19	Oct-21
		CSI22	0.03	0.00	0.11	0.03	28	May-20	Jun-22
		SW-1	0.03	0.02	0.04	0.01	4	Jun-22	Jul-22
		SW-2	0.03	0.02	0.03	0.00	4	Jun-22	Jul-22
		SW-3	0.03	0.02	0.04	0.01	4	Jun-22	Jul-22
		SW-4	0.03	0.01	0.05	0.02	4	Jun-22	Jul-22
TN	mg/L	CSI05	1.21	0.30	4.49	0.58	151	Apr-09	Jun-22
		CSI12	1.63	0.50	5.13	0.65	142	Apr-09	Jun-22
		CSI19	1.22	0.50	2.50	0.43	28	Aug-19	Oct-21
		CSI22	1.38	0.60	3.60	0.65	28	May-20	Jun-22
		SW-1	2.76	0.88	6.64	2.71	4	Jun-22	Jul-22
		SW-2	2.61	0.85	5.30	2.13	4	Jun-22	Jul-22
		SW-3	2.33	0.78	4.43	1.83	4	Jun-22	Jul-22
		SW-4	2.36	0.76	4.57	1.89	4	Jun-22	Jul-22
TKN	mg/L	CSI05	1.29	0.73	2.54	0.40	43	Apr-09	Nov-15
		CSI12	1.70	0.82	2.43	0.37	42	Apr-09	Dec-15
NO3-N	mg/L	CSI05	0.07	0.02	0.41	0.12	43	Apr-09	Nov-15
		CSI12	0.19	0.02	3.69	0.57	42	Apr-09	Dec-15
Flow	cfs	CSI05	4.11	-0.12	28.1	4.91	542	Apr-09	Aug-22
		CSI12	4.09	0.00	42.5	5.57	492	Apr-09	Aug-22
Elevation	ft NAVD88	Wasserman	944.8	938.0	947.2	0.72	790	Aug-64	Nov-22
		Creek	943.1	942.7	944.2	0.33	9,005	Jun-22	Sep-22
		CSI05	941.8	941.1	944.2	0.43	78	Mar-16	Jul-22
		SW-1	943.4	943.0	943.9	0.46	4	Jun-22	Jul-22
		SW-2	943.5	943.1	944.0	0.45	4	Jun-22	Jul-22
		SW-3	943.5	943.1	944.0	0.47	4	Jun-22	Jul-22

Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
		SW-4	943.7	943.2	944.4	0.59	4	Jun-22	Jul-22

Appendix B

Detailed Water Level Data


PZ-7
PZ-7 Surface
PZ-7 Shallow
PZ-7 Deep
Elev (ft NAVD88)
945
944.5
944
943.5
943
942.5
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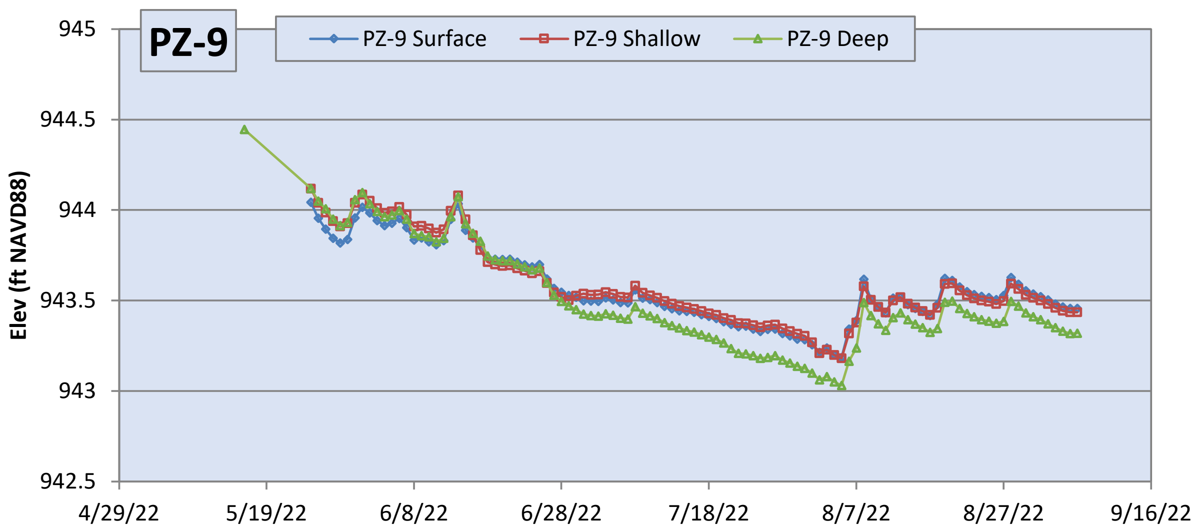
5/19/22
6/8/22
6/28/22
7/18/22
8/7/22
8/27/22
9/16/22


PZ-9
PZ-9 Surface
PZ-9 Shallow
PZ-9 Deep
Elev (ft NAVD88)
945
944.5
944
943.5
943
942.5
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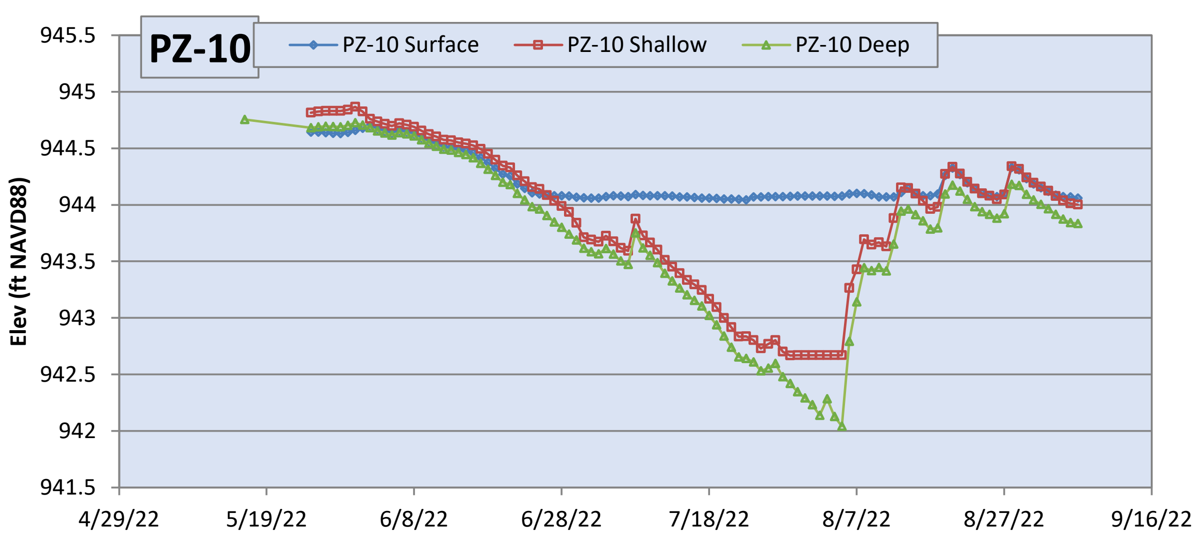
8/27/22
9/16/22


PZ-10
PZ-10 Surface
PZ-10 Shallow
PZ-10 Deep
Elev (ft NAVD88)
945.5
945
944.5
944
943.5
943
942.5
942
941.5
4/29/22
5/19/22
6/8/22
6/28/22
7/18/22
8/7/22
8/27/22
9/16/22

Appendix C

Sediment Sampling Data

STN	Depth	Phosphorus Loosely-bound mg/g	Fe-bound mg/g	Labile organic mg/g	Mobile Pool mg/g	Al-bound mg/g	Ca-bound mg/g	Refractory Organic mg/g	Permanent Pool mg/g	Total mg/g	Organic Content %	Moisture Content %	Dry Density g/cm^3	Wet Density g/cm^3
PZ-1	Surface	0.043	0.050	0.516	0.609	0.151	0.065	0.00	0.216	0.813	53.5	75.1	0.285	1.08
	Shallow	0.003	0.019	0.510	0.532	0.192	0.018	0.260	0.469	1.00	69.1	76.4	0.266	1.05
	Deep	0.024	0.031	0.003	0.058	0.092	0.056	0.212	0.360	0.418	75.4	84.1	0.171	1.02
PZ-2	Surface	0.010	0.026	0.311	0.347	0.082	0.030	0.369	0.481	0.828	42.1	70.1	0.357	1.12
	Shallow	0.030	0.018	0.135	0.183	0.108	0.010	0.341	0.459	0.642	80.3	80.1	0.218	1.02
	Deep	0.016	0.035	0.003	0.054	0.105	0.071	0.074	0.250	0.304	43.9	77.9	0.251	1.08
PZ-7	Surface	0.002	0.024	0.183	0.209	0.077	0.010	0.433	0.520	0.729	11.8	41.4	0.907	1.47
	Shallow	0.003	0.023	0.190	0.216	0.132	0.015	0.074	0.221	0.437	81.1	83.6	0.177	1.02
	Deep	0.022	0.032	0.058	0.112	0.086	0.024	0.357	0.466	0.578	76.9	86.9	0.139	1.02
PZ-9	Surface	0.010	0.030	0.178	0.218	0.074	0.034	0.261	0.369	0.587	55.6	81.9	0.200	1.05
	Shallow	0.029	0.023	0.330	0.382	0.138	0.037	0.068	0.243	0.625	75.3	88.9	0.117	1.02
	Deep	0.016	0.027	0.229	0.272	0.097	0.045	0.221	0.363	0.635	56.6	92.6	0.077	1.02
PZ-10	Surface	0.003	0.022	0.523	0.548	0.114	0.036	0.535	0.684	1.23	64.8	75.6	0.277	1.06
	Shallow	0.003	0.016	0.238	0.257	0.084	0.024	0.131	0.238	0.495	85.6	80.4	0.214	1.02
	Deep	0.033	0.029	0.021	0.083	0.043	0.028	0.221	0.292	0.375	84.5	90.4	0.100	1.01
PZ-12	Surface	0.002	0.035	0.331	0.368	0.127	0.020	0.212	0.359	0.727	48.4	74.0	0.302	1.09
	Shallow	0.002	0.014	0.092	0.108	0.040	0.009	0.529	0.577	0.685	33.4	62.4	0.477	1.18
	Deep	0.025	0.021	0.031	0.077	0.047	0.024	0.290	0.361	0.438	86.9	87.3	0.134	1.01
PZ-13	Surface	0.010	0.046	0.295	0.351	0.086	0.052	0.263	0.400	0.751	60.3	76.6	0.265	1.06
	Shallow	0.002	0.053	0.233	0.288	0.125	0.034	0.086	0.245	0.533	32.5	66.8	0.408	1.16
	Deep	0.022	0.039	0.130	0.191	0.073	0.019	0.267	0.359	0.550	81.3	86.2	0.147	1.02
PZ-14	Surface	0.018	0.074	0.257	0.349	0.062	0.075	0.062	0.199	0.548	31.4	64.2	0.450	1.18
	Shallow	0.002	0.026	0.184	0.212	0.066	0.049	0.549	0.663	0.875	36.5	68.0	0.389	1.14
	Deep	0.029	0.033	0.052	0.114	0.047	0.030	0.396	0.472	0.586	90.4	88.2	0.124	1.01
PZ-15	Surface	0.002	0.023	0.435	0.460	0.118	0.026	0.186	0.330	0.790	39.4	68.2	0.385	1.13

STN	Depth	Phosphorus Loosely-bound mg/g	Fe-bound mg/g	Labile organic mg/g	Mobile Pool mg/g	Al-bound mg/g	Ca-bound mg/g	Refractory Organic mg/g	Permanent Pool mg/g	Total mg/g	Organic Content %	Moisture Content %	Dry Density g/cm^3	Wet Density g/cm^3
	Shallow	0.023	0.015	0.166	0.204	0.097	0.020	0.225	0.342	0.546	85.8	84.1	0.171	1.01
	Deep	0.026	0.024	0.017	0.067	0.061	0.031	0.232	0.324	0.391	91.1	87.4	0.133	1.01
SW-1	Stream	0.039	0.305	0.262	0.606	0.104	0.062	0.000	0.166	0.700	28.4	71.6	0.340	1.14
SW-2	Stream	0.021	0.104	0.192	0.317	0.078	0.078	0.230	0.386	0.703	43.2	90.0	0.106	1.04
SW-3	Stream	0.024	0.072	0.216	0.312	0.098	0.090	0.301	0.490	0.802	38.9	83.2	0.185	1.07
SW-4	Stream	0.024	0.091	0.091	0.206	0.045	0.126	0.093	0.264	0.470	15.2	53.4	0.646	1.32

Appendix D

Groundwater Sampling Statistics

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
Temp	C	PZ-1	Surface	21.8	17.1	26.6	6.74	2	Jun-22	Jun-22
			Shallow	17.5	13.9	22.4	3.16	6	Jun-22	Aug-22
			Deep	10.8	7.80	13.1	2.20	7	May-22	Aug-22
		PZ-2	Surface	19.0	17.8	20.2	1.70	2	Jun-22	Jun-22
			Shallow	13.7	9.30	17.5	3.19	5	Jun-22	Jul-22
			Deep	9.23	5.30	13.0	2.69	8	May-22	Aug-22
		PZ-3	Surface	20.4	17.4	23.5	4.36	2	Jun-22	Jun-22
			Shallow	16.8	11.1	21.5	3.31	7	Jun-22	Aug-22
			Deep	8.99	4.72	12.0	2.72	8	May-22	Aug-22
		PZ-4	Surface	20.7	17.6	23.8	4.40	2	Jun-22	Jun-22
			Shallow	16.5	9.83	21.3	3.53	7	Jun-22	Aug-22
			Deep	9.71	5.53	13.4	2.97	8	May-22	Aug-22
		PZ-5	Surface	18.5	16.1	20.9	3.39	2	Jun-22	Jun-22
			Shallow	15.7	11.2	18.2	3.09	5	Jun-22	Jul-22
			Deep	8.42	5.07	12.3	2.39	8	May-22	Aug-22
		PZ-6	Surface	21.8	21.8	21.8	---	1	Jun-22	Jun-22
			Shallow	18.0	15.7	20.5	1.77	5	Jun-22	Aug-22
			Deep	11.8	8.36	15.5	2.31	7	May-22	Aug-22
		PZ-7	Surface	18.5	17.7	19.3	1.14	2	Jun-22	Jun-22
			Shallow	15.9	9.07	18.9	3.75	7	Jun-22	Aug-22
			Deep	9.57	4.86	13.5	3.15	8	May-22	Aug-22
		PZ-8	Deep	6.52	6.52	6.52	---	1	May-22	May-22
		PZ-9	Surface	21.2	18.7	25.6	2.47	7	Jun-22	Aug-22
			Shallow	16.0	13.3	17.3	1.41	6	Jun-22	Aug-22
			Deep	9.03	6.07	11.8	2.03	8	May-22	Aug-22
		PZ-10	Surface	20.2	19.8	20.6	0.57	2	Jun-22	Jun-22
			Shallow	16.7	12.4	18.9	2.44	6	Jun-22	Aug-22
			Deep	10.1	5.25	13.8	3.11	8	May-22	Aug-22
		PZ-11	Surface	12.5	10.4	14.0	1.87	3	Jun-22	Aug-22
		PZ-12	Surface	19.2	18.0	20.0	0.94	4	Jun-22	Aug-22
			Shallow	17.0	11.3	19.8	3.08	7	Jun-22	Aug-22
			Deep	9.39	5.26	14.3	3.15	9	May-22	Aug-22
		PZ-13	Surface	17.9	12.8	23.4	4.61	4	Jun-22	Aug-22
			Shallow	16.8	12.0	20.7	3.42	6	Jun-22	Aug-22
			Deep	10.0	4.83	15.8	3.47	8	May-22	Aug-22
		PZ-14	Surface	16.5	16.5	16.5	---	1	Jun-22	Jun-22
			Shallow	16.7	13.1	19.5	2.74	5	Jun-22	Aug-22
			Deep	8.90	5.53	12.1	2.37	8	May-22	Aug-22
		PZ-15	Surface	19.3	18.6	20.5	1.07	3	Jun-22	Aug-22
			Shallow	16.5	11.2	19.2	3.11	6	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	8.65	4.91	12.7	2.75	8	May-22	Aug-22
DO	mg/L	PZ-1	Surface	3.98	0.85	7.11	4.43	2	Jun-22	Jun-22
			Shallow	0.98	0.41	2.04	0.60	6	Jun-22	Aug-22
			Deep	0.37	0.16	0.59	0.16	7	May-22	Aug-22
		PZ-2	Surface	0.63	0.56	0.70	0.10	2	Jun-22	Jun-22
			Shallow	0.26	0.16	0.37	0.10	5	Jun-22	Jul-22
			Deep	0.17	-0.10	0.70	0.25	8	May-22	Aug-22
		PZ-3	Surface	2.42	1.93	2.91	0.69	2	Jun-22	Jun-22
			Shallow	1.44	0.37	6.17	2.10	7	Jun-22	Aug-22
			Deep	0.41	0.11	1.05	0.35	8	May-22	Aug-22
		PZ-4	Surface	0.44	0.33	0.54	0.15	2	Jun-22	Jun-22
			Shallow	0.59	0.16	0.98	0.32	7	Jun-22	Aug-22
			Deep	0.23	0.09	0.39	0.11	8	May-22	Aug-22
		PZ-5	Surface	2.00	1.17	2.82	1.17	2	Jun-22	Jun-22
			Shallow	0.37	0.20	0.60	0.15	5	Jun-22	Jul-22
			Deep	0.16	0.00	0.50	0.18	8	May-22	Aug-22
		PZ-6	Surface	0.26	0.26	0.26	---	1	Jun-22	Jun-22
			Shallow	0.79	0.23	1.87	0.67	5	Jun-22	Aug-22
			Deep	0.34	0.01	0.61	0.20	7	May-22	Aug-22
		PZ-7	Surface	0.23	0.20	0.26	0.04	2	Jun-22	Jun-22
			Shallow	0.83	0.30	1.24	0.29	7	Jun-22	Aug-22
			Deep	0.46	0.12	0.83	0.30	8	May-22	Aug-22
		PZ-8	Deep	0.12	0.12	0.12	---	1	May-22	May-22
		PZ-9	Surface	1.68	0.51	4.38	1.35	7	Jun-22	Aug-22
			Shallow	0.29	0.07	0.55	0.17	7	Jun-22	Aug-22
			Deep	0.06	-0.02	0.30	0.11	8	May-22	Aug-22
		PZ-10	Surface	1.09	0.45	1.73	0.91	2	Jun-22	Jun-22
			Shallow	1.31	0.18	4.28	1.75	6	Jun-22	Aug-22
			Deep	0.41	-0.05	1.20	0.45	8	May-22	Aug-22
		PZ-11	Surface	0.34	0.11	0.69	0.31	3	Jun-22	Aug-22
		PZ-12	Surface	0.52	0.23	0.72	0.23	4	Jun-22	Aug-22
			Shallow	0.60	0.14	1.01	0.37	7	Jun-22	Aug-22
			Deep	0.24	0.03	0.59	0.17	9	May-22	Aug-22
		PZ-13	Surface	2.76	0.65	7.84	3.41	4	Jun-22	Aug-22
			Shallow	3.68	0.38	18.9	7.45	6	Jun-22	Aug-22
			Deep	0.23	0.03	0.46	0.14	8	May-22	Aug-22
		PZ-14	Surface	4.65	4.65	4.65	---	1	Jun-22	Jun-22
			Shallow	1.30	0.53	3.96	1.49	5	Jun-22	Aug-22
			Deep	0.14	0.00	0.34	0.12	8	May-22	Aug-22
		PZ-15	Surface	0.48	0.42	0.54	0.06	3	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	0.90	0.35	3.00	1.04	6	Jun-22	Aug-22
			Deep	0.07	-0.06	0.28	0.11	8	May-22	Aug-22
pH	SU	PZ-1	Surface	6.74	6.64	6.83	0.13	2	Jun-22	Jun-22
			Shallow	6.45	6.20	6.68	0.16	6	Jun-22	Aug-22
			Deep	6.65	6.36	6.93	0.22	7	May-22	Aug-22
		PZ-2	Surface	6.83	6.83	6.83	---	1	Jun-22	Jun-22
			Shallow	6.35	6.31	6.39	0.04	4	Jun-22	Jul-22
			Deep	6.49	6.38	6.64	0.08	7	May-22	Aug-22
		PZ-3	Surface	6.37	6.32	6.41	0.06	2	Jun-22	Jun-22
			Shallow	6.15	5.77	6.32	0.18	7	Jun-22	Aug-22
			Deep	6.10	5.67	6.54	0.31	8	May-22	Aug-22
		PZ-4	Surface	6.32	6.20	6.44	0.17	2	Jun-22	Jun-22
			Shallow	6.20	6.01	6.42	0.15	7	Jun-22	Aug-22
			Deep	6.25	5.95	6.69	0.24	8	May-22	Aug-22
		PZ-5	Surface	6.85	6.85	6.85	---	1	Jun-22	Jun-22
			Shallow	6.27	6.17	6.37	0.08	4	Jun-22	Jul-22
			Deep	6.06	5.93	6.54	0.22	7	May-22	Aug-22
		PZ-6	Surface	6.49	6.49	6.49	---	1	Jun-22	Jun-22
			Shallow	6.29	5.98	6.42	0.18	5	Jun-22	Aug-22
			Deep	6.20	6.03	6.43	0.13	7	May-22	Aug-22
		PZ-7	Surface	6.71	6.70	6.72	0.01	2	Jun-22	Jun-22
			Shallow	6.10	5.69	6.30	0.21	7	Jun-22	Aug-22
			Deep	5.85	5.50	6.10	0.19	8	May-22	Aug-22
		PZ-8	Deep	6.44	6.44	6.44	---	1	May-22	May-22
		PZ-9	Surface	6.29	6.19	6.41	0.09	6	Jun-22	Aug-22
			Shallow	6.24	6.15	6.33	0.08	6	Jun-22	Aug-22
			Deep	6.15	5.96	6.31	0.13	7	May-22	Aug-22
		PZ-10	Surface	6.53	6.53	6.53	---	1	Jun-22	Jun-22
			Shallow	6.17	6.12	6.29	0.07	5	Jun-22	Aug-22
			Deep	6.21	5.97	6.49	0.17	7	May-22	Aug-22
		PZ-11	Surface	6.47	6.39	6.57	0.09	3	Jun-22	Aug-22
		PZ-12	Surface	6.51	6.36	6.73	0.16	4	Jun-22	Aug-22
			Shallow	6.36	5.89	6.61	0.23	7	Jun-22	Aug-22
			Deep	6.22	5.76	6.33	0.18	9	May-22	Aug-22
		PZ-13	Surface	6.93	6.83	7.02	0.08	4	Jun-22	Aug-22
			Shallow	6.69	6.56	6.93	0.14	6	Jun-22	Aug-22
			Deep	6.07	5.61	6.31	0.20	8	May-22	Aug-22
		PZ-14	Shallow	6.22	6.01	6.51	0.23	4	Jun-22	Aug-22
			Deep	6.16	6.02	6.35	0.10	7	May-22	Aug-22
		PZ-15	Surface	6.37	6.29	6.44	0.11	2	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	6.19	6.10	6.32	0.09	5	Jun-22	Aug-22
			Deep	6.08	5.97	6.21	0.08	7	May-22	Aug-22
Cond	uS/cm	PZ-1	Surface	575	543	607	44.7	2	Jun-22	Jun-22
			Shallow	476	407	551	46.3	6	Jun-22	Aug-22
			Deep	626	464	940	149	7	May-22	Aug-22
		PZ-2	Surface	634	584	684	70.7	2	Jun-22	Jun-22
			Shallow	522	483	538	23.1	5	Jun-22	Jul-22
			Deep	723	644	1,026	124	8	May-22	Aug-22
		PZ-3	Surface	663	634	692	41.5	2	Jun-22	Jun-22
			Shallow	336	210	566	116	7	Jun-22	Aug-22
			Deep	299	197	447	81.2	8	May-22	Aug-22
		PZ-4	Surface	532	458	606	104	2	Jun-22	Jun-22
			Shallow	423	284	638	109	7	Jun-22	Aug-22
			Deep	394	251	614	119	8	May-22	Aug-22
		PZ-5	Surface	806	748	863	81.3	2	Jun-22	Jun-22
			Shallow	566	554	588	13.5	5	Jun-22	Jul-22
			Deep	493	429	715	104	8	May-22	Aug-22
		PZ-6	Surface	1,137	1,137	1,137	---	1	Jun-22	Jun-22
			Shallow	989	713	1,162	199	5	Jun-22	Aug-22
			Deep	862	723	1,277	189	7	May-22	Aug-22
		PZ-7	Surface	624	537	711	123	2	Jun-22	Jun-22
			Shallow	424	253	676	130	7	Jun-22	Aug-22
			Deep	326	176	676	167	8	May-22	Aug-22
		PZ-8	Deep	651	651	651	---	1	May-22	May-22
		PZ-9	Surface	495	419	552	51.7	7	Jun-22	Aug-22
			Shallow	430	393	492	40.4	7	Jun-22	Aug-22
			Deep	429	384	636	84.2	8	May-22	Aug-22
		PZ-10	Surface	875	862	888	18.4	2	Jun-22	Jun-22
			Shallow	708	588	817	98.2	6	Jun-22	Aug-22
			Deep	658	576	917	107	8	May-22	Aug-22
		PZ-11	Surface	1,228	1,163	1,261	56.0	3	Jun-22	Aug-22
		PZ-12	Surface	759	606	901	124	4	Jun-22	Aug-22
			Shallow	816	622	1,255	208	7	Jun-22	Aug-22
			Deep	745	517	1,102	210	9	May-22	Aug-22
		PZ-13	Surface	740	664	897	108	4	Jun-22	Aug-22
			Shallow	845	703	918	73.9	6	Jun-22	Aug-22
			Deep	677	552	993	139	8	May-22	Aug-22
		PZ-14	Surface	726	726	726	---	1	Jun-22	Jun-22
			Shallow	686	620	744	50.3	5	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	625	557	954	134	8	May-22	Aug-22
		PZ-15	Surface	910	793	990	103	3	Jun-22	Aug-22
			Shallow	897	815	941	46.8	6	Jun-22	Aug-22
			Deep	821	745	1,211	158	8	May-22	Aug-22
ORP	mV	PZ-1	Surface	-104	-151	-57.2	66.1	2	Jun-22	Jun-22
			Shallow	-110	-194	-80.2	43.8	6	Jun-22	Aug-22
			Deep	-145	-189	-104	33.5	7	May-22	Aug-22
		PZ-2	Surface	-135	-135	-135	---	1	Jun-22	Jun-22
			Shallow	-1.18	-83.4	123	87.9	4	Jun-22	Jul-22
			Deep	-99.1	-196	-42.4	51.9	7	May-22	Aug-22
		PZ-3	Surface	-68.2	-84.0	-52.3	22.4	2	Jun-22	Jun-22
			Shallow	-124	-158	-70.0	27.4	7	Jun-22	Aug-22
			Deep	-159	-198	-106	31.1	8	May-22	Aug-22
		PZ-4	Surface	-104	-131	-77.5	38.1	2	Jun-22	Jun-22
			Shallow	-141	-201	-81.6	45.2	7	Jun-22	Aug-22
			Deep	-163	-204	-108	31.6	8	May-22	Aug-22
		PZ-5	Surface	-136	-136	-136	---	1	Jun-22	Jun-22
			Shallow	-82.0	-126	-42.2	45.7	4	Jun-22	Jul-22
			Deep	-66.9	-196	6.00	68.0	7	May-22	Aug-22
		PZ-6	Surface	-165	-165	-165	---	1	Jun-22	Jun-22
			Shallow	-68.5	-131	-29.2	38.8	5	Jun-22	Aug-22
			Deep	-87.5	-168	-29.3	47.9	7	May-22	Aug-22
		PZ-7	Surface	-151	-159	-143	11.7	2	Jun-22	Jun-22
			Shallow	-108	-174	-70.0	35.9	7	Jun-22	Aug-22
			Deep	-108	-193	106	93.4	8	May-22	Aug-22
		PZ-8	Deep	-230	-230	-230	---	1	May-22	May-22
		PZ-9	Surface	-53.7	-141	34.7	64.8	6	Jun-22	Aug-22
			Shallow	-88.9	-144	-26.6	51.1	6	Jun-22	Aug-22
			Deep	-26.9	-189	403	198	7	May-22	Aug-22
		PZ-10	Surface	-112	-112	-112	---	1	Jun-22	Jun-22
			Shallow	-60.7	-111	-10.0	41.5	4	Jun-22	Aug-22
			Deep	-92.4	-193	-6.20	64.1	7	May-22	Aug-22
		PZ-11	Surface	-56.3	-79.8	-26.4	27.3	3	Jun-22	Aug-22
		PZ-12	Surface	-118	-149	-102	21.1	4	Jun-22	Aug-22
			Shallow	-148	-227	-65.9	62.9	7	Jun-22	Aug-22
			Deep	-123	-195	124	98.9	9	May-22	Aug-22
		PZ-13	Surface	-40.2	-101	39.1	58.2	4	Jun-22	Aug-22
			Shallow	-91.4	-193	136	116	6	Jun-22	Aug-22
			Deep	-123	-202	-24.0	62.2	8	May-22	Aug-22
		PZ-14	Shallow	-27.1	-152	43.1	85.5	4	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	-92.5	-188	-3.50	65.7	7	May-22	Aug-22
		PZ-15	Surface	-106	-128	-84.5	30.5	2	Jun-22	Aug-22
			Shallow	-58.2	-115	-8.80	44.9	5	Jun-22	Aug-22
			Deep	-89.0	-192	-1.10	65.4	7	May-22	Aug-22
TFE	mg/L	PZ-1	Surface	2.68	2.22	3.14	0.65	2	Jun-22	Jun-22
			Shallow	5.36	2.33	7.77	2.12	6	Jun-22	Aug-22
			Deep	6.80	4.86	8.94	1.44	8	May-22	Aug-22
		PZ-2	Surface	2.12	1.70	2.54	0.59	2	Jun-22	Jun-22
			Shallow	5.14	3.40	6.26	1.19	5	Jun-22	Jul-22
			Deep	6.41	5.66	7.28	0.68	8	May-22	Aug-22
		PZ-3	Surface	4.50	4.19	4.81	0.44	2	Jun-22	Jun-22
			Shallow	4.17	2.43	5.65	1.21	7	Jun-22	Aug-22
			Deep	3.57	3.13	3.83	0.26	8	May-22	Aug-22
		PZ-4	Surface	3.91	3.84	3.97	0.09	2	Jun-22	Jun-22
			Shallow	2.91	2.24	4.20	0.64	7	Jun-22	Aug-22
			Deep	2.91	2.45	3.46	0.40	8	May-22	Aug-22
		PZ-5	Surface	3.23	2.43	4.03	1.13	2	Jun-22	Jun-22
			Shallow	5.82	3.32	6.72	1.45	5	Jun-22	Jul-22
			Deep	2.38	1.71	3.08	0.38	8	May-22	Aug-22
		PZ-6	Surface	17.4	10.7	24.0	9.40	2	Jun-22	Jun-22
			Shallow	11.1	2.45	15.7	4.91	6	Jun-22	Aug-22
			Deep	3.22	1.72	4.21	0.74	8	May-22	Aug-22
		PZ-7	Surface	8.11	6.01	10.2	2.96	2	Jun-22	Jun-22
			Shallow	7.44	3.33	12.2	2.81	7	Jun-22	Aug-22
			Deep	4.09	2.76	6.91	1.34	8	May-22	Aug-22
		PZ-8	Deep	1.58	1.58	1.58	---	1	May-22	May-22
		PZ-9	Surface	4.60	1.11	7.03	1.82	7	Jun-22	Aug-22
			Shallow	2.13	1.40	3.72	0.77	7	Jun-22	Aug-22
			Deep	1.47	1.36	1.56	0.08	8	May-22	Aug-22
		PZ-10	Surface	4.37	3.66	5.08	1.00	2	Jun-22	Jun-22
			Shallow	4.34	0.78	6.21	1.92	6	Jun-22	Aug-22
			Deep	4.07	3.49	5.00	0.51	8	May-22	Aug-22
		PZ-11	Surface	4.96	3.73	7.41	1.67	4	Jun-22	Aug-22
		PZ-12	Surface	4.31	1.84	6.89	2.29	4	Jun-22	Aug-22
			Shallow	7.47	2.66	11.4	3.34	7	Jun-22	Aug-22
			Deep	7.69	5.87	9.02	0.99	9	May-22	Aug-22
		PZ-13	Surface	1.74	0.78	2.68	0.83	4	Jun-22	Aug-22
			Shallow	5.19	3.10	8.57	1.85	6	Jun-22	Aug-22
			Deep	5.62	5.35	5.82	0.16	8	May-22	Aug-22
		PZ-14	Surface	7.78	7.78	7.78	---	1	Jun-22	Jun-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	7.15	1.56	10.4	3.47	5	Jun-22	Aug-22
			Deep	4.50	3.96	5.38	0.43	8	May-22	Aug-22
		PZ-15	Surface	6.32	2.79	8.58	3.09	3	Jun-22	Aug-22
			Shallow	8.08	3.25	13.8	4.58	6	Jun-22	Aug-22
			Deep	8.25	5.78	14.2	2.59	8	May-22	Aug-22
TP	mg/L	PZ-1	Surface	0.31	0.25	0.37	0.09	2	Jun-22	Jun-22
			Shallow	0.21	0.11	0.33	0.08	6	Jun-22	Aug-22
			Deep	0.38	0.22	0.70	0.16	8	May-22	Aug-22
		PZ-2	Surface	0.56	0.55	0.56	0.01	2	Jun-22	Jun-22
			Shallow	0.30	0.25	0.35	0.04	5	Jun-22	Jul-22
			Deep	0.52	0.42	0.63	0.08	8	May-22	Aug-22
		PZ-3	Surface	0.50	0.22	0.77	0.39	2	Jun-22	Jun-22
			Shallow	0.16	0.12	0.19	0.02	7	Jun-22	Aug-22
			Deep	0.13	0.09	0.22	0.04	8	May-22	Aug-22
		PZ-4	Surface	0.38	0.28	0.47	0.13	2	Jun-22	Jun-22
			Shallow	0.32	0.14	0.42	0.09	7	Jun-22	Aug-22
			Deep	0.53	0.40	0.65	0.09	8	May-22	Aug-22
		PZ-5	Surface	0.06	0.03	0.10	0.05	2	Jun-22	Jun-22
			Shallow	0.11	0.08	0.15	0.03	5	Jun-22	Jul-22
			Deep	0.20	0.07	0.38	0.10	8	May-22	Aug-22
		PZ-6	Surface	0.89	0.88	0.89	0.01	2	Jun-22	Jun-22
			Shallow	0.29	0.05	0.37	0.12	6	Jun-22	Aug-22
			Deep	0.42	0.38	0.47	0.04	8	May-22	Aug-22
		PZ-7	Surface	0.27	0.18	0.36	0.13	2	Jun-22	Jun-22
			Shallow	0.23	0.14	0.37	0.07	7	Jun-22	Aug-22
			Deep	0.42	0.29	0.55	0.08	8	May-22	Aug-22
		PZ-8	Deep	0.16	0.16	0.16	---	1	May-22	May-22
		PZ-9	Surface	0.31	0.06	0.71	0.21	7	Jun-22	Aug-22
			Shallow	0.23	0.16	0.36	0.08	7	Jun-22	Aug-22
			Deep	0.08	0.02	0.10	0.03	8	May-22	Aug-22
		PZ-10	Surface	0.23	0.07	0.40	0.23	2	Jun-22	Jun-22
			Shallow	0.10	0.03	0.19	0.06	6	Jun-22	Aug-22
			Deep	0.18	0.06	0.25	0.05	8	May-22	Aug-22
		PZ-11	Surface	0.37	0.08	0.68	0.25	4	Jun-22	Aug-22
		PZ-12	Surface	0.42	0.20	0.79	0.26	4	Jun-22	Aug-22
			Shallow	0.37	0.24	0.56	0.11	7	Jun-22	Aug-22
			Deep	0.26	0.21	0.31	0.04	9	May-22	Aug-22
		PZ-13	Surface	0.14	0.08	0.32	0.12	4	Jun-22	Aug-22
			Shallow	0.31	0.15	0.47	0.12	6	Jun-22	Aug-22
			Deep	0.57	0.50	0.64	0.05	8	May-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
		PZ-14	Surface	0.56	0.56	0.56	---	1	Jun-22	Jun-22
			Shallow	0.17	0.03	0.25	0.09	5	Jun-22	Aug-22
			Deep	1.04	0.87	1.20	0.14	8	May-22	Aug-22
		PZ-15	Surface	0.85	0.11	1.67	0.79	3	Jun-22	Aug-22
			Shallow	0.37	0.09	1.02	0.33	6	Jun-22	Aug-22
			Deep	0.32	0.24	0.43	0.06	8	May-22	Aug-22
OP	mg/L	PZ-1	Surface	0.16	0.15	0.16	0.01	2	Jun-22	Jun-22
			Shallow	0.07	0.04	0.12	0.03	6	Jun-22	Aug-22
			Deep	0.07	0.01	0.17	0.06	8	May-22	Aug-22
		PZ-2	Surface	0.28	0.21	0.34	0.09	2	Jun-22	Jun-22
			Shallow	0.22	0.17	0.26	0.04	5	Jun-22	Jul-22
			Deep	0.08	0.01	0.36	0.12	8	May-22	Aug-22
		PZ-3	Surface	0.38	0.13	0.63	0.35	2	Jun-22	Jun-22
			Shallow	0.08	0.04	0.14	0.03	7	Jun-22	Aug-22
			Deep	0.08	0.04	0.14	0.03	8	May-22	Aug-22
		PZ-4	Surface	0.24	0.20	0.27	0.05	2	Jun-22	Jun-22
			Shallow	0.21	0.09	0.26	0.06	7	Jun-22	Aug-22
			Deep	0.36	0.20	0.47	0.08	8	May-22	Aug-22
		PZ-5	Surface	0.05	0.04	0.06	0.01	2	Jun-22	Jun-22
			Shallow	0.06	0.03	0.08	0.02	5	Jun-22	Jul-22
			Deep	0.14	0.03	0.22	0.06	8	May-22	Aug-22
		PZ-6	Surface	0.15	0.03	0.27	0.17	2	Jun-22	Jun-22
			Shallow	0.07	0.01	0.17	0.07	6	Jun-22	Aug-22
			Deep	0.18	0.12	0.30	0.05	8	May-22	Aug-22
		PZ-7	Surface	0.08	0.05	0.11	0.04	2	Jun-22	Jun-22
			Shallow	0.12	0.05	0.19	0.05	7	Jun-22	Aug-22
			Deep	0.31	0.17	0.54	0.10	8	May-22	Aug-22
		PZ-8	Deep	0.07	0.07	0.07	---	1	May-22	May-22
		PZ-9	Surface	0.20	0.06	0.61	0.19	7	Jun-22	Aug-22
			Shallow	0.15	0.10	0.25	0.05	7	Jun-22	Aug-22
			Deep	0.08	0.05	0.09	0.01	8	May-22	Aug-22
		PZ-10	Surface	0.14	0.04	0.24	0.14	2	Jun-22	Jun-22
			Shallow	0.07	0.04	0.14	0.04	6	Jun-22	Aug-22
			Deep	0.11	0.04	0.13	0.03	8	May-22	Aug-22
		PZ-11	Surface	0.02	0.02	0.03	0.00	4	Jun-22	Aug-22
		PZ-12	Surface	0.21	0.06	0.46	0.17	4	Jun-22	Aug-22
			Shallow	0.23	0.07	0.38	0.10	7	Jun-22	Aug-22
			Deep	0.18	0.13	0.21	0.03	9	May-22	Aug-22
		PZ-13	Surface	0.03	0.01	0.04	0.01	4	Jun-22	Aug-22
			Shallow	0.14	0.08	0.22	0.06	6	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	0.29	0.16	0.40	0.09	8	May-22	Aug-22
		PZ-14	Surface	0.11	0.11	0.11	---	1	Jun-22	Jun-22
			Shallow	0.09	0.02	0.17	0.06	5	Jun-22	Aug-22
			Deep	0.31	0.14	0.48	0.10	8	May-22	Aug-22
		PZ-15	Surface	0.38	0.06	0.83	0.40	3	Jun-22	Aug-22
			Shallow	0.09	0.04	0.16	0.05	6	Jun-22	Aug-22
			Deep	0.22	0.08	0.29	0.06	8	May-22	Aug-22
TN	mg/L	PZ-1	Surface	2.46	1.94	2.97	0.73	2	Jun-22	Jun-22
			Shallow	3.76	2.26	5.24	1.22	6	Jun-22	Aug-22
			Deep	5.28	2.55	7.45	1.66	8	May-22	Aug-22
		PZ-2	Surface	2.85	2.75	2.94	0.13	2	Jun-22	Jun-22
			Shallow	2.95	2.51	3.85	0.55	5	Jun-22	Jul-22
			Deep	4.69	1.01	6.36	1.61	8	May-22	Aug-22
		PZ-3	Surface	2.30	2.15	2.45	0.21	2	Jun-22	Jun-22
			Shallow	1.90	1.58	2.24	0.29	7	Jun-22	Aug-22
			Deep	2.71	1.39	4.71	1.08	8	May-22	Aug-22
		PZ-4	Surface	1.84	1.75	1.93	0.13	2	Jun-22	Jun-22
			Shallow	3.71	1.52	7.77	1.96	7	Jun-22	Aug-22
			Deep	8.68	6.54	11.0	1.32	8	May-22	Aug-22
		PZ-5	Surface	1.38	1.15	1.60	0.32	2	Jun-22	Jun-22
			Shallow	1.64	1.32	2.13	0.38	5	Jun-22	Jul-22
			Deep	3.31	1.44	5.80	1.37	8	May-22	Aug-22
		PZ-6	Surface	2.50	1.90	3.10	0.85	2	Jun-22	Jun-22
			Shallow	2.16	1.42	3.08	0.53	6	Jun-22	Aug-22
			Deep	5.66	5.00	6.35	0.49	8	May-22	Aug-22
		PZ-7	Surface	1.25	1.10	1.39	0.21	2	Jun-22	Jun-22
			Shallow	1.95	1.36	3.03	0.58	7	Jun-22	Aug-22
			Deep	5.57	4.37	6.41	0.70	8	May-22	Aug-22
		PZ-8	Deep	2.67	2.67	2.67	---	1	May-22	May-22
		PZ-9	Surface	2.03	1.21	3.11	0.76	7	Jun-22	Aug-22
			Shallow	1.33	0.91	2.33	0.49	7	Jun-22	Aug-22
			Deep	1.73	1.33	2.85	0.53	8	May-22	Aug-22
		PZ-10	Surface	1.56	1.31	1.80	0.35	2	Jun-22	Jun-22
			Shallow	1.65	1.44	2.10	0.24	6	Jun-22	Aug-22
			Deep	2.44	1.14	3.59	0.75	8	May-22	Aug-22
		PZ-11	Surface	1.45	0.85	2.19	0.60	4	Jun-22	Aug-22
		PZ-12	Surface	1.47	0.82	2.03	0.50	4	Jun-22	Aug-22
			Shallow	2.83	2.01	5.70	1.35	7	Jun-22	Aug-22
			Deep	4.67	3.95	5.33	0.46	9	May-22	Aug-22
		PZ-13	Surface	1.19	0.81	1.75	0.45	4	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	1.59	1.12	3.17	0.79	6	Jun-22	Aug-22
			Deep	5.69	4.66	6.95	0.93	8	May-22	Aug-22
		PZ-14	Surface	2.81	2.81	2.81	---	1	Jun-22	Jun-22
			Shallow	2.11	1.08	2.54	0.59	5	Jun-22	Aug-22
			Deep	8.38	7.48	9.06	0.53	8	May-22	Aug-22
		PZ-15	Surface	2.96	1.83	3.79	1.02	3	Jun-22	Aug-22
			Shallow	3.18	1.73	7.99	2.39	6	Jun-22	Aug-22
			Deep	3.93	2.11	5.73	1.02	8	May-22	Aug-22
Elevation	ft NAVD 88	PZ-1	Surface	943.6	943.4	943.9	0.25	4	Jun-22	Aug-22
			Shallow	943.0	941.9	943.9	0.70	7	Jun-22	Aug-22
			Deep	943.1	941.7	944.1	0.81	8	May-22	Aug-22
		PZ-2	Surface	943.8	943.8	943.9	0.08	2	Jun-22	Jun-22
			Shallow	943.2	942.4	943.9	0.59	6	Jun-22	Aug-22
			Deep	943.1	941.7	944.2	0.83	8	May-22	Aug-22
		PZ-3	Surface	943.9	943.7	944.3	0.29	5	Jun-22	Jul-22
			Shallow	943.7	942.7	944.5	0.61	7	Jun-22	Aug-22
			Deep	943.6	942.7	944.3	0.63	8	May-22	Aug-22
		PZ-4	Surface	943.6	943.4	943.9	0.25	6	Jun-22	Aug-22
			Shallow	943.6	943.2	944.1	0.31	7	Jun-22	Aug-22
			Deep	944.1	943.0	948.3	1.73	8	May-22	Aug-22
		PZ-5	Surface	944.1	944.0	944.2	0.13	2	Jun-22	Jun-22
			Shallow	943.5	942.8	944.3	0.53	6	Jun-22	Aug-22
			Deep	943.5	942.7	944.4	0.60	8	May-22	Aug-22
		PZ-6	Surface	944.4	944.4	944.4	---	1	Jun-22	Jun-22
			Shallow	943.3	942.3	944.4	0.73	6	Jun-22	Aug-22
			Deep	943.4	942.0	944.7	0.93	7	May-22	Aug-22
		PZ-7	Surface	944.0	943.5	944.5	0.20	10,038	May-22	Sep-22
			Shallow	943.7	942.6	944.5	0.49	10,040	May-22	Sep-22
			Deep	943.6	942.5	944.5	0.48	9,320	May-22	Sep-22
		PZ-9	Surface	943.6	943.2	944.1	0.21	10,034	May-22	Sep-22
			Shallow	943.6	943.2	944.1	0.23	10,039	May-22	Sep-22
			Deep	943.5	943.0	944.4	0.29	10,039	May-22	Sep-22
		PZ-10	Surface	944.2	944.0	944.7	0.22	10,028	May-22	Sep-22
			Shallow	943.9	942.6	944.9	0.66	10,029	May-22	Sep-22
			Deep	943.7	942.0	944.8	0.73	10,032	May-22	Sep-22
		PZ-11	Up	943.8	942.2	944.8	0.69	9,281	Jun-22	Sep-22
		PZ-12	Surface	944.6	944.0	944.9	0.38	5	Jun-22	Aug-22
			Shallow	944.3	943.5	944.9	0.49	7	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	850.2	95.9	945.1	283	9	May-22	Aug-22
		PZ-13	Surface	944.2	943.8	944.6	0.30	6	Jun-22	Aug-22
			Shallow	944.0	943.0	944.6	0.57	7	Jun-22	Aug-22
			Deep	944.1	943.0	945.6	0.78	8	May-22	Aug-22
		PZ-14	Surface	944.2	943.9	944.4	0.26	3	Jun-22	Jun-22
			Shallow	943.8	942.9	944.5	0.55	6	Jun-22	Aug-22
			Deep	943.8	942.6	944.7	0.71	8	May-22	Aug-22
		PZ-15	Surface	944.4	944.1	944.7	0.28	4	Jun-22	Aug-22
			Shallow	944.2	943.5	944.7	0.45	6	Jun-22	Aug-22
			Deep	944.0	942.9	944.7	0.65	8	May-22	Aug-22

