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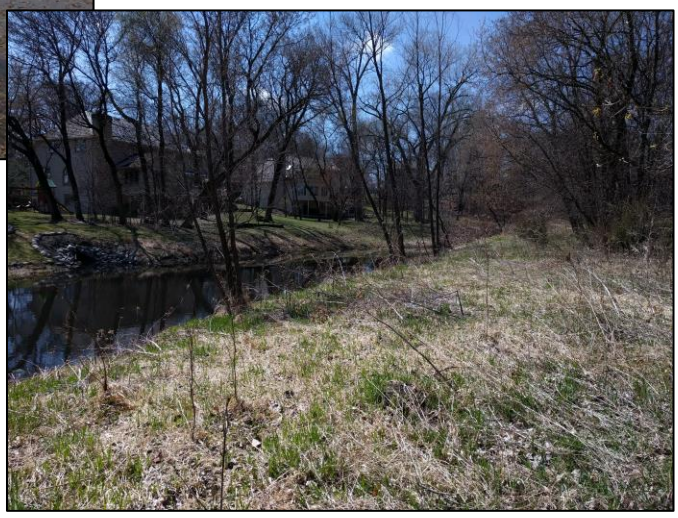
Cedar Island, Pike and Eagle Lakes Nutrient TMDL Five Year Review



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Executive Summary

This report is a review of progress toward meeting the load reductions identified in the Cedar island, Pike, and Eagle Lakes Nutrient TMDL (Wenck 2010a). It includes an assessment of recent data and information that have been collected on these lakes as well as actions that have been implemented to reduce nutrient loads since the TMDL was completed in 2010. Finally, this report describes the actions planned for the next 5 years of the implementation plan and sets forth how progress toward the TMDL will be measured.

Pike Lake, located in the cities of Plymouth and Maple Grove, was placed on the 2002 State of Minnesota's 303(d) list of impaired waters. Cedar Island, which is located in the city of Maple Grove, was placed on the 2004 list and Eagle Lake, which is also in Maple Grove, on the 2008 list. The 2010 TMDL determined that phosphorus load reductions of 67% (Cedar Island), 49% (Pike), and 40% (Eagle) would be necessary to ensure the lakes met or exceeded state water quality standards for nutrients.

The Implementation Plan (Wenck 2010b) identified priority actions and strategies for the first five years of implementation. Some of these were discrete actions or projects, and for the most part those have been completed or are in planning. Other actions such as implementing internal load reduction projects have not yet been completed.

Annual monitoring of lake water quality on Cedar Island, Pike, and Eagle Lakes has been conducted intermittently over the past 20 years, primarily through the Metropolitan Council's Citizen Assisted Monitoring Program (CAMP) and also by the City of Maple Grove. While management actions have reduced nutrient loading to all three lakes, no trend of improvement has been observed yet, and the lakes consistently exceed state standards.

A significant amount of data and information has been collected on all three lakes since the completion of the TMDL, including: in-lake water quality monitoring, vegetation surveys, fish surveys, and sediment core collection for internal load analysis. These data were used to update the watershed and lake response models used in the original TMDL study to prepare updated TMDL allocations and load reduction targets for each lake. The updated models suggest that phosphorus load reductions of 80%, 39%, and 29% are still needed for Cedar Island, Pike, and Eagle, respectively, for these lakes to meet state water quality standards. To meet these reductions, both lakes will need to focus on reducing nutrient loading from watershed and internal sources.

Priorities for the next five years will be:

- Identify the source of residual load in Cedar Island Lake.
- Reduce internal load released by sediments in Pike Lake.
- Develop and implement balanced short- and long-term aquatic vegetation and fish management plans for each lake.
- Continue to reduce watershed load to all three lakes by adding new BMPs, enhancing existing treatment BMPs and by increasing infiltration of runoff.
- Complete subwatershed assessments for the Maple Grove portion of Cedar Island, Pike and Eagle Lakes.
- Undertake targeted monitoring to better understand sources of watershed load.

1.0 TMDL Overview

1.1 BACKGROUND

Cedar Island, Pike and Eagle Lakes are located in the Cities of Maple Grove and Plymouth (Figure 1-1). Cedar Island and Pike Lakes are considered shallow lakes, and Eagle is classified as a deep lake. Pike Lake drains to Eagle Lake via a channel through a large wetland between the two lakes. Cedar Island Lake has no natural outlet, but discharges to Eagle Lake through a pumped outlet. Eagle Lake discharges into Eagle Creek, which is a tributary of Shingle Creek.

Almost the entire drainage area of these lakes is located within the city of Maple Grove, with a small area located in Plymouth. The drainage area to the lake chain is 2,880 acres of fully developed urban and suburban land.

Table 1-1. Lake characteristics.

Parameter	Cedar Island Lake	Pike Lake	Eagle Lake
Surface Area (ac)	79	58	296
Average (Maximum) Depth (ft)	3.6 (7)	8.3 (22)	10.4 (36)
Volume (ac-ft)	285	479	3,084
Residence Time (years)	2.2	0.9	2.9
Littoral Area (ac)	79 (100%)	55 (96%)	199 (67%)
Watershed Size (ac)	527	827	2,163

The Cedar Island, Pike and Eagle Lakes Nutrient Total Maximum Daily Load (TMDL) addressed nutrient impairments in these three lakes. The TMDL and associated Implementation Plan were approved in 2010 and implementation actions have been underway since that time. The total phosphorus (TP) load reductions calculated in the TMDL are shown in Table 1-2 for each lake.

Table 1-2: TP load reductions in the Cedar Island, Pike and Eagle Lakes TMDL.

			Existing TP Load [lbs/yr]	Allowable TP Load [lbs/yr]	Estimated Load Reduction	
					lbs/yr	Percent
Cedar Island	Wasteload	Watershed	244.7	106.9	137.8	56%
	Load	Atmospheric	19.0	19.0	0	0
		Internal	249.3	41.7	207.7	83
		TOTAL LOAD	513.0	167.6	345.5	67%
Pike	Wasteload	Watershed	446.4	281.5	164.9	37%
	Load	Atmospheric	14.3	14.3	0	0
		Internal	169.8	28.2	141.5	83
		TOTAL LOAD	630.5	324.1	306.4	49%
Eagle	Wasteload	Watershed	675.9	411.8	264.1	39%
		Upstream Lakes	461.9	240.5	221.3	48
	Load	Atmospheric	68.6	68.6	0	0
		Internal	--	11.0	--	--
		TOTAL LOAD	1,206.4	731.9	485.4	40%

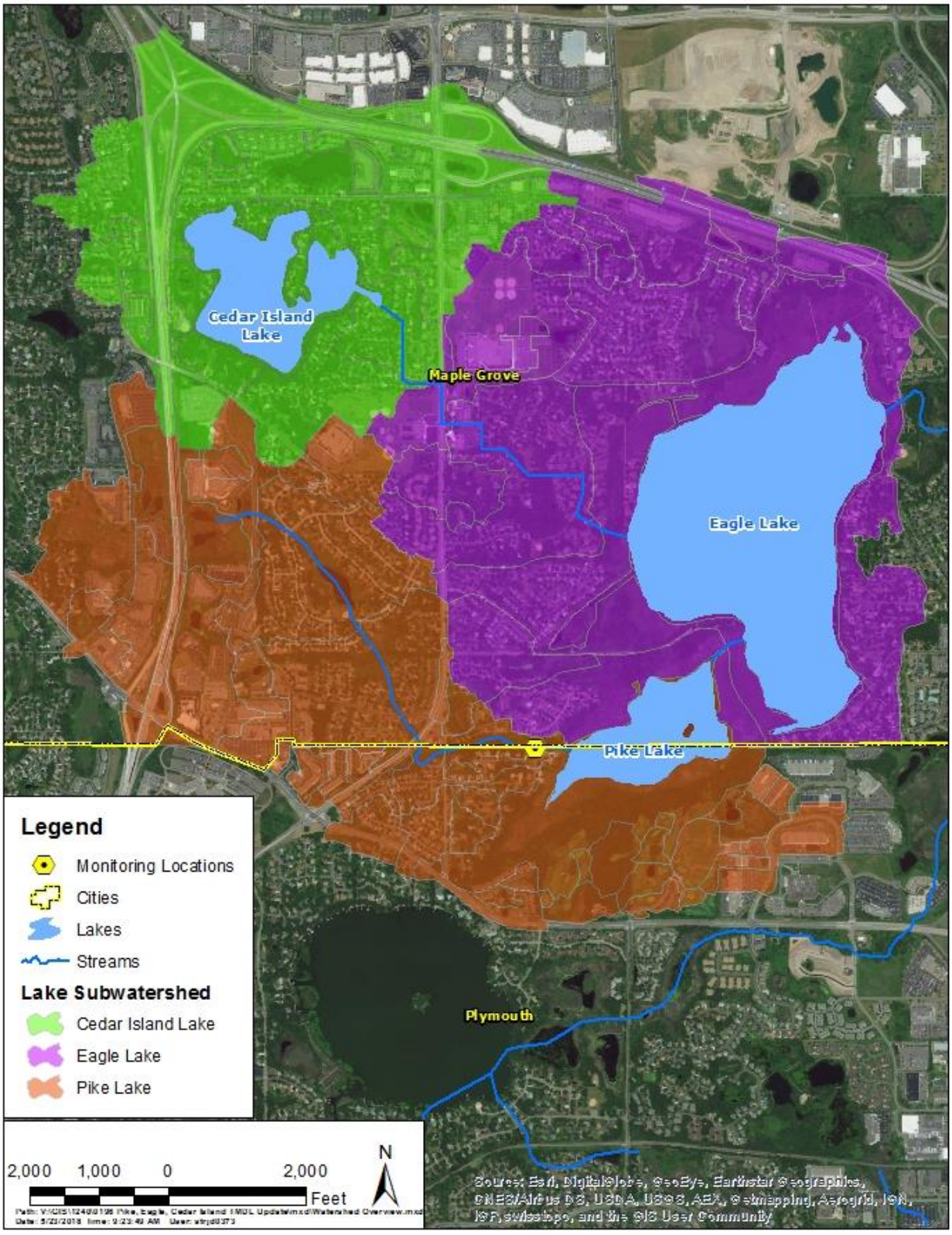

Figure 1-1. Cedar Island, Pike and Eagle Lake lakesheds.

