Item 5A.
BCWMC 4-17-25

Medicine Lake Total Maximum Daily Load (TMDL) Assessment

Prepared for
Bassett Creek Watershed Management Commission (BCWMC)

Prepared by
Barr Engineering Co.

April 2025

4300 MarketPointe Drive, Suite 200
Minneapolis, MN 55435
952.832.2600

barr.com

Certification

I hereby certify that this 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.

Gregory J. Wilson
PE #: 25782

April 10, 2025
Date

Medicine Lake Total Maximum Daily Load (TMDL) Assessment

April 2025

Contents

barr.com

Tables

Figures

Appendices

Abbreviations

AIS	Aquatic Invasive Species
BCWMC	Bassett Creek Watershed Management Commission
BMP	Best Management Practice
Chl-a	Chlorophyll-a
CLP	Curlyleaf Pondweed
EWM	Eurasian Watermilfoil
MDNR	Minnesota Department of Natural Resources
MNDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
P8	Program for Predicting Polluting Particle Passage Thru Pits, Puddles, and Ponds
SDT	Secchi Disc Transparency
SS	Starry Stonewort
TRPD	Three Rivers Park District
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
WLA	Wasteload Allocation
ZM	Zebra Mussels

1 Executive Summary

The Medicine Lake Excess Nutrients Total Maximum Daily Load (TMDL) Study was prepared in 2010 to address the Medicine Lake nutrient impairment. A TMDL study determines the maximum amount of a pollutant a body of water can receive without violating water quality standards and allocates that amount among the pollutant's sources such as cities with stormwater discharge permits and others. The TMDL determined that cities and other permit holders needed to reduce total phosphorus (TP) entering the lake by 28% reduction (or 1,287 pounds per year) for the lake to meet water quality standards. In addition, the TMDL identified that internal sources, such as phosphorus release from lake sediments and die-off of curly-leaf pondweed, are known to be significant contributors to overall phosphorus loading to the lake.

Many projects have been implemented in the Medicine Lake and its watershed since the 2006 TMDL baseline year, but the lake is still considered impaired, as it does not meet State water quality standards.

This report describes the Commission Engineer's assessment of progress toward meeting the Medicine Lake TMDL requirements, including significant water quality improvement projects implemented to date, TP load reductions achieved, current lake water quality compared to State standards, and additional load reductions and projects needed to achieve the lake's water quality goals. Primary findings and recommendations include:

- Recent water quality monitoring data confirms statistically significant improving trends for chlorophyll-a (Chl-a; a measure of algae in the lake) and Secchi disc transparency (SDT; a measurement of water clarity), while TP concentrations are unchanged.
- The most likely scenario for delisting Medicine Lake and meeting nutrient water quality standards involves reductions from sources within the lake (internal loading)
- Recent data collected by Three Rivers Park District (TRPD) indicate that the statistically significant reductions in Chl-a concentrations (and algae), along with improvements in SDT in Medicine Lake, are likely due to the increases in zebra mussels in the lake which filter out certain types of algae
- An alum application split into three phases is recommended for Medicine Lake following a carp survey and the development of a feasibility study, with monitoring in between alum applications, to help determine if future alum dose adjustments are warranted. Prescribing each phase of treatment for May is recommended.
- It is important to note that meeting the nutrient standard may have other unintended consequences for biological response from aquatic invasive species (AIS), some of which have already begun to be addressed. As a result, it is recommended that an adaptive management approach should be taken to further address and control AIS, including:
    - The current Lake Vegetation Management Plan (LVMP) allows for treatment of 25% to 30% of the littoral area, which is the maximum that DNR will allow at this time. It is expected that a whole lake treatment may become an option at some point, we recommend that current curlyleaf pondweed treatment efforts should continue through the LVMP process with an adaptive management approach for both curlyleaf pondweed & Eurasian watermilfoil in the future after alum treatment based on observed plant occurrence frequencies.
    - Current starry stonewort treatment efforts with copper/hydrothol/komeen may minimize the spread to other areas of the lake but hasn't kept it completely under control. We recommend continued treatment in the lake to prevent a surge in extent and biomass of

starry stonewort with the improved water clarity expected after the alum treatment. In addition, an adaptive management approach should be taken for alternative controls as new research becomes available.

    - Current and potential zebra mussel treatments (with molluscicides) have either been unsuccessful or cost prohibitive. Until a cost-effective product becomes available for long-term control of ZM on a whole lake situation, an adaptive management approach for alternative controls should be taken as new research becomes available.

- Street sweeping and/or enhanced treatment of stormwater runoff is recommended for the direct drainage area and a few small subwatersheds that drain directly to Medicine Lake.

2 Background

Medicine Lake is on the Minnesota Pollution Control Agency's (MPCA) impaired waters list for mercury and excess nutrients and is included on the draft 2024 impaired waters list for fish bioassessments. In 2010, a total maximum daily load (TMDL) study was prepared for Medicine Lake to address the nutrient impairment. A TMDL study determines the maximum amount of a pollutant a body of water can receive without violating water quality standards and allocates that amount among the pollutant's sources. Cities and other stormwater discharge permit holders are assigned a wasteload allocation (WLA) if they are considered a source of the pollution. The WLA is the pollutant reduction amount needed from each source. The BCWMC is the "convener" of a categorical WLA, or allowable point source loading, shared by the member cities. As the convener, the BCWMC cooperates with the member cities to identify and implement water quality improvements to achieve the desired reduction in pollutant loading.

Many projects and practices have been implemented in the Medicine Lake watershed and in the lake, in addition to the hundreds of existing best management practices (BMPs) in-place when the TMDL was completed, but the lake is still considered impaired for excess nutrients, as it fails to meet State water quality standards for a deep lake in the North Central Hardwood Forest Eco-Region.

As part of the Commission's 2025 watershed management plan update process, the Commission assigned a high priority to the goal of improving the water quality in Medicine Lake such that it meets nutrient water quality standards and is removed from the impaired waters list for nutrients. At the December 2023 Commission meeting, and based on the Plan Steering Committee's recommendation, the Commission approved a scope and budget for an assessment of the status of the Medicine Lake nutrient TMDL study. The outcome of the assessment is a list of projects, programs, or practices that could be included in the 2025 Watershed Plan to help reach the goal of delisting the lake.

This report describes the Commission Engineer's assessment of progress toward meeting the Medicine Lake TMDL requirements, including significant water quality improvement projects implemented to date, load reductions achieved, current lake water quality compared to State standards, and additional load reductions and projects needed to achieve the lake's water quality goals.

3 TMDL Summary

The Medicine Lake Excess Nutrients TMDL study (MPCA, 2010a) calls for a 28% reduction in total phosphorus load to the lake and estimates that point source discharges such as cities and other permit holders will need to be reduced by 1,287 pounds per year to comply with the TMDL. In addition, the TMDL identified that internal load as a significant source of TP based on the frequency of excess phosphorus concentrations throughout the monitoring record, internal sources such as phosphorus release from sediments and curly-leaf pondweed die-off (combined with wind mixing), are known to contribute to about one-third of the lake's total annual phosphorus load. According to the TMDL study, phosphorus from Medicine Lake's sediment is conveyed to the surface either by diffusion or wind mixing. Wind-mixing events completely mix the water column several times each year, typically in July, August, and September. As a result, the TMDL implementation plan included other controls to help reduce internal phosphorus load.

4 Water Quality and Biological Monitoring

4.1 Total Phosphorus, Chlorophyll-a and Secchi Disc Transparency

We compiled and reviewed the lake and watershed water quality monitoring and modeling data. We compared the lake water quality data to State lake eutrophication criteria (total phosphorus (TP), chlorophyll-a (Chl-a), and Secchi disc transparency (SDT)) and reviewed for trends in the water quality data, including seasonality of the data and the relationship of the data to climate conditions. Demonstrating compliance with MPCA's delisting requirements, based on review of the most recent 10 years of lake surface water monitoring data collected between June and September, requires that TP meets the standard **and** Chl-a **or** SDT meet the standard.

Figure 4-1 shows how surface water TP concentrations have compared to MPCA's standard of 40 µg/L for deep lakes like Medicine Lake. The ten-year average TP concentration currently is 55 µg/L and there is no apparent improving or declining trend since the 2006 TMDL baseline year.

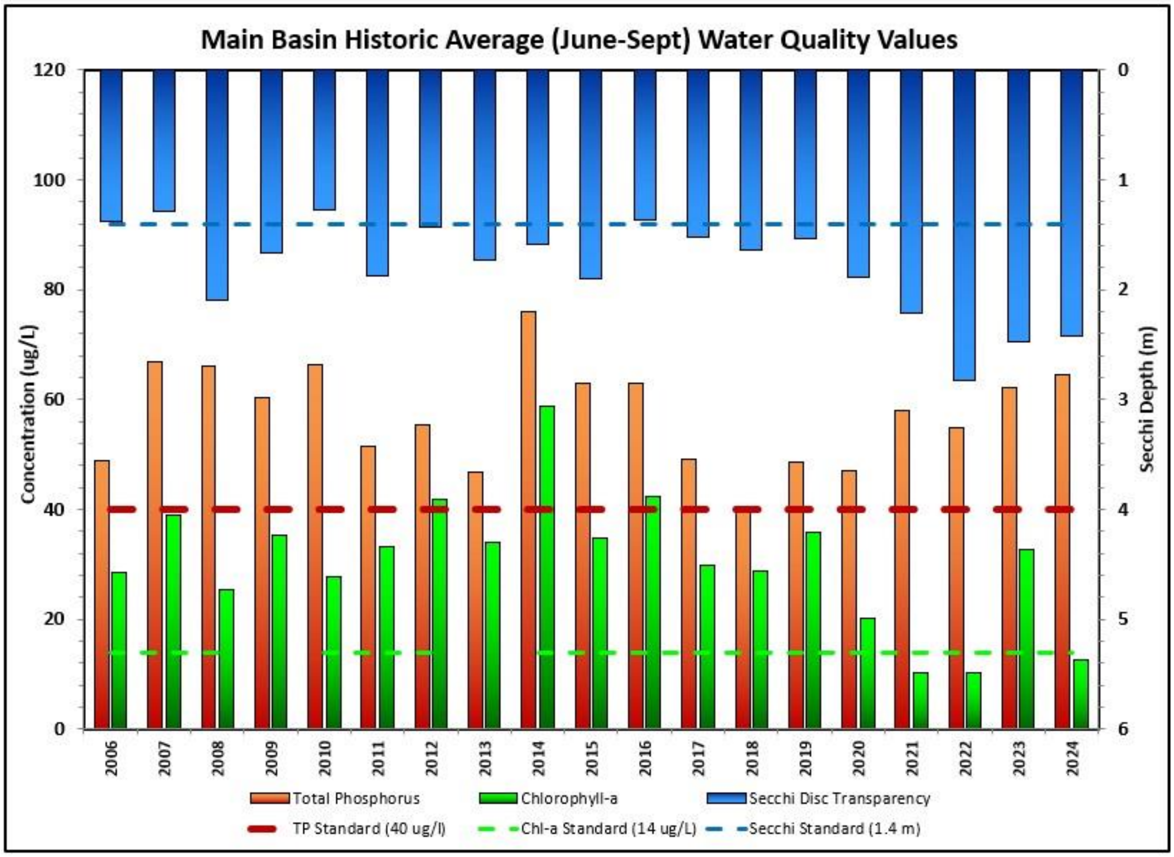


Figure 4-1 Comparison of Medicine Lake Water Quality to MPCA Standards

Figure 4-1 shows how surface water Chl-a concentrations have compared to MPCA's standard of 14 µg/L for deep lakes. The ten-year average Chl-a concentration currently is 26 µg/L, although summer averages met the standard three of the last four years and there is a statistically significant improving trend since 2016.

