Technical Memo

To: Three Lake Improvement District

From: Rebecca Carlson, P.E. (MN)
Lu Zhang
Wenck Associates, Inc.

Date: March 30, 2018

Subject: Findings-Alternatives Assessment

Residents on the Briggs Lake Chain experience frequent periods high water resulting in localized flooding and observance of a No Wake Ordinance. Water level stabilization is a priority for the residents.

The Three Lake Improvement District (TLID) hired Wenck to assess the cause(s) of the high-water conditions and identify three hydrologic/hydraulic alternatives to improve water level stabilization and improve the lake outlets. Secondary impacts on AIS and water quality for each alternative were also evaluated.

This technical memo is organized in the following sections:

1. Existing Conditions
   1.1. Water Balance
   1.2. Existing Lake Outlet Function
   1.3. Fisheries
   1.4. Water Quality
2. Drivers of High Water
3. Alternatives
4. Recommendations & Next Steps
5. Data Sources for this Study

1.0 Existing Conditions

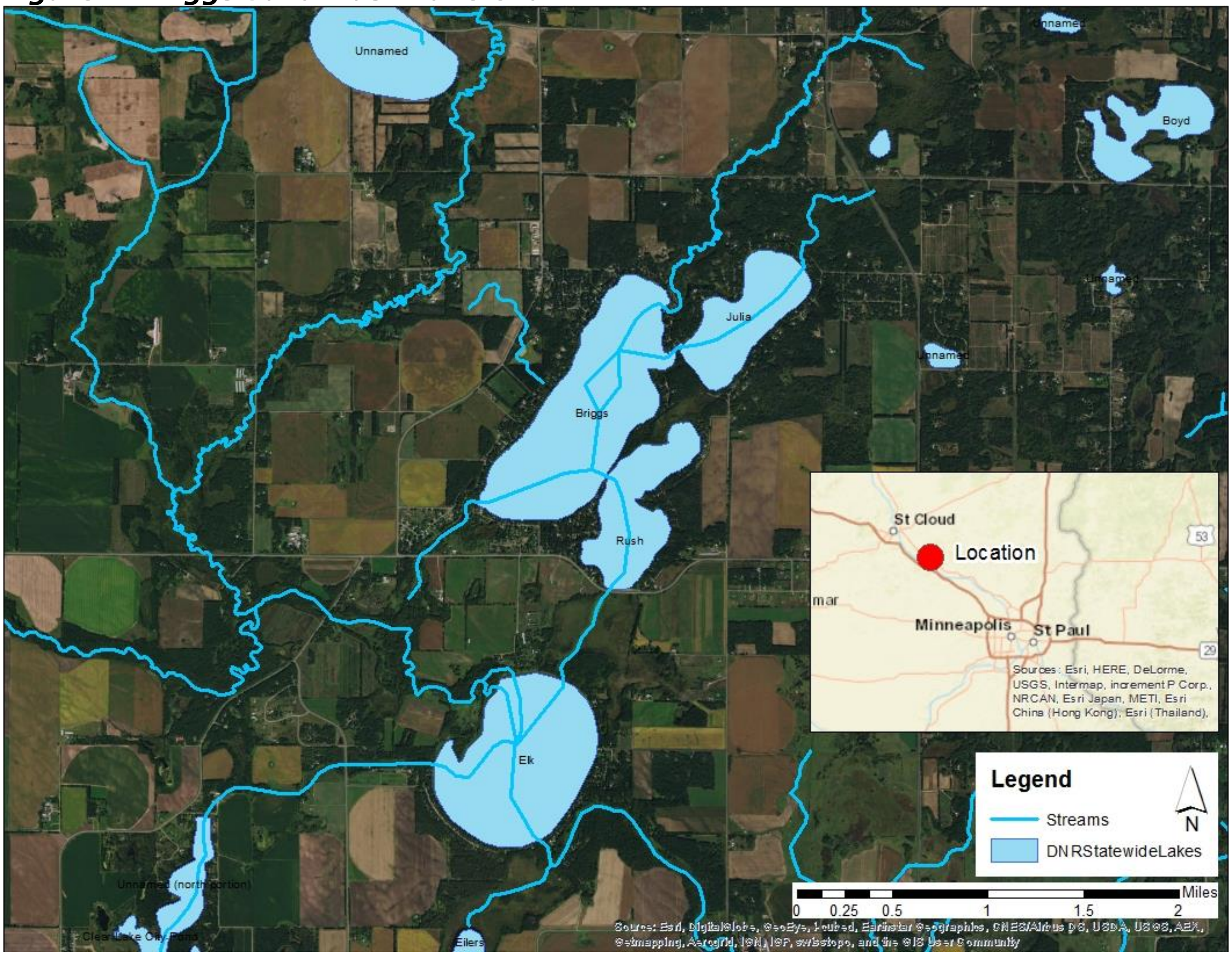
Briggs lake chain includes three lakes: Julia, Briggs, and Rush. They are located north of City of Clear Lake and drains into Big Elk Lake from Lily Creek. Big Elk is located on Elk River (Figure 1).

The dominant landuse of the lake subwatersheds is agriculture, making up 33% of the subwatersheds, followed by forest, 22% of the subwatersheds. Total area and percentage of wetland within the subwatersheds is 340 acres and 8% and the major soil type is A.

The Briggs Creek drainage area, also tributary to Briggs Lake, is 5,858 acres. Wetlands take up 1,773 acres and 30% of Briggs Creek subwatersheds. Most of the wetlands in the subwatershed are located adjacent to the creek.

This memo summarized the existing conditions of the lake chain and alternatives identified. Benefit, cost, regulatory issues and secondary benefits are presented for each alternative.

Figure 1. Briggs-Julia-Rush Lake Chain



1.1 Water Balance

Briggs Lake is a deep lake of 20′ maximum depth; Julia and Rush are both shallow lakes at 12′. All three lakes share the same Ordinary High Water Level (OHWL) of 964.2 ft. Based on the 10-yr lake level records, the lake chain has an OHWL exceedance probability of 7% historically and close to 11% in recent years with maximum recorded water levels of 967.42 ft on Briggs Lake and 968.03 on Rush Lake. The exceedance probability calculation is based on existing, incomplete, lake level records. Exceedance events could be underrepresented.