1.2 IMPLEMENTATION PLAN

1.2.1 Principles

The TMDL Implementation Plan enumerated the principles guiding development and implementation of the load reduction plan. These principles, in no order, included:

1. **Restoring biological integrity** and communities including fish, plants, and zooplankton;
2. **Controlling internal load** and reducing the internal phosphorus loading in the lakes;
3. **Retrofitting existing BMPs** and taking advantage of highway and redevelopment projects to add or upsize BMPs;
4. **Require pollutant load reduction and volume management for new development** according to Commission rules and standards as well as Low Impact Design principles;
5. **Fostering stewardship** and providing education and training opportunities to city staff to better understand how their areas of responsibility relate to the protection and water quality in the lakes;
6. **Communicating with the public** and providing general and specialized information for everyone within the community.

1.2.2 Approach

The impairments to these lakes developed over time as the watersheds draining to them urbanized. As the watershed developed, native prairie, woods and savanna were cleared, and wetlands were ditched and filled to support farming. Over the past century the farms and remaining undeveloped land were converted to urban and suburban uses, increasing the volume of runoff and the amount of pollutants conveyed to the lakes. As a result of this land use and land cover change, the lakes slowly degraded. Just as this degradation took many years, improvement will take many years through ongoing retrofit of the watershed with BMPs as well as eventual redevelopment of existing land uses with lower-impact development and stormwater treatment.

The Implementation Plan took into account both short-term and long-term projects. The short-term projects that could be accomplished in a 5-20 year timeframe focused on the high-priority areas of the watershed that are the largest contributors to phosphorus loading. The long-term practices aimed to establish policies and practices that lower phosphorus loading through retrofitting of BMPs, redevelopment, or new construction.

1.2.3 Priorities

Implementation priorities for Cedar Island, Pike and Eagle Lakes were identified in the form of BMP strategies. The following BMP strategies were of highest priority during the first five years of the TMDL. Their 2018 status is shown in *italics*. More detail on completed strategies is discussed later in this report.

Priorities for all lakes

- Evaluate adequacy of existing rules, standards, and ordinances for runoff water quality treatment and volume management and revise if necessary. *The rules and standards were modified in the Watershed Management Plan, increasing the volume management standard and expanding their application to smaller projects under 5 acres.*

- Add BMPs as opportunities arise to decrease runoff from the watershed and increase stormwater treatment. *Completed projects are shown in Table 2-1 below.*
- Monitor and maintain existing stormwater ponds and other BMPs to sustain removal effectiveness. *Ongoing through cities' programs*.
- Increase infiltration and abstraction in the watershed. *Completed projects are shown in Table 2-1 below.*
- Increase frequency of street sweeping in sensitive areas. *Plymouth and Maple Grove currently sweep streets multiple times per year throughout all three lake subwatersheds – see Table 2-1 below.*
- Conduct or update aquatic plant surveys and prepare management plans. Aquatic vegetation surveys were completed for Pike and Eagle Lakes in 2015. Vegetation surveys for Cedar Island Lake will be completed by the Commission in 2020.
- Encourage shoreline restoration to improve runoff filtration. *No information is available regarding restorations completed – see Table 2-1 below.*
- Measure actual internal load. *Sediment cores were collected and analyzed for phosphorus release in Pike Lake in 2009, in Cedar Island Lake in 2011 and in Eagle Lake in 2016. Results of these analyses are presented in Section 3.1.3.*
- Monitor water quality in the lakes on an ongoing basis. *Maple Grove has monitored all three lakes most years since 1995.*
    - *Cedar Island Lake water quality monitoring was done through the MCPA's Citizen Lake Monitoring Program in 2013, 2014, 2015 and 2016. The Commission also monitored Cedar Island Lake in 2015 as part of its Intensive Lake Monitoring Program.*
    - *Pike Lake water quality monitoring was conducted by the Commission in 2015 as part of its Intensive Lake Monitoring Program. Three Rivers Park District monitored Pike Lake in 2017.*
    - *Eagle Lake water quality monitoring was conducted by the MCPA's Citizen Lake Monitoring Program in 2014 and 2015. The Commission also monitored Eagle Lake in 2015 as part of its Intensive Lake Monitoring Program and Three Rivers Park District monitored Eagle Lake in 2017.*

Priorities for Cedar Island Lake

- Focus on reducing internal loads. *Lake association worked with Maple Grove and the DNR to complete a fish kill and restocking.*
- Update the aquatic plant survey and refine the aquatic plant management plan. *Has not been completed.*
- Focus on invasive species control. *Curlyleaf pondweed is known to be present*.
- Conduct zooplankton and phytoplankton surveys. *Surveys completed in 2010 by Freshwater Scientific Services, LLC*
- Consider rough fish removal. *Rotenone treatment performed in 2010, aerator was installed and fish stocking occurred shortly after rotenone treatment.*
- Consider internal load management such as lake drawdown, chemical treatment (for curly-leaf pondweed), etc. *Not complete.*
- Reduce external loads where possible.
    - Increase infiltration and filtration in lakeshed. *Completed projects are shown in Table 2-1 below.*
    - *Enco*urage property owners to plant a native shoreline buffer. *No information is available regarding restorations completed.*

Priorities for Pike Lake

- Focus on reducing both internal and external loads.

- Retrofit Best Management Practices engineering controls where possible. *Completed projects are shown in Table 2-1 below*

- Conduct an aquatic plant survey and prepare an aquatic plant management plan. *Aquatic plant surveys conducted in 2010 and 2015*.
- Conduct zooplankton and phytoplankton surveys. *Not done*
- Consider rough fish removal. *Not completed. Common Carp population assessment performed by SCWMC in 2018.*
- Internal load management. *Not completed.*
  - Biological management, biomanipulation most feasible.
  - Partner with DNR and Three Rivers Park District to manage a beneficial fish community.

Priorities for Eagle Lake

- Focus on reducing external loads. *Completed projects are shown in Table 2-1 below.*
  - Retrofit Best Management Practices engineering controls where possible.
  - Consider options for treating discharge from Cedar Island Lake.
  - Improve Cedar Island and Pike Lakes to reduce loads discharged from them to Eagle Lake.
  - Consider internal load management such as chemical treatment (i.e., alum).
- Conduct zooplankton and phytoplankton surveys. *Not completed.*
- Reduce Canada goose population. *Not completed*.
- Partner with DNR to manage a beneficial fishery. *Not completed.*
- Update the aquatic plank survey and prepare an aquatic plant management plan. *Not completed.*

1.3 TMDL IMPLEMENTATION PLAN ACTIONS

1.3.1 Commission Actions

The Commission agreed to take the lead on general coordination, education, and ongoing monitoring. This information has been incorporated into the Commission's annual Water Quality Reports. Taking the lead, the SCWMC has conducted and will continue to facilitate the following activities. 2018 status is shown in *italics*:

- General Coordination. *All ongoing activities.*
  - Coordinate water resource policy and the following general activities:
    - Provide advice and assistance to member cities on their implementation activities
    - Research and disseminate information on changing BMP technology and practices
    - Collect annual implementation activity data
    - Recommend activities such as vegetation and/or fishery management, partnering with the DNR
    - Periodically update the Commission's Capital Implement Program (CIP)
    - Maintain the watershed SWMM and P8 models
    - Conduct public hearings on proposed projects
    - Share the cost of qualifying improvement projects
    - Annual monitoring and activities report
    - Establishment of performance standards
- Education. *All ongoing activities except internal load management feasibility studies.*
  - Public education and outreach
  - Promotion and encouragement of Public Official and Staff education

- Presentations for lake associations, home ownership associations, block clubs, garden clubs, service organizations, senior associations, advisory commissions, City Councils, and other groups
- Shoreline restoration, rain garden, and other BMP demonstration projects
- Internal load management feasibility studies and recommendations

▲ Monitoring
- Monitor water quality in the lakes. *Completed and ongoing*.
- Track the effectiveness of activities implemented to reduce nutrient loading in the watershed. *Completed and ongoing*.
- Provide additional monitoring such as:
  - Aquatic vegetation surveys. *Completed Pike and Eagle; Cedar Island will be surveyed by SCWMC in 2020.*
  - Sediment chemistry. *Completed for all three lakes.*
  - Zooplankton sampling and other biological assessments. *Completed for Cedar Island Lake. Pike and Eagle Lakes not completed.*

1.3.2 Stakeholder Actions

The regulated stakeholders responsible for meeting the TMDL are the cities draining to the lake chain, Hennepin County, and MnDOT. In addition, property owners in the watershed have a role to play in implementing BMPs on their private properties. The stakeholders agreed to consider the following activities in implementing the TMDL. Their 2018 status is shown in italics. More detail on completed strategies is discussed later in this report.