Figure 4-1 shows how surface water SDT has historically compared to MPCA's standard of 1.4-meters for deep lakes. The ten-year average SDT currently is 1.98 meters and there is a statistically significant improving trend since 2016, with summer averages consistently meeting the standard the last eight years.

The statistically significant reductions in Chl-a concentrations (and algae), along with improvements in SDT in Medicine Lake, are likely due to the increases in zebra mussels (ZM), which were discovered in 2017. Starry stonewort (SS) was discovered in Medicine Lake in 2018.

Figure 4-1 shows that the ten-year average TP concentrations are still 33% higher than the State standard. Based on the most recent water quality monitoring data, we expect that it is more likely that further TP load reductions will result in continued improvement in SDT that can more consistently meet the MPCA standard. The most likely scenario for delisting Medicined Lake involves additional TP load reductions, consistent with the TMDL.

4.2 Hypolimnetic Total Phosphorus

Recent water quality monitoring data has generally been consistent with TMDL findings. Near-bottom oxygen levels in Medicine Lake are typically low in the Main Basin from June through August. Phosphorus release from sediments (a source of internal loading) during this same period causes near-bottom phosphorus concentrations to consistently increase during the summer (see Figure 4-2). Temperature and dissolved oxygen data indicate that the lake typically starts to mix between late August and early September, resulting in increased phosphorus concentrations at the surface and lower near-bottom (hypolimnetic) phosphorus concentrations.

Figure 4-2 shows that, except for 2023, there typically is a repeatable pattern with slight variations in the timing and magnitude of phosphorus buildup in the bottom waters of Medicine Lake, which explains the year-to-year variability of internal phosphorus impacts on the surface water quality of the lake. Except for 2023, which experienced two hypolimnetic TP concentrations below 90 µg/L in early August, Figure 4-2 confirms that recent monitoring data are consistent with hypolimnetic TP concentrations used in the TMDL. The hypolimnetic TP concentrations in 2024 started and ended the summer with slightly lower levels, but the mid-August sample concentration was very high. A closer examination of the water quality monitoring data from 2023 indicates that the bottom water was anoxic all summer (as is typical), but the temperature data indicates that there may have been weaker stratification in early August and lake levels were lower during this time. Since the surface water TP concentration in 2023 was as high or higher than most years, it is possible that wind mixing led to bottom water entrainment in the surface layer of the lake during the early August timeframe.

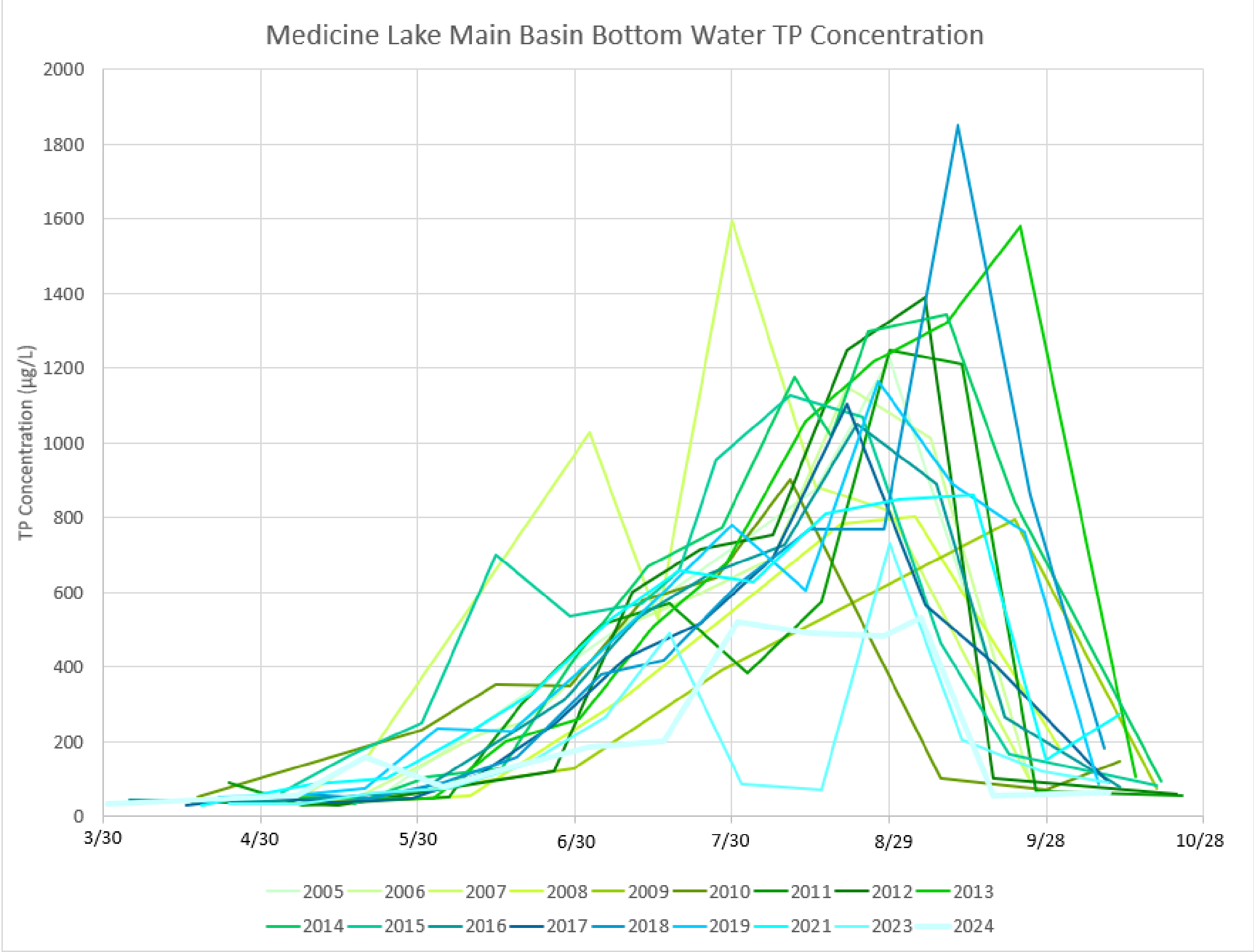


Figure 4-2 Medicine Lake Main Basin Seasonal Hypolimnetic TP Concentrations

4.3 Aquatic Invasive Species (AIS) Monitoring

Four aquatic invasive species have been documented in Medicine Lake: curly-leaf pondweed (CLP), Eurasian watermilfoil (EWM), starry stonewort (SS), and zebra mussels (ZM).

4.3.1 Curly-leaf pondweed

The plant's frequency has typically exceeded the threshold documented in the TMDL study. Because summer die-off of CLP is an internal source of nutrients for Medicine Lake, control of the plant helps reduce the lake's internal TP loading.

Since the development of a DNR-approved Lake Vegetation Management Plan, larger CLP treatments (>100 acres) began in 2022 using diquat and galleon. The 2010 TMDL implementation plan (MPCA, 2010b) for Medicine Lake specified that CLP should continue to be managed annually, although there have not been significant TP concentration changes documented in the lake.

4.3.2 Eurasian watermilfoil

EWM frequency of occurrence has remained low since 2018, indicating that the diquat spot treatments for CLP have also been effective in controlling EWM density.

4.3.3 Starry stonewort

The MNDNR funded treatment of the plant with herbicide (copper sulfate and endothall) from 2018 through 2022, followed by an experimental treatment (with copper sulfate/Hydrothol/Komeen) the past two years (2023-2024). Despite the treatments, SS has spread from its original infestation area near the boat landing to several other areas of the lake, but not in high concentrations. An increased frequency of occurrence (13%) was observed in 2024.

4.3.4 Zebra mussels

ZM which were discovered in in Medicine Lake in 2017. A 2020 ZM survey documented that ZM have spread from the southern end of the lake to the eastern and northern sides of the lake. The number of ZM collected during surveys increased significantly between 2020 and 2021, with similar levels of ZM observed between 2021 and 2023. ZM veligers (planktonic larvae) have also been observed in zooplankton samples.

ZM consume all types of algae, although they prefer the more palatable types such as diatoms, green algae, and cryptomonads. A shift in algae types and concentrations may be a result of ZM predation (see additional details in Section 4.4).

4.4 Phytoplankton and Zooplankton Monitoring

Samples of phytoplankton (microscopic algae) were collected from Medicine Lake to evaluate water quality and the quality of food available to zooplankton (microscopic animals) and ZM. Phytoplankton numbers in 2024 were, on average, lower than past years (2010, 2016 and 2020), consistent with the lake's lower average summer Chl-a concentrations during the same timeframe. As shown in Figure 4-3, phytoplankton numbers were low from April through June and October and increased from July through September due to increasing numbers of blue-green algae. While blue-green numbers increased with higher concentrations of phosphorus during this period other types of algae did not.

Green algae numbers observed in Medicine Lake in April 2020 and 2024 were more than an order of magnitude lower than numbers observed in April 2010 and 2016. Because green algae are a preferred food for ZM, the lower numbers of green algae observed in Medicine Lake in April 2020 and 2024 may be due to predation by ZM.

ZM grazing of green algae reduced early spring numbers in Medicine Lake by more than an order of magnitude in 2020 and 2024, and seasonal average numbers by more than half compared with 2010 and 2016. In spring, ZM filtration rates rise dramatically as waters warm from 41° F to 50° F and then stabilize. The 2020 and 2024 April through September average number of green algae was less than half the average observed in 2010 and 2016.

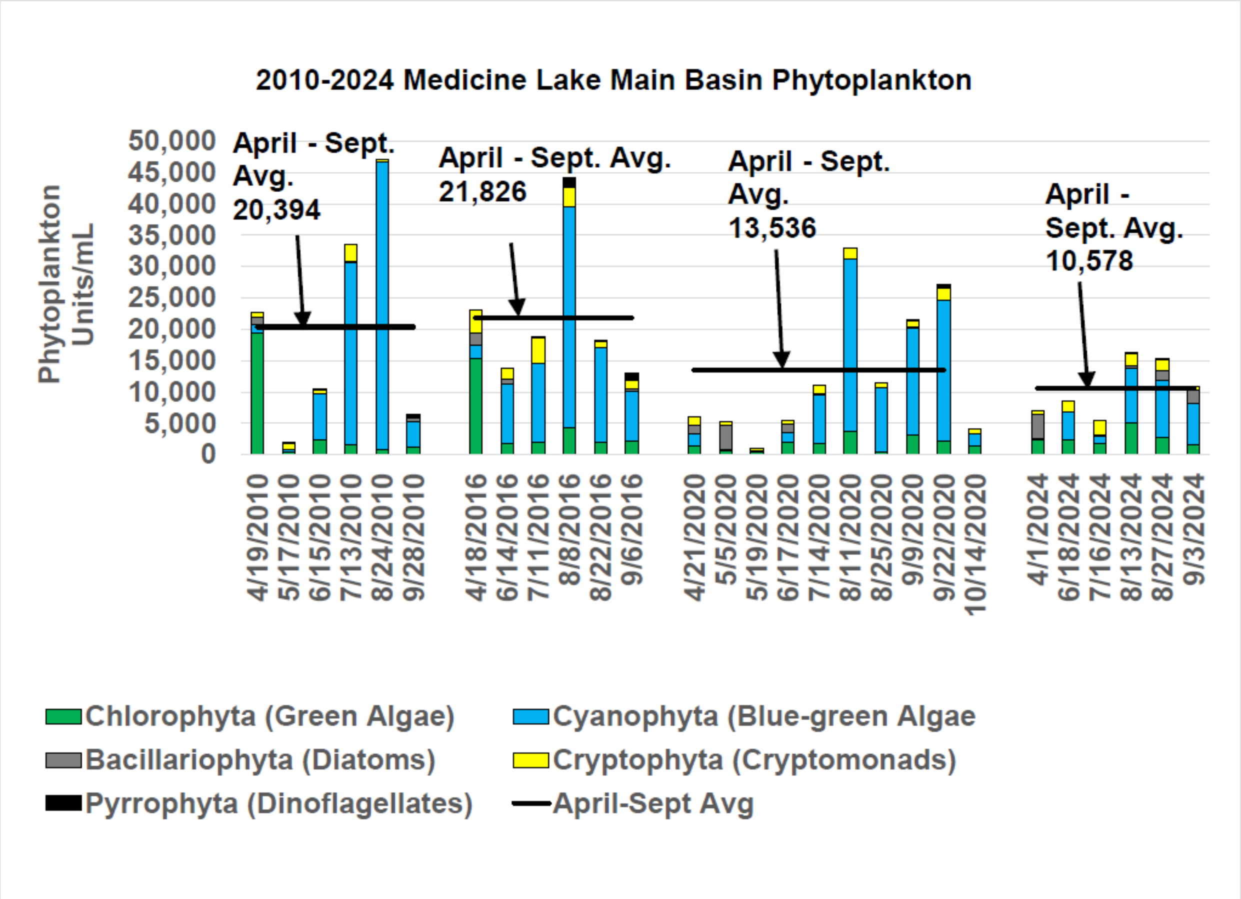


Figure 4-3 Historical Medicine Lake Main Basin Phytoplankton

Reductions in numbers of phytoplankton (microscopic aquatic plants) and rotifers (a type of zooplankton— microscopic animal) between 2016 and 2020 are likely due to predation by zebra mussels (see Figure 4-4). Zebra mussels primarily feed on algae, but also consume rotifers, which are small.

