# St. Clair Lake Total Maximum Daily Load (TMDL)

Quantification of the phosphorus reductions needed to improve lake water quality


Minnesota Pollution Control Agency

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wq-iw5-07e

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## Acknowledgements:

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The MPCA approved the third party TMDL work plan and assigned a project manager to ensure that the study was consistent with meeting state/federal requirements and expectations. The MPCA provided peer review of the preliminary draft, submitted it to U.S. Environmental Protection Agency (EPA) for preliminary approval, and provided administration for the public notice and final approval process.

The MPCA would like to thank the city of Detroit Lakes (City) for being an important partner in the TMDL process. The City provided time for its staff, including the Operator of the Waste Water Treatment Facility and the Manager of the Public Works Department to be integrally involved in the process of setting the WLA and the Implementation Plan.

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<tr><td>303(d) Listing Information</td><td>Describe the waterbody as it is identified on the State/Tribe's 303(d) list:
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<tr><td>St. Clair</td><td>03-0382-00</td><td>2008</td><td>2012/2015</td></tr>
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<li>Impaired Use: Aquatic Recreation</li>
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<tr><td>Applicable Water Quality Standards/ Numeric Targets</td><td>Class 2B Waters, MN Eutrophication Standards<br>Minn. R. 7050.0222, subp. 4, North Central Forests Ecoregion
<table>
<tr><th>Parameter</th><th>Shallow Lake Standard</th></tr>
<tr><td>Total Phosphorus (µg/l)</td><td>TP <60</td></tr>
<tr><td>Chlorophyll-a (µg/l)</td><td>Chl-a <20</td></tr>
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<tr><td colspan="2">
<table>
<tr><th></th><th></th><th></th><th></th><th>lb/yr</th><th>lb/day</th></tr>
<tr><td rowspan="8">Wasteload Allocations</td><td colspan="3">Total WLA</td><td>736</td><td>2.018</td></tr>
<tr><td colspan="2">Construction</td><td></td><td>8</td><td>0.022</td></tr>
<tr><td colspan="2">Industrial</td><td></td><td>8</td><td>0.022</td></tr>
<tr><td colspan="2">WWTP[1]</td><td></td><td>437</td><td>1.197</td></tr>
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<tr><td></td><td>Ditch 1</td><td>137</td><td>0.375</td></tr>
<tr><td></td><td>Ditch 14</td><td>134</td><td>0.368</td></tr>
<tr><td></td><td>Subtotal</td><td>283</td><td>0.776</td></tr>
<tr><td rowspan="8">Load Allocations</td><td colspan="3">Total LA</td><td>168</td><td>0.461</td></tr>
<tr><td colspan="2">Long Lake Outflow[2]</td><td></td><td>45</td><td>0.123</td></tr>
<tr><td colspan="2">Groundwater</td><td></td><td>8</td><td>0.022</td></tr>
<tr><td colspan="2">Atmosphere</td><td></td><td>30</td><td>0.082</td></tr>
<tr><td rowspan="4">Unregulated runoff</td><td></td><td>Direct drainage</td><td>14</td><td>0.040</td></tr>
<tr><td></td><td>Ditch 1</td><td>70</td><td>0.191</td></tr>
<tr><td></td><td>Ditch 14</td><td>1</td><td>0.002</td></tr>
<tr><td></td><td>Subtotal</td><td>85</td><td>0.233</td></tr>
<tr><td colspan="4">LOADING CAPACITY</td><td>1,005</td><td>2.753</td></tr>
</table></td><td>42</td></tr>
</table>

| | | |
|---|---|---|
| **Margin of Safety** | A 10% explicit margin of safety (MOS) was accounted for in the TMDL. This MOS is sufficient to account for uncertainties in predicting loads to the lake and predicting how the lake responds to changes in phosphorus loading. | 40 |
| **Seasonal Variation** | Critical conditions in these lakes occur in the summer, when TP concentrations peak and clarity is at its worst. The water quality standards are based on growing season averages. The load reductions are designed so that the lake will meet water quality standards over the course of the growing season (June-September). | 40 |
| **Reasonable Assurance** | Active Local Partners: Pelican River Watershed District, Long Lake Association, Local Communities<br>NPDES permit compliance | 44 |
| **Monitoring** | ***Monitoring Plan included?*** yes | 45 |
| **Implementation** | ***1. Implementation Strategy included?*** yes<br>***2. Cost estimate included?*** yes | 46 |
| **Public Participation** | · Public Comment period January 20 – February 19, 2015<br>· Comments received from Minnesota Department of Agriculture<br>· Stakeholder meetings held on October 9, 2012; October 25, 2012; April 16, 2013; April 30, 2014; and October 23, 2014.<br>· October 25, 2012; April 16, 2013; April 16, 2014; and August 13, 2014 meetings were structured specifically for regulated entities to review calculation methods and receive comments on draft WLAs. | 49 |

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**Abbreviations**

| | |
|---|---|
| BMP | best management practice |
| BWSR | Minnesota Board of Water and Soil Resources |
| CAFO | Concentrated Animal Feeding Operation |
| CALM | Consolidation Assessment and Listing Methodology |
| Chl-*a* | Chlorophyll-*a* |
| CWA | Clean Water Act |
| CN | Curve Number |
| CV | Coefficient of Variation |
| DNR | Minnesota Department of Natural Resources |
| EMC | Event Mean Concentration |
| EOR | Emmons and Olivier Resources, Incorporated |
| EPA | Environmental Protection Agency |
| GIS | Geographic Information Systems |
| GSM | Growing season mean |
| HSG | Hydrologic Soil Group |
| ITPHS | Imminent Threat to Public Heath Septic System |
| LA | Load Allocation |
| LC | Loading Capacity |
| MOS | Margin of Safety |
| MPCA | Minnesota Pollution Control Agency |
| MS4 | Municipal Separate Storm Sewer System |
| NCHF | North Central Hardwood Forests |
| NLCD | National Land Cover Dataset |
| NPDES | National Pollutant Discharge Elimination System |
| NPS | Non-point source |
| P | Phosphorus |
| PRWD | Pelican River Watershed District |
| PS | Point source |
| Secchi | Secchi disk transparency |
| SDS | State Disposal System |

| | |
|---|---|
| SE | Standard Error |
| SLICE | Sustaining Lakes in a Changing Environment |
| SSTS | Subsurface Sewage Treatment System |
| SWAT | Soil and Water Assessment Tool |
| SWPPP | Stormwater Prevention Pollution Plan |
| SWCD | Soil and Water Conservation District |
| TMDL | Total Maximum Daily Load |
| TP | Total Phosphorus |
| US ACOE | United States Army Corps of Engineers |
| USDA | United States Department of Agriculture |
| USGS | United States Geological Survey |
| WLA | Wasteload Allocation |
| WQBEL | Water Quality Based Effluent Limit |
| WRAP | Watershed restoration and protection plan |
| WWTF | Wastewater treatment facility |

# EXECUTIVE SUMMARY

This Total Maximum Daily Load (TMDL) study addresses the nutrient impairment of St. Clair Lake, located in Detroit Lakes, Minnesota. St. Clair Lake is 160 acres and receives runoff from 7,380 acres (or 11.5 square miles) of land. St. Clair Lake and its watershed are located in Becker County, Minnesota – a growth region of the State. This lake does not meet Minnesota's water quality standards due to excessive nutrient and algal concentrations. Lake St. Clair discharges via County Ditch 14 to Muskrat Lake and then to Sallie and Melissa Lakes. These lakes have been the subject of extensive city of Detroit Lakes and Pelican River Watershed District (PRWD) rehabilitation efforts over the past three decades that have resulted in measurable improvements in water quality. However, additional reductions in nutrient concentrations are required to fully achieve lake water quality standards and beneficial uses.

The nutrient phosphorus (P) is the primary focus of this TMDL. Phosphorus is a necessary nutrient in lake ecology; however, too much P can cause excessive algae blooms, oxygen depletion (loss of oxygen), low water clarity and shifts in the types of fish present. These collective impacts can cause lake conditions that are not preferred for primary contact recreation (swimming) and lead to a dominance of rough fish (carp and black bullhead) and fish kills. Elevated P concentrations also encourage noxious blue-green algae that can form surface scums, have very unpleasant odors and can sometimes be toxic.

St. Clair Lake was first listed on the Environmental Protection Agency's (EPA) 303(d) Impaired Waters List (or Draft list) in 2008 (see Table 1 for impairment listing). This TMDL report will address the impairment, provide an assessment of the ecological health of the lake, assess potential P sources, and provide guidelines on how to restore the aquatic recreational use of the lake. To address all of the potential nutrient sources and pollutant control methods, TMDLs have been standardized nationally to be expressed in terms of daily loads such as pounds of P per day, instead of what is more typically seen in PRWD reports as pounds of P per year.

Information from multiple sources was used to evaluate the ecological health of St. Clair Lake:

- In-lake water quality data over the past 10 years, including P and chlorophyll-*a* (Chl-*a* ) concentrations, and Secchi transparency
- In-lake biological characteristics provided by the local community and principal investigators of previous studies

The following P sources were evaluated for St. Clair Lake: watershed runoff, feedlots, wastewater treatment facilities, loading from upstream lakes, atmospheric deposition, shallow groundwater sources, and internal loading. An inventory of P sources was used as inputs to a lake water quality response model (BATHTUB), and this model was used to determine the P reductions needed for the lake to meet water quality standards. The implementation approach will include: education and outreach; technical assistance; and partnerships with landowners, the city of Detroit Lakes, townships, Becker County, Long Lake Association, and the PRWD. A summary of necessary P reductions is shown in the table below.

| Lake | Loading Capacity (TMDL) (lb/day) | MOS (lb/day) | Wasteload Allocation (lb /day) | Load Allocation (lb/day) | Reduction Needed (%) |
|---|---|---|---|---|---|
| St. Clair | 2.75 | 0.27 | 2.02 | 0.46 | 24% |

**St. Clair Lake Water Quality and Phosphorus Source Summary**

- Long-term growing season mean lake water quality exceeds (violates) the P and Chl-*a* water quality standards and just meets the Secchi transparency standard.
- In 1915, the lake was drained from approximately 600 acres to its current size of 160 acres.
- The city of Detroit Lakes' original wastewater treatment facility (WWTF) was constructed in 1929. A modern WWTF was constructed in 1976 which significantly reduced P loads to St. Clair Lake and downstream water bodies.
- Unconsolidated lake bottom sediment is as thick as 12 feet in portions of the lake. This, in combination with the lake's history of receiving sewage prior to modern wastewater treatment, indicates a high potential for internal loading from sediments. The lake was treated with alum in fall of 1998, and the suppression of internal P loading is evident in the datasets through 2013.
- Approximately 16% of the watershed is agricultural, and there is one feedlot in the watershed. Other land uses are comprised of urban (25%), forest (21%), grass and pasture (3% and 16%, respectively), wetlands (11%) and open water (8%).
- Motor boat access is restricted to the Minnesota Department of Natural Resources (DNR) and PRWD for data gathering purposes.
- The lake is heavily used by waterfowl.
- The lake is subject to periodic winterkill and is not supportive of permanent game fish populations.
- The shoreline is predominately cattail. Heavy algae growth is common during the summer months, which can limit light penetration for a healthy submergent macrophyte population. Wetlands surrounding the lake provide a buffer from adjacent very low density residential and commercial development.

# 1 PROJECT OVERVIEW

## 1.1 Purpose

This TMDL study addresses the impairment of St. Clair Lake for aquatic recreation use due to excess nutrients (phosphorus). St. Clair Lake is located in the Red River Basin of the North in the city of Detroit Lakes, Becker County, Minnesota. The goal of this TMDL is to provide wasteload allocations (WLAs) and load allocations (LAs) and quantify the pollutant reductions needed to meet the state water quality standards. This TMDL for P is being established in accordance with section 303(d) of the Clean Water Act (CWA), because the State of Minnesota has determined that this lake exceeds the state established standards.

## 1.2 Identification of Waterbodies

St. Clair Lake is currently on the EPA 303(d) Impaired Waters List due to excess nutrients (Table 1). Figure 1 illustrates the St. Clair Lake Watershed and its location in Minnesota.

The following applies to St. Clair Lake:

| | |
|---|---|
| *Impaired Use:* | Aquatic Recreation |
| *Pollutant or Stressor:* | Nutrient/Eutrophication Biological Indicators |
| *Basin:* | *Red River of the North* |
| *Major Watershed:* | *Otter Tail River Watershed* |
| *Hydrologic Unit Code:* | 090201030705 |

**Table 1. Impairment addressed by this report**

| Lake Name | Lake ID | Year Listed | Target Start/Completion | Lake Classification | EPA CALM Category |
|---|---|---|---|---|---|
| St. Clair | 03-0382-00 | 2008 | 2012/2015 | Shallow Lake | 5C |

## 1.3 Priority Ranking

The Minnesota Pollution Control Agency's (MPCA) projected schedule for TMDL completions (Table 1), as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

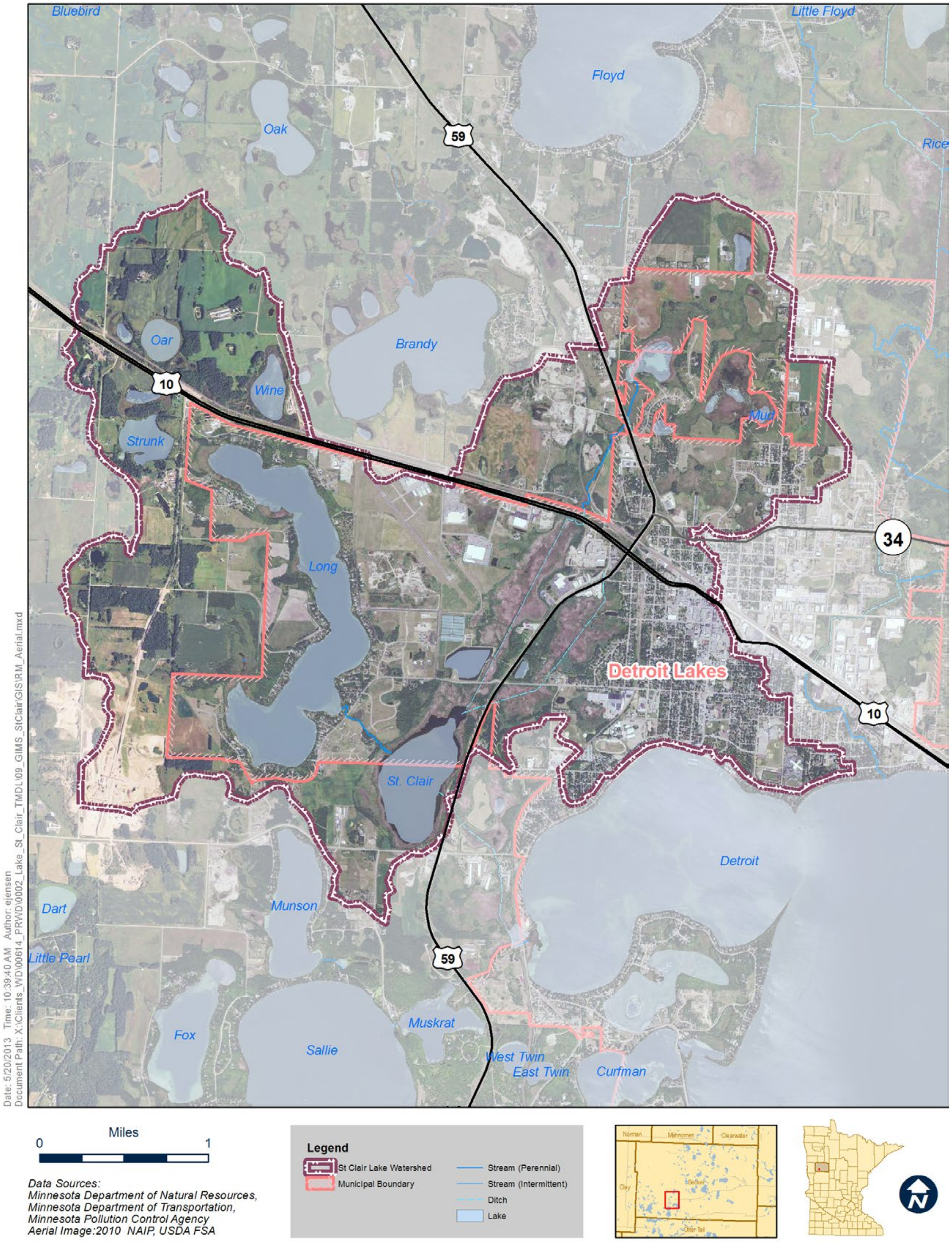



**Figure 1. St. Clair Lake Watershed and its location in Minnesota**

# 2 APPLICABLE WATER QUALITY STANDARDS

Each stream reach and lake has a Designated Use Classification defined by the MPCA, which defines the optimal purpose for that waterbody. St. Clair Lake is classified as 2B or 3C water. Class 2 waters are protected for aquatic life and aquatic recreation by Minn. R. ch. 7050.0140, subp. 3:

> *"Class 2 waters, aquatic life and recreation. Aquatic life and recreation includes all waters of the state that support or may support fish, other aquatic life, bathing, boating, or other recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life or their habitats or the public health, safety, or welfare."*

## 2.1 Lake Eutrophication

Minnesota's lake eutrophication standards (Minn. R. 7050.0222, subp. 4) were developed by the MPCA, covering a wide cross-section of lakes and lake types by aquatic ecoregion based on over two decades of research and associated peer-reviewed publications (Heiskary and Wilson 2005). Clear relationships were established between the causal factor (total phosphorus) and the response variables--Chl -*a* (a pigment found in algal cells) and Secchi transparency. Based on these relationships, it is expected that by meeting the P standard in a lake, the Chl-*a* and Secchi standards will likewise be met. Total phosphorus (TP) is often the limiting factor in primary production in freshwater lakes; as in-lake P concentrations increase, algal growth increases resulting in higher Chl-*a* concentrations and lower water transparency.