▲ External Load Reduction
- Retrofit BMPs to add stormwater treatment. *See Table 2-1*
  - *New and enhanced stormwater ponding*
  - *Infiltration basins and devices*
  - *In-line or off-line treatment manufactured devices*
  - *R*ain gardens and biofiltration
- Increase infiltration in the watershed. *See Table 2-1*
- Shoreline management and restoration. *See Table 2-1*
- Street Sweeping. *See Table 2-1*

▲ Internal Load Reduction
- Implement internal load reduction projects. *Not yet completed. Sediment cores have* been *collected for all three lakes. Results of these analyses are presented in Section 3.1.3.*

▲ Biologic Integrity Management
- Aquatic vegetation surveys and management plans*. Aquatic vegetation surveys were performed by SCWMC on Pike and Eagle Lakes in 2015. A vegetation survey was also performed on Pike Lake by Freshwater Scientific Services, LLC in 2011. No surveys have been performed for Cedar Island Lake. No vegetation management plans currently have been developed for these three lakes and none of these lakes routinely treat or harvest aquatic vegetation.*
- Rough Fish Management. *Not yet completed. Fish surveys were conducted by Blue Water Science on Cedar Island Lake in 2016 and on Pike Lake in 2015. Results of these surveys are discussed in Section 3.1.5. SCWMC conducted a common carp population assessment for Pike and Eagle Lakes in 2018.*
- Canada goose management. *Not completed.*

▲ Tracking and Reporting
- *Integration* of BMPs into stakeholders' SWPPs. *Completed on an ongoing basis.*

2.0 Progress Review

2.1 TMDL IMPLEMENTATION ACTIONS

2.1.1 Shingle Creek Watershed Management Commission

The Commission has completed a number of actions in implementation of this TMDL. Some of these are specific to the Cedar Island, Pike and Eagle TMDL, and some are general actions across the watershed that will also benefit these lakes.

- The Commission sponsors ongoing citizen volunteer water quality monitoring on the three lakes, and has undertaken water quality, sediment core, and aquatic vegetation monitoring through its Intensive Lake Monitoring Program.
- Since the TMDL and Implementation Plan were completed, the Commission has updated its development rules to be more stringent. The water quality and infiltration requirements now apply to non-single family residential parcels down to one-half acre in size. The previous threshold was five acres. As these develop or redevelop, they are now required to implement load-reduction Best Management Practices (BMPs).

2.1.2 Stakeholder Actions

The cities draining to the lake chain, Hennepin County, and MnDOT have implemented load reduction BMPs to improve water quality. The BMPs that have been implemented since 1999, which was the base year for the TMDL modeling used to set nutrient budgets and required load reductions, are listed in Table 2-1 along with each BMP's estimated phosphorus load reduction. This table does not include actions completed by individual property owners or by any lake associations.

Table 2-1: BMPs implemented since 1999 and estimated TP load reductions.

Lake	City	BMP Type	BMP Description	TP Load Reduction (lbs/yr)
Cedar Island	Maple Grove	Rotenone Treatment	Rotenone treatment and subsequent fish stocking and winter aeration	NA[1]
		Street Sweeping (~16 road miles)	Sweeping occurs approximately 3 times per year using a vacuum assisted street sweeper (~1 pound/road mile/event)	48
			Subtotal	**48**
Pike	Maple Grove & Plymouth	Pike Creek Gabion	Installation of gabion structure and sedimentation basin near outlet of Pike Creek to Pike Lake.	11
		Street Sweeping (~18 road miles)	Sweeping occurs approximately 3 times per year using a vacuum assisted street sweeper (~1 pound/road mile/event)	54
			Subtotal	**65**
Eagle	Maple Grove	Street Sweeping (~17 road miles)	Sweeping occurs approximately 3 times per year using a vacuum assisted street sweeper (~1 pound/road mile/event)	51
			Subtotal	**51**

NA[1] Not enough information available to estimate potential TP reductions for these projects

3.0 Modeling and TMDL Allocation Updates

3.1 DATA COLLECTED SINCE TMDL STUDY

3.1.1 Overview

A significant amount of watershed and in-lake data and information have been collected for Cedar Island, Pike and Eagle Lakes since the completion of the TMDL study. Monitoring activities have included in-lake water quality monitoring (all three lakes), collection and analysis of intact sediment cores, vegetation surveys, fish surveys, stream flow and stream water quality (Pike Creek). These monitoring activities have resulted in a better understanding and more robust dataset than the information available during the TMDL study. Each of these activities is described below in more detail.

3.1.2 Stream Monitoring

In 2017, the Commission monitored water level, flow, water quality and precipitation on Pike Creek, just upstream of Pike Lake (Figure 3-1). The subwatershed draining to this portion of Pike Creek covers approximately 89% (733 acres) of the Pike Lake watershed.

Flow monitoring results indicate annual flow volume during the six month monitoring period was approximately 400 acre-feet and the runoff depth was 7 inches (27% of rainfall). By comparison, watershed runoff depths for the Pike Lake watershed used in the original TMDL P8 model used to develop the TMDL was 14 inches, or approximately 45% of rainfall.

Water quality monitoring parameters included total phosphorus (TP), soluble reactive phosphorus (SRP) and total suspended solids (TSS). Results indicate that TP concentrations at the Pike Creek monitoring site range from 64-378 µg/L, with an average of 134 µg/L. The P8 model used in the original TMDL study predicted an average annual TP concentration of 158 µg/L for the entire watershed draining to Pike Lake.

3.1.1 Internal Loading from Sediment

Intact sediment cores were collected by the Commission on Pike Lake in 2009, Cedar Island Lake in 2011, and Eagle Lake in 2016. These cores were delivered to the University of Wisconsin - Stout where they were analyzed for sediment phosphorus release under anoxic conditions. Lab results indicate sediment phosphorus release rates were 1.5 and 3.72 $mg/m^2/day$ for Cedar Island and Eagle Lakes, respectively. Pike Lake's phosphorus release rate was 8.0 $mg/m^2/day$, which is considered high and exceeds the 75^{th} percentile of lakes in Minnesota with measured phosphorus release rates. These rates were combined with an anoxic factor calculation (Nurnberg 2004) to provide an updated estimate of each lake's average annual internal load.

The original TMDL study used literature values and model residual to assign internal loading values to each lake since the lab-measured release rate information was not available at the time of the study. Thus, the updated internal load estimates presented in this report provide a more accurate estimate of internal loading from sediments in these lakes.

3.1.2 Vegetation Surveys

Vegetation surveys were performed by the Commission in 2015 on Eagle and Pike Lakes as part of the Intensive Lake Monitoring Program. To the Commission's knowledge, no systematic vegetation surveys have been performed on Cedar Island Lake to date. However, early and late season vegetation surveys are scheduled for 2020 as part of the Commission's Intensive Lake Monitoring Program.

The 2015 vegetation surveys for Eagle Lake showed relatively good species diversity (10 species observed). Plant abundance was relatively high in areas with depths of 15 feet or less (86-93% coverage). Plant abundance would likely be higher if water clarity was better. (Since 2010, water clarity has not met state standards during five of the six years in which Secchi depth was measured.) One of the most commonly observed species of aquatic vegetation was coontail, which was observed at 53% of sites less than 15 feet deep during the June 2015 survey and 74% of sites during the August 2015 survey. In shallow shoreline areas (north and northeast), coontail appeared to form dense floating and submerged mats. While coontail is not believed to pose a threat to water quality in Eagle Lake and is not an invasive species, it may be a nuisance to boaters and property-owners in certain areas of the lake.

Curly-leaf pondweed (CLP) was also abundant during the June survey. As expected, August CLP coverage was low (5%) since CLP usually dies mid-summer. CLP is an invasive plant species that can out-compete native plant species and disrupt lake ecosystems by changing the dynamics of internal phosphorus loading. Eurasian watermilfoil (EWM), another invasive species, was observed at 16% of stations during the June survey and 15% during the August survey. The Eagle Lake Preservation Association conducted scuba pulling of EWM during the summer of 2017 in which they pulled EWM near the southern border of the lake, including the southern channel.