The average exceedance level for both lakes was 1 ft according to the records. Figures 2 and 3 are the 10-year water level plots for the lakes. Table 1 summarizes properties of the lakes. The 10-year lake level records suggest that OHWL exceedances have increased in severity and magnitude recently.

Figure 2. Briggs Lake Level 10-yr Records

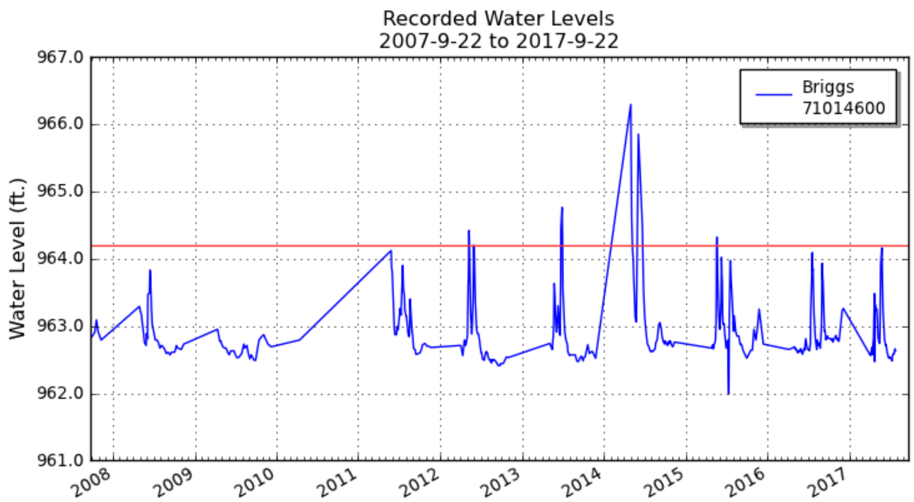


Figure 3. Rush Lake Level 10-yr Records

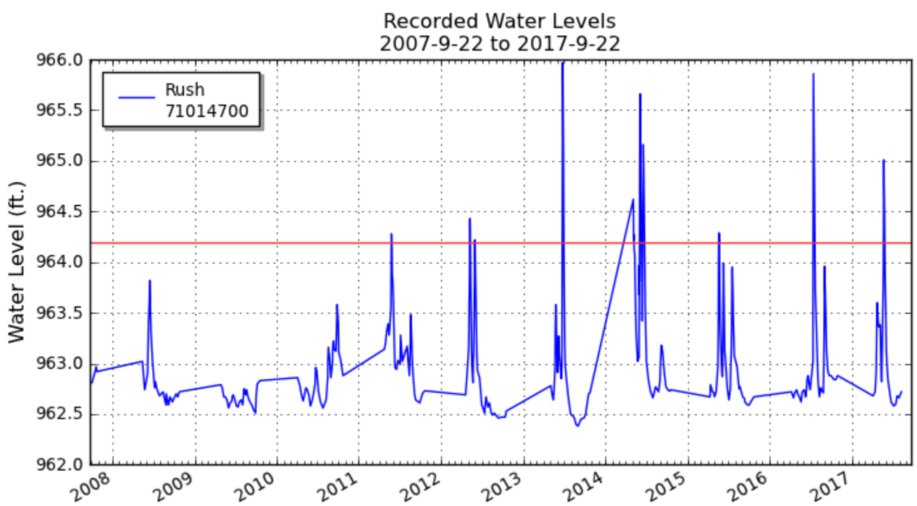
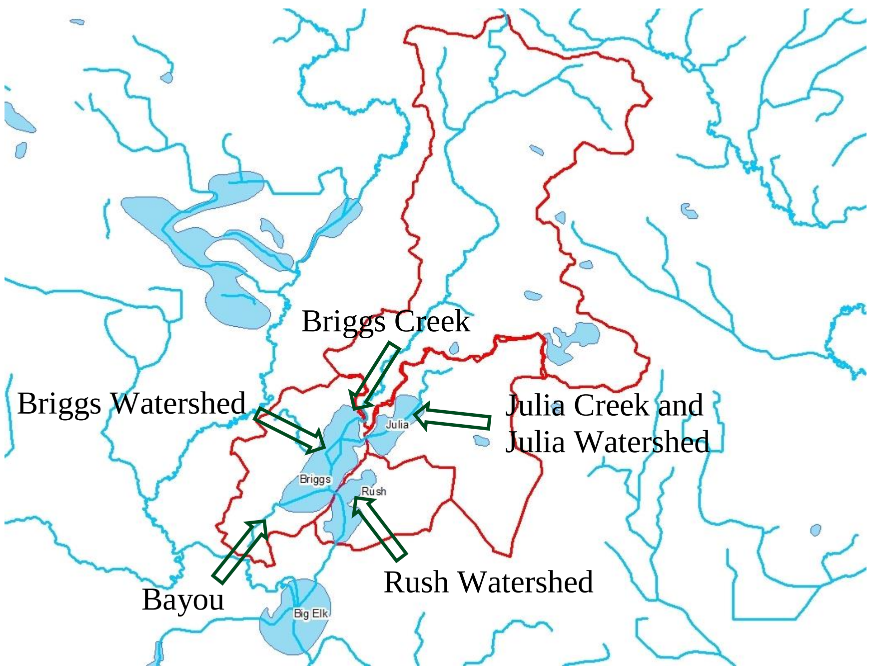


Table 1. Briggs, Julia, and Rush Lake Property

	Briggs	Julia	Rush
OHW	964.2 ft	964.2 ft	964.2 ft
Max Recorded Level	967.42 ft	967.2 ft	968.03 ft
Surface Area	404 ac	152 ac	161 ac
Lake Depth	20 ft	12 ft	12 ft
Lakeshed Area	1,510 acres- direct lakeshed 5,858 acres- Briggs Creek	1,939 acres	809 acres

As shown on Figure 4, Briggs Lake Chain receives surface water input from the watersheds draining to Briggs Creek and Julia Creek. The area known as the Bayou is the overflow channel connecting Elk River and Briggs Lake. The upstream portion of this channel a poorly defined wetland. Intermittent, seasonal (springtime) flows have been observed in the Bayou.