According to the MPCA's definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 feet, or if the littoral zone (area where depth is less than 15 feet) covers at least 80% of the lake's surface area. By both of these measures, St. Clair Lake is a shallow lake. St. Clair Lake is located within the Northern Central Hardwood Forests Ecoregion and applicable water quality standards are listed in Table 2.

To be listed as impaired (Minn. R. 7050.0150, subp. 5), the summer growing season (June through September) monitoring data must show that the standards for both TP (the causal factor) and either Chl-*a* or Secchi transparency (the response variables) were violated. If a lake is impaired with respect to only one of these criteria, it may be placed on a review list; a weight of evidence approach is then used to determine if it will be listed as impaired. For more details regarding the listing process, see the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List (MPCA 2012a).*

**Table 2. Lake Eutrophication Standards for Northern Central Hardwood Forest (NCHF) Ecoregion**

| Lake Type | TP (ppb) | Chl-*a* (ppb) | Secchi (m) |
|---|---|---|---|
| Shallow Lakes | < 60 | < 20 | > 1.0 |

# 3 WATERSHED AND WATERBODY CHARACTERIZATION

## 3.1 Lakes

St. Clair Lake (DNR Lake ID 03-0382-00) is a shallow lake located in the city of Detroit Lakes in Becker County. Table 3 summarizes the lake's physical characteristics, Figure 2 shows the 2012 aerial photography, and Figure 3 illustrates the available bathymetry.

**Table 3. St. Clair Lake Physical Characteristics**

| Characteristic | Value | Source |
|---|---|---|
| Lake total surface area (acre) | 160 | Aerial photography (2003, 2006, 2008) |
| Percent lake littoral surface area (%) | 100 | PRWD 1998 Bathymetry |
| Lake volume (acre-feet) | 784 | Calculated |
| Mean depth (feet) | 4.9 | PRWD 1998 Bathymetry |
| Maximum depth (feet) | 9 | PRWD 1998 Bathymetry |
| Drainage area (acre) | 7,380 | DNR Catchments and city of Detroit Lakes Stormsewer Drainage Layers |
| Watershed area: Lake area | 46:1 | Calculated |


**Figure 2. St. Clair Lake 2012 aerial photograph.**
Source: maps.google.com, Imagery ©2012 DigitalGlobe, GeoEye, USDA Farm Service Agency

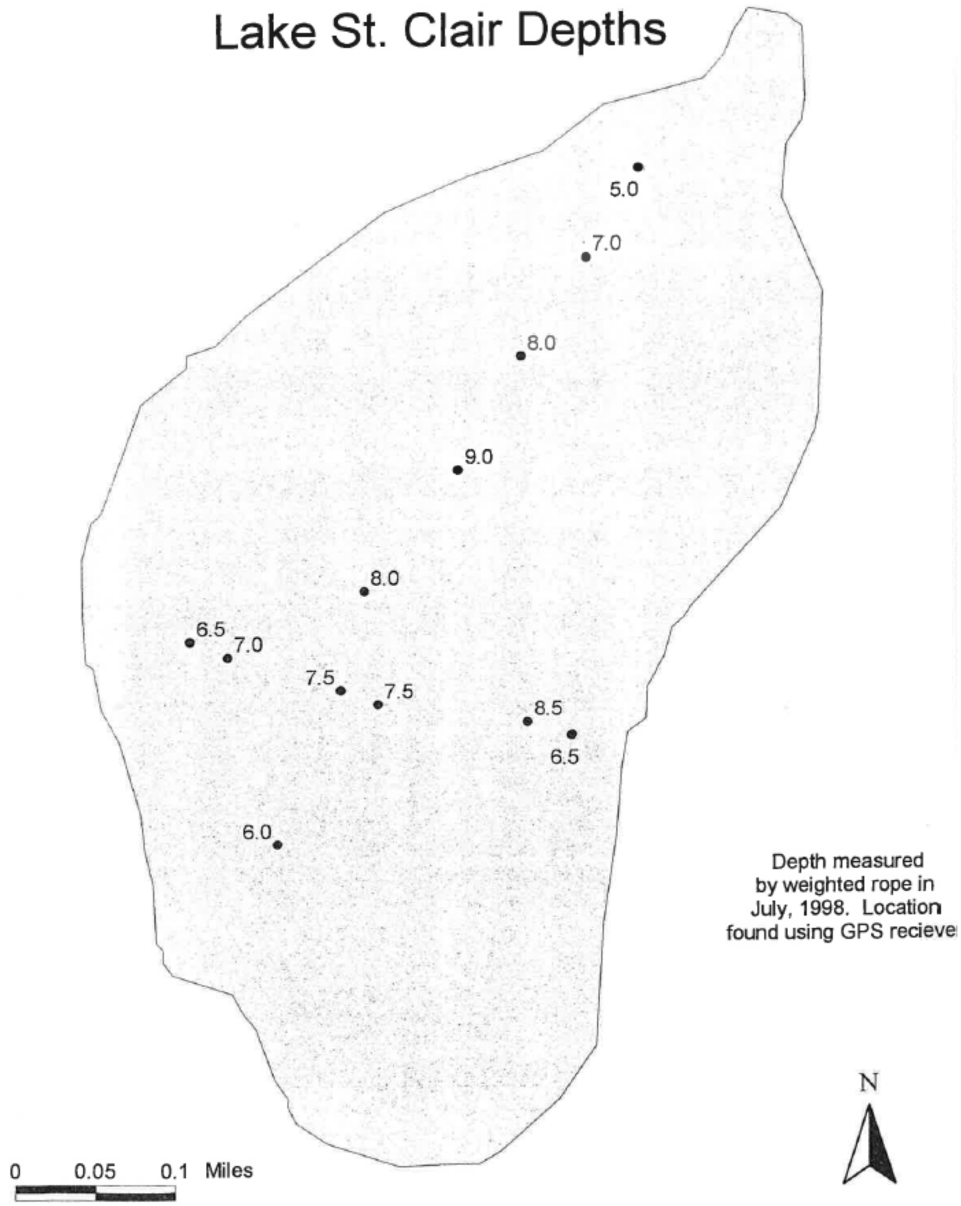



**Figure 3. St. Clair Lake spot bathymetry (PRWD 1998)**

## 3.2 Subwatersheds

The St. Clair Lake Watershed is located in Becker County. It is about 11.5 square miles in size and includes portions of the city of Detroit Lakes as well as several townships: Detroit Lakes, Audubon, Lake Eunice, and Lakeview (Figure 4). According to the 2010 U.S. Census Data (http://www.census.gov), the city of Detroit Lakes has a population of 8,569 people. Long Lake and its watershed discharge to St. Clair Lake from the west. Stormwater from the city of Detroit Lakes discharges to St. Clair Lake from the northeast, largely via Ditch 14. The outlet from St. Clair Lake is located to the southeast and flows south to Muskrat Lake, which discharges to Lakes Sallie and Melissa and ultimately to the Otter Tail River. There are several wetland complexes in the watershed (Figure 5). Wetlands are centralized around St. Clair Lake and the two ditch systems discharging to the lake from the north/northeast.

Figure 4 includes the recent annexation of land adjacent to Long Lake, adopted by the City Council on October 9, 2012, effective November 15, 2012. According to the Detroit Lakes Comprehensive Plan, residential and commercial growth is projected to occur south and west of the current city limits, in particular, the area around the Detroit Lakes Airport, Long Lake, and St. Clair Lake, to the west of Highway 59, north of County State Aid Highway 6, and south of Highway 10 area. A lengthy list of area annexations is tabulated in Appendix E. Demographic growth projections indicate increased density and more residential development are to occur in the watershed.

The city of Detroit Lakes WWTF is centrally located in the watershed (Figure 10). The WWTF uses approximately 100 acres of the watershed as a part of its treatment processes (rapid infiltration basins, spray irrigation fields, and polishing pond). Treated effluent discharges into the wetlands adjacent to and north of St. Clair Lake.

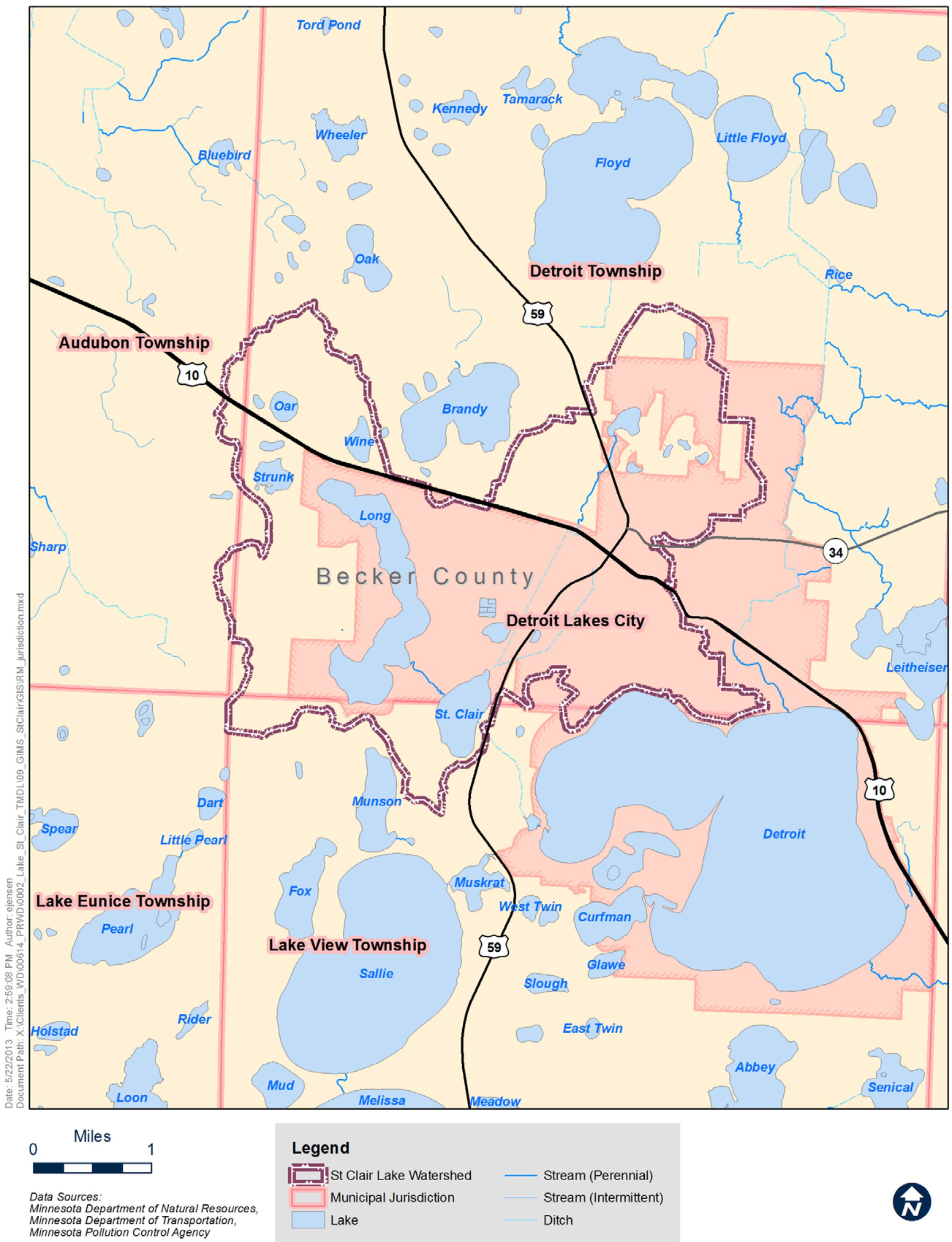



**Figure 4. St. Clair Lake Watershed city and township boundaries**

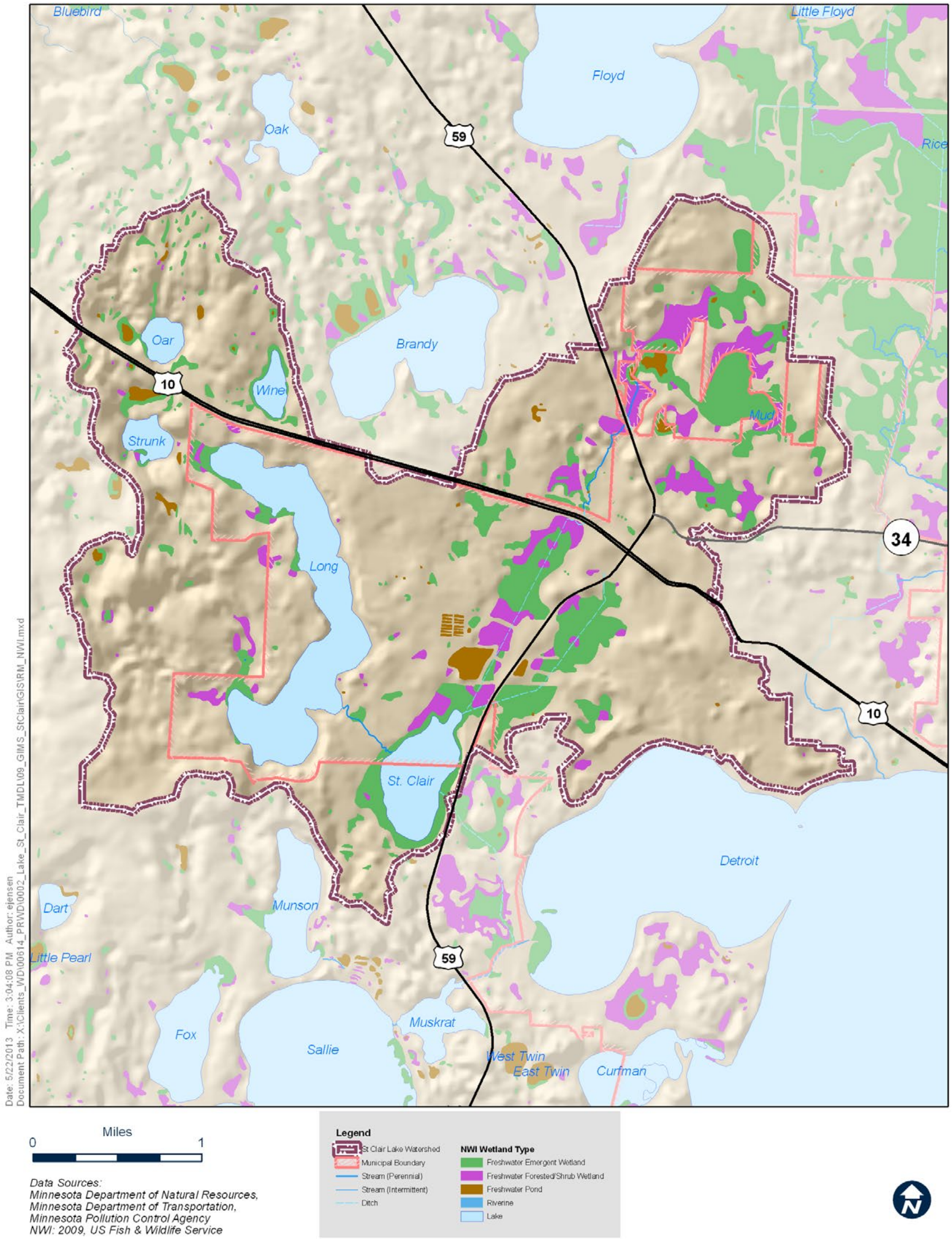



**Figure 5. Wetland Types of the St. Clair Lake Watershed**

## 3.3 Land Use

Land covers in the St. Clair Lake Watershed are shown in Figure 6. Table 4 summarizes the proportion of land cover for the Long Lake drainage area, St. Clair Lake direct drainage area (excluding Long Lake drainage), and the total watershed area of St. Clair Lake.

