Lake Augusta Water Quality Improvement and Outlet Feasibility Study

Prepared for
Lower Mississippi River Watershed Management Organization and
City of Mendota Heights

December 2023

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Certifications

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the state of Minnesota.

	12/29/23
Greg Wilson PE #: 25782	Date

Abbreviations

BMP	Best Management Practice
CAMP	Citizen-Assisted Monitoring Program
Chl-a	Chlorophyll-a
HSG	Hydrologic Soil Group
LiDAR	Light Detection and Ranging
LMRWMO	Lower Mississippi River Watershed Management Organization
MSL	Mean Sea Level
MCES	Metropolitan Council Environmental Services
MDNR	Minnesota Department of Natural Resources
MDOT	Minnesota Department of Transportation
OHWL	Ordinary High Water Level
P8	Program for Predicting Polluting Particle Passage Thru Pits, Puddles, and Ponds
SDT	Secchi Disc Transparency
SSURGO	Soil Survey Geographic Database
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
WRAPs	Watershed Restoration and Protection Strategies

1 Executive Summary

The Lower Mississippi River Watershed Management Organization (LMRWMO) in partnership with the City of Mendota Heights initiated this feasibility study to determine options for water quality improvements in Lake Augusta. One of those options is to consider a lake outlet, as Lake Augusta is currently landlocked and water levels have risen dramatically, between 12 and 16 feet, in the last 30 to 40 years. The estimated lake level from 2020 was about 8 feet higher than 2013 and about 15 feet higher than the Ordinary High Water level (OHWL).

A comparison of the Lake Augusta 2022 lake water quality monitoring results with monitoring from the recent past revealed that surface water total phosphorus (TP) concentrations are higher than the post-alum treatment monitoring events from 2017 through 2019 and that chlorophyll-a (Chl-a) levels were highest in 2022 and Secchi disc transparency (SDT) was lower in 2022, compared to all the available monitoring data. As a result, nutrient reductions will be needed to shift away from algal dominance in the lake. The TP sample results from the 2022 stormwater monitoring indicate that improvements to water quality treatment from both the northeast inlet and localized cemetery drainage (southeast inlet) are needed to reduce excess TP loadings from the Lake Augusta watershed.

To better understand and evaluate the water quality treatment performance of the existing best management practices (BMPs) in the Lake Augusta subwatershed, Barr Engineering Co. (Barr) revised the existing LMRWMO P8 watershed model to reflect GIS subwatershed delineations and modeling inputs for each subwatershed and respective BMPs. We then updated the revised P8 model with 2022 growing-season climate data (hourly precipitation and daily temperatures) to develop the phosphorus (total and dissolved) and total suspended solids (TSS) loadings for the period.

We used the updated P8 modeling results and GIS mapping to identify high priority areas for implementing watershed BMPs. Long-term simulation of the calibrated P8 modeling indicates that 39 percent of the current overall phosphorus load to Lake Augusta receives stormwater treatment before discharge to the lake.

An in-lake water quality model was developed using daily inputs from the calibrated P8 watershed modeling. The in-lake water quality model was used to develop the water and phosphorus budgets for the lake, which were used to identify and develop implementation strategies for improving lake water-quality.

The high lake levels and lack of flushing from a lake outlet limit the capacity for biological uptake of the summer runoff phosphorus loads from the direct drainage area, as well as the overall watershed. A detailed analysis of the monitoring data, combined with the lake water quality modeling, confirmed that phosphorus loading from cormorants can be an important source of phosphorus input to the lake during the summer and fall. Cormorant droppings accounted for 68% of the phosphorus budget to Lake Augusta during the 2022 growing season, with internal phosphorus load (21%), watershed runoff (10%) and atmospheric deposition (1%) accounting for the remainder of phosphorus inputs to the lake. The calibrated in-lake modeling was used to simulate conditions for the 2013 through 2022 water years to estimate relative watershed and in-lake TP loadings that are more representative of typical climatic conditions (2022 was an unusually dry year). Cormorant droppings accounted for 36% of the phosphorus budget to Lake Augusta, while internal TP load (21%), watershed runoff (41%) and atmospheric deposition (2%) accounting for the remaining TP load for the 2013 through 2022 simulation.

Based on the lake assessment and calibrated watershed and in-lake water quality modeling, the following watershed Best Management Practices (BMPs) and in-lake management practices are recommended to substantially reduce the respective phosphorus loadings and enhance recreational suitability of the lake:

- Install an outlet to control water levels for Lake Augusta

- Install structural BMPs and/or pretreatment protection measures to prevent sediment delivery and reduce nutrient loading into the lake with design(s) intended to meet water quality goals. Untreated stormwater runoff from the southeast outfall and undertreated runoff from the northeast inlet to Lake Augusta are prioritized for implementation. Though specific large structural BMPs are identified though this study, any structural or non-structural BMPs in the watershed to reduce nutrient loading to the lake are considered beneficial and are recommended.

- Remove dead trees from the lake shoreline as the first large step to discourage cormorant population establishment and control summer TP loads. Other strategies may need to be considered to deter the cormorant population from roosting at Lake Augusta, should removal of the dead trees be insufficient.

- Include stabilization/restoration of surrounding shoreline that will be exposed as a separate project. Having this in the final report will help with future grant applications for such a project.

Note that these recommended practices are considered the best and first steps in lake management at this point.

2 Background

Water quality in Lake Augusta was evaluated as part of the Lower Mississippi River WMO Watershed Restoration and Protection Strategy (WRAPs) and Total Maximum Daily Load (TMDL) study completed in 2014 (Barr, 2014). An in-lake alum treatment of Lake Augusta was completed in the spring of 2017 to minimize the release of phosphorus from lake bottom sediments. Since the alum treatment, water quality showed some improvement, as compared with monitoring from prior years, but has generally remained poor especially in 2022. There is a strong likelihood that wet weather patterns in 2013-2020 and associated high lake levels have exacerbated the water quality conditions for Lake Augusta. The LMRWMO in partnership with the City of Mendota Heights initiated this feasibility study to determine options for lake water quality improvement. One of those options is to consider a lake outlet, as Lake Augusta is currently landlocked and water levels have risen dramatically, between 12 and 16 feet in the last 30 to 40 years. The lake shoreline is largely undeveloped so inundation from the higher lake levels has killed many older growth trees that surround the lake.

Given the recent wet weather patterns and high lake levels, there are significant changes and data gaps since the previous modeling and in-lake alum treatment. As a result, this feasibility study is intended to account for the following aspects of total phosphorus (TP) loading to determine future implementation activities that can improve the water quality of Lake Augusta:

- Excess phosphorus contributions from flooded shoreline soils, erosion, wildlife and decaying vegetation at varying lake levels
- Potential impacts of internal phosphorus load in shallow areas of the lake
- Changes in stormwater runoff associated with watershed development/redevelopment, including an assessment of the performance of how well the existing stormwater BMPs are working
- Changes in lake mixing characteristics, evaluated through lake and watershed model calibration, to consider impacts of possible lake outlet controls

In addition, this feasibility study included a cost-benefit analysis and priority practice ranking of potential improvement options, including BMP combinations necessary to meet lake water quality standards.

2.1 Lake and Watershed Description

Based on 2022 lake levels, Lake Augusta is a 50-acre lake located in the City of Mendota Heights, with an average depth of 18 feet and maximum depth of 34 feet. It was estimated that a recent 5-foot increase in lake level corresponded with a 34% increase in lake volume, which greatly increases the mass of TP that can be retained within the landlocked lake. The Minnesota Department of Natural Resources (MDNR) set the Ordinary High Water Level (OHWL) at 832.5 feet.

Figure 2-1 shows the lake bathymetry and sampling location for historical lake water quality monitoring (shown in red). Lake Augusta was previously monitored through the Gun Club Watershed Management Organization for years 2007-2009. Secchi depth transparency (SDT) monitoring has a longer period of record, dating back to 1998, through the Metropolitan Council Environmental Services (MCES) Citizen-Assisted Monitoring Program (CAMP). Recent monitoring (between 2013 and 2019) has been conducted through the LMRWMO.

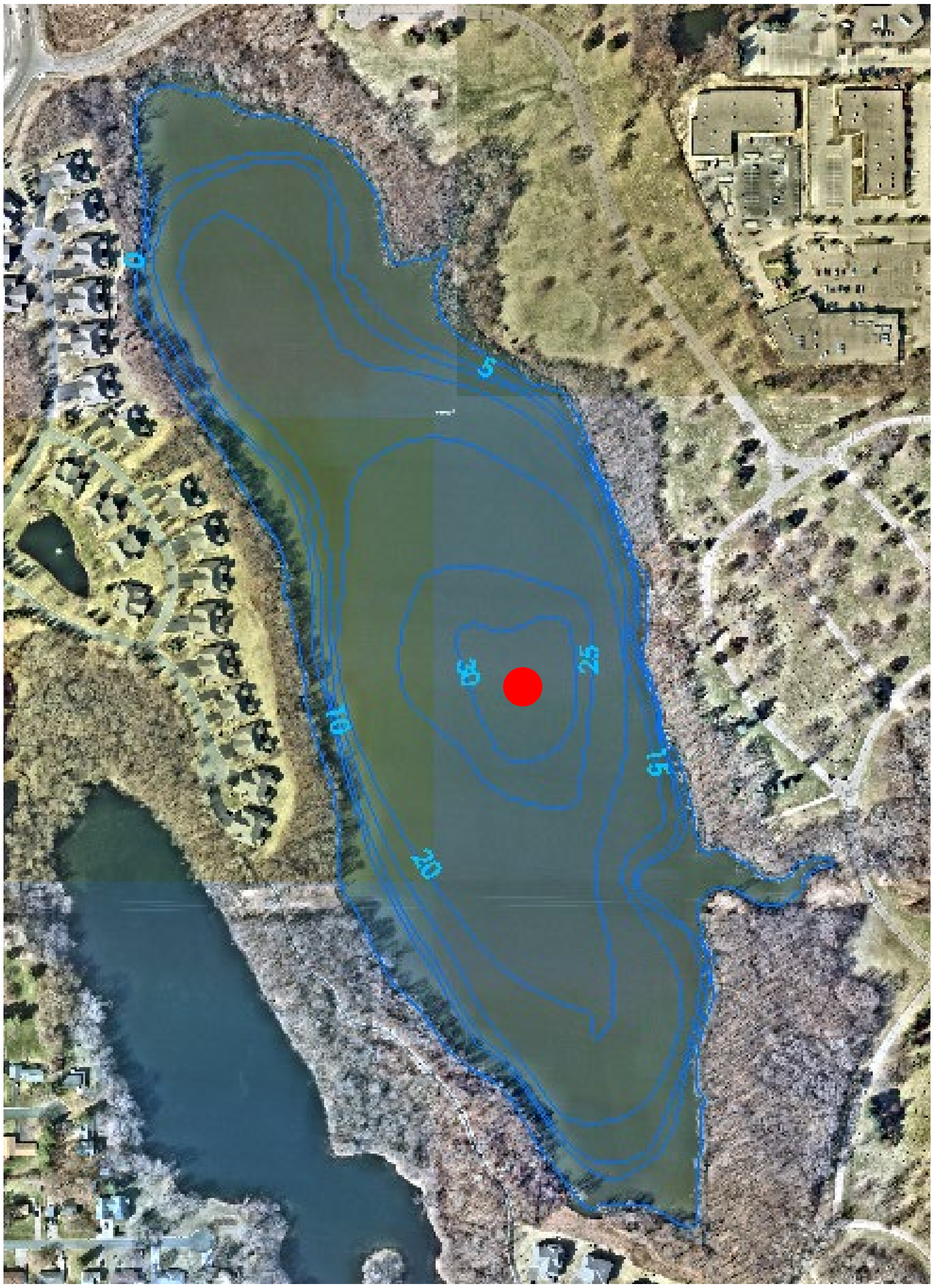


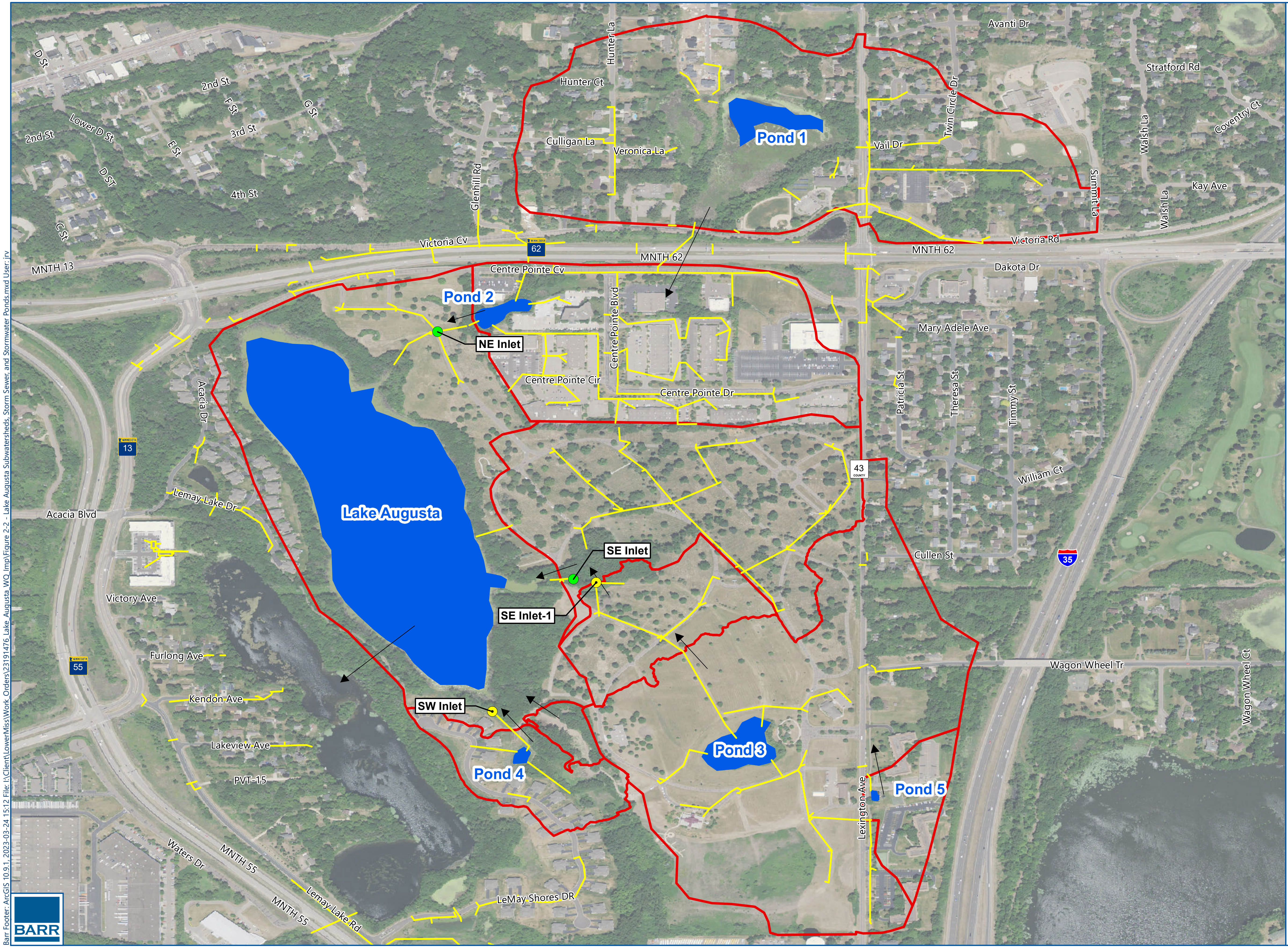
Figure 2-1 Lake Augusta Bathymetry and Monitoring Location