Figure 4. Briggs Lake Chain Flow Directions



Our calculated water balance aligned with the findings of the SWCD 2006-2007 phosphorus mass balance study: Briggs Creek contributes, on average, 46% of the flow to the lake system when Bayou channel is not flowing, and 39% when the Bayou is flowing. Figure 5 is the water balance summary. Evidence suggests that while runoff from Briggs Creek is a consistent, annual volume to the lake chain, the impact of inflow from the Bayou is intermittent. This points to prioritizing runoff volume management in Briggs Creek sub-watershed over the watershed upstream of the Bayou. Figure 6 shows lake levels and precipitation.

It is important to note that the water balance was based on two years of data, 2006 and 2007, where exceedances of the No Wake Zone Elevation were not recorded in the lake level record (Figure 6).

From a water quality perspective, the phosphorus contribution to the lake chain in years where the Bayou contributes is high, almost 50% to the total phosphorus load to the lake. The concentrations in Briggs Creek are lower than those measured in the Bayou and total phosphorus contributions from Briggs Creek are numerically are just over half of what the Bayou inflow contributes in years where it does flow into the lake.

Current available data suggests that the hydraulic contribution of inflow to the lake chain from the Bayou Channel is small and intermittent. Existing data suggests the Bayou doesn't contribute to the lake chain every year. However, anecdotal accounts indicate that inflows from the Bayou are highly correlated to exceedances of the No Wake Zone elevation. Further, there is no data collected in years where exceedances of the no wake zone elevation occurred. Additional data collection is recommended to fully assess impacts of the Bayou on the lake chain elevations. Data collection recommendations are summarized at the end of this memo.

Figure 5. Water Balance

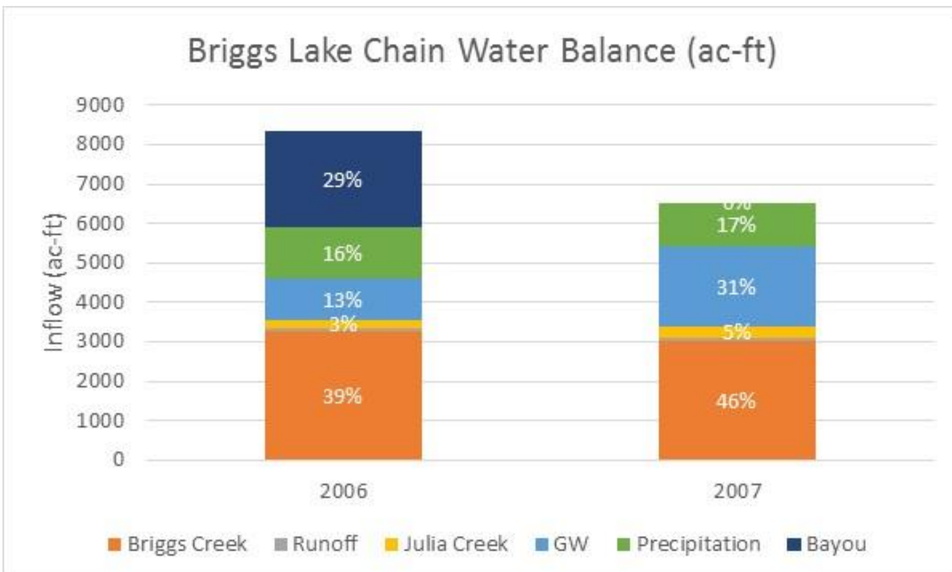
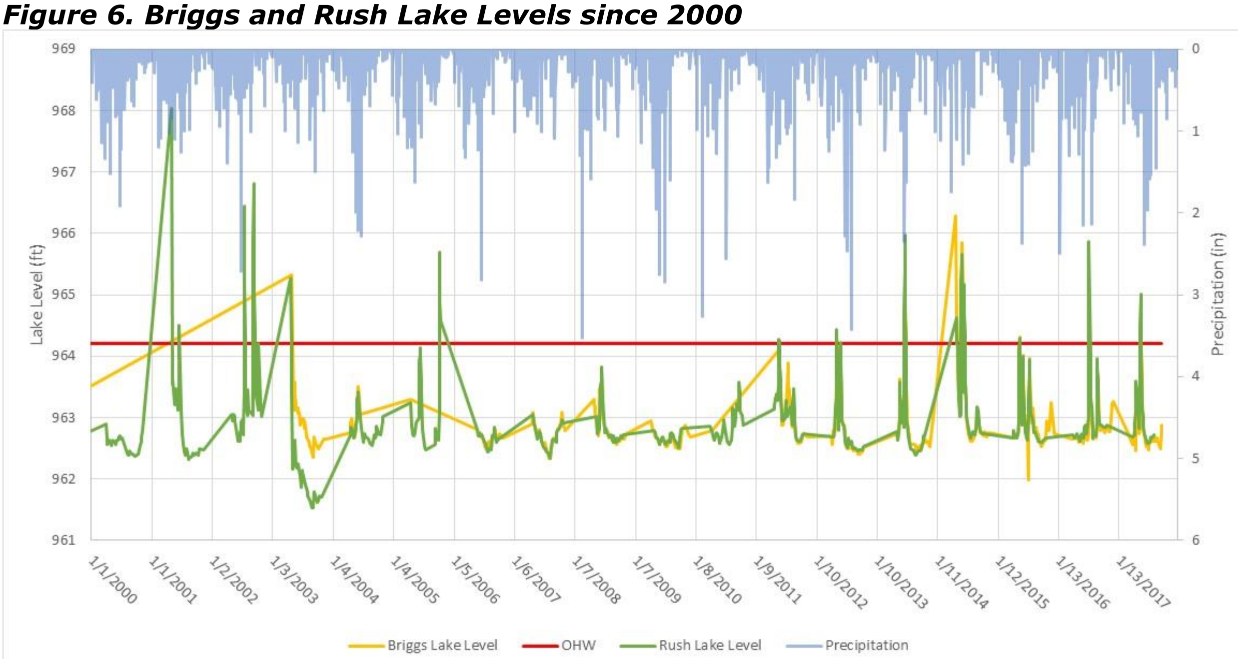