In 2020, cladocerans, the preferred food for fish, were found in lower numbers than copepods and rotifers. Fewer rotifers and copepods were observed in 2020 and 2024 than 2010 and 2016. Lower numbers of rotifers were likely due to ZM predation. It is not known whether the lower numbers of copepods were due to fish predation or to food limitation caused by ZM grazing on algae.

It is expected that an alum treatment would reduce nutrients in the lake such that ZM population is food limited. However, some of the alum treated lakes that experienced blue-green algal blooms were clearer lakes, suggesting that ZM could have the potential to cause blue-green blooms in Medicine Lake after water quality is improved by an alum treatment.

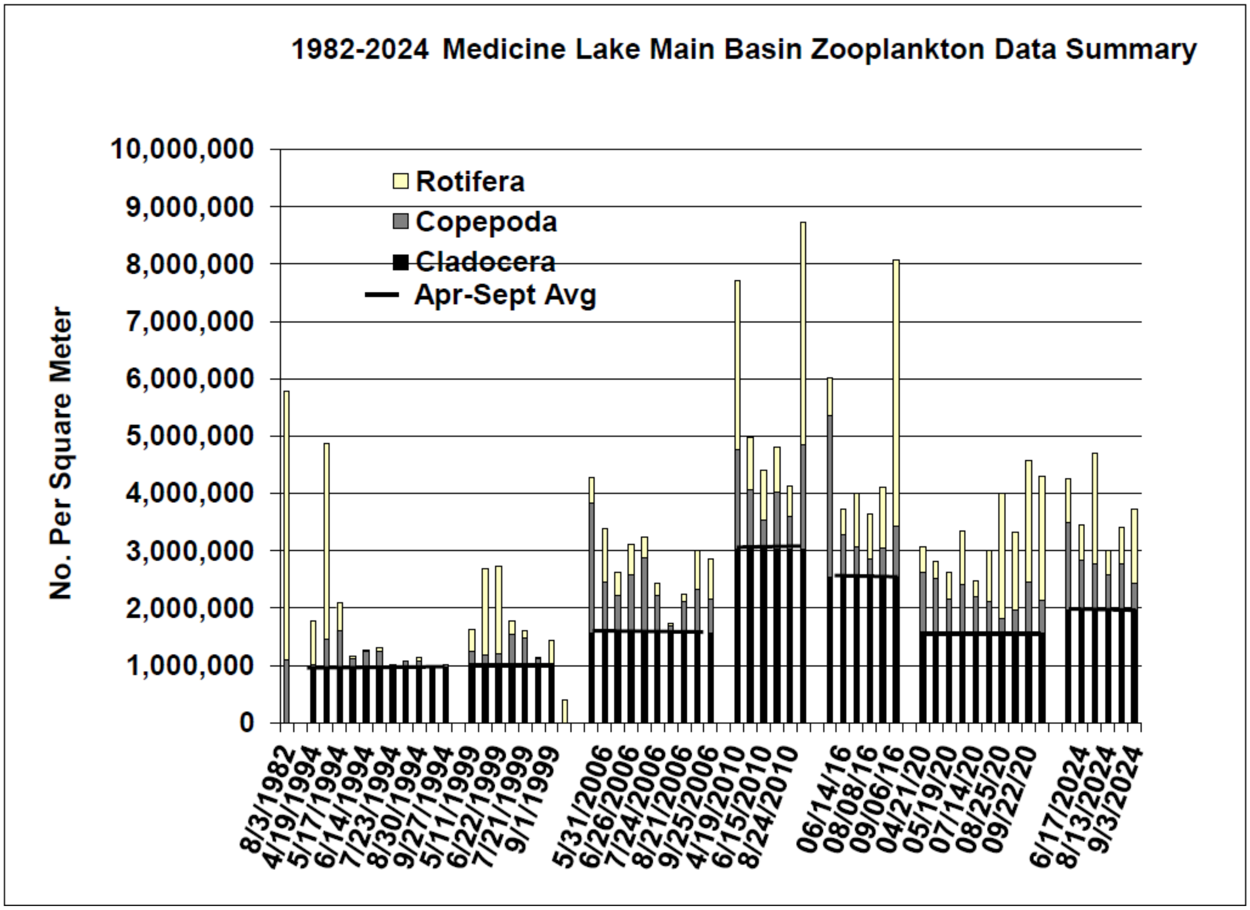


Figure 4-4 Historical Medicine Lake Main Basin Zooplankton

5 Completed BMPs and Total Phosphorus Load Reductions

We updated the P8 pollution model with projects and practices completed since 2006 (where possible) and Twin Cities' hourly precipitation and daily temperature records through 2023. The updated P8 modeling was then re-run for the 2006 water year to allow for direct comparison between that baseline year and current conditions and to identify gaps between the current TP load reductions and the published TMDL wasteload allocations (WLAs).

Figure 5-1 shows the updated subwatershed areas for each of the major watershed areas that drain to Medicine Lake. Individual maps developed for each major watershed area, showing the BMP locations and drainage direction for each subwatershed are included in Appendix A.

Table 5-1 summarizes the overall TP treatment estimated from the updated P8 modeling for each of the major watershed areas tributary to the lake. The results indicate that current total pollutant removal is about 889 pounds per year compared to the 1,287 pounds per year reductions assigned to watershed sources in the TMDL. However, Table 5-1 also shows that the combined TP treatment efficiency of all the BMPs in the Medicine Lake watershed is more than 70%, which is already at the upper threshold of what structural BMPs can typically attain for TP treatment. As discussed in the next section, it appears that the P8 model is underestimating the current TP load reductions that have been achieved in the Plymouth Creek watershed since the 2006 TMDL baseline year and that watershed monitoring data represents a better measure for evaluating compliance with the TMDL WLAs.

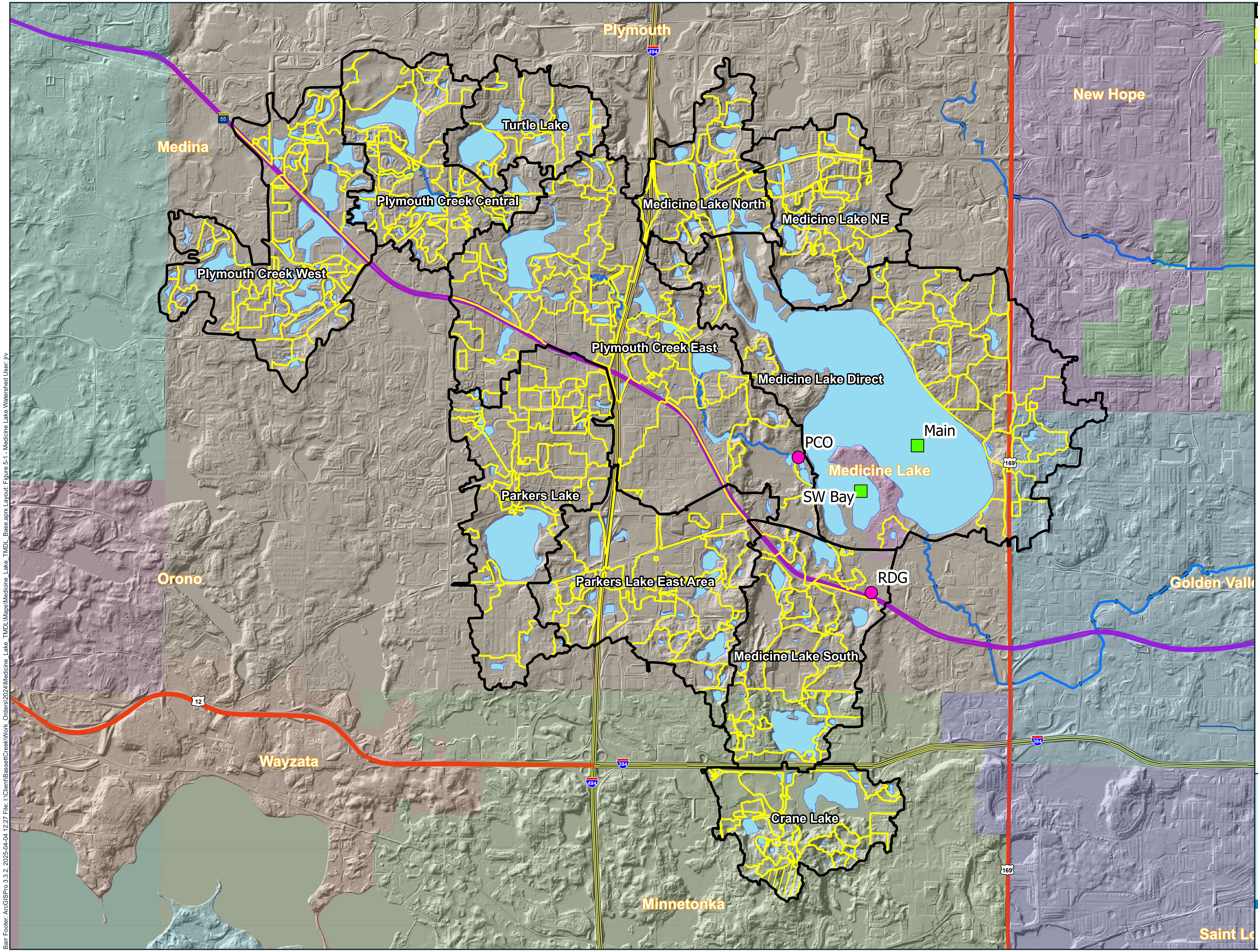
Table 5-1 Modeled BMP TP Treatment Summary by Watershed Area

Watershed	Total TP Removed by BMPs (lbs/yr)[1]	Current Overall TP Treatment Efficiency (%)
Plymouth Creek[2]	649.4	71
Ridgedale Creek	47.3	70
Medicine Lake Direct	114.0	71
Medicine Lake NE	18.1	76
Medicine Lake North	60.0	74
Total	**888.8**	**72**

[1] Increased removal based on model changes documented since 2006 TMDL baseline year
[2] Includes Parkers Lake and Parkers Lake East Area watersheds.

A complete list of TP load reduction estimates from the updated P8 modeling for all BMPs with documented changes since the 2006 TMDL baseline year are included in Appendix B.

The updated P8 modeling results were also used to develop hotspot mapping (shown in Figure 5-2), which shows the flow-weighted mean TP concentrations in the outflow from each subwatershed. Figure 5-2 confirms that TP concentrations discharging to the lake from the major watershed tributaries are quite low compared to untreated stormwater runoff (as described above). In addition, it shows that the direct drainage area and a few small subwatersheds that drain directly to the lake may be good locations for street sweeping and/or enhanced treatment of stormwater runoff.