The Lake Augusta watershed is approximately 436 acres, including the lake surface area. Land use within the watershed is primarily institutional (cemetery), commercial, and residential (low and high density). Figure 2-2 shows the Lake Augusta subwatersheds, storm sewer and stormwater ponds, while Figure 2-3 shows the watershed soil characteristics, based on hydrologic soil group (HSG) classifications. Approximately 65 percent of the watershed receives pond treatment of stormwater runoff. Most of the untreated runoff either enters the lake through overland flow from the direct watershed or through stormwater conveyances within the Resurrection Cemetery on the east side of the lake.

2.2 Water Quality Goals and Standards

Lake impairments are based on an aquatic recreation-based standard centered on protecting the ability to recreate in and support ecological habitat in Minnesota waters. This is considered as a Class 2 standard (MPCA, 2022). Lake Augusta is listed due to nutrient eutrophication biological indicators. The eutrophication standards applied are based on the ecoregion and lake depth. The lake is in the North Central Hardwood Forest Ecoregion (MPCA, 2022). Lake Augusta is subject to the deep lake eutrophication standards, which require TP concentrations less than 40 µg/l, chlorophyll-a (Chl-a) concentrations less than 14 µg/l, and Secchi depth greater than 1.4 meters (4.6 feet).

Lakes where annual average TP and at least one of the response variables (Chl-a or SDT) do not meet the standard are considered impaired (MPCA, 2022). Lake Augusta was added to the Impaired Waters List in 2010 for impairment to aquatic recreation with a pollutant or stressor classification of Nutrient/ Eutrophication Biological Indicators.



Stormwater Flow and Water Quality Monitoring Site

Stormwater Grab Sampling Site

Flow Direction

Pipes (Mendota Heights)

Watersheds

Water Bodies

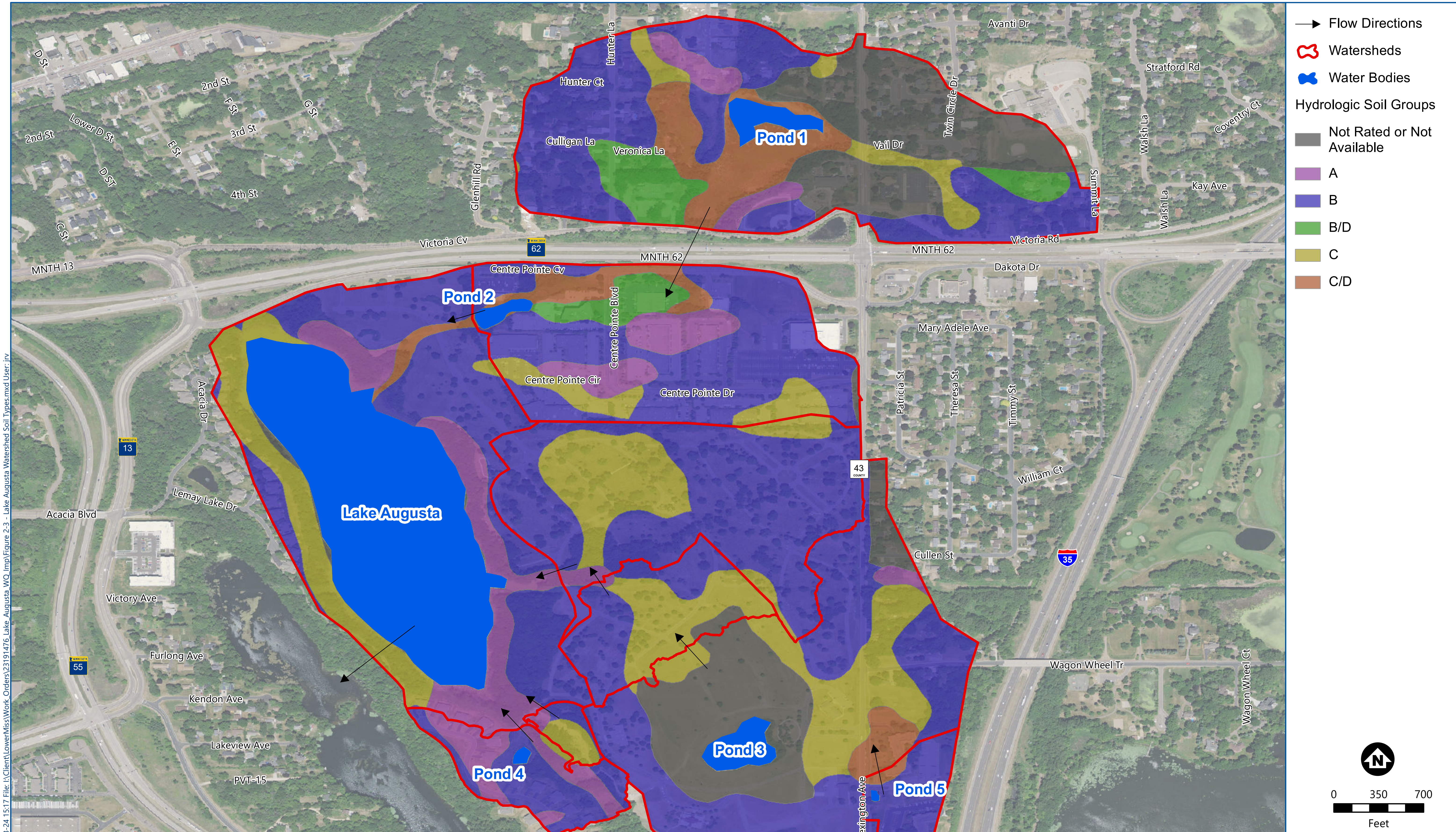
0 350 700

Feet

BARR

LAKE AUGUSTA SUBWATERSHEDS, STORM SEWER AND STORMWATER PONDS

FIGURE 2-2



LAKE AUGUSTA WATER WATERSHED SOIL TYPES

FIGURE 2-3

BARR

3 Monitoring

Data collected for this study included lake water quality monitoring, stormwater monitoring (flow and water quality) at several locations, and continuous water level measurements in Lake Augusta during most of the 2022 growing season. Figure 2-1 shows the lake water quality sampling location. Figure 2-2 shows the automated flow and grab sample sites for stormwater monitoring. The automated monitoring sites included flow monitoring equipment to facilitate the development of pollutant load estimates.

3.1 Lake Monitoring

Table A-1 shows the individual sample constituent concentrations and field monitoring results for each 2022 lake sampling event at the monitoring location shown in Figure 2-1, which represents the deepest portion of the lake. Barr staff completed nine separate lake water quality monitoring events during the 2022 growing season. During each sample event: (1) a 0–2-meter composite water sample was collected and analyzed for TP and Chl-a (2) water samples were generally collected from the 4, 7, 10-meter depths, and 0.5 meters above the bottom and analyzed for TP, and (3) water samples were collected from 0-2 meters and from 0.5 meters above the bottom and analyzed for chloride. Dissolved oxygen (DO), temperature, specific conductance, pH, and turbidity were measured at 1-meter intervals from surface to bottom and the SDT was also measured during each sampling event.

The results of the 2022 lake water quality sampling events indicated the following:

- Lake Augusta was strongly stratified, with DO/temperature data indicating the top two to four meters were mixing throughout the growing season. Biological uptake of new inflows of phosphorus to the lake is limited, especially since there is no water flushing (through an outlet) and the high water levels limit lake mixing each spring and fall.
- Water clarity, measured as SDT, was very poor throughout the summer
- Bottom-water anoxia contributed to some elevated phosphorus—bacteria do not efficiently break down decaying organic material and sediment chemistry will typically result in the release of phosphorus to the overlying lake water under low oxygen levels.
- TP was generally elevated at the water surface, but was lower throughout most of the rest of the water column, except for the lake bottom depth where TP was elevated during the summer
- High Chl-a—confirms that blue-green algae are the primary source of color in the lake (i.e., sediment/erosion is not a significant contributor to the appearance); higher Chl-a concentrations correspond with higher turbidity and lower water clarity
- Chloride is slightly higher in the bottom waters, which confirms the lack of lake mixing, but all the concentrations are lower than the 230 mg/L chronic standard.

3.1.1 Total Phosphorus, Chlorophyll-a and Secchi Disc Transparency

Figure 3-1 shows the historic summer average (June-September) TP, Chl-a and SDT data for Lake Augusta. Water quality in Lake Augusta is not meeting any of the deep lake water quality criteria. Secchi depth clarity was less the 1.4-meter eutrophication standard throughout the entire period. TP and Chl-a exceeded the eutrophication standards of 40 µg/l and 14 µg/l, respectively, during all monitored years.

Peak summer average values were recorded in 2007 with a summer average TP of 227 µg/l, while the most recent monitored year (2022) resulted in the poorest summer average values of 165 µg/l for chlorophyll-a, and 0.18 meters for Secchi depth. A comparison of the 2022 lake water quality monitoring results to the Lake Augusta water quality from the recent past (2017-2019) revealed the following (see Figure 3-1):

- 2022 surface water phosphorus concentrations are higher than the post-alum treatment monitoring events from 2017 through 2019, comparable to the pre-alum treatment monitoring.
- Chl-a levels were highest in 2022, compared to all the available monitoring data.
- Water clarity, measured as SDT, was lower in 2022 than any other year.

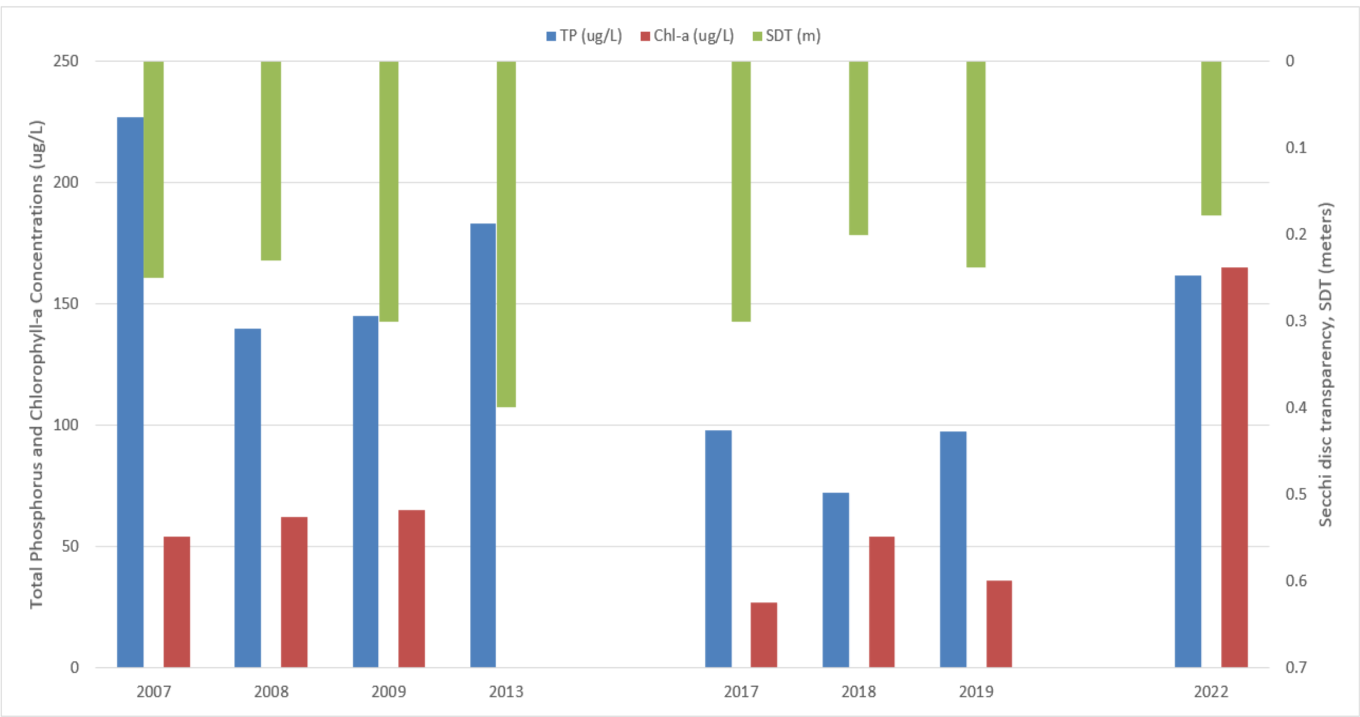


Figure 3-1 Lake Augusta Total Phosphorus, Chlorophyll-a, and Secchi Disc Transparency

Nutrient reductions will be needed to shift away from algal dominance in the lake.