**Table 4. St. Clair Lake Watershed Land Cover**

| Land Cover | Long Lake Drainage | | St. Clair Lake Direct Drainage | | St. Clair Lake Total Watershed | |
|---|---|---|---|---|---|---|
| | (acres) | (% total) | (acres) | (% total) | (acres) | (% total) |
| Open Water/ Wetlands | 214 | 7% | 721 | 17% | 935 | 11% |
| Urban | 376 | 12% | 1,422 | 33% | 1,798 | 25% |
| Forest | 939 | 30% | 594 | 14% | 1,533 | 21% |
| Grassland | 119 | 4% | 86 | 2% | 205 | 3% |
| Pasture | 504 | 16% | 648 | 15% | 1,152 | 16% |
| Agriculture | 543 | 18% | 645 | 15% | 1,188 | 16% |
| St. Clair Surface Area | 0 | 0% | 160 | 4% | 160 | 2% |
| Long Lake Surface Area | 409 | 13% | 0 | 0% | 409 | 6% |
| **Total** | **3,104** | **100%** | **4,276** | **100%** | **7,380** | **100%** |

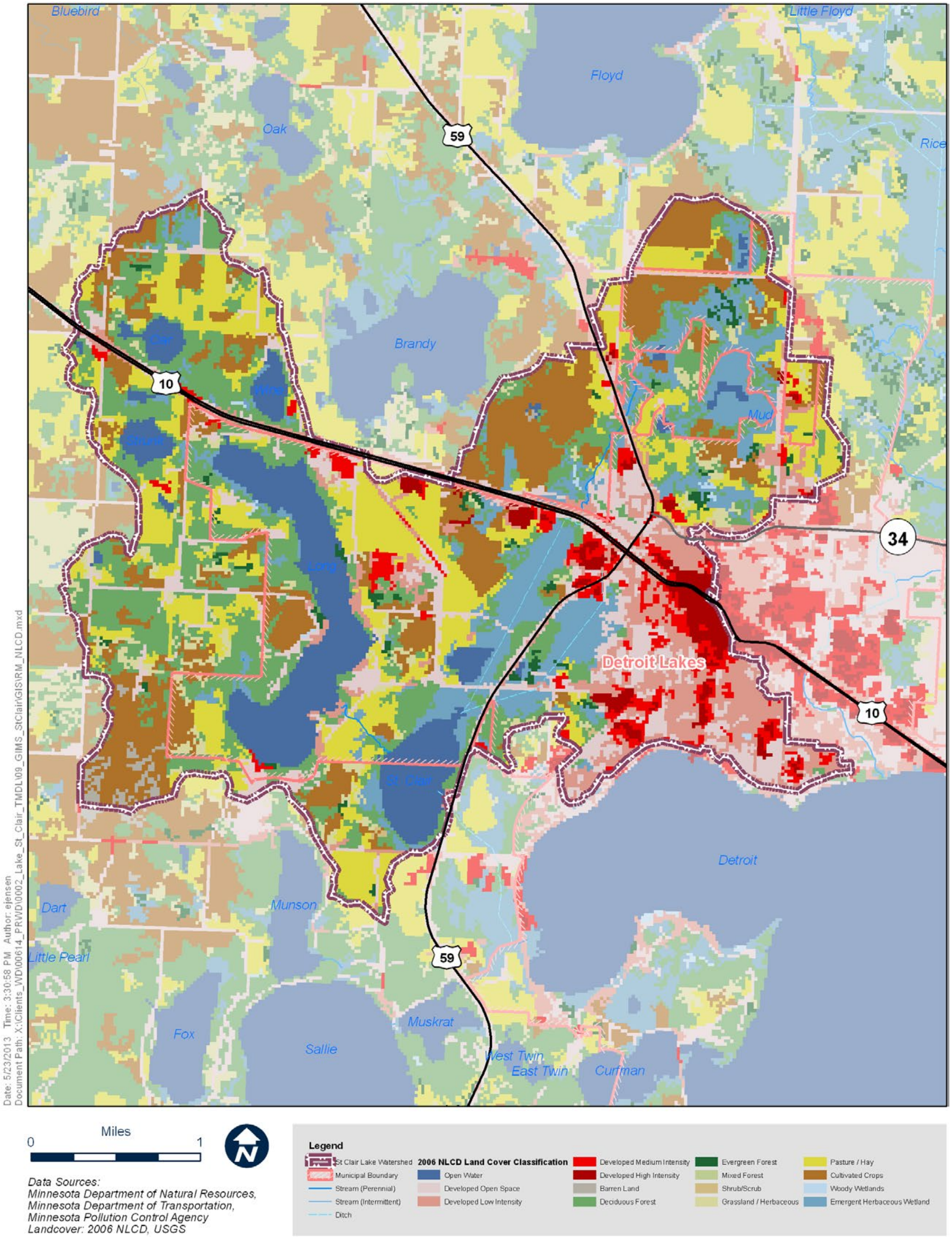



**Figure 6. St. Clair Lake Watershed Land Cover**

## 3.4 Current/Historic Water Quality

Water quality monitoring data for St. Clair Lake are available from 1948-2010 and were obtained from the MPCA Environmental Data Access database in August of 2012. Growing season (June through September) means were calculated from the most recent 10 year (2002 through 2011) time period to evaluate compliance with water quality standards and to calibrate the BATHTUB model. The lake does not meet shallow lake water quality standards for TP or Chl-*a*, and just meets the Secchi transparency standard (Table 5).

Long-term trends in growing season mean TP, Chl-*a* and Secchi transparency are shown in Figure 7, Figure 8, and Figure 9. Water quality appears to be improving over the years (2005 through 2010) with growing season mean TP, Chl-*a*, and Secchi transparency meeting the shallow lake water quality standards in 2010. However, data collected in 2012 (not shown) indicate a slightly higher summer TP average concentrations on the order of 77 µg/L. Annual variability in water quality is typical for Minnesota lakes. As a result, water quality standards are based on long-term growing season averages to account for the natural fluctuations in water quality from year to year due to climatic variability, with some years having much better water quality than others even though watershed conditions may remain the same.

Water temperature profiles (available from 1998 to 2010) indicate that the lake is polymictic or that it does not thermally stratify over the growing season. In recent history, the maximum surface water temperature experienced was just over 28 degrees Celsius (82 degrees Fahrenheit). The maximum temperatures experienced by Lake St. Clair are not atypical but excessively warm lakes can be subject to low dissolved oxygen (DO), cause stress to lake biota (e.g. fish), and provide habitat for pollution tolerant warm-water species. The DO profiles (available from 1998 through 2010) indicate that DO levels are supportive of aquatic life throughout the growing season. Along the lake bottom, DO levels approach and are periodically lower than 2 mg/L likely due to plant decomposition.

**Table 5. 10-year Growing Season Mean TP, Chl-*a*, and Secchi for St. Clair Lake, 2002-2011**

| Parameter | Growing Season Mean (June – September) | Growing Season CV (June – September) | Shallow Lake Standard |
|---|---|---|---|
| Total phosphorus (µg/L) | 68 | 0.084 | ≤ 60 |
| Chlorophyll-*a* (µg/L) | 25 | 0.17 | ≤ 20 |
| Secchi transparency (m) | 1.1 | 0.11 | ≥ 1.0 |

*CV = coefficient of variation, defined in BATHTUB as standard error divided by mean

There have been no macrophyte surveys on St. Clair Lake. Anecdotal information from stakeholders indicates that the shoreline is predominately cattail, and that heavy algae growth is common during the summer months. There is no comprehensive DNR fish survey on record for St. Clair Lake. A game fish survey in 1996 identified northern pike and sunfish in un-recorded quantities. The lake is subject to winterkill and is not likely supportive of permanent game fish populations.

**Figure 7. Growing Season Means ± SE of Total Phosphorus for St. Clair Lake by Year**
The dashed line represents the shallow lake water quality standard for TP (60 µg/L).The red line represents the 2002-2011 growing season mean TP concentration. Note the x-axis scale break.

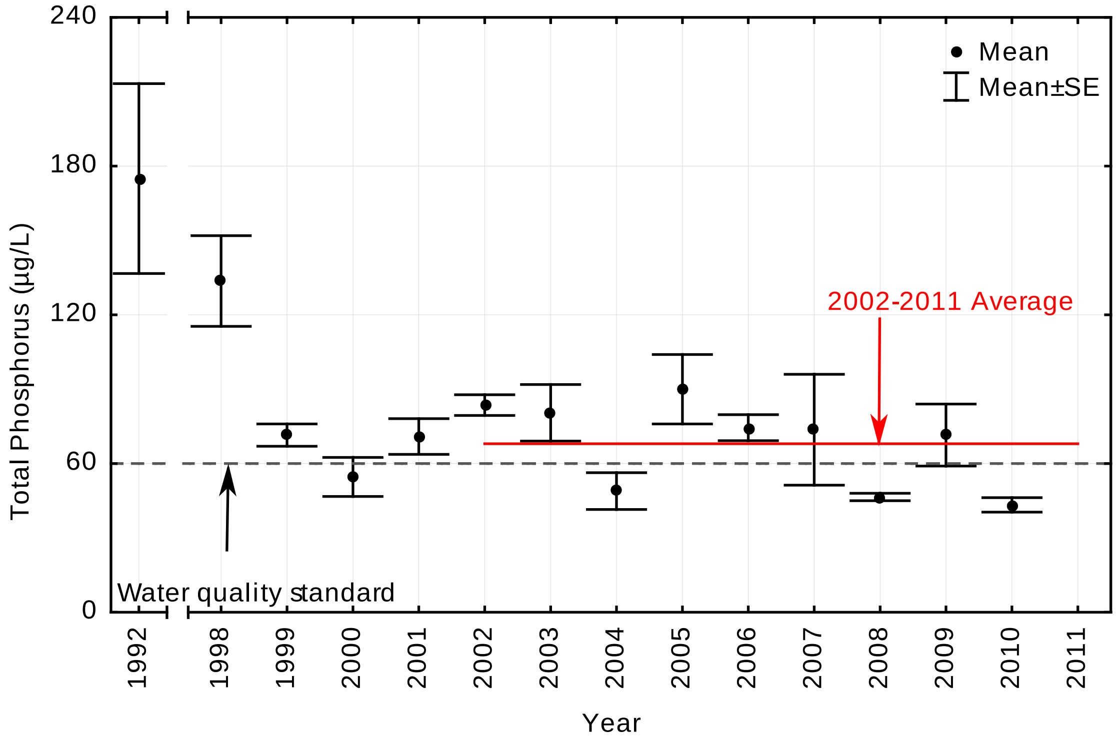



**Figure 8. Growing Season Means ± SE of Chlorophyll-*a* for St. Clair Lake by Year**
The dashed line represents the shallow lake water quality standard for Chl-*a* (20 µg/L). The red line represents the 2002-2011 growing season mean Chl-a concentration. Note the x-axis scale break.

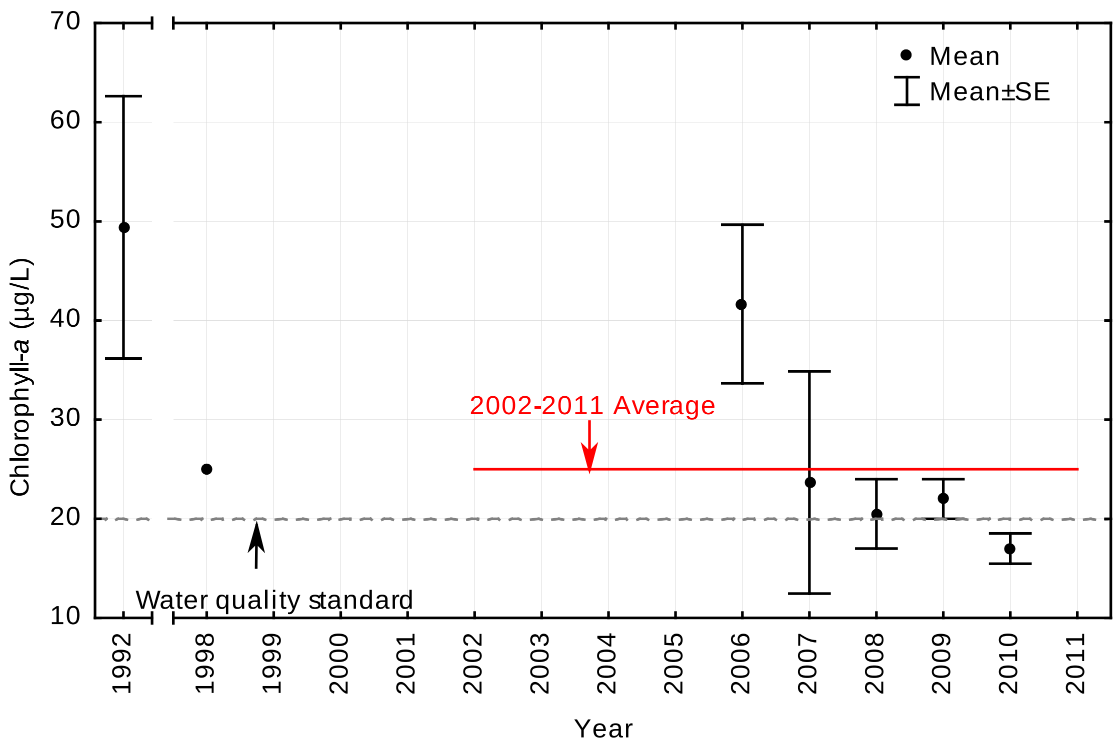
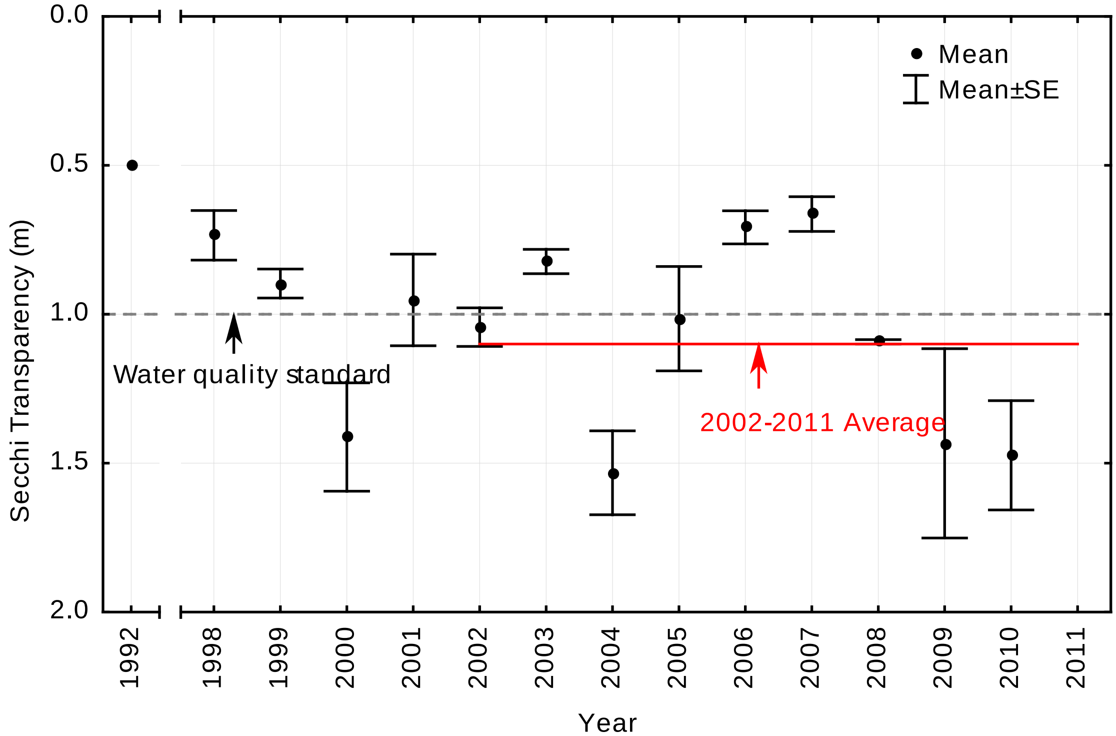


**Figure 9. Growing Season Means ± SE of Secchi Transparency for St. Clair Lake by Year**
The dashed line represents the shallow lake water quality standard for transparency (1.0 m).
Note the x-axis scale break.




## 3.5 Phosphorus Source Summary

This section provides a description of the potential sources of P to St. Clair Lake and the methods used to estimate existing P loads. These estimates were used to determine the lake loading capacity and to distribute TMDL reductions.

### 3.5.1 Permitted Sources of Phosphorus

The regulated sources of P within the study area are point sources – those originating from a single, identifiable source in the watershed – and are regulated through the National Pollutant Discharge Elimination System (NPDES) and State Disposal System (SDS) Permits:

- Regulated stormwater
- Municipal and industrial wastewater treatment systems
- Feedlots requiring NPDES Permit coverage

*Regulated Stormwater*

Watershed runoff is generated during precipitation and snowmelt events. Certain types of watershed runoff are permitted under the NPDES/SDS program including regulated Municipal Separate Storm Sewer Systems (MS4), construction stormwater, and industrial stormwater. Phosphorus loads from regulated stormwater runoff were estimated using the Simple Method as described in Section 3.5.2.

*MS4*

The MS4s are defined by the MPCA as conveyance systems owned or operated by an entity such as a state, city, town, county, district, or other public body having jurisdiction over disposal of stormwater or other wastes. A conveyance system includes ditches, roads, storm sewers, stormwater ponds, etc. Certain MS4 discharges are regulated by NPDES/SDS Permits administered by the MPCA.

The MS4s outside of urbanized areas with a population of at least 5,000 and discharging or having the potential to discharge to impaired waters are required to obtain an NPDES stormwater permit. The city of Detroit Lakes is a regulated MS4 community that falls into this category (Table 6) and overlaps with the watershed draining to St. Clair Lake. Figure 4 illustrates the city of Detroit Lakes municipal boundary, which includes the recent annexation of land adjacent to Long Lake adopted by the City Council on October 9, 2012, effective November 15, 2012.