Attachment B

Resolution No. 2024-12

Moved by Evansky
Seconded by Reiff

A RESOLUTION OF SUPPORT FROM THE CITY OF VICTORIA FOR THE EAST AUBURN WETLAND RESTORATION PROJECT

WHEREAS, historically, the Minnehaha Creek Watershed District ("District") and the City of Victoria have partnered successfully to coordinate planning, implement capital improvement projects, and manage development activity within the Six Mile-Halsted Bay subwatershed to allow Victoria to fulfill its community development vision while protecting its natural resource base and providing natural amenities for the community, including:

- Cooperatively planning and constructing park and water quality improvements adjacent to Wassermann Lake;
- Leveraging a State of Minnesota Clean Water Fund grant to enhance the treatment capacity of two ponds near downtown Victoria to reduce phosphorus loading to East Auburn Lake;
- Securing a legislative appropriation through the Lessard-Sams Outdoor Heritage Council for system-wide management of common carp, and successfully implementing a program to reduce carp populations for improving water quality and ecological conditions within Piersons Lake, Wasserman Lake, East Auburn Lake, West Auburn Lake, Parley Lake, and Mud Lake;

WHEREAS, the District, in its 2017 Watershed Management Plan (WMP), has identified the need to address nutrient impairments in East Auburn Lake that are driven primarily by external watershed loading;

WHEREAS, the WMP has identified the wetland system on an outlot owned by the City of Victoria between Wassermann Lake and East Auburn Lake as a restoration opportunity to address nutrient export to East Auburn Lake;

WHEREAS, the District commissioned a feasibility study by Moore Engineering, Inc., completed in October 2023, that assessed seven alternative approaches and has identified a wetland restoration and outlet control project that it estimates may reduce nutrient export to East Auburn Lake by half, in a cost-effective manner; and

WHEREAS, the City of Victoria supports the District's project goals and wishes to facilitate project development and implementation, and potentially to integrate city trail improvements with the proposed outlet control structure.

NOW, THEREFORE, BE IT RESOLVED that the City of Victoria shares a vision for the Six Mile-Halsted Bay subwatershed that integrates land use and water resources to protect and enhance natural resources, support the growth of vibrant communities, value and preserve distinct natural areas, and build strong community connections with those areas;

BE IT FURTHER RESOLVED that the City supports the District's East Auburn Wetland Restoration project, and authorizes the District to access the city-owned outlot within the project area and to perform surveys and investigations for the purpose of project design; and

BE IT FINALLY RESOLVED that city staff shall remain engaged with District staff and are authorized to work with District staff to develop such project agreements or other documents to allow the District to construct and maintain the project on the city-owned outlot, and to bring such documents forward for consideration by the City Council.

This Resolution is adopted by the City of Victoria and approved by the Mayor this 26 day of February 2024

Debra McMillan

Debra McMillan, Mayor

ATTEST:

Claudia Ettesvold

Claudia Ettesvold, City Clerk

Attachment C

REQUEST FOR PROPOSALS

Engineering for

EAST AUBURN WETLAND RESTORATION

Church Lake Blvd, Victoria MN

Minnehaha Creek Watershed District

PART 1: BACKGROUND AND PROJECT OVERVIEW

General

The Minnehaha Creek Watershed District (MCWD or District) is seeking a qualified consultant team to provide engineering design services for the East Auburn Wetland Restoration project. The project involves design, cost analysis, plans and specifications, permitting, and construction oversight for the construction of hydrologic control structures.

<u>MCWD will host an informational meeting on this RFP on April 1, 2024, at 11:00 am at the MCWD offices at 15320 Minnetonka Blvd, Minnetonka, MN 55345. You are encouraged to RSVP to Sophia Green, MCWD Planner-Project Manager.</u>

<u>If you would like to receive project updates during the RFP process, please sign up on the RFP webpage at the following link: [insert]</u>

Project Description

The East Auburn Wetland Restoration site is in the City of Victoria, in Carver County, comprised of a complex of four wetland cells along Six Mile Creek between Wasserman Lake upstream and East Auburn Lake downstream. The Cell 1 Wetland located at the upstream of the East Auburn Wetland Complex has been identified as the likely source of elevated total phosphorus loads (TP) to East Auburn Lake through previously collected water quality, flow, level, and sediment data for the Cell 1 Wetland. Based on the evaluation of data, the dominant mechanisms contributing to the export of TP occur via a process in which the water levels of the wetland decrease in the summer months allowing phosphorus from the contaminated sediments to be released during subsequent flow events. The primary outcome of this project is the restoration of Cell 1 Wetland to address elevated TP loads to East Auburn Lake through the construction of a sheet pile weir between the Cell 1 and Cell 2 Wetlands of the East Auburn Wetland Complex. This weir would be constructed to reduce the short-circuiting and drainage of water with higher phosphorus concentrations through the channel in the marsh during the summer months when this system dries out.

The boardwalk between Cell 1 and Cell 2 is an aging infrastructure that will likely be impacted during construction to accommodate for the sheet pile weir. The city of Victoria (City) owns the boardwalk trail and supports the District's project goals and implementation efforts. The City has asked MCWD and its design team to explore integration of improvements to the City's boardwalk connection through this design process Design proposals received should consider the development of the weir structure in concert with the boardwalk.

Work to Date

The district has previously conducted wetland assessments with assistance from Stantec engineering and has contracted with Moore engineering to conduct a feasibility study Select information has been included as attachments to this RFP. All other information gathered to date will be transmitted to the consultant upon contract award. The information summarized below serves as an example of available information. The consultant's proposal should assume all information gathered is complete and accurate.

Auburn Wetland Monitoring Project (Attachment A)

- Hydrologic and water quality data
- Sediment and soil chemistry data

East Auburn Wetland Restoration Feasibility Study (Attachment B)

- *Topographic data*
- *Hydrologic and water quality data including flow, water level, groundwater, and chemistry data*
- *Restoration solutions with alternatives matrix including specifications for sheet pile weir*

Project Team

Sophia Green
Planner-Project Manager, MCWD
sgreen@minnehahacreek.org
952-641-4523

Part 2: SCOPE OF WORK

The overall project cost, including design, capital construction, contingency and construction oversight, is anticipated to cost up to $550,000. The consultant will work closely with the District to complete tasks 1-3 within a projected budget of $68,000. Construction oversight costs should be estimated and are not to be included as part of the design budget.

The project, as detailed below, will include the following tasks:

1. 30% Design
2. 60-90% Design
3. Final Plans and Bid Support
4. Construction Oversight

The consultant will complete 90% design for presentation to the City Council and District Board of Managers no later than September 16, 2024, and September 26, 2024, respectively. Approval of 90% design will then allow the consultant to prepare final design and bid the project in October.

The scope of services for this work may include, but will not be limited to, the tasks described as follows:

Task 1:30% Design

The consultant will develop 30% plans following the design recommendations provided in the 2023 Feasibility Study. 30% design will be vetted by District and City staff and reviewed by the MCWD Board and City Council prior to further advancing design.

Task 2: 60-90% Design

60% Design (Design Development)

The consultant will develop 60% plans following the design recommendations provided in the 2023 Feasibility Study and based on feedback and direction from the 30% design review. 60% design will be vetted by District and City staff, and may be reviewed by the MCWD Board and City Council prior to further advancing design.

Permitting

The consultant will assist staff by providing materials for all required permits, including permits required by the City, the District, DNR, and any other public agencies. Staff will lead in the preparation and submission of the permits, with the consultant supporting through the preparation of required exhibits and calculations.

90% Design

The consultant will produce all elements standard to 90% design, including drawings, draft technical specifications, an opinion of probable costs, and any other needed figures identified by the consultant and client. The consultant is expected to apply a value engineering approach to work within the established project budget.

Task 3: Final Plans and Bid Support

100% Design Plans

Prepare plans and technical specifications, which will include site plans and any and all other necessary details to construct the project. The final design will include engineering estimates to accompany the final project design. The consultant will further develop specification and bid documents for construction contracting. The consultant will utilize the District's draft front end documentation for the bid packet while drafting the final bid packet for review. The consultant will coordinate with the District on the choice of standard contract documents and specifications to be used in conjunction with the District's front end template.

Bid Period Support

In addition to developing the bid packet, the consultant will provide support during project bidding. This will include participation at a pre-bid meeting, responding to requests for information from prospective contractors, attending the bid opening, reviewing bid responses, and making an award recommendation.

Task 4: Construction Oversight

The consultant will provide construction oversight and management services in partnership with District staff, including construction administration and observation services. Required tasks will include participation in the preconstruction meeting, site staking, pay application review, submittal review, onsite construction observation of major tasks, responding to requests for information, providing postconstruction as-builts, and any other construction administration, oversight, and management activities deemed necessary to completing the project as designed. The consultant should assume that the District will provide some routine on site observation, and will have ultimate approval authority. In preparing the response to the construction oversight task, the consultant should clearly state all assumptions, including estimated numbers for any tasks requiring the review of submittals, pay applications, etc. The construction oversight work will be funded separately from tasks 1-3 and is not included in the $68,000 design budget.

PART 3: INSTRUCTION TO PROPOSERS

Submittal Requirements

Responses to the RFP should be submitted to Sophia Green no later than 4:00 pm on April 10, 2024

The District requests that all responses be submitted digitally through the District's DropBox file request link: "link place holder"

Please visit the RFP webpage to view updates: "link placeholder"

No page limit is required, however respondents will be evaluated on clarity and conciseness. Each proposal should include the following items:

1. Cover Letter – please provide a primary point of contact through the transmission of a cover letter.
2. Project understanding – describe your understanding of the scope of work, the approach to be taken, and your vision for the project. Identify any additional information the District will need to supply or obtain to enhance your understanding of the project and successfully complete the work, and/or any issues you might anticipate in performing the work.
3. Approach and methodology – provide a detailed description of your approach to the scope of work, including how you will coordinate with District staff. Include a description of all anticipated tasks and deliverables, and any supplemental tasks not described in the RFP. The proposal should include a spreadsheet showing tasks, project team members, and associated hours. The proposal should also include a schedule of milestones identified in this RFP and by the consultant and a cost proposal. Include major assumptions impacting cost and time allocation with associated rates.
4. Qualifications and experience – Provide an overview of the firm(s) and project team members and qualifications. Include descriptions of projects undertaken by the firm(s) and team members similar in nature to the one being proposed. Speak to the team's ability to deliver the project on time and on budget.

5. References – Provide three recent references for your proposed principal team members, including names, addresses, and phone numbers.
6. District Resources – note a list of resources, expectations, or requirements which the consultant expects from the District in order to complete the project as proposed.
7. Subcontracting – if the consultant intends to use any subcontracting, submit the firms' information and an overview of the team members proposed from the firm(s).

Timeline

A review committee led by the project manager, MCWD Planning Project Manager Sophia Green along with other select staff will evaluate proposals and recommend a consultant to the MCWD Board of Managers.

The anticipated timeline for the proposal review process, which is subject to change, is as follows:

- Submit RFP questions: March 27, 2024 (answers will be reviewed at informational meeting)
- Optional RFP informational meeting: April 01, 2024
- Deadline for receipt of proposals: April 10, 2024
- Interviews: April 22 and April 23, 2024
- Consultant selection: May 09, 2024

Selection Criteria

Methodology

1. Project understanding: The consultant understands the scope, goals and requirements of the project, and must be willing to work closely with MCWD staff.
2. Completeness and specificity: The proposal concisely and comprehensively explains what the consultant will do to meet all facets of the project, including a project schedule.
3. Identification of needs: The proposal outlines what resources will be required to complete the tasks, including MCWD staff time, additional information, etc.

Experience

1. Expertise and experience with comparable wetland restoration projects.
2. Project team has a proven track record for completing projects on time and within budget. The role of the project manager, in particular, is considered critical to the success of the project, given the high degree of coordination and other complexities of the project.
3. Project team has demonstrated ability to bring project from design through construction.

Cost

1. Fee structure: The proposal must clearly outline the fees and costs to complete all aspects of this project. Include hourly rates for each project team member along with hours for each task. The final fee structure and contract price are subject to negotiation.

Contact

Any questions and RSVPs to the informational meeting should be directed to Sophia Green at 952-641-4523 or sgreen@minnehahacreek.org.

PART 4: DISCLOSURES

Non-Binding

The District reserves the right to accept or reject any or all responses, in part or in whole, and to waive any minor informalities, as deemed in the District's best interests. In determining the most advantageous proposal, the District reserves the right to consider matters such as, but not limited to, consistency with the District's watershed management plan goals and the City's comprehensive land use plan, and the quality and completeness of the consultant's completed projects similar to the proposed project.

This RFP does not obligate the respondent to enter into a contract with the District, nor does it obligate the District to enter into a relationship with any entity that responds, or limit the District's right to enter into a contract with any entity that does not respond, to this RFP. The District also reserves the right, in its sole discretion, to cancel this RFP at any time for any reason.

Each respondent is solely responsible for all costs that it incurs to respond to this RFP and, if selected, to engage in the process including, but not limited to, costs associated with preparing a response or participating in any interviews, presentations or negotiations related to this RFP.

Right to Modify, Suspend, and Waive

The District reserves the right to:

- Modify and/or suspend any or all elements of this RFP;
- Request additional information or clarification from any or all respondents
- Allow one or more respondents to correct errors or omissions or otherwise alter or supplement a proposal;
- Waive any unintentional defects as to form or content of the RFP or any response submitted.

Any substantial change in a requirement of the RFP will be disseminated in writing to all parties that have given written notice to the District of an interest in preparing a response.

Disclosure and Disclaimer

This RFP is for informational purposes only. Any action taken by the District in response to proposals made pursuant to this RFP, or in making any selection or failing or refusing to make any selection, is without liability or obligation on the part of the District or any of its officers, employees or advisors. This RFP is being provided by the District without any warranty or representation, expressed or implied, as to its content, accuracy or completeness. Any reliance on the information contained in this RFP, or on any communications with District officials, employees or advisors, is at the consultant's own risk. Prospective consultants must rely exclusively on their own investigations, interpretations and analysis in connection with this matter. This RFP is made subject to correction of errors, omissions, or withdrawal without notice.

The District will handle proposals and related submittals in accordance with the Minnesota Data Practices Act, Minnesota Statutes §13.591, subdivision 3(b).

Stantec

Memo

To:	Kailey Cermak, MCWD Brian Beck, MCWD Daniel Mock, MCWD Michael Hayman, MCWD	From:	Dendy Lofton, PhD, CLM Tom Beneke Joel Thompson, PG Erik Megow, PE Mike Holly, PhD, PE
Project/File:	227704313	Date:	October 19, 2022

Reference: Auburn Wetland Monitoring Project - Technical Memo

BACKGROUND

The Auburn wetland is located along Six Mile Creek between Wasserman Lake and Lake Auburn in Victoria, MN. The Minnehaha Creek Watershed District (MCWD) monitored water quality and flow in Six Mile Creek from upstream and downstream of the Auburn wetland system from 2009 through 2015. Data analysis indicated that the stream channel gained phosphorus from inlet to outlet serving as a potential phosphorus load to downstream Auburn Lake, which is impaired due to excess phosphorus. Through more refined monitoring, MCWD identified that the most upstream cell from the Wasserman Lake outlet to the boardwalk across from the Butternut Court is responsible for the majority of the phosphorus export from the wetland system. Stantec was contracted by MCWD to assist with development and execution of a targeted monitoring plan that would support future feasibility work. The scope of work included three primary tasks:

- Task 1 – Develop targeted monitoring plan
- Task 2 – Execute monitoring plan
- Task 3 – Evaluate engineering options

This technical memo describes the monitoring approach and results of the hydrology and water quality monitoring effort (Tasks 1 and 2). Stantec has provided conceptual engineering options (Task 3) that could mitigate phosphorus loads from the wetland to East Auburn Lake, which are shown in Appendix A.

WETLAND MONITORING APPROACH

To further understand the mechanism behind nutrient export from this portion of the wetland, additional monitoring needed to be conducted with the goal of addressing two primary questions:

1) Is phosphorus high in the wetland complex (soils, sediments, groundwater, channel water)?
2) If phosphorus is high in the wetland complex, then is it able to mobilize to the stream channel?

To answer the questions above, Stantec developed a targeted monitoring plan, which was reviewed and approved by MCWD in January 2022 (Stantec 2022). Details of the monitoring approach can be found in Stantec (2022) and are briefly described below.

The main elements of the monitoring approach included the following components:

- Installation of multilevel piezometers and collection of groundwater level measurements and water quality samples;
- Installation of stilling wells within Six Mile Creek and collections of surface water level measurements, and water quality samples; and
- In-channel sediment and wetland soil chemistry sampling.

WETLAND MONITORING METHODS

Fifteen multi-level nested piezometers were installed at the locations shown in Figure 1 to facilitate measurement of groundwater elevation and collection of water quality samples. Each nested location within the wetland complex consisted of 3 piezometers (surface, shallow and deep) installed at progressively deeper intervals. The surface, shallow and deep depths corresponded to 0-1 feet, 1-2 feet, and 4-5 feet below the surface. The piezometers were oriented in four east-west oriented transects across the wetland (perpendicular to the channel) to provide sufficient areal coverage to support characterization of site hydrology and characterize the horizontal and vertical distribution of phosphorus in groundwater and surface water. One piezometer location was located east of the wetland complex in the upland soils. The purpose of this piezometer was to monitor local groundwater elevations outside of the wetland complex and facilitate evaluation of the interaction between groundwater within upland soils groundwater within the wetland soils.

The deep piezometers were installed in December 2021 before the ground froze and the remaining infrastructure was installed in April/May 2022 once thawed conditions returned. Bog-like conditions at PZ-8 prevented installation of piezometer in that location so no data was collected from that location.

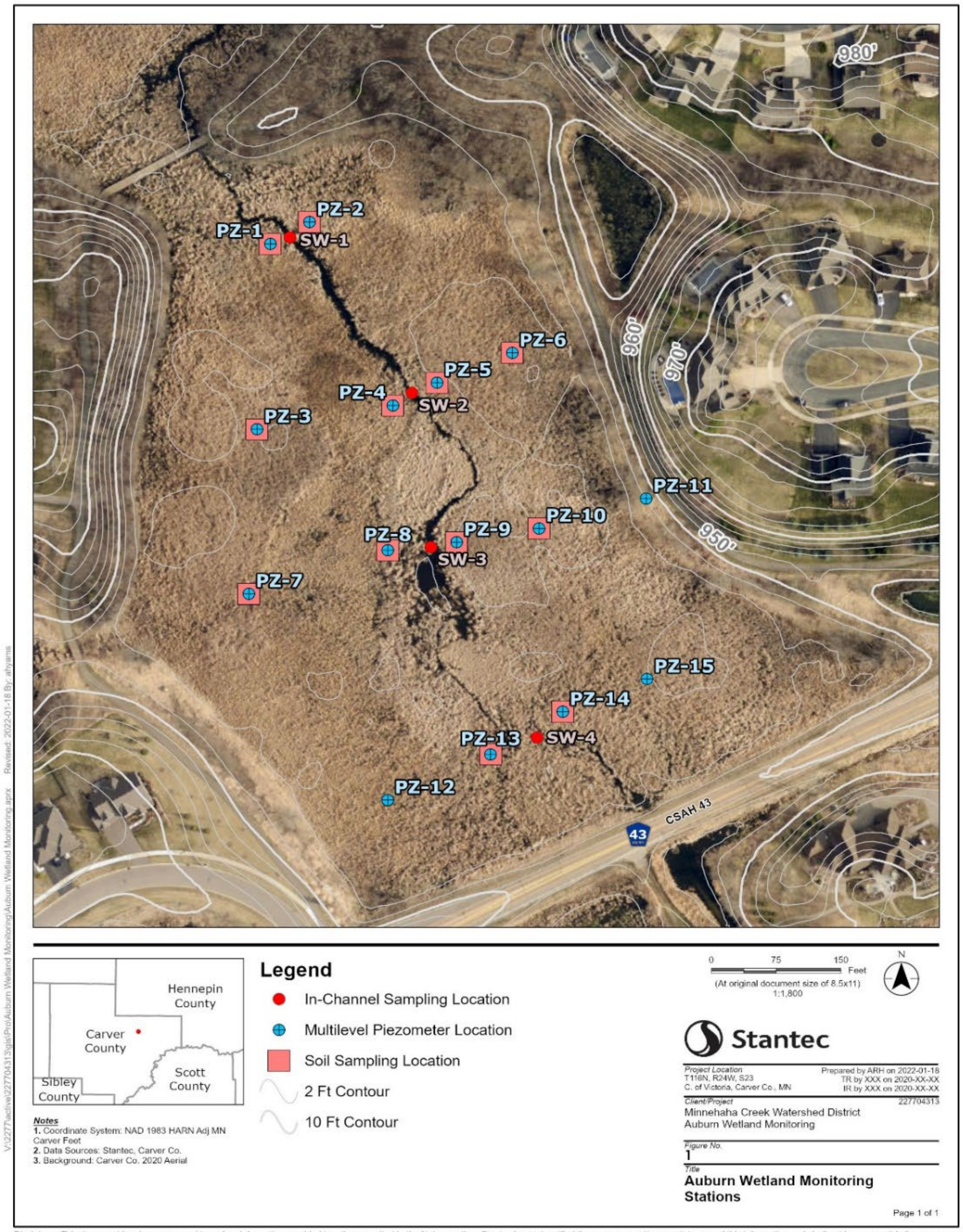
Four stilling wells were installed within the wetland channel of Six Mile Creek that bisects the Auburn Wetland. Stilling wells provided a stable location for measurement of surface water elevations to provide data to evaluate surface water/ groundwater interaction.

The piezometers and stilling wells were surveyed to document horizontal coordinates, elevations of ground surface and top of riser casing. Manual water level measurements were collected periodically from each of the piezometers and stilling wells following installation. In addition, pressure and temperature logging transducers were installed in PZ-7, PZ-9, PZ-10, PZ-11 (upland site) and S3 which is the stream channel site that lies within that transect perpendicular to the stream channel (Figure 1). The pressure transducers provided information on (1) short-term variations in water levels, (2) wetland hydraulics in response to precipitation events, and (3) variability of groundwater flow within the wetland. Groundwater elevation data was collected throughout the monitoring period (approximately May 25, 2022 through September 6, 2022) and is discussed in the Results section.

Data from the piezometers provided depth-specific measurements to support characterization of the vertical variability in phosphorus, geochemical environment, and vertical and horizontal components of groundwater flow while the stilling wells provided information regarding groundwater and surface water interactions.

Water samples were collected from the piezometers and surface water stilling wells to characterize phosphorus dynamics throughout the site. Total nitrogen, temperature, dissolved oxygen, and conductivity were also measured in each well and stream sample during each sampling event where possible. Stream and groundwater well samples were collected by MCWD and sent to RMB laboratory for analyses.

Reference: Auburn Wetland Monitoring Project - Technical Memo



Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Figure 1. Monitoring locations within the Auburn wetland.

Soil and sediment samples were collected on August 1, 2022 for quantification of the phosphorus in the native soils and sediments. Sediments were collected from each of the four stream channel sites and near PZ-1, 2, 7, 9, 10. 12, 14, 14, and 15 according to the depths shown in Table 1.

Table 1. Sediment core depths by sample location.

Location	Sample Depth (below substrate surface)
Stream Channel	0-3 inches
Monitoring Wells (Surface)	0-1 feet
Monitoring Wells (Shallow)	1-2 feet
Monitoring Wells (Deep)	4-5 feet

Soil and sediment samples were delivered to the University of Wisconsin-Stout for phosphorus chemistry analyses. These analyses quantified the phosphorus into pools that are operationally defined as mobile and non-mobile phosphorus fractions (Table 2). The mobile phosphorus pool is more readily available for biological uptake and processing and has a higher likelihood of diffusion and transport due to its chemical composition. In contrast, the non-mobile pool is not readily available for biological uptake and processing because the chemical structure is more complex than the mobile pool of phosphorus. These chemistry data were evaluated with the hydrology data to assess the potential for phosphorus mobilization with groundwater across the wetland complex to the stream channel.

Table 2. Operational grouping and recycling potential of phosphorus fractions

Operational Grouping	P Fraction	Recycling Potential
Mobile P pool	Iron-bound P Loosely-bound P Labile organic P	Biologically-labile and may be recycling through biogeochemical and geochemical reactions
Permanent P pool	Aluminum-bound P Calcium-bound P Refractory organic P	Biologically-refractory and subject to burial

It is important to note that summer 2022 was a period of extreme drought in central Minnesota. In fact, flows ceased in the stream channel after early July which was accompanied by instances where some of the surface and shallow wells also dried up. However, the hydrological patterns and chemistry data that were collected provided useful information on the potential sources and pathways of phosphorus to the channel, which are discussed in the following section.

RESULTS

The following sections describe Stantec's observations in the hydrogeology and water quality data collected in the Auburn wetland complex.

Hydrogeological Observations

The hydrograph data indicated four distinct groundwater flow patterns over the monitoring period as described below. Figure 2 and Figure 3 are provided to visually support the following narrative.

The early monitoring period (late May through late June) is characterized by higher groundwater levels and inundation across much of the transect as indicated by water levels observed at surface locations PZ-7, PZ-9, and PZ-10 which monitor the surface soils and overland flow (Figure 2). During this period PZ-9 surface location water levels are nearly identical to the channel water level indicating that the surface water level is likely over the banks at this location. In general, groundwater flow is observed from the east and west and converging on the central channel within the wetlands as indicated by decreasing heads from PZ-10 to channel and from PZ-7 to the channel. Vertical hydraulic gradients within the nested piezometer sets are low as indicated by similar monitored groundwater elevations at each location.

During the late June to early July period, the channel surface water elevation drops below the groundwater elevation at all areas indicating that the channel stage has receded to within the banks of the channel and surface inundation recedes at piezometer locations PZ-7 and PZ-10 as indicated by the flat line transducer data indicating water levels that are below the transducer (Figure 2). Horizontal flow direction remains from the margins of the wetland toward the channel and vertical gradients within the nested piezometers remain low.

Early July to approximately August 6 is characterized by low rainfall and a relatively rapid decrease in water levels at PZ-7, PZ-10, and PZ-11 (Figure 2). By the end of this period, PZ-10 and PZ-7 are both below the creek elevation indicating a reversal, or partial reversal of groundwater flow direction towards the margins of the wetland. Downward vertical hydraulic gradients are observed to increase at PZ-9 during this period as evidenced by the increased difference between shallow and deep groundwater elevations.

Finally, the period between Early August and early September is characterized by higher precipitation that results in shifts the groundwater flow back from the margins of the wetland toward the channel.

As indicated above the highest flux of groundwater to the channel is anticipated to have occurred during the wetter period August 6 through early September as indicated by a higher hydraulic gradient from the margins of the wetland towards the channel and the lowest period of flux of groundwater to the channel is during the period from early July to early August when there was low precipitation and presumably high evapotranspiration (Figure 3).

Detailed hydrographs by monitoring well location are provided in Appendix B.

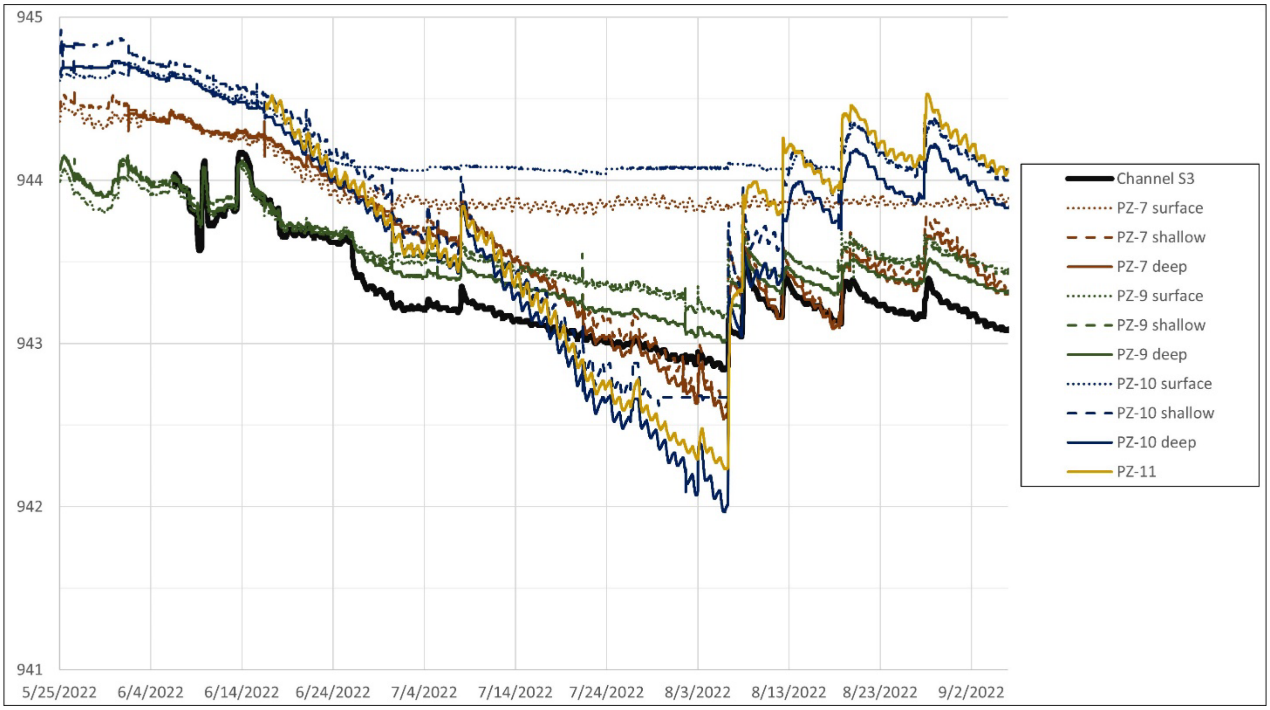


Figure 2. Hydrograph showing groundwater and surface water elevations during continuous monitoring.

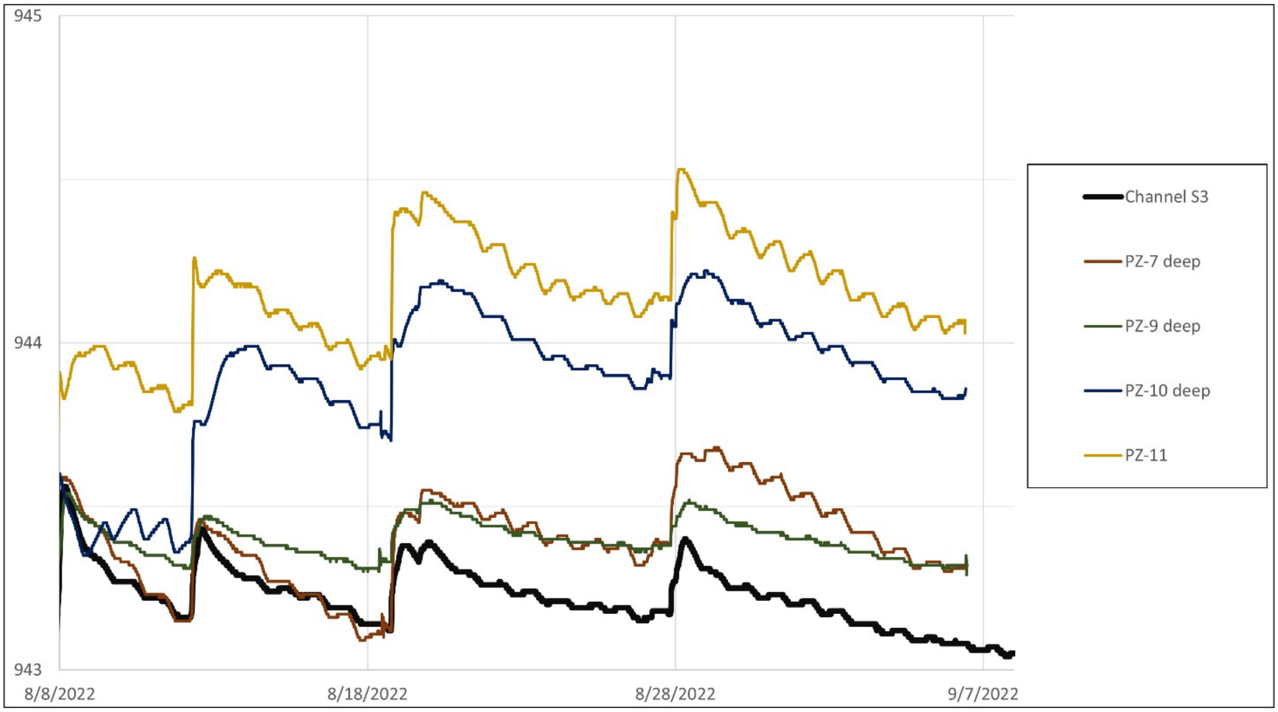


Figure 3. Hydrograph showing groundwater and surface water elevations during period from August 8, 2022 through September 8, 2022. Lateral flow within the subsurface groundwater is inferred to be from the margins of the wetland toward the channel as exhibited by water elevation decreasing from upland (PZ-11) to mid-wetland (PZ-10 and PZ-7) to near channel wetland (PZ-9) to channel (S-3).

Water Quality Results

Stream channel and groundwater monitoring well phosphorus concentrations were evaluated both temporally and spatially. Median groundwater total phosphorus concentrations (0.28 mg/L) are approximately 4.5 times higher than median surface water concentrations (0.06 mg/L) in the stream channel, presenting groundwater as a potential source of phosphorus to the stream channel (Figure 4). Substantial inflows of phosphorus to wetland streams through groundwater have been observed elsewhere (Reddy et al. 1999).

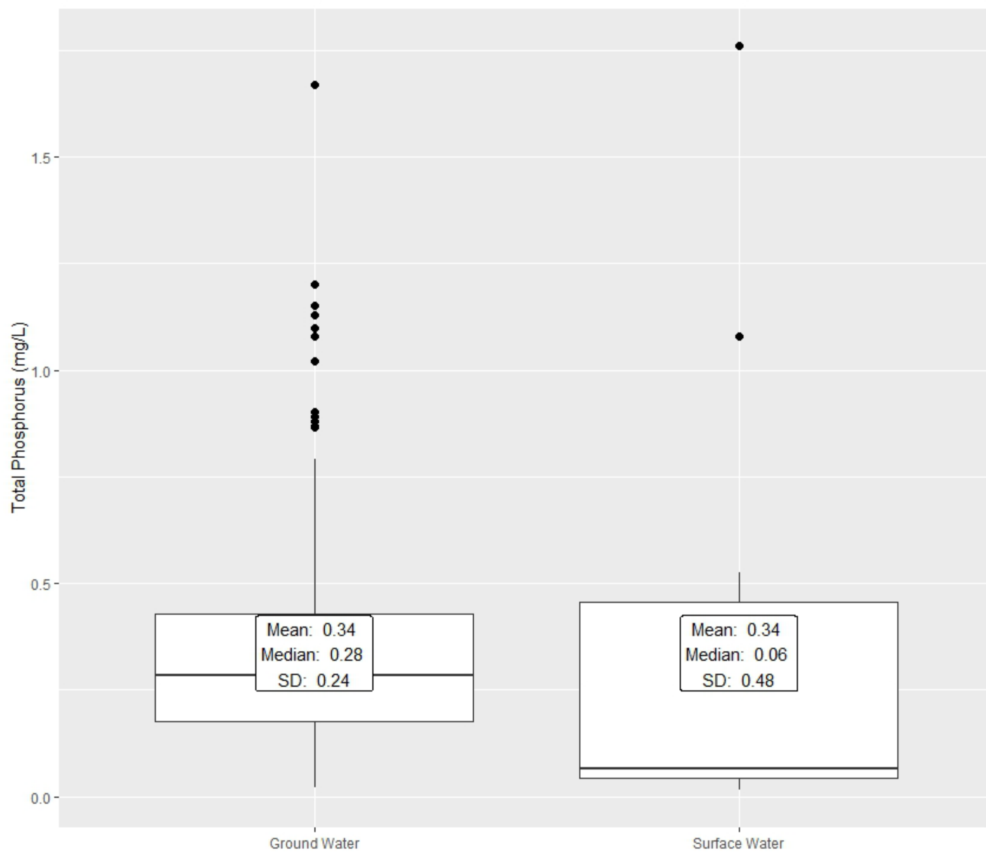


Figure 4. Box plot showing the distribution of total phosphorus concentrations in groundwater versus the stream channel. Note that the surface water samples are comprised of just four samples due to the ongoing drought conditions.