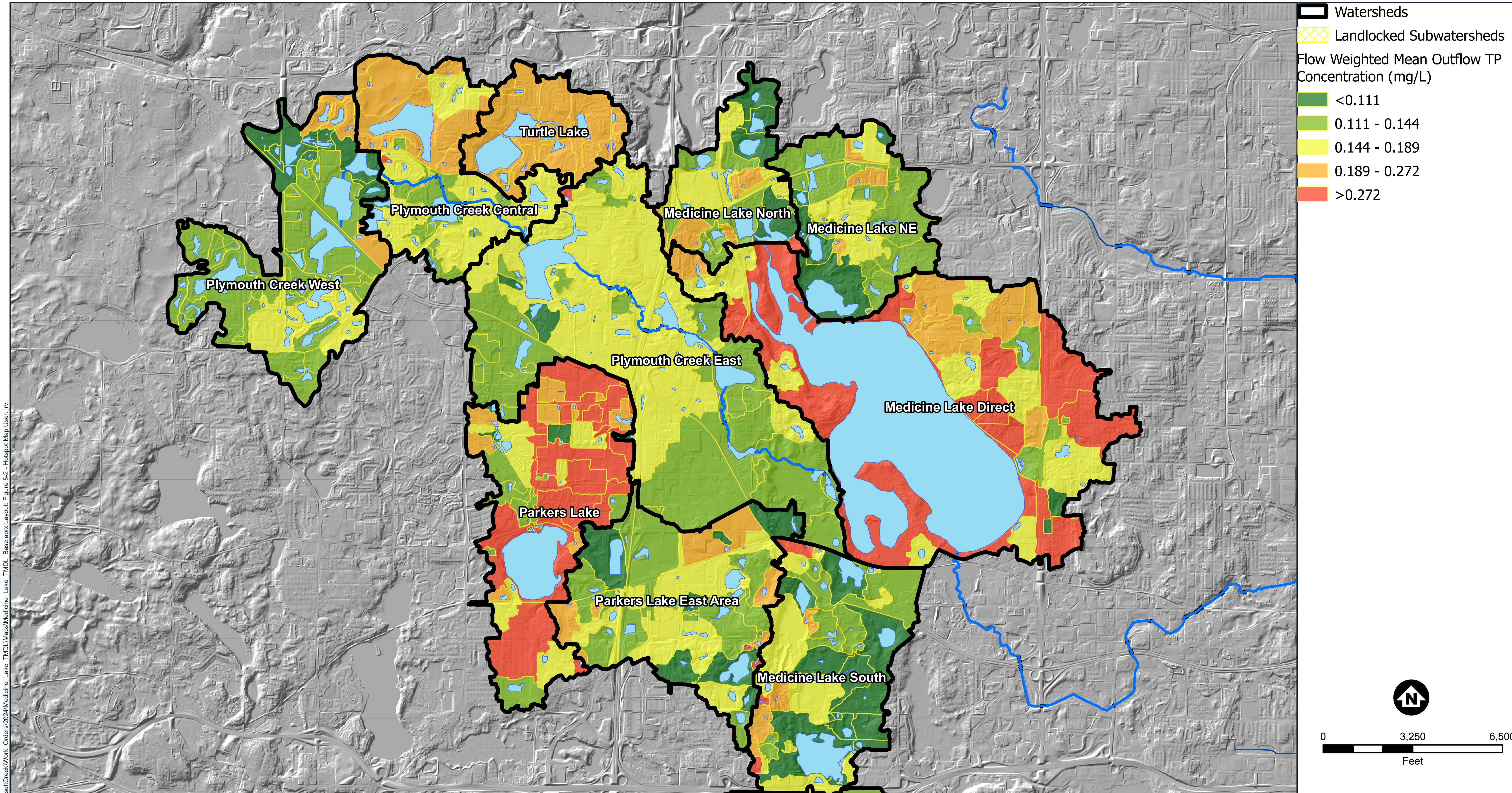
Watersheds
Subwatersheds
Landlocked Subwatersheds
Lake Monitoring Station
Major Tributary Monitoring Station

0 3,250 6,500
Feet

Medicine Lake Watershed
Medicine Lake TMDL Assessment
Bassett Creek Watershed
Management Commission

FIGURE 5-1

BARR



Hotspot Map
Medicine Lake TMDL Assessment
Bassett Creek Watershed
Management Commission

FIGURE 5-2

BARR

6 Gaps Between Expected and Required TP Load Reductions

Since there has not been significant improvement in lake total phosphorus concentrations since the TMDL was completed, our next steps involved review of the tributary monitoring data, with a specific focus on Plymouth Creek, which has 23 years of flow and water quality monitoring data, as well as annual pollutant load estimates. Based on the TMDL, Plymouth Creek contributed 52% of the total watershed TP loading to Medicine Lake. Since the TMDL baseline year (2006), several significant BMP projects have been implemented in locations that would be expected to provide significant TP load reductions to the lake, including construction of the West Medicine Lake Park Ponds project, which was on-line and functioning by the spring of 2010. Figure 6-1 shows that the flow-weighted mean TP concentration at the downstream Plymouth Creek monitoring station has improved significantly since this BMP was constructed.

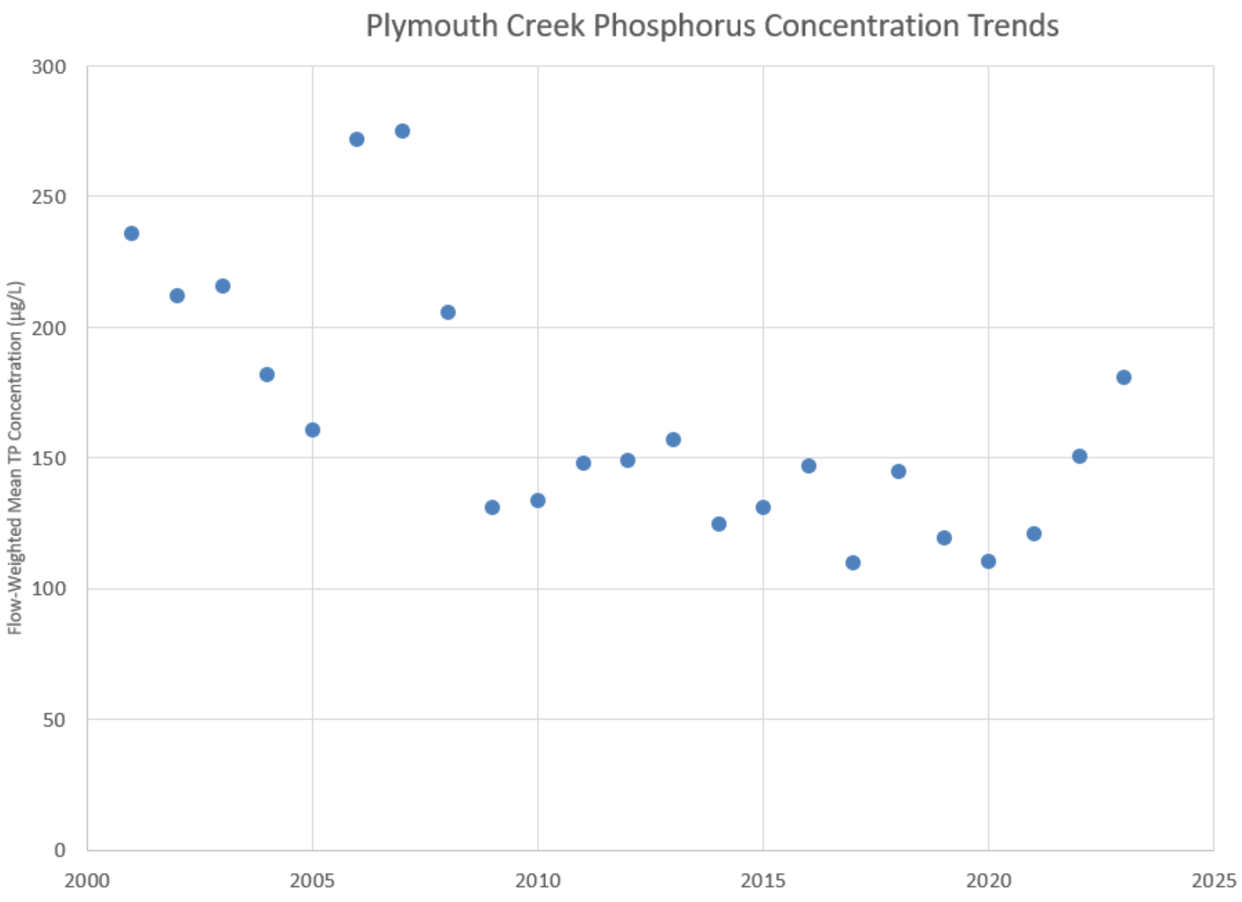


Figure 6-1 Flow-Weighted Mean Total Phosphorus Concentration Trends from Plymouth Creek Monitoring

While the flow-weighted mean TP concentrations from the Plymouth Creek monitoring station show consistently lower concentrations in recent years, the resulting TP loadings delivered to the lake are a byproduct of flow volumes in Plymouth Creek, which are more highly variable TP concentrations (as shown in Figure 6-2). To get a better sense for how well the lower flow-weighted mean TP concentrations (shown in Figure 6-1) might compare to the 1,287 pounds per year TP load reduction necessary to meet the TMDL WLA requirement, we highlighted (as “Average Year”) in Figure 6-2 the monitored years with flow conditions that more closely resembled the 2006 conditions used in the TMDL. We then computed the difference between the 2006 average annual TP loading and the more recent average annual TP loading and found they generally exceeded 1,300 pounds per year. As a result, we estimated that the West Medicine Lake Park Ponds BMP improvements, alone, would satisfy the WLA allocations in the TMDL report.