**Table 6. Municipal Separate Storm Sewers (MS4)**

| Permittee | NPDES Permit Number | MS4 Preferred ID |
|---|---|---|
| City of Detroit Lakes | MNR040000 | MS400230 |

*Construction*

Construction sites can contribute substantial amounts of sediment and P to watershed runoff. The NPDES/SDS Construction Stormwater Permit administered by the MPCA requires that all construction activity disturbing areas equal to or greater than one acre of land must obtain a permit and create a Stormwater Prevention Pollution Plan (SWPPP) that outlines how runoff pollution from the construction site will be minimized during and after construction. Construction stormwater permits cover construction sites throughout the duration of the construction activities.

The estimated percent area regulated by the NPDES/SDS Construction Stormwater Permit in the St. Clair Lake Watershed is equal to the average annual percent area of Becker County that is regulated by the construction permit over the most recent 5-year period (2007-2012) according to MPCA records: 2.1%. The TMDL watershed allocations for Construction Stormwater will be based upon this low percentage rate producing relatively small values in the allocations tables.

*Industrial*

The NPDES/SDS Industrial Stormwater Multi-Sector General Permit re-issued in April 2010 applies to facilities with Standard Industrial Classification Codes in 29 categories of industrial activity with the potential for significant materials and activities to be exposed to stormwater. Significant materials include any material handled, used, processed, or generated that when exposed to stormwater may leak, leach, or decompose and carried offsite. The permit identifies a P benchmark monitoring value for facilities within certain sectors that are known to be P sources.

Based on a record review of the MPCA data, there are no industrial stormwater permitted facilities with P benchmarks in the St. Clair Lake Watershed.

*Regulated Municipal and Industrial Wastewater*

For any discharge of municipal or industrial wastewater to a surface water, ground-surface, or subsurface, an NPDES/SDS Permit is required and administered by the MPCA. Based on the review of the MPCA data, there are two NPDES WWTFs that contribute P loads to St. Clair Lake (Table 7): Detroit Lakes WWTF and Central Specialties Inc. Discharge volumes and P loads from the Detroit Lakes WWTF were calculated based on discharge monitoring records from 2002 to 2011. Average annual P loading from the Detroit Lakes WWTF is 342 pounds per year (Table 8). Discharge from Central Specialties Inc. is received by Long Lake prior to discharge into St. Clair Lake. Loading from Long Lake and its watershed was estimated based on Long Lake data (refer to Section 3.5.2 *Loading from Upstream Waters*), including discharge from Central Specialties Inc. Forest Hills Golf & RV Resort WWTF (NPDES Permit Number MN0056685) is also in the St. Clair Watershed. However, wastewater discharge from this facility does not leave the site as surface runoff; discharge is stored in on-site ponds and ultimately used for irrigation.

**Table 7. Municipal and Industrial Wastewater Treatment Systems**

| Permittee | Facility Name | NPDES Permit Number |
|---|---|---|
| City of Detroit Lakes | Detroit Lakes Wastewater Treatment Facility | MN0020192 |
| Central Specialties Inc | Central Specialties Inc | MNG490071 |

**Table 8. City of Detroit Lakes WWTF Annual Flow and Phosphorus Load**

| Phosphorus Source | Annual P Load (lb/yr) | Percent of P Load (%) | Flow Volume (AF/yr) | Average P Conc. (µg/L)[1] |
|---|---|---|---|---|
| Detroit Lakes WWTF | 342 | 19% | 405 | 311 |

[1] Annual TP load (lb/yr) divided by average annual flow volume; values are rounded to the nearest whole number

*Feedlots Requiring NPDES Permit Coverage*

Based on a review of the MPCA permitted facility locations, there are no feedlots under NPDES Permit coverage within the study area.

### 3.5.2 Non-permitted Sources of Phosphorus

The following are the sources of P not requiring NPDES Permit coverage that were evaluated:

- Direct watershed runoff
- Loading from upstream waters
- Runoff from feedlots not requiring NPDES permit coverage
- Atmospheric deposition
- Groundwater
- Internal loading

*Direct Watershed Runoff*

The Simple Method (Schueler 1987) was used to calculate direct watershed runoff volumes and TP loads. This modeling method transforms rainfall to runoff based on imperviousness, and applies an event mean runoff pollutant concentration (EMC) to the runoff from each land cover type to determine TP loads. An estimated total of 760 pounds of P is discharged annually into St. Clair Lake from direct watershed runoff (Table 9). The MPCA conducted a TP Water Quality Based Effluent Limit (WQBEL) analysis for the city of Detroit Lakes WWTP to St. Clair Lake in 2012 (see Appendix B). The direct watershed runoff volumes and TP loads calculated for the MPCA 2012 WQBEL are presented in Table 9 for comparison.

The St. Clair Lake Watershed was delineated from DNR catchment boundaries and the city of Detroit Lakes stormsewer drainage. The Long Lake Watershed area was excluded from the Simple Method calculation because the lake provides treatment of watershed runoff before discharging to St. Clair Lake. The load from Long Lake was calculated independently in the *Loading from Upstream Waters* section below. Average annual precipitation was estimated based on the nearest long-term daily precipitation gage reported by the National Climatic Data Center (COOP: 212142 Detroit Lakes 1NNE). The average annual precipitation depth for the period 2002-2011 was 29.1 inches.

The imperviousness of the watershed was determined based on land cover and soil types. Land cover data described in Section 3, Table 4, and Figure 6 were obtained from the 2006 National Land Cover Dataset (NLCD) created by the Multi-Resolution Land Characteristics Consortium, a partnership of Federal agencies led by the U.S. Geological Survey. The soils in the St. Clair Watershed were classified into hydrologic soil groups (HSG), which characterize the runoff potential of the soils (USDA NRCS 2007). Table 10 and Figure 11 summarize the soil distribution within the St. Clair Watershed. A Natural Resources Conservation Service (NRCS) curve number (CN) was assigned to each land cover-HSG combination in the watershed with the exception of urban land covers, which were assigned an impervious percentage based on the NLCD 2006 definition of imperviousness for urban land cover types. NRCS CNs are used to transform rainfall to runoff in the Simple Method model.

Each land cover type was assigned an average runoff Event Mean Concentration (EMC) based on ranges from published literature (Lin 2004), consistent with the MPCA WQBEL analysis. Land covers like forest, grassland, and wetland/open water were assumed to represent “baseline conditions”. Baseline land covers contribute a minimal amount of loading and have no further load reduction potential. Loading from other land covers, like agriculture, pasture, and urban, are assumed to be reducible only to baseline conditions. Baseline land cover EMCs from the literature are consistent with monitoring conducted by the PRWD (2008) and the MPCA (2009).

The Simple Method model was calibrated to 5.7 inches of runoff depth over the total watershed area based on the 2002-2011 average annual stream flow from the nearest long term USGS gauging station (658 $hm^3$/yr at USGS 0504600 Otter Tail River below the Orwell Dam near Fergus Falls, Minnesota) and the drainage area to the gauging station (1,740 square miles).

**Table 9. St. Clair Lake direct watershed runoff volume and TP load**

| Study | Area (ac) | Runoff depth (in) | Flow Volume (AF/yr) | Annual P Load (lb/yr) |
|---|---|---|---|---|
| St. Clair Lake TMDL | 4,276 | 5.7 | 2,256 | 760 |
| MPCA 2012 WQBEL | 4,275 | 5.0 | 1,784 | 703 |

**Table 10. St. Clair Lake Watershed HSGs**

| HSG | Wet infiltration rate | Brief Description | Area | |
|---|---|---|---|---|
| | | | (ac) | (% total) |
| A | High (Low runoff potential) | Deep, well drained, sand or gravelly sand | 498 | 7% |
| B | Moderate | Moderately deep, moderately well drained, moderately coarse textured | 4,800 | 70% |
| C | Slow | Contains a layer that impedes the downward movement of water, or fine textured | 33 | 1% |
| D | Very slow (High runoff potential) | Predominantly clay or clay layer, high permanent water table, shallow over impervious material | 1,480 | 22% |

**Table 11. TP Event Mean Concentration Values by Land Cover Type**

| Land Cover Type | | Present day TP EMC (µg/L) | TMDL Goal TP EMC (µg/L) |
|---|---|---|---|
| Barren Land<br>Emergent Herbaceous Wetland<br>Grassland/Herbaceous<br>Shrub/Scrub | Deciduous Forest<br>Evergreen Forest<br>Open Water<br>Woody Wetlands | 50 | 50 |
| Pasture/Hay | | 150 | 100 |
| Cultivated Crops | | 200 | 100 |
| Developed, High Intensity<br>Developed, Medium Intensity<br>Developed, Low Intensity<br>Developed, Open Space | | 200<br>175<br>150<br>150 | 100 |

*Incorporation of Best Management Practices into Watershed Load*

Load reductions from five best management practices (BMPs) implemented in the St. Clair Watershed were accounted for explicitly in the model (Table 12). Existing P loads to the BMPs were summed for each BMP contributing drainage area using the Simple Method model. The city of Detroit Lakes has indicated that they use bristle brush street sweepers which are deployed twice a week downtown and about once a week (plus events) near St. Clair Lake. This is a relatively high frequency and does provide reductions of pollutants. However, bristle brush street sweepers can create and expose the smaller particles, increasing their rate of wash-off; regenerative-air and vacuum-assist sweepers are known to pick up fines much more effectively (Selbig and Bannerman 2007). Based on this information and a comparison with findings from a Center for Watershed Protection Study, P removal from this activity is assumed to be 6% (CWP 2006). This rate of P removal was applied to Simple Method P loading estimates for *Developed, Medium Intensity* and *Developed, High Intensity* NLCD 2006 land covers within the city of Detroit Lakes. Through the PRWD permitting process, the Fairgrounds pond was modeled in PondNET and predicted to provide 12.5% P removal. All other BMP reductions were estimated based on average expected P reductions by BMP type: 60% for stormwater ponds and 75% for infiltration basins; however the P removal efficiency of the Walmart infiltration basin was lowered to 50% to account for observed reduced performance.

**Table 12. Existing BMP phosphorus reductions**

| BMP | Drainage Area (ac) | P Load to BMP (lb/yr) | BMP Removal (%) | P Reduction (lb/yr) |
|---|---|---|---|---|
| Street Sweeping | 395 | 143 | 6% | 8 |
| Fairgrounds Stormwater Pond | 490 | 88 | 12.5% | 11 |
| Holmes Street Stormwater Pond | 121.7 | 34 | 60% | 20 |
| St. Mary Stormwater Pond | 1.76 | 0.7 | 60% | 0.4 |
| Walmart Infiltration Basin | 20.0 | 2.6 | 50% | 1.3 |

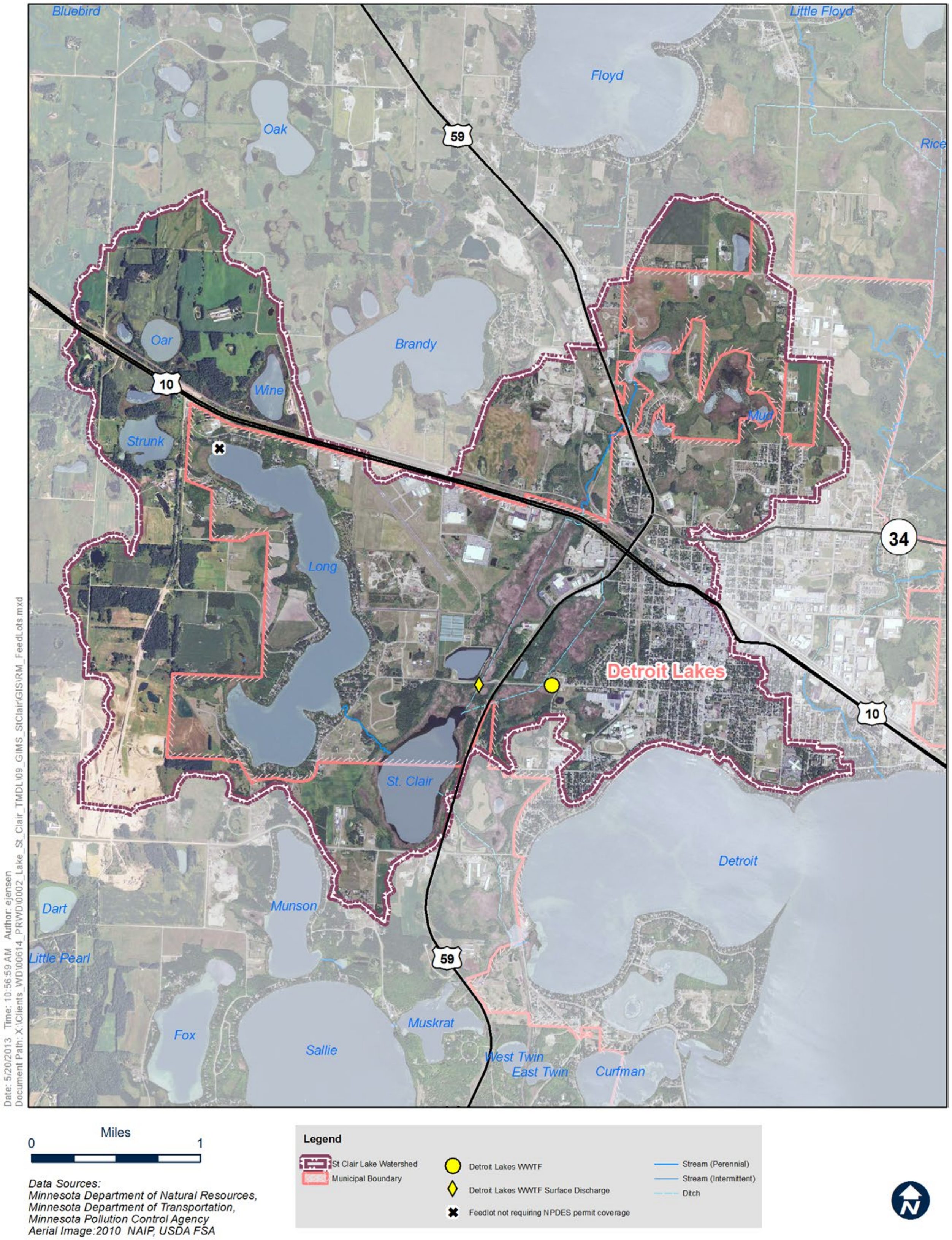



**Figure 10. St. Clair Lake Watershed MPCA Registered Feedlots and city of Detroit Lakes WWTF**

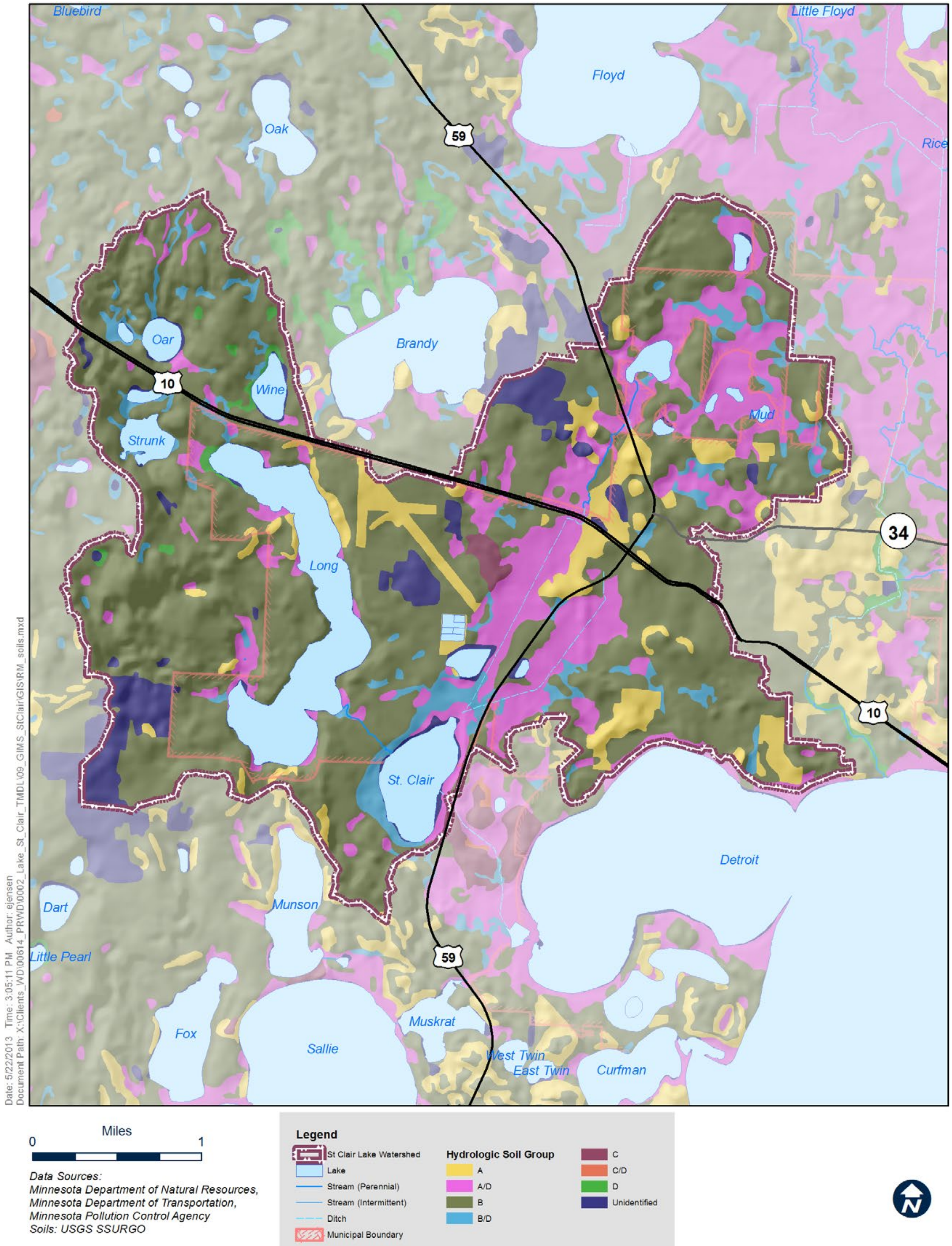



**Figure 11. St. Clair Lake Watershed hydrologic soil groups**

*Loading from Upstream Waters*

The annual average TP load from Long Lake (MDNR 03-0383-00) was calculated based on average in-lake P concentration and flow (average annual depth of runoff over the watershed area). Long Lake is a high quality lake with a small watershed relative to the lake surface area (watershed area to lake surface area ratio of 7.6:1). Table 13 summarizes the upstream lake loading calculations. These estimates are consistent with the 2012 MPCA WQBEL study.