Figure 5 illustrates how these same concentrations varied over the course of the monitoring period, summarized by month. In aggregate across all well sites (vertically and laterally), groundwater TP concentrations show slight variability from month to month, but no clear temporal pattern emerged. Notably, however, stream channel concentrations increased from June to July from 0.05 mg/L to 0.76 mg/L. This trend is limited in data robustness given sampling frequency limitations due to the extreme drought that persisted for most of the summer. For example, July is only represented by a single sampling date whereas

June is represented by three sampling dates. No flow was observed in stream channel sites beyond June 13, 2022.

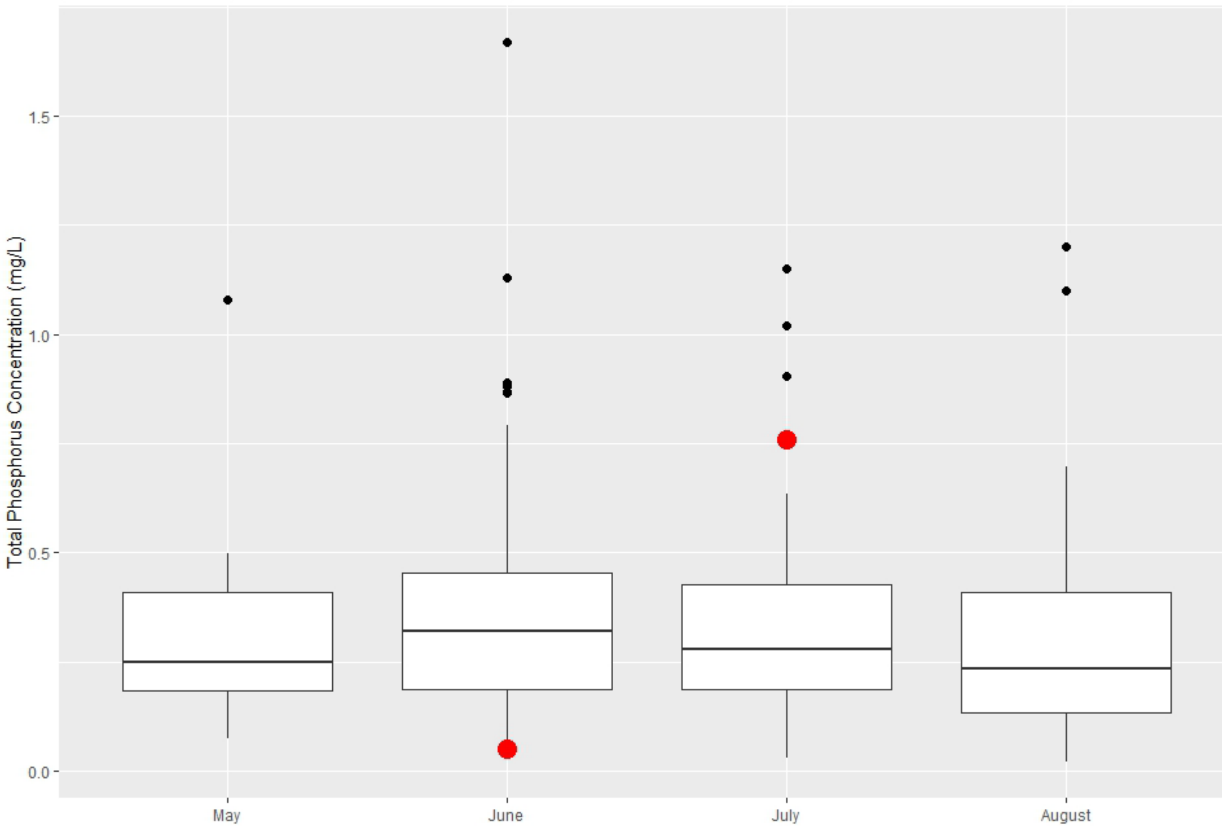


Figure 5. Monthly total phosphorus concentration boxplots for groundwater wells. Boxplots represent well data across all depths (surface, shallow, and deep). Red dots represent total phosphorus concentrations in the Auburn stream channel for months with sample data. June represents the median concentration across three sampling dates while July represents only a single sampling date.

A spatial assessment of elevated groundwater TP concentrations provides evidence that phosphorus concentrations are highly variable across the project extent, but generally high across the entire site (Figure 6). There are no established TP standards that apply to all wetlands in Minnesota to compare the Auburn wetland data to, however, groundwater TP concentrations are much higher than state eutrophication standards for TP in streams in Central Minnesota (≤ 100 µg/L; MN Statute 7050.0222).

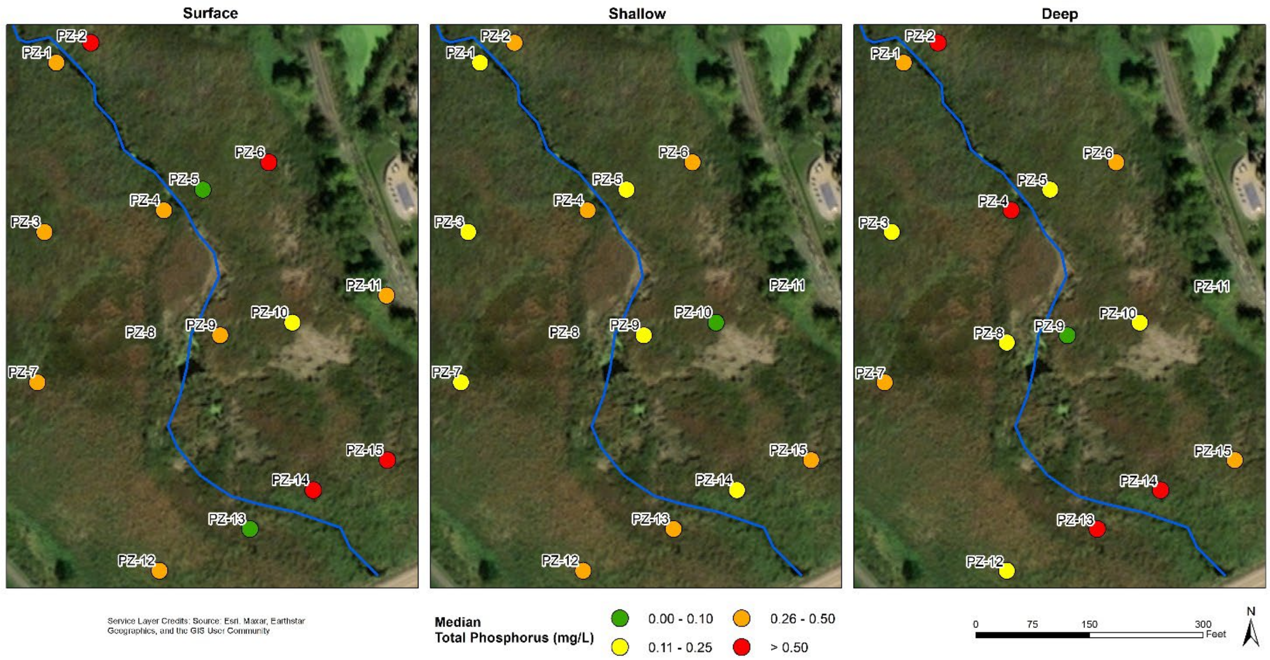


Figure 6. Spatial distribution of median total phosphorus in monitoring well samples (left to right: surface, shallow, deep wells). Green indicates median total phosphorus concentrations meeting the Minnesota eutrophication standard for TP in streams of 0.1 mg/L.

A time-series of TP concentrations in the Auburn stream channel, at each groundwater monitoring well depth, and at the upstream outlet from Wasserman Lake is shown in Figure 7. This figure demonstrates a general trend in increasing groundwater phosphorus concentrations at the deepest wells throughout the summer, whereas the surface and shallow wells demonstrate generally decreasing trends. This trend is supported by the observed downward flux of groundwater from mid-late summer. Notably, these trends are somewhat confounded by drought conditions during summer 2022, however, that caused inconsistent sampling conditions in the surface and shallow well depths (i.e., absence of water to sample).

Figure 6 also indicates that stream channel TP concentrations increased around the time that streamflow from the upstream Wasserman Lake outlet dried up (indicated by the vertical black dashed line). This provides one possible explanation for the increase in TP in the Auburn stream channel, where the absence of incoming streamflow coupled with an increase in phosphorus concentrations within the Auburn stream channel indicates groundwater phosphorus influence on stream channel phosphorus. The hydrologic exchange of groundwater and surface water is demonstrated in the prior section; the water elevation data indicates that there are periods where a groundwater and surface water interface exist thus providing evidence that groundwater phosphorus can transport to the stream channel.

Reference: Auburn Wetland Monitoring Project - Technical Memo

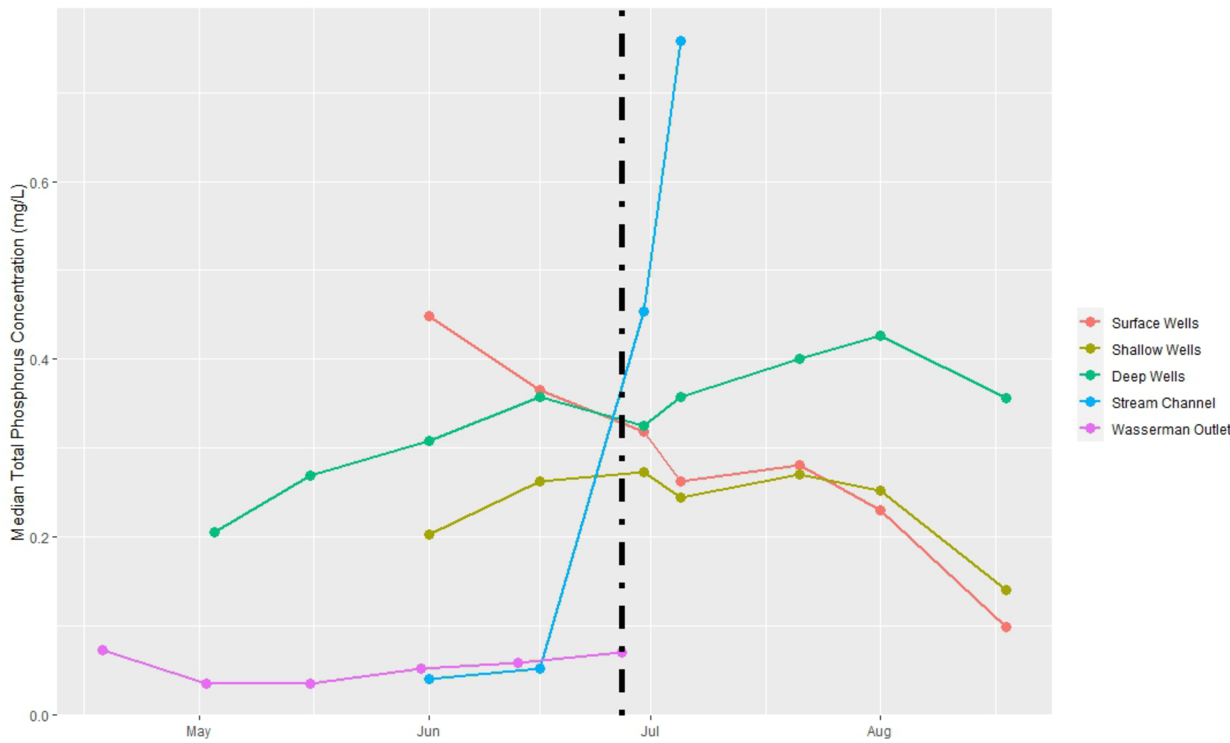


Figure 7. Median daily total phosphorus concentration for the three well depths (surface, shallow, and deep), the Auburn wetland stream channel, and the Wasserman Lake outlet. The black dashed line indicates when streamflow at the Wasserman outlet was first documented to be 0 cfs (June 27, 2022).

Soil and Sediment Results

The soil and sediment phosphorus chemistry results were also evaluated to understand the background content of phosphorus in the wetland and to quantify the pool of phosphorus that could potentially mobilize through groundwater or diffuse from the stream sediments under certain redox conditions. Sediment from the stream channel and soils from a subset of the groundwater monitoring well locations were taken at the depths listed in Table 1. The results of the soil and sediment samples are shown in Figure 8. Results from the wetland soils analyses demonstrate the highest concentrations of mobile P (see Table 2 for operational definition) at the surface depth in the monitoring wells followed closely by the stream channel. These results are consistent with other regional monitoring efforts in lakes where the largest concentrations of mobile P are closer to the substrate surface and the lowest concentrations of mobile P are furthest (deepest) from the substrate surface. This pattern is expected with soils and sediments containing high amounts of organic matter, such as productive lakes and wetlands. The organic matter present in deeper soils is older and has been subject to microbial processing leaving behind more recalcitrant material being buried in deeper layers and are therefore dominated by the non-mobile pools of P. In contrast, the surface soil layers contain younger organic matter with ongoing microbial processing that releases bioavailable phosphorus (i.e. non-mobile P) through decomposition processes. The Auburn wetland soils are consistent with expectations for vertical gradients of mobile P and non-mobile P (Reddy et al. 1999) in wetland soils. Figures demonstrating concentrations of both mobile and non-mobile P by site can be found in Appendix C.

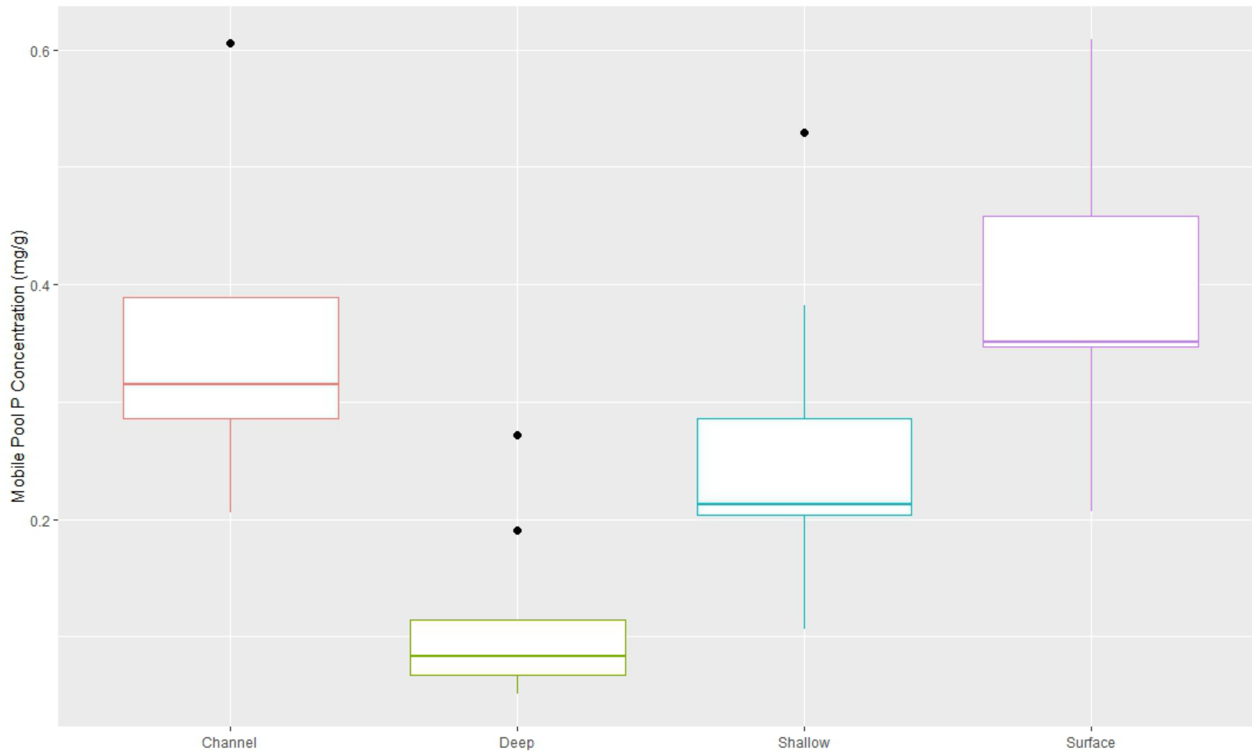


Figure 8. Box plot of mobile pool phosphorus (P) concentration in soil and sediment samples, by sample location. Note that the channel sample location is represented by only four data points, whereas typically five is the minimum requisite number of data points for a box plot. Due to this, the maximum value is also classified as an outlier based on the small distribution, hence there is no whisker between the upper quartile and the maximum value.

SUMMARY

During the monitored period groundwater flow was observed to be dynamic ranging from largely inundated/high groundwater conditions in spring, to low groundwater elevations and low groundwater discharge during the mid-summer, to a series of precipitation driven recharge events in August.

Water quality sampling in the groundwater wells and stream samples indicated that median total phosphorus concentrations in groundwater were approximately 4.5 times higher than median total phosphorus concentrations in the stream channel.

Groundwater flow observations indicated lateral movement towards the channel in the early-mid summer which was then dominated by downward vertical movement as drought conditions persisted through mid-late summer.

Groundwater flow observations indicated the potential for groundwater flux of total phosphorus to the channel

Our findings in the context of our original research questions are briefly summarized below.

1) **Is phosphorus high in the wetland complex (soils, sediments, groundwater, channel water)? *Yes***
   - Phosphorus is generally high in the East Auburn wetland soils and groundwater which is consistent with observations in other wetlands where extensive studies on phosphorus dynamics have been conducted (e.g. Reddy et al. 1999).
   - Total phosphorus concentrations were highly variable spatially and temporally but generally high throughout the site. For a frame of reference on what concentrations are considered high, we compared groundwater total phosphorus to the state standard for streams in Central Minnesota which is ≤ 100 µg/L (or 0.1 mg/L). Groundwater total phosphorus exceeded this standard in nearly all cases.
   - Mobile phosphorus was generally higher in surface soils compared to the deeper soils which is consistent with regional observations in lake sediments that display similar gradients.

2) **If phosphorus is high in the wetland complex, then is it able to mobilize to the stream channel? *Yes***
   - Hydrogeological observations indicate that groundwater was likely contributing flows, and thus total phosphorus, to the stream channel in early to mid-summer. The increase in total phosphorus in the stream observed after flow ceased from the Wasserman Lake outlet support this as a likely pathway for total phosphorus load to the stream.
   - The high concentration of mobile phosphorus in the surface and shallow soil depths indicate high likelihood of transport with groundwater as the mobile phosphorus constituents tend to be more soluble than the non-mobile phosphorus fractions (Reddy et al. 1999).

Streams and wetlands have high capacity for retention and biological processing of phosphorus, which leads to high temporal and spatial variability in the relative proportion of dissolved vs particulate and organic vs inorganic fractions. There are multiple potential pathways for phosphorus to be delivered to the stream channel from the wetland cell evaluated in this study. Thus, mitigation alternatives that seek to reduce the potential for total phosphorus loads from groundwater to the channel and/or treat or filter water at the end of the channel hold the most promise for reducing phosphorus loads to Auburn Lake.

RECOMMENDATIONS

Through this study, Stantec has identified a few recommendations that could be implemented to better constrain understanding of the hydrology and nutrient dynamics in support of design alternatives to mitigate phosphorus loads from the wetland to Auburn Lake.

- Stream channel data indicated a higher proportion of orthophosphate relative to total phosphorus early in the monitoring period (6/1/2022 and 6/16/2022) with a lower proportion of orthophosphate later in the sample record (6/30/2022 and 7/5/2022). Phosphorus forms in wetlands and streams include not only the dissolved inorganic phosphorus fraction (i.e. orthophosphate) but also dissolved organic phosphorus, particulate inorganic and particulate organic fractions (Dunne and Reddy 2005). The organic dissolved and organic particulate phosphorus components of the stream samples were not directly quantified but could represent a large proportion of the phosphorus. The proportion of particulate versus dissolved fractions has implications for longevity and maintenance requirements for some engineered solutions to capture phosphorus in the stream channel. Therefore, a better understanding of the temporal variability in dissolved versus particulate phosphorus might be needed for advancement of mitigation solution design, especially if reactive media is considered.

- There are additional pathways for phosphorus transport to the stream channel which were beyond the scope of this project. The relative magnitude of these pathways to deliver phosphorus to the stream channel could be investigated further, which includes the following potential mechanisms:
    - Release of mobile phosphorus from channel sediments through redox reactions and/or organic matter processing,
    - Overland flow through non-permanent water tracks in wetland complex

- The magnitude of the groundwater total phosphorus load is uncertain and cannot be estimated in a meaningful way with the available data. Stantec recommends single well instantaneous displacement tests (slug tests) be conducted at a subset of piezometer locations to estimate hydraulic conductivity of the wetland sediments. This data, in combination with hydraulic gradient and porosity may be used to estimate TP flux from groundwater to the channel. These could be compared to early season loads from the Wasserman outlet where total phosphorus samples were paired with flow measurements.

Additional recommendations appear in Appendix A for each of Stantec's conceptual alternatives.

REFERENCES

Dunne E.J. and K.R. Reddy. 2005. Phosphorus biogeochemistry of wetlands in agricultural watersheds pp. 105-119 in Nutrient Management in Agricultural Watersheds: A Wetlands Solution. 288 pages. Wageningen Academic Publishers.

Reddy K.R., R.H. Kadlec, E. Flaig and P.M. Gale. 1999.

Stantec. 2022. Auburn Wetland Targeted Monitoring Plan. Prepared for Minnehaha Creek Watershed District on January 19, 2022.

Appendix A – Engineering Options

The following engineering options represent Stantec's best professional judgement on potential management alternatives to mitigate loads from the wetland to Auburn Lake, rather than a comprehensive list of all possible projects that could be evaluated to achieve goals.

Option 1. Hydrological Modification/Re-routing of Channel in the Wetland

Conceptual Description: Hydrological modifications to the wetland can be achieved (1) by altering the wetlands outlet, or (2) by a combination of altering flow through the wetland, introducing some open water settling pools, managing vegetation, and lining a new channel to disconnect groundwater flows to downstream surface waters. Altering the outlet of the wetland could be as simple as implementing a ditch check to increase the duration of inundation during low flows, or it could be done by implementing a reactive media barrier (See Option 2). Modifying the wetland outland will increase hydrology within the wetland and limit the desiccation of plant material that may be contributing to higher dissolved phosphorus levels within the wetland soils and groundwater. Altering flow through the wetland by constructing a new channel would allow for the implementation of excavated open water settling pools to increase particulate phosphorus removal during wet years. A more involved option may include a clay lined channel and a vegetation management plan to reduce groundwater flows to surface waters and implement higher quality vegetation that would be more resilient to fluctuations between wet and dry years.

Uncertainties around this alternative:

- The source of the phosphorus. This option would be most effective if the source of the dissolved phosphorus is due to the internal desiccation cycle of the vegetation and not some off-site groundwater contamination.

- Permit-ability. Depending on the class of the wetland and the decisions of the local WCA LGU will determine whether, and how, the hydrologic and hydraulic regime of this wetland can be altered.

- Upstream water-levels. To increase inundation in this wetland may increase inundation and high-water levels upstream in Lake Wasserman. Lake Wasserman is in a FEMA Zone A, so the base flood elevation may be able to be increased if the increased inundation footprint does not affect adjacent property owners or structures.

Additional data/information needed to evaluate feasibility of alternative:

- Additional analysis between wet and dry years should be evaluated to determine whether the high dissolved phosphorus source is the groundwater or the leaching of dissolved P to the groundwater from the soils via desiccation of vegetation.

- A vegetation survey should also be conducted to confirm the presence of low-quality vegetation seen in aerial photos.

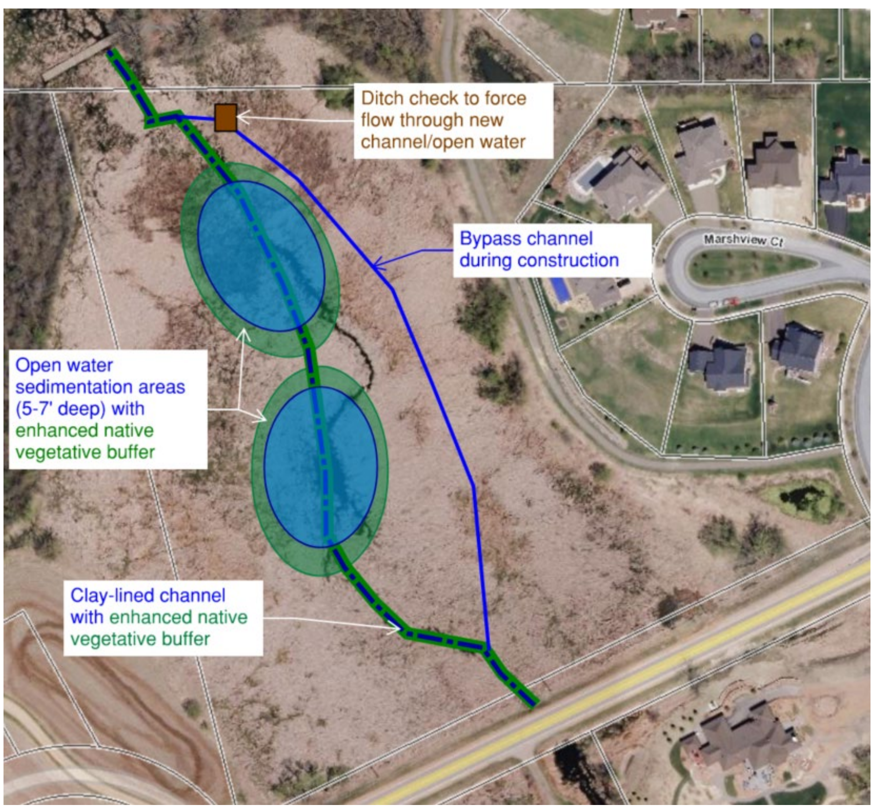
- Conversations with BWSR, the local WCA LGU, and the DNR should be conducted to determine the permitting feasibility for this wetland.

- Low floor and low opening elevations adjacent to Lake Wasserman and any other basins upstream where base flood elevations increase.

Total expected range of costs (less O&M): $95,000 to $1,400,000

- Construction Subtotal Cost = $75,000 - $1,250,000
- Design and Construction Engineering (~20%) = $15,000 - $100,000
- Permitting (~5%) = $4,000 – $50,000

Conceptual sketch of alternative:



Option 2. Reactive Media Barrier

Conceptual Description: Permeable reactive barriers (PRB) installed on the perimeter, or the downstream end of the wetland would intercept and remove dissolved phosphorus from groundwater flows before moving further downstream. Groundwater phosphorus is a significant source of P (4 times higher than stream channel) and capturing phosphorus before groundwater interacts with surface water would reduce P loading to Lake Auburn. PRB are commonly installed by excavating a long trench perpendicular to groundwater flow and backfilling with conventional reactive media (e.g. iron, zeolite, limestone, biochar). Reactive media are then capped to eliminate visibility from the surface.

Uncertainties around this alternative:

- The reactivity of a PRB will reduce overtime and when media reaches its sorption capacity it will need to be excavated and replaced. Time to exhaustion (commonly 10 to 100 years) will depend on the media selected, size of the barrier, and groundwater P concentrations, and groundwater flow rates.

- The selection and effectiveness of a phosphorus sorbing media would need to be analyzed when constantly inundated, as iron filings may not be best suited for this alternative due to its ability to become anoxic during long inundation periods.

- The installation of a PRB within will require a wetland alteration plan as the installation of the PRB would be classified as wetland fill and a wetland replacement plan or credits would likely be required.

- The feasibility and required operation and maintenance of a PRB within a wetland is relatively unknown.

Additional data/information needed to evaluate feasibility of alternative:

- Horizontal groundwater flow and direction will need to be determined through measurements and modeling.

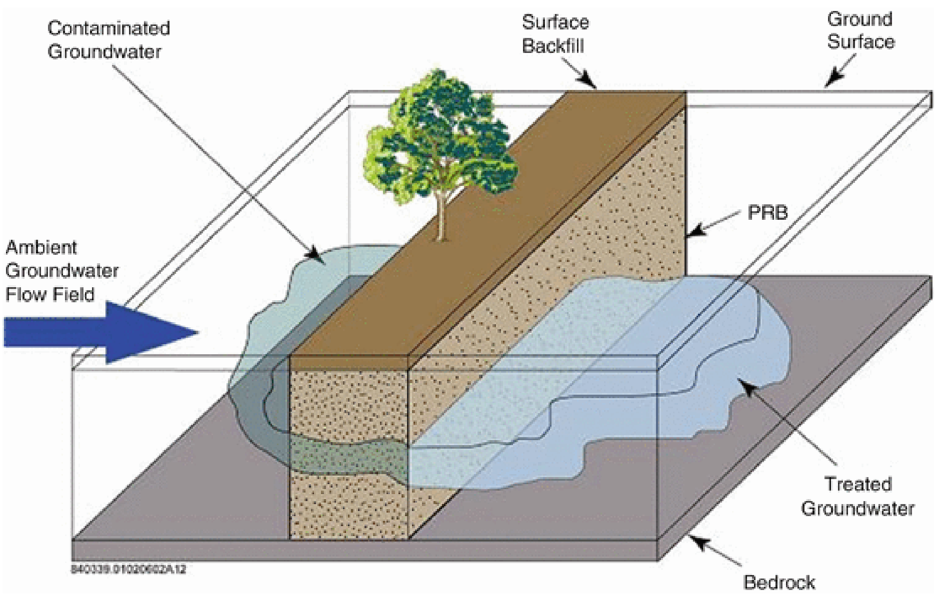
- Conversations with BWSR, the local WCA LGU, and the DNR should be conducted to determine the permitting feasibility for this wetland.

- Low floor and low opening elevations adjacent to Wasserman Lake and any other basins upstream where the installation of a PRB would increase base flood elevations.

Total Expected range of costs (less O&M): $95,000 to $435,000

- Construction Subtotal Cost = $75,000 - $350,000
- Design and Construction Engineering (20%) = $15,000 - $70,000
- Permitting (5%) = $4,000 – 17,500

Conceptual sketch of alternative:



Source: Asokbunyarat, V., Lens, P.N.L., Annachhatre, A.P. (2017). Permeable Reactive Barriers for Heavy Metal Removal. In: Rene, E., Sahinkaya, E., Lewis, A., Lens, P. (eds) Sustainable Heavy Metal Remediation. Environmental Chemistry for a Sustainable World, vol 8. Springer, Cham. https://doi.org/10.1007/978-3-319-58622-9_3

Option 3. Sedimentation Basin + Filtration (gravity or pumped) Using Reactive Media

Conceptual Description: Reactive media will remove dissolved P from surface flow within the channel when installed as filter. Sedimentation basins installed prior to reactive media filters would reduce the potential for media clogging and reduce particulate phosphorus. Sedimentation basins and reactive media have been installed as gravity fed treatment for agricultural runoff. Sedimentation basin could be installed inline while filtration system could be installed offline outside of the wetland area in upland area as a pumped filtration system.

Uncertainties around this alternative:

- Selection of the reactive media for an inline filter will be important as the effectiveness of the media will decrease over time and need replacement.
- For an inline, gravity fed filter, the media may be difficult to maintain as hydraulic conductivity through the filter will be greatly reduced through fine sediments.
- For a pumped filter, getting power to the pump and finding upland area nearby will be difficult and quite costly, however, a pumped filter will be able to use iron-enhancements for a reactive media as the pump could be timed to allow for periods of drawdown for maintenance.

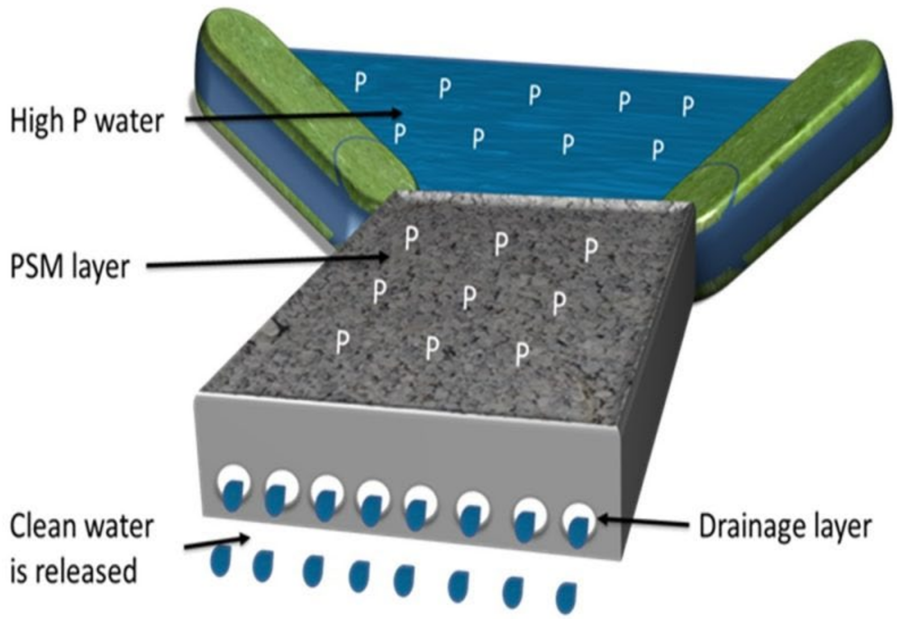
Additional data/information needed to evaluate feasibility of alternative:

- Surface water flow rates and particle size of suspended sediment is needed for prescriptive design.
- Groundwater level fluctuations will need to be studied for a gravity system. To ensure hydraulic conductivity can be achieved.
- For a pumped system, we will need to further understand how the dissolved phosphorus mobilizes. We do not want to just pull high concentrations of groundwater from a sedimentation basin, treat it through filtration, and send it downstream if we are just further mobilizing it, but a pumped system could act as a recirculation system so surface water discharged downstream of our wetland have reduced concentrations of phosphorus.
- Hydraulic flows through the wetland will need to be modeled to accurately size a filter for the large upstream drainage area.

Total Expected range of costs (less O&M): $312,500 to $625,000

- Construction Subtotal Cost = $250,000 - $500,000
- Design and Construction Engineering (20%) = $50,000 - $100,000
- Permitting (5%) = $12,500 – $25,000

Conceptual sketch of alternative:



Source: Penn, C.J., McGrath, J.M., J. Bowen, and S. Wilson. 2014. Phosphorus removal structures: a management option for legacy phosphorus. J. Soil. Wat. Cons. 69:51A-56A.

Reference: Auburn Wetland Monitoring Project - Technical Memo

Appendix B - Hydrographs

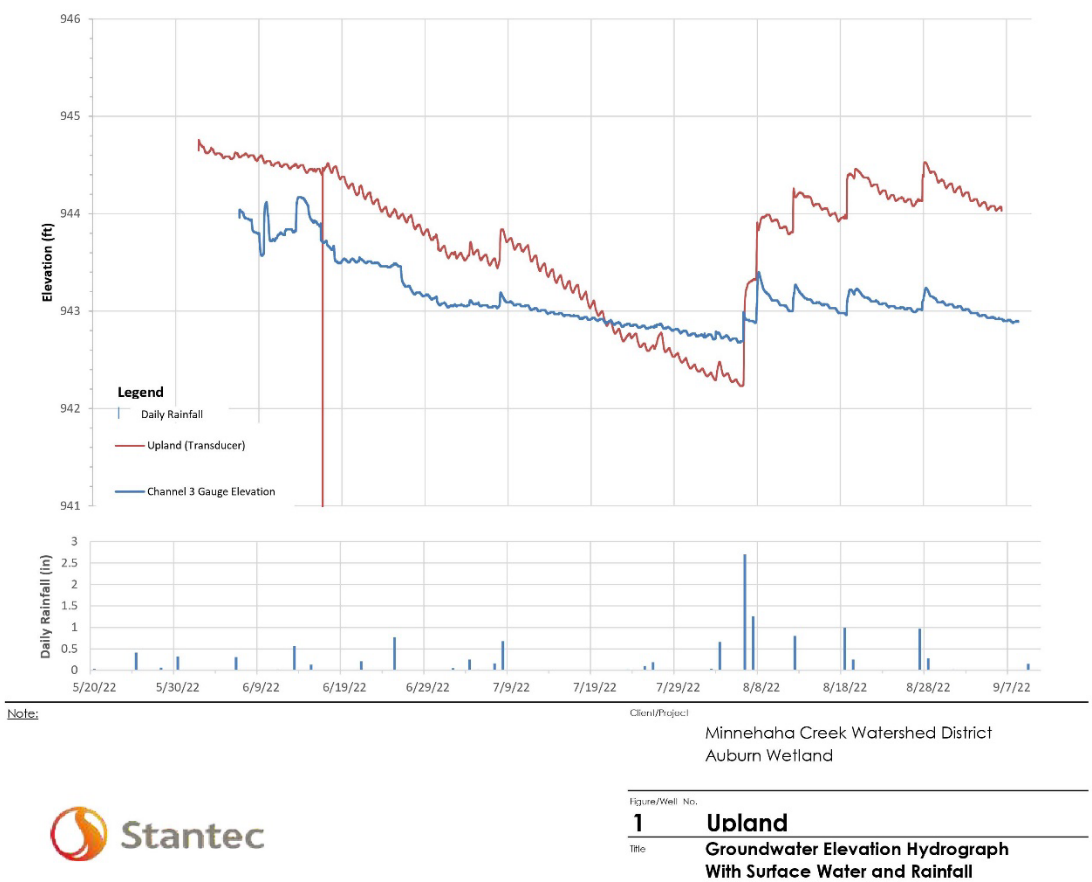


Figure B1. Hydrograph showing groundwater elevation at the upland monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Reference: Auburn Wetland Monitoring Project - Technical Memo

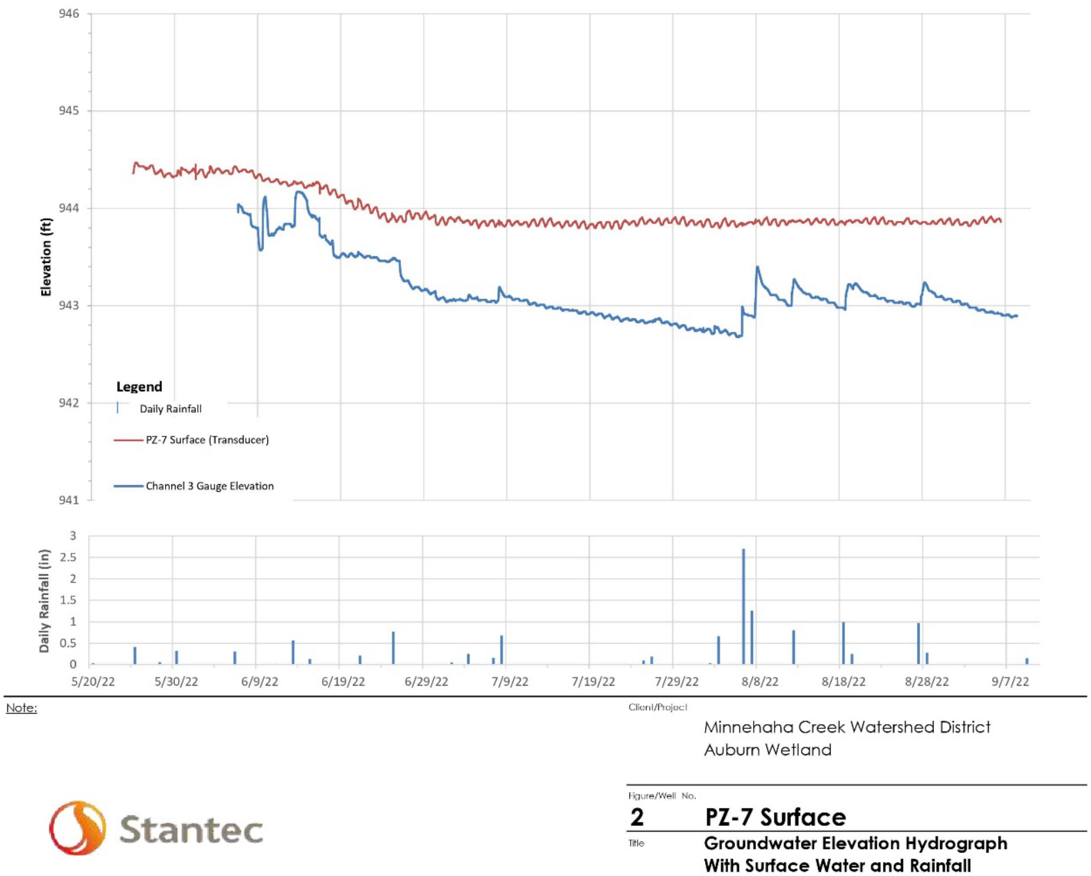


Figure B2. Hydrograph showing groundwater elevation at the surface PZ-7 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Reference: Auburn Wetland Monitoring Project - Technical Memo

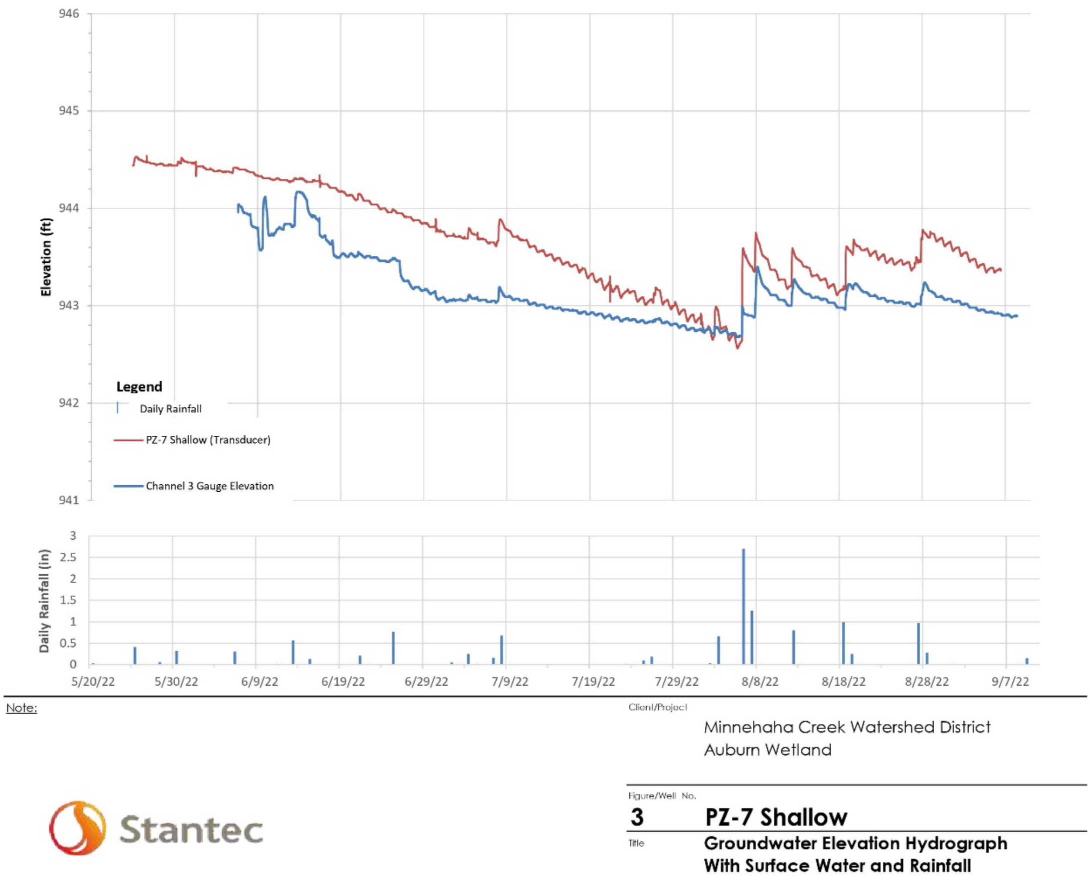
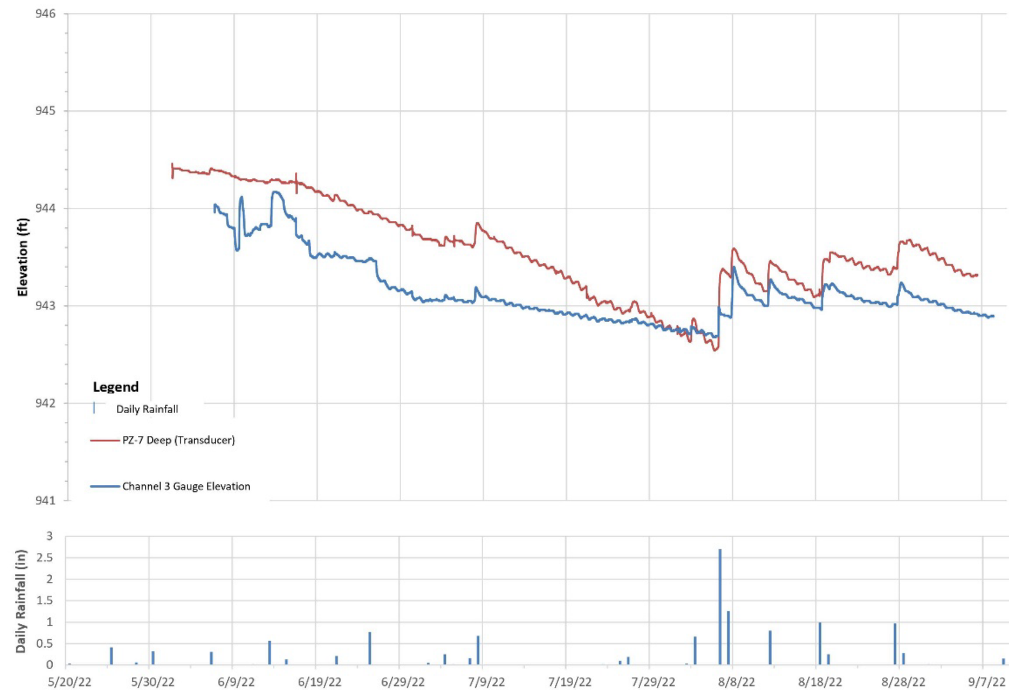


Figure B3. Hydrograph showing groundwater elevation at the shallow PZ-7 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Reference: Auburn Wetland Monitoring Project - Technical Memo



Note:

Client/Project

Minnehaha Creek Watershed District
Auburn Wetland

Stantec

Figure/Well No.