Figure 6. Briggs and Rush Lake Levels since 2000



1.2 Existing Lake Outlet Function

Briggs Lake is connected to both Julia and Rush by natural channels. Rush Lake outlets to Lily Creek discharging into Big Elk Lake through a sharp crested weir. No elevation was available for the top of the weir, the elevation was estimated from USACE records. According to the information provided by DNR Fisheries, the weir was constructed in 1932. The steel screen fish barrier was installed to control the carp population in 1979. The screen was extended into the banks in 1984 to improve carp exclusion. The Lake Association added panels in front of the weir between 1984 and 1988, these were removed due to due to flooding.

The high in-lake macrophyte population (especially the high concentration near the outlet of Rush Lake) and the presence of curly leaf pondweed contribute to periodic clogging of the screens and reduced outflow of the lake chain despite consistent maintenance.

Hydraulically, the components of the outlet include the sharp crested weir itself, the channel restriction at the bridge, the remainder of the channel and the fish barrier. The sketch (Figure 7) below represents the weir elevation relative to the OHWL and the outlet channel bottom. Weir crest elevation shown in the USACE report and the channel bottom elevation estimated from the record drawing.

Data indicates restrictions on lake outlet itself are a factor in exceedances of the OHWL.

Each component of the outlet was evaluated for capacity and its impact on lake drawdown time. The bridge flow capacity was calculated using manning's flow; the weir flow capacity was calculated as a suppressed sharp-crested weir; and the fish barrier flow capacity was estimated as a series of orifices with and without 25% clogging. Table 2 below summarized the calculated flow and drawdown time for each structure.

Figure 7. Rush Lake Outlet Schematic ~50' horse-shoe weir length

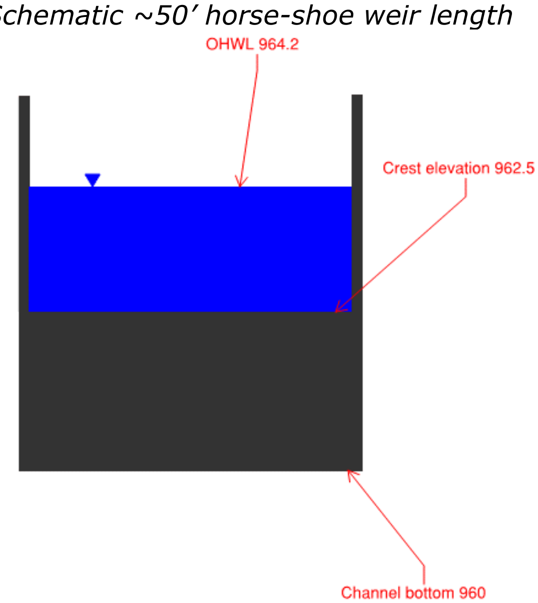


Table 2. Flow Capacity and Drawdown Time to assumed weir crest (962.5) for each Outlet Structure

	Bridge		Weir		Fish Barrier		Fish Barrier (25% clogged)	
Starting Lake El.	Q (cfs)	Drawdown (hrs)	Q (cfs)	Drawdown (hrs)	Q (cfs)	Drawdown (hrs)	Q (cfs)	Drawdown (hrs)
964.2	679	21	356	40	320	44	240	59
965.5	882	31	712	52	641	58	481	77
966.2	1101	39	1142	61	833	69	625	92
967.2	1336	46	1635	68	939	79	704	105
968.2	1588	52	2184	74	1034	88	776	118

The bridge structure cross-section was estimated using the bridge survey record drawings. However, this is different from the cross section presented in the USACE report from 1987. It was unclear which plan set was correct. The USACE cross section for the bridge shows that it only restricts outflow during high flow (when lake elevation is above 966).

Modeling shows that the existing weir doubles the outlet time (adding about 1 day to drawdown periods). The fish barrier, fully open, adds about 4 hours, to drawdown time and even a small amount of clogging, adds almost 2 days to the drawdown time for the lake.

Without the weir or fish barrier, the bridge will allow drawdown of 4 feet of water above OHWL within 52 hours. By having the weir in place, the drawdown time will increase to 74 hours. The drawdown time increases significantly when the fish barrier is clogged by curly leaf pondweed.