**Table 13. Summary of Phosphorus Loading from Upstream Waters**

| Upstream Lake | Averaging Period | Drainage Area (acres)[1] | Equivalent Depth of Flow (in/yr) | Flow Volume (AF/yr) | In-Lake TP (µg/L) | Phosphorus Load (lb/yr) |
|---|---|---|---|---|---|---|
| Long | 1998-2011 | 3,104 | 5.7 | 978 | 17 | 45 |

[1] Calculations are from the lake outlet; includes lake area and drainage area

*Feedlots*

Runoff during precipitation and snow melt can carry P from uncovered feedlots to nearby surface waters. For the purpose of this study, non-permitted feedlots are defined as being all registered feedlots without an NPDES/SDS Permit that house under 1,000 animal units. While these feedlots do not fall under NPDES regulation, other regulations still apply.

One feedlot is known to exist across the watershed (Figure 10). The feedlot is registered with the MPCA Feedlot Program. Registered feedlots do not necessarily have animals at any specific point in time. Other, non-registered feedlots or animal operations may exist within the watershed but have not been identified. Loading from the feedlot was included implicitly in the calculations of loading from upstream waters (Long Lake).

*Atmospheric Deposition*

Atmospheric deposition represents the P that is bound to particulates in the atmosphere and is deposited directly onto surface waters as the particulates settle out of the atmosphere. Average P atmospheric deposition loading rates were calculated for the Red River Basin (MPCA 2004). The MPCA report determined that atmospheric deposition equals 0.21 kg/ha (0.19 lb/ac) of TP per year. This rate was applied to the lake's surface area to determine the total pounds per year of atmospheric P deposition to St. Clair Lake.

Atmospheric deposition is estimated to be 30 lb/yr.

*Groundwater*

The 1998 study: A Study of the Contribution of Groundwater to P Loadings for Selected Lakes in the Pelican River Watershed, included St. Clair Lake (Section 13.2 - Existing Studies). The report found that groundwater patterns convey groundwater (and associated P) from the Detroit Lakes WWTF rapid infiltration basins (RIBs) and spray irrigation fields to Ditch 14, which discharges to St. Clair Lake. Other sources of P to groundwater include natural contributions and contributions from sites having enhanced exposure (e.g. long term or high concentrations) of P applications (e.g fertilizers). At the time of the report, groundwater contributions to St. Clair Lake were found to make up 17% of the watershed flow and 1.6% of the external P loads to St. Clair Lake. These values were used for this analysis, which are equivalent to 550 acre-feet per year and 13 pounds of P per year.

*Internal Loading*

For the purposes of this TMDL study, lake internal loading refers to the P quantities that originate from lake sediments or macrophytes and is released back into the water column. Internal loading can occur via:

1. Chemical release from the sediments is caused by anoxic (lack of oxygen) conditions in the overlying waters or high pH (> 9) resulting from intense algal/macrophyte productivity. If a lake's hypolimnion (bottom area) remains anoxic (low or no oxygen, less than ~1.0 mg/L) for a portion of the growing season, the P can be released, particularly from low iron content sediments, and mixed throughout the water column by storm events and seasonal whole-lake mixing (spring and fall). In shallow lakes, the periods of profundal (deeper areas lacking light) sediment anoxia may occur frequently over short periods of time causing sediment P release. Oxic sediments can also release lower quantities of P due to chemical gradients, low sediment binding capacity (low iron/aluminum/calcium absorption), high pH ( > 9) and diurnal circulations along the littoral and pelagic (open water) boundaries (James and Barko 1991).
2. Physical disturbance of the sediments caused by bottom-feeding fish (such as carp and bullhead), motorized boat activity, and wind mixing. This is more common in shallow lakes and areas than in deeper lake zones.
3. Macrophyte scenescence and decay particularly relating to Eurasian water milfoil and curly-leaf pondweed (Potamogeton crispus) that are aggressive invasives capable of rapid colonization and domination of littoral areas. Curly-leaf pondweed typically dies back in early to mid-summer and is subject to rapid decay in warm-water thereby contributing to peak growing season P concentrations. In other instances, macrophytes are effective at stabilizing sediment and retard internal loading. They can also alter pH and DO at the sediment-water interface in the littoral zone, causing P release from sediments with subsequent transport of enriched water into open-water areas via temperature change and wind mixing.

Internal loading due to the anoxic release from the sediments of each lake was estimated in this study based on the expected release rate (RR) of P from the lakebed sediment, the lake anoxic factor (AF), and the lake area. Lake sediment samples were taken and tested for concentration of TP. Phosphorus release rates were calculated using statistical regression equations developed from measured release rates, and sediment P concentrations from a large set of North American lakes and compared to published values for lakes world-wide (Nürnberg 1988; Nürnberg 1996).

In the case of St. Clair Lake, a single sediment P concentration reading was taken prior to alum treatment (0.4 g TP per kg, dry weight; Hecock 2001). This sediment TP concentration fell outside the range of data used to develop the North American lakes regression equation, but fell within the range of the world-wide published data. The modeled internal load based on sediment P content and the world-wide regression equation indicates that internal loading accounted for approximately 336 lb/yr of P loading to the lake prior to the 1998 alum treatment. The current internal load is unknown.

These internal loading estimates were not used as direct inputs to the BATHTUB lake models, since the BATHTUB model includes an implicit amount of internal loading. A very small additional load was needed to calibrate the BATHTUB model (22 lb/yr), suggesting that since the 1998 alum treatment, nearly all of the internal loading in St. Clair Lake has been accounted for implicitly in the BATHTUB model. These implicit internal loads represent natural background levels; therefore no reductions of the internal load to St. Clair Lake are needed at this time. However, internal load monitoring will be included in the implementation plan to determine if internal loading increases in the future as effectiveness of the 1998 alum treatment decreases.

# 4 TMDL DEVELOPMENT

This section presents the overall approach to estimating the components of the TMDL. The pollutant sources were first identified and estimated in the P source assessment. The loading capacity (TMDL) of the lake was then estimated using an in-lake P response model and was divided among WLAs and LAs. A TMDL for a waterbody that is impaired as the result of excessive loading of a particular pollutant can be described by the following equation:

**TMDL = LC = ∑WLA + ∑LA + MOS + RC**

Where:

- **Loading capacity (LC):** the greatest pollutant load a waterbody can receive without violating water quality standards;
- **Wasteload allocation (WLA):** the pollutant load that is allocated to point sources, including wastewater treatment facilities, regulated construction stormwater, and regulated industrial stormwater, all covered under NPDES permits for a current or future permitted pollutant source;
- **Load allocation (LA):** the pollutant load that is allocated to sources not requiring NPDES permit coverage, including non-regulated stormwater runoff, atmospheric deposition, and internal loading;
- **Margin of Safety (MOS):** an accounting of uncertainty about the relationship between pollutant loads and receiving water quality;
- **Reserve Capacity (RC):** the portion of the loading capacity attributed to the growth of existing and future load sources.

## 4.1 Loading Capacity: Lake Response Model

The modeling software BATHTUB (Version 6.1) was selected to link P loads with in-lake water quality. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). It has been used successfully in many lake studies in Minnesota and throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June through September) mean surface water quality. BATHTUB's time-scales are appropriate because watershed P loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance P model that accounts for: water and P inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and groundwater; and outputs through the lake outlet, water loss via evaporation, and P sedimentation and retention in the lake sediments.

### 4.1.1 System Representation in Model

In typical applications of BATHTUB, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. The St. Clair Lake Watershed system was modeled as one segment (St. Clair Lake), and nine tributaries: Long Lake outflow, Detroit Lakes WWTF, groundwater, MS4 regulated direct drainage, MS4 regulated Ditch 1, MS4 regulated Ditch 14, unregulated direct drainage, unregulated Ditch 1, unregulated Ditch 14 (Figure 12).

### 4.1.2 Model Input

The input required to run the BATHTUB model includes lake geometry, climate data, and water quality and flow data for runoff contributing to the lake. Observed lake water quality data are also entered into the BATHTUB program in order to facilitate model verification and calibration.

Table 15 lists the key input values used in the simulations.

**Table 14. BATHTUB tributary input data**

| Watershed Source | Area (acres) | Flow (ac-ft/ yr) | TP (µg/L) | TP Load (lb/yr) |
|---|---|---|---|---|
| Detroit Lakes WWTF | N/A | 405 | 311 | 342 |
| Regulated Direct Drainage | 215 | 88 | 88 | 21 |
| Regulated Ditch 1 | 1,618 | 858 | 117 | 272 |
| Regulated Ditch 14 | 1,085 | 776 | 127 | 267 |
| Unregulated Direct Drainage | 262 | 93 | 115 | 29 |
| Unregulated Ditch 1 | 921 | 435 | 125 | 147 |
| Unregulated Ditch 14 | 14 | 6 | 123 | 2 |
| Long Lake Outflow | 3,104 | 978 | 17 | 45 |
| Groundwater | N/A | 550 | 8.7 | 13 |

N/A = Point source input, no surface area required for modeling

**Table 15. BATHTUB segment and global variable input data**

| Lake Surface Area (acres) | Fetch (ft) | Mean Depth (ft) | Observed Lake Quality (Surface growing season mean, 2002-11) | | | Precipitation (in/yr) | Evaporation (in/yr) |
|---|---|---|---|---|---|---|---|
| | | | TP (µg/L) | Chl-a (µg/L) | Secchi (m) | | |
| 160 | 2,900 | 4.9 | 68 | 25 | 1.1 | 29.1 | 34 |

*Global Variables: Precipitation, Evaporation, and Atmospheric Deposition*

Average annual precipitation for the period 2002-2011 was 29.1 inches at the nearest long-term daily precipitation gage reported by the National Climatic Data Center (COOP: 212142 Detroit Lakes 1NNE). Average annual evaporation was obtained from the Minnesota Hydrology Guide (SCS 1992). Average P atmospheric deposition loading rates were estimated to be 0.19 lb/ac-yr for the Red River Basin (MPCA 2004), applied over the lake's surface area for a total load of 30 lb/yr.

*Segment Data: Lake Morphometry, Observed Water Quality, and Internal Load*

Lake morphometry data were gathered from a 1998 bathymetric survey (refer to Figure 3). Observed water quality was based on 10-year (2002-2011) growing season means (June through September) for TP, chlorophyll-*a*, and Secchi transparency (Table 5). An average rate of internal loading is implicit in BATHTUB since the model is based on empirical data from a broad number of lakes and reservoirs. The model provides an option to include an internal load, but is typically not recommended unless data and circumstances warrant. In the St. Clair modeling, inclusion of internal loading was not required for model calibration.

*Tributary Data: Flow Rate and Phosphorus Concentration*

The Simple Method was used to estimate P loading from the direct St. Clair Watershed. Phosphorus loading results from the Simple Method were input into the model as nine tributaries: Long Lake outflow, Detroit Lakes WWTF, groundwater, MS4 regulated direct drainage, MS4 regulated Ditch 1, MS4 regulated Ditch 14, unregulated direct drainage, unregulated Ditch 1, and unregulated Ditch 14.

*Model Equations*

BATHTUB allows a choice among several different mass balance P models. For deep lakes in Minnesota, the option of the Canfield-Bachmann lake formulation (Canfield and Bachmann 1981) has proven to be appropriate in most cases. In order to perform a uniform analysis it was selected as the standard equation for the study.

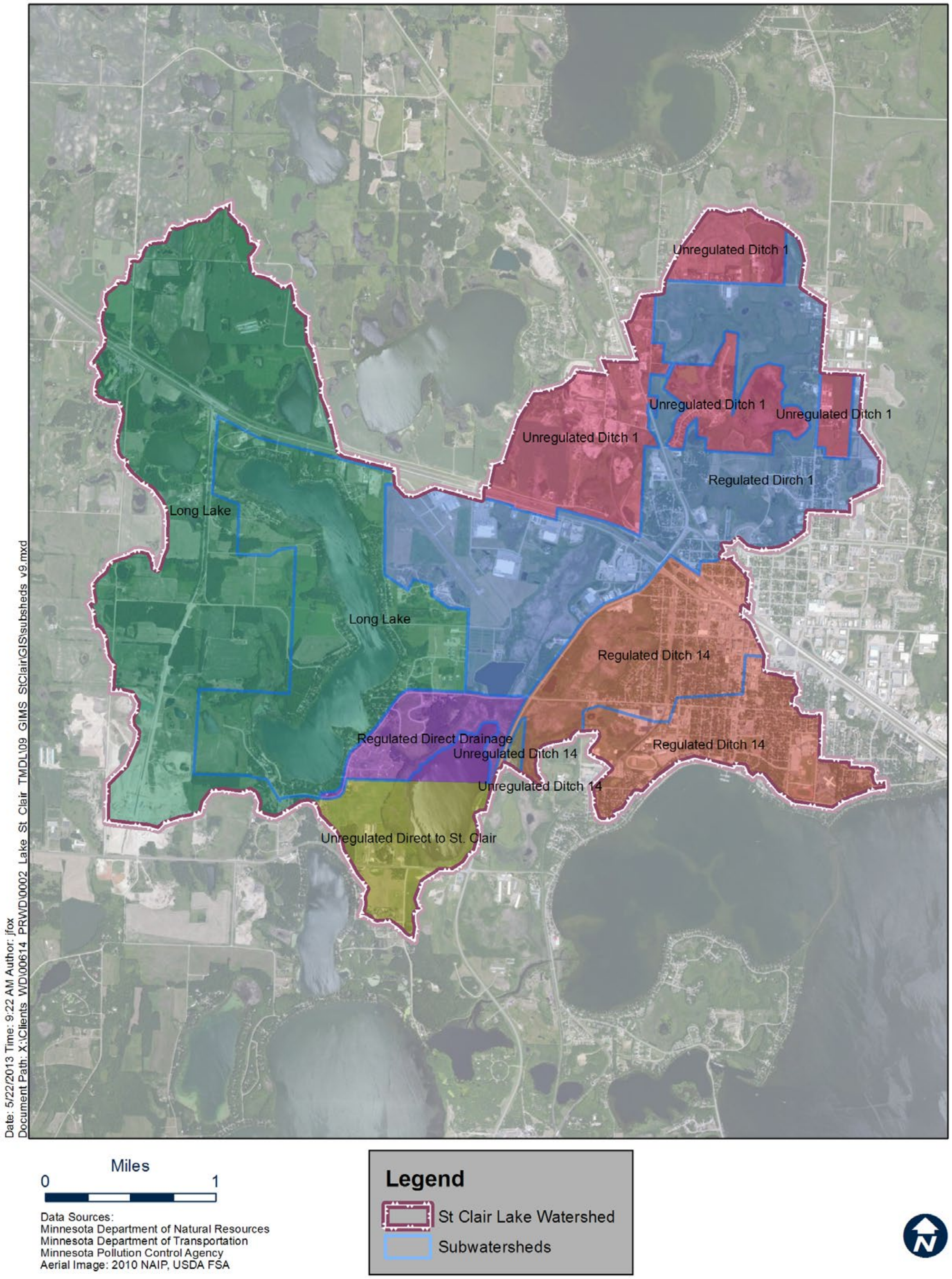



**Figure 12. BATHTUB modeled tributaries**

### 4.1.3 Loading Goals

The BATHTUB model was calibrated to existing in-lake water quality data (10-year growing season mean) by reducing the urban land cover EMCs (Table 11) until the observed in-lake TP concentration matched the predicted in-lake TP concentration. The EMCs of urban land covers were further reduced (Table 11) until the in-lake TP concentration met the State in-lake water quality P standard to determine the lake loading capacity (TMDL).

In developing the lake nutrient standards for Minnesota lakes (Minn. R. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson 2005). Clear relationships were established between the causal factor TP and the response variables Chl-*a* and Secchi transparency. Based on these well documented Minnesota lake relationships it is expected that by meeting the P target in the lake, the Chl-*a* and Secchi standards will likewise be met.

The TMDL (or loading capacity) was first determined in terms of *annual* load. In-lake water quality models predict annual averages of water quality parameters based on annual loads. Symptoms of nutrient enrichment normally are the most severe during the summer months; the state eutrophication standards (and, therefore, the TMDL goals) were established with this seasonal variability in mind. The annual loads were then converted to daily loads by dividing the annual loads by 365. The TMDL was then split into WLAs, LAs, and a MOS according to Table 16.