3.1.2 Water Levels

Figure 3-2 shows the monitored water levels for Lake Augusta during the 2022 monitoring season. The largest storm events during the monitoring period resulted in water level increases between 0.2 and 0.4 feet in Lake Augusta in the spring and later in the fall. Extremely dry conditions during June and July resulted in a lake level drop of approximately 1.2 feet.

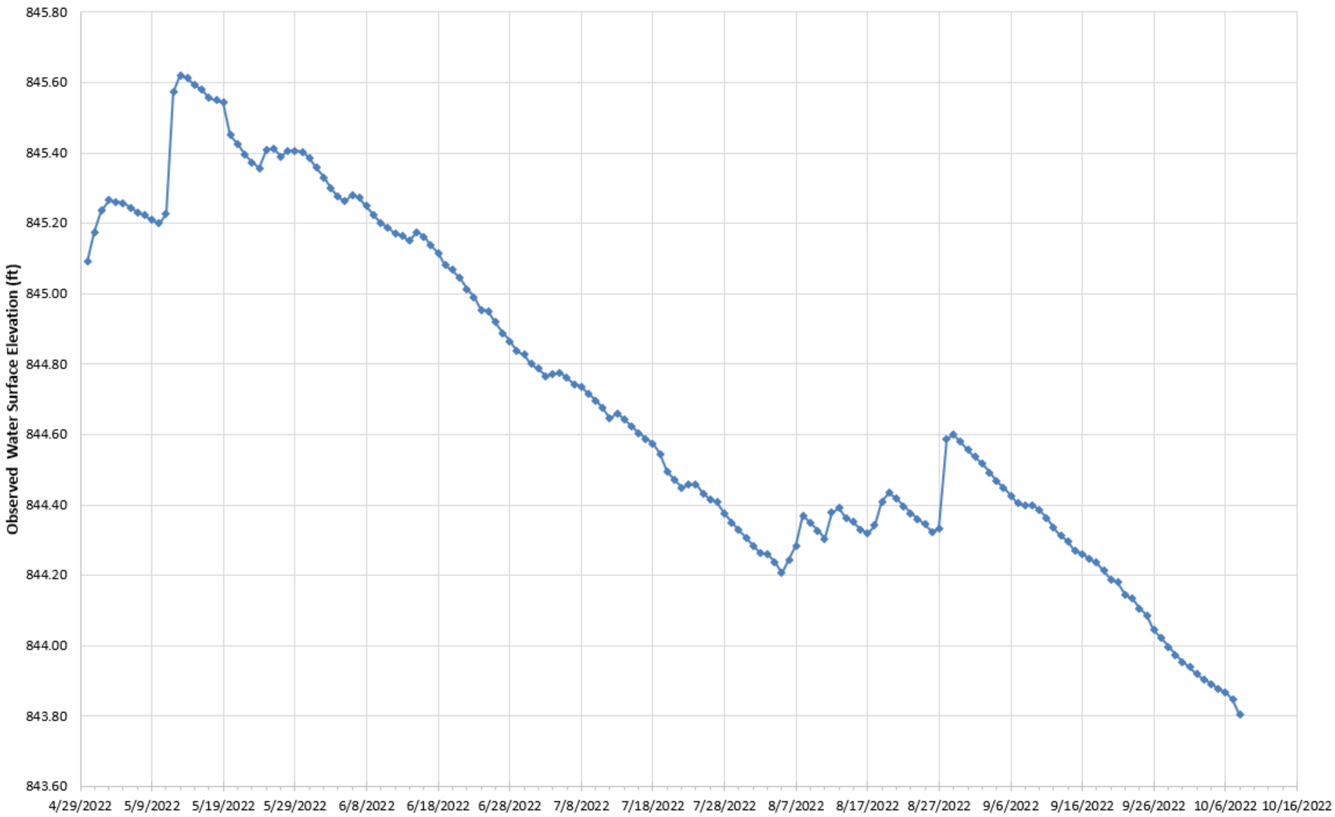


Figure 3-2 2022 Lake Water Levels

Limited historic lake level observations are available for Lake Augusta. Past survey elevations and aerial photos were used to approximate how water levels in Lake Augusta responded to wetter than average conditions between 2013 and 2020. Figure 3-3 shows the combined record of past lake level measurements and estimates, along with comparison to older lake level measurements and the OHWL. Figure 3-3 shows that the estimated lake level from 2020 was about 8 feet higher than 2013 and about 15 feet higher than the OHWL.

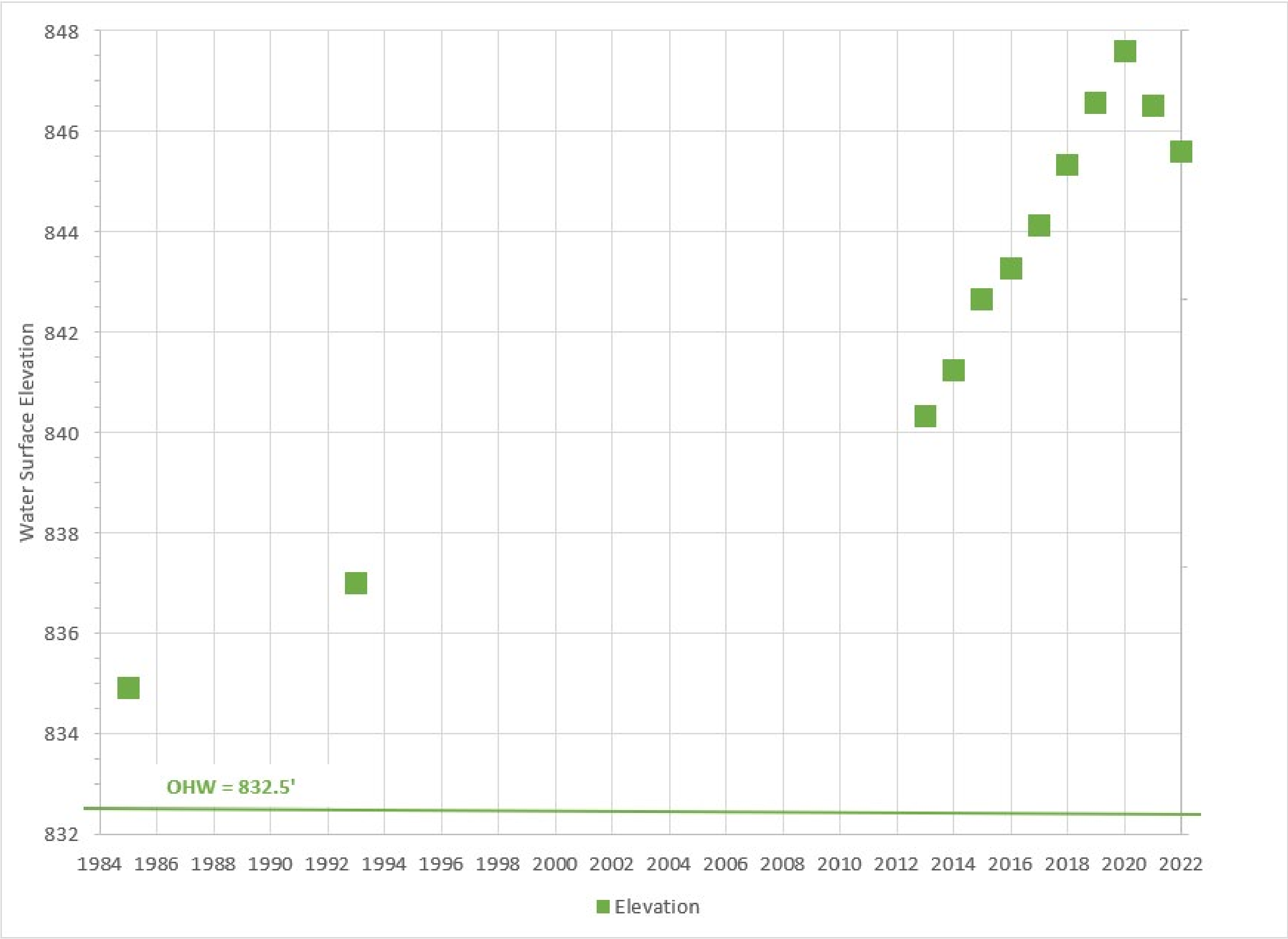


Figure 3-3 Historical Lake Level Estimates

3.2 Stormwater Monitoring

Stormwater water quality and flow monitoring data from each stormwater monitoring station was used to compare with modeled pollutant loadings. Table A-2 shows the individual sample constituent concentrations for each watershed monitoring site (shown in Figure 2-2). The TP sample results indicate that improvements to water quality treatment from Pond 2 (NE Inlet) and localized cemetery drainage (SE Inlet) are needed for some of the observed runoff events. The higher TP concentrations observed at both the NE Inlet and SE Inlet corresponded with higher TSS and turbidity.

4 Watershed and Lake Water Quality Modeling

To develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or pollutant sources impacting or threatening them must be identified and evaluated. Identification of the potential pollutant sources, magnitudes, and resulting in-lake water quality in relation to the state water quality standards is one of the primary objectives of this study. Further problem identification and targeting of water quality improvement efforts includes an evaluation of watershed loadings under various observed flow and seasonal conditions and the resulting changes to in-lake water quality. Water and lake phosphorus budgets have been determined and calibrated for the critical summer period when water quality standards were exceeded to evaluate the relative contributions from subwatershed runoff, atmospheric deposition, and other internal sources of phosphorus.

Water quality modeling of the lake watershed was conducted using the P8 Urban Catchment Model (Program for Predicting Polluting Particle Passage thru Pits, Puddles, and Ponds). P8 is a model used for predicting the generation and transport of stormwater runoff and pollutants in urban watersheds. The model tracks the movement of particulate matter (fine sand, dust, soil particles, etc.) as it is carried by stormwater runoff traveling over land and impervious surfaces. Particle deposition in ponds is tracked to estimate pollutant load, carried by the particles that eventually reach a water body.

Previous modeling from the WRAPS/TMDL study (Barr, 2014) was revised for current conditions in the Lake Augusta watershed, which includes existing BMPs that provide phosphorus removal prior to runoff reaching the lake. The revised P8 model was then updated with 2022 growing-season climate data (hourly precipitation and daily temperatures) to calibrate the phosphorus (total and dissolved) and develop total suspended solids (TSS) loadings for the period. To estimate the phosphorus removal achieved from existing BMPs, the modeled annual phosphorus inflow loading to the lake was compared to the total phosphorus load generated from the watershed. P8 model results indicate that the existing BMPs remove approximately 39% of the phosphorus load from the Lake Augusta watershed based on a long-term simulation.

An in-lake water and mass balance model for phosphorus was developed for Lake Augusta to predict water volume and in-lake phosphorus concentrations based on flow and phosphorus loads to the lake. A daily time-step mass balance spreadsheet model that tracked the flow of water and phosphorus through the lake over the summer period was selected for modeling. The calibrated watershed modeling was used to concurrently develop the water and phosphorus budgets that optimized the daily lake water quantity and quality modeling fit to the 2022 summer lake monitoring data. Following calibration, both the P8 and in-lake models were used to simulate conditions for the 2013 through 2022 water years to better represent typical climatic conditions and set a representative baseline for evaluation of lake water quality improvement options.

Figure 4-1 shows how the calibrated daily water balance simulation from the in-lake modeling agreed with the monitored lake levels, based on the P8 modeling inputs, local precipitation records and estimated evaporation and net groundwater exchange during the summer of 2022.

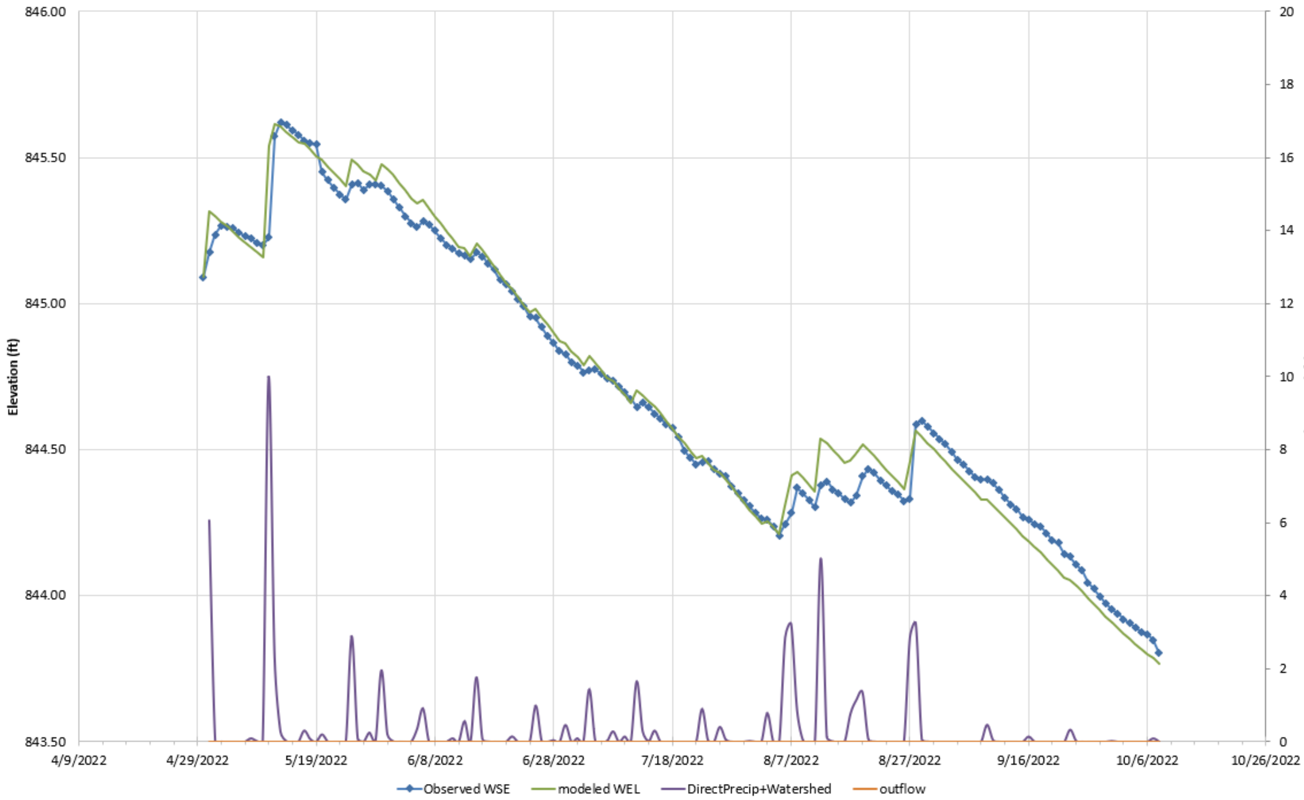


Figure 4-1 Calibrated Water Balance Modeling Results

As previously noted, the landlocked condition of Lake Augusta has led to high lake levels that, in turn, have killed hundreds of the older growth trees that surround the lake shoreline as well as the forested understory. As shown in Figure 4-2, the dead trees are typically surrounded by lake water and are preferred habitat for large numbers of cormorants. Based on discussions with lake area residents, it was determined that fecal droppings from cormorants could represent another potentially significant source of TP load to Lake Augusta. Residents had compiled longer-term records about the number of birds and their daily patterns during the open water season. It was believed that many of the birds are fishing elsewhere during the day and returning to Lake Augusta during the evening and early morning hours. As a result, it is assumed that fecal matter from the birds represents a direct source of TP load to the lake that is derived from outside of the Lake Augusta watershed.