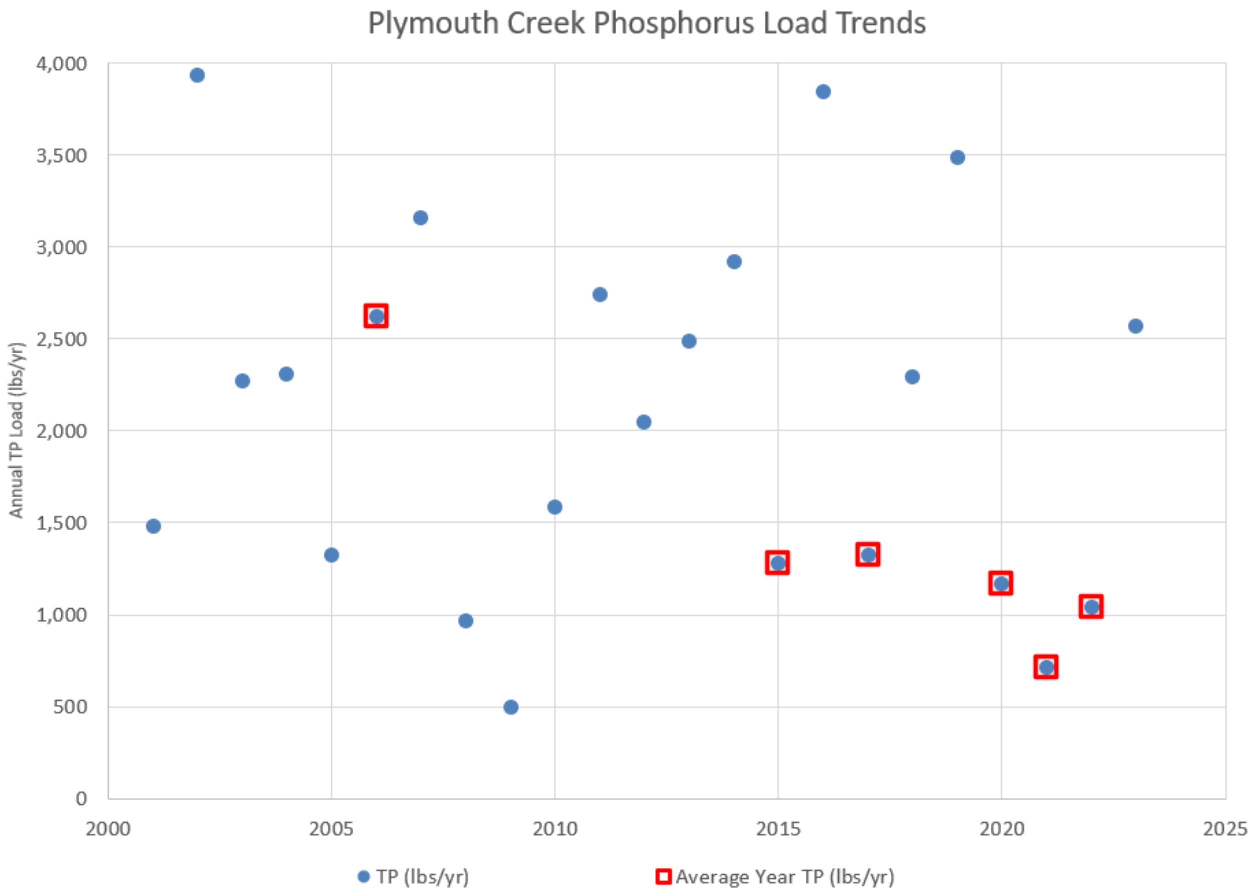


Figure 6-2 Annual Total Phosphorus Loading Trends from Plymouth Creek Monitoring

Despite the significant TP load reductions resulting from the implementation of the West Medicine Lake Park Ponds BMPs and several other major watershed tributaries to the lake, Figure 4-1 shows that there has not been a significant improved water quality response in Medicine Lake. As a result, internal phosphorus loading appears to be the primary cause for water quality impairment, and we expect that the TP load reduction associated with an in-lake alum treatment would address the gaps between observed in-lake TP concentrations and the State TP standard.

7 Remaining Water Quality Improvements Needed

7.1 Alum Treatment to Address Sediment Phosphorus Release

Because the water quality modeling shows the lake will not meet State standards without addressing internal phosphorus load, we reviewed a sediment study (University of Wisconsin-Stout, 2018) prepared for Three Rivers Park District (TRPD) to gain a better understanding of internal loading and the potential for realizing TP load reductions consistent with the TMDL. Unless sedimentation rates are high, we expect that the sediment core data collected for the 2018 study should still be relevant. The alum treatment plan in the sediment study looks sound. While the TP sediment fraction that is most susceptible to release under anoxic conditions is high all the way down to 15 cm with a peak in the upper 3 cm, dosing the top 5 cm makes sense and splitting the dose into more than one alum application, with monitoring in between alum applications, can help to determine whether adjustments to the dose are warranted. Given the high redox P deep in the sediment cores, it is conceivable that a third phase of alum treatment might be warranted to immobilize the remaining mobile P in the top 10 cm of the active sediment layer. Prescribing the treatment for May also makes sense to increase the binding efficiency by selecting a time when phosphate is free in the water column such that the treatment is not compromised by an early season algal bloom. With this approach we recommend that additional aluminum (at a 10:1 Al:P ratio) be added to the dose to account for the aluminum that will be combined with the TP in the lake water.

Based on the TRPD sediment study recommendations for total alum dosage for the treatment zone of Medicine Lake, we estimate that total alum treatment costs, combined for all three phases, will be in the range of $1.5 million to $2 million.

An alum application split into three phases is recommended for Medicine Lake following a carp survey and the development of a feasibility study, with monitoring in between alum applications, to help determine if future alum dose adjustments are warranted.

7.2 AIS Control

There is currently very limited information about the common carp population in Medicine Lake, and the potential impact that it they may have on internal phosphorus load and the implications for alum treatment dosing. As a result, a carp survey is recommended to coincide with the development of a feasibility study for the lake alum treatment.

It is important to note that meeting the nutrient standard may have other unintended consequences for AIS response, some of which has already begun to be addressed. As a result, it is recommended that an adaptive management approach should be taken to further address and control AIS, including:

- The current Lake Vegetation Management Plan (LVMP) allows for treatment of 25% to 30% of the littoral area, which is the maximum that DNR will allow at this time. It is expected that a whole lake treatment may become an option at some point. Diquat is currently getting used in smaller treatment areas, which is intended to control both EWM & CLP. We recommend that current CLP treatment efforts should continue through the LVMP process with an adaptive management approach for both CLP & EWM in the future after alum treatment based on observed plant occurrence frequencies.

- TRPD has been treating starry stonewort near the boat landing and beach and not in other areas of the lake. Data indicates that our current treatment efforts with copper/hydrothol/komeen may minimize the spread to other areas of the lake but hasn't kept it completely under control. We recommend continued treatment of starry stonewort in the lake to prevent a surge in extent and biomass with the improved water clarity expected after the alum treatment. In addition, an adaptive management approach should be taken as new research becomes available.
- Recent data collected by TRPD indicate that the statistically significant reductions in Chl-a concentrations (and algae), along with SDT increases in Medicine Lake, are likely due to the increases in zebra mussel numbers in the lake. Current and potential treatments (with molluscicides) have either been unsuccessful or cost prohibitive. Until a cost-effective product becomes available for long-term control of ZM on a whole lake situation, an adaptive management approach should be taken as new research becomes available. Control of the lake's zebra mussels should prevent blue-green algal blooms in the future.

7.3 Watershed BMPs

As discussed in Section 5, the hotspot mapping shown in Figure 5-2 shows that the direct drainage area and a few small subwatersheds that drain directly to the lake may be good locations for street sweeping and/or enhanced treatment of stormwater runoff.

References

Minnesota Pollution Control Agency (MPCA). 2010a. *Medicine Lake Excess Nutrients TMDL*. https://www.pca.state.mn.us/sites/default/files/wq-iw8-19e.pdf

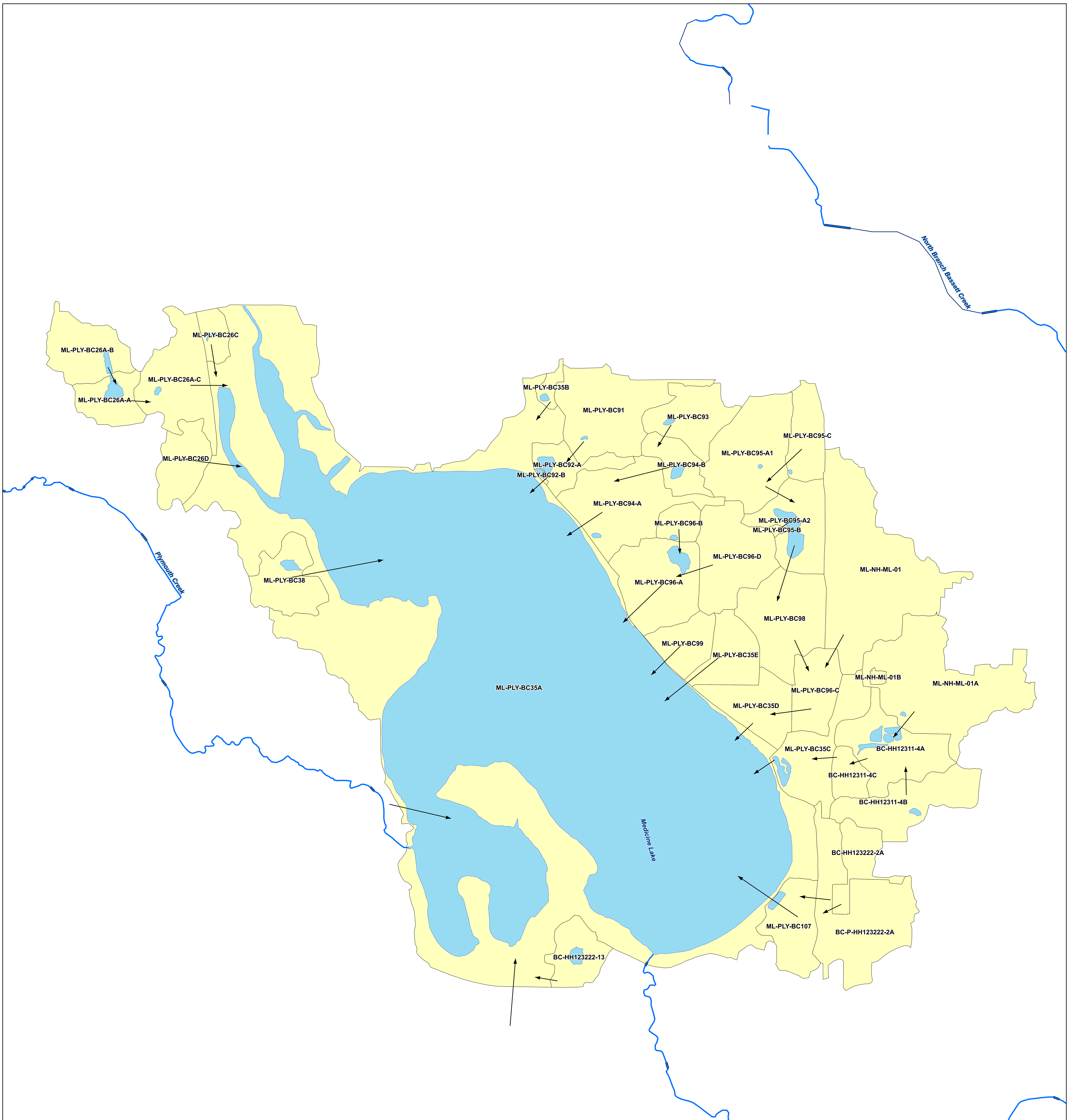
Minnesota Pollution Control Agency (MPCA). 2010b. *Medicine Lake Excess Nutrients TMDL Implementation Plan*. https://www.pca.state.mn.us/sites/default/files/wq-iw8-19c.pdf

Minnesota Pollution Control Agency (MPCA). 2024. *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.

University of Wisconsin-Stout. 2018. *Internal Phosphorus Loading and Alum Dose Considerations for Medicine Lake, Minnesota*. Prepared for Three Rivers Park District.