See *Appendix A: Supporting Data for BATHTUB Models* for all BATHTUB modeling case data (inputs), diagnostics (results), and segment balances (water and P budgets) for both the calibrated (benchmark/existing) model and the TMDL scenario.

## 4.2 Load Allocation Methodology

One LA was set for St. Clair Lake as the remainder of the loading capacity (TMDL) minus the MOS (see Section 4.4) and WLAs (see Section 4.3). The LA includes all sources of P that do not require NPDES Permit coverage, including unregulated watershed runoff, internal loading, groundwater, and atmospheric deposition.

## 4.3 Wasteload Allocation Methodology

Federal Regulations 40 C.F.R. § 130.2(h), states that a WLA is "the portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution."

### 4.3.1 Regulated MS4 Stormwater

The city of Detroit Lakes is the only regulated MS4 in the watershed. Figure 4 illustrates the city of Detroit Lakes municipal boundary, which includes the recent annexation of land adjacent to Long Lake adopted by the City Council on October 9, 2012, effective November 15, 2012. The city of Detroit Lakes is benefitted by County Ditch 14, which runs through a portion of the city and continues on the downstream side of St. Clair Lake. As such, the entire city of Detroit Lakes is regulated by the MS4 permit, which includes portions of the St. Clair Lake direct drainage area, the Ditch 1 drainage area, and the Ditch 14 drainage area (Figure 1).

### 4.3.2 Regulated Construction Stormwater

A categorical WLA was assigned to all construction activity in the watershed. First, the median annual fraction of the watershed area under construction activity over the past five years was calculated based on the MPCA Construction Stormwater Permit data from January 1, 2007, to October 6, 2012 (see Section 3.5.1). This percentage was multiplied by the total TMDL (loading capacity) minus the MOS to determine the construction stormwater WLA.

### 4.3.3 Regulated Industrial Stormwater

A categorical WLA was assigned to all industrial activity in each impaired lake subwatershed. The industrial stormwater WLA was set equal to the construction stormwater WLA because industrial activities make up a very small fraction of the watershed area.

### 4.3.4 Regulated Municipal and Industrial Wastewater

An individual WLA was assigned to the Detroit Lakes WWTF based on the MPCA 2012 WQBEL study (see Appendix B) and reinforced by BATHTUB modeling conducted for this TMDL study. The Detroit Lakes WWTF P WLA at 437 lb/yr (or 198 kg/yr) that is presented in this TMDL and in the Detroit Lakes WWTF 2014 NPDES permit was decreased by 5,712 lb/yr (or 93%) compared to the Detroit Lakes WWTF pre-2014 NPDES permit annual effluent limit (6,149 lb/yr). However, the WLA at 437 lb/yr is 95 lb/yr (or 28%) greater than the Detroit Lakes WWTF 2002-2011 historical seasonal discharge average to St. Clair Lake of 342 lb/yr, to account for expected future annexations to the city of Detroit Lakes. St. Clair Lake historically receives treated effluent from Detroit Lakes WWTF from mid-November through April. From 2002-2011, this accounted for 0.362 mgd (or 31%) of the total average annual influent waste stream flow of 1.157 mgd. The remaining flow is applied to RIBs and spray irrigation fields for treatment and does not result in surface discharge to St. Clair Lake. The proposed WLA assumes Detroit WWTF will continue utilizing land treatment or move the current discharge location away from St. Clair Lake. If land treatment is not utilized and the current discharge location is not moved away from St. Clair Lake, the WLA would result in a very stringent effluent limit concentration for P: ranging from 0.124 mg/L based on the 2002-2011 total average annual influent waste stream flow of 1.157 mgd, to as low as 0.071 mg/L based on the current NPDES permitted design flow of 2.02 mgd.

## 4.4 Margin of Safety

This MOS is sufficient to account for uncertainties in predicting loads to the lake and predicting how the lake responds to changes in P loading. This explicit MOS is considered to be appropriate based on the generally good agreement between the water quality models' predicted and observed values. A 10% explicit MOS was included in the TMDL.

## 4.5 Seasonal Variation

While lake water quality varies seasonally in Minnesota lakes, summer (June through September) water quality is a largely a function of annual watershed P loading. If, however, a lake's sediments are recycling P (or internal loading of P), lake P concentrations can increase substantially over the growing season resulting in greater accumulations of algae, higher Chl-*a* concentrations and lower water clarity (or Secchi transparency). In that case, internal P loading must be explicitly included as an additional P source in modeling assessments. The BATHTUB lake response model used in this TMDL did not require additional loads for internal sources.

Seasonal variation is factored into the TMDL by using Minnesota's lake eutrophication standards which were developed from statewide analyses of within-year and year-to-year variation of lake water quality. It was found that the critical time period for lake beneficial uses occur during the summer growing season with peak temperatures causing peak growth and decomposition rates. Peak algal conditions affecting aquatic recreation, fisheries and habitat thus occur in the summer growing season. Hence, the TMDL's load reductions are calculated so that the lake will meet the water quality standards over the course of the critical conditions occurring during the growing season (June through September).

### 4.6 Future Growth and Reserve Capacity

Potential changes in populations and land use over time in the St. Clair Watershed could result in changing sources of P. Possible changes and how they may or may not impact TMDL allocations are discussed below.

*New or Expanding Permitted MS4 WLA Transfer Process*

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded Urban Area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting allocations in the TMDL, and loads will be transferred on a simple land-area basis. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

The city of Detroit Lakes is a growth area with expansion of its airport and wastewater service collection area anticipated to occur in the near future. Detroit Lakes is also investigating the possibility of relocating its WWTF discharge location to outside of the St. Clair Lake watershed. As such, the WWTF portion of the WLA would be available to any entity in the St. Clair Watershed if that relocation becomes reality. Accordingly, the city of Detroit Lakes' TMDL WLA for their MS4 permit can be adjusted, subject to agreement by all the parties affected by the TMDL and public notice requirements of the MPCA.

The City has grown over the years as evidenced by its annexation record (see Appendix C) with several areas being added to the municipal boundaries over time. It is likely that annexation considerations will continue in future years as robust growth is projected for this region due to the availability of quality recreational waters and larger regional (Dakotas) economic development. State demographers predict that the population of Detroit Lakes will increase 20% from 2010 to 2035. As seen in other lake regions such as the Alexandria Lakes area, it may be expected that the city of Detroit Lakes will be requested to extend sanitary sewer connections to unsewered lakeshore and rural residential areas. This could include, for example, portions of the Floyd Lakes Watershed with its excellent water quality.

In the St. Clair Watershed unregulated land uses, such as pasture/hay, could shift to other unregulated land uses, such as row crops. However, the loading capacities were estimated using a long-term data set and slight shifts in land use will likely not substantially increase or decrease annual flows or loads. Larger shifts in land use could very well make meeting the TMDL more difficult over time.

*Reserve Capacity*

Reserve capacity is the portion of the loading capacity attributed to growth of existing and future load sources. A reserve capacity of 10% was implicitly incorporated into the TMDL by allocating a wasteload to the Detroit Lakes WWTF that is greater than existing long-term discharge monitoring records to account for expected future annexations to the city of Detroit Lakes. The WWTF WLA is consistent with the MPCA 2012 WQBEL study.

## 4.7 TMDL Summary

The P loading capacity of St. Clair Lake is 1,005 lb/yr, to be divided among allocations according to Table 16. Refer to Section 4.6 for a description of transfer rates if a new portion of the watershed comes under MS4 Permit coverage.

To meet the TMDL with a 10% MOS, the total load to the lake needs to be reduced by 286 lb/yr (24%). The load reduction goals were based on the following:

- Load reductions from Long Lake outflow were set to zero since Long Lake is a high quality lake and provides sufficient treatment of watershed runoff prior to discharging to St. Clair Lake.
- Load reductions from atmospheric deposition were also set to zero.
- The Detroit Lakes WWTF P WLA at 437 lb/yr (or 198 kg/yr) was decreased by 5,712 lb/yr (or 93%) compared to the Detroit Lakes WWTF pre-2014 NPDES permit annual effluent limit (6,149 lb/yr). However, the WLA at 437 lb/yr is 95 lb/yr (or 28%) greater than the Detroit Lakes WWTF 2002-2011 historical seasonal discharge average to St. Clair Lake of 342 lb/yr, to account for expected future annexations to the city of Detroit Lakes. St. Clair Lake historically receives treated effluent from Detroit Lakes WWTF from mid-November through April. From 2002-2011, this accounted for 0.362 mgd (or 31%) of the total average annual influent waste stream flow of 1.157 mgd. The remaining flow is applied to the land for treatment and does not result in surface discharge to St. Clair Lake. The proposed WLA assumes Detroit WWTF will continue utilizing land treatment or move the current discharge location away from St. Clair Lake.
- The load from regulated and unregulated watershed runoff was reduced by changing the EMC of urban land covers, resulting in a 51% reduction of regulated runoff loads and a 52% reduction of unregulated runoff loads. These reductions were distributed among the three major subwatersheds (direct drainage, Ditch 1, and Ditch 14), with Ditch 14 requiring slightly more reductions due to higher fractions of urban land covers than the direct drainage or Ditch 1 subwatersheds.
- It is assumed that groundwater load reductions will occur concomitantly with surface load reductions because the groundwater load is a reflection of the surface water load.

**Table 16. St. Clair Lake TMDL and Allocations**

| St. Clair Lake Load Component | | | Existing | Goal | | Reduction | |
|---|---|---|---|---|---|---|---|
| | | | lb/yr | lb/yr | lb/day | lb/yr | % |
| **Wasteload Allocations** | **Total WLA** | | **902** | **736** | **2.018** | | |
| | Construction | | | 8 | 0.022 | | |
| | Industrial | | | 8 | 0.022 | | |
| | WWTP[1] | | 342* | 437 | 1.197 | 95 | 28% |
| | Detroit Lakes MS4 | *Direct drainage* | *21* | *12* | *0.033* | *-9* | *-42%* |
| | | *Ditch 1* | *272* | *137* | *0.375* | *-135* | *-50%* |
| | | *Ditch 14* | *267* | *134* | *0.368* | *-133* | *-50%* |
| | | Subtotal | 560 | 283 | 0.776 | -277 | -49% |
| **Load Allocations** | **Total LA** | | **288** | **168** | **0.461** | | |
| | Long Lake Outflow[2] | | 45 | 45 | 0.123 | 0 | 0% |
| | Internal Load | | 22 | 0 | 0.000 | -22 | -100% |
| | Groundwater | | 13 | 8 | 0.022 | -5 | -38% |
| | Atmosphere | | 30 | 30 | 0.082 | 0 | 0% |
| | Unregulated runoff | *Direct drainage* | *29* | *14* | *0.040* | *-15* | *-50%* |
| | | *Ditch 1* | *147* | *70* | *0.191* | *-77* | *-52%* |
| | | *Ditch 14* | *2* | *1* | *0.002* | *-1* | *-62%* |
| | | Subtotal | 178 | 85 | 0.233 | -93 | -52% |
| **LOADING CAPACITY** | | | | **1,005** | **2.753** | | |
| **MOS** | | | | **-101** | **-0.275** | | |
| **TOTAL** | | | **1,190** | **904** | **2.477** | **-286** | **-24%** |

* The Existing Load for the Detroit Lakes WWTF is based on actual effluent loads from the 2003-2012 discharge monitoring records and does not reflect the NPDES permitted phosphorus effluent limit from that time period.

[1] The WWTP goal load is greater than the existing load to account for population growth projections (Reserve Capacity)

[2] Phosphorus loads from the upstream Long Lake drainage area are the load received by St. Clair Lake from the Long Lake *outlet* as the phosphorus loads have already undergone some removal processes through the treatment provided by Long Lake

# 5 REASONABLE ASSURANCES

As part of an implementation strategy, reasonable assurances provide a level of confidence that the TMDL allocations will be implemented by federal, state, or local authorities. Implementation of the St. Clair Lake TMDL will be accomplished by both local and state action, both regulatory and non-regulatory. Multiple entities in the watershed already work towards improving the lake's water quality. Water quality restoration efforts will be led by the PRWD along with assistance from the city of Detroit Lakes.

## 5.1 Non-Regulatory

At the local level, the PRWD implements programs for water quality improvement and has a long list of completed projects to improve water quality. It is anticipated that PRWD involvement will continue into the future. Potential state funding of TMDL implementation projects includes the Clean Water Fund grants. At the federal level, funding can be provided through Clean Water Act Section 319 grants that provide cost share dollars to implement activities in the watershed. Various other funding and cost-share sources exist, which will be listed in the St. Clair Lake TMDL Implementation Plan.

The implementation strategies described in Section 7 of this TMDL have been demonstrated to be effective in reducing nutrient loadings to lakes. The PRWD has programs in place to continue many of the recommended activities. Monitoring will continue and adaptive management will be in place to evaluate progress made towards achieving the beneficial use.

## 5.2 Regulatory

Federal Regulations 40 CFR § 122.4(i) prohibits the net increase of any pollutant that will cause or contribute to a numeric or narrative water quality standard violation. Federal Regulations 40 CFR § 122.44(d) requires effluent limits in permits to ensure discharges do not cause, have a reasonable potential to cause, or contribute to the violation of a numeric or narrative water quality standard.

To meet these requirements, wastewater facilities have the following options:

1. Provide treatment to meet the applicable WQBEL. If a schedule of compliance is determined to be appropriate, make interim reductions in pollutant load and/or concentration such that ultimate compliance with the WQBEL is attained as soon as possible.
2. Eliminate some or all surface water discharge by using land treatment options such as spray irrigation, rapid infiltration basin, or soil treatment systems. Extensive portions of the watershed with HSG A and B soils will offer significant opportunities for infiltration stormwater volume control practices.
3. Initiate pollution prevention actions to reduce source pollutant to meet the mass limit.
4. Discharge to a permitted WWTF that has available phosphorus capacity.
5. Participate in pre-TMDL trading by purchasing the needed pollutant load from another facility.

State implementation of the TMDL will be through action on NPDES permits for MS4 stormwater and construction stormwater. Minnesota's MS4 General Permit requires an MS4 to review, within 18 months of EPA approval of a TMDL, the adequacy of its Stormwater Pollution Prevention Program (SWPPP) to meet the TMDL WLA. To meet the WLA for construction stormwater, construction stormwater activities are required to meet the conditions of the Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

To meet the WLA for industrial stormwater, industrial stormwater activities are required to meet the conditions of the industrial stormwater general permit or Nonmetallic Mining & Associated Activities general permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

# 6 MONITORING PLAN

## 6.1 Lake Monitoring

St. Clair Lake's water quality has been monitored by the PRWD, the MPCA and volunteers for about two decades with historical data in the MPCA's water quality database dating back to 1948. More recently, the PRWD has been collecting lake data on an annual basis since 1998 and will continue this monitoring as a part of their monitoring network. For trend detection purposes, the PRWD has targeted 8-10 summer surface samples of TP, Chl-*a* and Secchi transparency and is including 3-4 lake bottom samples for TP and total iron as an additional gauge of internal loading potential. Monthly temperature and DO profiling data collection will be continued. Water level data is only available for partial periods during 1996 and 2003 and future lake levels will also be recorded. Monitoring of Ditch 14 downstream of Lake St. Clair has been conducted as a part of PRWD studies and future monitoring will include Ditch 14 flows into St. Clair Lake.

## 6.2 BMP Monitoring

On-site monitoring of implementation practices should be conducted to better assess the BMP pollutant reduction effectiveness. For this purpose the University of Minnesota has identified four levels of stormwater BMP assessment monitoring ranging from simple visual examinations, to capacity testing, synthetic runoff and fully instrumented water flow and sampling assessments (Gulliver et al. 2010). Any of these assessment methods may be employed depending upon the BMP type, setting and performance assessment objectives. A variety of criteria such as land use, soils, type of BMP and watershed characteristic as well as monitoring feasibility, will be used to determine which BMPs to monitor. Representative monitoring of a specific type of implementation practice can be accomplished and applied to similar practices under similar criteria and scenarios. Effectiveness of other BMPs may be extrapolated based BMP designs, construction and operation/maintenance considerations.

# 7 IMPLEMENTATION STRATEGY

The TMDL is based on data through 2011. Any activities implemented during or after 2011 that lead to a reduction in P loads to the lake or an improvement in lake water quality may be considered as progress towards meeting a WLA or LA.

## 7.1 Regulated Construction Stormwater

The WLA for stormwater discharges from sites where there are construction activities reflects the number of construction sites one or more acres expected to be active in the watershed at any one time, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS Permit General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local construction stormwater requirements must also be met.

## 7.2 Regulated Industrial Stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES Industrial Stormwater Permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local stormwater management requirements must also be met.

## 7.3 Adaptive Management

St. Clair Lake's responses over time will be evaluated as various management practices are implemented and as city growth occurs. This evaluation will occur every five years after the commencement of implementation actions and forward over the next 25 years by the PRWD based on evaluation of lake monitoring data. For example, retrofitting of dry basins to infiltration and/or wet basins along with enhanced street sweeping may achieve the majority of the TMDL P reductions. Or, additional measures may need to be implemented if St. Clair Lake does not achieve its numeric management goals.