Seasonal bird counts for 2022, along with estimates from previous years, were compiled (as shown in Table 4-1) and combined with literature values to estimate the daily TP load delivered to Lake Augusta from bird droppings. Scherer et al. (1995) estimated that the respective dry weights of cormorant and egret droppings is 45 and 20.25 grams per day, with a phosphorus content of 1.87%. Table 4-1 shows how the current and past seasonal bird counts (based on full-day equivalents), combined with the literature values, were translated to daily TP load estimates that could then be incorporated into the Lake Augusta phosphorus mass balance modeling. Dead trees have been noted on the lake going back further than 2013.

Figure 4-2 Cormorants Congregating on Dead Shoreline Trees

Table 4-1 Methods and Assumptions for Estimating Lake Augusta TP Load from Cormorants

Modeled Timeframe	Seasonal Period	Equivalent Bird Counts (#/day)	Combined Daily TP Load (lbs/day)
2022	April 15-September 15	600 cormorants 200 egrets	1.28
	September 15-October 15	1500 cormorants	2.78
2013-2021	April 15-September 15	240 cormorants	0.44
	September 15-October 15	680 cormorants	1.26

Figure 4-3 shows how the calibrated daily phosphorus mass balance simulation from the in-lake modeling agreed with the monitored lake phosphorus concentrations (expressed as a volume-averaged TP concentration), based on the calibrated P8 modeling inputs, along with the estimated internal phosphorus loading rate and TP load from bird droppings during the summer of 2022.

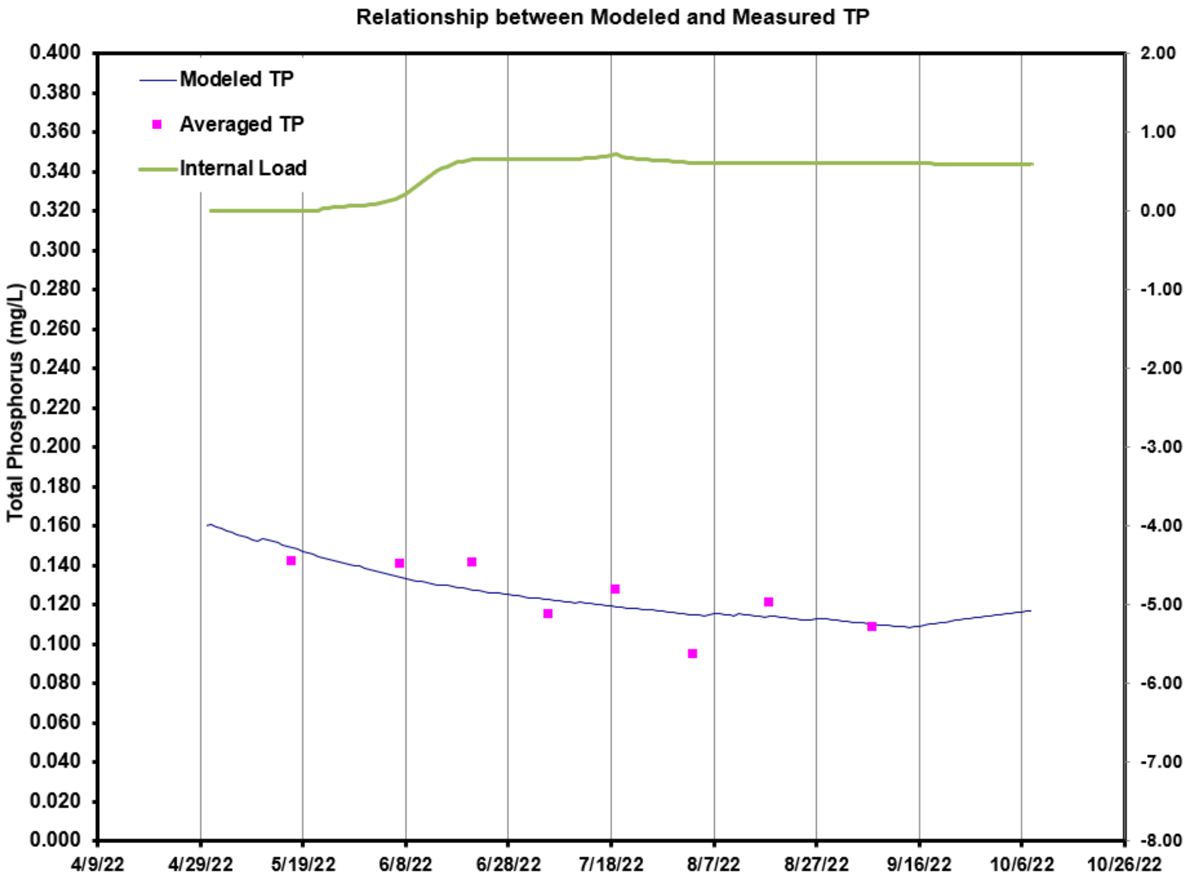


Figure 4-3 Calibrated Water Quality Monitoring and Modeling Results

Based on the calibrated in-lake modeling, Figure 4-4 shows that the cormorant droppings accounted for 68% of the phosphorus budget to Lake Augusta during the 2022 growing season, with internal phosphorus load (21%), watershed runoff (10%) and direct deposition from the atmosphere (1%) accounting for the remainder of phosphorus inputs to the lake.

Following calibration, the P8 and in-lake modeling was run for the 2013 through 2022 water years to determine relative watershed and in-lake phosphorus loadings that are more representative of typical climatic conditions. Figure 4-5 shows that the cormorant droppings accounted for 36% of the phosphorus budget to Lake Augusta for the 2013 through 2022 simulation, with internal TP load (21%), watershed runoff (41%) and atmospheric deposition (2%) accounting for the remaining phosphorus inputs.

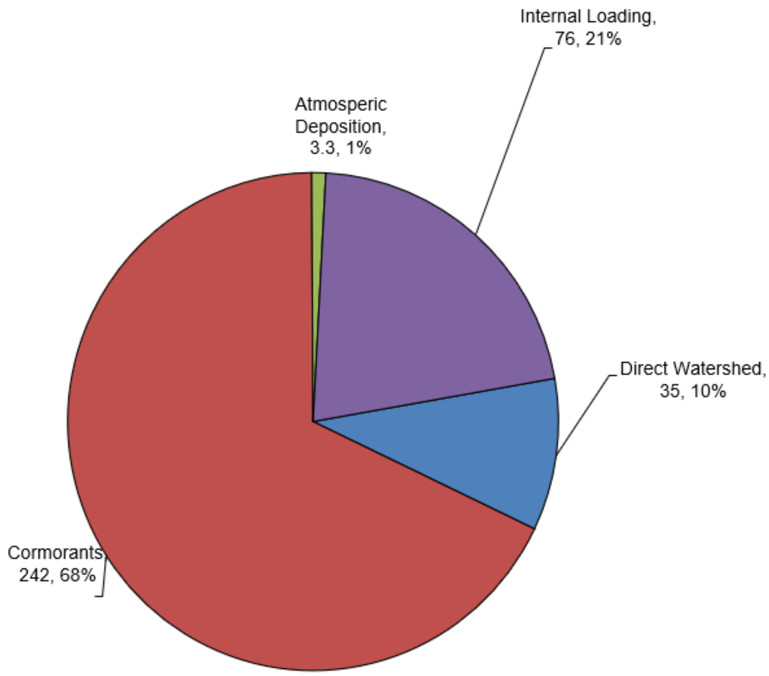


Figure 4-4 Modeled 2022 Growing Season TP Sources (lbs,%) for Lake Augusta

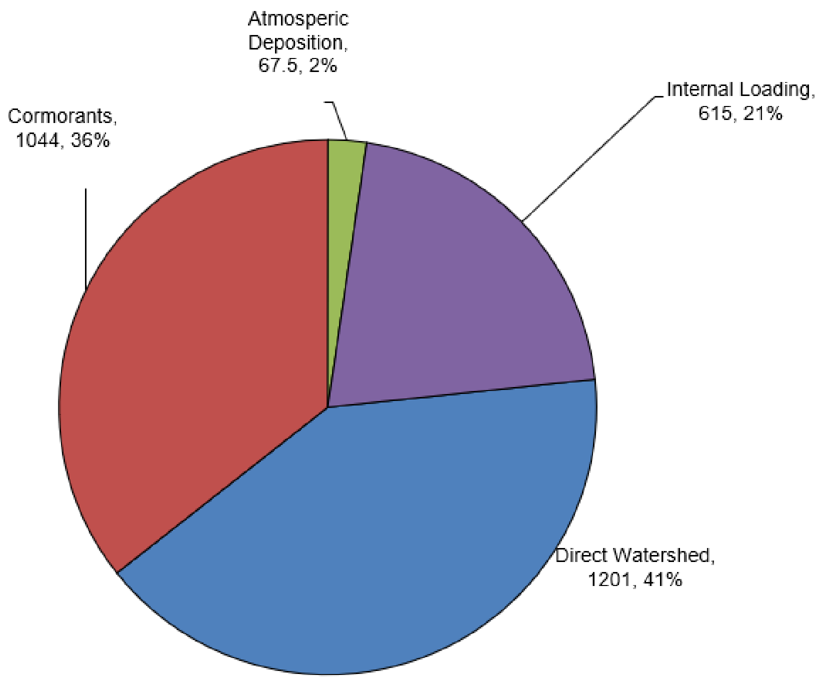


Figure 4-5 Modeled 2013-2022 Annual TP Sources (lbs,%) for Lake Augusta

The calibrated watershed modeling was used to identify and evaluate the potential load reduction that could be expected from implementation of various watershed BMPs. The lake's response to the expected load reductions determined from the watershed analysis was also evaluated with the calibrated in-lake modeling. In addition, an in-lake improvement option was also evaluated with the calibrated in-lake modeling.

The calibrated water quality modeling was run for the 2013-2022 period and used to simulate how implementation of watershed BMPs, combined with a lake outlet and shoreland tree removal, would have improved water quality of the lake. The baseline TP concentration predicted for Lake Augusta, without BMP implementation, was 77 ppb. The predicted baseline TP concentration is significantly lower than the simulation of the 2022 (calibrated) condition because higher TP concentrations associated with the higher lake inflows are flushed out and the lower lake level reduces the area of anoxic sediment from the lake bottom that would otherwise contribute to higher internal load, so the starting TP concentration was set to align with the results of the long-term simulation more closely and reflect the ongoing effect of lake flushing from watershed runoff.

Table 4-2 shows how much the average summer total phosphorus concentrations would improve following implementation of the recommended watershed structural BMPs and combination of lake outlet installation and shoreland tree removal (further discussed in Section 5). The TP load reductions estimated for Option 1, in Table 4-2, assume that the number of cormorant days at Lake Augusta would be reduced by 87% from the levels estimated in 2022, which is estimated to be comparable to the bird population from twenty years prior. The predicted in-lake TP concentration for Option 1 is 50 ppb. The calibrated P8 modeling was used to simulate the TP load reductions for the combination of watershed BMPs included in Option 2, shown in Table 4-2. Table 4-2 shows that implementation of the projects associated with both Options 1 and 2 will result in predicted in-lake TP concentration of 40 ppb, which meets MPCA's TP criteria.

Table 4-2 Average Summer Load Reduction and Modeled TP Following BMP Implementation

Modeled Parameter	Option 1: Lake Outlet and Shoreline Tree Removal	Option 2: Pond 2 Enhancements and New Cemetery Pond	Combination of Options 1 and 2
Watershed TP Load Reduction (%)	--	24	24
Cormorant TP Load Reduction (%)	80	--	80
Predicted TP (ppb) Following BMP Implementation	50	67	40

The in-lake modeling was also used to simulate its sensitivity to the calibrated internal phosphorus loading rate which showed that complete elimination of internal load would only reduce the predicted TP concentration by 7 percent. As a result, another alum treatment is not recommended at this time, but could warrant future consideration after implementation of the other improvement options. The absolute values of the TP predictions in Table 4-2 have considerably more uncertainty than the relative difference between the baseline and predicted TP concentrations due to the difficulty in accounting for all the potential water quantity and quality interactions that will change following implementation of a lake outlet.

5 Lake Improvement Options

5.1 Recommendations

This section involves development and targeting of management actions that will protect and improve water quality conditions in each lake. The Mendota Heights Surface Water Management Plan was reviewed for existing pond characteristics and functioning as a part of the calibrated watershed modeling, which was used to identify and evaluate the effectiveness of potential BMP practices and the amount of potential load reduction that could be expected from various BMP types and locations within the direct watershed. The lakes' response to the expected load reductions determined in the watershed analyses have been evaluated with the calibrated in-lake modeling. Potential in-lake improvement options have also been evaluated with the calibrated in-lake modeling. This process allows for the evaluation of the direct effect of a specific BMP or in-lake improvement option on lake water quality, which can then be used to evaluate the expected cost and benefits, as well as implementation strategies for the phosphorus load reduction required to meet the water quality goals.