Appendix A

P8 Model Watershed and BMP Mapping



Watershed	Device	Watershed	Device
BC-HH12311-4A	ML2	ML-NH-ML-01B	ML01B
BC-HH12311-4B	BC-HH12311-4B	ML-PLY-BC38	BC38
BC-HH12311-4C	BC-HH12311-P-4C	ML-PLY-BC91	BC91
BC-HH123222-13	BC-HH123222-13	ML-PLY-BC92-A	BC94C
BC-HH123222-2A	BC-HH123222-2A	ML-PLY-BC92-B	BC92B
BC-P-HH123222-2A	BC-P-HH123222-2A	ML-PLY-BC93	BC93
ML-NH-ML-01	ML-NH-ML-P-01	ML-PLY-BC94-A	BC94A
ML-NH-ML-01A	ML01A	ML-PLY-BC94-B	BC94B
ML-PLY-BC107	BC107 Medicine Lake Park	ML-PLY-BC95-A1	BC95A1
ML-PLY-BC26A-A	BC26A	ML-PLY-BC95-A2	BC95A2
ML-PLY-BC26A-B	BC26B	ML-PLY-BC95-B	BC95B
ML-PLY-BC26A-C	BC26C	ML-PLY-BC95-C	BC95C
ML-PLY-BC26C	BC26E	ML-PLY-BC96-A	BC96
ML-PLY-BC26D	BC26D	ML-PLY-BC96-B	BC96B
ML-PLY-BC35A	BC35 Medicine Lake	ML-PLY-BC96-C	ML-PLY-P-BC96-C
ML-PLY-BC35B	BC91A	ML-PLY-BC96-D	ML-PLY-P-BC96-D
ML-PLY-BC35C	BCP-98a	ML-PLY-BC98	ML-PLY-BC-P-98
ML-PLY-BC35D	MP-P-BC35D	ML-PLY-BC99	ML-PLY-P-BC99
ML-PLY-BC35E	ML-P-BC35E		

Watershed

Ponds

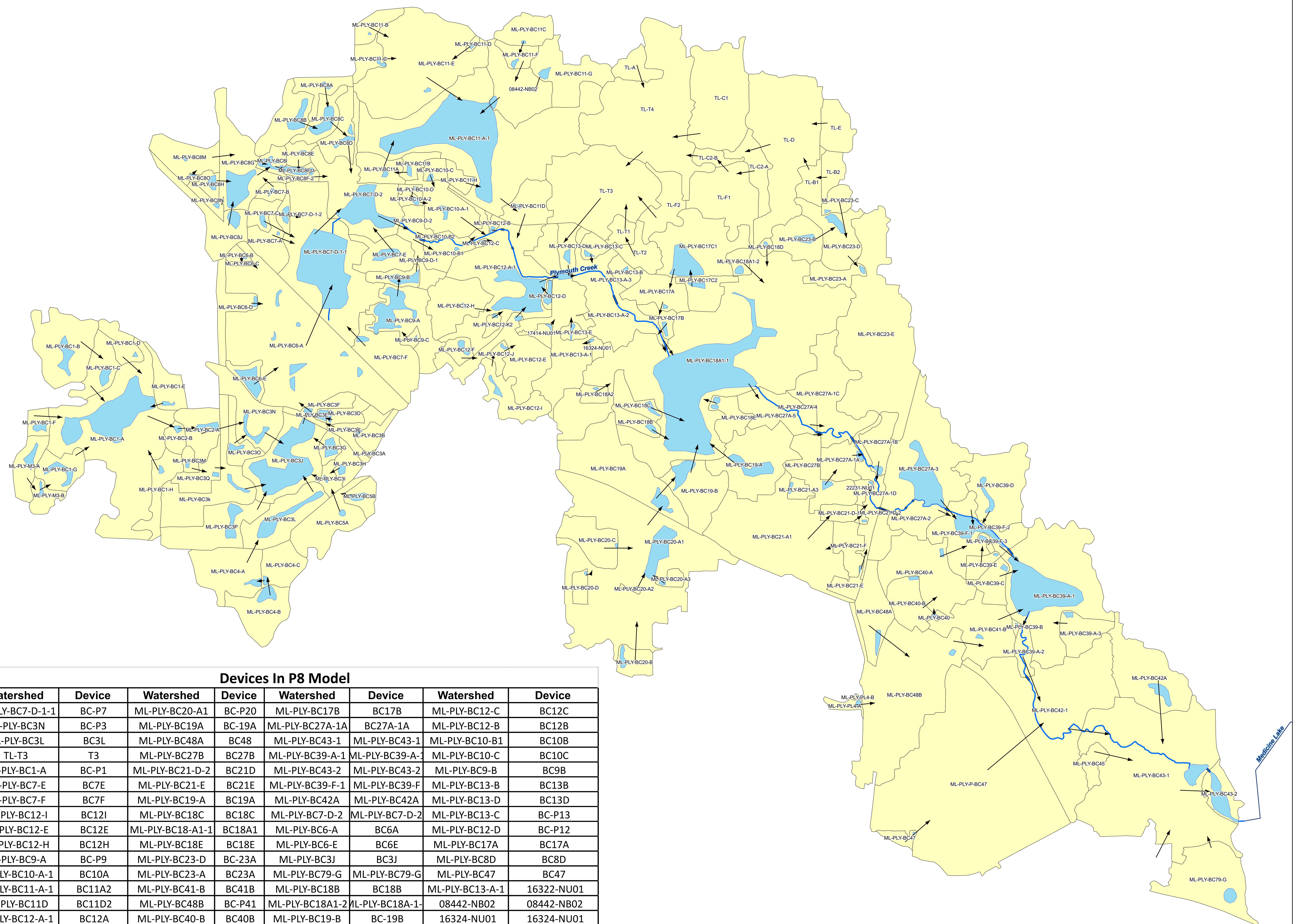
Flow Lines

N

Feet

0 800 1,600 2,400 3,200

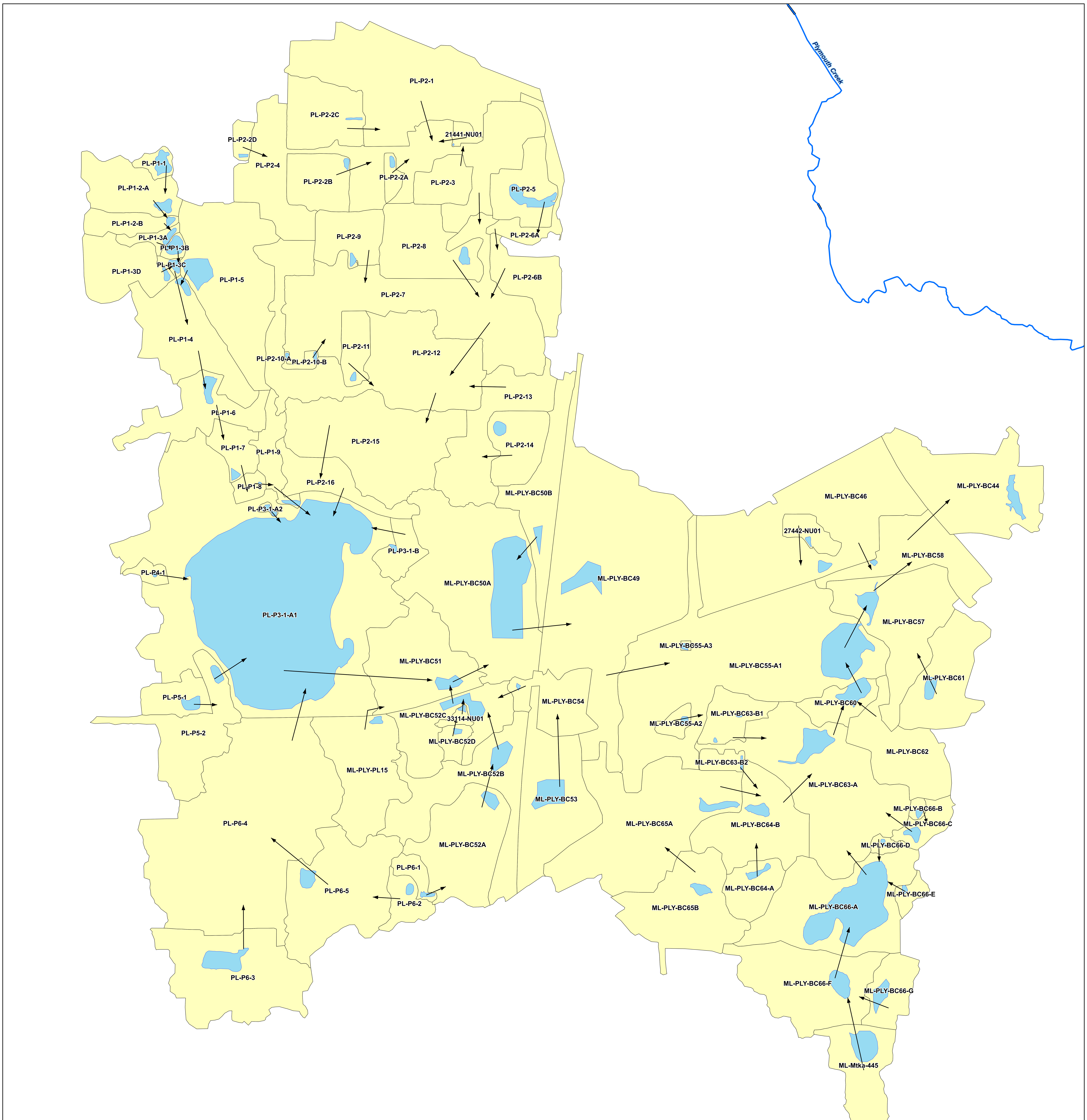
MEDICINE LAKE DIRECT
Water Modeling Updates
Bassett Creek Watershed Management Commission



Devices In P8 Model

Watershed	Device	Watershed	Device	Watershed	Device	Watershed	Device
ML-PLY-BC7-D-1-1	BC-P7	ML-PLY-BC20-A1	BC-P20	ML-PLY-BC17B	BC17B	ML-PLY-BC12-C	BC12C
ML-PLY-BC3N	BC-P3	ML-PLY-BC19A	BC-19A	ML-PLY-BC27A-1A	BC27A-1A	ML-PLY-BC12-B	BC12B
ML-PLY-BC3L	BC3L	ML-PLY-BC48A	BC48	ML-PLY-BC43-1	ML-PLY-BC43-1	ML-PLY-BC10-B1	BC10B
TL-T3	T3	ML-PLY-BC27B	BC27B	ML-PLY-BC39-A-1	ML-PLY-BC39-A-1	ML-PLY-BC10-C	BC10C
ML-PLY-BC1-A	BC-P1	ML-PLY-BC21-D-2	BC21D	ML-PLY-BC43-2	ML-PLY-BC43-2	ML-PLY-BC9-B	BC9B
ML-PLY-BC7-E	BC7E	ML-PLY-BC21-E	BC21E	ML-PLY-BC39-F-1	ML-PLY-BC39-F	ML-PLY-BC13-B	BC13B
ML-PLY-BC7-F	BC7F	ML-PLY-BC19-A	BC19A	ML-PLY-BC42A	ML-PLY-BC42A	ML-PLY-BC13-D	BC13D
ML-PLY-BC12-I	BC12I	ML-PLY-BC18C	BC18C	ML-PLY-BC7-D-2	ML-PLY-BC7-D-2	ML-PLY-BC13-C	BC-P13
ML-PLY-BC12-E	BC12E	ML-PLY-BC18-A1-1	BC18A1	ML-PLY-BC6-A	BC6A	ML-PLY-BC12-D	BC-P12
ML-PLY-BC12-H	BC12H	ML-PLY-BC18E	BC18E	ML-PLY-BC6-E	BC6E	ML-PLY-BC17A	BC17A
ML-PLY-BC9-A	BC-P9	ML-PLY-BC23-D	BC-23A	ML-PLY-BC3J	BC3J	ML-PLY-BC8D	BC8D
ML-PLY-BC10-A-1	BC10A	ML-PLY-BC23-A	BC23A	ML-PLY-BC79-G	ML-PLY-BC79-G	ML-PLY-BC47	BC47
ML-PLY-BC11-A-1	BC11A2	ML-PLY-BC41-B	BC41B	ML-PLY-BC18B	BC18B	ML-PLY-BC13-A-1	16322-NU01
ML-PLY-BC11D	BC11D2	ML-PLY-BC48B	BC-P41	ML-PLY-BC18A1-2	ML-PLY-BC18A-1-	08442-NB02	08442-NB02
ML-PLY-BC12-A-1	BC12A	ML-PLY-BC40-B	BC40B	ML-PLY-BC19-B	BC-19B	16324-NU01	16324-NU01
ML-PLY-BC13-E	BC-P13A	ML-PLY-BC40-A	BC40A	ML-PLY-BC23-B	BC23B	ML-PLY-BC12-K2	BC12K2
ML-PLY-BC17C1	BC17C1	ML-PLY-BC39-D	BC39D	ML-PLY-BC10-A-2	ML-PLY-BC10-A-2	ML-PLY-BC39-A-3	BC-P39
ML-PLY-BC17C2	BC17C2	ML-PLY-BC39-E	BC39E	ML-PLY-BC12-F	BC12F	ML-PLY-PL4-A	PL4-A
ML-PLY-BC27A-1B	BC27A-1B	ML-PLY-BC39-C	BC39C	ML-PLY-BC12-J	BC12J		