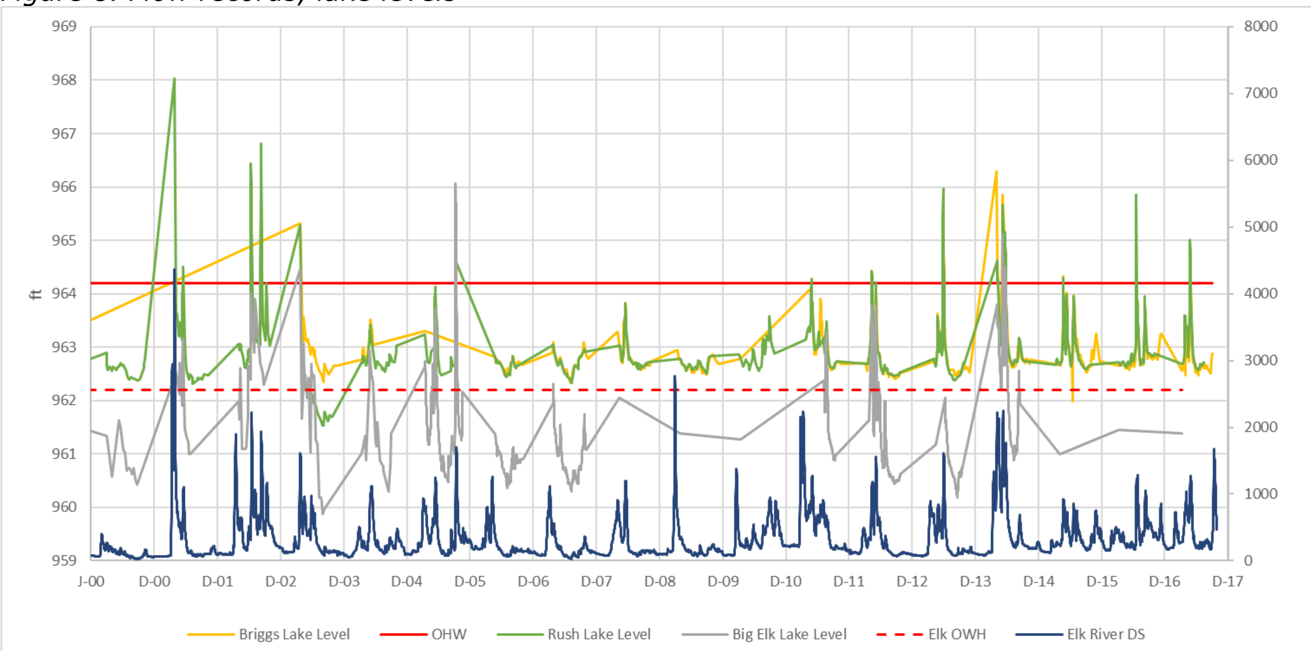
The evaluations above assume a free-flowing outlet and ample downstream capacity. This may not be the case in all OWHL exceedance events for the Briggs Chain. The incomplete lake elevation record shows that at least 40% of the time that the Briggs Chain is experiencing an exceedance of its OWHL, Big Elk Lake also exceeds its OWHL of 962.2. The actual correlation could be higher as lake elevations are highly correlated. The exceedances are also highly correlated with exceedances of the 10 and 100-year flow events for the Elk River downstream of Big Elk Lake, Figure 8, Table 3.

Table 3. Comparison of OHWL Exceedance Frequencies

	OWHL Exceedance Frequency Briggs-Julia-Rush Lakes	OHWL Exceedance Frequency Big Elk Lake
1948-2017	5.58%	21.09%
1980-2017	5.62%	21.31%
2008-2017	7.03%	21.78%
2013-2017	10.60%	28.15%

(no data from 1980 to 1983)

Figure 8. Flow records, lake levels



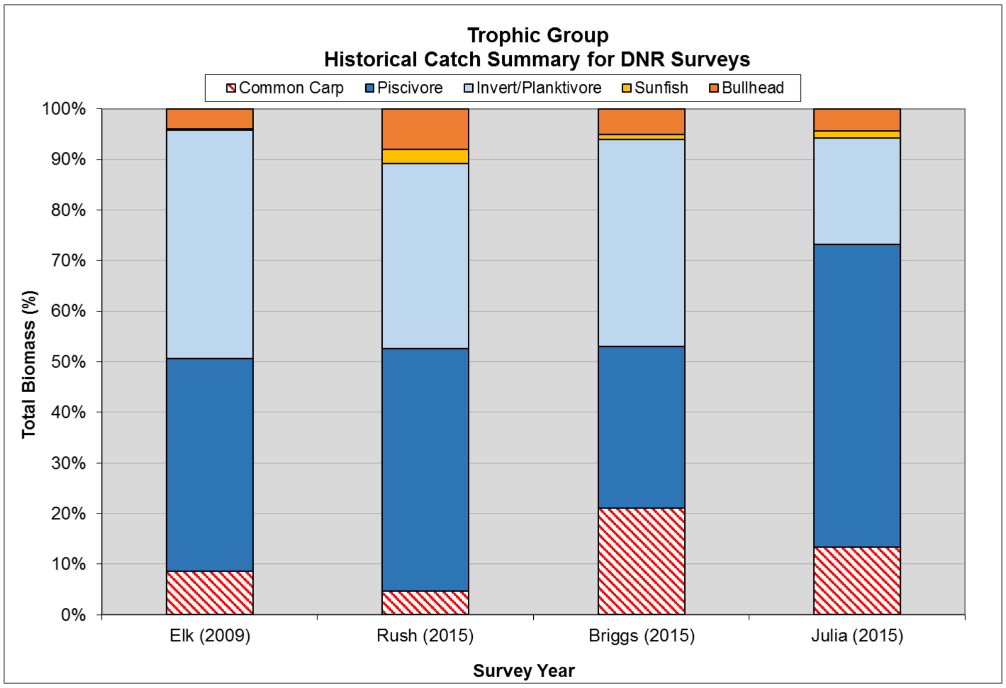
This indicates that while improving the condition on the Rush Lake Outlet is important and will provide some benefit, it alone will not be sufficient to reduce the frequency and duration of OHWL exceedance on the Briggs-Julia- Rush Chain. Assessing the capacity of the Big Elk Lake outlet as well as the capacity in the Elk River just downstream of Elk Lake will be necessary.

1.3 Fisheries & AIS

The fish barrier is intended to prevent carp from migrating from Big Elk Lake to Rush Lake. A review of the fisheries data suggested carp presence in all 4 lakes (Figure 9). Young of year carp were observed in Julia and Rush lakes (0 to 5-inch individuals). Large individuals (20 to 34-inch individuals) were observed in all 4 lakes. There is no evidence that the current fish barrier prevents movement of common carp from Big Elk Lake into Rush Lake.

The age/ size distribution of the existing carp population in the Briggs Chain strongly suggests recruitment upstream of the fish barrier. This means that the existing population within the lake chain is self-sustaining and even if the barrier does prevent migration, it is not a factor in reducing upstream carp populations. The fish barrier appears to have an insignificant impact on the ability of common carp to persist on both sides of the barrier.