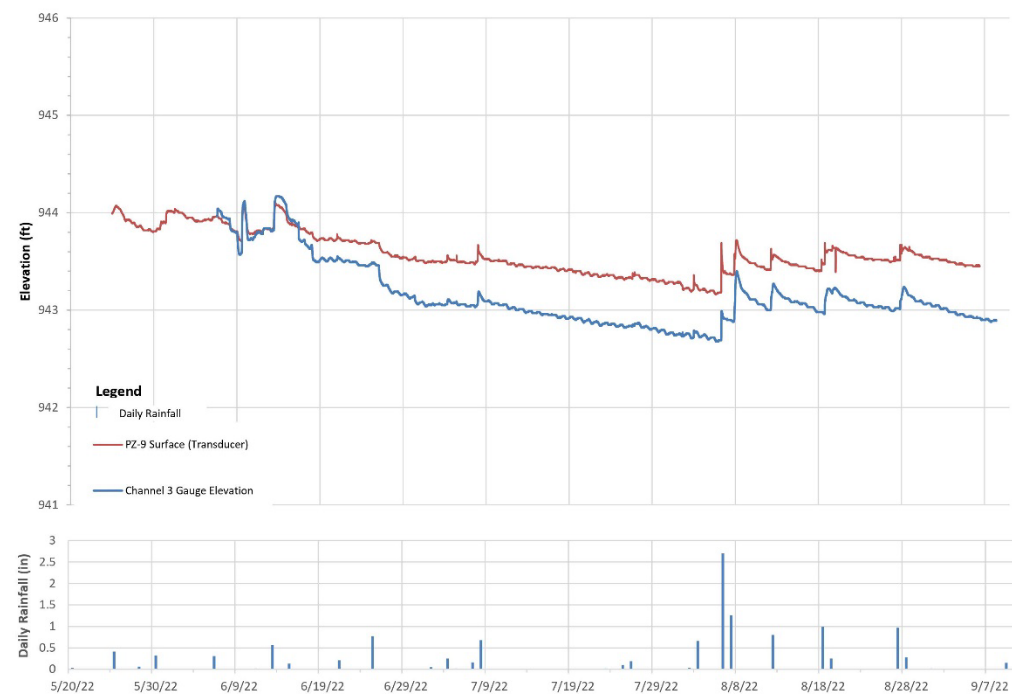
4 **PZ-7 Deep**

Title

Groundwater Elevation Hydrograph
With Surface Water and Rainfall

Figure B4. Hydrograph showing groundwater elevation at the deep PZ-7 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Reference: Auburn Wetland Monitoring Project - Technical Memo



Note:

Client/Project
Minnehaha Creek Watershed District
Auburn Wetland

Stantec

Figure/Well No.
5 **PZ-9 Surface**
Title **Groundwater Elevation Hydrograph With Surface Water and Rainfall**

Figure B5. Hydrograph showing groundwater elevation at the surface PZ-9 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Reference: Auburn Wetland Monitoring Project - Technical Memo

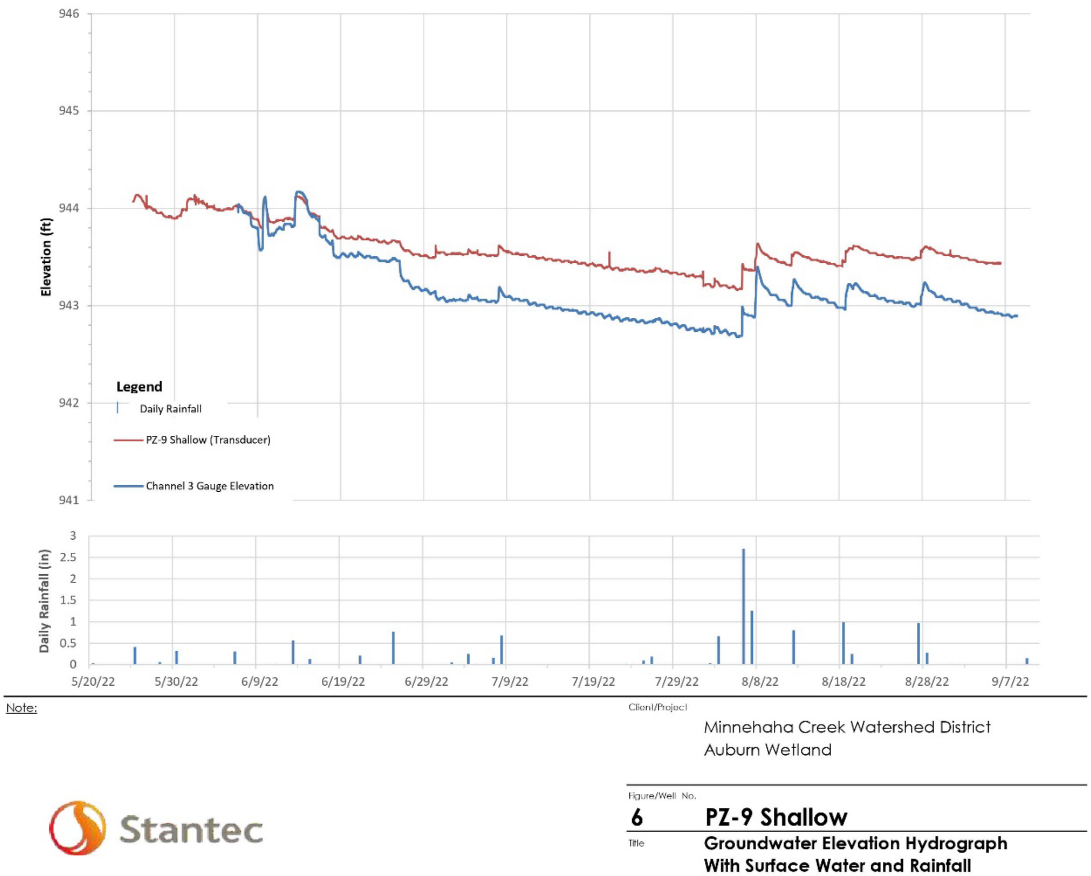
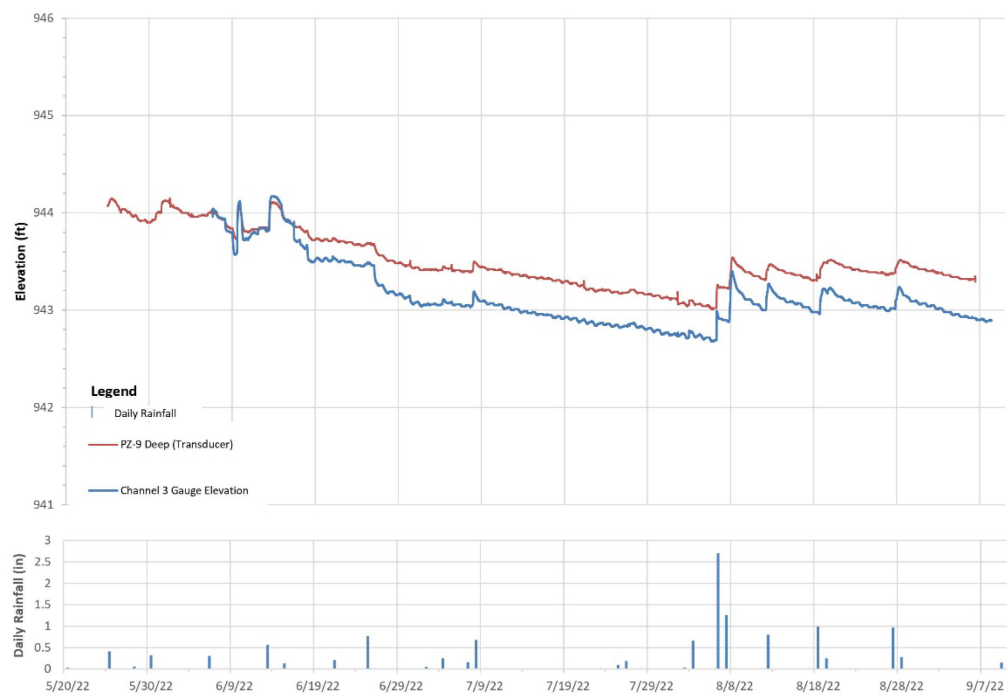


Figure B6. Hydrograph showing groundwater elevation at the shallow PZ-9 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.



Note:

Client/Project

Minnehaha Creek Watershed District
Auburn Wetland

Stantec

Figure/Well No.

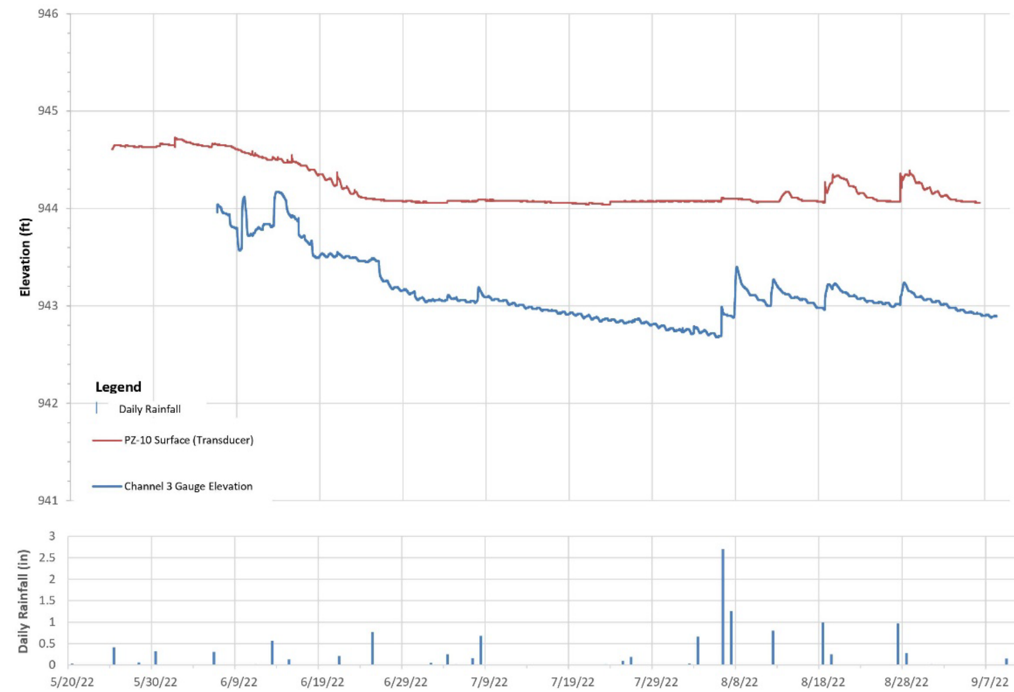
7 **PZ-9 Deep**

Title

Groundwater Elevation Hydrograph
With Surface Water and Rainfall

Figure B7. Hydrograph showing groundwater elevation at the deep PZ-9 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Reference: Auburn Wetland Monitoring Project - Technical Memo



Note:

Client/Project
Minnehaha Creek Watershed District
Auburn Wetland

Stantec

Figure/Well No.
8 **PZ-10 Surface**

Title
Groundwater Elevation Hydrograph With Surface Water and Rainfall

Figure B8. Hydrograph showing groundwater elevation at the surface PZ-10 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Reference: Auburn Wetland Monitoring Project - Technical Memo

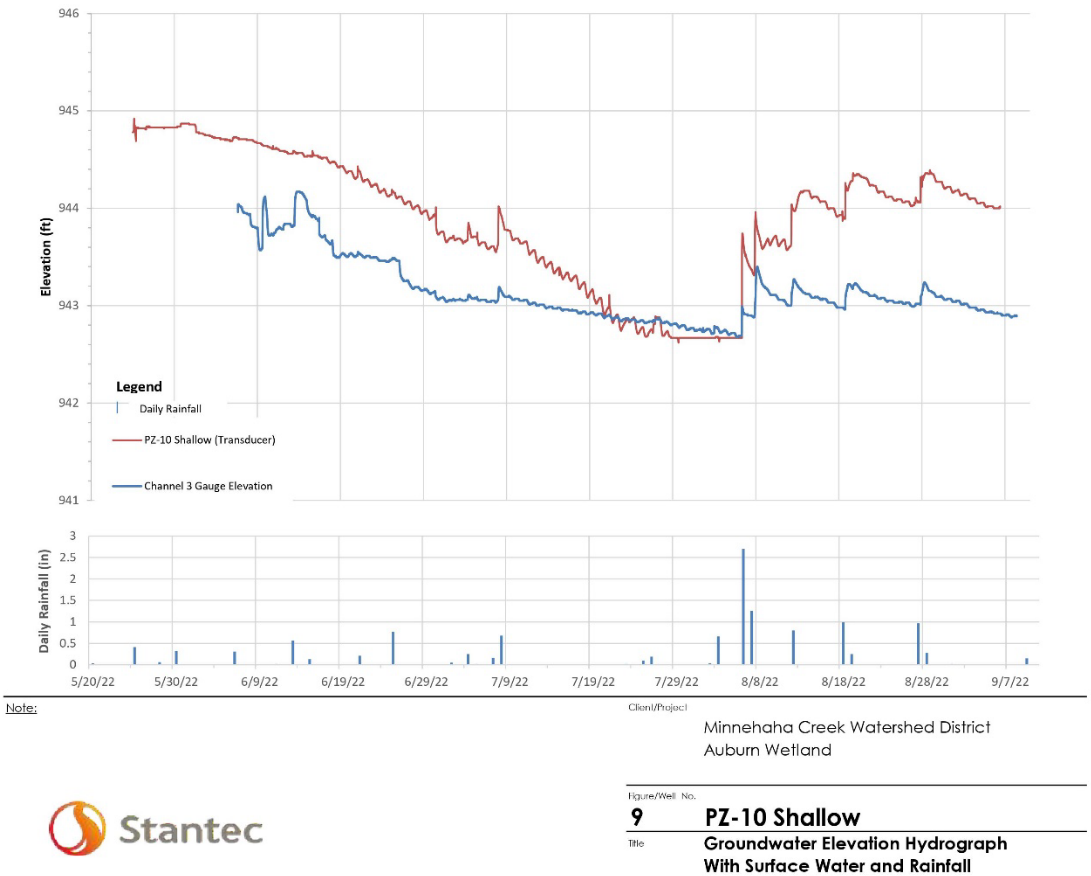
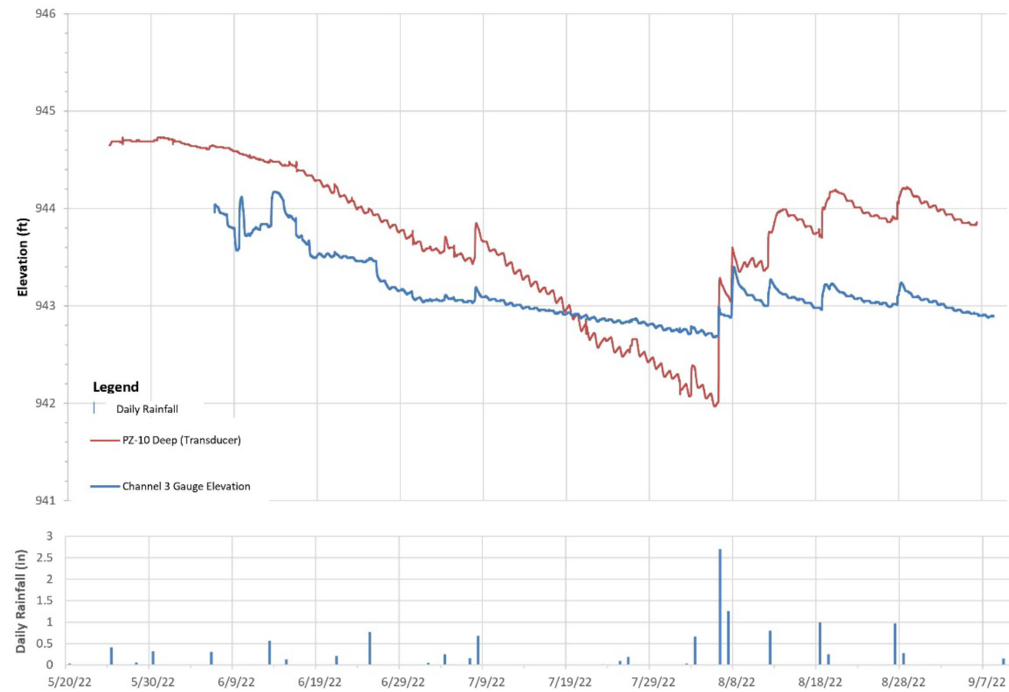


Figure B9. Hydrograph showing groundwater elevation at the shallow PZ-10 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Reference: Auburn Wetland Monitoring Project - Technical Memo



Note:

Client/Project
Minnehaha Creek Watershed District
Auburn Wetland

Figure/Well No.
10 **PZ-10 Deep**

Title
Groundwater Elevation Hydrograph With Surface Water and Rainfall

Figure B10. Hydrograph showing groundwater elevation at the deep PZ-10 monitoring well, surface water (Channel 3) elevation, and daily rainfall during continuous monitoring.

Appendix C – Phosphorus Pools in Soils and Sediments

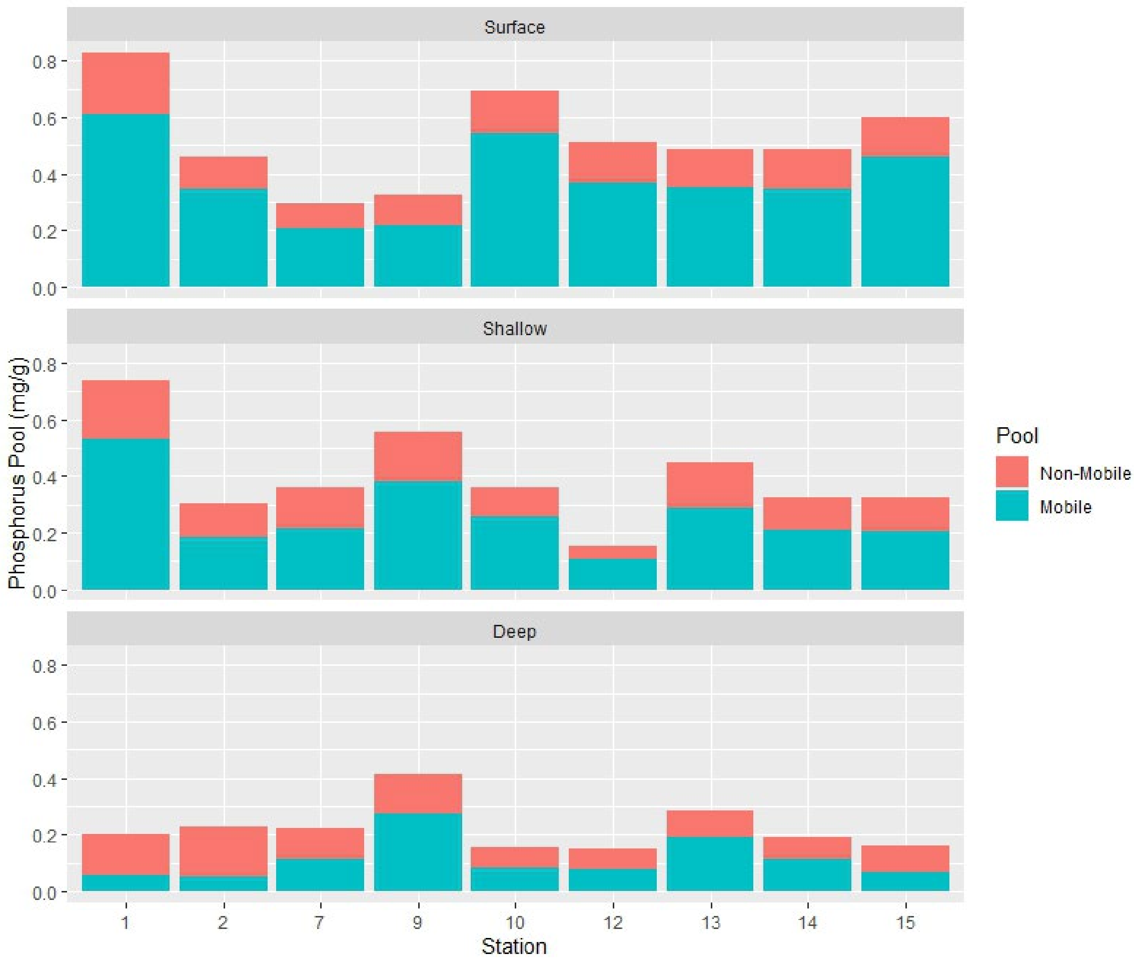


Figure C1. Mobile versus non-mobile pool phosphorus concentrations at monitoring well sites, summarized by surface, shallow, and deep samples.

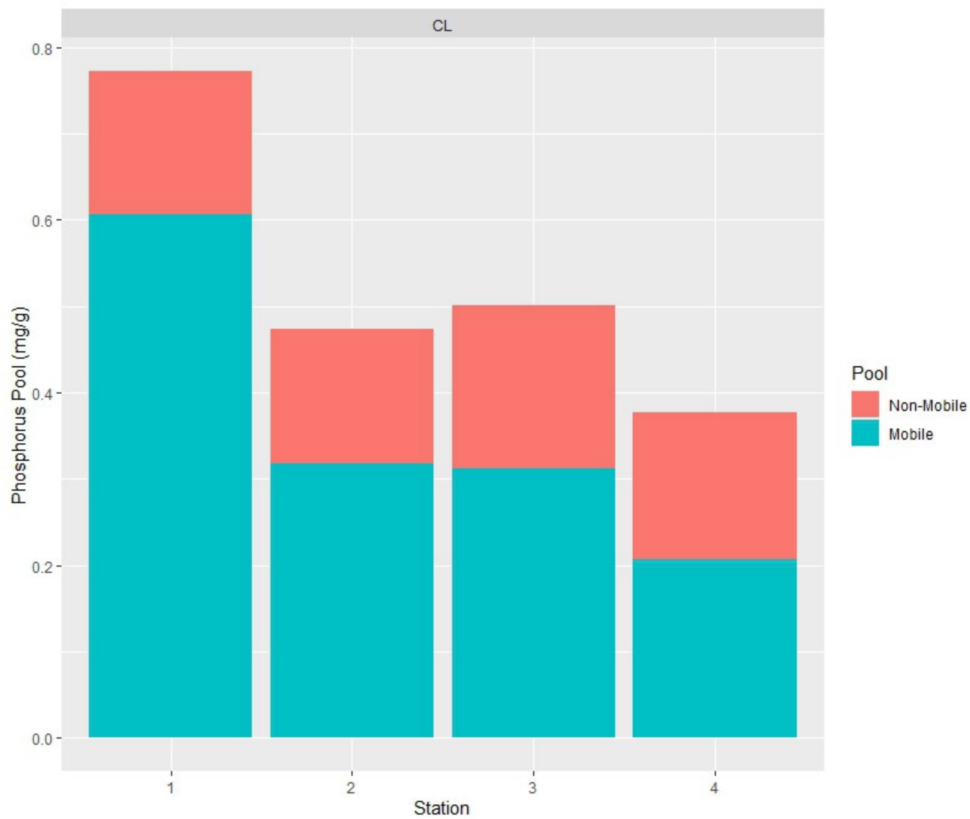


Figure C2. Mobile versus non-mobile pool phosphorus concentrations at stream channel sites. Station 4 corresponds to the most upstream station in the project extent and Station 1 is sited near the boardwalk in the most downstream location of the study site.

East Auburn Wetland Restoration Feasibility Study

October 2023
Moore Project No. 22924

moore engineering, inc.

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Figures

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Appendices

1. Introduction

In their 2017 Water Resources Management Plan (WRMP), the Minnehaha Creek Watershed District (MCWD) identified a goal to address nutrient export to East Auburn Lake (Minnehaha Creek Watershed District, 2017). Based on internal research and monitoring, MCWD identified Cell 1 in the wetland complex that feeds East Auburn Lake (referred to as the East Auburn Wetland) as the primary contributor of phosphorus to the lake. MCWD selected the Moore Engineering Team (Moore Engineering, Inc. [Moore], Wetland Solutions, Inc. [WSI], and Dr. Nathan Johnson) to develop a feasibility assessment for the Cell 1 Wetland to evaluate and recommend alternative strategies to manage phosphorus export from the wetland to East Auburn Lake.

1.1. Project Location

The Cell 1 Wetland site is in the City of Victoria, in Carver County, along Six Mile Creek between Wasserman Lake (upstream) and East Auburn Lake (downstream). Six Mile Creek is either an excavated or artificially incised creek that flows through a complex of four wetlands between the two lakes. Six Mile Creek flows into the Cell 1 Wetland at the outlet from Wasserman Lake where it passes through a 24-inch pipe under Church Lake Boulevard (County Road 43). The Cell 1 Wetland extends from below this culvert to a narrow cross-section where there is a pedestrian footpath at its north end. Below this footpath the creek continues through a series of additional wetland cells. The location of the Cell 1 Wetland and surrounding features is shown in Figure 1-1.

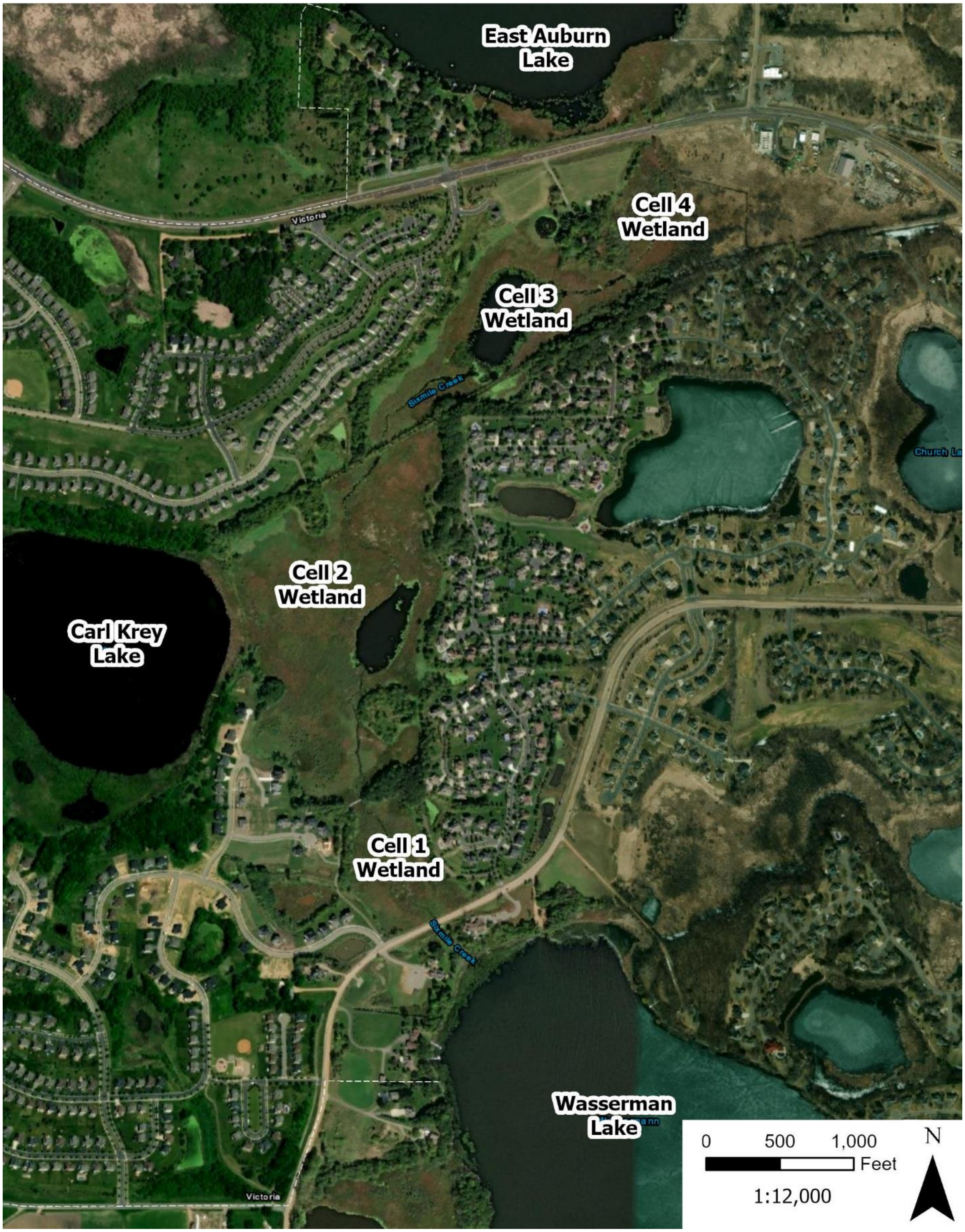

Figure 1-1. Cell 1 Wetland Location

1.2. Cell 1 Wetland History

The Cell 1 Wetland is not shown on the 1853 surveys of the area. However, Wasserman Lake and Lake Auburn are shown and Six Mile Creek is shown largely bypassing Lake Auburn to the west (Figure 1-2). In the 1905 United States Geological Survey (USGS) topographic map Six Mile Creek is shown connecting to the southeast corner of Lake Auburn as it exists today. This map also shows a road in place near the existing location of Church Lake Boulevard at the southern end of Cell 1, indicating that a culvert was already in place at the outlet of Wasserman Lake by 1905 (Figure 1-3). Review of more recent aerial photographs dating back to the 1940s demonstrates that the channel through the Cell 1 Wetland has been manipulated from its natural condition and straightened to improve drainage.

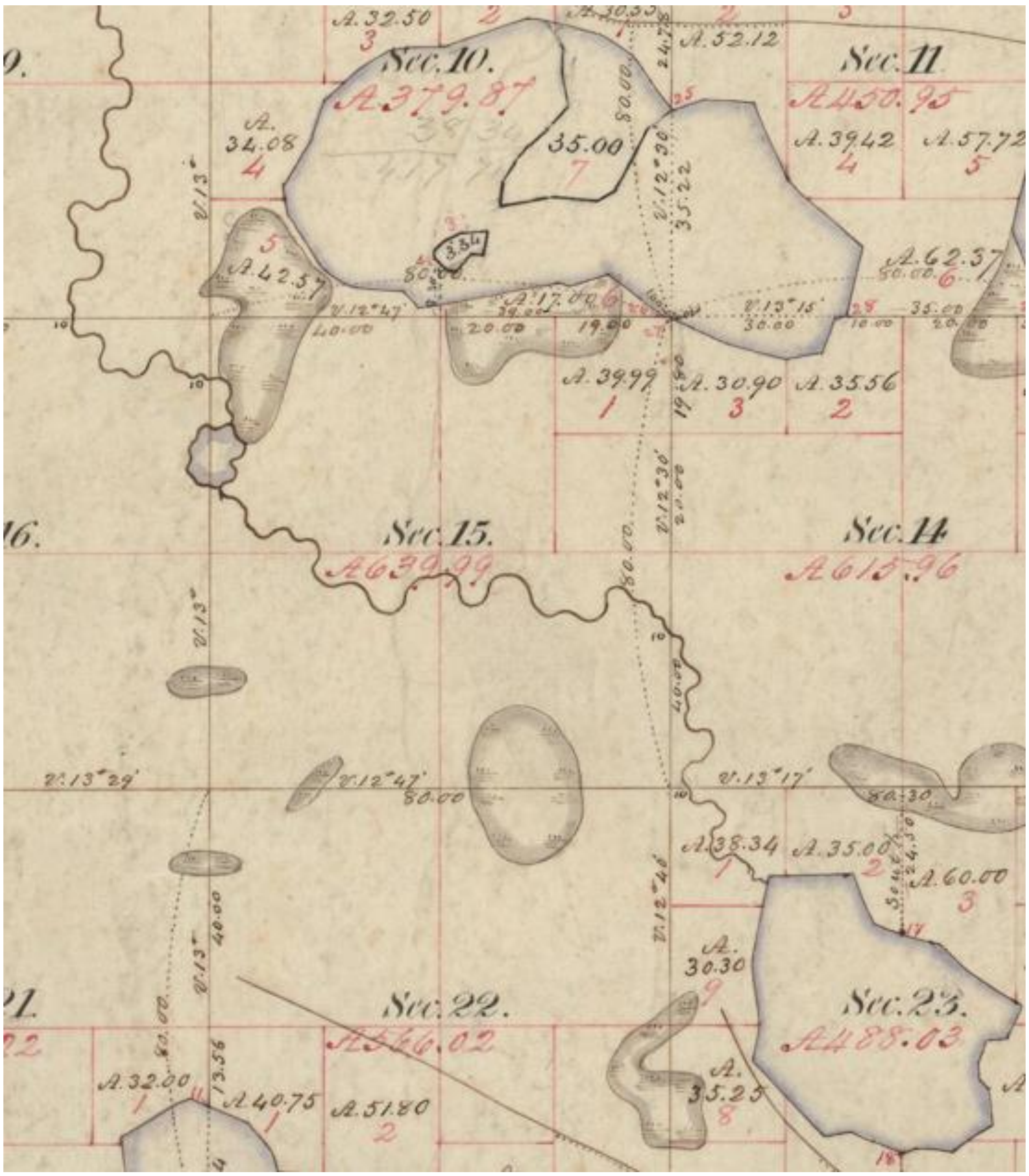

Figure 1-2. 1853 Survey of Wasserman Lake (Bottom Right) and Auburn Lake (Top Center)

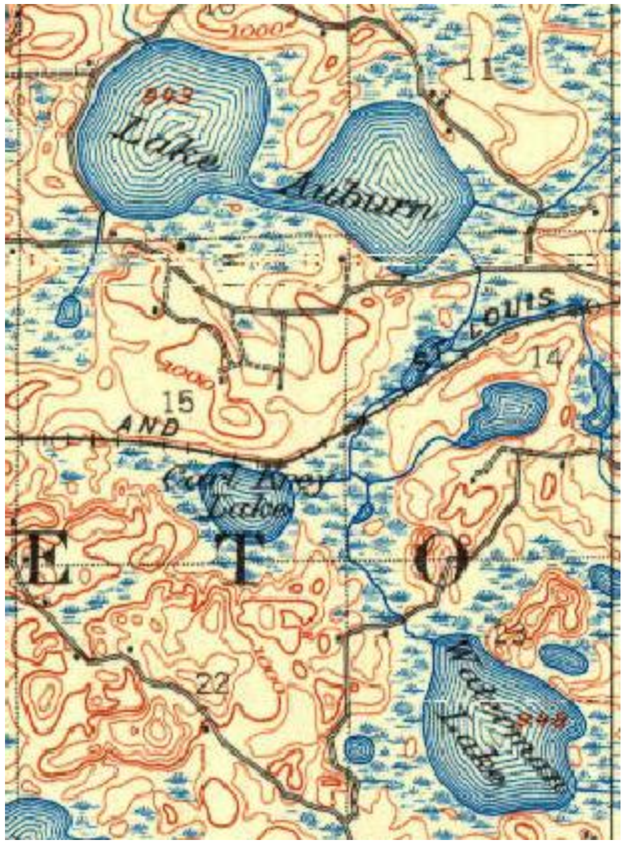

Figure 1-3. 1905 USGS Survey

1.3. Cell 1 Wetland Description

The Cell 1 Wetland is one of four wetland cells in the East Auburn Wetland between Wasserman Lake and Lake Auburn along Six Mile Creek. The Cell 1 Wetland is the most upstream wetland cell and is an emergent marsh with a channel that meanders through the cell and under the bridge at the downstream (northern) extent of the wetland. In this location the wetland narrows and the channel flows under the bridge before expanding into the next marsh (Cell 2) located to the north of the walkway. The Cell 2 downstream boundary is considered to be a trail where the wetland flows through a 36-inch culvert. After going under the trail, the wetland continues in Cell 3 before narrowing and entering Cell 4. Cell 4 continues until the wetland flows under Arboretum Boulevard (MN Highway 5) and into East Auburn Lake.

1.3.1. Wetland Vegetation Community

The wetland community in the East Auburn Wetland is dominated by emergent vegetation with a channel that meanders through all the wetland cells from Wasserman Lake to East Auburn Lake. In addition, there are some areas of shallow open water in the wetlands and Carl Krey Lake located west of the wetland. Based on an evaluation of Cells 3 and 4, the dominant plant communities in the marsh were invasives including narrow leaf cattail (*Typha angustifolia*), common reed (*Phragmites australis*), and reed canary grass (*Phalaris arundinacea*) (Wenck Associates, Inc., 2017). In addition to these communities there were some native species observed at lower densities.

1.3.2. Wetland Topography

Survey elevations were collected in select locations in the Cell 1 Wetland as part of a recent study by Stantec in 2021 and 2022. This topographic detail showed that the light detection and ranging (LiDAR) data previously collected for the site was not particularly accurate in the marsh, likely due to vegetation density, LiDAR point density, and potentially standing water. The field topographic survey showed that the wetland bottom in the marsh was approximately 943.5 to 945 feet (NAVD88). The elevations within the channel were about one foot lower and between 942.5 and 943.5 feet. The wetland survey points are shown in Figure 1-4. These survey points and the aerial photograph were used to develop estimated contours for the marsh that are shown in Figure 1-5.