The 2015 vegetation surveys for Pike Lake showed relatively good species diversity (eight species observed) and moderate plant abundance in areas less than 15 feet (approximately 50% coverage). The maximum depth at which vegetation was found was 10.2 feet, with frequency of occurrence and diversity decreasing with depth. The most common species observed during the June and August surveys was coontail (48% and 43%, respectively). As in Eagle Lake, coontail formed dense surface mats in many shallower areas of the lake. Unlike in Eagle Lake, CLP was not as abundant during the early summer growing season. CLP was observed at 20% of survey locations in June and 7% in August, and was primarily confined to the southwestern portion of the lake. Eurasian water milfoil was not observed in June, but occurred at 8% of the sample points in August.

To the Commission's knowledge, chemical treatments and/or harvesting are routinely conducted on Cedar Island, Pike, and Eagle Lakes to manage AIS or other vegetation species. Iron amendments on two one-acre plots in Eagle Lake and one one-acre plot in Pike Lake were conducted in 2005 and 2009 as part of an experimental study funded by the Eagle and Pike Lake Associations, Maple Grove Lake Quality Commission, and the City of Maple Grove (Blue Water Science, 2017). Results of these amendments suggest curly-leaf pondweed stem counts in the iron amended plots are lower than nearby control plots. This study did not investigate or attempt to measure potential changes to the sediment release of phosphorus in the iron amended plots.

3.1.3 Fish Surveys

3.1.3.1 Cedar Island Lake

Fish surveys were conducted on Cedar Island Lake by Blue Water Science in 2008 and 2016 (Blue Water Science, 2016). In 2008, six species were captured in the lake and the fish community was mainly comprised of sunfish and bullhead species. In 2010 a rotenone treatment was conducted to kill all fish within the lake. Fish were restocked into the lake and an aeration system has been operated in the lake since the rotenone treatment. The 2016 survey revealed similar bullhead and bluegill species as well as walleye and largemouth bass being observed in the lake. Fish abundance appears to have increased ~10x between the 2008 and 2016 surveys. In both fish surveys the nets used did not allow the capture of small minnow, shiner, darter species within the lake.

It is possible that the fish community pre-aeration was subject to periodic winterkills and recolonization events. This boom-bust type of fishery is common in eutrophic shallow lake systems throughout Minnesota. These types of fisheries are often dominated by stress tolerant species (black bullhead, fathead minnow) which have also been linked to causing poor water quality conditions. It is common in the year following a fish kill (i.e. winterkill, rotenone treatment) to see a significant improvement in water clarity due to the reduced water quality impacts of fish. This clear water state is often short lived due to recruitment of the fish that survived the winterkill conditions, recolonization of fish through seasonal flooding events and/or stocking of fish by lake managers or illegal activities.

The fish community post-aeration is no longer susceptible to winterkill (assuming no equipment malfunction). The reduction of winterkill has likely been the result of walleye and largemouth bass survival in the system (walleye were likely illegally stocked into the system as they do not have the correct habitat to naturally reproduce). Aeration in the lake may have also lead to a greater biomass and density of fish within the lake. This increased abundance may have shifted the fisheries induced water quality issue from one of species that facilitate poor water quality to a sheer biomass/density concern. With very few if any large predatory individuals (bass, pike) the system lacks a balanced fishery. Shallow systems that are void of top predators do not have the ability to control an overabundance of very small panfish populations (black crappie, sunfish, bullhead). In time this can create a very stunted fish population and lead to water quality impairments.

The 2016 fisheries survey by Blue Water Science was conducted in the fall, outside the DNR's normal summer month sampling window. Some of the other methods used were not in accordance with the DNR's sampling protocol. An updated survey conducted according to the DNR's SOP would provide a more accurate year-to-year record of changes in the fish population and be consistent with the standards the DNR uses to assess fish community health.

3.1.3.2 Eagle Lake

Eagle Lake is a heavily MnDNR-managed fishery with annual stocking of either walleye or muskellunge. The most recent trap and gill net survey was conducted in 2016 and demonstrated a diversity of species, across various trophic positions and at relatively healthy abundances. In 2011, the MnDNR conducted a fisheries health assessment of the lake (Fisheries Indices of Biotic Integrity assessment) which revealed that the current fishery is biologically impaired as it fell just below the threshold score. Review of the specific metrics comprising the IBI suggest there is limited occurrence of certain desired forage species (i.e. darters, etc.) and an overabundance of tolerant species (i.e. bullheads, green sunfish) within the system. These metrics can be associated to habitat conditions. Increased

shoreline restorations may facilitate resurgence of desired forage species and efforts to improve water quality and in lake habitats may correct stress tolerant species overabundance in the lake.

In 2018, an electrofishing survey was performed to document and estimate the abundance and density of common carp in Eagle Lake. There were no common carp observed during the July 17, 2018 suggesting common carp density in Eagle Lake is very low at this time and not impacting water quality. However, due to the lake's connectivity to Shingle Creek, Pike Lake and shallow basins within the watershed, it is recommended that carp surveys be performed periodically to track changes over time.

3.1.3.3 Pike Lake

The fishery of Pike Lake is strongly influenced by Eagle Lake due to its connection through the shallow wetland channel between the two lakes. Pike Lake alone is likely subjected to periodic winterkills due to its shallow and eutrophic conditions. Fish are likely to migrate into Eagle Lake during fall months as waters cool as an over wintering refuge. The most recent fish survey was conducted in 2015 and revealed a limited diversity of species in general and compared to Eagle Lake. The community was largely comprised of sunfish and bullhead species and presents a limited recreational opportunity and a community that may facilitate a poor water quality condition. Efforts to manage the fishery on Pike Lake need to be coupled with management goals on Eagle as the two basins are highly connected from a fisheries standpoint.

As with the Cedar Island Lake fish survey data, the 2015 fisheries survey by Blue Water Science was conducted in the fall, outside the DNR's normal summer month sampling window. Some of the other methods used were not in accordance with the DNR's sampling protocol. An updated survey conducted according to the DNR's SOP would provide a more accurate year-to-year record of changes in the fish population and be consistent with the standards the DNR uses to assess fish community health.

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3.1.4 In-lake Water Quality Monitoring

Monitoring of lake water quality on Cedar Island, Pike and Eagle Lakes has been conducted periodically since the original TMDL study. Much of the data was collected through the Metropolitan Council Environmental Services' Citizen Assisted Monitoring Program (CAMP), the Minnesota Pollution Control Agency's Citizen Lake Monitoring Program, and Three Rivers Park District. The Commission monitored water quality on Eagle, Pike and Cedar Island in 2015 through its Intensive Lake Monitoring Program. Results of this monitoring are presented in the Commission's 2015 Annual Water Quality Report (link to report). Average annual total phosphorus (TP), chlorophyll-a (chl-a), and Secchi depth for the past 25 years is also summarized in Appendix A of this report.

In general, water quality has gotten worse in both Cedar Island Lake and Pike Lake, and there is no clear water quality trend in Eagle Lake. In Cedar Island Lake, both chl-a concentrations and Secchi depth have gotten significantly worse since monitoring began. TP

shows no clear trend in Cedar Island Lake, but remains above the standard every year that monitoring has taken place. In Pike Lake, TP has significantly increased since monitoring began, indicating that water quality is deteriorating, while Secchi depth and chl-a show no significant trends. Data from Eagle Lake show that TP concentrations have increased significantly and have not met the state standard since 2009. However, the data from Eagle Lake also show that Secchi depth is increasing, indicating improvement in water clarity.

3.2 MODELING AND TMDL UPDATES

The original TMDL study used P8 to estimate watershed phosphorus loads to each lake, literature rates to estimate internal load, and BATHTUB lake response models to estimate phosphorus budgets and assign TMDL allocations for each lake. As discussed in sections 2.1 and 3.1, several BMPs have been implemented and a significant amount of data has been collected for each lake since the completion of the original TMDL study. These data have greatly improved our knowledge and understanding of each lake and their watershed and in-lake phosphorus sources.

Current conditions and allowable TP loads developed during the original TMDL study were set using monitored data and the P8 watershed and lake response model results from the late 1990s and early 2000s. For the purposes of this report, these models were updated, adjusted, and calibrated using the more recent 10-year data and information discussed in Section 3.1. The updated lake response models were then used to develop TP reduction targets for each lake to meet in-lake water quality standards. The updated models, existing TP budgets, and allowable TP targets for each lake are presented below.

3.2.1 Cedar Island Lake Updated Targets

The original TMDL models used 1999 as a base year for estimating the existing nutrient loading and TMDL allocations for Cedar Island Lake. The original TMDL model called for watershed and residual/internal TP load reduction goals of approximately 138 lbs/year and 208 lbs/year, respectively (Table 1-1). Recent in-lake monitoring, lift station data, and sediment core collection and analysis have greatly improved our understanding of the current condition TP budget Cedar Island Lake. The updated lake response model suggests a residual load of 304 lbs/yr for Cedar Island Lake. This load represents additional load needed to calibrate the lake response model to in-lake monitored data. The source of the residual load is unknown at this time, however it could include inputs from one or several sources such as rough fish and/or an imbalanced fishery, CLP senescence, and wind/wave action from wind or boating/recreation. In order for Cedar Island Lake to meet State water quality standards, the source of residual load will need to be identified and removed and/or managed appropriately. Additionally, watershed loading will need to be reduced by approximately 44 lbs/year and sediment release of phosphorus by 45 lbs/year (Table 3-1). Figure 3-2 shows how our understanding of the existing and allowable TP loads in Cedar Island Lake have changed since the original TMDL study.