Based on the lake assessment and calibrated watershed and lake water quality modeling, the following watershed BMPs and in-lake management options are recommended to substantially reduce the respective phosphorus loadings and enhance recreational suitability of the lake:

- Install an outlet to control water levels for Lake Augusta and remove dead trees from the lake shoreline to discourage cormorant population establishment and control summer TP loads. It is also expected that controlled water levels will mitigate the potential impact of lakeshore sediment erosion, including excess phosphorus contributions from flooded shoreline soils and decaying vegetation.
- Install structural BMPs and/or pretreatment protection measures to prevent future sediment delivery and reduce nutrient loading into the lake with design(s) intended to meet water quality goals. Untreated stormwater runoff from the SE inlet discharge outfall and undertreated runoff from the NE inlet to Lake Augusta are prioritized for implementation.

Additional smaller scale stormwater BMPs within the watershed of the lake would also be beneficial in reducing the overall phosphorus load to the lake and can/should be considered as possible and appropriate. These could include required or voluntary stormwater BMPs implemented through redevelopment or street reconstructions for example. These were not quantified as part of this study.

5.2 Conceptual Design

Figure 5-1 shows the location of the potential lake improvement options in the watershed. The proposed BMP located in the Pond 2 subwatershed involves stormwater pond expansion and an iron-enhanced sand filter retrofit to improve TP treatment. The proposed BMP located in the Pipe 1 subwatershed involves installation of a new wet detention pond for untreated runoff, while the improvement options in the direct watershed involve implementation of a lake outlet and removal of dead trees at the location shown in Figure 5-1.

For the watershed BMPs evaluated, the calibrated P8 modeling was used to evaluate the proposed BMPs and estimate the annual TP removals. The model was run for the same water years (2013 through 2022: 10/1/2012 – 9/30/2022) that cover the modeling timeframe used to determine relative, long-term TP loadings representative of typical climatic conditions.

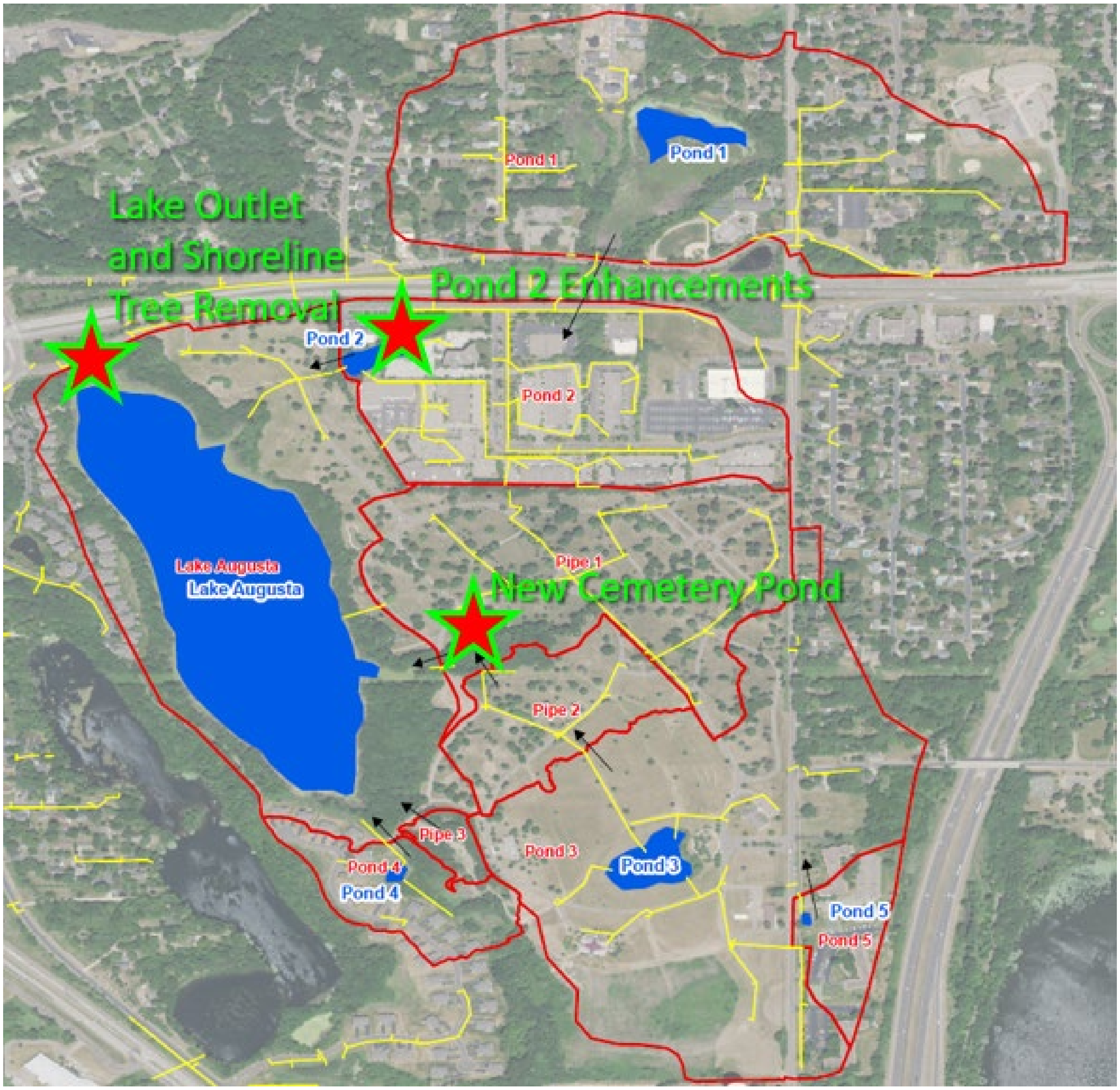


Figure 5-1 Recommended Lake Augusta Subwatershed Locations for Structural BMPs

5.2.1 Proposed Lake Outlet and Shoreline Dead Tree Removal

The lake modeling was used to evaluate the potential water balance impact of various pumped outlet capacities and to optimize its operation to maintain relatively stable lake levels during the long-term simulation, which had an assumed starting water level of 840.0 feet (that may or may not be indicative of future management). Based on the preliminary model simulations, the lake outlet pumping can likely be optimized such that the maximum pumping rate would not exceed 1 cfs, and in most cases, a pumping rate of 0.33 cfs (150 gpm) or less, from one pump, would generally maintain lake level bounce below 2 feet (as shown in Figure 5-2, which shows the modeled water surface elevation [WEL], along with estimated/calibrated outflow rates for evapotranspiration [ET] and groundwater). Figure 5-2 shows that a 150 gpm pumping capacity during the extreme events of the spring of 2014 would result in approximately a six-foot increase in lake level, but the potential use of pumping redundancy (in the form of a backup pump) could mitigate the bounce and inundation time during these extreme events. The backup pump would be installed as a part of this improvement option in case the primary pump requires service.

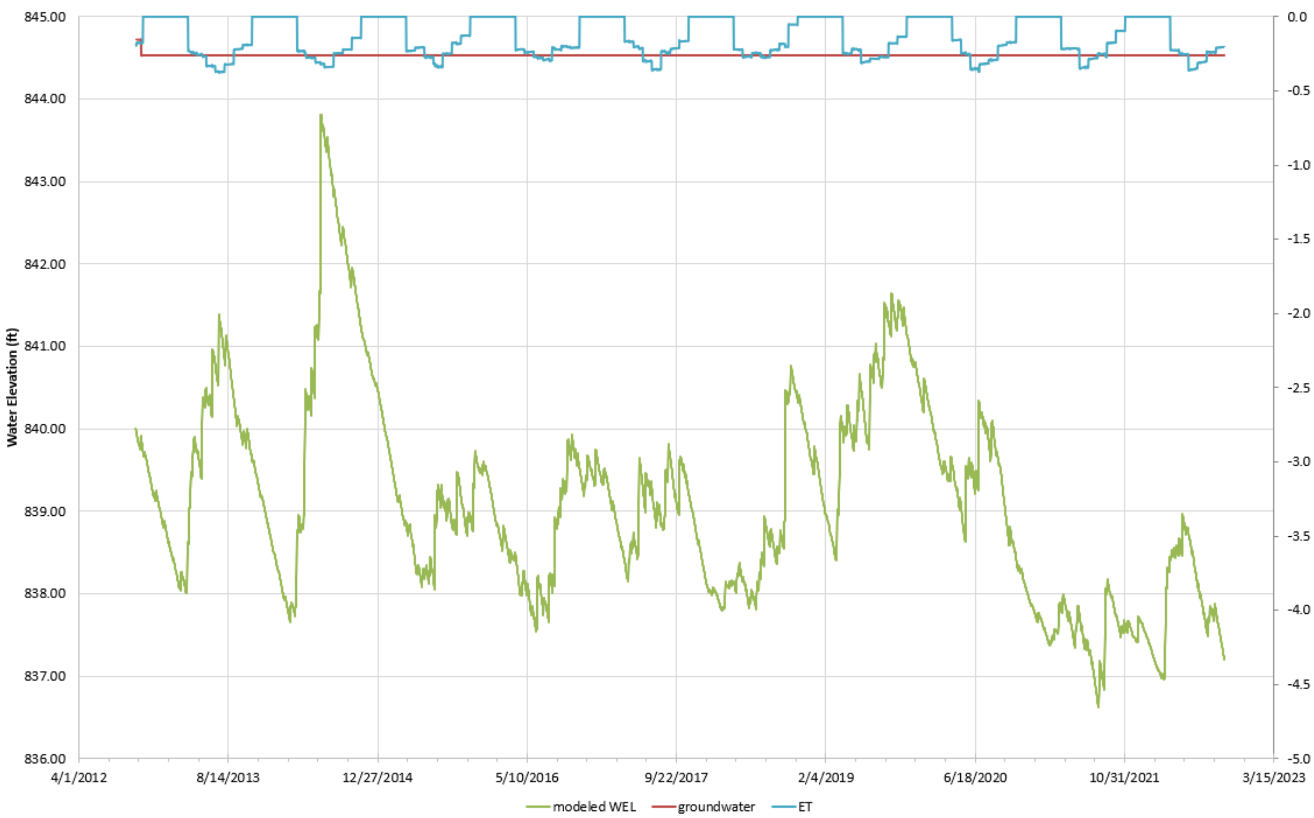


Figure 5-2 Long-Term Simulated Lake Augusta Lake Levels with Proposed Lake Outlet

To further assess the permit conditions and feasibility of a pumped outlet, a meeting was held with representatives from MDNR and Minnesota Department of Transportation (MnDOT), since MDOT owns and operates the storm sewer systems north and west of Lake Augusta and MDNR would have jurisdiction over public waters permit requirements. At the meeting, the following options were discussed:

- Gravity discharge to Lake Lemay (located to the southwest of Lake Augusta), which discharges to the storm sewer system southwest of Lake Augusta that ultimately reaches the Minnesota River along Highway 494—this option was eliminated because Lake Lemay currently has significantly better water quality (average TP concentration of 38 µg/l) that would initially become degraded from the Lake Augusta discharge
- Pumped discharge outlet to the frontage road (which is owned by the City of Mendota Heights), and ultimately, the MnDOT Highway 62 storm sewer system north and west of Lake Augusta, which would require a lift of approximately 20 to 25 feet with a discharge rate not to exceed 1 cfs—this option was preferred because it would not adversely impact downstream water bodies and can feasibly be constructed with limited infrastructure and ongoing maintenance.

MDNR indicated that the rules allow a provision for creating outlets to landlocked basins and that the proposed project would not require a public waters work permit since in this case, the outlet would be constructed above the OHWL. MDNR also indicated the following permit considerations for the proposed lake outlet:

- Water appropriations permit would be needed to "dewater" lake or partially drawdown lake and that:
    - Non-game wildlife biologists need to review permit application to ensure that lake is drawn down slowly
    - May not be able to drawdown over winter or may need to be drawn-down before Sept. 15th to protect amphibians
- May do partial lake drawdown to remedy flooding and allow survey
- Efforts to control cormorants may trigger fish and wildlife permit considerations at the Federal level.

MnDOT indicated that the proposed project would require a drainage permit, with conditions that could include the following:

- 1 to 2 cfs maximum pumping rate
- Temporary pumping would be allowed, aside from when 2′′ rain is forecast in next 48 hours
- Would require good long term erosion control at the proposed lake outlet

MnDOT will be confirming the quality of downstream pipes in 2023, but did not expect that any other issues would prevent permitting for the proposed outlet.

Figure 5-3 shows the proposed lake outlet conceptual design features, which include two 150 gpm submersible pumps (for redundancy, as noted above) with a wetwell and discharge piping to the closest frontage road catch basin. It is expected that the system would ordinarily be programmed to operate one pump at a maximum discharge rate of 150 gpm, but pump operation could be manually changed during high water conditions. The proposed intake pipe would extend far enough into Lake Augusta to allow for a drawdown that would facilitate the removal of the dead trees that surround the lake shoreline. Removal of the dead trees is expected to deter many of the cormorants from roosting at Lake Augusta. The cormorant population should continue to be monitored. Additional study may be needed to determine other options should the cormorants remain at the lake after the dead tree removal.