Figure 9. Trophic Summary of Total Biomass Expressed as a Percent of Total Biomass



1.4 Water Quality

Briggs Lake Chain is included in the Mississippi River (St. Cloud) Watershed TMDL (2015). All three lakes are impaired with nutrients. Sherburne County SWCD also conducted a water quality study in 2015. The water quality for each lake is summarized below:

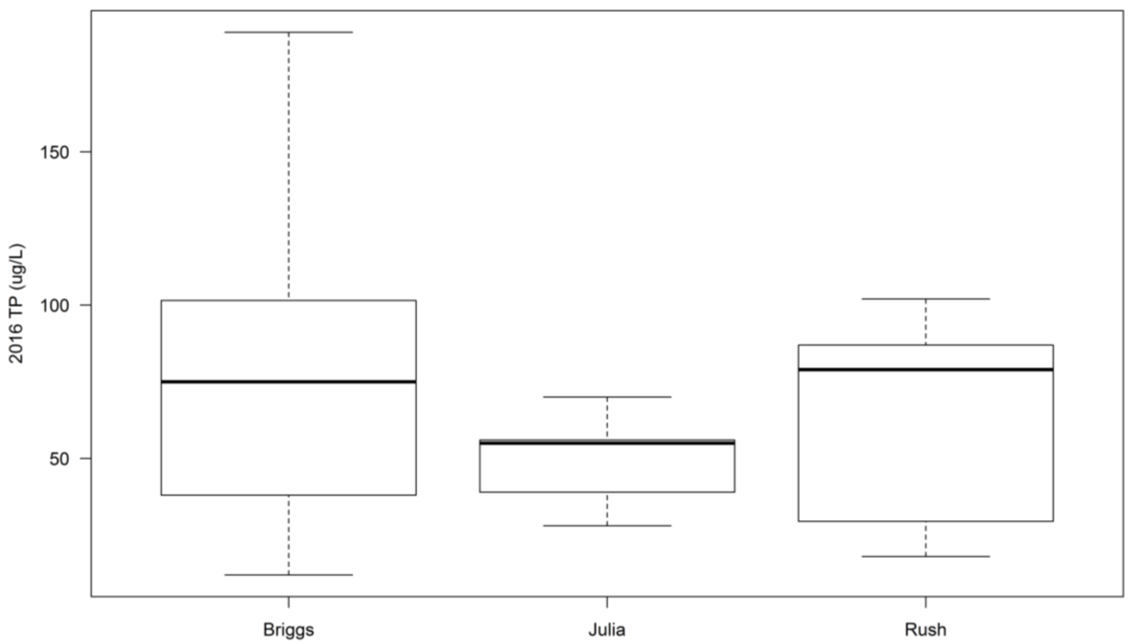
- Julia Lake
  - TMDL stated that in-lake summer phosphorus and chlorophyll-a was near or even below the state standard for shallow lakes (60 ug/L). The Lake Response Model predicted the in-lake TP concentration to be 60 ug/L where observed was 61.8 ug/L. Internal loading was the biggest input, making up 56% of the total load.
  - The 2015 water quality from the SWCD report measured TP entering the lake from Julia Creek to be ranging from 49 ug/L to 298 ug/L, where the highest TP was measured in May.
  - TMDL indicated that no nutrient reduction was required for Julia Lake.
- Briggs Lake
  - TMDL stated that in-lake summer phosphorus and chlorophyll-a have exceeded the deep lake standard (40 ug/L). The Lake Response Model predicted the in-lake TP concentration to be 72.1 ug/L where observed was 75 ug/L. Internal loading was the biggest input as well, making up 56% of the total load.
  - SWCD measured Briggs Creek water quality. TP in the creek ranged from 27 ug/L to 108 ug/L, where the highest was in June.

- TMDL indicated that reduction in Briggs Lake direct watershed TP load by 70% and reduction in sediment release rate by 85% will help Briggs Lake meet the water quality goal.

- Rush Lake
  - TMDL stated that in-lake summer phosphorus, chlorophyll-a and Secchi disk depth have exceeded the state standard for shallow lake (60 ug/L). The Lake Response Model predicted the in-lake TP concentration to be 103.7 ug/L where the observed was 105.7 ug/L.
  - TMDL indicated that reduction in Rush Lake direct watershed TP load by 68% and reduction from internal loading by 45%, combined with water quality improvement from Briggs Lakes will help Rush Lake meet the water quality goal.

The 2016 monitoring results are summarized in Figure 10. Julia Lake stayed close to the standard and Briggs and Rush Lake both exceeded the water quality standard. The alternatives for lake level management outlined in later section address the water quality impact for each option.

Figure 10. 2016 TP Concentration in Briggs, Julia, and Rush Lake



2.0 Drivers of High Water Conditions

Available data suggests that the primary drivers of the highwater conditions are

- Limitations in the lake outlet capacity
- Downstream capacity (Elk Lake and Elk River capacity)
- Drainage from the Briggs Lake sub-watershed

These findings are validated by the HSPF model as well as previous water balance work conducted by County SWCD staff.

However, anecdotal accounts suggest that the Bayou may be a bigger part of overall contributions to the hydrology and to exceedances of the No Wake Zone. Existing data shows that inflows from the Bayou can be as much as 50% of the total phosphorus load to Briggs Lake in years where the Bayou is discharging.

Eliminating the phosphorus load to the Briggs Lake Chain from the Bayou would have a significant positive impact on water quality in Briggs Lake, and may have a positive impact on lake levels.

3.0 Alternatives

Given the drivers of OHWL exceedance, the demonstrated drivers and the perceived drivers, the alternatives to mitigate fall into three categories:

- Additional data collection- to document the Bayou contribution to the Briggs Chain of lakes.
- Upstream storage- specifically in the Briggs sub-watershed, or potentially the Big Elk Watershed.
- Inlet modification- Altering the Bayou inlet to Briggs Lake
- Outlet modification-Improve the efficiency of the Lilly Creek Outlet.

It is likely that pursuing multiple options will provide the best overall outcome in terms of reduced frequency and duration of exceedance of the OHWL. It is important to consider that the information available for review is historical, and that precipitation patterns have shifted and may continue to shift. Precipitation events tend to be larger in volume, number, increasingly localized with higher intensities. The alternatives presented to reduce frequency and duration of OHWL exceedances should be applied with safety factors to account for potential increases in precipitation and runoff.