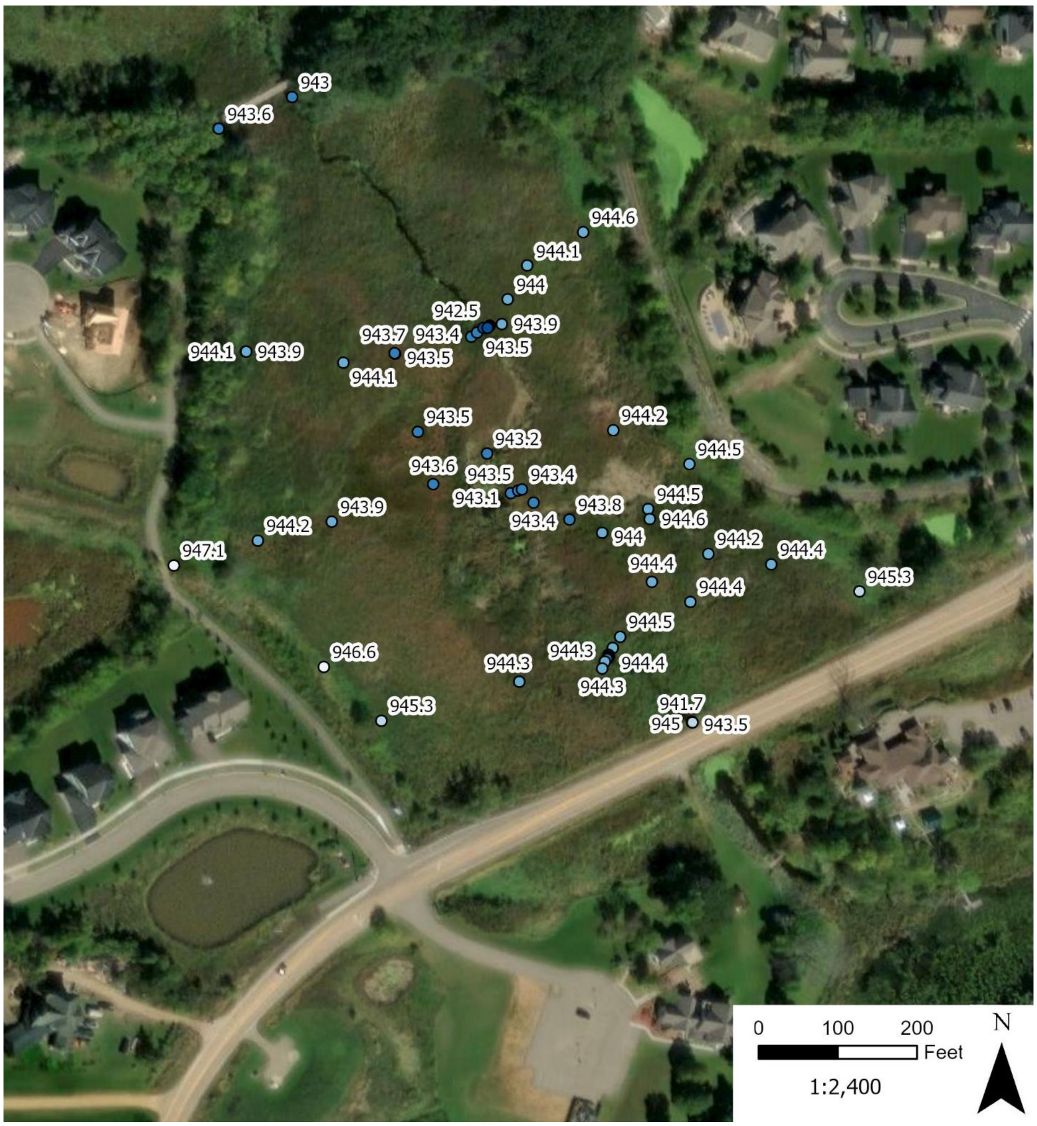

Figure 1-4. Cell 1 Wetland Survey (ft NAVD88)

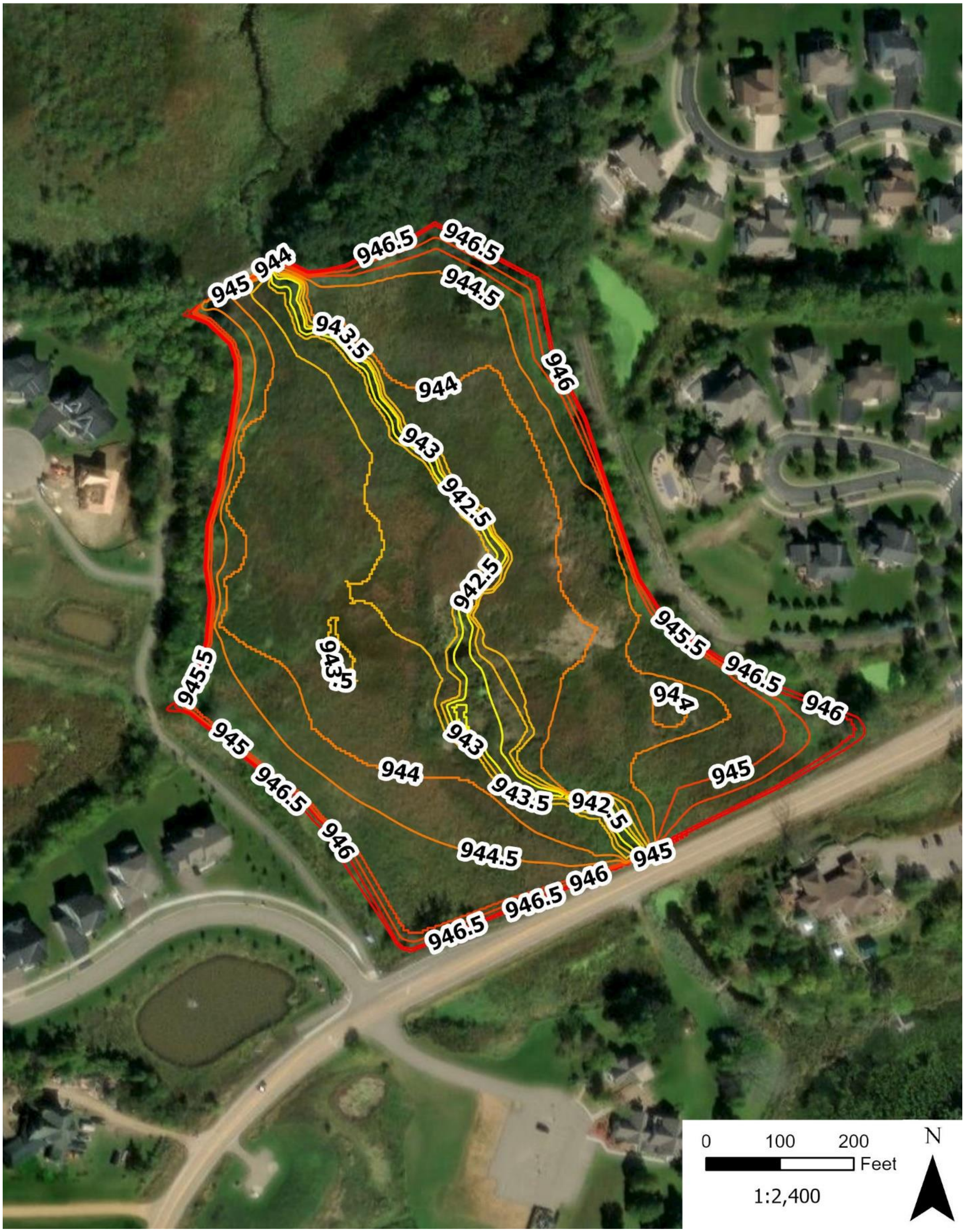

Figure 1-5. Cell 1 Wetland Elevation Contours (ft NAVD88)

2. Data Analysis

This feasibility assessment relied on data collected by others during previous studies. These data included surface water and groundwater quality, flows, sediment samples, water levels, and vegetation data. The collected data were used to evaluate the wetland and develop alternatives to reduce nutrient exports from the wetland. The following sections discuss the data that were evaluated and observations from this analysis.

2.1. Sampling Locations

The wetland complex has been sampled for water quality and hydrology at several stations during different time periods. The longest-term dataset is available for the wetland complex inlet and outlet with station CSI12 (upstream station) located at Church Lake Boulevard downstream of Wasserman Lake and CSI05 (downstream station) located upstream of East Auburn Lake at Arboretum Boulevard. In addition to these stations, data collection has occurred at the wetland midpoint, between Cell 2 and Cell 3, at CSI19. Finally, data collection also occurred between Cell 1 and Cell 2 at CSI22. These sampling locations are shown in Figure 2-1. The statistics and periods-of-record (PORs) for these stations are provided in the Appendices.

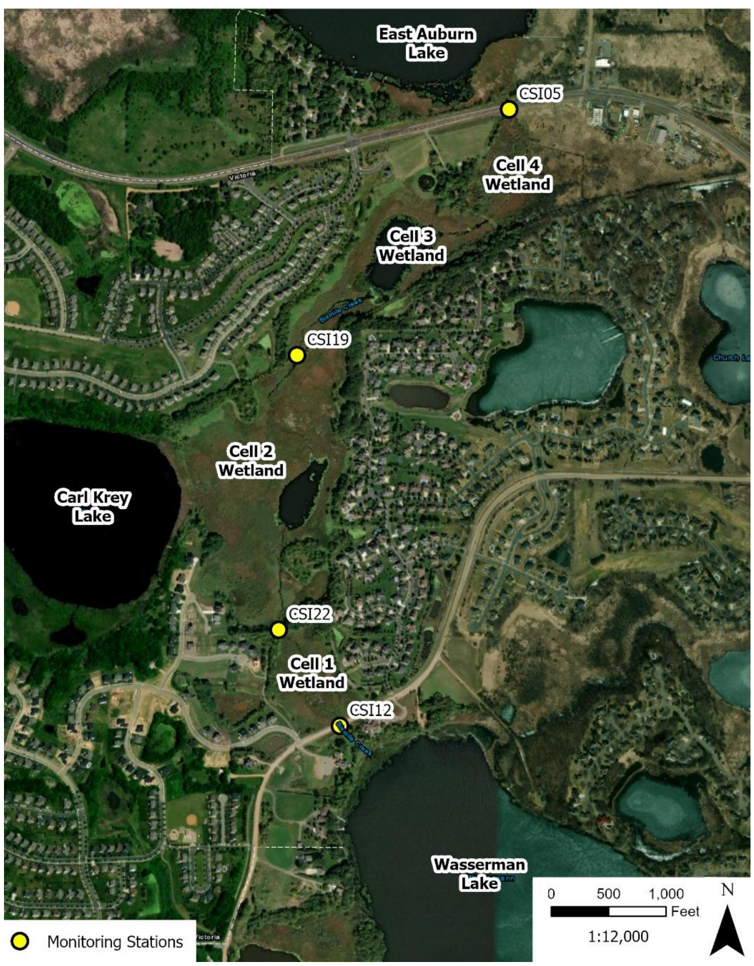

Figure 2-1. Sampling Stations on Six Mile Creek

In addition to these longer-term data, detailed data have been collected within the Cell 1 Wetland. This included data collection by MCWD in 2022 for water quality, water levels, and sediment characteristics. These data were collected at a series of locations within the channel, marsh, fringe, and adjacent uplands. These data were collected between May and September of 2022. These Cell 1 sampling stations are shown in Figure 2-2.

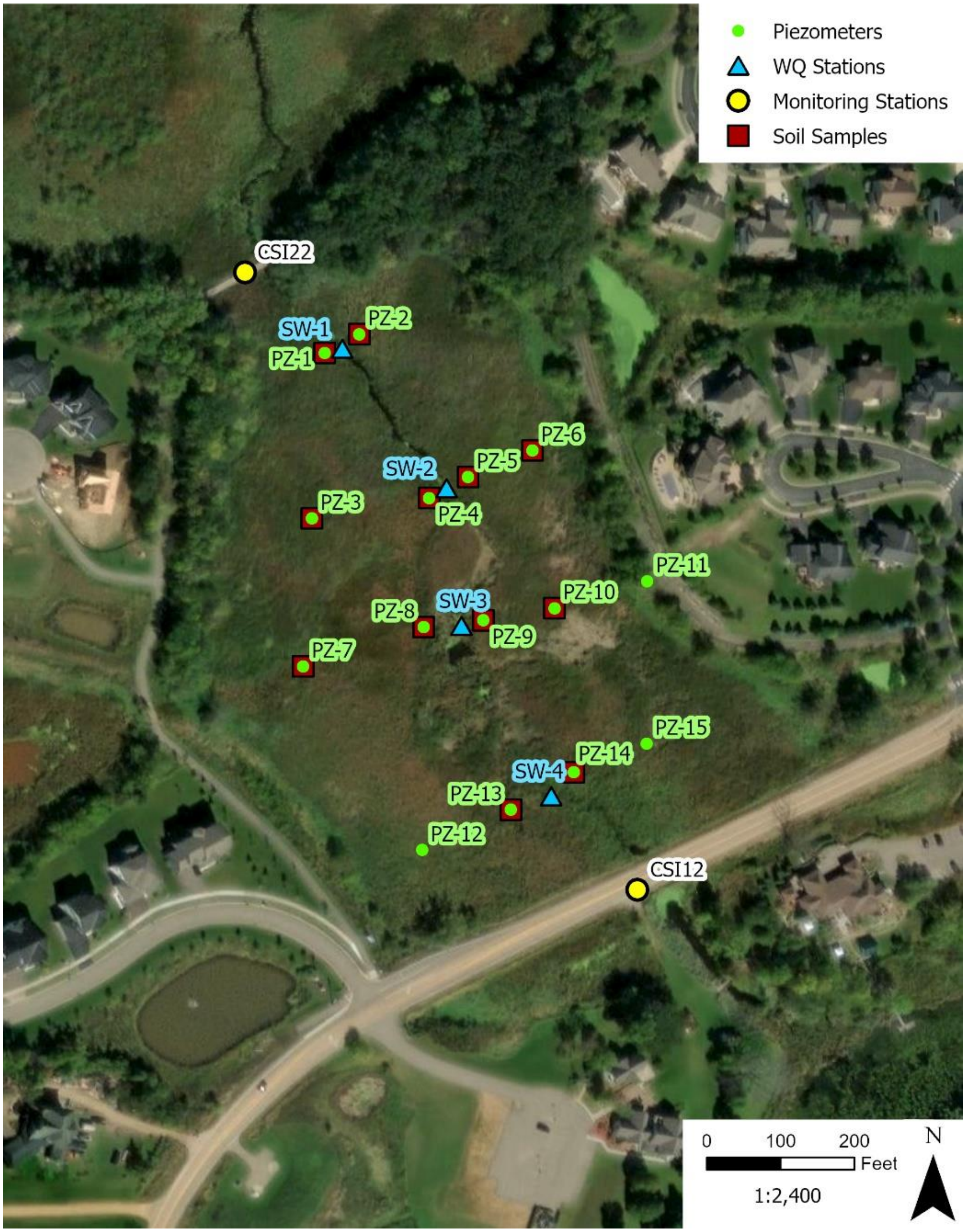

Figure 2-2. Cell 1 Wetland Sampling Stations

2.1. Flow Measurements

Flow measurements were collected at the inlet and outlet of the wetland complex beginning in 2009. These measurements showed a slight increase in flows through the wetland (Figure 2-3). This increase is expected due to direct rainfall on the wetland and runoff from the areas adjacent to the wetland that contribute stormwater. Median flows at the inlet and outlet were 2.30 cfs and 2.72 cfs, respectively with peak measured flows of 42.5 cfs at the inlet and 28.1 cfs at the outlet. This generally indicates that the existing culverts that control wetland inflows and outflows are sized appropriately to pass low storm events and baseflows without causing extensive ponding but do restrict discharge for higher events (as indicated between a minimal difference in median and low flows, and a significant difference in peak flows).

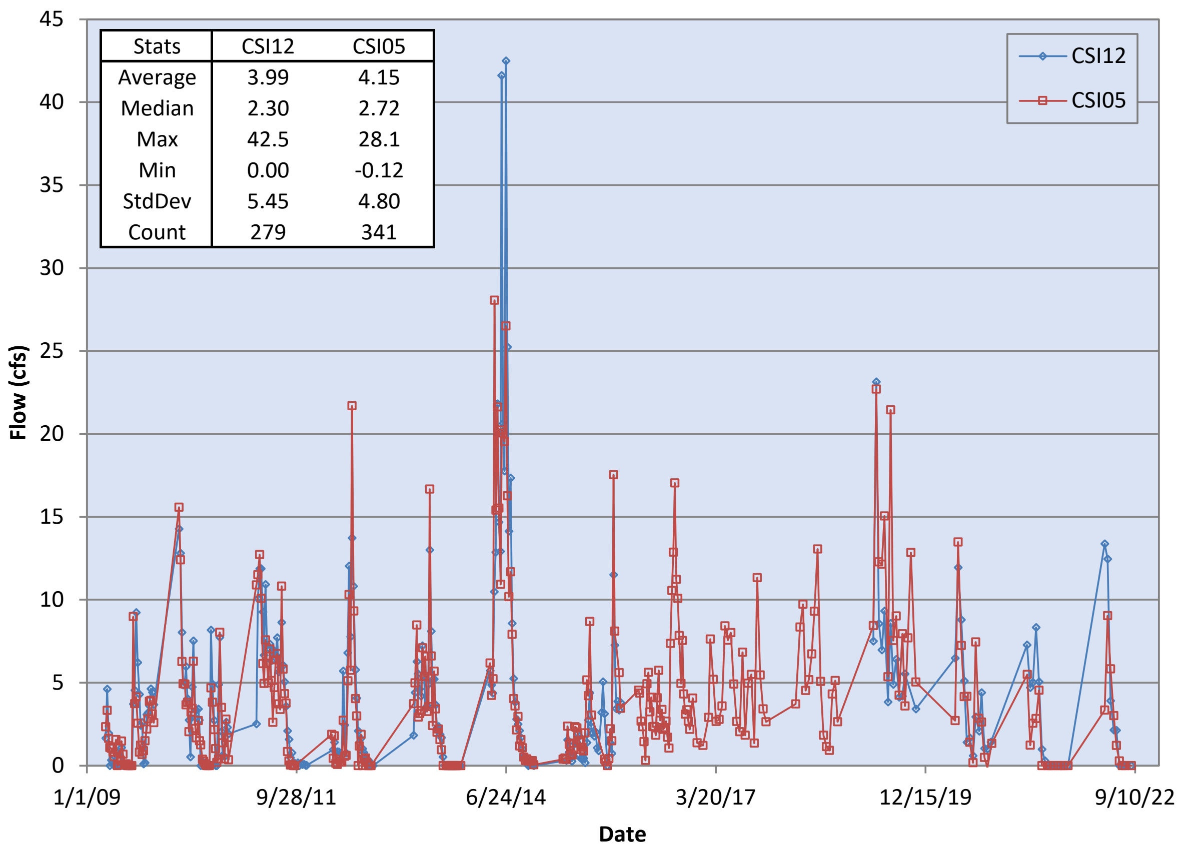

Figure 2-3. Flow Measurements at the Inlet and Outlet of the Wetland Complex

In addition to evaluating the time series, the annual pattern of flows was also considered to examine the magnitude of flows during different months. These data show that flows were highest in spring and early summer before tapering off in the late summer until increasing slightly in the fall in years with wetter than normal precipitation as shown in Figure 2-4. These seasonal changes in flow were particularly pronounced in the upstream areas of the wetland at CSI12.

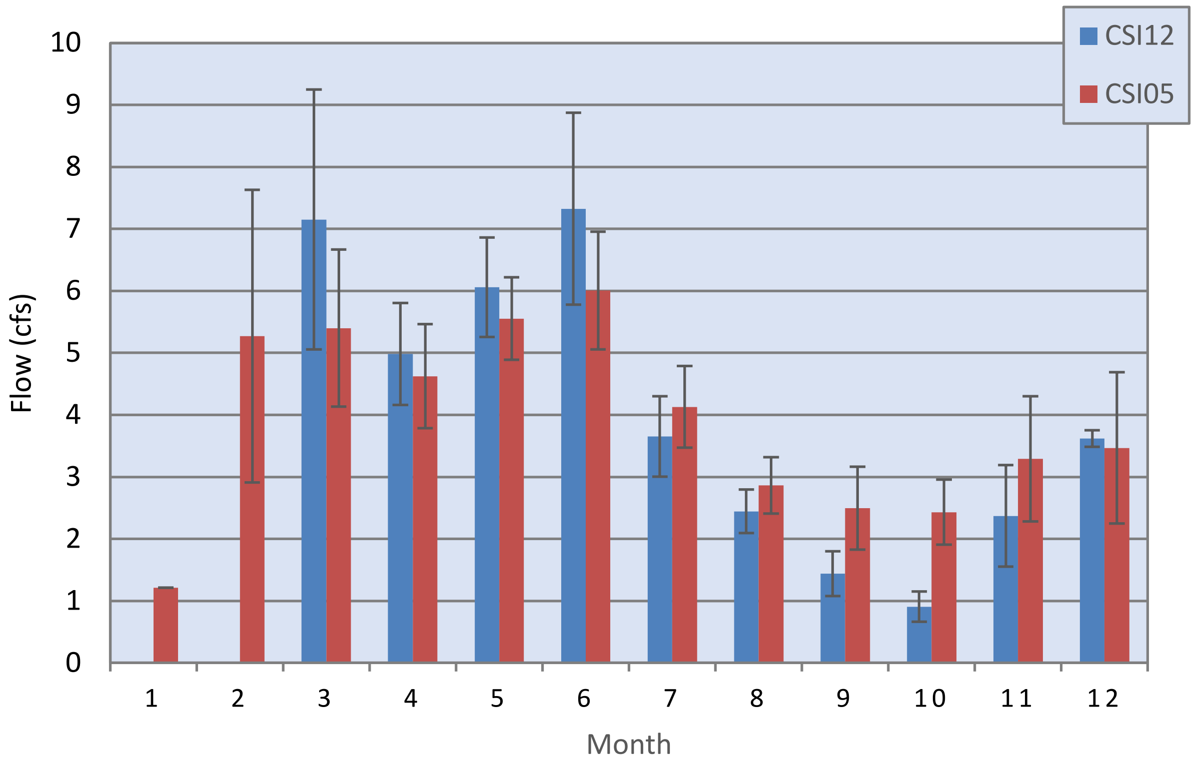

Figure 2-4. Average Monthly Flows at the Inlet and Outlet of the Wetland Complex

2.2. Water Quality

Water quality data have been collected from the previously described stations at varying frequencies and over variable PORs. The stations with the longest PORs are located immediately upstream of the Cell 1 Wetland (CSI12) and at the outlet of the wetland complex (CSI05). These stations have data extending back to 2009. At these stations the total phosphorus (TP) increased between the wetland inlet and outlet with higher average and median values at the downstream station (Figure 2-5). Additionally, the data showed a consistent seasonal trend with higher concentrations being released in the summer from the wetland complex (Figure 2-6).

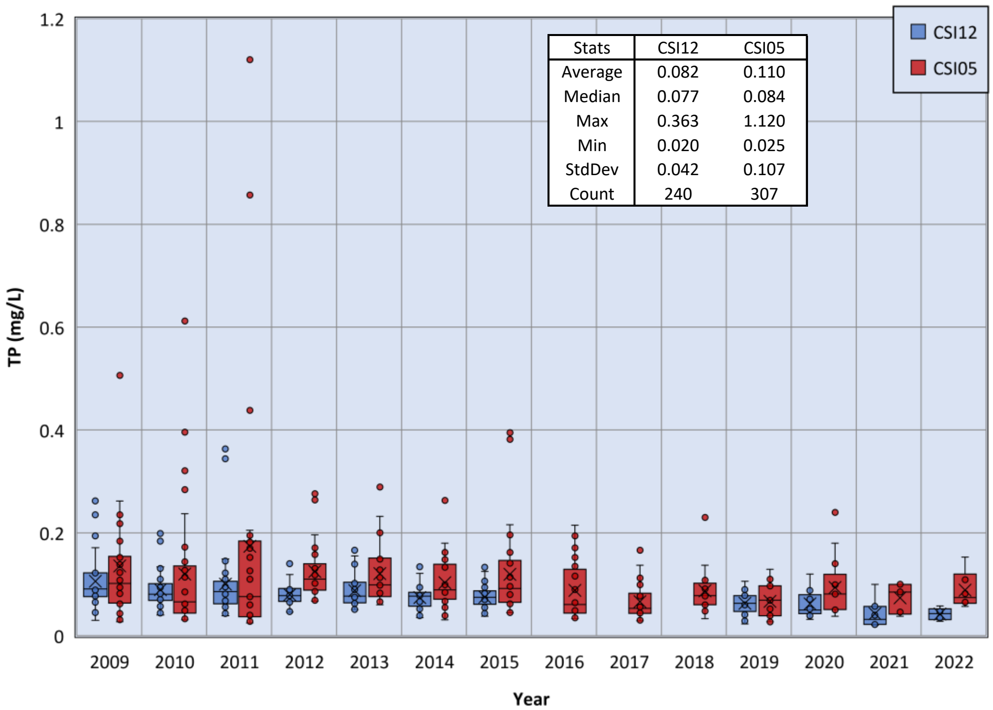

Figure 2-5. Total Phosphorus Concentration at the Inlet and Outlet of the Wetland Complex

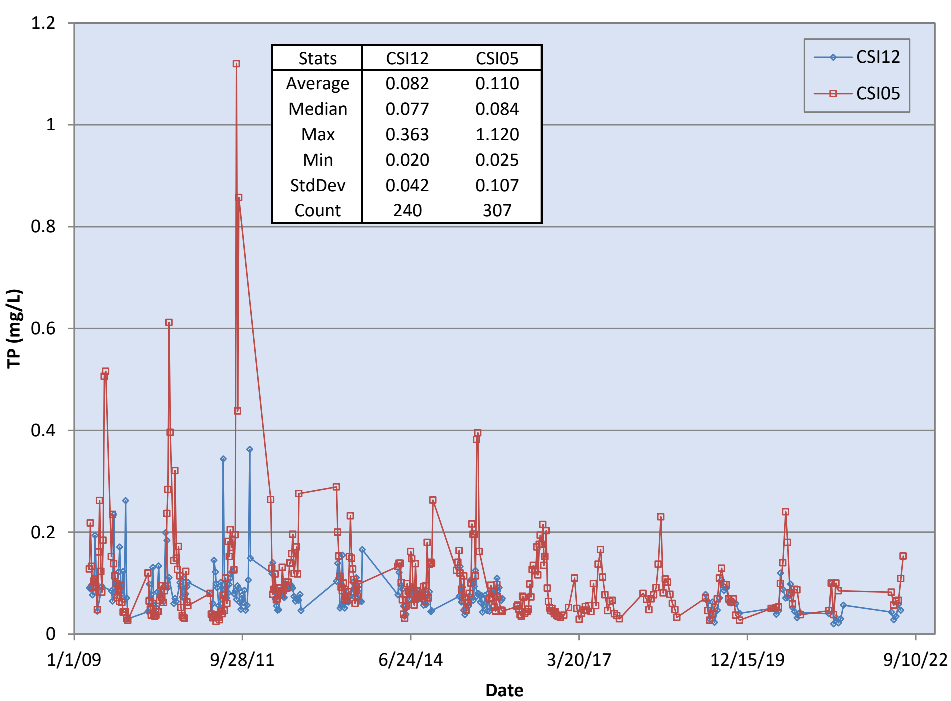

Figure 2-6. Total Phosphorus Concentration Time Series at the Inlet and Outlet of the Wetland Complex

Ortho-phosphorus (OP) at these same stations showed a more substantial increase between the wetland inlet and outlet (Figure 2-7). OP discharge increased in both total mass and the ratio of OP to TP through the wetland; at the wetland inlet approximately 10-percent of the TP was in the OP form while at the wetland outlet approximately 40-percent of the TP was in the OP form. These data also showed a seasonal pattern with increasing concentrations later in the year at the downstream station (Figure 2-8). Stormwater sampling statistics for all sampled stations are provided in Appendix A.

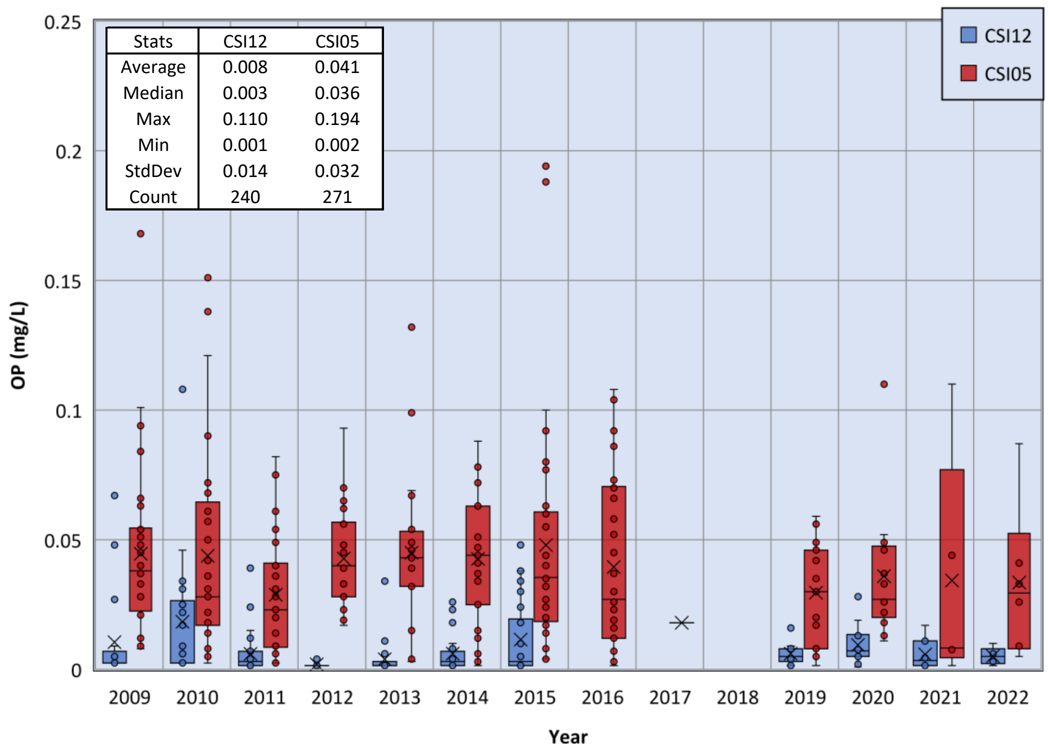

Figure 2-7. Ortho-Phosphorus Concentration at the Inlet and Outlet of the Wetland Complex

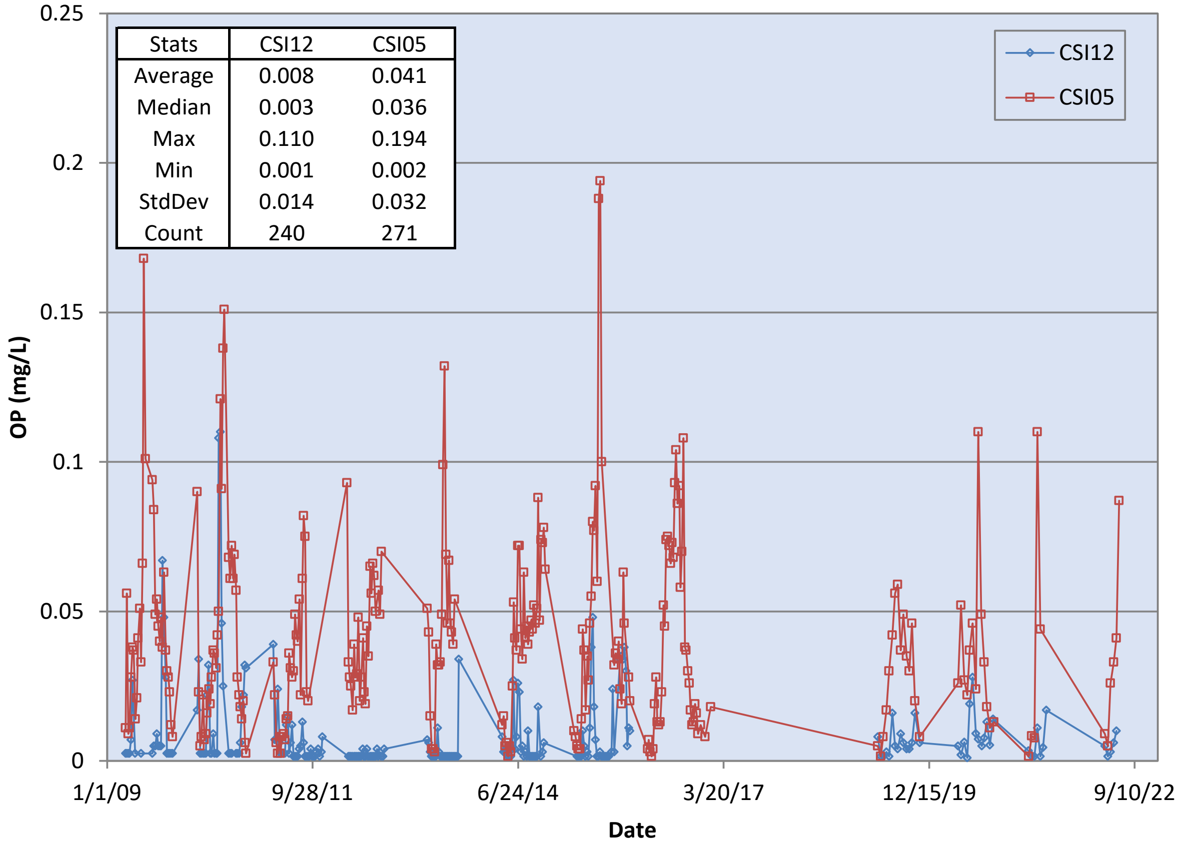

Figure 2-8. Ortho-Phosphorus Concentration Time Series at the Inlet and Outlet of the Wetland Complex

Concentrations of TP and OP were also evaluated monthly to examine trends in concentration during different months. For TP, this examination showed average outflow concentrations exceeding average inflow concentrations from March through September. (Figure 2-9). Increases in concentration were particularly apparent from June to September. OP showed the same increases in concentration through the wetland with a consistent release of OP in all months (Figure 2-10). This release was particularly pronounced from June through September.

Concentrations of TP and OP were paired with flows to evaluate the mass of phosphorus entering and leaving the wetland. These data showed a consistent export of TP except during infrequent occasions when the load entering exceeded the load leaving the wetland (Figure 2-11). OP showed a similar relationship with the load leaving the wetland exceeding the load entering the wetland (Figure 2-12).

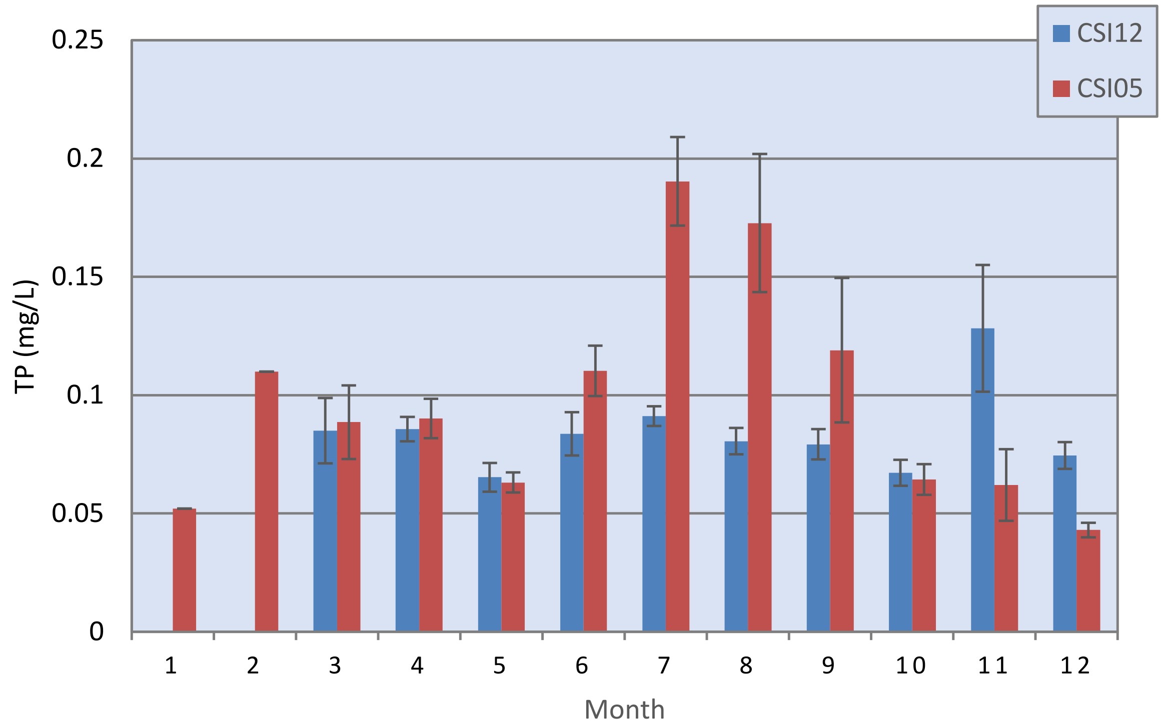

Figure 2-9. Average Monthly Total Phosphorus Concentrations at the Inlet and Outlet of the Wetland Complex

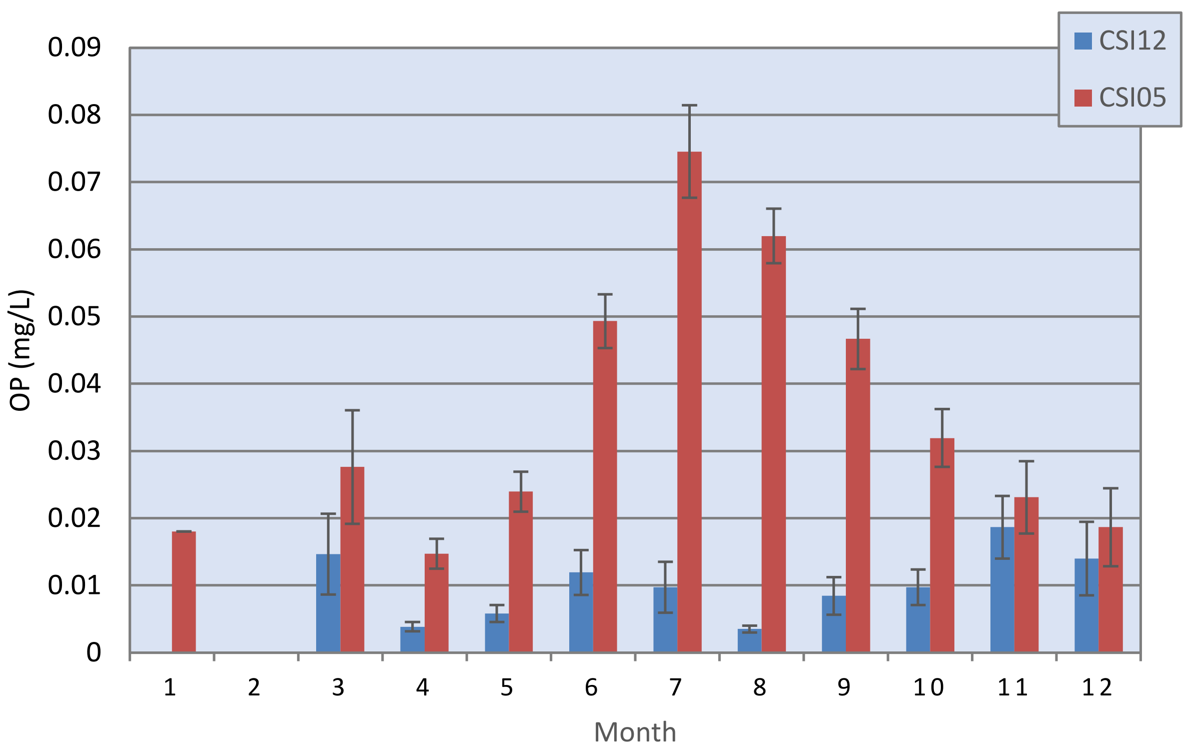

Figure 2-10. Average Monthly Ortho-Phosphorus Concentrations at the Inlet and Outlet of the Wetland Complex

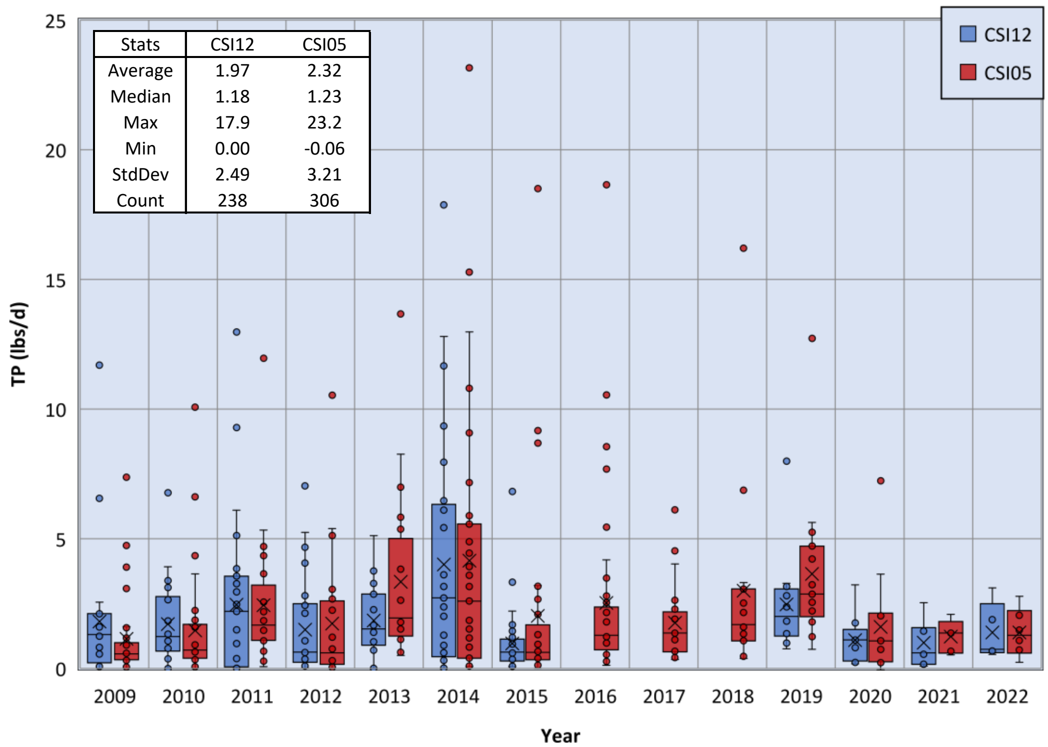

Figure 2-11. Total Phosphorus Load Entering and Leaving the Wetland Complex

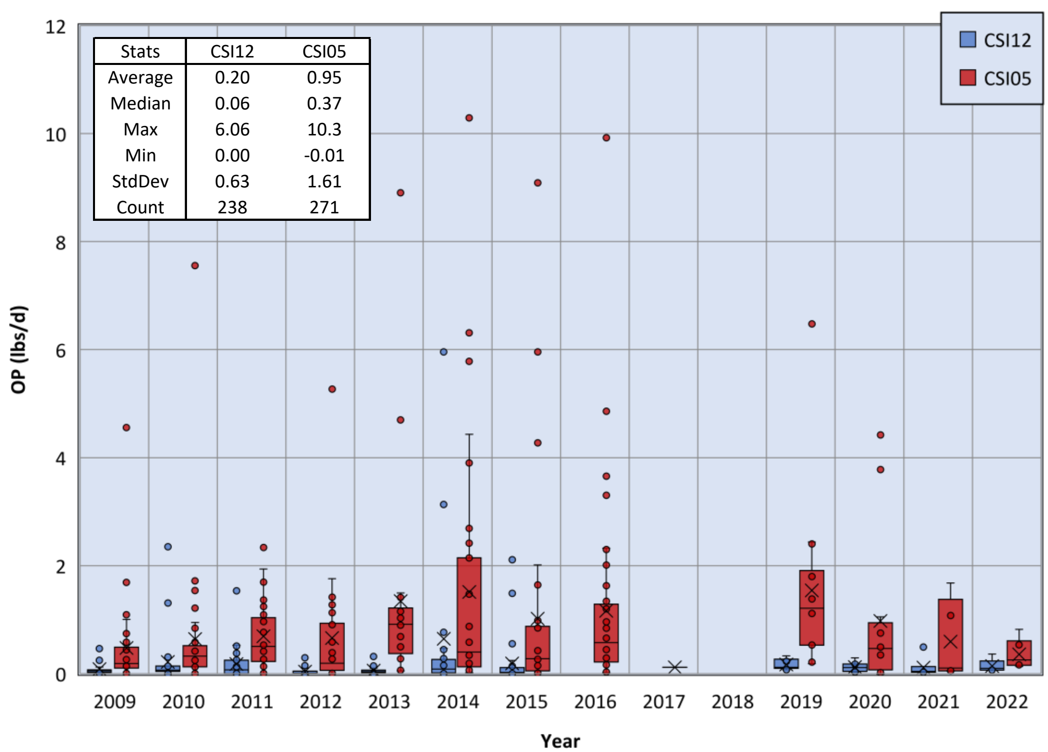

Figure 2-12. Ortho-Phosphorus Load Entering and Leaving the Wetland Complex

Monthly loading was also evaluated for TP and OP. These data show that, excluding January and February which had single samples, the months with consistent export were July through October, with October only having a minor export as shown in Figure 2-13. A similar loading pattern existed for OP except that export occurred in most months, and June through September had the largest increases in OP loading (Figure 2-14).