Table 3-1. Updated existing and allowable TP loads for the Cedar Island Lake.

			Existing TP Load [lbs/yr]	Allowable TP Load [lbs/yr]	Estimated Load Reduction	
					lbs/yr	Percent
Cedar Island	Wasteload	Watershed MS4	98	54	44	45%
	Load	Atmospheric	19	19	0	0%
		Sediment	68	23	45	66%
		Residual	304	0	304	100%
		TOTAL LOAD	489	96	393	80%

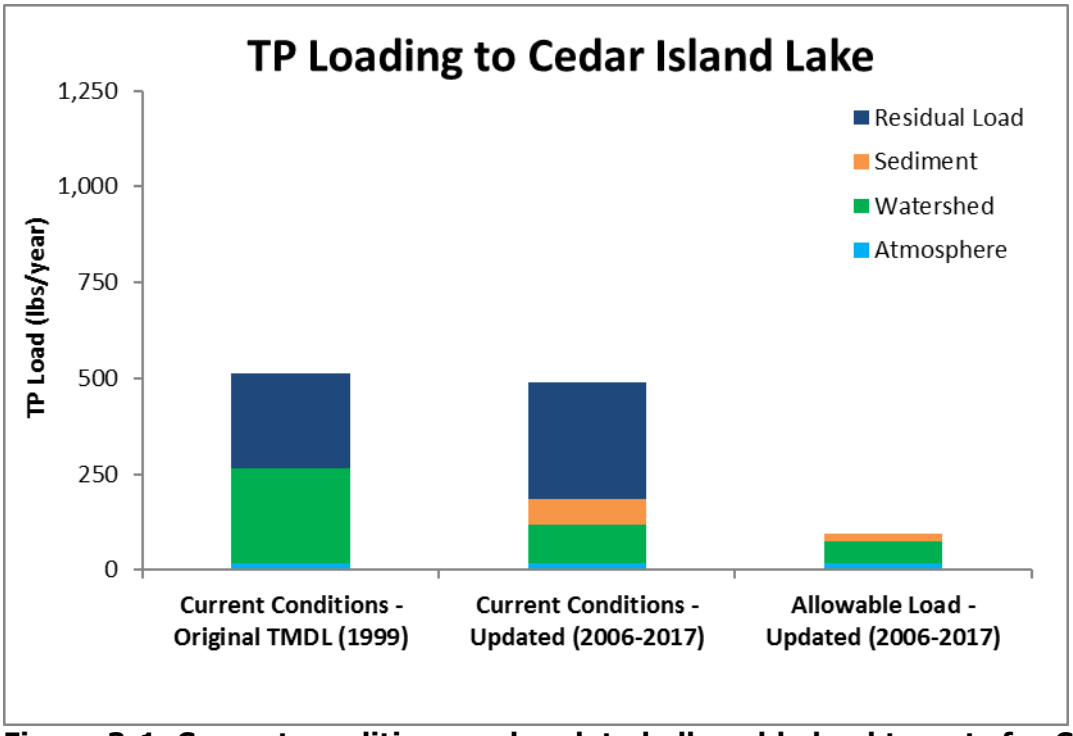

Figure 3-1. Current conditions and updated allowable load targets for Cedar Island Lake.

3.2.2 Pike Lake Updated Targets

The original TMDL model used 1999 as a base year for estimating existing nutrient loads and setting the TMDL allocations for Pike Lake. This model called for watershed and residual/internal TP load reduction goals of approximately 165 lbs/year and 142 lb/year, respectively (Table 1-1). In order for Pike Lake to meet State water quality standards, watershed loading will need to be reduced by approximately 62 lbs/year and sediment release of phosphorus by 109 lbs/year (Table 3-2). Figure 3-3 shows how our understanding of the existing and allowable TP loads in Pike Lake have changed since the original TMDL study.

Table 3-2. Updated existing and allowable TP loads for Pike Lake.

			Existing TP Load [lbs/yr]	Allowable TP Load [lbs/yr]	Estimated Load Reduction	
					lbs/yr	Percent
Pike	Wasteload	Watershed MS4	228	166	62	27%
	Load	Atmospheric	14	14	0	0%
		Sediment	191	82	109	57%
		TOTAL LOAD	433	262	171	39%

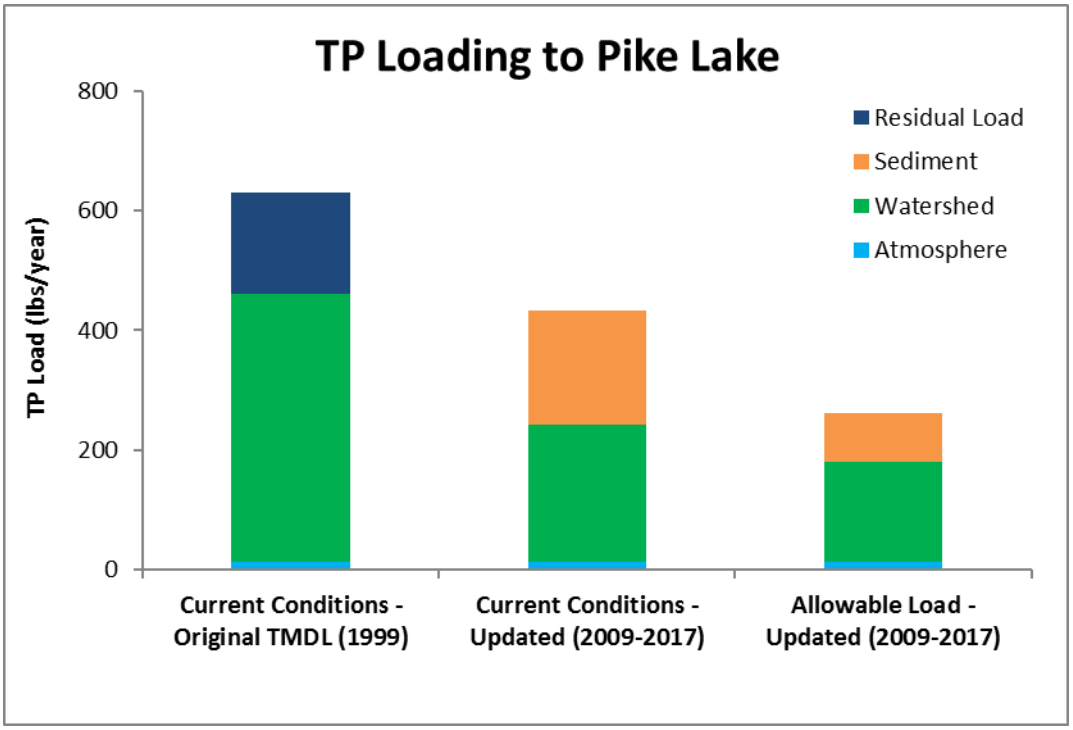

Figure 3-2. Current conditions and updated allowable load targets for Pike Lake.

3.2.3 Eagle Lake Updated Targets

The original TMDL models used 1999 as a base year for estimating the existing nutrient loading and TMDL allocations for Eagle Lake. The original TMDL model called for watershed and upstream lake TP load reduction goals of approximately 264 lbs/year and 221 lbs/year, respectively (Table 1-1). Recent in-lake monitoring, stream monitoring, and sediment core collection and analysis have greatly improved our understanding of the current condition TP budget for Eagle Lake. The updated lake response model suggests upstream impaired lakes (Cedar Island and Pike Lakes) will need to achieve State water quality standards. Improvements in these lakes should result in TP load reductions to Eagle Lake of approximately 66 lbs/yr. Finally, watershed loading will need to be reduced by approximately 88 lbs/year and sediment release of phosphorus by 48 lbs/year (Table 3-1). Figure 3-2 shows how our understanding of the existing and allowable TP loads in Eagle Lake have changed since the original TMDL study.

Table 3-3. Updated existing and allowable TP loads for the Eagle Lake.