PLYMOUTH CREEK
Water Modeling Updates
Bassett Creek Watershed
Management Commission



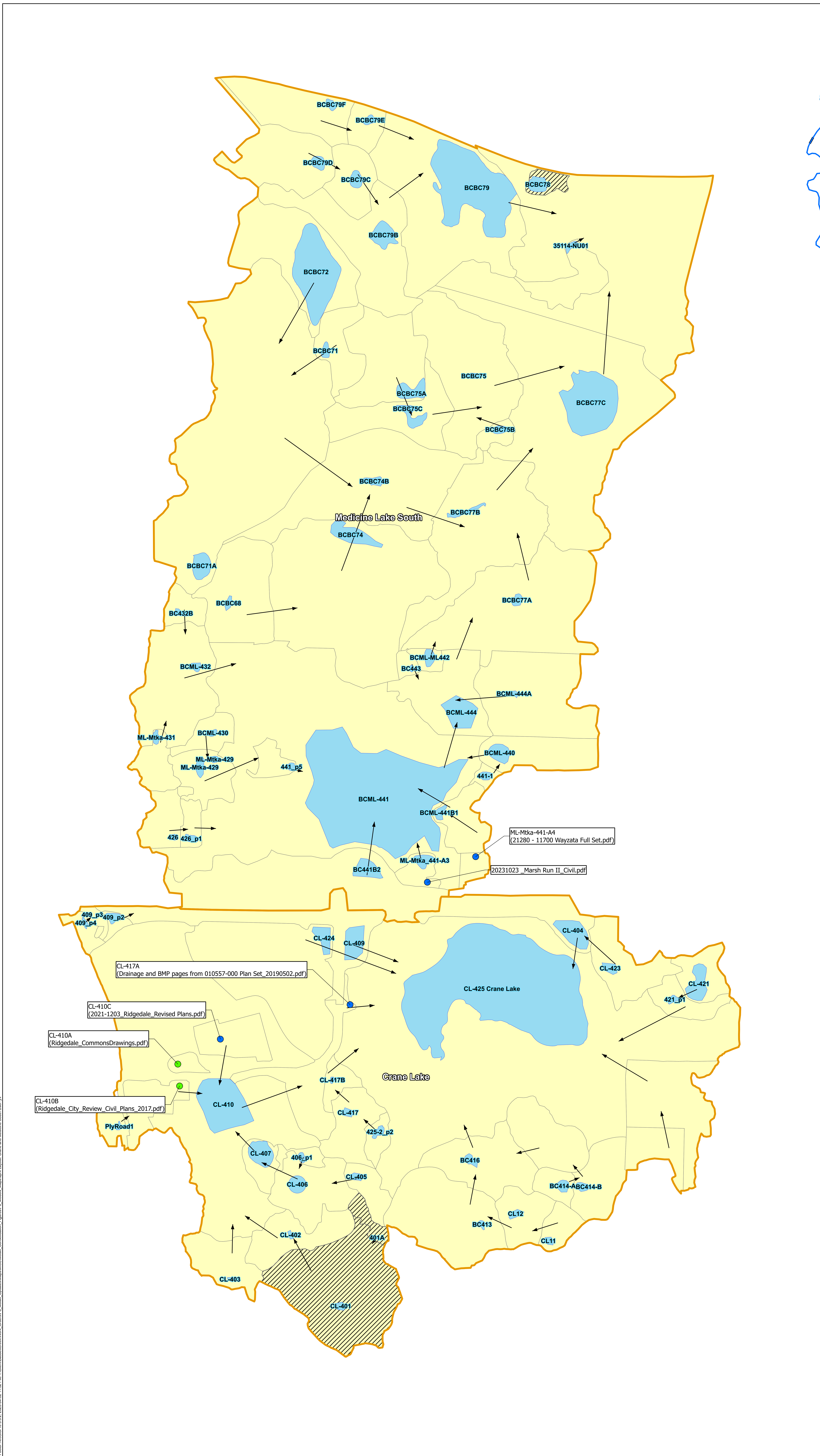
Watershed	Device	Watershed	Device	Watershed	Device	Watershed	Device
ML-Mtka-445	BCML-445	ML-PLY-BC61	BCBC61	PL-P1-4	PL-P22	ML-PLY-BC52C	BC52C
PL-P6-3	PL-P4	ML-PLY-BC51	BC51	PL-P2-6B	PL-P2-P-7	PL-P6-2	PL-P2
PL-P6-1	PL-P6-1	ML-PLY-BC57	BCBC57	PL-P2-12	PL-P2-16	PL-P3-1-B	PL-P3-1-B
ML-PLY-BC65B	BCBC65B	PL-P4-1	PL-P9	PL-P1-3D	PL-P20	PL-P1-3C	PL-P21
PL-P6-5	PL-P3	ML-PLY-BC58	BCBC58	PL-P1-3A	PL-P18	PL-P1-3B	PL-P19
ML-PLY-BC66-A	BCBC66A Cavanaugh Lake	PL-P3-1-A1	PL-P1	PL-P2-9	PL-P12	PL-P1-2-B	PL-P17
ML-PLY-BC64-B	BCBC64B	PL-P1-8	PL-P11	PL-P2-7	PL-P2-P-7	PL-P2-10-A	PL-P2-10-A
ML-PLY-BC65A	BCBC65A	ML-PLY-BC49	BC49	PL-P1-5	PL-P1-5	PL-P2-10-B	PL-P2-10-B
PL-P6-4	PL-P1	ML-PLY-BC44	ML-PLY-BC4	PL-P2-8	PL-P15	PL-P2-2C	PL-P2-2C
ML-PLY-PL15	PL15	ML-PLY-BC46	BCBC46	PL-P2-5	PL-P7	PL-P2-2B	PL-P2-2B
ML-PLY-BC62	BCBC60	PL-P2-16	PL-P2-16	PL-P2-3	PL-P2-P-7	ML-PLY-BC66-B	BCBC66B
ML-PLY-BC63-A	BCBC63	PL-P1-7	PL-P1-7	PL-P1-2-A	PL-P1-2-A	ML-PLY-BC66-C	BCBC66C
ML-PLY-BC53	BC53	PL-P2-14	PL-P5	PL-P1-1	PL-P6	ML-PLY-BC66-D	BCBC66D
ML-PLY-BC60	BCBC60	PL-P2-15	PL-P2-16	PL-P2-2D	PL-P8	ML-PLY-BC66-E	BCBC66E
ML-PLY-BC52B	BC52B	ML-PLY-BC50A	BC50A	PL-P2-4	PL-P2-P-7	ML-PLY-BC66-F	BCBC66F
PL-P5-1	PL-P5-1	PL-P1-9	PL-P16	PL-P2-6A	PL-P2-P-7	ML-PLY-BC64-A	BCBC64A
ML-PLY-BC54	BC54	PL-P2-11	PL-P14	PL-P2-1	PL-P2-P-7	ML-PLY-BC63-B1	BCBC63B1
PL-P5-2	PL-P13	PL-P1-6	PL-P10	ML-PLY-BC52A	BC52A	ML-PLY-BC66-G	BCBC66G
ML-PLY-BC55-A1	BCBC59	PL-P2-13	PL-P2-16	ML-PLY-BC52D	BC52D	ML-PLY-BC50B	BC50B
PL-P3-1-A2	PL-P3-1-A	ML-PLY-BC55-A2	BCBC55	PL-P2-2A	PL-P2-2A	27442-NU01	27442-NU01
ML-PLY-BC63-B2	BCBC63B2	ML-PLY-BC55-A3	BCBC55A	33114-NU01	33114-NU01	21441-NU01	21441-NU01

Watershed
Ponds
Flow Lines

N

Feet
0 600 1,200 1,800 2,400

PARKERS AND PARKERS EAST
Water Modeling Updates
Bassett Creek Watershed Management Commission



Watershed	Device
426	426
426_p1	426_p1
ML-Mtka-429	ML-Mtka-429
ML-Mtka-440	BCML-440
ML-Mtka-431	ML-Mtka-431
ML-Mtka-430	BCML-430
ML-Mtka-441-A1	BCML-441
ML-Mtka-444A	BCML-444A
ML-Mtka-444	BCML-444
ML-Mtka-432-A	BCML-432
ML-Mtka-442	BCML-ML442
BC443	BC443
ML-PLY-BC68	BCBC68
ML-PLY-BC77A	BCBC77A
ML-PLY-BC74-A	BCBC74
ML-PLY-BC75A	BCBC75A
ML-PLY-BC77C	BCBC77C
ML-PLY-BC75-A	BCBC75
ML-PLY-BC71-A	BCBC71A
ML-PLY-BC72	BCBC72
ML-PLY-BC78A	ML-PLY-BC78A
ML-PLY-BC79-A	BCBC79
ML-PLY-BC74-B	BCBC74B
ML-PLY-BC77B	BCBC77B
ML-PLY-BC71-B	BCBC71
ML-PLY-BC75B	BCBC75C
ML-PLY-BC75-B	BCBC75B
ML-Mtka-441-B	BCML-441B1
ML-Mtka-432-B	BC432B
ML-PLY-BC79-B	BCBC79B
ML-PLY-BC79-C	BCBC79C
ML-PLY-BC79-D	BCBC79D
ML-PLY-BC79-E	BCBC79E
ML-PLY-BC79-F	BCBC79F
ML-Mtka-441-A2	BC441B2
CL-403	CL-403
CL-402	CL-402
CL-405	CL-405
CL-406	CL-406
CL-407	CL-407
CL-418	CL-P-418
CL-417	CL-417B
CL-422	CL-P-422
CL-421	CL-421
CL-424	CL-424
CL-410	CL-410
CL-425	CL-425 Crane Lake
CL-423	CL-423
CL-409	CL-409
ML-CL-404	CL-404
CL-417B	CL-417
CL-414-A	BC414-A
CL-414-B	BC414-B
CL-415	CL-P-415
CL-411	CL11
CL-412	CL12
CL-413	BC413
CL-416	BC416
441-1	441-1
441_p5	441_p5
452-2_p2	452-2_p2
406_p1	406_p1
421_p1	421_p1