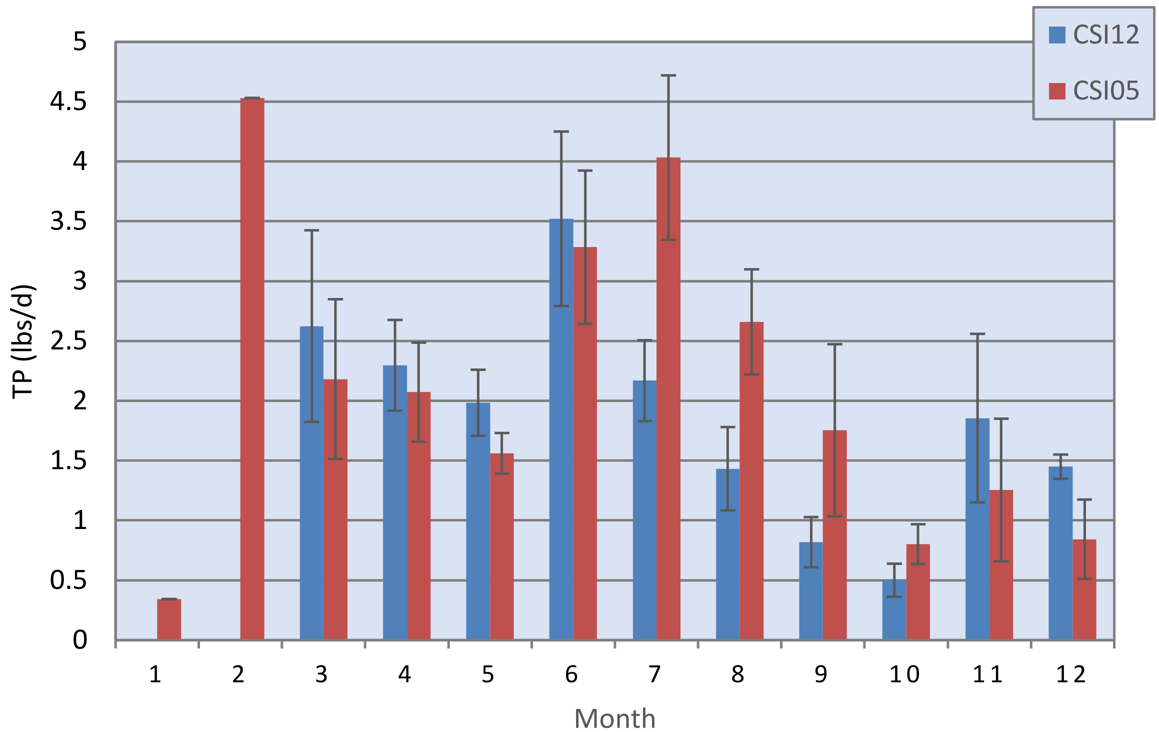

Figure 2-13. Average Monthly Total Phosphorus Loads at the Inlet and Outlet of the Wetland Complex

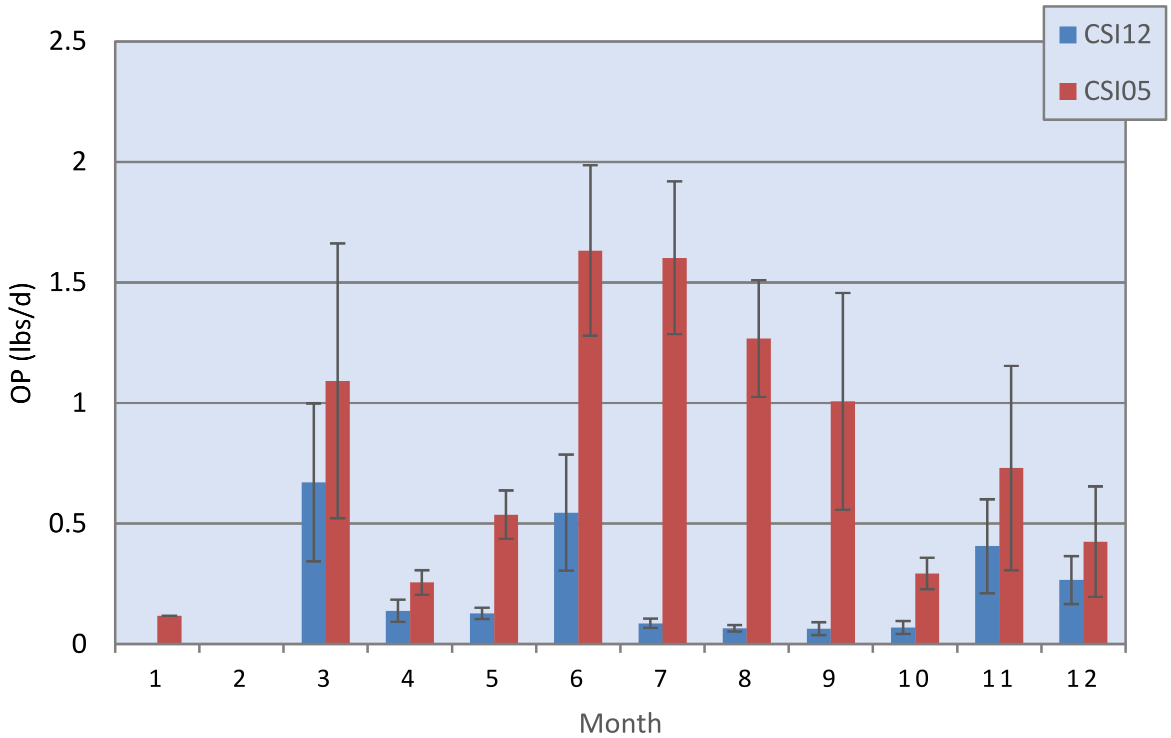

Figure 2-14. Average Monthly Ortho-Phosphorus Loads at the Inlet and Outlet of the Wetland Complex

2.2.1. Cell 1 Wetland Surface Water Quality Sampling

Limited surface water quality samples have been collected at station CSI22 at the outlet from Cell 1 to Cell 2. These data were collected between mid-2020 through mid-2022. At CSI22, TP concentrations were elevated when compared to samples collected at CSI12, the inflow from Wasserman Lake to Cell 1 (Figure 2-15). Similar but more pronounced increases were observed for OP in the Cell 1 Wetland as shown in Figure 2-16. Figure 2-17 shows a positive, increasing relationship between TP and total iron (TFe) concentrations in the Cell 1 wetland surface water samples. This occurs during reducing conditions when iron-bound phosphorus can be released from the sediments to the overlying water. As shown in the sediment results (Section 2.4), the estimated mass of iron-bound phosphorus is relatively small, but the potential release may still be an important contribution seasonally.

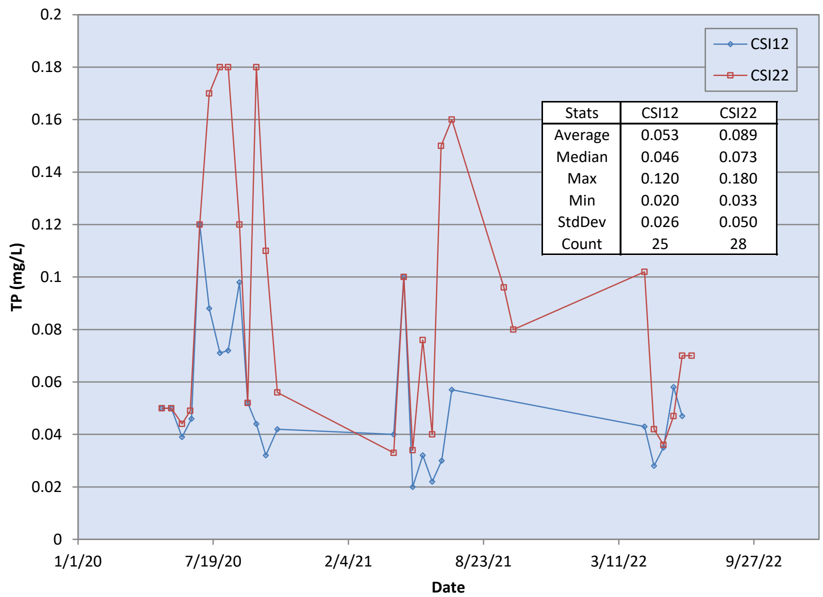

Figure 2-15. Total Phosphorus Concentrations for the Cell 1 Wetland Inflow and Outflow

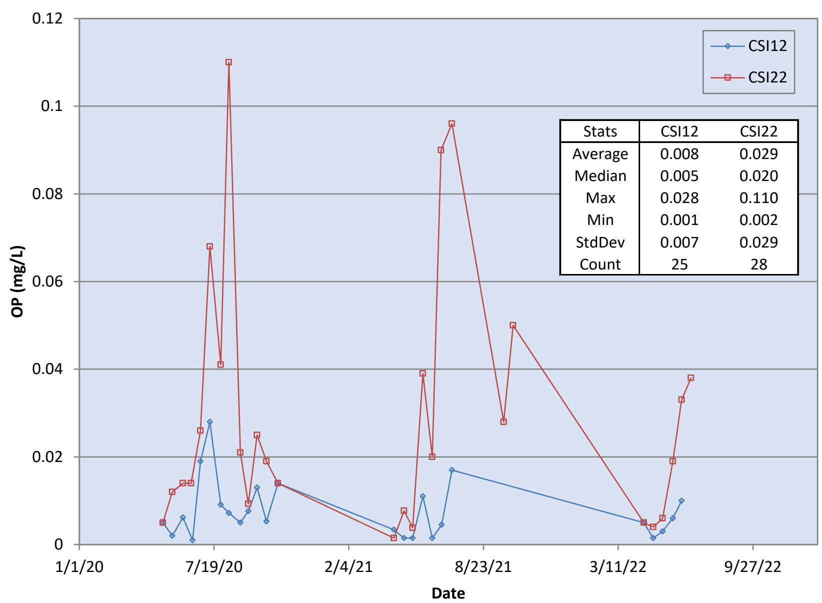

Figure 2-16. Ortho-Phosphorus Concentrations for the Cell 1 Wetland Inflow and Outflow

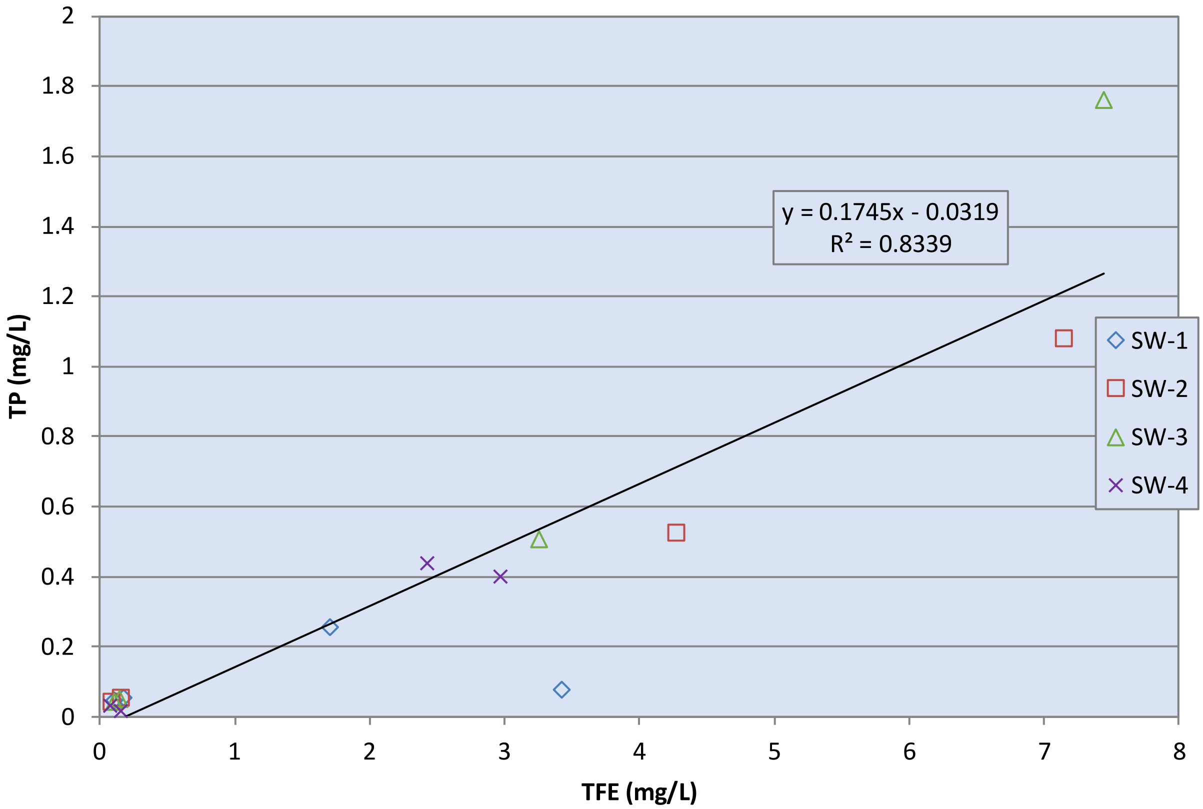

Figure 2-17. Relationship Between TP and Total Iron in Cell 1 Surface Water

2.3. Water Levels

Water level data were collected at shallow monitoring wells installed in the Cell 1 Wetland as part of the detailed study completed by Stantec in 2022 (Stantec, 2022). Within Cell 1, water levels were collected at five locations (1 channel, 3 in the wetland, and 1 upland), shown in Figure 2-2. At the wetland monitoring well locations, water levels were collected at three depths, surface, shallow, and deep. The water levels were plotted and are shown in Figure 2-18. These data show that most of the marsh dried out by mid-June and that water was primarily contained in the channel (elevations less than 943.5 feet) by early-July. Review of water levels demonstrates the sub-surface drainage of water to the channel with a gradual drop in levels during the summer months before re-hydration of the entire marsh during August and early-September following precipitation events. The complete details for each sampling location including all three collected water levels are shown in Appendix B.

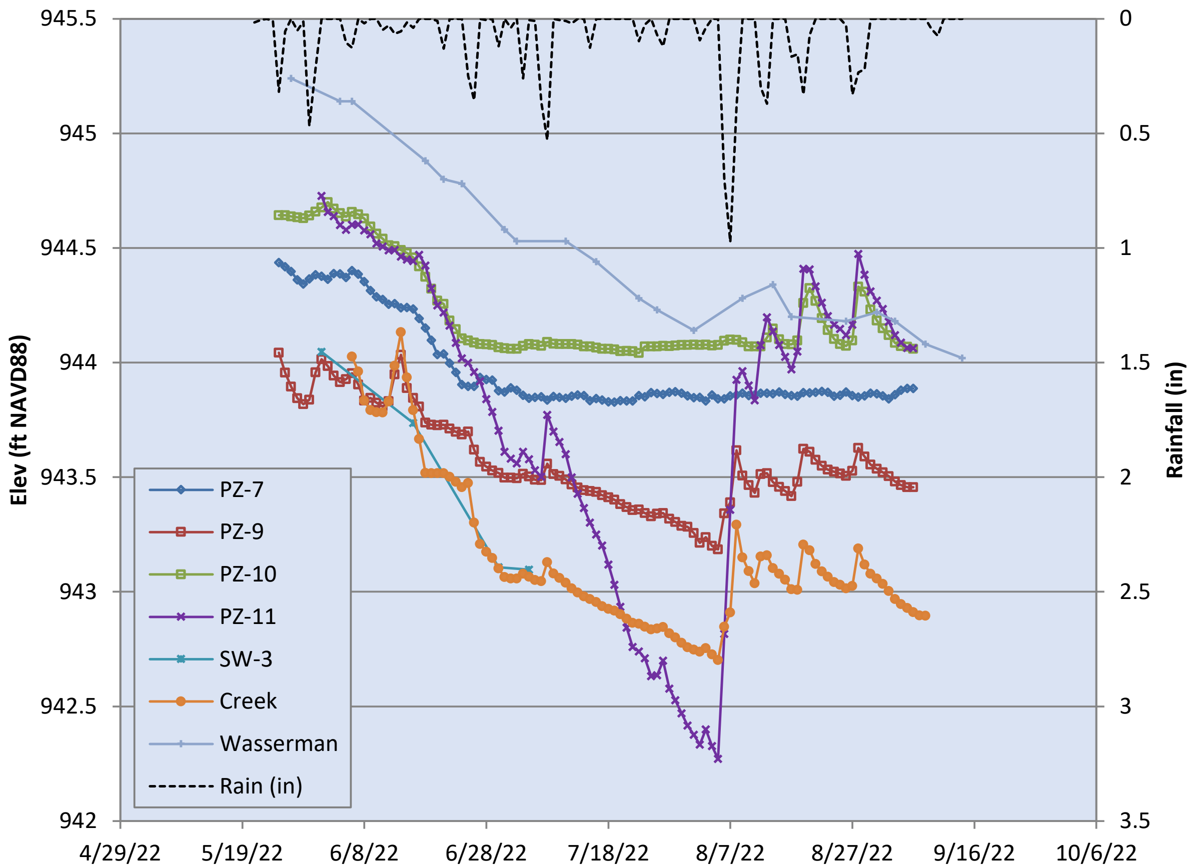

Figure 2-18. Cell 1 Wetland Water Levels and Rainfall

2.4. Soil Sampling

Soil sampling was completed as part of the detailed study of the Cell 1 Wetland by Stantec (Stantec, 2022). This included collection of samples at each of the piezometer locations at three depths: surface (0-1 feet), shallow (1-2 feet), and deep (4-5 feet) and in the stream. At each of these depths/locations the soil TP fractionation was measured and reported. Forms of soil phosphorus (P) that were measured and reported included: loosely-bound P, iron-bound P, labile organic P, aluminum-bound P, calcium-bound P, and refractory organic P. This order also generally corresponds to the bioavailability of these sources with the loosely-bound P, iron-bound P, and labile organic P being mobile and the aluminum-bound P, calcium-bound P, and refractory organic P being non-mobile under normal conditions. The average soil fractionation for the depths/locations are shown in Figure 2-19. These samples show that there is more mobile P in the stream and surface stations than in the shallow and deep samples. For these same samples average non-mobile P was similar amongst the depths/locations. The sediment data sampling results for all of the locations and depths are provided in Appendix C.

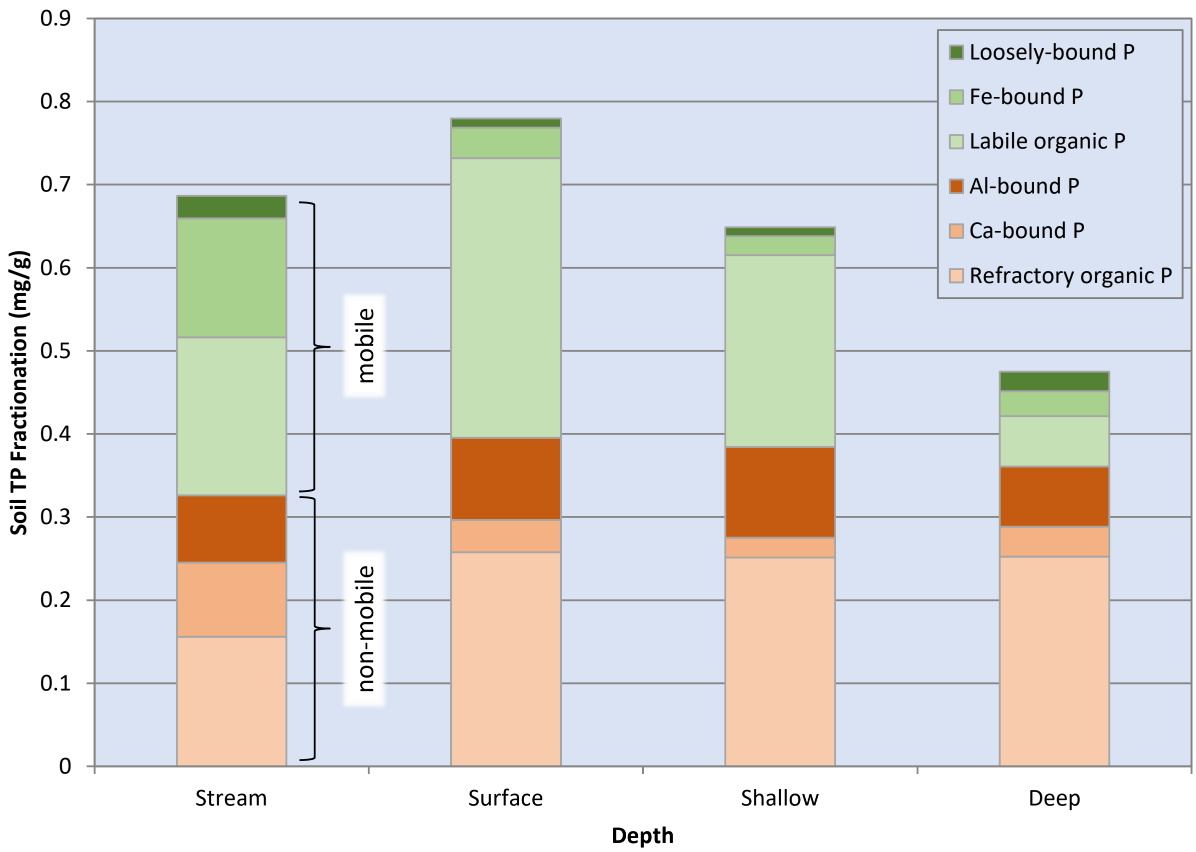

Figure 2-19. Sediment Total Phosphorus Fractionation Averages by Depth/Location

Concentrations of these components are shown for the surface samples in Figure 2-20. In the surface samples, TP varied between 0.55 and 1.23 mg/g. Some variability in concentrations were observed across the wetland with PZ-10 having the highest TP of the samples.

The shallow sediment samples showed a range of TP concentrations from 0.44 to 1.00 mg/g. As with the surface samples some variability was observed between sampling stations with PZ-1 having the highest concentrations of TP. The TP fractionation for all of the shallow samples is shown in Figure 2-21.

The deep sediment samples had the lowest TP concentrations on average of the sampling depths. The range of concentrations were from 0.30 to 0.64 mg/g. These samples also showed the most consistent concentrations and the lowest mobile P fraction. The TP fractionation for the deep samples is shown in Figure 2-22.

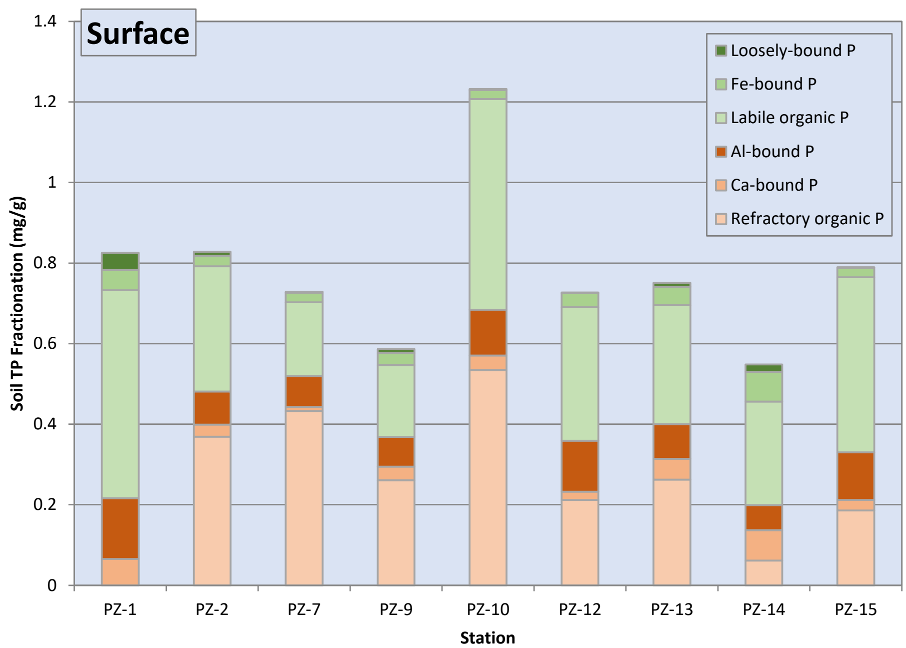

Figure 2-20. Sediment Total Phosphorus Fractionation for Surface Samples

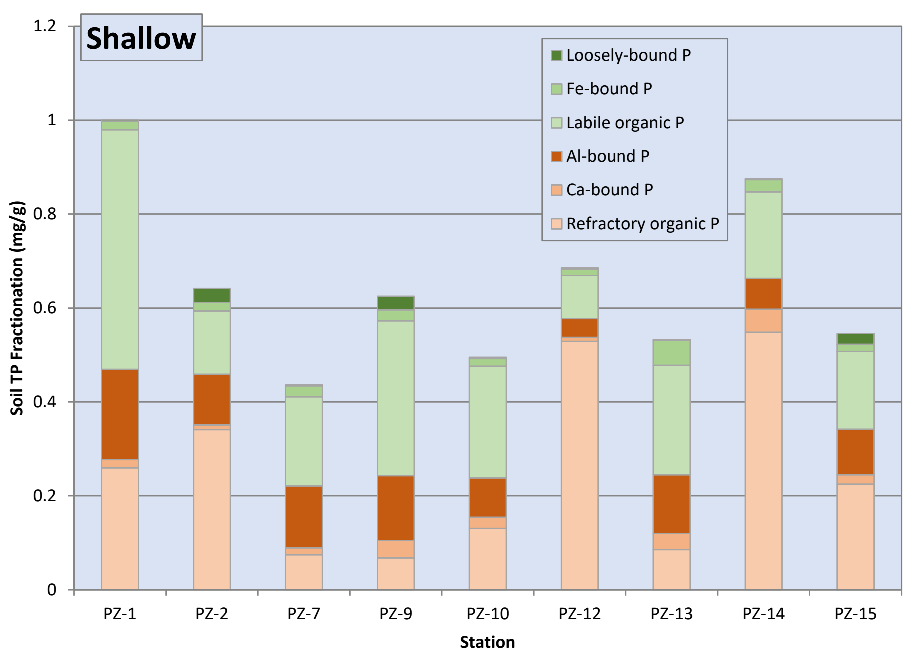

Figure 2-21. Sediment Total Phosphorus Fractionation for Shallow Samples

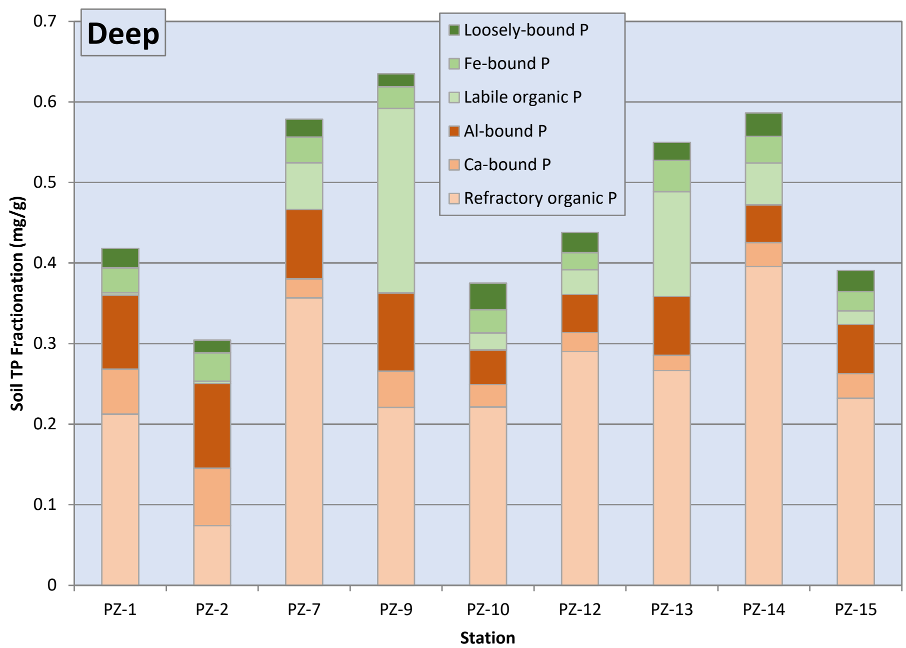

Figure 2-22. Sediment Total Phosphorus Fractionation for Deep Samples

2.5. Groundwater Sampling

Groundwater quality samples were collected in conjunction with installation of the piezometers and sediment sampling described in Sections 2.3 and 2.4. Samples were collected from the same subsurface depth zones as the sediments (0-1 feet, 1-2 feet, and 4-5 feet below surface) and the results represent pore water quality. Samples were collected at varying frequencies between May and August 2022 (Stantec, 2022). Surface pore water TP averaged 0.417 mg/L and ranged from 0.064 to 0.886 mg/L across the site. Surface OP concentrations were lower averaging 0.172 mg/L and ranging from 0.023 to 0.379 mg/L. Figure 2-23 shows the spatial variability in near-surface pore water average TP and OP concentrations. Figure 2-24 shows the groundwater TP and OP concentrations for the shallow pore water interval and Figure 2-25 for the deep pore water interval. Pore water TP and OP concentrations generally increased with depth below the wetland surface. TP averaged 0.244 mg/L for the shallow samples and 0.372 mg/L for the deep samples. OP averaged 0.124 mg/L for the shallow samples and 0.178 mg/L for the deep samples. Figure 2-26 shows the fractions of total particulate phosphorus (TPP) and ortho (soluble) phosphorus in the groundwater. Detailed results are provided in Appendix D.

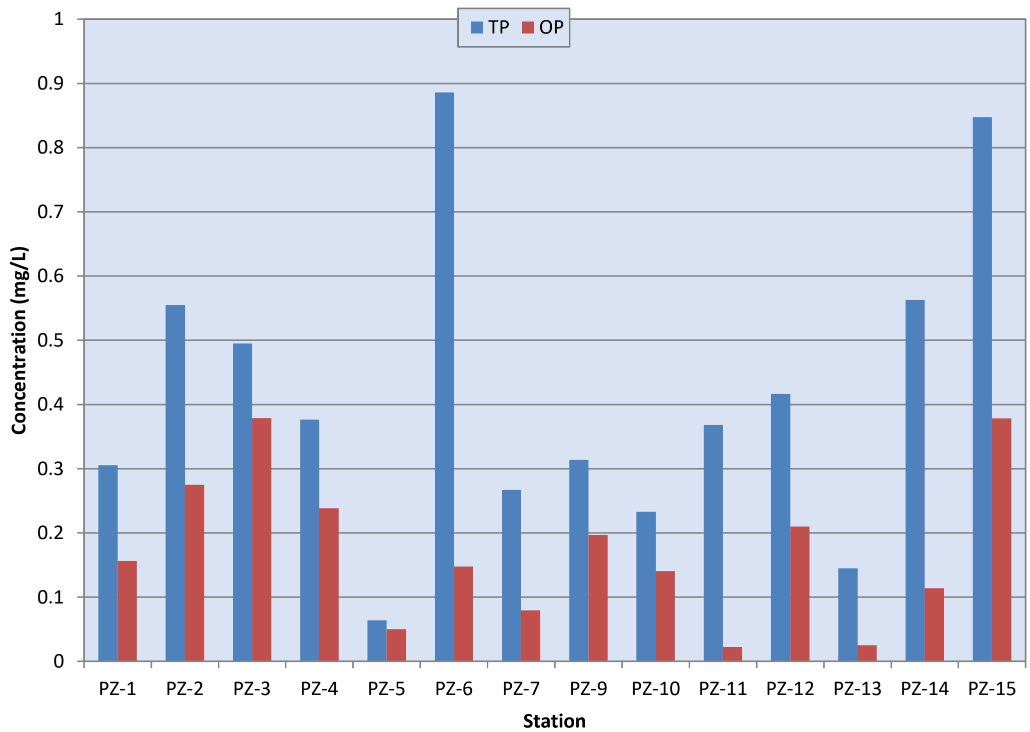

Figure 2-23. Surface (0-1 feet) Groundwater Phosphorus Concentrations

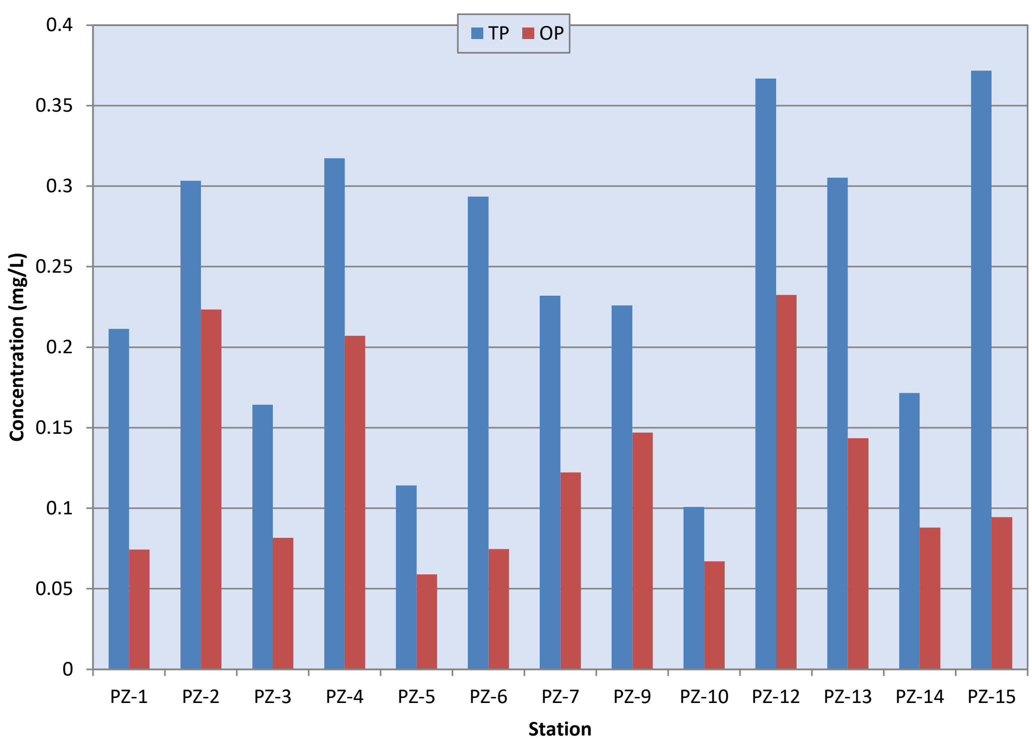

Figure 2-24. Shallow (1-2 feet) Groundwater Phosphorus Concentrations

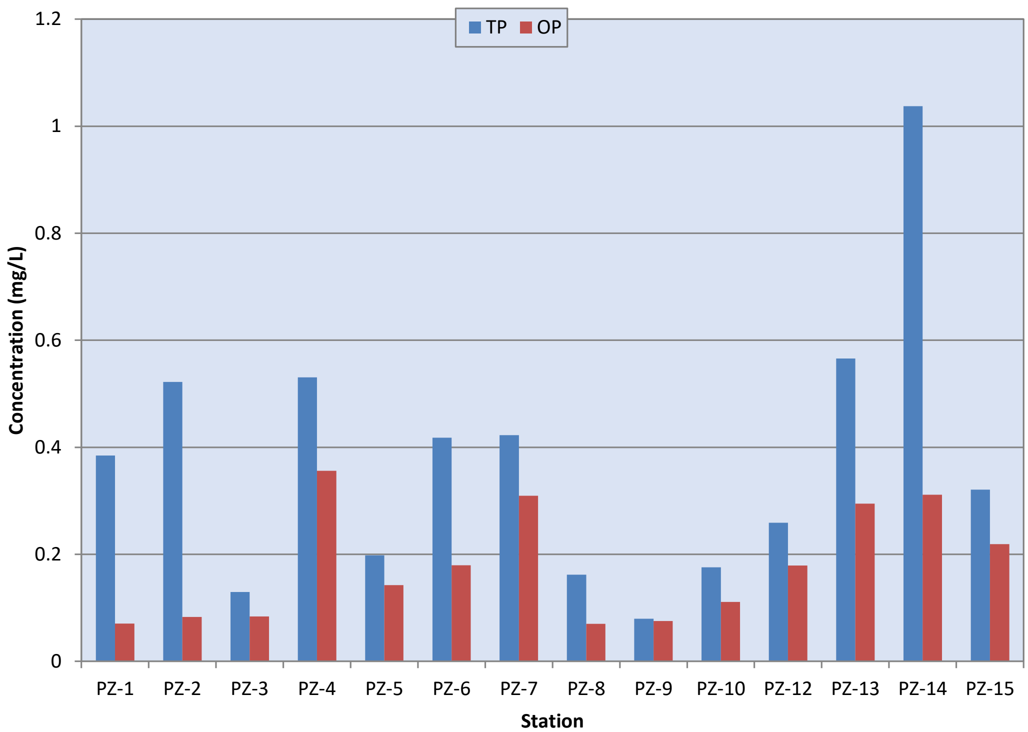

Figure 2-25. Deep (4-5 feet) Groundwater Phosphorus Concentrations

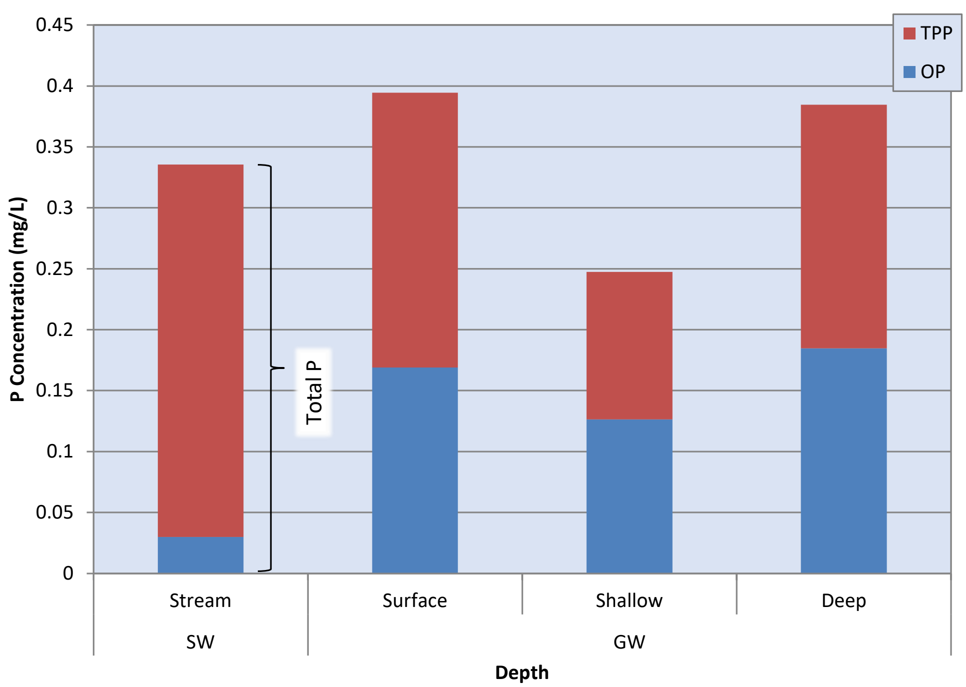

Figure 2-26. Particulate (TPP) and Ortho Phosphorus Surface Water and Groundwater Concentrations

2.6. Summary of Cell 1 Wetland Impairments

The East Auburn Wetland has been identified as a source of phosphorus loading to East Auburn Lake. This finding was documented in the *East Auburn Wetland Phosphorus Analysis* (Beck, 2019). In this analysis MCWD evaluated phosphorus concentrations into and out of the East Auburn Wetland. The analysis found that TP was higher at the outlet than at the inlet. It also showed that TP was relatively constant through the wetland while OP increased, and that these changes were most pronounced during summer (warmer months). This analysis also considered mass loading and found that the Auburn Wetland exported 135 pounds per year of OP on average.