			Existing TP Load [lbs/yr]	Allowable TP Load [lbs/yr]	Estimated Load Reduction	
					lbs/yr	Percent
Eagle	Wasteload	Watershed MS4	209	121	88	42%
		Upstream Lakes	192	126	66	34%
	Load	Atmospheric	71	71	0	0%
		Sediment	219	171	48	22%
		TOTAL LOAD	691	489	202	29%

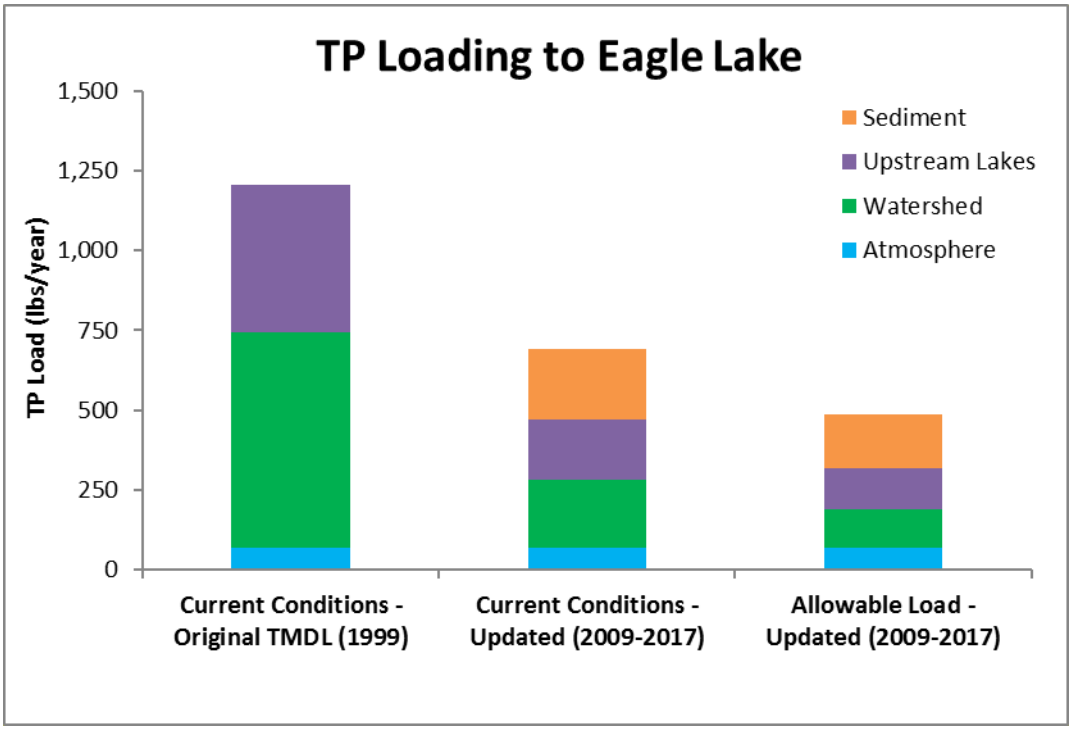

Figure 3-3. Current conditions and updated allowable load targets for Eagle Lake.

4.0 Next 5 Year Actions

4.1 PRIORITIES

The Cities of Maple Grove and Plymouth and the Commission's Technical Advisory Committee reviewed and discussed the data and potential future actions. Priorities for Cedar Island, Pike, and Eagle Lakes for the next five years will be:

- Identify the source of residual load in Cedar Island Lake.
  - Investigate the potential for boating/recreation as a loading source
  - Collect additional sediment core(s) in Cedar Island Lake to evaluate whether the cores collected in 2011 are representative of the entire lake
- Reduce internal load released by sediments in Pike Lake.
- Develop and implement balanced short- and long-term aquatic vegetation and fish management plans for each lake.
  - Perform aquatic vegetation surveys for Cedar Island Lake
  - Develop plan to treat/manage CLP in Eagle and Pike Lakes
  - Explore iron amendments as a potential BMP to reduce CLP density and internal loading from the sediments in selected shallow areas
  - Conduct periodic common carp surveys to track carp populations/density and compare to 2018 survey results
  - Consider future fish surveys for Pike and Cedar Island Lakes during reference period
- Continue to reduce watershed load to all three lakes by adding new BMPs, enhancing existing treatment BMPs and by increasing infiltration of runoff.
- Complete subwatershed assessments for the Maple Grove portion of Cedar Island, Pike and Eagle Lakes.
- Undertake targeted monitoring to better understand sources of watershed load.

4.2 COMMISSION IMPLEMENTATION ACTIONS

The Commission will continue to rely on volunteers to conduct water quality monitoring on the lakes through the Citizen Assisted Monitoring Program (CAMP) program, supplemented by surface and water column sampling every five to seven years. More thorough monitoring was completed on Cedar Island, Pike and Eagle Lakes in 2015, with the next assessment expected in 2020. The detailed assessments also include aquatic vegetation surveys.

4.2.1 Subwatershed Assessments

The Commission will work in partnership with Maple Grove to complete assessments in priority subwatersheds. A subwatershed assessment was completed in 2017 for the Plymouth portion of the Pike Lake watershed. This assessment identified 20 potential BMP options throughout the study area that, if all practices were implemented, could reduce watershed loading by approximately 49 pounds per year. This assessment and future assessments will identify and prioritize opportunities for small-scale retrofit BMPs such as iron-enhanced sand filters, boulevard rain gardens and public space bioinfiltration BMPs. The Commission will maintain a Cost Share Fund to be used to assist its member cities in implementing identified small BMPs.

4.2.2 Education and Outreach

With the West Metro Water Alliance (WMWA), the Commission will work with the cities of Maple Grove and Plymouth to provide targeted information messages and outreach opportunities.

4.2.3 Project Financial Assistance

The Commission's Cost Share Policy provides that member cities may submit capital improvement projects to the Commission's Capital Improvement Program (CIP), and the Commission will fund 25% of the cost of watershed load reduction projects and 100% of internal load reduction projects, with a maximum share of $250,000. The Commission has also been successful in obtaining grant funding for projects, and will continue to seek out sources of funding to assist the cities in completing projects. The Commission also operates a Cost Share program for small BMPs that is intended to provide assistance in completing projects identified in the subwatershed assessments described above.

4.2.4 Five Year Evaluation

The Commission will complete another Five Year Review in 2023-2024.

4.3 STAKEHOLDER ACTIONS

4.3.1 Identify and Manage Residual Load

Cedar Island Lake exhibits a high residual load that could be attributed to potentially wetland export of nutrients, rough fish and/or an imbalanced fishery, CLP senescence, and wind/wave action from wind or boating/recreation. In order for Cedar Island Lake to meet State water quality standards, the source of residual load will need to be identified and removed and/or managed appropriately. Further diagnostic work could be pursued to narrow down the potential causes or sources.

4.3.2 Reduce Internal Load from Sediment

Monitoring and modeling performed subsequent to the TMDLs showed that internal load plays a greater than expected role in limiting water quality in both Pike and Eagle Lakes. At this time, Pike Lake is a good candidate for an alum treatment to seal the sediments in the deeper parts of the lake that experience periods of low-oxygen when phosphorus is released into the water column. The City of Maple Grove and Plymouth will work with the Commission to evaluate the feasibility of alum treatments for Pike Lake and if warranted, undertake them. Additionally, SCWMC will be evaluating the density of common carp in Pike Lake in 2018 to determine if fish management is necessary.

4.3.3 Aquatic Vegetation Management

Cedar Island, Pike, and Eagle Lakes are not actively managed for aquatic invasive vegetation. Internal load management projects will include a vegetation management plan component to identify options for future management based on changes to the plant communities following improvements in lake water clarity. Additionally, Eagle Lake has demonstrated high CLP coverage and density during recent surveys and therefore development of an AIS management plan is recommended.

4.3.4 Opportunistic Projects

Maple Grove, Plymouth, Hennepin County, and MnDOT have been routinely including load reduction and infiltration BMPs into their highway and street reconstruction projects. The Cities will continue to evaluate potential opportunities to incorporate load and volume reduction BMPs in street, park, and other improvement projects.

4.3.5 Street Sweeping

Maple Grove and Plymouth currently conduct targeted street sweeping to help minimize phosphorus and sediment loading to its lakes and wetlands. The Cities will continue to identify critical areas and sweep streets more frequently as necessary.

4.3.6 Shoreline Buffers and Restoration

Maple Grove and Plymouth will continue to urge shoreline property owners to install and maintain shoreline buffers and to restore any unstable or eroded shorelines, and will undertake buffer and restoration projects on city-owned lakeshore property where feasible.