Appendix B includes separate planning level cost estimates for the lake outlet lift station and the tree removal. It is expected that the dead tree removal to discourage cormorant habitation could best be accomplished in the winter, following fall lake level drawdown, to facilitate better access to the larger dead trees from the lake ice. The cost estimate for shoreline tree removal includes (and assumes) the following level of effort:

- Ten days of felling dead trees with removal to near ground level
- Ten days of forestry mowing with the larger trees ground up as much as possible
- Larger butt logs (>24″ diameter) would be hauled out of the lake basin and disposal would be coordinated with outside party(ies)

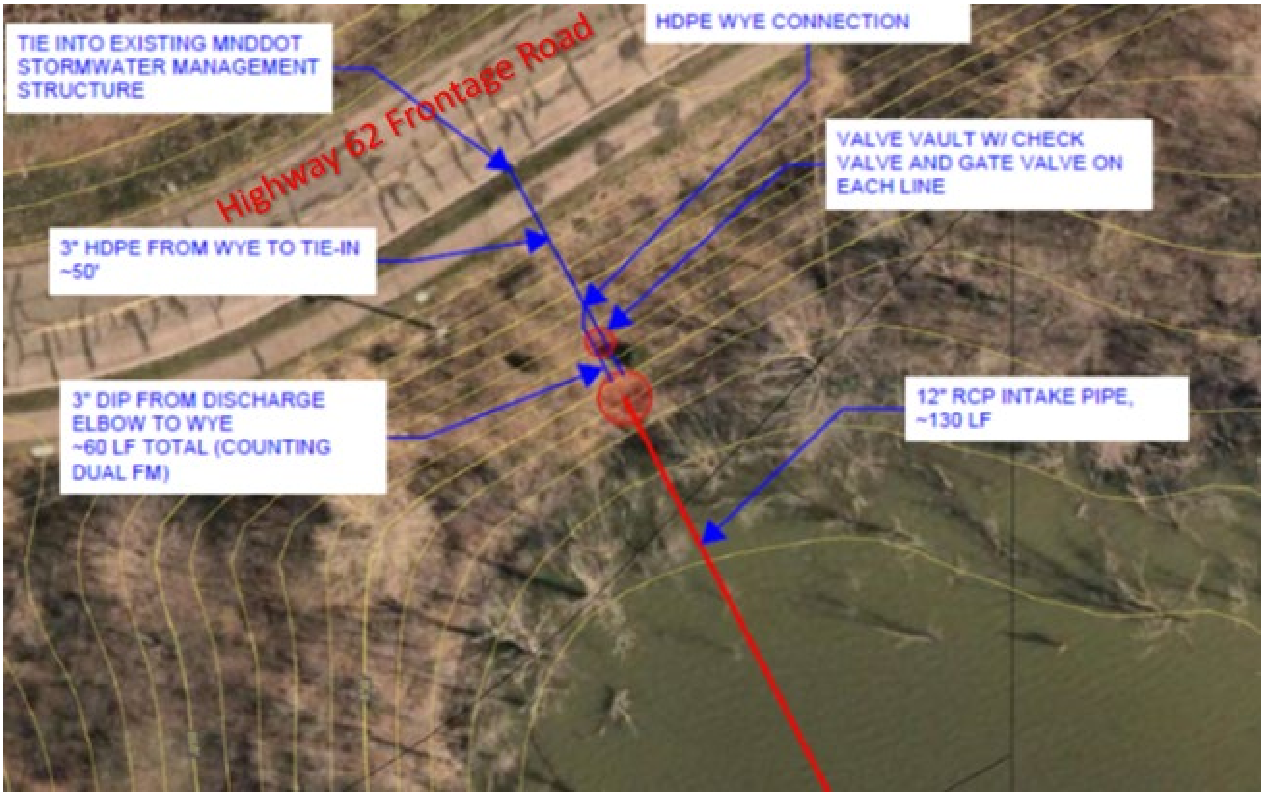


Figure 5-3 Lake Outlet Conceptual Design

5.2.2 Stormwater Pond 2 Enhancements

Figure 5-4 shows the conceptual design for enhancements to stormwater treatment at the Pond 2 site. Under current conditions, the calibrated long-term P8 model simulation estimates that Pond 2 is removing 29% of the incoming TP load before discharge to Lake Augusta. The conceptual design includes significant expansion of the existing pond surface area and depth for improved particulate phosphorus removal, as well as an iron-enhanced sand filter to provide treatment of dissolved phosphorus from the pond effluent. The proposed pond surface area is twice as large as the existing area and the proposed dead storage volume is three times larger than current conditions. A TP load reduction of 17 pounds per year is estimated for the proposed condition, based on the long-term P8 model simulation. This pond is located on private property and would need close coordination with the property owners to implement improvements. Similar to the lake outlet, the expansion proposed for this improvement option will involve multiple landowners and future considerations for ongoing operation and maintenance, including drainage and access easements.

Figure 5-4 Conceptual Design of Stormwater Pond 2 Enhancements

5.2.3 Proposed Cemetery Pond

Figure 5-5 shows the conceptual design at the SE inlet monitoring site which, under current conditions, does not have stormwater treatment for runoff from the Pipe 1 and Pipe 2 subwatersheds (shown in Figure 5-1 with the pond area delineated in red) before the flow is conveyed to Lake Augusta through an existing culvert under the cemetery road. As a result, the conceptual design includes installation of a pond outlet structure that would be integrated into the upstream end of the existing culvert to create a permanent pool volume for stormwater treatment, in addition to a small area of excavation on the northern half of the proposed pond to minimize short-circuiting of the flow and provide pretreatment from the Pipe 1 subwatershed. The surface area of the permanent pool for the proposed pond is approximately half an acre and the proposed permanent pool storage volume is 2.9 acre-feet. A TP load reduction of 12 pounds per year is estimated for the proposed condition, based on the long-term P8 model simulation. The Cemetery was engaged during the study and their cooperation would be necessary to implement any stormwater improvements at this location.

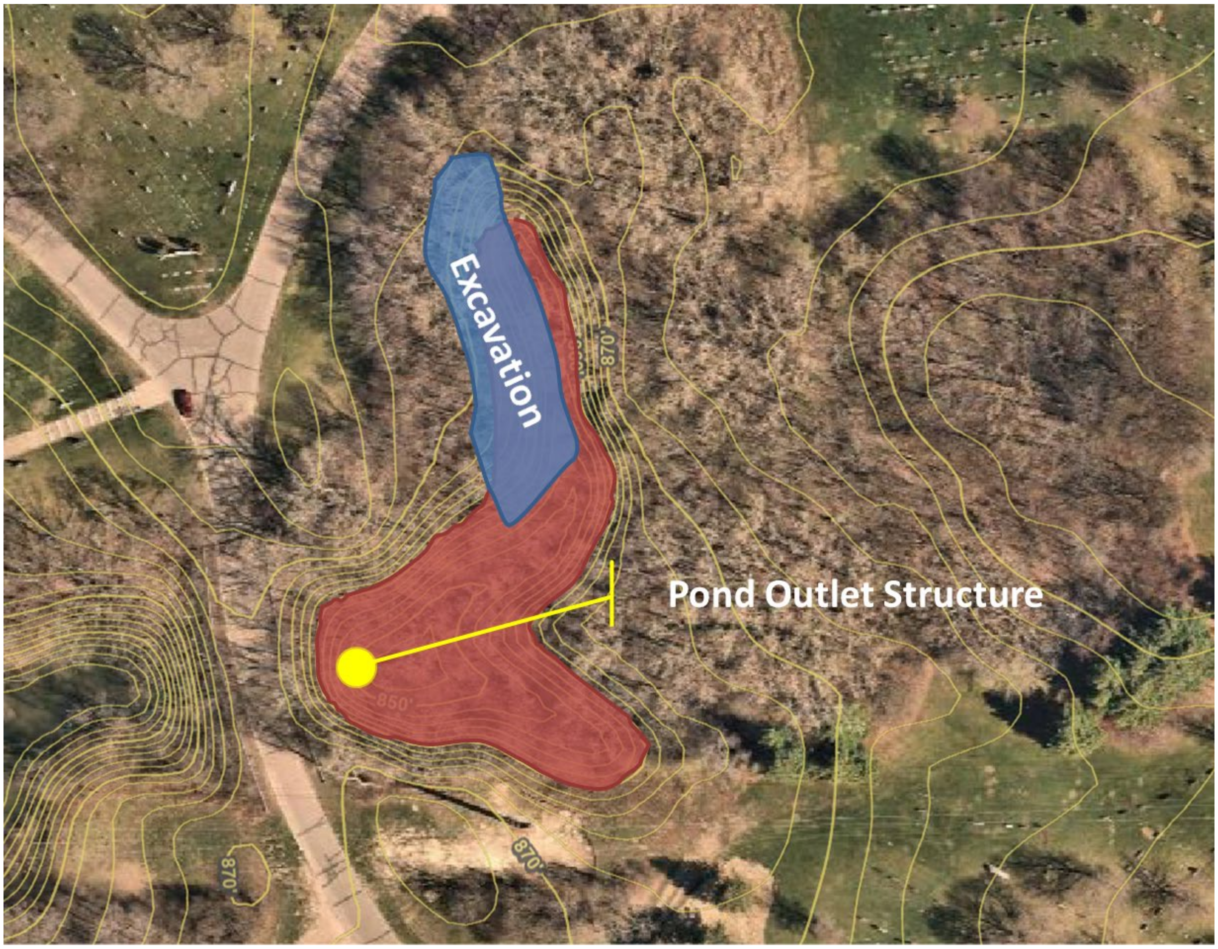


Figure 5-5 Proposed Cemetery Pond Conceptual Design

5.3 Estimated Cost-Benefit of Lake Improvement Options

Planning level cost estimates were developed for the various BMPs based on the conceptual design of each project. Although the point estimate of cost was used for the cost-benefit analysis, there is cost uncertainty and risk associated with this concept-level cost estimate. The costs reported for the BMPs include engineering, design, permitting, and construction management. The costs assume that the excavated soils are not contaminated, and the projects do not require significant utility modifications or relocations. The range of probable costs presented reflects the level of uncertainty, unknowns, and risk due to the conceptual nature of the individual project designs. Based on the current level of design (planning level estimate), the cost range is expected to vary by -30 percent to +50 percent from the planning level point opinion of cost.

Appendix B includes the itemized planning level cost estimates for the water quality improvement options evaluated. These more detailed cost estimates should be reviewed and considered when planning and budgeting for the larger CIP projects and/or applications for grant funding.

A cost-benefit assessment was completed for each BMP to assist with prioritizing and selecting the preferred and most cost-effective BMPs to help achieve the necessary phosphorus load reductions. The capital costs (engineering, design, and construction) were annualized assuming a 20-year life span at a 4 percent interest rate. Although this timeframe is commonly used for these cost-benefit assessments, the actual lifespan of ponds, other BMPs, and infrastructure can be significantly longer if maintained regularly. Annual operation and maintenance costs were estimated for each project, assuming 1 percent of the capital cost. The benefit was estimated as an annualized cost per pound of total phosphorus removed per year. The estimated benefit does not take credit for excess phosphorus contributions from flooded shoreline soils, erosion, or decaying vegetation following outlet installation and mitigation of extreme lake level variations.

Table 5-1 summarizes the potential lake improvement options, estimated annual total phosphorus removal, planning level capital cost estimate, and annualized cost-benefit for implementation of each improvement option.

Table 5-1 Summary of Potential Improvement Option Benefit and Planning Level Costs

BMP ID/Location	Annual TP Removal (lbs/yr)	Planning Level Capital Cost Estimate	Annualized Cost-Benefit ($/lb TP Removed/yr)
Lake outlet and shoreline tree removal	84	$545,000	$540
Construct cemetery pond	12	$184,000	$1,300
Pond 2 enhancements	17	$650,000	$3,200

The following funding sources may be available for implementation of some of the recommended improvement options:

- BWSR Clean Water Funds
- Conservation Partners Legacy (for habitat components)
- MPCA grants and MN Public Facilities Authority funds
- MDNR short term action request grants
- Partner CIP funds (for potential grant match)

5.4 Adaptive Management

Adaptive management is a structured, iterative decision-making process intended to reduce uncertainty over time through system monitoring and response. As previously discussed, Lake Augusta has experienced extreme shifts in the recent past due to it being a land-locked basin that has had large lake level fluctuations and increases in the resident cormorant population that corresponded with deteriorating water quality. There is significant uncertainty about how Lake Augusta water quality will respond to the installation of a lake outlet, along with the recommended watershed BMPs and removal of dead shoreline trees. As a result, additional monitoring and adaptive management will be required to respond to future changes. The following activities are recommended for future monitoring and analysis:

- Continue to collect lake level data and water quality sampling following the 2022 monitoring protocols.
- Since existing internal phosphorus loading estimates could not differentiate individual sources, beyond sediment phosphorus release, a rough fish survey should be completed to determine if rough fish may be contributing to impaired water quality.
- Perform bathymetric survey and visual inspections of watershed BMPs to ensure that existing practices are fully functioning and providing optimal treatment of stormwater runoff.
- Cormorant populations should continue to be documented and tracked following lake outlet installation and removal of dead shoreline trees. If resident bird populations do not subside, US Fish and Wildlife Service and/or Minnesota Department of Natural Resources should be consulted for alternative methods to control the resident bird population.

References

Barr Engineering. 2014. *Lower Mississippi River WMO Watershed Restoration and Protection Strategy (WRAPS) and Total Maximum Daily Load (TMDL) Report.* Prepared for Minnesota Pollution Control Agency and Lower Mississippi River WMO. wq-iw8-43e.pdf.

Minnesota Pollution Control Agency. 2022. *2013 Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List, 2022 Assessment and Listing Cycle*. wq-iw1-04l.

Nancy M. Scherer, Harry L. Gibbons, Kevin B. Stoops & Martin Muller. 1995. Phosphorus Loading of an Urban Lake by Bird Droppings, Lake and Reservoir Management, 11:4, 317-327, DOI: 10.1080/07438149509354213.