To further isolate where changes in water quality took place, samples were collected at the wetland midpoint, downstream of Cell 2. These supplemental data showed that the first half of the wetland had higher phosphorus release than the second half, which showed very little additional increase. The increase in phosphorus was attributed to historic phosphorus loading from Wasserman Lake due to historically poor water quality in the lake. Cell 1 was implicated as the most likely source of phosphorus release because of the higher loading that would have occurred from the lake to this wetland cell. The analysis of sediment samples discussed in Section 2.4 support this theory with elevated TP concentrations observed in the stream and surface sediments, with lower concentrations of TP in the shallow and deep sediment samples.

This study used available data to further examine the phosphorus dynamics of the system and found that, as shown in the MCWD study, phosphorus increased through the Cell 1 Wetland and that the most significant mass loads occurred during the June through August timeframe. This study further considered the potential root causes of the phosphorus releases and developed a hypothesis based on the following data:

- Sediment phosphorus data indicate that the labile organic fraction is the dominant mobile TP fraction.
- The increase in TP through the wetland is dominated by exports in June, July, and August (Figure 2-11).
- Water levels in the wetland collected in 2022 show the system drying out in mid-June with water only present in the channel and levels slowly dropping as the channel drains the marsh.

Based on these observations in the data, it is hypothesized that phosphorus increases in the Cell 1 Wetland are being driven by a wet-dry cycling and release of TP primarily from the labile organic P fraction in the wetland sediments. This labile organic P, the most prevalent mobile fraction in the wetland, is potentially related to the export and settling of particulate phosphorus from Wasserman Lake during periods of poorer lake water quality and increased algae. In the current hydrologic condition, the wet-dry cycling is occurring because of the channel that cuts through the wetland that allows the marsh to completely dry out during the summer months when snowmelt has ended and runoff and rainfall is less frequent and driven by larger events.

This hydrologic regime allows the wetland to dry out, which both releases TP during oxidation of organic matter and allows subsurface flow from the marsh through the organic soils, transporting TP in the pore water, to the channel where it flows downstream. During subsequent rainfall events, flows and levels increase, flushing the water with higher concentrations of TP out of the wetland and downstream before the cycle repeats.

3. Alternatives Development

This study focused on identifying existing issues in the Cell 1 Wetland that are contributing to the release and export of phosphorus to the downstream wetlands and East Auburn Lake. After identifying the existing issues, the range of potential alternatives that might be used to address these releases were developed.

The alternatives developed for this project fell into one or more of three general categories: hydrologic modification, topographic modification, and chemical treatment. A total of seven alternatives were identified that might be implemented to address the release of phosphorus to varying extents. The estimated effectiveness of these alternatives was considered based on the assumption that the hypothesized cause of the phosphorus release was correct. These estimates of effectiveness were developed based on professional judgment and the mechanisms of release and export that were being addressed by the alternative.

Costs were estimated for each alternative based on the rough concepts the project developed. These cost estimates included a design and construction engineering estimate of 15-percent of the construction cost and a 30-percent construction contingency assuming potential work in wet conditions. Costs were prepared at the Class 4 level (Concept Study) as defined by the Association for the Advancement of Cost Engineering International (AACEI) for *Engineering, Procurement, and Construction for the Building and General Construction Industries* with a lower bound of -20 percent and an upper bound of +30 percent.

3.1. Hydrologic Restoration

This alternative involves the installation of a water level control structure at the downstream end of the Cell 1 Wetland. This control structure would be designed to allow water to be held in the marsh at or above the wetland bottom. The anticipated structure for this alternative is a sheet pile weir installed at the bridge between the Cell 1 and Cell 2 Wetlands. The rationale for this alternative is to prevent the complete dehydration of the marsh with associated oxidation of organic material and phosphorus release during re-hydration. This alternative would also keep water within the channelized portion of the wetland which would reduce the subsurface drainage of water through the marsh bottom to the channel. This is expected to reduce the transport of pore-water phosphorus to the channel that then flows downstream between events when the marsh is flooded. Depending on the level of inundation, this alternative may also increase the residence time of water in the wetland which may increase phosphorus removal in the marsh through plant uptake and particulate settling. Potential disadvantages of this alternative include making the marsh more anaerobic which could release iron-bound phosphorus and result in potential stage increases during storms.

Estimated costs for this alternative were $299,000 for the installation of a sheet pile weir across the marsh between Cell 1 and Cell 2 of the East Auburn Wetland. The conceptual cost estimate for Alternative 1 is shown in Table 3-1.

Table 3-1. Alternative 1 – Sheet Pile Weir Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 15,000	$ 15,000
2	CLEARING AND GRUBBING	AC	0.5	$ 15,000	$ 7,500
3	SHEETPILE (70'Lx15'D AND 50'Lx10'D)	SF	1,550	$ 75	$ 116,250
4	COMMON EXCAVATION	CY	40	$ 20	$ 800
5	RIPRAP	CY	40	$ 150	$ 6,000
6	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
7	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
8	VEGETATION ESTABLISHMENT	LS	1	$ 5,000	$ 5,000
				CONSTRUCTION SUBTOTAL	$ 170,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 34,000
				PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 26,000
				CONTINGENCY (30% ASSUMED)	$ 69,000
				TOTAL	**$ 299,000**
				LOW ESTIMATE (-20%)	$ 240,000
				HIGH ESTIMATE (+30%)	$ 390,000

3.2. Channel Elimination

This alternative involves backfilling the channel through the marsh to increase levels in the marsh, provide additional residence time, and reduce the pore-water flow subsurface through the marsh bottom into and downstream in the channel. This alternative is expected to reduce phosphorus by increasing residence time from spreading flow throughout the wetland rather than it being concentrated in the channel. This increases effective use of the marsh area for treatment and reduces pore water phosphorus transport in the channel between inundation events. Potential disadvantages include stage increases due to reduced conveyance capacity through the marsh and complexity with permitting that would be required to get approval to place fill in the wetland.

Estimated costs for this alternative were $211,000 and dominated by the cost to fill, assuming material would need to be brought in from offsite. This alternative also assumed the installation of three rip-rap ditch blocks to reduce the potential for water to erode the placed fill. The cost estimate is shown in Table 3-2.

Table 3-2. Alternative 2 – Backfilling Channel Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 11,000	$ 11,000
2	COMMON EXCAVATION (1200'Lx10'Wx3'D)	CY	1,500	$ 40	$ 60,000
3	RIPRAP (3X 10'Lx10'Wx3'D)	CY	33	$ 150	$ 5,000
4	IMPORT TOPSOIL	CY	300	$ 50	$ 15,000
5	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
6	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
7	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
				CONSTRUCTION SUBTOTAL	$ 120,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 24,000
				PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 18,000
				CONTINGENCY (30% ASSUMED)	$ 49,000
				TOTAL	**$ 211,000**
				LOW ESTIMATE (-20%)	$ 170,000
				HIGH ESTIMATE (+30%)	$ 280,000

3.3. Channel Elimination with In-Channel Treatment

This alternative is a modification of the previous alternative that would have the channel backfilled with an adsorptive material (*e.g.,* water treatment plant residuals). This alternative is expected to have the same benefits as the previous alternative, but with additional removal associated with adsorption on the channel fill. This also reduces the risk of continued pore-water drainage and preferential flow of water through the channel fill. Potential disadvantages are the same as those described for the previous alternative.

Estimated costs for this alternative were $370,000 with costs dominated by the cost to import fill with adsorptive capacity (e.g., water treatment plant residuals). The cost estimate is provided in Table 3-3.

Table 3-3. Alternative 3 – Backfilling Channel with Adsorptive Media Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 19,000	$ 19,000
2	MEDIA	CY	1,500	$ 100	$ 150,000
3	RIPRAP (3X 10'Lx10'Wx3'D)	CY	33	$ 150	$ 5,000
4	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
5	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
6	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
CONSTRUCTION SUBTOTAL					$ 210,000
DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)					$ 42,000
PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)					$ 32,000
CONTINGENCY (30% ASSUMED)					$ 86,000
TOTAL					$ 370,000
LOW ESTIMATE (-20%)					$ 300,000
HIGH ESTIMATE (+30%)					$ 490,000

3.4. Wetland Regrading

This alternative involves the re-grading of the entire Cell 1 Wetland. This would allow for improved hydraulics through the wetland, increased residence time, reduced phosphorus export and mobilization, and an expected increase in removal efficiency for water flowing through the system. This would also have the added benefit of allowing for a more desirable wetland plant community to be established. The primary removal associated with this alternative is increased treatment due to residence time and hydraulic efficiency and the reduction of pore-water phosphorus release by removal of the channel. Primary disadvantages of this alternative are anticipated capital cost, challenges of working in unstable soils in wet conditions, wetland disturbance, and permitting complexity required for altering the wetland. Improving the hydraulic efficiency and removal efficiency, however, may be masked by the effects of sediment phosphorus release and porewater export described in Section 2.

The estimated cost for this alternative was $1,226,000. The primary driver of this cost was the estimated cost to re-contour the wetland as shown in Table 3-4.

Table 3-4. Alternative 4 – Wetland Regrading Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 54,000	$ 54,000
2	DEWATERING	LS	1	$ 150,000	$ 150,000
3	CLEARING AND GRUBBING	AC	11.5	$ 10,000	$ 115,000
4	COMMON EXCAVATION (1.5'Dx11.5AC)	CY	27,830	$ 15	$ 417,450
5	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
6	WETLAND PLANTING	SY	55,660	$ 1	$ 55,660
				CONSTRUCTION SUBTOTAL	$ 820,000
				DESIGN AND CONSTRUCTION ENGINEERING (10% OF CONSTRUCTION COSTS ASSUMED)	$ 82,000
				PERMITTING (5% OF CONSTRUCTION COSTS ASSUMED)	$ 41,000
				CONTINGENCY (30% ASSUMED)	$ 283,000
				TOTAL	**$ 1,226,000**
				LOW ESTIMATE (-20%)	$ 990,000
				HIGH ESTIMATE (+30%)	$ 1,600,000

3.5. Wetland Modification with Deep Zones

This alternative has similar goals to the previous alternative and involves back-filling the channel and excavating deep zones in the marsh. This would increase residence time and hydraulic efficiency which is expected to increase treatment and reduce pore water phosphorus release. Primary disadvantages include permitting complexity, capital cost, and degree of wetland disturbance.

The estimated costs for this alternative were $683,000. The cost estimate is provided in Table 3-5.

Table 3-5. Alternative 5 – Wetland Deep Zones Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 38,000	$ 38,000
2	DEWATERING	LS	1	$ 100,000	$ 100,000
3	CLEARING AND GRUBBING	AC	1.5	$ 15,000	$ 22,500
4	COMMON EXCAVATION	CY	5,000	$ 40	$ 200,000
5	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
6	ACCESS ROUTE RESTORATION	LS	1	$ 10,000	$ 10,000
7	VEGETATION ESTABLISHMENT	LS	1	$ 20,000	$ 20,000
				CONSTRUCTION SUBTOTAL	$ 420,000
				DESIGN AND CONSTRUCTION ENGINEERING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 63,000
				PERMITTING (10% OF CONSTRUCTION COSTS ASSUMED)	$ 42,000
				CONTINGENCY (30% ASSUMED)	$ 158,000
				TOTAL	**$ 683,000**
				LOW ESTIMATE (-20%)	$ 550,000
				HIGH ESTIMATE (+30%)	$ 890,000

3.6. Sediment Treatment

This alternative involves the treatment of the wetland area with an adsorptive amendment such as alum solution. This alternative could include treatment across the entire marsh, or just within and adjacent to the channel. This alternative would provide treatment by binding phosphorus that is released from sediments and to a lesser degree binding phosphorus in water that flows through the marsh near the sediment interface. The primary challenge of this alternative is an application method that would ensure that the amendment reached the sediment given the density of the vegetation in the marsh. Disadvantages of this alternative are potential impacts to the benthic community and capital cost depending on application rate and wetland preparation for treatment (burning, mowing, etc.).

The following assumptions were used to develop the estimated alum requirement:

- Average mobile phosphorus concentration in 0-30 cm sediment layer = 0.385 mg/g
- Dry density of 0-30 cm sediment layer = 0.381 g/cm^3
- Effective sediment treatment depth = 10 cm
- Molar alum dose (moles Al:P) = 10:1
- %Al in bulk alum solution = 4.4%
- Bulk alum solution density = 11.1 lb/gal

Two cost estimates were developed for this alternative. The first assumed wetland wide sediment treatment with mowing of the wetland in advance of application. This cost was estimated to be $592,000 as shown in Table 3-6.

Table 3-6. Alternative 6a – Sediment Treatment Whole Wetland Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 17,000	$ 17,000
2	WETLAND MOWING	AC	11.5	$ 5,000	$ 57,500
3	ALUM TREATMENT	GAL	36,600	$ 6	$ 219,600
4	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
5	VEGETATION ESTABLISHMENT	LS	1	$ 25,000	$ 25,000
				CONSTRUCTION SUBTOTAL	$ 350,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 70,000
				PERMITTING (10% OF CONSTRUCTION COSTS ASSUMED)	$ 35,000
				CONTINGENCY (30% ASSUMED)	$ 137,000
				TOTAL	**$ 592,000**
				LOW ESTIMATE (-20%)	$ 480,000
				HIGH ESTIMATE (+30%)	$ 770,000

The second scenario was treatment of just the channel and assumed the channel area comprised 10% of the total area. The estimated cost for this scenario was $71,000. The cost estimate for this scenario is provided in Table 3-7.

Table 3-7. Alternative 6b – Sediment Treatment Channel Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 4,000	$ 4,000
2	ALUM TREATMENT	GAL	3,660	$ 6	$ 21,960
3	TEMPORARY EROSION CONTROL	LS	1	$ 4,000	$ 4,000
4	VEGETATION ESTABLISHMENT	LS	1	$ 10,000	$ 10,000
				CONSTRUCTION SUBTOTAL	$ 40,000
				DESIGN AND CONSTRUCTION ENGINEERING (20% OF CONSTRUCTION COSTS ASSUMED)	$ 8,000
				PERMITTING (15% OF CONSTRUCTION COSTS ASSUMED)	$ 6,000
				CONTINGENCY (30% ASSUMED)	$ 17,000
				TOTAL	**$ 71,000**
				LOW ESTIMATE (-20%)	$ 60,000
				HIGH ESTIMATE (+30%)	$ 100,000

3.7. Inflow or Outflow Alum Treatment

This alternative would use an alum feed system to provide continuous treatment of flows coming into or out of the wetland. This would reduce concentrations of phosphorus in the water column. This would provide treatment for both phosphorus in the water and potential sediment release. The primary disadvantage of this alternative is a feed system that adequately mixes the alum in the water to be treated and the operation and maintenance associated with an alum feed system. There is also the potential for generation of floc that may accumulate downstream in the wetland and require maintenance.

The estimated cost for this alternative was $1,016,000. Costs evaluated for the alum treatment system were based on the average cost for alum treatment systems (Harper & Herr, 1998) with price escalated from 1998 to 2023 using the Consumer Price Index. These systems are highly site dependent and can have significant variations in price based on the level of infrastructure needed to measure flows, supply power, inject the alum, ensure adequate mixing, and capture floc for removal. The estimated costs are shown in Table 3-8.

Table 3-8. Alternative 7 – Alum Treatment System Conceptual Cost Estimate

ITEM NO.	ITEM DESCRIPTION	UNIT	TOTAL QUANTITY	UNIT COST	TOTAL PROJECT COST
1	MOBILIZATION	LS	1	$ 54,000	$ 54,000
2	CIVIL SITE IMPROVEMENTS	LS	1	$ 50,000	$ 50,000
3	ALUM TREATMENT SYSTEM	LS	1	$ 500,000	$ 500,000
4	TEMPORARY EROSION CONTROL	LS	1	$ 25,000	$ 25,000
5	VEGETATION ESTABLISHMENT	LS	1	$ 15,000	$ 15,000
				CONSTRUCTION SUBTOTAL	$ 650,000
	DESIGN AND CONSTRUCTION ENGINEERING (15% OF CONSTRUCTION COSTS ASSUMED)				$ 98,000
	PERMITTING (5% OF CONSTRUCTION COSTS ASSUMED)				$ 33,000
				CONTINGENCY (30% ASSUMED)	$ 235,000
				TOTAL	$ 1,016,000
				LOW ESTIMATE (-20%)	$ 820,000
				HIGH ESTIMATE (+30%)	$ 1,330,000

4. Alternatives Analysis

4.1. Ranking Criteria

Following development of the available alternatives, each alternative was scored for each of 10 criteria that address the project and permitting complexity, project impacts, expected degree of success, costs, and risk. Each of the evaluated criteria are briefly discussed in the following sections. Regardless of specific criterion evaluation methodology, a higher quantitative score corresponds to a qualitatively better outcome, or easier practice to implement.

4.1.1. Wetland Impacts

Each of these alternatives is expected to have some degree of impact on the existing Cell 1 Wetland. This criterion considered a smaller degree of impact more favorable with a higher score equating to less impact. Alternatives that were expected to have substantial impacts on vegetation and modification of the wetland surface from excavation or fill were scored a one, while those with impacts affecting only a small area (<0.1 acres) or no area scored a three, and alternatives between these scored a two.

4.1.2. Permitting Complexity

Since the proposed project is in a wetland that is designated as a Minnesota Department of Natural Resources Public Water and regulated by multiple local, state, and federal agencies, it is expected that the alternatives that were developed will require some level of permitting approval to implement. It is also assumed that alternatives would generally need to maintain or improve the function of the wetland in order to not be determined as an impact to wetland that could potentially require mitigation. This criterion evaluates the expected degree of permitting that will be required and the anticipated difficulty of the associated permitting with a higher score equating to easier permitting. Alternatives that were expected to have challenging permitting were scored a one, alternatives with little expected permitting were scored a three, and others were scored a two.

4.1.3. Engineering Complexity

This criterion considers the expected degree of engineering complexity associated with project implementation. A high score for this criterion is associated with projects that are expected to be less complex to develop. As with permitting, alternatives that required significant engineering complexity were scored a one, those with little required engineering were scored a three, and others scored a two.

4.1.4. Phosphorus Export Reduction

The developed alternatives are expected to have a range of effectiveness for phosphorus retention and/or removal. Based on the data analysis completed it appears that a majority of the phosphorus being exported from this system is internally generated and released during periods when the wetland experiences intermittent inundation. This criterion considers the expected degree of phosphorus export reduction with high reductions having a high score. Alternatives that were estimated to reduce export by 50% or more were scored a three, those with expected reductions of 20-50% were scored a two, and others were scored a one.

4.1.5. Capital Costs

Each of the presented alternatives will have a capital cost associated with its development. This criterion considers the expected cost associated with construction of the proposed alternative with a high score equating to a lower capital cost. Alternatives with an estimated cost greater than $800,000 received a one, between $400,000-$800,000 received a two, and less than $400,000 received a three.

4.1.6. Operations and Maintenance Costs

Once constructed, each of the proposed alternatives is expected to have varying degrees of operations and maintenance costs. This criterion considers the expected degree of ongoing costs associated with the project with a higher score for projects with expected lower costs.

4.1.7. Reduction Time Scale

Not all of the evaluated alternatives will provide a reduction on the same time scale. This criterion evaluates the expected duration before phosphorus reductions would be expected with a higher score equating to a quicker expected reduction. Alternatives with an expected two year or greater lag received a one, one to two years received a two, and a less than one year lag received a three.

4.1.8. Risk

There are unknowns associated with the alternatives that could result in different than expected outcomes. This criterion describes the expected risk associated with the alternatives. Alternatives with a high degree of uncertainty received a one, those with a moderate degree of uncertainty received a two, and those that would be expected to perform well regardless of the cause of the export received a three.

4.1.9. Ability to Mitigate Risk

Some of the evaluated alternatives have the potential to mitigate risks associated with their implementation (e.g., making weir plates removable so levels in the marsh can be adjusted if too high or too low). This criterion considers the ability to modify the alternative once implemented to reduce potential adverse outcomes. Alternatives with limited potential for mitigation received a one, those with some degree of ability to mitigate received a two, and those with one or more options for mitigation received a three.

4.2. Alternatives Matrix

For each of the considered alternatives the evaluated criteria were ranked on the three-point scale with a higher score signifying the desirable outcome (i.e. lower risk, lower complexity, lower cost, etc.). Scores on each criterion were then summed to yield a total score for each alternative. These scores were then used to rank the projects from best to worst with the highest scoring project receiving the highest score. The alternatives matrix is shown in Table 4-1, ranked in order of score from high to low. In addition to the alternatives matrix, estimated TP export reductions were developed for each alternative. These values were estimated based on professional judgement and the mechanisms of export being addressed by each alternative. The estimated export reductions for each alternative are shown in Table 4-2. Estimated reductions ranged from 20-80% for the evaluated alternatives.

Based on the scoring criteria and ranking, manipulating hydrology through installation of sheet pile was the highest-ranked option. The next highest-ranked alternative was sediment treatment with alum. The highest estimated export reduction was for alum treatment of inflow water, followed by sediment treatment, with manipulating hydrology in third.

Though this methodology provides an absolute ranking, it should be considered that the differences in the first ranked option (sheet pile weir) and the fourth ranked option (alum treatment system) is only three ranking points. However, the difference between the first ranked option and the seventh ranked option (regrading entire wetland) is 12 ranking points. Based on this method and detail of analysis, it can be said with high confidence that the sheet pile alternative is a better alternative than regrading the entire wetland. However, it is less clear whether the sheet pile is absolutely the better alternative than treating the channel or entire wetland with an adsorptive material (second ranked alternatives). Rather, it can be concluded that the top four alternatives likely would be better than the bottom three alternatives.

MCWD can use this ranking matrix to consider which alternative to pursue, based on MCWD specific parameters. The current ranking methodology weights each criterion equally. For example, if the initial capital costs are not a concern, and the highest degree of TP treatment is desired, this shifts alum treatment of the water ahead of the sheet pile or sediment treatment alternatives. Finally, combinations of alternatives were not considered in the ranking, but the MCWD could choose to implement multiple alternatives to address the same or different mechanisms and increase the likelihood of successfully reducing phosphorus export from the wetland.

Table 4-1. Alternatives Ranking Matrix

No.	Alternative	Description	Wetland Impacts	Permitting Complexity	Engineering Complexity	TP Export Reduction	Capital Costs	O&M Costs	Reduction Time Scale	Risk	Ability to Mitigate Risk	Total Score	Rank
1	Manipulate Hydrology	Outlet water level control structure	3	2	3	2	3	3	2	2	3	23	1
6	Sediment Treatment	Adsorptive treatment of sediments	2	2	3	3	2	3	3	2	2	22	2
3	Channel Treatment	Fill channel with adsorptive media	2	1	3	2	3	3	3	3	1	21	3
7	Inflow/Outflow Alum Treatment	Alum treatment of water	3	2	1	3	1	1	3	3	3	20	4
2	Channel Elimination	Fill channel	2	1	3	1	3	3	2	2	1	18	5
5	Topographic Modification	Deep zones and fill channel	1	1	2	1	2	3	1	2	1	14	6
4	Topographic Modification	Regrade wetland	1	1	1	1	1	3	1	1	1	11	7

Table 4-2. Estimated Export Reduction for Evaluated Alternatives

No.	Alternative	Description	Est. Export Reduction
1	Manipulate Hydrology	Outlet water level control structure	50%
2	Channel Elimination	Fill channel	20%
3	Channel Treatment	Fill channel with adsorptive media	35%
4	Topographic Modification	Regrade wetland	30%
5	Topographic Modification	Deep zones and fill channel	25%
6	Sediment Treatment	Adsorptive treatment of sediments	70%
7	Inflow/Outflow Alum Treatment	Alum treatment of water	80%

5. Hydraulic Evaluation

To evaluate the potential implications of manipulating hydrology the project team requested a copy of the District's XPSWMM stormwater model to better understand the wetland's hydraulic behavior under existing and proposed conditions. The project team truncated the District's model, updated it based on previously collected survey information, and subdivided the wetland into its four cells, as the provided model considered the entire wetland complex as a single cell. New, cell-specific storage curves were developed using a combination of previously collected survey data and LiDAR. Hydraulic connections from one cell to another were input based on survey information. Overflows between the cells were modeled based on LiDAR, where survey information was unavailable. Hydrologic inputs were updated to reflect the smaller, cell-specific drainage area. However, area was the only input parameter that was changed for the hydrologic components; watershed percent impervious, widths, and soils information were not altered.

The model was executed for the 100-year event to understand high water levels in the wetland, and adjacent waterbodies. The project team then developed a series of conceptual proposed conditions to determine what effect manipulating the runout elevation of the wetland would have on the wetland and adjacent waterbodies, assuming a sheet pile weir structure would be constructed to modify the wetland's runout elevation. Sheet pile widths varied from 10-feet wide to 500-feet wide, and elevations varied from 943.0 to 944.5. The intent of developing a series of models across this range of values is not to suggest that a 500-foot-wide sheet pile weir should be constructed. Rather, this is to provide a data point beyond what is a reasonable project, such that it can be understood how the system functions, and direct discussions such as: "if the objective is to raise the wetland's normal water level as high as possible, how wide of a weir is necessary such that the floodplain is unaltered?".

The extent of the area evaluated included Wasserman Lake to the south, Carl Krey Lake to the west, and Lake Auburn to the north. Table 5-1 summarizes existing high-water levels, and the assumed design constraints for the points of analysis.

Table 5-1: Assumed High Water Level Constraints

Comment	Existing 100-yr HWL	Assumed Maximum Elevation	Constraint Comment
Wasserman Lake	946.60	946.60	No-rise is required; in Zone A
Carl Krey Lake	945.99	945.99	No-rise is required; in Zone A
Lake Auburn	942.51	942.51	No-rise is required; in Zone A
Cell 1	945.23	950.00	No floodplain; cannot flood residents
Cell 2	945.23	946.00	No floodplain; cannot flood residents
Cell 3	944.66	944.66	No floodplain; existing HWL on private property; default to no-rise
Cell 4	944.66	944.66	No floodplain; existing HWL on private property; default to no-rise

Under existing conditions, the wetland (Cell 1) overflows at an elevation of 942.25. Based on the conceptual sheet pile model runs, this runout elevation could be raised to approximately 944.0 and still achieve the design criteria listed above. To achieve no-rise conditions on Wasserman Lake and maintain a runout elevation of 944.0, a sheet pile weir of between 25- to 50-feet would be required. A shorter length of sheet pile would be feasible if the proposed runout elevation is less than 944.0. These finer details would be addressed depending on the exact elevation and configuration desired, as part of a final design.

6. Conclusions and Recommendations

The Cell 1 Wetland located at the upstream end of the East Auburn Wetland Complex has been identified as the likely source of elevated total phosphorus (TP) loads to East Auburn Lake. This study collected and evaluated available water quality, flow, level, and sediment data for the Cell 1 Wetland and wetland complex with the goal of identifying the likely source of this TP loading.

Based on that evaluation, the dominant mechanisms that appear to contribute to the export of TP are decreased water levels in early summer that result in the wetland drying out. These dry outs result in subsurface drainage of the marsh to the channel which transports TP, primarily as ortho-phosphorus (OP), to the channel where it flows out or is flushed out during summer storm events. This dehydration of the wetland also results in mobilization of labile organic phosphorus in the sediments which is flushed out during these same rainfall and flow events.

To develop recommendations, this study considered seven potential alternative management strategies. These alternatives were ranked based on nine criteria and estimated TP export reductions were developed. Each of these alternatives had estimated capital costs developed to implement the projects. From the alternatives ranking and reduction estimates there were two alternatives that tied for the highest rank and had similar reduction estimates and capital costs. The recommended alternative is restoration of hydrology through installation of a sheet pile weir between the Cell 1 and Cell 2 Wetlands.

This weir would be constructed to reduce the short-circuiting and drainage of water with higher phosphorus concentrations through the channel in the marsh during the summer months when this system dries out. It is recommended that this weir include weir plates that can be removed in the event that elevated phosphorus concentrations occur due to the release of iron-bound phosphorus and anaerobic conditions.

To further reduce the potential for release, a second alternative could be applied in concert with hydrologic restoration. This recommended alternative is either sediment treatment with alum solution across the wetland or application of sediment treatment media within the channel. Either would reduce the export of phosphorus from subsurface drainage to the channel and would reduce the likelihood of sediment release associated with increasing the wetland hydroperiod and anaerobic conditions.

To provide additional information that can be used to advance a final design this study would recommend collection of continuous flow and level data at the inlet to the Cell 1 Wetland and continued collection of water quality samples at CSI12, CSI05, and CSI22. Additionally, it is recommended that drone-based LiDAR topography, supplemented with ground-based survey be collected to improve the understanding of the wetland bathymetry to guide design of a sheet pile weir. The optimal timing of this data collection would be during mid- to late-summer when the wetland water levels are very low.

7. References

Beck, B. (2019). *East Auburn Wetland Phosphorus Analysis* (p. 6) [Technical Memorandum]. Minnehaha Creek Watershed District.

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Stantec. (2022). *Auburn Wetland Monitoring Project—Technical Memo* (227704313).

Wenck Associates, Inc. (2017). *Six Mile Marsh Phosphorus Loading Analysis* (p. 13).

Appendix A

Stormwater Sampling Statistics

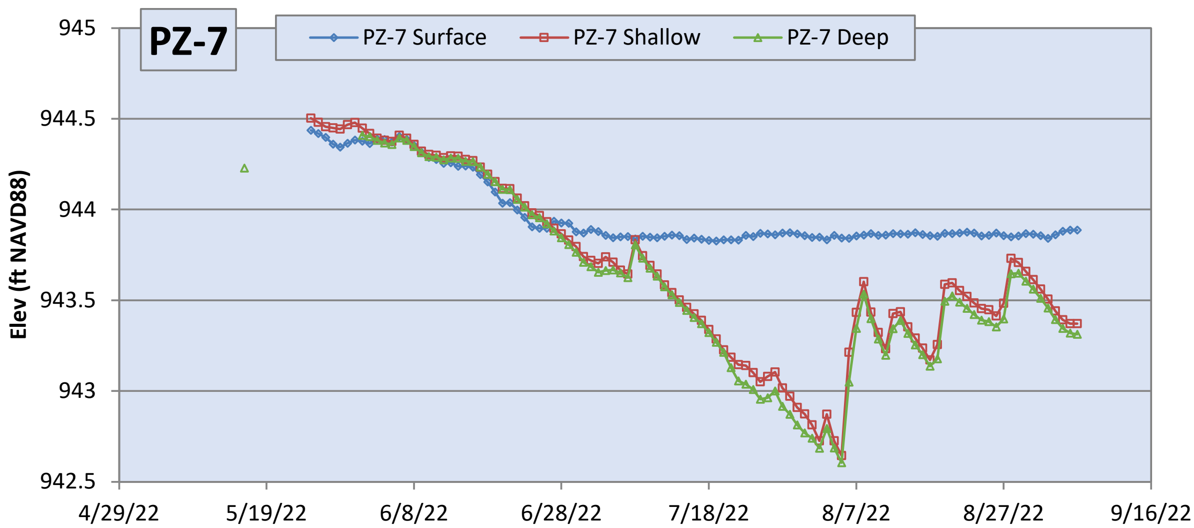
Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
Temp	C	CSI05	15.2	-0.06	28.8	7.60	508	Apr-09	Jun-22
		CSI12	16.9	0.00	30.2	7.81	451	Apr-09	Jun-22
		CSI19	15.7	0.00	27.2	8.86	27	May-20	Oct-21
		CSI22	14.4	0.00	27.1	8.82	33	May-20	Jun-22
		SW-1	23.4	21.9	25.5	1.51	4	Jun-22	Jul-22
		SW-2	23.4	22.1	24.5	1.08	4	Jun-22	Jul-22
		SW-3	20.4	19.0	20.9	0.93	4	Jun-22	Jul-22
		SW-4	21.1	20.3	22.2	0.84	4	Jun-22	Jul-22
DO	%	SW-1	4.16	0.14	8.52	3.93	4	Jun-22	Jul-22
		SW-2	4.39	0.16	8.51	4.15	4	Jun-22	Jul-22
		SW-3	4.03	0.33	8.60	4.09	4	Jun-22	Jul-22
		SW-4	3.71	0.52	8.33	3.69	4	Jun-22	Jul-22
	mg/L	CSI05	4.00	0.00	20.9	3.39	508	Apr-09	Jun-22
		CSI12	6.83	0.00	27.3	4.55	451	Apr-09	Jun-22
		CSI19	3.72	0.00	10.8	3.20	34	Jul-19	Oct-21
		CSI22	5.66	0.00	49.4	8.74	33	May-20	Jun-22
pH	SU	CSI05	7.34	4.25	9.10	0.42	487	Apr-09	Jun-22
		CSI12	7.98	6.68	17.1	0.79	435	Apr-09	Jun-22
		CSI19	7.54	7.28	7.99	0.21	23	May-20	Oct-21
		CSI22	7.56	6.92	8.49	0.43	27	May-20	Jun-22
		SW-1	7.39	6.76	7.98	0.65	4	Jun-22	Jul-22
		SW-2	7.43	6.68	8.18	0.83	4	Jun-22	Jul-22
		SW-3	6.61	6.44	6.76	0.16	3	Jun-22	Jul-22
		SW-4	7.54	7.15	8.25	0.61	3	Jun-22	Jul-22
Cond	uS/cm	CSI05	404	244	745	57.3	500	Apr-09	Jun-22
		CSI12	356	233	621	35.2	444	Apr-09	Jun-22
		CSI19	392	314	487	45.6	23	May-20	Oct-21
		CSI22	420	292	755	98.0	28	May-20	Jun-22
		SW-1	461	352	610	129	4	Jun-22	Jul-22
		SW-2	445	338	557	119	4	Jun-22	Jul-22
		SW-3	495	352	598	111	4	Jun-22	Jul-22
		SW-4	488	345	705	174	4	Jun-22	Jul-22
ORP	mV	SW-1	-38.3	-136	34.7	75.3	4	Jun-22	Jul-22
		SW-2	-4.83	-37.6	13.3	22.6	4	Jun-22	Jul-22
		SW-3	-30.8	-132	86.3	110	3	Jun-22	Jul-22
		SW-4	-39.4	-78.0	-6.50	36.1	3	Jun-22	Jul-22
TSS	mg/L	CSI05	7.31	0.50	268	27.6	100	Apr-09	Dec-15
		CSI12	8.80	0.50	104	11.7	100	Apr-09	Dec-15
Chloride	mg/L	CSI05	36.1	19.8	104	14.8	50	Apr-09	Nov-15
		CSI12	26.9	21.0	39.3	2.99	52	Apr-09	Dec-15

Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
TFE	mg/L	SW-1	1.35	0.11	3.42	1.56	4	Jun-22	Jul-22
		SW-2	2.92	0.09	7.15	3.43	4	Jun-22	Jul-22
		SW-3	2.74	0.11	7.44	3.46	4	Jun-22	Jul-22
		SW-4	1.41	0.08	2.97	1.51	4	Jun-22	Jul-22
TP	mg/L	CSI05	0.12	0.03	1.12	0.12	500	Apr-09	Jun-22
		CSI12	0.08	0.02	0.36	0.04	440	Apr-09	Jun-22
		CSI19	0.10	0.03	0.51	0.09	31	Jul-19	Oct-21
		CSI22	0.09	0.03	0.18	0.05	28	May-20	Jun-22
		SW-1	0.11	0.05	0.26	0.10	4	Jun-22	Jul-22
		SW-2	0.43	0.04	1.08	0.49	4	Jun-22	Jul-22
		SW-3	0.59	0.04	1.76	0.81	4	Jun-22	Jul-22
		SW-4	0.22	0.01	0.44	0.23	4	Jun-22	Jul-22
OP	mg/L	CSI05	0.04	0.00	0.19	0.03	460	Apr-09	Jun-22
		CSI12	0.01	0.00	0.11	0.01	440	Apr-09	Jun-22
		CSI19	0.04	0.00	0.23	0.04	31	Jul-19	Oct-21
		CSI22	0.03	0.00	0.11	0.03	28	May-20	Jun-22
		SW-1	0.03	0.02	0.04	0.01	4	Jun-22	Jul-22
		SW-2	0.03	0.02	0.03	0.00	4	Jun-22	Jul-22
		SW-3	0.03	0.02	0.04	0.01	4	Jun-22	Jul-22
		SW-4	0.03	0.01	0.05	0.02	4	Jun-22	Jul-22
TN	mg/L	CSI05	1.21	0.30	4.49	0.58	151	Apr-09	Jun-22
		CSI12	1.63	0.50	5.13	0.65	142	Apr-09	Jun-22
		CSI19	1.22	0.50	2.50	0.43	28	Aug-19	Oct-21
		CSI22	1.38	0.60	3.60	0.65	28	May-20	Jun-22
		SW-1	2.76	0.88	6.64	2.71	4	Jun-22	Jul-22
		SW-2	2.61	0.85	5.30	2.13	4	Jun-22	Jul-22
		SW-3	2.33	0.78	4.43	1.83	4	Jun-22	Jul-22
		SW-4	2.36	0.76	4.57	1.89	4	Jun-22	Jul-22
TKN	mg/L	CSI05	1.29	0.73	2.54	0.40	43	Apr-09	Nov-15
		CSI12	1.70	0.82	2.43	0.37	42	Apr-09	Dec-15
NO3-N	mg/L	CSI05	0.07	0.02	0.41	0.12	43	Apr-09	Nov-15
		CSI12	0.19	0.02	3.69	0.57	42	Apr-09	Dec-15
Flow	cfs	CSI05	4.11	-0.12	28.1	4.91	542	Apr-09	Aug-22
		CSI12	4.09	0.00	42.5	5.57	492	Apr-09	Aug-22
Elevation	ft NAVD88	Wasserman	944.8	938.0	947.2	0.72	790	Aug-64	Nov-22
		Creek	943.1	942.7	944.2	0.33	9,005	Jun-22	Sep-22
		CSI05	941.8	941.1	944.2	0.43	78	Mar-16	Jul-22
		SW-1	943.4	943.0	943.9	0.46	4	Jun-22	Jul-22
		SW-2	943.5	943.1	944.0	0.45	4	Jun-22	Jul-22
		SW-3	943.5	943.1	944.0	0.47	4	Jun-22	Jul-22

Parameter	Units	STN	Average	Min	Max	StdDev	Count	Period-of-Record	
		SW-4	943.7	943.2	944.4	0.59	4	Jun-22	Jul-22

Appendix B

Detailed Water Level Data


PZ-7
PZ-7 Surface
PZ-7 Shallow
PZ-7 Deep
Elev (ft NAVD88)
945
944.5
944
943.5
943
942.5
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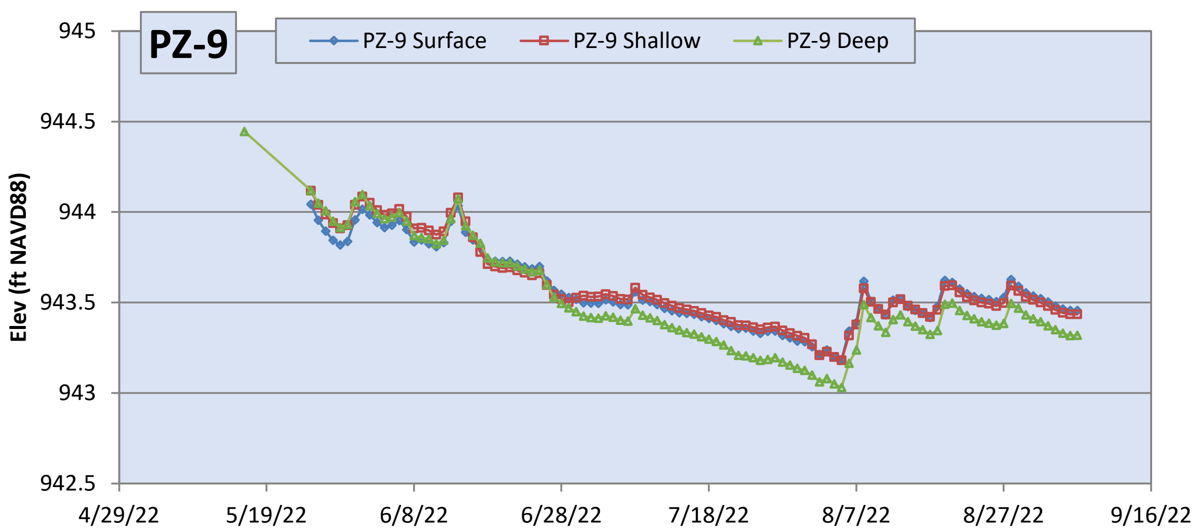
5/19/22
6/8/22
6/28/22
7/18/22
8/7/22
8/27/22
9/16/22