1. **Data Collection-** Gaps in the data record inhibit a full accounting of the contribution of the Bayou inflows to the lake chain. The following data collection is recommended. In kind staff time support from the Sherburne SWCD may be available to implement this work. Level loggers are generally $1,000 each. Five are recommended. The MPCA may have equipment Sherburne SWCD could borrow.
    a. Survey data for
        i. Lilly Creek outlet channel
        ii. The Bayou inlet channel
        iii. Big Elk Lake Outlet
        iv. Elk River just downstream of Big Elk Lake
    b. Daily lake level/stage records to produce a daily flow record
        i. Big Elk Lake
        ii. Rush Lake at outlet
        iii. Lilly Creek
        iv. Elk River at Big Elk Lake Outlet
        v. Elk River at CSAH 6
    c. Weekly flow gauging to develop a rating curve at
        i. Elk River at Big Elk Lake Outlet
        ii. Elk River at CSAH 6
        iii. The Bayou (Backwater is suspected, and a full flow record may not be possible)
        iv. Lilly Creek

d. Optional: Collect water quality samples. $50/sample to analyze for TP, SRP and TSS. Conduct 12 sampling events at 5 locations. The lab costs plus shipping is estimated to be $4,500, not including lab costs or data evaluation.

2. **Upstream storage**
   a. **Briggs Creek Sub-watershed:** Data shows that the highest cost/ benefit for meaningful upstream live storage can be achieved by impounding water in the Briggs Creek sub-watershed. This subwatershed is prioritized due to its size and the consistency in nature of runoff volume vs the intermittent inflow from the Bayou. While impoundments along Briggs Creek would be less expensive in terms of capital costs, these are not recommended because of it's status as a trout stream. Any impoundments in this watershed will need to be evaluated for impacts on trout habitat.
   b. **Elk River Watershed:** The Elk River Watershed provides more opportunity in terms of land area, but the positive impacts of impoundments are not as easy to predict. Prior to any impoundments in this sub-watershed, further hydrologic and hydraulic evaluation will be necessary to quantify direct benefits in terms of storage. Direct impoundments on the river are not feasible. Review of existing public drainage systems, and potential for storage funding there is highly recommended. BWSR has prioritized grants for storage along existing public drainage systems.
   c. **Benefit:** Providing upstream temporary storage with slow release, or the opportunity for infiltration/ evapotranspiration can reduce peak lake elevations under many conditions. The limit of the benefit is proportional to the amount of storage provided and depends on where in the hydrograph the impounded water would impact downstream waters. Upstream impoundments work primarily at the low end of the hydrograph (ie low flows). The amount of storage is not a 1:1 reduction in terms of the direct impact on the lake levels.
   d. **Cost:** Cost will depend on the amount of storage achievable. The table below shows the area needed based on depth to achieve various amounts of storage over the lake surface. The cost will primarily consist of installation of a series of outlet structures to restore storage in upstream watersheds.

Table 4. Storage Alternative Summary

	0.5 Feet Storage over lake chain surface area	1 Foot Storage over lake chain surface area
Volume (ac-ft)	470	930
Land Area (acres)	230	470
# of 25-acre projects	10	20
Total Cost	$750,000	$1,250,000
50% Local Match	$375,000	$625,000
25% Local Match	$187,500	$312,500

Assumptions:

- 30% safety factor added to volume
- Reduction would not necessarily be 1 to 1 in terms of reduction in lake levels- overall runoff values for the Elk River Watershed indicate that infiltration is naturally occurring, so location will be critical to achieving results.

- Average storage depth is 2’
- Average project size is 25 acres
- Easement cost is $1200/ ac
- Design/Implementation $12,000
- Includes $150,000 for administration and H&H modeling

e. **Funding**
This type of alternative is well suited to pursuing a grant in partnership with the SWCDs and or the Elk River Watershed Association. Between 50%- 75% match may be allowed depending on source of finding. For funding sources like EQUIP, individual applications are necessary, and the projects may not receive funding. Other funding sources the provide larger scale grants like Board of Water and Soil Resources (BWSR). Both Clean Water Legacy funds or drainage system management funds may be available as storage and impoundments are currently a priority for BWSR, and storage projects that can be linked to water quality benefits would be even higher priority.

f. **Other Impacts:**
Water Quality: Simply impounding wetlands, while beneficial for nitrogen removal, can exacerbate soluble phosphorus loading and low dissolved oxygen conditions to downstream waters. While wetlands can trap excess sediment and the associated particulate phosphorus, they can also export soluble phosphorus in late summer months. This additional biologically available phosphorus exported during the height of the recreational season can exacerbate algal blooms and water quality can deteriorate. If this alternative is selected, evaluation of potentially inundated sediments is recommended. It is likely that a soluble phosphorus removal filter will be needed to offset potential impacts. Further, storage areas in Briggs Lake sub-watershed (even those further up in the watershed) will be more difficult to permit due to trout streams in the area. Impoundments allow water to warm and can be detrimental to trout habitat. However, if areas for infiltration are prioritized, projects could increase baseflow.
AIS: The outlet of any potential impoundment should be fitted with carp exclusion barriers to prevent spring spawning if possible. It is possible that providing additional impoundments might increase carp populations recruited in some years. However, there is already significant carp spawning habitat in the sub-watersheds upstream of the lake chain.
Other: Landowner permission and participation is critical to implementing this alternative. It is important to consider that landowners can show interest early on and then reconsider only after the design process is underway. This can mean significant cost wasted up front.

3. **Potential improvements to the Rush Lake outlet- Fish Barrier** Evaluating the outlet of Rush Lake provided insight into multiple potential improvements on efficiency. These are discussed in order of potential impact.
   a. **Benefit:** Removing the fish barrier or simply improving maintenance will reduce the duration of OHWL exceedances in free-flowing conditions (no

tailwater).