Appendix A

2022 Water Quality Monitoring Data

Lake Augusta Water Quality Improvement and Outlet Feasibility Study

Table A-1 Lake Augusta 2022 Water Quality Monitoring Results

		Parameter	Chloride	Chlorophyll a, pheophytin-adjusted	Phosphorus, total, as P	Depth	Dissolved oxygen	pH	Secchi disc	Specific conductance @ 25 ºC	Temperature	Turbidity
		Analysis Location	Lab	Lab	Lab	Field	Field	Field	Field	Field	Field	Field
		Units	mg/l	ug/l	mg/l	m	mg/l	pH units	m	umhos/cm	deg C	NTU
Location	Date	Depth										
Augusta	4/19/2022	0 - 2 m	132	33.6	0.129	12.7	--	--	0.55	--	--	16.2
Augusta	4/19/2022	0 m	--	--	--	--	9.4	7.20	--	619	4.9	--
Augusta	4/19/2022	1 m	--	--	--	--	8.2	7.12	--	619	4.8	--
Augusta	4/19/2022	2 m	--	--	--	--	7.9	7.00	--	618	4.5	--
Augusta	4/19/2022	3 m	--	--	--	--	7.7	7.00	--	618	4.5	--
Augusta	4/19/2022	4 m	--	--	0.133	--	7.8	6.95	--	618	4.5	--
Augusta	4/19/2022	5 m	--	--	--	--	7.8	6.93	--	617	4.5	--
Augusta	4/19/2022	6 m	--	--	--	--	7.7	6.92	--	617	4.5	--
Augusta	4/19/2022	7 m	--	--	0.129	--	7.8	6.90	--	618	4.5	--
Augusta	4/19/2022	8 m	--	--	--	--	7.7	6.91	--	617	4.4	--
Augusta	4/19/2022	9 m	--	--	0.131	--	7.7	6.91	--	618	4.4	--
Augusta	4/19/2022	10 m	--	--	--	--	7.6	6.90	--	623	4.5	--
Augusta	4/19/2022	11 m	--	--	--	--	7.4	6.89	--	622	4.5	--
Augusta	4/19/2022	12 m	135	--	0.130	--	2.2	6.85	--	755	4.2	--
Augusta	5/17/2022	0 - 2 m	116	101	0.185	11.9	--	--	0.2	--	--	40.6
Augusta	5/17/2022	0 m	--	--	--	--	14.1	8.9	--	574	18.9	--
Augusta	5/17/2022	1 m	--	--	--	--	14.0	9.0	--	573	18.7	--
Augusta	5/17/2022	2 m	--	--	--	--	13.8	9.0	--	580	18.5	--
Augusta	5/17/2022	3 m	--	--	--	--	8.0	8.0	--	624	12.9	--
Augusta	5/17/2022	4 m	--	--	0.113	--	8.0	7.9	--	624	11.2	--
Augusta	5/17/2022	5 m	--	--	--	--	7.5	7.8	--	624	9.0	--
Augusta	5/17/2022	6 m	--	--	--	--	7.3	7.7	--	625	7.8	--
Augusta	5/17/2022	7 m	--	--	0.088	--	6.7	7.7	--	626	7.2	--
Augusta	5/17/2022	8 m	--	--	--	--	5.3	7.6	--	630	6.7	--
Augusta	5/17/2022	9 m	--	--	--	--	4.8	7.5	--	632	6.3	--
Augusta	5/17/2022	10 m	--	--	0.077	--	3.2	7.5	--	635	6.2	--
Augusta	5/17/2022	11 m	--	--	--	--	1.9	7.4	--	644	6.1	--
Augusta	5/17/2022	11.5 m	128	--	0.083	--	0.9	7.4	--	644	6.1	--
Augusta	6/07/2022	0 - 2 m	133	125	0.180	12.3	--	--	0.2	--	--	51.5
Augusta	6/07/2022	0 m	--	--	--	--	13.5	9.3	--	573	20.3	--
Augusta	6/07/2022	1 m	--	--	--	--	11.4	9.2	--	578	19.8	--
Augusta	6/07/2022	2 m	--	--	--	--	7.3	8.9	--	588	18.9	--
Augusta	6/07/2022	3 m	--	--	--	--	3.8	8.5	--	600	18.0	--
Augusta	6/07/2022	4 m	--	--	< 0.003 U	--	1.4	8.0	--	640	12.8	--
Augusta	6/07/2022	5 m	--	--	--	--	1.9	7.9	--	636	9.4	--
Augusta	6/07/2022	6 m	--	--	--	--	2.1	7.8	--	636	8.0	--
Augusta	6/07/2022	7 m	--	--	0.056	--	2.0	7.7	--	640	7.3	--
Augusta	6/07/2022	8 m	--	--	--	--	0.8	7.6	--	642	6.8	--
Augusta	6/07/2022	9 m	--	--	--	--	0.6	7.6	--	645	6.5	--
Augusta	6/07/2022	10 m	--	--	0.096	--	0.4	7.6	--	653	6.4	--
Augusta	6/07/2022	11 m	--	--	--	--	0.3	7.6	--	665	6.2	--
Augusta	6/07/2022	12 m	135	--	0.288	--	0.2	7.5	--	668	6.1	--
Augusta	6/21/2022	0 - 2 m	121	157	0.219	12.7	--	--	0.2	--	--	57.3
Augusta	6/21/2022	0 m	--	--	--	--	6.2	9.3	--	665	26.6	--
Augusta	6/21/2022	1 m	--	--	--	--	7.1	9.3	--	668	26.2	--
Augusta	6/21/2022	2 m	--	--	--	--	5.7	9.2	--	671	25.2	--
Augusta	6/21/2022	3 m	--	--	--	--	0.8	8.4	--	716	19.4	--
Augusta	6/21/2022	4 m	--	--	0.065	--	0.3	8.4	--	775	13.2	--
Augusta	6/21/2022	5 m	--	--	--	--	0.2	8.2	--	797	9.1	--
Augusta	6/21/2022	6 m	--	--	--	--	0.2	8.1	--	762	7.7	--
Augusta	6/21/2022	7 m	--	--	0.063	--	0.2	8.0	--	742	7.1	--
Augusta	6/21/2022	8 m	--	--	--	--	0.1	7.9	--	730	6.7	--
Augusta	6/21/2022	9 m	--	--	--	--	0.1	7.8	--	728	6.3	--
Augusta	6/21/2022	10 m	--	--	0.164	--	0.1	7.7	--	724	6.2	--
Augusta	6/21/2022	11 m	--	--	--	--	0.1	7.6	--	717	6.0	--
Augusta	6/21/2022	12 m	135	--	0.461	--	0.1	7.6	--	715	6.0	--
Augusta	7/06/2022	0 - 2 m	133	144	0.175	12.7	--	--	0.2	--	--	48.7
Augusta	7/06/2022	0 m	--	--	--	--	12.5	9.63	--	626	26.0	--
Augusta	7/06/2022	1 m	--	--	--	--	10.4	9.60	--	626	25.9	--
Augusta	7/06/2022	2 m	--	--	--	--	4.6	8.87	--	638	23.8	--
Augusta	7/06/2022	3 m	--	--	--	--	0.5	8.26	--	639	21.7	--
Augusta	7/06/2022	4 m	--	--	0.050	--	0.4	8.05	--	691	12.5	--
Augusta	7/06/2022	5 m	--	--	--	--	0.3	7.97	--	688	10.3	--
Augusta	7/06/2022	6 m	--	--	--	--	0.3	7.91	--	688	8.0	--
Augusta	7/06/2022	7 m	--	--	0.061	--	0.2	7.83	--	690	7.0	--
Augusta	7/06/2022	8 m	--	--	--	--	0.2	7.76	--	698	6.7	--
Augusta	7/06/2022	9 m	--	--	--	--	0.2	7.74	--	704	6.3	--
Augusta	7/06/2022	10 m	--	--	0.161	--	0.2	7.63	--	717	6.2	--
Augusta	7/06/2022	11 m	--	--	--	--	0.2	7.53	--	738	6.1	--
Augusta	7/06/2022	12 m	134	--	0.447	--	0.2	7.48	--	746	6.0	--
Augusta	7/19/2022	0 - 2 m	125 J-	157	0.187	12.8	--	--	0.15	--	--	57.9
Augusta	7/19/2022	0 m	--	--	--	--	8.3	9.2	--	571	27.1	--
Augusta	7/19/2022	1 m	--	--	--	--	7.9	9.1	--	572	27.1	--
Augusta	7/19/2022	2 m	--	--	--	--	0.9	8.0	--	591	24.5	--
Augusta	7/19/2022	3 m	--	--	--	--	0.7	7.7	--	606	20.1	--
Augusta	7/19/2022	4 m	--	--	0.060	--	0.6	7.7	--	632	13.7	--
Augusta	7/19/2022	5 m	--	--	--	--	0.5	7.6	--	635	10.4	--
Augusta	7/19/2022	6 m	--	--	--	--	0.4	7.5	--	630	8.2	--
Augusta	7/19/2022	7 m	--	--	0.068	--	0.4	7.4	--	634	7.3	--
Augusta	7/19/2022	8 m	--	--	--	--	0.4	7.3	--	645	6.8	--
Augusta	7/19/2022	9 m	--	--	0.156	--	0.4	7.2	--	653	6.5	--
Augusta	7/19/2022	10 m	--	--	--	--	0.3	7.1	--	665	6.3	--
Augusta	7/19/2022	11 m	--	--	--	--	0.3	7.1	--	676	6.1	--
Augusta	7/19/2022	12 m	122 J-	--	0.440	--	0.3	7.0	--	680	6.0	--
Augusta	8/03/2022	0 - 2 m	128	171	0.114	13.6	--	--	0.2	--	--	--
Augusta	8/03/2022	0 m	--	--	--	--	11.2	9.2	--	620	25.9	--
Augusta	8/03/2022	1 m	--	--	--	--	9.0	9.1	--	622	25.9	--
Augusta	8/03/2022	2 m	--	--	--	--	8.3	9.0	--	624	25.3	--
Augusta	8/03/2022	3 m	--	--	--	--	3.6	8.2	--	632	23.3	--
Augusta	8/03/2022	4 m	--	--	0.060	--	0.8	7.9	--	685	15.0	--
Augusta	8/03/2022	5 m	--	--	--	--	0.7	7.6	--	672	10.2	--
Augusta	8/03/2022	6 m	--	--	--	--	0.6	7.5	--	677	8.2	--
Augusta	8/03/2022	7 m	--	--	--	--	0.6	7.4	--	678	7.3	--
Augusta	8/03/2022	8 m	--	--	0.099	--	0.5	7.4	--	690	6.7	--
Augusta	8/03/2022	9 m	--	--	--	--	0.4	7.3	--	703	6.5	--
Augusta	8/03/2022	10 m	--	--	0.252	--	0.4	7.2	--	723	6.2	--
Augusta	8/03/2022	11 m	--	--	--	--	0.4	7.1	--	740	6.1	--
Augusta	8/03/2022	12 m	--	--	--	--	0.3	7.0	--	745	6.1	--
Augusta	8/03/2022	13 m	124	--	0.458	--	0.3	7.0	--	753	6.1	--
Augusta	8/17/2022	0 - 2 m	--	--	--	12.8	--	--	0.15	--	--	47.3
Augusta	8/17/2022	0 m	--	--	--	--	12.6	9.3	--	584	23.8	--
Augusta	8/17/2022	1 m	--	--	--	--	9.2	8.9	--	591	23.6	--
Augusta	8/17/2022	2 m	--	--	--	--	4.0	8.3	--	601	22.5	--
Augusta	8/17/2022	3 m	--	--	--	--	1.8	8.0	--	602	22.0	--
Augusta	8/17/2022	4 m	--	--	--	--	0.6	7.9	--	690	16.5	--
Augusta	8/17/2022	5 m	--	--	--	--	0.6	7.9	--	680	10.7	--
Augusta	8/17/2022	6 m	--	--	--	--	0.5	7.8	--	677	8.6	--
Augusta	8/17/2022	7 m	--	--	--	--	0.5	7.7	--	680	7.4	--
Augusta	8/17/2022	8 m	--	--	--	--	0.5	7.6	--	695	6.8	--
Augusta	8/17/2022	9 m	--	--	--	--	0.4	7.5	--	708	6.5	--
Augusta	8/17/2022	10 m	--	--	--	--	0.4	7.4	--	735	6.2	--
Augusta	8/17/2022	11 m	--	--	--	--	0.4	7.3	--	746	6.1	--
Augusta	8/17/2022	12 m	--	--	--	--	0.3	7.2	--	760	6.0	--
Augusta	8/18/2022	0 - 2 m	125	226	0.132	12.8	--	--	0.15	--	--	47.3
Augusta	8/18/2022	0 m	--	--	--	--	12.6	9.3	--	584	23.8	--
Augusta	8/18/2022	1 m	--	--	--	--	9.2	8.9	--	591	23.6	--
Augusta	8/18/2022	2 m	--	--	--	--	4.0	8.3	--	601	22.5	--
Augusta	8/18/2022	3 m	--	--	--	--	1.8	8.0	--	602	22.0	--
Augusta	8/18/2022	4 m	--	--	0.093	--	0.6	7.9	--	690	16.5	--
Augusta	8/18/2022	5 m	--	--	--	--	0.6	7.9	--	680	10.7	--
Augusta	8/18/2022	6 m	--	--	--	--	0.5	7.8	--	677	8.6	--
Augusta	8/18/2022	7 m	--	--	--	--	0.5	7.7	--	680	7.4	--
Augusta	8/18/2022	8 m	--	--	0.130	--	0.5	7.6	--	695	6.8	--
Augusta	8/18/2022	9 m	--	--	--	--	0.4	7.5	--	708	6.5	--
Augusta	8/18/2022	10 m	--	--	0.346	--	0.4	7.4	--	735	6.2	--
Augusta	8/18/2022	11 m	--	--	--	--	0.4	7.3	--	746	6.1	--
Augusta	8/18/2022	12 m	117	--	0.538	--	0.3	7.2	--	760	6.0	--
Augusta	9/07/2022	0 - 2 m	117	176	0.124	13.2	--	--	0.15	--	--	46.8
Augusta	9/07/2022	0 m	--	--	--	--	13.2	9.3	--	551	24.8	--
Augusta	9/07/2022	1 m	--	--	--	--	9.5	8.9	--	551	23.2	--
Augusta	9/07/2022	2 m	--	--	--	--	5.5	8.6	--	554	22.4	--
Augusta	9/07/2022	3 m	--	--	--	--	1.2	8.1	--	558	22.0	--
Augusta	9/07/2022	4 m	--	--	0.080 J+	--	0.7	7.8	--	640	17.6	--
Augusta	9/07/2022	5 m	--	--	--	--	0.7	7.7	--	646	12.0	--
Augusta	9/07/2022	6 m	--	--	--	--	0.6	7.6	--	646	9.2	--
Augusta	9/07/2022	7 m	--	--	--	--	0.6	7.5	--	651	7.8	--
Augusta	9/07/2022	8 m	--	--	0.105	--	0.5	7.5	--	660	7.1	--
Augusta	9/07/2022	9 m	--	--	--	--	0.5	7.3	--	679	6.6	--
Augusta	9/07/2022	10 m	--	--	0.326	--	0.4	7.2	--	700	6.3	--
Augusta	9/07/2022	11 m	--	--	--	--	0.4	7.1	--	709	6.3	--
Augusta	9/07/2022	12 m	--	--	--	--	0.4	7.1	--	715	6.2	--
Augusta	9/07/2022	13 m	126	--	0.407	--	0.3	7.0	--	720	6.2	--

J-	The result is an estimated quantity and may be biased low.
J+	The result is an estimated quantity and may be biased high.
U	The analyte was analyzed for, but was not detected.