5.0 References

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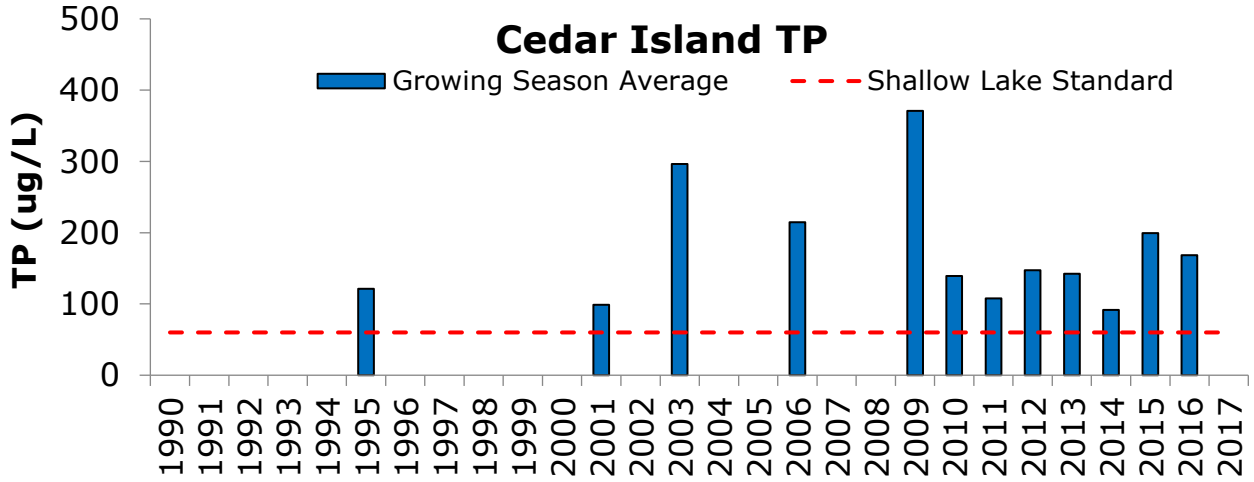
Cedar Island TP
Growing Season Average
Shallow Lake Standard
TP (ug/L)
500
400
300
200
100
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
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2003
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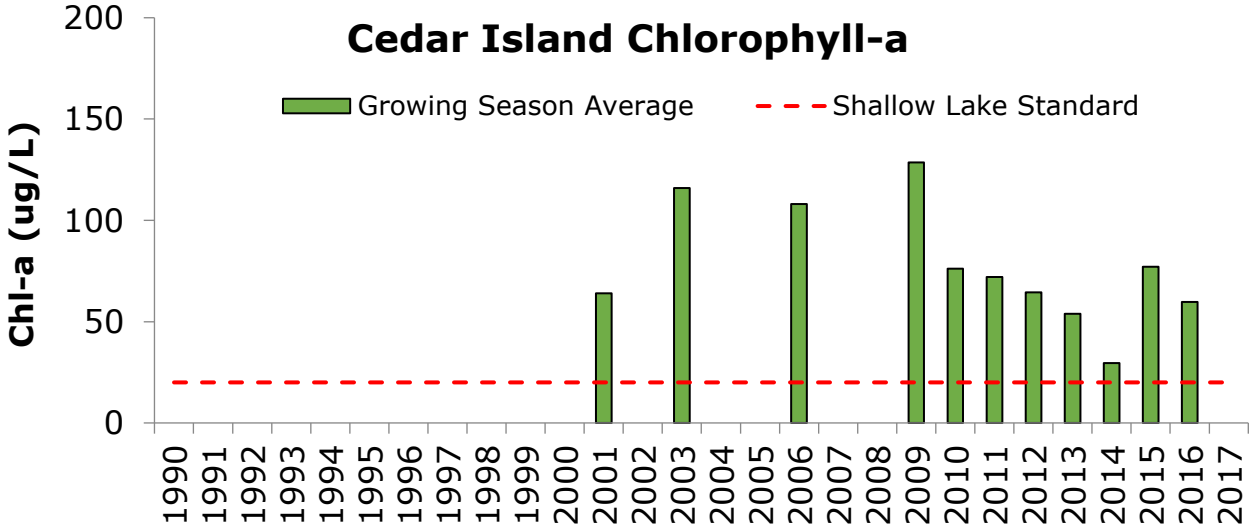
2015
2016
2017


Cedar Island Chlorophyll-a
Growing Season Average
Shallow Lake Standard
Chl-a (ug/L)
200
150
100
50
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
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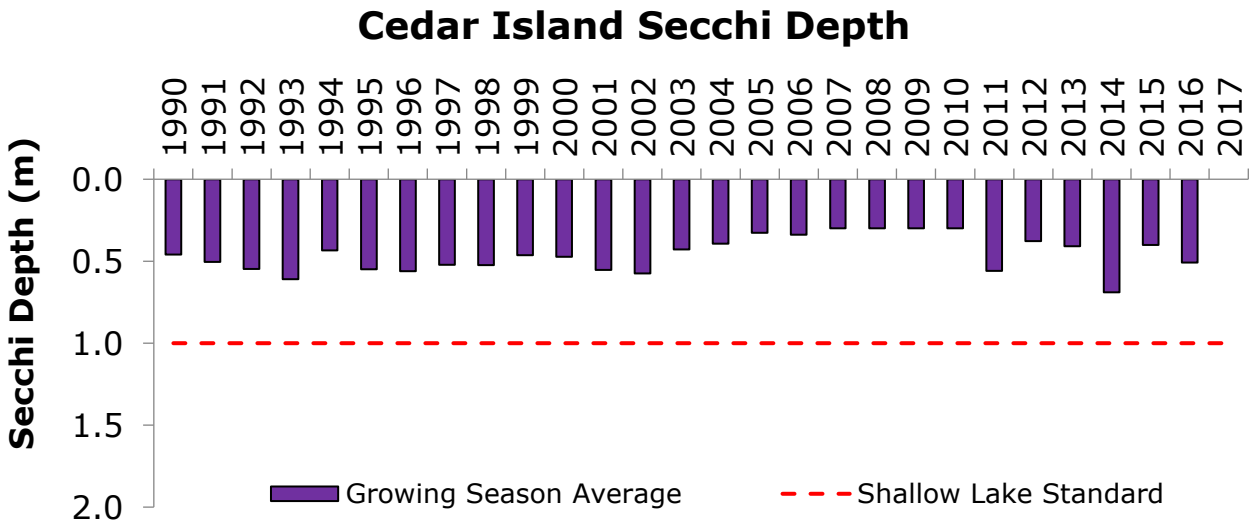
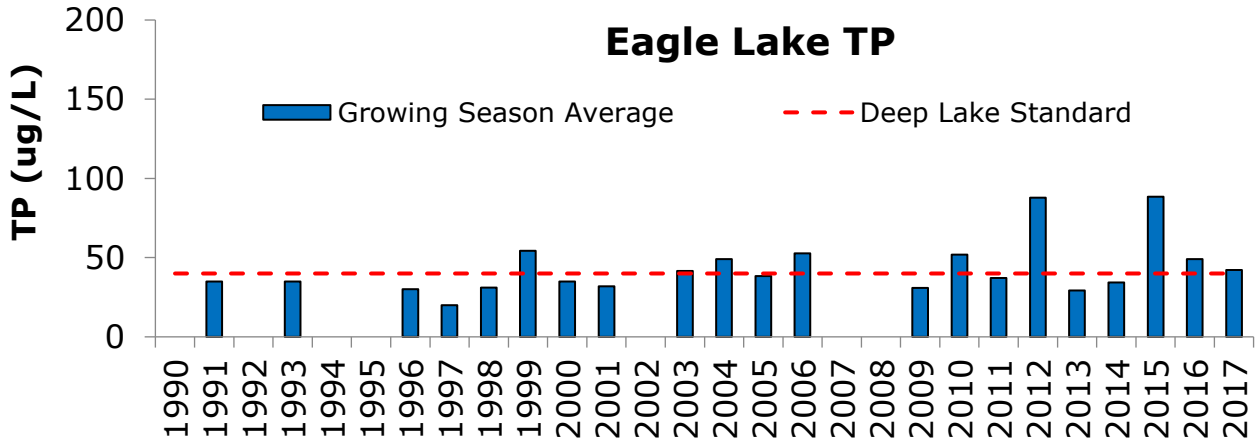
2015
2016
2017


Cedar Island Secchi Depth
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Growing Season Average
Shallow Lake Standard


Eagle Lake TP
TP (ug/L)
200
150
100
50
0
Growing Season Average
Deep Lake Standard
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
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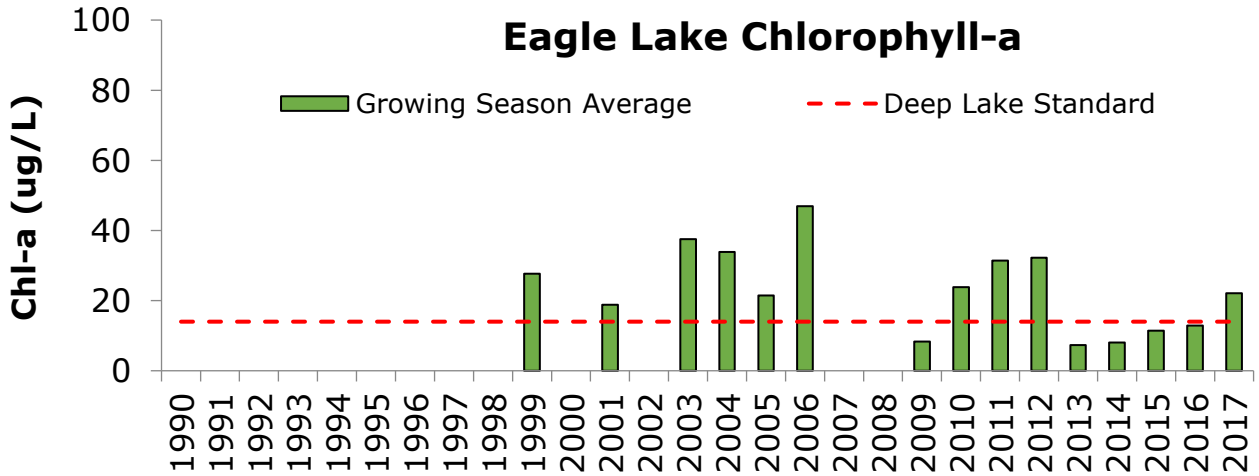
2015
2016
2017