PZ-9
PZ-9 Surface
PZ-9 Shallow
PZ-9 Deep
Elev (ft NAVD88)
945
944.5
944
943.5
943
942.5
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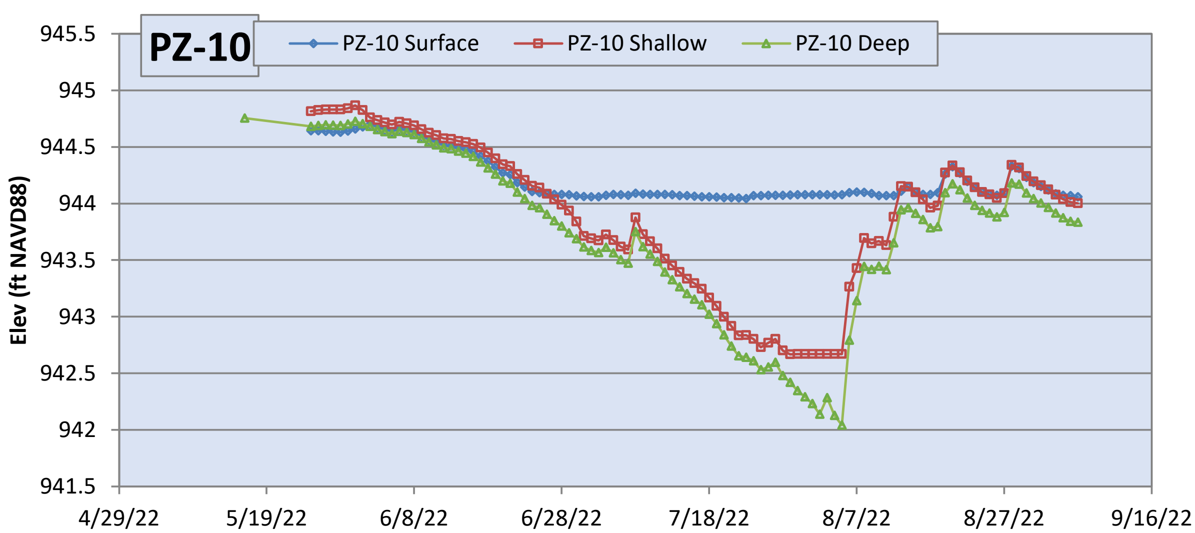
8/27/22
9/16/22


PZ-10
PZ-10 Surface
PZ-10 Shallow
PZ-10 Deep
Elev (ft NAVD88)
945.5
945
944.5
944
943.5
943
942.5
942
941.5
4/29/22
5/19/22
6/8/22
6/28/22
7/18/22
8/7/22
8/27/22
9/16/22

Appendix C

Sediment Sampling Data

		Phosphorus												
		Loosely-bound	Fe-bound	Labile organic	Mobile Pool	Al-bound	Ca-bound	Refractory Organic	Permanent Pool	Total	Organic Content	Moisture Content	Dry Density	Wet Density
STN	Depth	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	%	%	g/cm^3	g/cm^3
PZ-1	Surface	0.043	0.050	0.516	0.609	0.151	0.065	0.00	0.216	0.813	53.5	75.1	0.285	1.08
	Shallow	0.003	0.019	0.510	0.532	0.192	0.018	0.260	0.469	1.00	69.1	76.4	0.266	1.05
	Deep	0.024	0.031	0.003	0.058	0.092	0.056	0.212	0.360	0.418	75.4	84.1	0.171	1.02
PZ-2	Surface	0.010	0.026	0.311	0.347	0.082	0.030	0.369	0.481	0.828	42.1	70.1	0.357	1.12
	Shallow	0.030	0.018	0.135	0.183	0.108	0.010	0.341	0.459	0.642	80.3	80.1	0.218	1.02
	Deep	0.016	0.035	0.003	0.054	0.105	0.071	0.074	0.250	0.304	43.9	77.9	0.251	1.08
PZ-7	Surface	0.002	0.024	0.183	0.209	0.077	0.010	0.433	0.520	0.729	11.8	41.4	0.907	1.47
	Shallow	0.003	0.023	0.190	0.216	0.132	0.015	0.074	0.221	0.437	81.1	83.6	0.177	1.02
	Deep	0.022	0.032	0.058	0.112	0.086	0.024	0.357	0.466	0.578	76.9	86.9	0.139	1.02
PZ-9	Surface	0.010	0.030	0.178	0.218	0.074	0.034	0.261	0.369	0.587	55.6	81.9	0.200	1.05
	Shallow	0.029	0.023	0.330	0.382	0.138	0.037	0.068	0.243	0.625	75.3	88.9	0.117	1.02
	Deep	0.016	0.027	0.229	0.272	0.097	0.045	0.221	0.363	0.635	56.6	92.6	0.077	1.02
PZ-10	Surface	0.003	0.022	0.523	0.548	0.114	0.036	0.535	0.684	1.23	64.8	75.6	0.277	1.06
	Shallow	0.003	0.016	0.238	0.257	0.084	0.024	0.131	0.238	0.495	85.6	80.4	0.214	1.02
	Deep	0.033	0.029	0.021	0.083	0.043	0.028	0.221	0.292	0.375	84.5	90.4	0.100	1.01
PZ-12	Surface	0.002	0.035	0.331	0.368	0.127	0.020	0.212	0.359	0.727	48.4	74.0	0.302	1.09
	Shallow	0.002	0.014	0.092	0.108	0.040	0.009	0.529	0.577	0.685	33.4	62.4	0.477	1.18
	Deep	0.025	0.021	0.031	0.077	0.047	0.024	0.290	0.361	0.438	86.9	87.3	0.134	1.01
PZ-13	Surface	0.010	0.046	0.295	0.351	0.086	0.052	0.263	0.400	0.751	60.3	76.6	0.265	1.06
	Shallow	0.002	0.053	0.233	0.288	0.125	0.034	0.086	0.245	0.533	32.5	66.8	0.408	1.16
	Deep	0.022	0.039	0.130	0.191	0.073	0.019	0.267	0.359	0.550	81.3	86.2	0.147	1.02
PZ-14	Surface	0.018	0.074	0.257	0.349	0.062	0.075	0.062	0.199	0.548	31.4	64.2	0.450	1.18
	Shallow	0.002	0.026	0.184	0.212	0.066	0.049	0.549	0.663	0.875	36.5	68.0	0.389	1.14
	Deep	0.029	0.033	0.052	0.114	0.047	0.030	0.396	0.472	0.586	90.4	88.2	0.124	1.01
PZ-15	Surface	0.002	0.023	0.435	0.460	0.118	0.026	0.186	0.330	0.790	39.4	68.2	0.385	1.13

STN	Depth	Phosphorus Loosely-bound mg/g	Phosphorus Fe-bound mg/g	Phosphorus Labile organic mg/g	Phosphorus Mobile Pool mg/g	Phosphorus Al-bound mg/g	Phosphorus Ca-bound mg/g	Phosphorus Refractory Organic mg/g	Phosphorus Permanent Pool mg/g	Phosphorus Total mg/g	Organic Content %	Moisture Content %	Dry Density g/cm^3	Wet Density g/cm^3
	Shallow	0.023	0.015	0.166	0.204	0.097	0.020	0.225	0.342	0.546	85.8	84.1	0.171	1.01
	Deep	0.026	0.024	0.017	0.067	0.061	0.031	0.232	0.324	0.391	91.1	87.4	0.133	1.01
SW-1	Stream	0.039	0.305	0.262	0.606	0.104	0.062	0.000	0.166	0.700	28.4	71.6	0.340	1.14
SW-2	Stream	0.021	0.104	0.192	0.317	0.078	0.078	0.230	0.386	0.703	43.2	90.0	0.106	1.04
SW-3	Stream	0.024	0.072	0.216	0.312	0.098	0.090	0.301	0.490	0.802	38.9	83.2	0.185	1.07
SW-4	Stream	0.024	0.091	0.091	0.206	0.045	0.126	0.093	0.264	0.470	15.2	53.4	0.646	1.32

Appendix D

Groundwater Sampling Statistics

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
Temp	C	PZ-1	Surface	21.8	17.1	26.6	6.74	2	Jun-22	Jun-22
			Shallow	17.5	13.9	22.4	3.16	6	Jun-22	Aug-22
			Deep	10.8	7.80	13.1	2.20	7	May-22	Aug-22
		PZ-2	Surface	19.0	17.8	20.2	1.70	2	Jun-22	Jun-22
			Shallow	13.7	9.30	17.5	3.19	5	Jun-22	Jul-22
			Deep	9.23	5.30	13.0	2.69	8	May-22	Aug-22
		PZ-3	Surface	20.4	17.4	23.5	4.36	2	Jun-22	Jun-22
			Shallow	16.8	11.1	21.5	3.31	7	Jun-22	Aug-22
			Deep	8.99	4.72	12.0	2.72	8	May-22	Aug-22
		PZ-4	Surface	20.7	17.6	23.8	4.40	2	Jun-22	Jun-22
			Shallow	16.5	9.83	21.3	3.53	7	Jun-22	Aug-22
			Deep	9.71	5.53	13.4	2.97	8	May-22	Aug-22
		PZ-5	Surface	18.5	16.1	20.9	3.39	2	Jun-22	Jun-22
			Shallow	15.7	11.2	18.2	3.09	5	Jun-22	Jul-22
			Deep	8.42	5.07	12.3	2.39	8	May-22	Aug-22
		PZ-6	Surface	21.8	21.8	21.8	---	1	Jun-22	Jun-22
			Shallow	18.0	15.7	20.5	1.77	5	Jun-22	Aug-22
			Deep	11.8	8.36	15.5	2.31	7	May-22	Aug-22
		PZ-7	Surface	18.5	17.7	19.3	1.14	2	Jun-22	Jun-22
			Shallow	15.9	9.07	18.9	3.75	7	Jun-22	Aug-22
			Deep	9.57	4.86	13.5	3.15	8	May-22	Aug-22
		PZ-8	Deep	6.52	6.52	6.52	---	1	May-22	May-22
		PZ-9	Surface	21.2	18.7	25.6	2.47	7	Jun-22	Aug-22
			Shallow	16.0	13.3	17.3	1.41	6	Jun-22	Aug-22
			Deep	9.03	6.07	11.8	2.03	8	May-22	Aug-22
		PZ-10	Surface	20.2	19.8	20.6	0.57	2	Jun-22	Jun-22
			Shallow	16.7	12.4	18.9	2.44	6	Jun-22	Aug-22
			Deep	10.1	5.25	13.8	3.11	8	May-22	Aug-22
		PZ-11	Surface	12.5	10.4	14.0	1.87	3	Jun-22	Aug-22
		PZ-12	Surface	19.2	18.0	20.0	0.94	4	Jun-22	Aug-22
			Shallow	17.0	11.3	19.8	3.08	7	Jun-22	Aug-22
			Deep	9.39	5.26	14.3	3.15	9	May-22	Aug-22
		PZ-13	Surface	17.9	12.8	23.4	4.61	4	Jun-22	Aug-22
			Shallow	16.8	12.0	20.7	3.42	6	Jun-22	Aug-22
			Deep	10.0	4.83	15.8	3.47	8	May-22	Aug-22
		PZ-14	Surface	16.5	16.5	16.5	---	1	Jun-22	Jun-22
			Shallow	16.7	13.1	19.5	2.74	5	Jun-22	Aug-22
			Deep	8.90	5.53	12.1	2.37	8	May-22	Aug-22
		PZ-15	Surface	19.3	18.6	20.5	1.07	3	Jun-22	Aug-22
			Shallow	16.5	11.2	19.2	3.11	6	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	8.65	4.91	12.7	2.75	8	May-22	Aug-22
DO	mg/L	PZ-1	Surface	3.98	0.85	7.11	4.43	2	Jun-22	Jun-22
			Shallow	0.98	0.41	2.04	0.60	6	Jun-22	Aug-22
			Deep	0.37	0.16	0.59	0.16	7	May-22	Aug-22
		PZ-2	Surface	0.63	0.56	0.70	0.10	2	Jun-22	Jun-22
			Shallow	0.26	0.16	0.37	0.10	5	Jun-22	Jul-22
			Deep	0.17	-0.10	0.70	0.25	8	May-22	Aug-22
		PZ-3	Surface	2.42	1.93	2.91	0.69	2	Jun-22	Jun-22
			Shallow	1.44	0.37	6.17	2.10	7	Jun-22	Aug-22
			Deep	0.41	0.11	1.05	0.35	8	May-22	Aug-22
		PZ-4	Surface	0.44	0.33	0.54	0.15	2	Jun-22	Jun-22
			Shallow	0.59	0.16	0.98	0.32	7	Jun-22	Aug-22
			Deep	0.23	0.09	0.39	0.11	8	May-22	Aug-22
		PZ-5	Surface	2.00	1.17	2.82	1.17	2	Jun-22	Jun-22
			Shallow	0.37	0.20	0.60	0.15	5	Jun-22	Jul-22
			Deep	0.16	0.00	0.50	0.18	8	May-22	Aug-22
		PZ-6	Surface	0.26	0.26	0.26	---	1	Jun-22	Jun-22
			Shallow	0.79	0.23	1.87	0.67	5	Jun-22	Aug-22
			Deep	0.34	0.01	0.61	0.20	7	May-22	Aug-22
		PZ-7	Surface	0.23	0.20	0.26	0.04	2	Jun-22	Jun-22
			Shallow	0.83	0.30	1.24	0.29	7	Jun-22	Aug-22
			Deep	0.46	0.12	0.83	0.30	8	May-22	Aug-22
		PZ-8	Deep	0.12	0.12	0.12	---	1	May-22	May-22
		PZ-9	Surface	1.68	0.51	4.38	1.35	7	Jun-22	Aug-22
			Shallow	0.29	0.07	0.55	0.17	7	Jun-22	Aug-22
			Deep	0.06	-0.02	0.30	0.11	8	May-22	Aug-22
		PZ-10	Surface	1.09	0.45	1.73	0.91	2	Jun-22	Jun-22
			Shallow	1.31	0.18	4.28	1.75	6	Jun-22	Aug-22
			Deep	0.41	-0.05	1.20	0.45	8	May-22	Aug-22
		PZ-11	Surface	0.34	0.11	0.69	0.31	3	Jun-22	Aug-22
		PZ-12	Surface	0.52	0.23	0.72	0.23	4	Jun-22	Aug-22
			Shallow	0.60	0.14	1.01	0.37	7	Jun-22	Aug-22
			Deep	0.24	0.03	0.59	0.17	9	May-22	Aug-22
		PZ-13	Surface	2.76	0.65	7.84	3.41	4	Jun-22	Aug-22
			Shallow	3.68	0.38	18.9	7.45	6	Jun-22	Aug-22
			Deep	0.23	0.03	0.46	0.14	8	May-22	Aug-22
		PZ-14	Surface	4.65	4.65	4.65	---	1	Jun-22	Jun-22
			Shallow	1.30	0.53	3.96	1.49	5	Jun-22	Aug-22
			Deep	0.14	0.00	0.34	0.12	8	May-22	Aug-22
		PZ-15	Surface	0.48	0.42	0.54	0.06	3	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	0.90	0.35	3.00	1.04	6	Jun-22	Aug-22
			Deep	0.07	-0.06	0.28	0.11	8	May-22	Aug-22
pH	SU	PZ-1	Surface	6.74	6.64	6.83	0.13	2	Jun-22	Jun-22
			Shallow	6.45	6.20	6.68	0.16	6	Jun-22	Aug-22
			Deep	6.65	6.36	6.93	0.22	7	May-22	Aug-22
		PZ-2	Surface	6.83	6.83	6.83	---	1	Jun-22	Jun-22
			Shallow	6.35	6.31	6.39	0.04	4	Jun-22	Jul-22
			Deep	6.49	6.38	6.64	0.08	7	May-22	Aug-22
		PZ-3	Surface	6.37	6.32	6.41	0.06	2	Jun-22	Jun-22
			Shallow	6.15	5.77	6.32	0.18	7	Jun-22	Aug-22
			Deep	6.10	5.67	6.54	0.31	8	May-22	Aug-22
		PZ-4	Surface	6.32	6.20	6.44	0.17	2	Jun-22	Jun-22
			Shallow	6.20	6.01	6.42	0.15	7	Jun-22	Aug-22
			Deep	6.25	5.95	6.69	0.24	8	May-22	Aug-22
		PZ-5	Surface	6.85	6.85	6.85	---	1	Jun-22	Jun-22
			Shallow	6.27	6.17	6.37	0.08	4	Jun-22	Jul-22
			Deep	6.06	5.93	6.54	0.22	7	May-22	Aug-22
		PZ-6	Surface	6.49	6.49	6.49	---	1	Jun-22	Jun-22
			Shallow	6.29	5.98	6.42	0.18	5	Jun-22	Aug-22
			Deep	6.20	6.03	6.43	0.13	7	May-22	Aug-22
		PZ-7	Surface	6.71	6.70	6.72	0.01	2	Jun-22	Jun-22
			Shallow	6.10	5.69	6.30	0.21	7	Jun-22	Aug-22
			Deep	5.85	5.50	6.10	0.19	8	May-22	Aug-22
		PZ-8	Deep	6.44	6.44	6.44	---	1	May-22	May-22
		PZ-9	Surface	6.29	6.19	6.41	0.09	6	Jun-22	Aug-22
			Shallow	6.24	6.15	6.33	0.08	6	Jun-22	Aug-22
			Deep	6.15	5.96	6.31	0.13	7	May-22	Aug-22
		PZ-10	Surface	6.53	6.53	6.53	---	1	Jun-22	Jun-22
			Shallow	6.17	6.12	6.29	0.07	5	Jun-22	Aug-22
			Deep	6.21	5.97	6.49	0.17	7	May-22	Aug-22
		PZ-11	Surface	6.47	6.39	6.57	0.09	3	Jun-22	Aug-22
		PZ-12	Surface	6.51	6.36	6.73	0.16	4	Jun-22	Aug-22
			Shallow	6.36	5.89	6.61	0.23	7	Jun-22	Aug-22
			Deep	6.22	5.76	6.33	0.18	9	May-22	Aug-22
		PZ-13	Surface	6.93	6.83	7.02	0.08	4	Jun-22	Aug-22
			Shallow	6.69	6.56	6.93	0.14	6	Jun-22	Aug-22
			Deep	6.07	5.61	6.31	0.20	8	May-22	Aug-22
		PZ-14	Shallow	6.22	6.01	6.51	0.23	4	Jun-22	Aug-22
			Deep	6.16	6.02	6.35	0.10	7	May-22	Aug-22
		PZ-15	Surface	6.37	6.29	6.44	0.11	2	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	6.19	6.10	6.32	0.09	5	Jun-22	Aug-22
			Deep	6.08	5.97	6.21	0.08	7	May-22	Aug-22
Cond	uS/cm	PZ-1	Surface	575	543	607	44.7	2	Jun-22	Jun-22
			Shallow	476	407	551	46.3	6	Jun-22	Aug-22
			Deep	626	464	940	149	7	May-22	Aug-22
		PZ-2	Surface	634	584	684	70.7	2	Jun-22	Jun-22
			Shallow	522	483	538	23.1	5	Jun-22	Jul-22
			Deep	723	644	1,026	124	8	May-22	Aug-22
		PZ-3	Surface	663	634	692	41.5	2	Jun-22	Jun-22
			Shallow	336	210	566	116	7	Jun-22	Aug-22
			Deep	299	197	447	81.2	8	May-22	Aug-22
		PZ-4	Surface	532	458	606	104	2	Jun-22	Jun-22
			Shallow	423	284	638	109	7	Jun-22	Aug-22
			Deep	394	251	614	119	8	May-22	Aug-22
		PZ-5	Surface	806	748	863	81.3	2	Jun-22	Jun-22
			Shallow	566	554	588	13.5	5	Jun-22	Jul-22
			Deep	493	429	715	104	8	May-22	Aug-22
		PZ-6	Surface	1,137	1,137	1,137	---	1	Jun-22	Jun-22
			Shallow	989	713	1,162	199	5	Jun-22	Aug-22
			Deep	862	723	1,277	189	7	May-22	Aug-22
		PZ-7	Surface	624	537	711	123	2	Jun-22	Jun-22
			Shallow	424	253	676	130	7	Jun-22	Aug-22
			Deep	326	176	676	167	8	May-22	Aug-22
		PZ-8	Deep	651	651	651	---	1	May-22	May-22
		PZ-9	Surface	495	419	552	51.7	7	Jun-22	Aug-22
			Shallow	430	393	492	40.4	7	Jun-22	Aug-22
			Deep	429	384	636	84.2	8	May-22	Aug-22
		PZ-10	Surface	875	862	888	18.4	2	Jun-22	Jun-22
			Shallow	708	588	817	98.2	6	Jun-22	Aug-22
			Deep	658	576	917	107	8	May-22	Aug-22
		PZ-11	Surface	1,228	1,163	1,261	56.0	3	Jun-22	Aug-22
		PZ-12	Surface	759	606	901	124	4	Jun-22	Aug-22
			Shallow	816	622	1,255	208	7	Jun-22	Aug-22
			Deep	745	517	1,102	210	9	May-22	Aug-22
		PZ-13	Surface	740	664	897	108	4	Jun-22	Aug-22
			Shallow	845	703	918	73.9	6	Jun-22	Aug-22
			Deep	677	552	993	139	8	May-22	Aug-22
		PZ-14	Surface	726	726	726	---	1	Jun-22	Jun-22
			Shallow	686	620	744	50.3	5	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	625	557	954	134	8	May-22	Aug-22
		PZ-15	Surface	910	793	990	103	3	Jun-22	Aug-22
			Shallow	897	815	941	46.8	6	Jun-22	Aug-22
			Deep	821	745	1,211	158	8	May-22	Aug-22
ORP	mV	PZ-1	Surface	-104	-151	-57.2	66.1	2	Jun-22	Jun-22
			Shallow	-110	-194	-80.2	43.8	6	Jun-22	Aug-22
			Deep	-145	-189	-104	33.5	7	May-22	Aug-22
		PZ-2	Surface	-135	-135	-135	---	1	Jun-22	Jun-22
			Shallow	-1.18	-83.4	123	87.9	4	Jun-22	Jul-22
			Deep	-99.1	-196	-42.4	51.9	7	May-22	Aug-22
		PZ-3	Surface	-68.2	-84.0	-52.3	22.4	2	Jun-22	Jun-22
			Shallow	-124	-158	-70.0	27.4	7	Jun-22	Aug-22
			Deep	-159	-198	-106	31.1	8	May-22	Aug-22
		PZ-4	Surface	-104	-131	-77.5	38.1	2	Jun-22	Jun-22
			Shallow	-141	-201	-81.6	45.2	7	Jun-22	Aug-22
			Deep	-163	-204	-108	31.6	8	May-22	Aug-22
		PZ-5	Surface	-136	-136	-136	---	1	Jun-22	Jun-22
			Shallow	-82.0	-126	-42.2	45.7	4	Jun-22	Jul-22
			Deep	-66.9	-196	6.00	68.0	7	May-22	Aug-22
		PZ-6	Surface	-165	-165	-165	---	1	Jun-22	Jun-22
			Shallow	-68.5	-131	-29.2	38.8	5	Jun-22	Aug-22
			Deep	-87.5	-168	-29.3	47.9	7	May-22	Aug-22
		PZ-7	Surface	-151	-159	-143	11.7	2	Jun-22	Jun-22
			Shallow	-108	-174	-70.0	35.9	7	Jun-22	Aug-22
			Deep	-108	-193	106	93.4	8	May-22	Aug-22
		PZ-8	Deep	-230	-230	-230	---	1	May-22	May-22
		PZ-9	Surface	-53.7	-141	34.7	64.8	6	Jun-22	Aug-22
			Shallow	-88.9	-144	-26.6	51.1	6	Jun-22	Aug-22
			Deep	-26.9	-189	403	198	7	May-22	Aug-22
		PZ-10	Surface	-112	-112	-112	---	1	Jun-22	Jun-22
			Shallow	-60.7	-111	-10.0	41.5	4	Jun-22	Aug-22
			Deep	-92.4	-193	-6.20	64.1	7	May-22	Aug-22
		PZ-11	Surface	-56.3	-79.8	-26.4	27.3	3	Jun-22	Aug-22
		PZ-12	Surface	-118	-149	-102	21.1	4	Jun-22	Aug-22
			Shallow	-148	-227	-65.9	62.9	7	Jun-22	Aug-22
			Deep	-123	-195	124	98.9	9	May-22	Aug-22
		PZ-13	Surface	-40.2	-101	39.1	58.2	4	Jun-22	Aug-22
			Shallow	-91.4	-193	136	116	6	Jun-22	Aug-22
			Deep	-123	-202	-24.0	62.2	8	May-22	Aug-22
		PZ-14	Shallow	-27.1	-152	43.1	85.5	4	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	-92.5	-188	-3.50	65.7	7	May-22	Aug-22
		PZ-15	Surface	-106	-128	-84.5	30.5	2	Jun-22	Aug-22
			Shallow	-58.2	-115	-8.80	44.9	5	Jun-22	Aug-22
			Deep	-89.0	-192	-1.10	65.4	7	May-22	Aug-22
TFE	mg/L	PZ-1	Surface	2.68	2.22	3.14	0.65	2	Jun-22	Jun-22
			Shallow	5.36	2.33	7.77	2.12	6	Jun-22	Aug-22
			Deep	6.80	4.86	8.94	1.44	8	May-22	Aug-22
		PZ-2	Surface	2.12	1.70	2.54	0.59	2	Jun-22	Jun-22
			Shallow	5.14	3.40	6.26	1.19	5	Jun-22	Jul-22
			Deep	6.41	5.66	7.28	0.68	8	May-22	Aug-22
		PZ-3	Surface	4.50	4.19	4.81	0.44	2	Jun-22	Jun-22
			Shallow	4.17	2.43	5.65	1.21	7	Jun-22	Aug-22
			Deep	3.57	3.13	3.83	0.26	8	May-22	Aug-22
		PZ-4	Surface	3.91	3.84	3.97	0.09	2	Jun-22	Jun-22
			Shallow	2.91	2.24	4.20	0.64	7	Jun-22	Aug-22
			Deep	2.91	2.45	3.46	0.40	8	May-22	Aug-22
		PZ-5	Surface	3.23	2.43	4.03	1.13	2	Jun-22	Jun-22
			Shallow	5.82	3.32	6.72	1.45	5	Jun-22	Jul-22
			Deep	2.38	1.71	3.08	0.38	8	May-22	Aug-22
		PZ-6	Surface	17.4	10.7	24.0	9.40	2	Jun-22	Jun-22
			Shallow	11.1	2.45	15.7	4.91	6	Jun-22	Aug-22
			Deep	3.22	1.72	4.21	0.74	8	May-22	Aug-22
		PZ-7	Surface	8.11	6.01	10.2	2.96	2	Jun-22	Jun-22
			Shallow	7.44	3.33	12.2	2.81	7	Jun-22	Aug-22
			Deep	4.09	2.76	6.91	1.34	8	May-22	Aug-22
		PZ-8	Deep	1.58	1.58	1.58	---	1	May-22	May-22
		PZ-9	Surface	4.60	1.11	7.03	1.82	7	Jun-22	Aug-22
			Shallow	2.13	1.40	3.72	0.77	7	Jun-22	Aug-22
			Deep	1.47	1.36	1.56	0.08	8	May-22	Aug-22
		PZ-10	Surface	4.37	3.66	5.08	1.00	2	Jun-22	Jun-22
			Shallow	4.34	0.78	6.21	1.92	6	Jun-22	Aug-22
			Deep	4.07	3.49	5.00	0.51	8	May-22	Aug-22
		PZ-11	Surface	4.96	3.73	7.41	1.67	4	Jun-22	Aug-22
		PZ-12	Surface	4.31	1.84	6.89	2.29	4	Jun-22	Aug-22
			Shallow	7.47	2.66	11.4	3.34	7	Jun-22	Aug-22
			Deep	7.69	5.87	9.02	0.99	9	May-22	Aug-22
		PZ-13	Surface	1.74	0.78	2.68	0.83	4	Jun-22	Aug-22
			Shallow	5.19	3.10	8.57	1.85	6	Jun-22	Aug-22
			Deep	5.62	5.35	5.82	0.16	8	May-22	Aug-22
		PZ-14	Surface	7.78	7.78	7.78	---	1	Jun-22	Jun-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	7.15	1.56	10.4	3.47	5	Jun-22	Aug-22
			Deep	4.50	3.96	5.38	0.43	8	May-22	Aug-22
		PZ-15	Surface	6.32	2.79	8.58	3.09	3	Jun-22	Aug-22
			Shallow	8.08	3.25	13.8	4.58	6	Jun-22	Aug-22
			Deep	8.25	5.78	14.2	2.59	8	May-22	Aug-22
TP	mg/L	PZ-1	Surface	0.31	0.25	0.37	0.09	2	Jun-22	Jun-22
			Shallow	0.21	0.11	0.33	0.08	6	Jun-22	Aug-22
			Deep	0.38	0.22	0.70	0.16	8	May-22	Aug-22
		PZ-2	Surface	0.56	0.55	0.56	0.01	2	Jun-22	Jun-22
			Shallow	0.30	0.25	0.35	0.04	5	Jun-22	Jul-22
			Deep	0.52	0.42	0.63	0.08	8	May-22	Aug-22
		PZ-3	Surface	0.50	0.22	0.77	0.39	2	Jun-22	Jun-22
			Shallow	0.16	0.12	0.19	0.02	7	Jun-22	Aug-22
			Deep	0.13	0.09	0.22	0.04	8	May-22	Aug-22
		PZ-4	Surface	0.38	0.28	0.47	0.13	2	Jun-22	Jun-22
			Shallow	0.32	0.14	0.42	0.09	7	Jun-22	Aug-22
			Deep	0.53	0.40	0.65	0.09	8	May-22	Aug-22
		PZ-5	Surface	0.06	0.03	0.10	0.05	2	Jun-22	Jun-22
			Shallow	0.11	0.08	0.15	0.03	5	Jun-22	Jul-22
			Deep	0.20	0.07	0.38	0.10	8	May-22	Aug-22
		PZ-6	Surface	0.89	0.88	0.89	0.01	2	Jun-22	Jun-22
			Shallow	0.29	0.05	0.37	0.12	6	Jun-22	Aug-22
			Deep	0.42	0.38	0.47	0.04	8	May-22	Aug-22
		PZ-7	Surface	0.27	0.18	0.36	0.13	2	Jun-22	Jun-22
			Shallow	0.23	0.14	0.37	0.07	7	Jun-22	Aug-22
			Deep	0.42	0.29	0.55	0.08	8	May-22	Aug-22
		PZ-8	Deep	0.16	0.16	0.16	---	1	May-22	May-22
		PZ-9	Surface	0.31	0.06	0.71	0.21	7	Jun-22	Aug-22
			Shallow	0.23	0.16	0.36	0.08	7	Jun-22	Aug-22
			Deep	0.08	0.02	0.10	0.03	8	May-22	Aug-22
		PZ-10	Surface	0.23	0.07	0.40	0.23	2	Jun-22	Jun-22
			Shallow	0.10	0.03	0.19	0.06	6	Jun-22	Aug-22
			Deep	0.18	0.06	0.25	0.05	8	May-22	Aug-22
		PZ-11	Surface	0.37	0.08	0.68	0.25	4	Jun-22	Aug-22
		PZ-12	Surface	0.42	0.20	0.79	0.26	4	Jun-22	Aug-22
			Shallow	0.37	0.24	0.56	0.11	7	Jun-22	Aug-22
			Deep	0.26	0.21	0.31	0.04	9	May-22	Aug-22
		PZ-13	Surface	0.14	0.08	0.32	0.12	4	Jun-22	Aug-22
			Shallow	0.31	0.15	0.47	0.12	6	Jun-22	Aug-22
			Deep	0.57	0.50	0.64	0.05	8	May-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
		PZ-14	Surface	0.56	0.56	0.56	---	1	Jun-22	Jun-22
			Shallow	0.17	0.03	0.25	0.09	5	Jun-22	Aug-22
			Deep	1.04	0.87	1.20	0.14	8	May-22	Aug-22
		PZ-15	Surface	0.85	0.11	1.67	0.79	3	Jun-22	Aug-22
			Shallow	0.37	0.09	1.02	0.33	6	Jun-22	Aug-22
			Deep	0.32	0.24	0.43	0.06	8	May-22	Aug-22
OP	mg/L	PZ-1	Surface	0.16	0.15	0.16	0.01	2	Jun-22	Jun-22
			Shallow	0.07	0.04	0.12	0.03	6	Jun-22	Aug-22
			Deep	0.07	0.01	0.17	0.06	8	May-22	Aug-22
		PZ-2	Surface	0.28	0.21	0.34	0.09	2	Jun-22	Jun-22
			Shallow	0.22	0.17	0.26	0.04	5	Jun-22	Jul-22
			Deep	0.08	0.01	0.36	0.12	8	May-22	Aug-22
		PZ-3	Surface	0.38	0.13	0.63	0.35	2	Jun-22	Jun-22
			Shallow	0.08	0.04	0.14	0.03	7	Jun-22	Aug-22
			Deep	0.08	0.04	0.14	0.03	8	May-22	Aug-22
		PZ-4	Surface	0.24	0.20	0.27	0.05	2	Jun-22	Jun-22
			Shallow	0.21	0.09	0.26	0.06	7	Jun-22	Aug-22
			Deep	0.36	0.20	0.47	0.08	8	May-22	Aug-22
		PZ-5	Surface	0.05	0.04	0.06	0.01	2	Jun-22	Jun-22
			Shallow	0.06	0.03	0.08	0.02	5	Jun-22	Jul-22
			Deep	0.14	0.03	0.22	0.06	8	May-22	Aug-22
		PZ-6	Surface	0.15	0.03	0.27	0.17	2	Jun-22	Jun-22
			Shallow	0.07	0.01	0.17	0.07	6	Jun-22	Aug-22
			Deep	0.18	0.12	0.30	0.05	8	May-22	Aug-22
		PZ-7	Surface	0.08	0.05	0.11	0.04	2	Jun-22	Jun-22
			Shallow	0.12	0.05	0.19	0.05	7	Jun-22	Aug-22
			Deep	0.31	0.17	0.54	0.10	8	May-22	Aug-22
		PZ-8	Deep	0.07	0.07	0.07	---	1	May-22	May-22
		PZ-9	Surface	0.20	0.06	0.61	0.19	7	Jun-22	Aug-22
			Shallow	0.15	0.10	0.25	0.05	7	Jun-22	Aug-22
			Deep	0.08	0.05	0.09	0.01	8	May-22	Aug-22
		PZ-10	Surface	0.14	0.04	0.24	0.14	2	Jun-22	Jun-22
			Shallow	0.07	0.04	0.14	0.04	6	Jun-22	Aug-22
			Deep	0.11	0.04	0.13	0.03	8	May-22	Aug-22
		PZ-11	Surface	0.02	0.02	0.03	0.00	4	Jun-22	Aug-22
		PZ-12	Surface	0.21	0.06	0.46	0.17	4	Jun-22	Aug-22
			Shallow	0.23	0.07	0.38	0.10	7	Jun-22	Aug-22
			Deep	0.18	0.13	0.21	0.03	9	May-22	Aug-22
		PZ-13	Surface	0.03	0.01	0.04	0.01	4	Jun-22	Aug-22
			Shallow	0.14	0.08	0.22	0.06	6	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	0.29	0.16	0.40	0.09	8	May-22	Aug-22
		PZ-14	Surface	0.11	0.11	0.11	---	1	Jun-22	Jun-22
			Shallow	0.09	0.02	0.17	0.06	5	Jun-22	Aug-22
			Deep	0.31	0.14	0.48	0.10	8	May-22	Aug-22
		PZ-15	Surface	0.38	0.06	0.83	0.40	3	Jun-22	Aug-22
			Shallow	0.09	0.04	0.16	0.05	6	Jun-22	Aug-22
			Deep	0.22	0.08	0.29	0.06	8	May-22	Aug-22
TN	mg/L	PZ-1	Surface	2.46	1.94	2.97	0.73	2	Jun-22	Jun-22
			Shallow	3.76	2.26	5.24	1.22	6	Jun-22	Aug-22
			Deep	5.28	2.55	7.45	1.66	8	May-22	Aug-22
		PZ-2	Surface	2.85	2.75	2.94	0.13	2	Jun-22	Jun-22
			Shallow	2.95	2.51	3.85	0.55	5	Jun-22	Jul-22
			Deep	4.69	1.01	6.36	1.61	8	May-22	Aug-22
		PZ-3	Surface	2.30	2.15	2.45	0.21	2	Jun-22	Jun-22
			Shallow	1.90	1.58	2.24	0.29	7	Jun-22	Aug-22
			Deep	2.71	1.39	4.71	1.08	8	May-22	Aug-22
		PZ-4	Surface	1.84	1.75	1.93	0.13	2	Jun-22	Jun-22
			Shallow	3.71	1.52	7.77	1.96	7	Jun-22	Aug-22
			Deep	8.68	6.54	11.0	1.32	8	May-22	Aug-22
		PZ-5	Surface	1.38	1.15	1.60	0.32	2	Jun-22	Jun-22
			Shallow	1.64	1.32	2.13	0.38	5	Jun-22	Jul-22
			Deep	3.31	1.44	5.80	1.37	8	May-22	Aug-22
		PZ-6	Surface	2.50	1.90	3.10	0.85	2	Jun-22	Jun-22
			Shallow	2.16	1.42	3.08	0.53	6	Jun-22	Aug-22
			Deep	5.66	5.00	6.35	0.49	8	May-22	Aug-22
		PZ-7	Surface	1.25	1.10	1.39	0.21	2	Jun-22	Jun-22
			Shallow	1.95	1.36	3.03	0.58	7	Jun-22	Aug-22
			Deep	5.57	4.37	6.41	0.70	8	May-22	Aug-22
		PZ-8	Deep	2.67	2.67	2.67	---	1	May-22	May-22
		PZ-9	Surface	2.03	1.21	3.11	0.76	7	Jun-22	Aug-22
			Shallow	1.33	0.91	2.33	0.49	7	Jun-22	Aug-22
			Deep	1.73	1.33	2.85	0.53	8	May-22	Aug-22
		PZ-10	Surface	1.56	1.31	1.80	0.35	2	Jun-22	Jun-22
			Shallow	1.65	1.44	2.10	0.24	6	Jun-22	Aug-22
			Deep	2.44	1.14	3.59	0.75	8	May-22	Aug-22
		PZ-11	Surface	1.45	0.85	2.19	0.60	4	Jun-22	Aug-22
		PZ-12	Surface	1.47	0.82	2.03	0.50	4	Jun-22	Aug-22
			Shallow	2.83	2.01	5.70	1.35	7	Jun-22	Aug-22
			Deep	4.67	3.95	5.33	0.46	9	May-22	Aug-22
		PZ-13	Surface	1.19	0.81	1.75	0.45	4	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Shallow	1.59	1.12	3.17	0.79	6	Jun-22	Aug-22
			Deep	5.69	4.66	6.95	0.93	8	May-22	Aug-22
		PZ-14	Surface	2.81	2.81	2.81	---	1	Jun-22	Jun-22
			Shallow	2.11	1.08	2.54	0.59	5	Jun-22	Aug-22
			Deep	8.38	7.48	9.06	0.53	8	May-22	Aug-22
		PZ-15	Surface	2.96	1.83	3.79	1.02	3	Jun-22	Aug-22
			Shallow	3.18	1.73	7.99	2.39	6	Jun-22	Aug-22
			Deep	3.93	2.11	5.73	1.02	8	May-22	Aug-22
Elevation	ft NAVD 88	PZ-1	Surface	943.6	943.4	943.9	0.25	4	Jun-22	Aug-22
			Shallow	943.0	941.9	943.9	0.70	7	Jun-22	Aug-22
			Deep	943.1	941.7	944.1	0.81	8	May-22	Aug-22
		PZ-2	Surface	943.8	943.8	943.9	0.08	2	Jun-22	Jun-22
			Shallow	943.2	942.4	943.9	0.59	6	Jun-22	Aug-22
			Deep	943.1	941.7	944.2	0.83	8	May-22	Aug-22
		PZ-3	Surface	943.9	943.7	944.3	0.29	5	Jun-22	Jul-22
			Shallow	943.7	942.7	944.5	0.61	7	Jun-22	Aug-22
			Deep	943.6	942.7	944.3	0.63	8	May-22	Aug-22
		PZ-4	Surface	943.6	943.4	943.9	0.25	6	Jun-22	Aug-22
			Shallow	943.6	943.2	944.1	0.31	7	Jun-22	Aug-22
			Deep	944.1	943.0	948.3	1.73	8	May-22	Aug-22
		PZ-5	Surface	944.1	944.0	944.2	0.13	2	Jun-22	Jun-22
			Shallow	943.5	942.8	944.3	0.53	6	Jun-22	Aug-22
			Deep	943.5	942.7	944.4	0.60	8	May-22	Aug-22
		PZ-6	Surface	944.4	944.4	944.4	---	1	Jun-22	Jun-22
			Shallow	943.3	942.3	944.4	0.73	6	Jun-22	Aug-22
			Deep	943.4	942.0	944.7	0.93	7	May-22	Aug-22
		PZ-7	Surface	944.0	943.5	944.5	0.20	10,038	May-22	Sep-22
			Shallow	943.7	942.6	944.5	0.49	10,040	May-22	Sep-22
			Deep	943.6	942.5	944.5	0.48	9,320	May-22	Sep-22
		PZ-9	Surface	943.6	943.2	944.1	0.21	10,034	May-22	Sep-22
			Shallow	943.6	943.2	944.1	0.23	10,039	May-22	Sep-22
			Deep	943.5	943.0	944.4	0.29	10,039	May-22	Sep-22
		PZ-10	Surface	944.2	944.0	944.7	0.22	10,028	May-22	Sep-22
			Shallow	943.9	942.6	944.9	0.66	10,029	May-22	Sep-22
			Deep	943.7	942.0	944.8	0.73	10,032	May-22	Sep-22
		PZ-11	Up	943.8	942.2	944.8	0.69	9,281	Jun-22	Sep-22
		PZ-12	Surface	944.6	944.0	944.9	0.38	5	Jun-22	Aug-22
			Shallow	944.3	943.5	944.9	0.49	7	Jun-22	Aug-22

Parameter	Units	Stn	Depth	Avg	Min	Max	StDev	Count	Period-of-Record	
			Deep	850.2	95.9	945.1	283	9	May-22	Aug-22
		PZ-13	Surface	944.2	943.8	944.6	0.30	6	Jun-22	Aug-22
			Shallow	944.0	943.0	944.6	0.57	7	Jun-22	Aug-22
			Deep	944.1	943.0	945.6	0.78	8	May-22	Aug-22
		PZ-14	Surface	944.2	943.9	944.4	0.26	3	Jun-22	Jun-22
			Shallow	943.8	942.9	944.5	0.55	6	Jun-22	Aug-22
			Deep	943.8	942.6	944.7	0.71	8	May-22	Aug-22
		PZ-15	Surface	944.4	944.1	944.7	0.28	4	Jun-22	Aug-22
			Shallow	944.2	943.5	944.7	0.45	6	Jun-22	Aug-22
			Deep	944.0	942.9	944.7	0.65	8	May-22	Aug-22