Table 5. Fish Barrier Modification Summary

	Improvement in Discharge Capacity (assuming no tailwater)	
Starting Lake El.	No Fish Barrier (No Clogging Included)	No Fish Barrier (25% logging Considered)
964.2	11%	136%
965.5	11%	208%
966.2	37%	226%
967.2	74%	224%
968.2	111%	219%

b. **Cost & Regulatory Considerations:**
The capital cost for the work to remove of the barrier will likely be under $10,000. This is likely something that could simply be quoted out by the lake association vs. producing design/ construction documents. It is recommended that the TLID coordinate closely with the county and DNR on any specific permit requirements and implement the recommended data collection. These costs will likely be minimal and range from $3,500- $12,000. Increased maintenance however may entail retaining a service to keep the barrier free of debris. Contracting this out may cost between $12,000- and $24,000 per year depending on staff.

c. **Other Impacts:**
This alternative is unlikely to impact water quality or AIS infestations significantly. Downstream capacity is a consideration for this alternative.

4. **Other Rush Lake Outlet Improvements/ Modifications** Table 2 shows the relative impacts of each hydraulic component of the outlet. Assessment of the hydraulic limitations of system components can be conducted during bridge replacement. Channel cleanout may also be considered pending results of the recommended survey.

5. **Bayou Re-Route** Table 6 shows the potential costs for re-routing the Bayou downstream by constructing a sheet pile weir at CSAH 16, preventing inflow from the Elk River to Briggs Lake through the Bayou channel. Significant up-front work would be required for this alternative, with no guarantee of implementation. Anecdotally, the Bayou plays a large role in increasing water levels. Additional data is needed to document the hydrologic, hydraulic and water quality impact of the Bayou. Permitting requirements from the DNR, the USACE and the county will likely include evaluating downstream impacts on Big Elk Lake and the upper portion of the Elk River. A simplified model with input hydrograph and additional data collection documented in alternative 1, should provide the information required. Early coordination with the USACE and DNR is highly recommended.

This alternative is unlikely to have a significant impact on AIS. It has the potential for significant improvements in water quality. Eliminating this inflow may reduce the total phosphorus load to Briggs Lake by 50% in some years. Depending on the findings of the recommended study, lake levels may improve as well.

The impact on the existing road would need to be assessed. It would be possible that reconstruction would be necessary which would make the project infeasible unless the replacement schedule was short term.

A levee along the river would be significantly more expensive and require even more permitting. It was considered cost-prohibitive and results are not presented here.

Table 6. Potential Costs for Bayou Re-Route Alternative

Bayou Bypass- Sheet Pile Weir at CSAH 16					
Item	**Desctiption**	**Unit**	**Qty**	**Est. Unit Cost**	**Extended Cost**
1	Mobilization	LS	1	$ 37,500	$ 37,500
2	Sheet Pile Levee @ CSAH 16	SF	6,000	$ 100	$ 600,000
3	Downstream Outlet Improvement	LS	1	$ 350,000	$ 350,000
				Sub-total	**$ 987,500**
				Design	$ 98,800
				Permitting	$ 148,200
				Construction Support	$ 98,800
				Project Administration	$ 49,400
				Total	**$ 1,382,700**
	Potential Additional Costs				
	Bridge Reconstruction	LF	50	$ 15,000	$ 750,000

6. **Assess Big Elk Lake Outlet/ Elk River Capacity** This alternative involves an assessment of alternatives to improve downstream capacity of the Elk River and Big Elk Lake outlets. This alternative includes using data recommended in Alternative 1 to assess downstream impacts, and identify potential costs for restoring the Big Elk Lake Outlet, a likely requirement for any flow modification project.

4.0 Summary and recommended next steps

The table below summarized the alternatives, and costs and benefits. The recommended next steps are:

1. Fill data gaps. If water quality data can be funded
2. Remove carp barrier from Rush Lake Outlet and evaluate improvements

3. Pursue a grant for either upper watershed funding for storage, or a sheet pile weir to block off the Bayou. The upper watershed storage grant can be written with the information available, with data analysis and modeling backloaded. The Bayou project will require additional investigation of the outlet capacity, downstream hydrologic, hydraulic and water quality impacts, and impact of the Bayou on water quality of Briggs Lake Chain. It is likely that the Bayou alternative would be more effective in terms of water quality and quantity, however it is less likely to be funded or permitted.

Table 7. Summary of Alternatives

Alternative	Cost	Potential Benefit	Implementation Difficulty	Risk	Required Up Front Work
Data Collection	$0 – Possible in kind from SWCD staff	Necessary to support other alternatives	Low	None	Coordination with SWCD staff
Lilly Creek Carp Barrier Removal	<$20,000	Improve drawdown times between 32 and 37%	Low	Potential Downstream Impacts. Need DNR permission.	Coordination with SWCD/ DNR
½ foot of storage	$375,000*	0-1' reduction in peak lake levels water quality benefit will likely not be measurable, and	Moderate	Detailed modeling and safety factor needed to locate basins. Longer timeframe to initiate, dependent on upstream landowner participation.	Grant funding and coordination with local SWCDs
1 foot of storage	$625,000*				
Bayou Re-route (sheet pile weir at CSAH 16)	$1,400,000 **	0-2 foot reduction in peak flows, reduction of 50% or more TP loads in some years	High	Detailed modeling is needed to verify downstream impacts.	Significant work up front is needed without guarantee of implementation

*Cost of local match, assumes 50% grant funded
**Water quality benefits to Briggs Lake may warrant some grant funding, the amount is unlikely to be 50%

The recommended next step is to plan for the data collection in 2018, and begin the process of coordinating with the DNR to remove the carp barrier. Submit application for storage program funding in partnership with SWCDs, prioritizing storage in Sherburne County.

Evaluate data collected in late 2018 and select either storage or Bayou re-direct alternatives.

5.0 Data sources for this Study

Below is a list of data and reports used in this study:

- 2006-2007 phosphorus mass balance study from Sherburne SWCD
- 2015 Briggs & Julia Creek water quality monitoring from Sherburne SWCD
- USACE report July 17, 1987
- HSPF model for the lake chain watershed from MPCA
- Rush lake outlet bridge record drawing from Sherburne County
- Lake TMDL reports
- Flood insurance study from FEMA
- Lake level records from DNR
- Stage and flow records from monitoring stations
- USGS flow records
- Available GIS data including Lidar, landuse, soil type, NWI wetlands, etc.