Eagle Lake Chlorophyll-a
Chl-a (ug/L)
100
80
60
40
20
0
Growing Season Average
Deep Lake Standard
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
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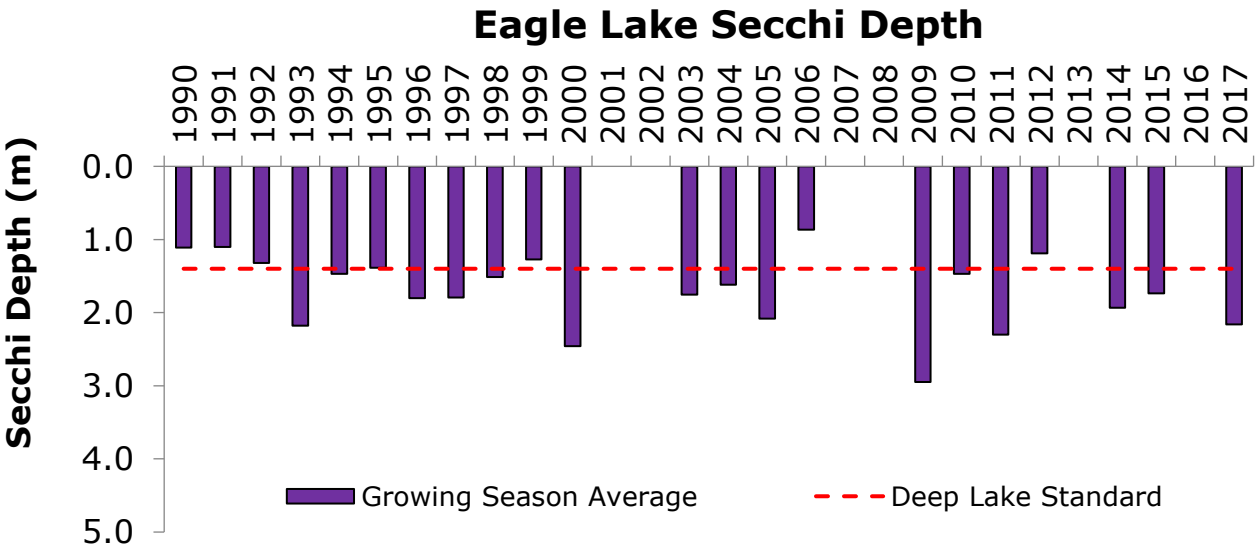
Eagle Lake Secchi Depth
Secchi Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
Growing Season Average
Deep Lake Standard
1990
1991
1992
1993
1994
1995
1996
1997
1998
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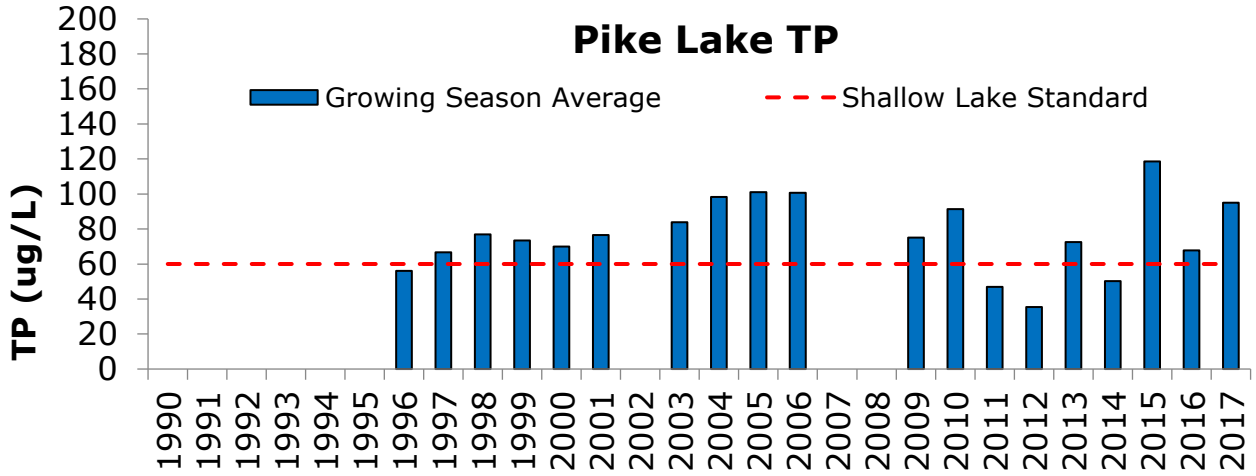
2017


Pike Lake TP
TP (ug/L)
200
180
160
140
120
100
80
60
40
20
0
Growing Season Average
Shallow Lake Standard
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
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2004
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2006
2007
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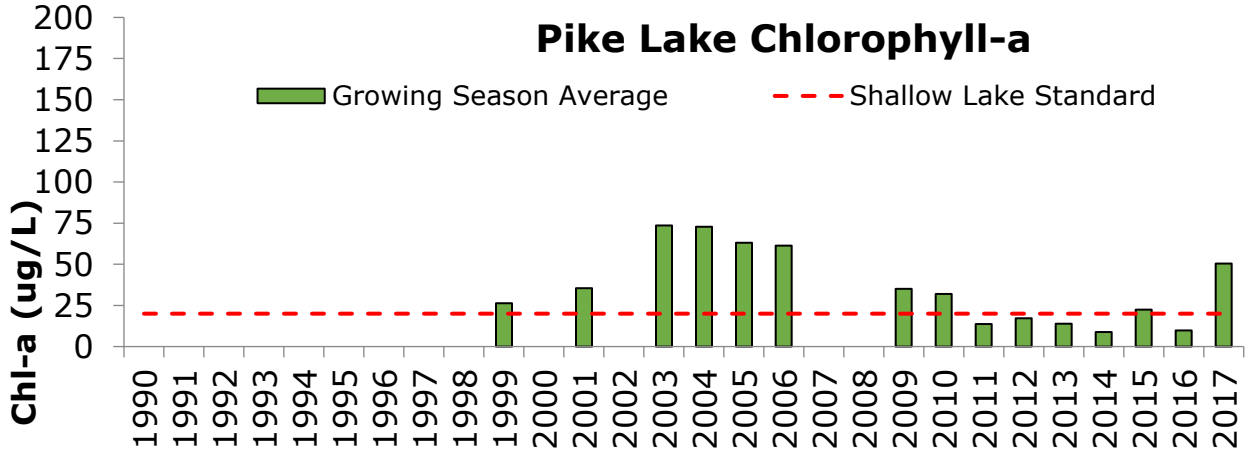
Pike Lake Chlorophyll-a
Chl-a (ug/L)
200
175
150
125
100
75
50
25
0
Growing Season Average
Shallow Lake Standard
1990
1991
1992
1993
1994
1995
1996
1997
1998
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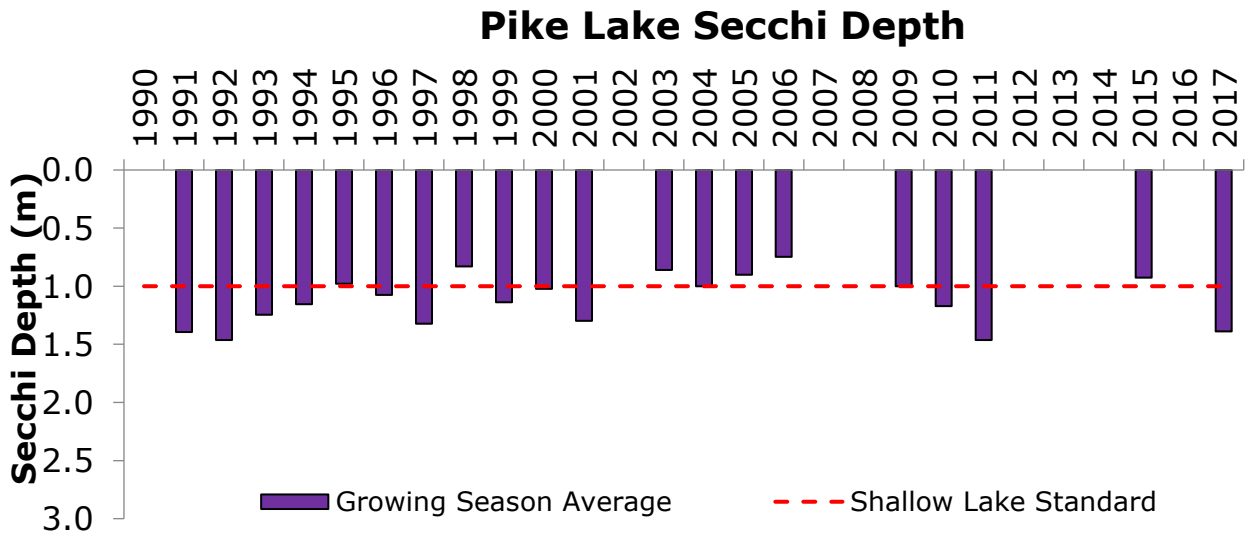
Pike Lake Secchi Depth
Secchi Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Growing Season Average
Shallow Lake Standard
1990
1991
1992
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1994
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