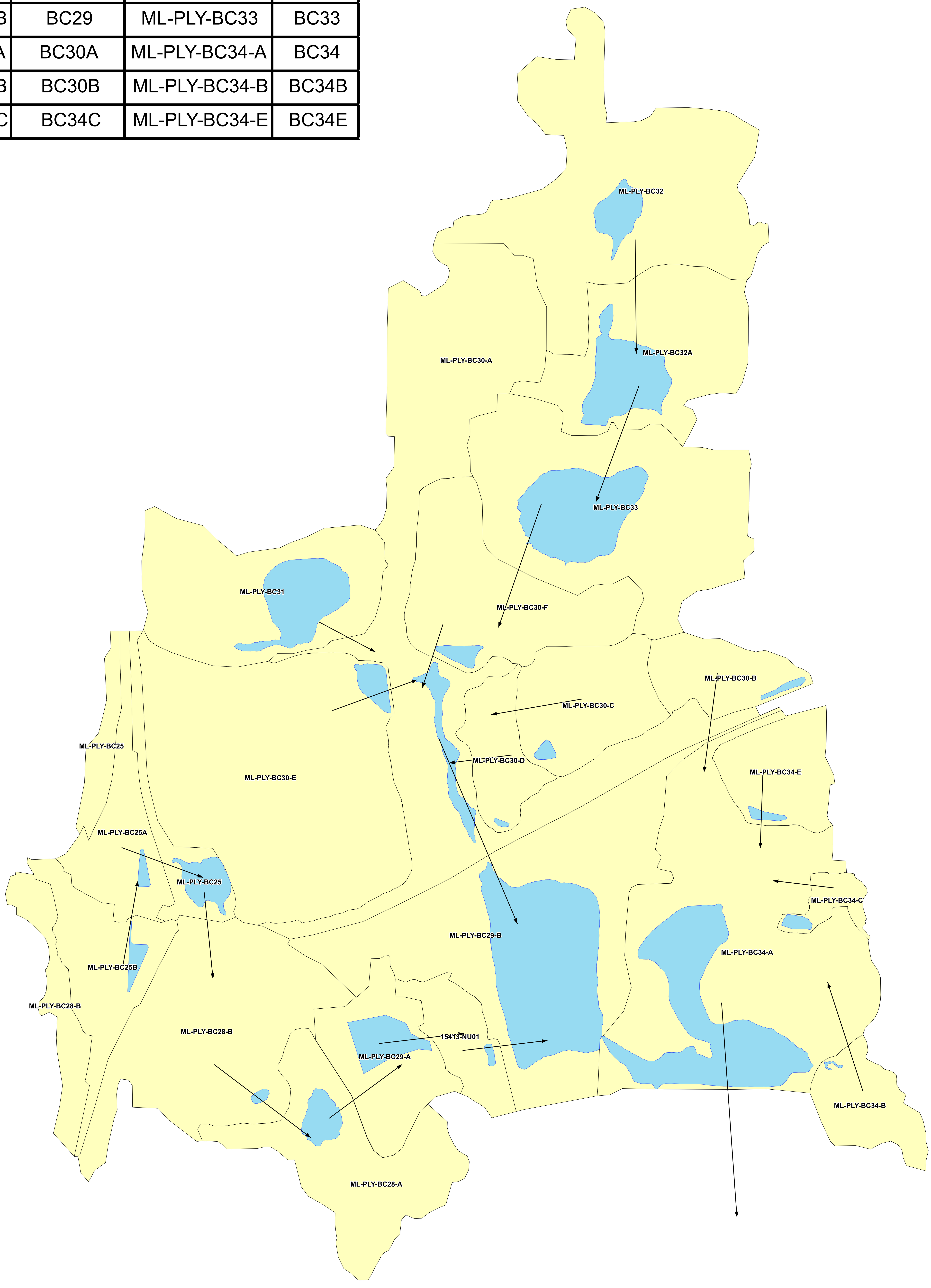
Landlocked Watershed
Flow Lines
Watershed
Minnetonka BMPs
Ponds
Underground Detention
Underground Filtration

N

Feet
0 500 1,000 1,500 2,000

CRANE AND MEDICINE SOUTH
Water Modeling Updates
Bassett Creek Watershed Management Commission

Watershed	Device	Watershed	Device
15413-NU01	15413-NU01	ML-PLY-BC30-C	BC30C
ML-PLY-BC25	BC25	ML-PLY-BC30-D	BC30D
ML-PLY-BC25A	BC25A	ML-PLY-BC30-E	BC30
ML-PLY-BC25B	BC25B	ML-PLY-BC30-F	BC30F
ML-PLY-BC28-A	BC28	ML-PLY-BC31	BC31
ML-PLY-BC28-B	BC28B	ML-PLY-BC32	BC32B
ML-PLY-BC29-A	BC-P29	ML-PLY-BC32A	BC32A
ML-PLY-BC29-B	BC29	ML-PLY-BC33	BC33
ML-PLY-BC30-A	BC30A	ML-PLY-BC34-A	BC34
ML-PLY-BC30-B	BC30B	ML-PLY-BC34-B	BC34B
ML-PLY-BC34-C	BC34C	ML-PLY-BC34-E	BC34E



Ponds

Watershed

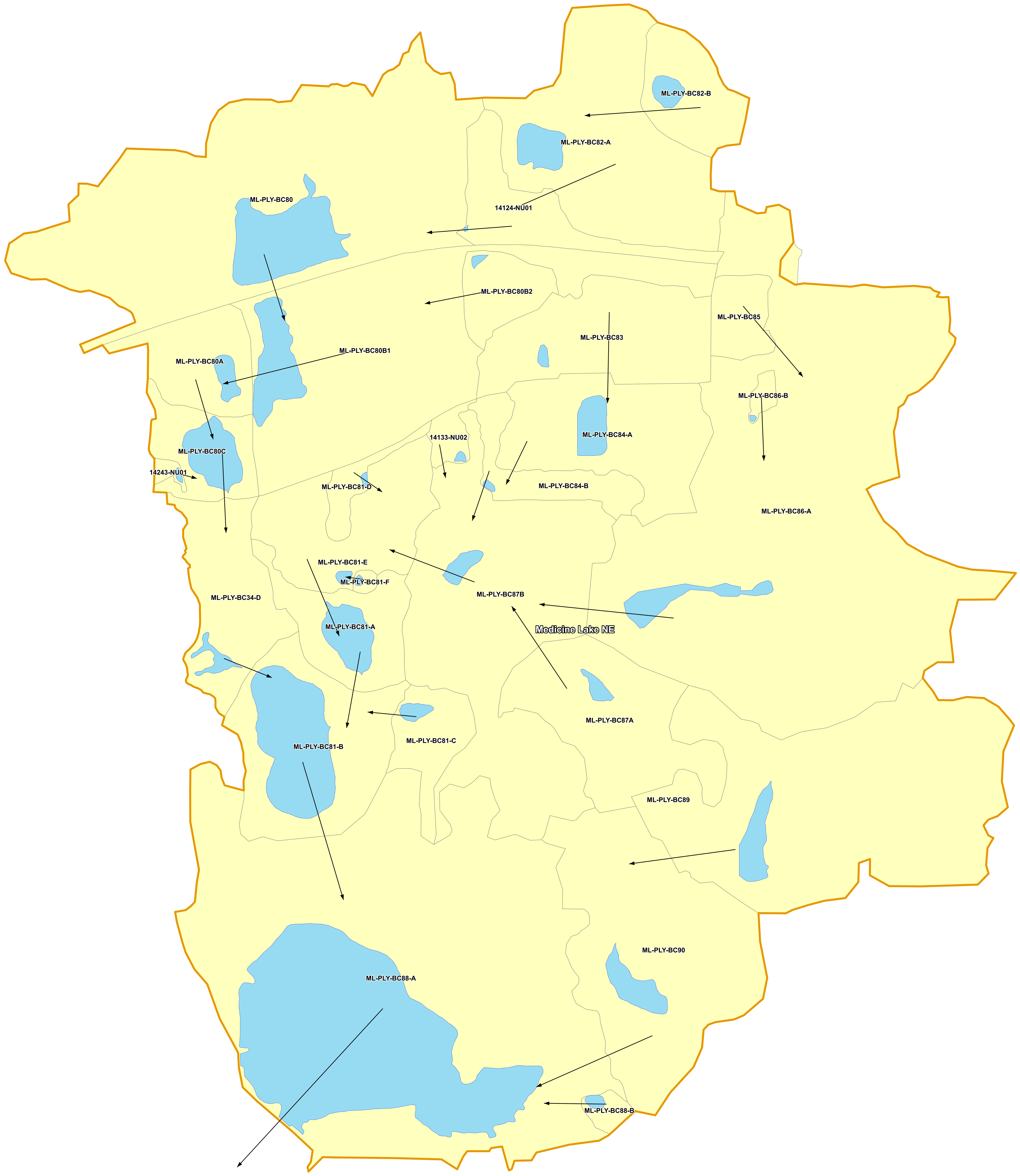
Flow Lines

N

Feet

0 750

MEDICINE LAKE NORTH
Water Modeling Updates
Bassett Creek Watershed Management Commission



Watershed	Device	Watershed	Device	Watershed	Device
ML-PLY-BC90	BC90	ML-PLY-BC83	BC83	ML-PLY-BC82-A	BC82A
ML-PLY-BC88-A	BC88	ML-PLY-BC80B1	BC80B	ML-PLY-BC82-B	BC82B
ML-PLY-BC89	BC89	ML-PLY-BC80	BC80	ML-PLY-BC88-B	BC88B
ML-PLY-BC87A	BC87A	ML-PLY-BC80C	BC80C	ML-PLY-BC84-B	BC84B
ML-PLY-BC87B	BC87	ML-PLY-BC34-D	BC34D	ML-PLY-BC80B2	BC80D
ML-PLY-BC81-A	BC81	ML-PLY-BC81-C	BC81C	14124-NU01	14124-NU01
ML-PLY-BC84-A	BC84A	ML-PLY-BC81-B	BC81B	ML-PLY-BC85	14141-NU01
ML-PLY-BC80A	BC80A	ML-PLY-BC81-D	BC81D	14133-NU02	14133-NU02
ML-PLY-BC86-A	BC86A	ML-PLY-BC81-E	BC81E	ML-PLY-BC86-B	BC86B
ML-PLY-BC81-F	BC81F	14243-NU01	14243-NU01		

Watershed
Ponds
Flow Lines

N

Feet
0 300 600 900 1,200

MEDICINE LAKE NORTHEAST
Water Modeling Updates
Bassett Creek Watershed Management Commission

Appendix B

Detailed Summary of TP Load Reductions (lbs/yr) Estimated for Each Watershed BMP

Watershed	Subwatershed	Annual TP Load Reduction (lbs)
Plymouth Creek**	ML-PLY-BC43-1	249.31
Plymouth Creek**	BC6A	105.45
Plymouth Creek**	ML-PLY-BC43-2	89.71
Plymouth Creek**	BC-P7	75.76
Plymouth Creek**	08442-NB02	14.43
Plymouth Creek**	16322-NU01	11.40
Plymouth Creek**	BC8D	10.49
Plymouth Creek**	BC-P9	8.91
Plymouth Creek**	BC6E	2.74
Plymouth Creek**	16324-NU01	2.44
Plymouth Creek**	BC12F	1.71
Plymouth Creek**	BC-P13A	0.93
Plymouth Creek**	27442-NU01	7.19
Plymouth Creek**	BCBC63B1	6.74
Plymouth Creek**	21441-NU01	1.56
Plymouth Creek**	33114-NU01	0.12
Ridgedale Creek	CL-410C	8.72
Ridgedale Creek	CL-410B	8.25
Ridgedale Creek	426_p1	4.39
Ridgedale Creek	ML-Mtka-429	3.71
Ridgedale Creek	CL-417A	3.71
Ridgedale Creek	35114-NU01	3.50
Ridgedale Creek	PlyRoad1	2.11
Ridgedale Creek	CL-410A	2.00
Ridgedale Creek	409_p2	1.99
Ridgedale Creek	ML-Mtka-441-A3	1.92
Ridgedale Creek	ML-Mtka-441-A4	1.79
Ridgedale Creek	421_p1	1.69
Ridgedale Creek	409_p4	1.59
Ridgedale Creek	ML-Mtka-431	1.15
Ridgedale Creek	441_p5	0.70
Ridgedale Creek	409_p3	0.67
Ridgedale Creek	441-1	0.42
Ridgedale Creek	425-2_p2	0.37
Ridgedale Creek	406_p1	0.33
Medicine Lake Direct	ML2	44.70
Medicine Lake Direct	BC107 Medicine Lake Park	40.73
Medicine Lake Direct	BC-P98a	23.88
Medicine Lake Direct	BC-HH123222-2A	4.31
Medicine Lake Direct	ML01B	0.41
Medicine Lake NE	BC83	7.92
Medicine Lake NE	BC81E	2.68
Medicine Lake NE	14141-NU01	2.42
Medicine Lake NE	BC84B	1.68
Medicine Lake NE	14133-NU02	1.07
Medicine Lake NE	14124-NU01	0.88
Medicine Lake NE	BC81F	0.67
Medicine Lake NE	BC86B	0.55
Medicine Lake NE	14243-NU01	0.28
Medicine Lake North	BC34	42.29
Medicine Lake North	BC25B	7.84
Medicine Lake North	BC30B	4.25
Medicine Lake North	BC25A	4.16
Medicine Lake North	15413-NU01	1.44