Table A-2 Lake Augusta 2022 Stormwater Quality Monitoring Results

Parameter / Analysis Location / Units		Phosphorus, total, as P / Lab / mg/l	Solids, total suspended / Lab / mg/l	Dissolved oxygen / Field / mg/l	pH / Field / pH units	Specific conductance @ 25 ºC / Field / umhos/cm	Temperature / Field / deg C	Turbidity / Field / NTU
Location	Date							
NE Inlet	4/30/2022	**0.056**	**10.8**	--	--	--	--	--
NE Inlet	5/25/2022	**0.100**	**11.4**	--	--	--	--	--
NE Inlet	6/29/2022	**0.313**	**7.0**	--	--	--	--	--
NE Inlet	8/06/2022	**0.183**	**46.4**	**8.8**	**7.8**	**104**	**23.4**	**58.1**
NE Inlet	8/12/2022	**0.169**	**76.5**	**9.6**	**7.6**	**110**	**18.6**	**106**
NE Inlet	8/22/2022	**0.101**	**8.2**	--	--	--	--	--
NE Inlet	8/28/2022	**0.096 H**	**24.0 H**	**6.8**	**7.4**	**259**	**20.1**	**34.7**
NE Inlet	9/02/2022	**0.104**	**3.2**	**5.59**	**7.88**	**1210**	**19.4**	**5.04**
NE Inlet	9/14/2022	**0.121**	**4.2**	**2.0**	**7.7**	**1074**	**16.2**	**10.1**
NE Inlet	9/25/2022	**0.146**	**6.5**	**6.4**	**7.0**	**1360**	**14.0**	**14.7**
SE Inlet	4/30/2022	**0.118**	**12.6**	--	--	--	--	--
SE Inlet	5/25/2022	**0.082**	**5.7**	--	--	--	--	--
SE Inlet	6/29/2022	**0.049**	**7.8**	--	--	--	--	--
SE Inlet	8/06/2022	**0.242**	**20.7**	**8.6**	**8.3**	**555**	**23.1**	**16.5**
SE Inlet	8/12/2022	**0.195**	**19.0**	**9.3**	**8.0**	**348**	**20.3**	**17.4**
SE Inlet	8/22/2022	**0.106**	**3.6**	--	--	--	--	--
SE Inlet	8/28/2022	**0.231 H**	**21.0 H**	**6.0**	**6.9**	**316**	**20.7**	**28.9**
SE Inlet	9/02/2022	**0.100**	< 1.0 U	**6.85**	**7.35**	**955**	**15.54**	**1.4**
SE Inlet	9/14/2022	**0.066**	**2.2**	**7.77**	**7.00**	**908**	**14.6**	**1.1**
SE Inlet	9/25/2022	**0.090**	**27.8**	**7.5**	**7.2**	**864**	**13.8**	**6.4**
SE Inlet-1	5/25/2022	**0.068**	**5.1**	--	--	--	--	--
SE Inlet-1	6/29/2022	**0.021**	< 1.0 U	--	--	--	--	--
SE Inlet-1	8/06/2022	**0.253**	**17.7**	**8.7**	**7.9**	**574**	**23.2**	**13.7**
SE Inlet-1	8/12/2022	**0.207**	**18.0**	**8.2**	**8.3**	**440**	**21.3**	**16.4**
SE Inlet-1	8/22/2022	**0.039**	**15.8**	--	--	--	--	--
SE Inlet-1	8/28/2022	**0.234 H**	**18.6 H**	**6.1**	**6.9**	**363**	**21.2**	**31.1**
SE Inlet-1	9/02/2022	**0.040**	**1.6**	**8.42**	**7.32**	**950**	**14.81**	**0.9**
SE Inlet-1	9/14/2022	**0.031**	**1.4**	**8.2**	**6.8**	**894**	**14.3**	**0.5**
SE Inlet-1	9/25/2022	**0.038**	**1.6**	**8.7**	**7.0**	**845**	**13.6**	**1.3**
SW Inlet	8/28/2022	**0.210 H**	**22.0 H**	**4.5**	**7.4**	**419**	**21.3**	**25.9**

H Recommended sample preservation, extraction or analysis holding time was exceeded.

U The analyte was analyzed for, but was not detected.

Appendix B

Detailed Cost Estimates for Improvement Options

Lake Augusta Water Quality Improvement
and Outlet Feasibility Study

PREPARED BY: BARR ENGINEERING COMPANY

PROJECT DESIGN	
ENGINEER'S OPINION OF PROBABLE PROJECT COST	BY: NST2 DATE: 2/28/2023
PROJECT: Lake Augustana Water Quality Improvements	CHECKED BY: DATE:
LOCATION: City of Mendota Heights - Mendota Heights, MN	APPROVED BY: DATE:
PROJECT #: 23191476	ISSUED: DATE:
OPINION OF COST - SUMMARY	ISSUED: DATE:
	ISSUED: DATE:
	ISSUED: DATE:

Engineer's Opinion of Probable Project Cost
Lake Augusta Lift Station
10% Design

	Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
GENERAL AND EROSION CONTROL							
		Mobilization/Demobilization	LS	1	$24,000.00	$24,000	
		Site Prep, Maintenance, and Restoration	LS	1	$20,000.00	$20,000	
		Erosion and Sediment Control	LS	1	$10,000.00	$10,000	
		Dewatering	LS	1	$10,000.00	$10,000	
PUMP STATION AND UTILITIES							
		6 ft Precast Lift Station	Each	1	$16,000.00	$16,000	
		5 ft Valve Vault	Each	1	$10,000.00	$10,000	
		Forcemain Tie in	Each	1	$900.00	$900	
		12" RCP	LF	130	$50.00	$6,500	
		12" Flared End Section	Each	1	$200.00	$200	
		3" DIP	LF	60	$130.00	$7,800	
		3" DIP 90-degree Bends	Each	2	$400.00	$800	
		3" HDPE Pipe	LF	50	$15.00	$750	
		3" Butterfly Valve	Each	2	$1,750.00	$3,500	
		3" Check Valve	Each	2	$2,000.00	$4,000	
		3" HDPE Bends	Each	2	$200.00	$400	
		3"x3"x3" DIP Wye	Each	1	$1,000.00	$1,000	
		Trash Rack	Each	1	$4,000.00	$4,000	
		Pump	LS	1	$35,000.00	$35,000	
		Hatches	LS	1	$10,000.00	$10,000	
		Vent Pipe	Each	1	$100.00	$100	
		Electrical	LS	1	$100,000.00	$100,000	
		CONSTRUCTION SUBTOTAL				$265,000	
		CONSTRUCTION CONTINGENCY/CHANGE ORDERS (10%)				$27,000	
		ESTIMATED CONSTRUCTION COST				$292,000	
		ENGINEERING, DESIGN, PERMITTING				$60,000	
		CONSTRUCTION OBSERVATION (~5%)				$50,000	
		ESTIMATED TOTAL PROJECT COST				**$402,000**	
		ESTIMATED ACCURACY RANGE, CLASS 5	**-30%**			**$282,000**	
			50%			**$603,000**	

Notes

1 10% Design Work Completed

2 Quantities Based on Preliminary Design Work Completed.

3 Unit Prices Based on Information Available at This Time.

4 Some Soil and Field Investigations Completed. Costs include disposal of estimated quantities of contaminated soils.

5 This Class 5 (10% design completion per ASTM E 2516-11) cost estimate is based on 10% design, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -30% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

6 Estimate costs are reported to nearest thousand dollars.

PREPARED BY: BARR ENGINEERING COMPANY				
BARR	BY: GJW	DATE: 3/8/2023		
PROJECT DESIGN	CHECKED BY:	DATE:		
ENGINEER'S OPINION OF PROBABLE PROJECT COST	APPROVED BY:	DATE:		
PROJECT: Lake Augusta Water Quality Improvements	ISSUED:	DATE:		
LOCATION: City of Mendota Heights - Mendota Heights, MN	ISSUED:	DATE:		
PROJECT #: 23191476	ISSUED:	DATE:		
OPINION OF COST - SUMMARY	ISSUED:	DATE:		

Engineer's Opinion of Probable Project Cost
Lake Augusta Shoreline Tree Removal
10% Design

	Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
GENERAL AND EROSION CONTROL							
		Felling Dead Trees	LS	1	$36,000.00	$36,000	
		Forestry Mowing	LS	1	$20,000.00	$20,000	
		Large Tree Removal	LS	1	$50,000.00	$50,000	
		SUBTOTAL				$106,000	
		CONTINGENCY/CHANGE ORDERS (10%)				$11,000	
		ESTIMATED COST				$117,000	
		DESIGN, PERMITTING				$20,000	
		CONTRACTOR OVERSIGHT (~5%)				$6,000	
		ESTIMATED TOTAL PROJECT COST				**$143,000**	
		ESTIMATED ACCURACY RANGE, CLASS 5	**-30%**			**$101,000**	
			50%			**$215,000**	

Notes

[1] 10% Design Work Completed

[2] Quantities Based on Preliminary Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] Some Soil and Field Investigations Completed. Costs include disposal of estimated quantities of contaminated soils.

[5] This Class 5 (10% design completion per ASTM E 2516-11) cost estimate is based on 10% design, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -30% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate costs are reported to nearest thousand dollars.

PREPARED BY: BARR ENGINEERING COMPANY

BARR

	BY:	GJW	DATE:	3/14/2023
	CHECKED BY:		DATE:	
	APPROVED BY:		DATE:	
	ISSUED:		DATE:	
	ISSUED:		DATE:	
	ISSUED:		DATE:	
	ISSUED:		DATE:	

PROJECT DESIGN

ENGINEER'S OPINION OF PROBABLE PROJECT COST

PROJECT: Lake Augustana Water Quality Improvements

LOCATION: City of Mendota Heights - Mendota Heights, MN

PROJECT #: 23191476

OPINION OF COST - SUMMARY

Engineer's Opinion of Probable Project Cost
Cemetery Pond
10% Design

	Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
GENERAL AND EROSION CONTROL							
		Mobilization/Demobilization	LS	1	$12,000.00	$12,000	
		Erosion and Sediment Control, Restoration	LS	1	$20,000.00	$20,000	
		Tree Removal, Clearing and Grubbing	LS	1	$20,000.00	$20,000	
		Land/Easement Acquisition	Acre	1	$20,000.00	$20,000	
GRADING AND UTILITIES							
		Excavation	CY	1,000	$35.00	$35,000	
		Outlet Structure	LS	1	$20,000.00	$20,000	
		CONSTRUCTION SUBTOTAL				$127,000	
		CONSTRUCTION CONTINGENCY/CHANGE ORDERS (10%)				$13,000	
		ESTIMATED CONSTRUCTION COST				$140,000	
		ENGINEERING, DESIGN, PERMITTING				$30,000	
		CONSTRUCTION OBSERVATION (10%)				$14,000	
		ESTIMATED TOTAL PROJECT COST				**$184,000**	
		ESTIMATED ACCURACY RANGE, CLASS 5	**-30%**			**$129,000**	
			50%			**$276,000**	

Notes

[1] 10% Design Work Completed

[2] Quantities Based on Preliminary Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] Some Soil and Field Investigations Completed. Costs include disposal of estimated quantities of contaminated soils.

[5] This Class 5 (10% design completion per ASTM E 2516-11) cost estimate is based on 10% design, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -30% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate costs are reported to nearest thousand dollars.

PREPARED BY: BARR ENGINEERING COMPANY

PROJECT DESIGN
ENGINEER'S OPINION OF PROBABLE PROJECT COST
PROJECT: Lake Augustana Water Quality Improvements
LOCATION: City of Mendota Heights - Mendota Heights, MN
PROJECT #: 23191476
OPINION OF COST - SUMMARY

BY:	GJW	DATE:	3/14/2023
CHECKED BY:		DATE:	
APPROVED BY:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost
Pond 2 Enhancements
10% Design

	Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
GENERAL AND EROSION CONTROL							
		Mobilization/Demobilization	LS	1	$47,000.00	$47,000	
		Erosion and Sediment Control, Restoration	LS	1	$20,000.00	$20,000	
		Tree Removal, Clearing and Grubbing	LS	1	$10,000.00	$10,000	
		Land/Easement Acquisition, Wetland Mitigation	Acre	1	$50,000.00	$50,000	
GRADING AND UTILITIES							
		Excavation	CY	10,000	$30.00	$300,000	
		24" RCP	LF	50	$90.00	$4,500	
		Flow Distribution Structure	LS	1	$10,000.00	$10,000	
		Geotextile	SY	495	$5.00	$2,475	
		Clean Washed Filter Sand	Ton	280	$100.00	$28,000	
		Iron Aggregate	Ton	19	$1,500.00	$28,500	
		Underdrain/Cleanouts	LS	1	$20,000.00	$20,000	
		CONSTRUCTION SUBTOTAL				$520,000	
		CONSTRUCTION CONTINGENCY/CHANGE ORDERS (10%)				$52,000	
		ESTIMATED CONSTRUCTION COST				$572,000	
		ENGINEERING, DESIGN, PERMITTING				$50,000	
		CONSTRUCTION OBSERVATION (~5%)				$28,000	
		ESTIMATED TOTAL PROJECT COST				**$650,000**	
		ESTIMATED ACCURACY RANGE, CLASS 5	**-30%**			**$455,000**	
			50%			**$975,000**	

Notes

[1] 10% Design Work Completed

[2] Quantities Based on Preliminary Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] Some Soil and Field Investigations Completed. Costs include disposal of estimated quantities of contaminated soils.

[5] This Class 5 (10% design completion per ASTM E 2516-11) cost estimate is based on 10% design, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -30% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate costs are reported to nearest thousand dollars.