Detroit Lakes is defined as MS4 community (MS4 - the state's small city municipal storm sewer system water permit), which means that it is required to have strong ordinances to protect impaired and unimpaired waters. The MS4 general permit contains language regarding TMDL allocations and incorporating the City's stormwater management practices to achieve these allocations. Given the coverage by HSG A and B soils in the drainage basin, strong consideration should be given to implementation of volume control – or practices that infiltrate or filter surface runoff via rain gardens or infiltration basins. The voluntary Minimal Impact Design Standard (MIDS) practices should be considered in this regard and contains three main elements that will help address present challenges:

- **A higher clean water performance goal** for new development and redevelopment that will provide enhanced protection for Minnesota's water resources.
- **New modeling methods and credit calculations** that will standardize the use of a range of "innovative" structural and nonstructural stormwater techniques.
- **A credits system and ordinance package** that will allow for increased flexibility and a streamlined approach to regulatory programs for developers and communities.

The development of MIDS is based on **low impact development** (LID) – an approach to storm water management that mimics a site's natural hydrology as the landscape is developed. Using the LID approach, storm water is managed on site and the rate and volume of predevelopment storm water reaching receiving waters is unchanged. The calculation of predevelopment hydrology is based on present-day native soil and vegetation. (Minn. Stat. 2009, § 115.03, subd. 5c). This program will provide assistance with reviewing and updating existing stormwater-related ordinances to better protect and restore water resources. It could also streamline compliance under the state's NPDES Construction Permit (which applies to all grading activities that disturb more than an acre), as this permit has stricter requirements for impaired waters and has greater anti-degradation restrictions. Detroit Lakes will be able to enhance new development and redevelopment ordinances and allow the integration of LID concepts into local codes and procedures, especially important with planned annexation around Floyd Lake and Lake Sallie lakeshore areas.

### 7.4 Funding Sources

At the local level, the PRWD has targeted water quality improvement programs with a long list of completed projects. It is anticipated that PRWD involvement will continue into the future. Potential state funding of TMDL implementation projects includes the Clean Water Fund grants. At the federal level, funding can be provided through Clean Water Act Section 319 grants that provide cost share dollars to implement activities in the watershed. Various other funding and cost-share sources exist, which will be listed in the Lake St. Clair TMDL Implementation Plan. Programs such as State cost-share, Clean Water Legacy funding, Environmental Quality Incentives Program (EQIP), and Conservation Reserve Program (CRP) are available to help implement the best conservation practices that each parcel of land is eligible for to target the best conservation practices per site. Conservation practices may include, but are not limited to: stormwater bioretention, septic system upgrades, invasive species control, wastewater treatment practices, and internal loading reduction. More information about types of practices and implementation of BMPs may be viewed on the PRWD website http://prwd.org/.

### 7.5 Prioritization

From observations and discussions with the City, three stormwater management adaptations may offer cost-effective stormwater treatment improvement: (1) retrofitting/upgrading of existing dry/wet stormwater basins; (2) enhancement of existing street sweeping capabilities; and (3) implementation of volume control approaches in areas with suitable soil infiltration capacities for new and redevelopments. Dry sediment basins, while they may offer control of runoff rates, do not typically offer significant pollutant reduction potentials. Retrofitting of existing dry and wet basins into wet stormwater ponds with filtration trenches may be considered, as accomplished by the city of Prior Lake, Minnesota. Secondly, purchase of advanced regenerative street sweepers that offer dry or wet vacuuming capabilities may increase the temporal coverage of seasonal sweeping opportunities as well as the removal of small particulates and P created by typical bristle brush street sweepers. Lastly, Detroit Lakes uses polyphosphates for treatment of domestic water supplies with an average of 1.422 mg PO4/L or expressed as elemental P, 455 ug P/L. The City should check with suppliers and ascertain the type of polyphosphate compounds being used (e.g. orthophosphorus or fertilizer) and explore methods of reducing or diverting fire hydrant flushing, irrigation overspray, leaking pipes and other domestic sources from entering the storm sewer system.

## 7.6 Education and Outreach

Education and outreach to residents and businesses about reducing their stormwater and P 'footprints' will be an important component of the TMDL implementation effort and may include:

- Management of seasonal yard wastes including grass clippings, leaves, branches with residents and commercial landscaping services to prevent organic debris from entering the stormwater conveyance system (curbs, gutters and stormdrains);
- Improving turf management to increase sheet flow filtration and minimize seasonal P and sediment losses;
- Minimizing yard/driveway/remodeling erosion;
- Seasonal yard waste recycling programs
- Minimizing irrigational losses; and
- Helping improve street sweeping efficiencies.

A variety of educational opportunities may be used with targeted audiences throughout the watershed such as the downtown, residential, strip mall and large commercial and industrial entities. The recent St. Mary's Hospital redevelopment with extensive infiltration BMPs may serve as a model of reducing stormwater runoff and to protect down gradient flooding. Partnership activities may include assistance from UM Master Gardeners, PRWD, Becker County SWCD and a variety of civic organizations. The more traditional approaches include workshops, focus groups, press releases and training sessions along with newer web/twitter approaches involving video training and information.

## 7.7 Technical Assistance

Technical assistance is provided by a variety of entities, including but not limited to the PRWD and Becker County SWCD and NRCS. The PRWD and Becker Soil and Water Conservation District provide assistance to landowners for a variety of projects that benefit water quality throughout Detroit Lakes. Assistance provided to landowners varies from agricultural and rural BMPs to urban and lakeshore BMPs. This technical assistance includes education and one-on-one training. Many opportunities for technical assistance result from educational workshops and training sessions and it is important that these outreach opportunities for Detroit Lakes area residents continue. Landowners' motivation to participate in voluntary cost-share assistance programs will be crucial.

### 7.8 Partnerships

Partnerships with counties, cities, townships, citizens, businesses, and lake associations are one mechanism through which the PRWD and Becker County SWCD protect and improve water quality. The PRWD and Becker County SWCD will continue their strong tradition of partnering with state and local government to protect and improve water resources and to bring waters within the Detroit Lakes Watershed into compliance with State standards.

### 7.9 Cost

The Clean Water Legacy Act requires that a TMDL include an overall approximation of the cost to implement a TMDL [Minn. Stat. 2007, § 114D.25]. The initial estimate for implementing the St. Clair Lake TMDL is approximately $ 500,000 to $ 1,500,000. The wide range is due to uncertainties regarding the number, size, duration and location of the implementation projects/programs needed to achieve the P reduction goals. This estimate does NOT include the costs of any future improvements needed by the Detroit Lakes WWTF to meet the lowered effluent P concentration limits as the scope and projected costs of these improvements are not yet available. This estimate will be refined when the more detailed implementation plan is developed.

## 8 STAKEHOLDER PARTICIPATION

### 8.1 Stakeholder Meetings

Public Meetings were held on the following dates:

The first public meeting was held on October 9, 2012, with a second public meeting held on October 25, 2012, both at Detroit Lakes City Hall. A follow-up meeting was held with Detroit Lakes City officials on April 16, 2013, to review city loadings and urban stormwater BMPs. Since that time, the City has been evaluating interconnected issues relating to expansion of the airport, expansion of its wastewater service collection area and change of its wastewater discharge location. Meetings were held with Detroit Lakes Public Works and City Administrators on April 30, 2014, and August 13, 2014, to review the details of lake predictive modeling and TMDL calculations and potential linkage to the City's expansion plans. Afternoon and evening combined public and stakeholder meetings were held on October 23, 2014 to present the final TMDL report and allocations prior to public notice.

### 8.2 Regular Updates

Regular updates about the TMDL process are given at the regularly scheduled PRWD Board meetings. Another update on the process is also given each year via the PRWD Annual Report. Board members are also given chance to review the documents and provide comments along the way. The board members on the PRWD each represent different areas of the PRWD including Detroit Lakes its associated watershed. The city of Detroit Lakes City Council has also requested periodic updates.

## 9 REFERENCES

Canfield, D. and R. Bachmann, 1981. Prediction of Total Phosphorus Concentrations, Chlorophyll- *a*, and Secchi Depths in Natural and Artificial Lakes. *Canadian Journal of Fisheries and Aquatic Science* 38:414-423.

CWP (Center for Watershed Protection). 2006. Technical Memorandum 1 – Literature Review: Research in support of an interim pollutant removal rate for street sweeping and storm drain cleanout activities. Supported by the U.S. Chesapeake Bay Program, Grant CB-97322201-0.

Gulliver, J.S., A.J. Erickson and P.T. Weis. 2010. Stormwater Treatment: Assessment and Maintenance. University of Minnesota, St. Anthony Falls Laboratory, Minneapolis, MN http://stormwaterbook.safl.umn.edu/

Hecock, R.D. February 2001. St. Clair alum treatment: an evaluation. Pelican River Watershed District.

Heiskary, S.A. and C.B. Wilson. 2005. Minnesota lake water quality assessment report:

Developing nutrient criteria. Minnesota Pollution Control Agency. St. Paul, Minnesota.

James, William F. and John W. Barko. 1991. Estimation of phosphorus exchange between littoral and pelagic zones during nighttime convective circulation. Limol.Oceanogr. 36(1): 179-187.

Lin, J.P. 2004. Review of published export coefficient and event mean concentration (EMC) data. WRAP Technical Notes Collection (ERDC TN-WRAP-04-3). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/wrap

MnDOT District 4, City of Detroit Lakes, Becker County. June 2011. *Transportation Planning Study: Detroit Lakes, Minnesota*. Prepared by HRGreen.

MPCA (Minnesota Pollution Control Agency). 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Prepared by Barr Engineering.

MPCA (Minnesota Pollution Control Agency). 2009. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment. wq-iw1-04.

MPCA. Minimal Impact Design Standards (MIDS) Project. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-minimal-impact-design-standards-mids.html

]MWPS (Midwest Plan Service). 2004. Manure Characteristics: Manure Management Systems Series. MWPS-18 Section 1 Second Edition. Iowa State University.

PRWD (Pelican River Watershed District). 2006. Ditch 14 Hydraulic and Water Quality Study. Prepared by Wenck Associates, Inc (File#1311-05).

PRWD. 1998. A study of the contribution of groundwater to phosphorous loadings for selected lakes in the Pelican River Watershed. Prepared by Barr Engineering Company.

Nürnberg, G. K. 1988. The prediction of phosphorus release rates from total and reductant-soluble phosphorus in anoxic lake sediments. Can. J. Fish. Aquat. Sci. 45: 453-462.

Nürnberg, G.K. 1996. Trophic state of clear and colored, soft- and hard-water lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake Reserv. Manage. 12: 432-447.

Schueler, T., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing

urban BMPs. Publ. No. 87703. Metropolitan Washington Council of Governments, Washington D.C.

SCS (Soil Conservation Service). 1992. Hydrology Guide for Minnesota.

Selbig, W.R. and Bannerman, R.T. 2007. Evaluation of Street Sweeping as a Stormwater-Quality-Management Tool in Three Residential Basins in Madison, Wisconsin. USGS Scientific Evaluation.

U.S. Department of Agriculture (USDA) and Natural Resources Conservation Service (NRCS). 2007. Part 630 Hydrology National Engineering Handbook. Chapter 7 Hydrologic Soil Groups. Document No. 210–VI–NEH.

Walker, W. W., 1999. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual*. Prepared for Headquarters, U.S. Army Corps of Engineers, Waterways Experiment Station Report W-96-2. http://wwwalker.net/bathtub/, Walker 1999 (October 30, 2002).

Walker, W.W., 1999. BATHTUB training guidance documents provided to the Minnesota Pollution Control Agency.

Welch, E.B. and G.D. Cooke. 1999. Effectiveness and longevity of phosphorus inactivation with alum. *Journal of Lake and Reservoir Management*. 15:5-27.

Weiss, S. June 7, 2012. Total phosphorus WQBEL analysis: City of Detroit Lakes WWTP to St. Clair Lake. Effluent Limits Unit, Environmental Outcomes and Analysis Division, MPCA.

# 10 APPENDIX A – SUPPORTING DATA FOR BATHTUB MODEL

BATHTUB modeling diagnostics (results) and segment balances (water and P budgets) are presented for both the calibrated (benchmark/existing) model and the TMDL scenario. In-lake water quality concentrations for the calibrated and TMDL scenarios were evaluated to the nearest tenth for TP. The tributary goal reported in the BATHTUB model output does not take into account the MOS, and is therefore larger than the loading goal listed in the TMDL and allocation table in Section 4.7.

**Table 17. Calibrated (benchmark) BATHTUB model diagnostics (model results) for St. Clair Lake**

| **Predicted & Observed Values Ranked Against CE Model Development Dataset** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Segment:** | | **1** | **St. Clair Lake** | | | | |
| | | **Predicted Values--->** | | | **Observed Values--->** | | |
| **Variable** | | **Mean** | **CV** | **Rank** | **Mean** | **CV** | **Rank** |
| TOTAL P | MG/M3 | 68.1 | 0.18 | 65.2% | 68.0 | 0.09 | 65.1% |

**Table 18. Calibrated (benchmark) BATHTUB model segment balances (water) for St. Clair Lake**

| Overall Water Balance | | | | | Averaging Period = | 1.00 | years | |
|---|---|---|---|---|---|---|---|---|
| | | | | Area | Flow | Variance | CV | Runoff |
| Trb | Type | Seg | Name | $km^2$ | $hm^3/yr$ | $(hm3/yr)^2$ | - | m/yr |
| 1 | 3 | 1 | Long Lake Direct Drainage | | 1.2 | 1.45E-02 | 0.10 | |
| 2 | 3 | 1 | WWTP | | 0.5 | 2.48E-03 | 0.10 | |
| 3 | 3 | 1 | Groundwater | | 0.7 | 2.86E-02 | 0.25 | |
| 4 | 1 | 1 | Direct Drainage (MS4) | 0.9 | 0.1 | 4.67E-04 | 0.20 | 0.12 |
| 5 | 1 | 1 | Ditch 1 (MS4) | 6.6 | 1.1 | 4.45E-02 | 0.20 | 0.16 |
| 6 | 1 | 1 | Ditch 14 (MS4) | 4.4 | 1.0 | 3.64E-02 | 0.20 | 0.22 |
| 7 | 1 | 1 | Direct Drainage (unregulat | 1.1 | 0.1 | 5.20E-04 | 0.20 | 0.11 |
| 8 | 1 | 1 | Ditch 1 (unregulated) | 3.7 | 0.5 | 1.14E-02 | 0.20 | 0.14 |
| 9 | 1 | 1 | Ditch 14 (unregulated) | 0.1 | 0.0 | 1.96E-06 | 0.20 | 0.12 |
| PRECIPITATION | | | | 0.6 | 0.5 | 0.00E+00 | 0.00 | 0.74 |
| TRIBUTARY INFLOW | | | | 16.7 | 2.8 | 9.34E-02 | 0.11 | 0.17 |
| POINT-SOURCE INFLOW | | | | | 2.4 | 4.56E-02 | 0.09 | |
| ***TOTAL INFLOW | | | | 17.3 | 5.6 | 1.39E-01 | 0.07 | 0.33 |
| ADVECTIVE OUTFLOW | | | | 17.3 | 5.1 | 1.39E-01 | 0.07 | 0.29 |
| ***TOTAL OUTFLOW | | | | 17.3 | 5.1 | 1.39E-01 | 0.07 | 0.29 |
| ***EVAPORATION | | | | | 0.6 | 0.00E+00 | 0.00 | |

**Table 19. Calibrated (benchmark) BATHTUB model segment balances (phosphorus) for St. Clair Lake**

| Overall Mass Balance Based Upon | | | | Predicted | | Outflow & Reservoir Concentrations | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Component: | | | | TOTAL P | | | | | | |
| | | | | Load | | Load Variance | | | Conc | Export |
| Trb | Type | Seg | Name | kg/yr | %Total | $(kg/yr)^2$ | %Total | CV | $mg/m^3$ | $kg/km^2/yr$ |
| 1 | 3 | 1 | Long Lake Direct Drainage | 20.5 | 3.8% | 8.36E+00 | 0.2% | 0.14 | 17.0 | |
| 2 | 3 | 1 | WWTP | 154.9 | 28.7% | 4.80E+02 | 13.7% | 0.14 | 311.0 | |
| 3 | 3 | 1 | Groundwater | 5.9 | 1.1% | 4.34E+00 | 0.1% | 0.35 | 8.7 | |
| 4 | 1 | 1 | Direct Drainage (MS4) | 9.5 | 1.8% | 7.23E+00 | 0.2% | 0.28 | 88.0 | 10.9 |
| 5 | 1 | 1 | Ditch 1 (MS4) | 123.4 | 22.9% | 1.22E+03 | 34.8% | 0.28 | 117.0 | 18.8 |
| 6 | 1 | 1 | Ditch 14 (MS4) | 130.7 | 24.2% | 1.37E+03 | 39.0% | 0.28 | 137.0 | 29.8 |
| 7 | 1 | 1 | Direct Drainage (unregulat | 13.1 | 2.4% | 1.37E+01 | 0.4% | 0.28 | 115.0 | 12.4 |
| 8 | 1 | 1 | Ditch 1 (unregulated) | 66.9 | 12.4% | 3.58E+02 | 10.2% | 0.28 | 125.0 | 17.9 |
| 9 | 1 | 1 | Ditch 14 (unregulated) | 0.9 | 0.2% | 5.93E-02 | 0.0% | 0.28 | 123.0 | 14.4 |
| PRECIPITATION | | | | 13.6 | 2.5% | 4.62E+01 | 1.3% | 0.50 | 28.4 | 21.0 |
| TRIBUTARY INFLOW | | | | 344.5 | 63.9% | 2.96E+03 | 84.6% | 0.16 | 124.2 | 20.7 |
| POINT-SOURCE INFLOW | | | | 181.2 | 33.6% | 4.92E+02 | 14.1% | 0.12 | 76.2 | |
| ***TOTAL INFLOW | | | | 539.3 | 100.0% | 3.50E+03 | 100.0% | 0.11 | 95.8 | 31.2 |
| ADVECTIVE OUTFLOW | | | | 345.7 | 64.1% | 4.48E+03 | | 0.19 | 68.1 | 20.0 |
| ***TOTAL OUTFLOW | | | | 345.7 | 64.1% | 4.48E+03 | | 0.19 | 68.1 | 20.0 |
| ***RETENTION | | | | 193.6 | 35.9% | 3.60E+03 | | 0.31 | | |
| | | | Overflow Rate (m/yr) | 7.8 | | Nutrient Resid. Time (yrs) | | | 0.1226 | |
| | | | Hydraulic Resid. Time (yrs) | 0.1913 | | Turnover Ratio | | | 8.2 | |
| | | | Reservoir Conc (mg/m3) | 68 | | Retention Coef. | | | 0.359 | |

**Table 20. TMDL scenario BATHTUB model diagnostics (model results) for St. Clair Lake**

| Predicted & Observed Values Ranked Against CE Model Development Dataset | | | | | | |
|---|---|---|---|---|---|---|
| Segment: | 1 | St. Clair Lake | | | | |
| | Predicted Values---> | | | Observed Values---> | | |
| Variable | Mean | CV | Rank | Mean | CV | Rank |
| TOTAL P MG/M3 | 59.1 | 0.17 | 59.2% | 68.0 | 0.09 | 65.1% |

**Table 21. TMDL scenario BATHTUB model segment balances (water) for St. Clair Lake**

| Overall Water Balance | | | | | Averaging Period = | | 1.00 | years |
|---|---|---|---|---|---|---|---|---|
| | | | | Area | Flow | Variance | CV | Runoff |
| Trb | Type | Seg | Name | $km^2$ | $hm^3/yr$ | $(hm3/yr)^2$ | - | m/yr |
| 1 | 3 | 1 | Long Lake Direct Drainage | | 1.2 | 1.45E-02 | 0.10 | |
| 2 | 3 | 1 | WWTP | | 0.5 | 2.48E-03 | 0.10 | |
| 3 | 3 | 1 | Groundwater | | 0.7 | 2.86E-02 | 0.25 | |
| 4 | 1 | 1 | Direct Drainage (MS4) | 0.9 | 0.1 | 4.67E-04 | 0.20 | 0.12 |
| 5 | 1 | 1 | Ditch 1 (MS4) | 6.6 | 1.1 | 4.45E-02 | 0.20 | 0.16 |
| 6 | 1 | 1 | Ditch 14 (MS4) | 4.4 | 1.0 | 3.64E-02 | 0.20 | 0.22 |
| 7 | 1 | 1 | Direct Drainage (unregulat | 1.1 | 0.1 | 5.20E-04 | 0.20 | 0.11 |
| 8 | 1 | 1 | Ditch 1 (unregulated) | 3.7 | 0.5 | 1.14E-02 | 0.20 | 0.14 |
| 9 | 1 | 1 | Ditch 14 (unregulated) | 0.1 | 0.0 | 1.96E-06 | 0.20 | 0.12 |
| PRECIPITATION | | | | 0.6 | 0.5 | 0.00E+00 | 0.00 | 0.74 |
| TRIBUTARY INFLOW | | | | 16.7 | 2.8 | 9.34E-02 | 0.11 | 0.17 |
| POINT-SOURCE INFLOW | | | | | 2.4 | 4.56E-02 | 0.09 | |
| ***TOTAL INFLOW | | | | 17.3 | 5.6 | 1.39E-01 | 0.07 | 0.33 |
| ADVECTIVE OUTFLOW | | | | 17.3 | 5.1 | 1.39E-01 | 0.07 | 0.29 |
| ***TOTAL OUTFLOW | | | | 17.3 | 5.1 | 1.39E-01 | 0.07 | 0.29 |
| ***EVAPORATION | | | | | 0.6 | 0.00E+00 | 0.00 | |

**Table 22. TMDL scenario BATHTUB model segment balances (phosphorus) for St. Clair Lake**

| Overall Mass Balance Based Upon | | | | Predicted | | Outflow & Reservoir Concentrations | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Component: | | | | TOTAL P | | | | | | |
| | | | | Load | | Load Variance | | | Conc | Export |
| Trb | Type | Seg | Name | kg/yr | %Total | $(kg/yr)^2$ | %Total | CV | $mg/m^3$ | $kg/km^2/yr$ |
| 1 | 3 | 1 | Long Lake Direct Drainage | 20.5 | 4.5% | 8.36E+00 | 0.4% | 0.14 | 17.0 | |
| 2 | 3 | 1 | WWTP | 198.2 | 43.5% | 7.86E+02 | 38.6% | 0.14 | 398.0 | |
| 3 | 3 | 1 | Groundwater | 3.7 | 0.8% | 1.67E+00 | 0.1% | 0.35 | 5.4 | |
| 4 | 1 | 1 | Direct Drainage (MS4) | 7.2 | 1.6% | 4.19E+00 | 0.2% | 0.28 | 67.0 | 8.3 |
| 5 | 1 | 1 | Ditch 1 (MS4) | 81.2 | 17.8% | 5.28E+02 | 26.0% | 0.28 | 77.0 | 12.4 |
| 6 | 1 | 1 | Ditch 14 (MS4) | 80.1 | 17.6% | 5.14E+02 | 25.3% | 0.28 | 84.0 | 18.3 |
| 7 | 1 | 1 | Direct Drainage (unregulat | 8.6 | 1.9% | 5.85E+00 | 0.3% | 0.28 | 75.0 | 8.1 |
| 8 | 1 | 1 | Ditch 1 (unregulated) | 41.7 | 9.2% | 1.39E+02 | 6.9% | 0.28 | 78.0 | 11.2 |
| 9 | 1 | 1 | Ditch 14 (unregulated) | 0.4 | 0.1% | 1.46E-02 | 0.0% | 0.28 | 61.0 | 7.1 |
| PRECIPITATION | | | | 13.6 | 3.0% | 4.62E+01 | 2.3% | 0.50 | 28.4 | 21.0 |
| TRIBUTARY INFLOW | | | | 219.3 | 48.2% | 1.19E+03 | 58.6% | 0.16 | 79.1 | 13.2 |
| POINT-SOURCE INFLOW | | | | 222.3 | 48.8% | 7.96E+02 | 39.1% | 0.13 | 93.5 | |
| ***TOTAL INFLOW | | | | 455.2 | 100.0% | 2.03E+03 | 100.0% | 0.10 | 80.9 | 26.3 |
| ADVECTIVE OUTFLOW | | | | 299.8 | 65.9% | 2.96E+03 | | 0.18 | 59.1 | 17.3 |
| ***TOTAL OUTFLOW | | | | 299.8 | 65.9% | 2.96E+03 | | 0.18 | 59.1 | 17.3 |
| ***RETENTION | | | | 155.4 | 34.1% | 2.38E+03 | | 0.31 | | |
| | Overflow Rate (m/yr) | | | 7.8 | | Nutrient Resid. Time (yrs) | | | 0.1260 | |
| | Hydraulic Resid. Time (yrs) | | | 0.1913 | | Turnover Ratio | | | 7.9 | |
| | Reservoir Conc (mg/m3) | | | 59 | | Retention Coef. | | | 0.341 | |

# 11 APPENDIX B – MPCA 2012 WQBEL STUDY

DATE : 06/07/2012

TO : File SF-00006-05(4/86)

FROM : Steven Weiss
Effluent Limits Unit
Environmental Outcomes and Analysis Division

PHONE : 651/757-2814

SUBJECT : Total Phosphorus Water Quality Based Effluent Limit Analysis: City of Detroit Lakes WWTP to St. Clair Lake

The following memorandum is a reasonable potential analysis for TP discharged by the city of Detroit Lakes WWTP to the immediate receiving water, St. Clair Lake. This version supersedes the previous memorandum completed on May 2, 2012. Modifications were made in this version to correct an error discovered in the land use area of the contributing watershed. Accordingly, some nonpoint EMCs were adjusted, and model output values were updated. It should be noted that no change in the recommended TP limit or the percentage of nonpoint source reductions were necessary.

This analysis will not examine water quality impacts of relocating the outfall pipe outside of St. Clair Lake, which may impact other downstream lakes. These options may be examined at a later time if the MPCA is presented with such a proposal. The Detroit Lakes WWTP (NPDES Number MN0020192) is a mechanical facility consisting of a trickling filter. Part of the effluent is routed to RIBs or is spray irrigated. Given the combination of treatment types, effluent is discharged intermittently to surface water. Although the facility average wet weather design flow (AWWDF) is 2.02 mgd, actual effluent flow discharged to surface water is typically less than 0.2 mgd based on records from 2002-2011. Detroit Lakes currently has a 1.0 mg/L TP limit. At full AWWDF equates to a permitted TP load of 2,792 kg/yr. However, the long-term average actual TP load from this facility is 157 kg/yr.

St. Clair Lake (Lake ID # 03-0382) was placed on the Federal 303(d) list of impaired waters in 2008 for eutrophication due to excess phosphorus. Federal law [40 CFR 122.44(d)] restricts mass increases upstream of impaired waters and states that all NPDES dischargers that have the reasonable potential (RP) to cause or contribute to downstream impaired waters are required to have a WQBEL. Permittees are found to have RP if all of the following conditions exist: 1) they discharge upstream of a nutrient impaired waterbody, 2) they discharge at a TP concentration greater than the ambient target, and 3) there is no geographical barrier capable of trapping a significant mass of nutrients between the outfall and the impairment. For all three reasons, the Detroit Lakes WWTP is found to have RP.

When determining RP, the Code of Federal Regulations also states that the MPCA shall use procedures which account for existing controls on point and nonpoint sources of pollution. Currently, the Detroit Lakes WWTP is estimated to contribute roughly 29% of the annual TP load to St. Clair Lake. Nonpoint sources, including runoff from agriculture and urban stormwater, account for roughly 65% of the annual TP load. The purpose of the following analysis is to: 1) explore combinations of point and nonpoint source load reductions, and 2) to recommend a WQBEL for the city of Detroit Lakes WWTP with the ultimate goal of meeting the water quality target in St. Clair Lake.

***Watershed***

St. Clair Lake is adjacent to the city of Detroit Lakes in the headwaters of the Otter Tail River Watershed (Appendix A). The St. Clair Lake watershed is 30 $km^2$ and is divided into two sections; one that drains through Long Lake (13 $km^2$, Lake ID# 03-0383) and one that drains directly into St. Clair Lake (17 $km^2$ ,Table 1). Long Lake is not impaired due to excess P. Long Lake outlet TP was estimated to be 17 µg/L based on 17 summers of lake data from 1993-2011. Flow was estimated by multiplying the drainage area by annual regional runoff values as described below. Together, loading from Long Lake was estimated to range from 52 to 16 kg/yr with an average of 28 kg/yr.

**Table 1: Landcover within the St. Clair Lake Watershed.**

| Landcover* | Direct Drainage | | Long Lake Drainage | |
|---|---|---|---|---|
| | % | $km^2$ | % | $km^2$ |
| Water | 15% | 2.6 | 19% | 2.5 |
| Urban | 39% | 6.7 | 12% | 1.6 |
| Forest | 14% | 2.4 | 27% | 3.6 |
| Grassland | 2% | 0.4 | 5% | 0.6 |
| Pasture | 16% | 2.7 | 19% | 2.6 |
| Agriculture | 15% | 2.6 | 17% | 2.3 |
| Total | 100% | 17.3 | 100% | 13.1 |

*Derived from NLCD 2006

Landcover in the direct drainage watershed consists of urban (39%), pasture (16%), agriculture (15%), water (15%), which is composed of both wetland and open water, and forest (14%; Table 1). A nominal area of grassland (2%) is also present. The 2006 National Landcover Dataset (NLCD 2006) and the DNR catchment delineation dataset were used to determine contributing land cover types and areas (Fry et al 2011, Vaughn 2010). Summer runoff mean concentration values, within a range published in literature, were used to estimate TP load contributions from landcover types (Lin 2004). Landcovers like forest, grassland, and wetland/open water were assumed to represent “baseline conditions”. Baseline landcovers contribute a minimal amount of loading and have no further load reduction potential. Other land covers like agriculture, pasture, and urban are assumed to be reducible only to baseline levels. Reductions beyond baseline are assumed to be infeasible. Annual runoff was calculated by dividing the mean daily flow at the nearest long term USGS river flow gauging station (USGS 0504600 Otter tail river below the Orwell Dam near Fergus Falls, Minnesota) by the drainage area at that location (4,507 $km^2$). The resulting runoff values ranged from 2.6 to 9.2 inches depending on the year. Given the small size of the watershed, no transport losses were explicitly represented within the model. Current average (1998-2010) nonpoint runoff loads from the direct drainage watershed were estimated to be 347 kg/yr.

### *St. Clair Lake*

St. Clair Lake is a shallow, eutrophic lake with a mean depth of 1.2 m, a surface area of 0.98 $km^2$, and a watershed to lake surface area ratio of 31:1. Under average conditions, the hydraulic residence time is estimated to be 99 days, but depending on the year modeled (1998-2010) could range from 57-161 days. Water quality data, including TP and some Chl-a samples have been collected at St. Clair Lake since 1942. More recent data (1998-2010) were collected at three different sampling stations located, essentially, in the center of the lake. Summer average TP and Chl-a were 69 µg/L (n=168) and 26 µg/L (n=19), respectively (Table 2). The applicable numeric lake eutrophication standard for shallow lakes in the north central hardwood ecoregion (NCHF) for TP and Chl-a are 60 and 20 µg/L.

**Table 2: St. Clair Lake TP and Chl-a observations compared to the applicable numeric nutrient standard.**

| Description | TP | | Chl-a | |
|---|---|---|---|---|
| | (µg/L) | (n) | (µg/L) | (n) |
| Current Actual* | 69 | 168 | 26 | 19 |
| Applicable Standard** | 60 | | 20 | |

*based on mean of annual mean values (1998-2010)

** North Central Hardwood Forest

Older historical records demonstrate that prior to the implementation of the existing 1.0 mg/L TP limit; the lake was much more severely impaired. In the 1970s summer average TP exceeded 400 µg/L. Historical data demonstrates that implementation of the 1.0 mg/L concentration limit resulted in substantial water quality improvements. In addition, in 1998 the PRWD performed an alum treatment aimed at both reducing internal P release in St. Claire Lake and also to reduce the mass of P discharged to other downstream lakes including Lake Sallie (PRWD 2005). Nonetheless, despite the water quality improvements resulting from the lake alum treatment and WWTP upgrades, the load reductions are insufficient to meet lake eutrophication standards.

## *Model Description*

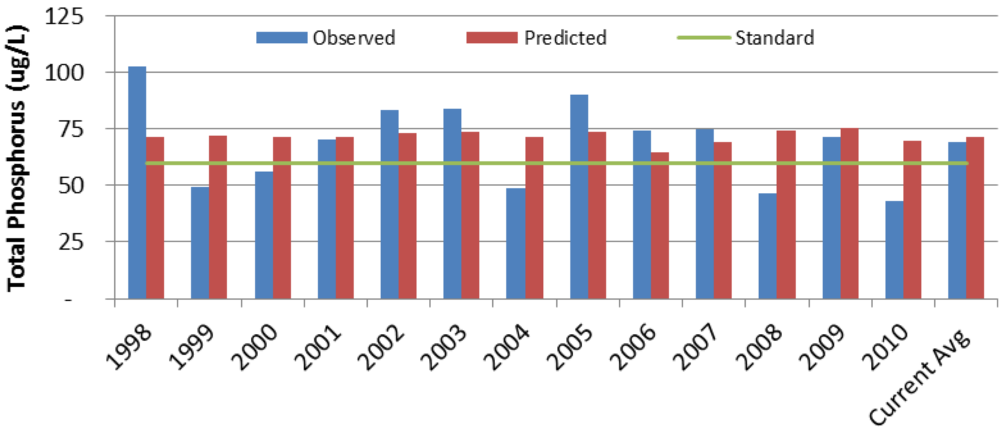
A Bathtub computer lake model, including six scenarios, was developed to evaluate existing water quality conditions and to calculate an appropriate WQBEL for the city of Detroit Lakes WWTP (Walker, 1985, 1986). The primary scenarios (1-4) include one simulation of existing conditions and three load reduction strategies. In Scenario 5 and 6, mass and concentration limits are simulated as facility flow is modified. Detailed input parameters for Scenario 1 are listed in Appendix C. Scenarios 2 through 6 can be replicated by making the following adjustments listed below.

All scenarios use a full one year averaging period. As such, flow and loading from the WWTP are represented as discrete single annual units. Actual facility flow is derived from annual total values reported in million gallons (MG) and converted to million gallons per day (mgd) and cubic hectometers per year ($hm^3/yr$) for use with the model.

Modifications to nonpoint source contributions were only done in the direct drainage watershed because Long Lake outlet concentrations are well below standards and as such would be difficult to be further reduced.

Scenario 1 was calibrated to existing conditions based on the average of inputs for individual year models from 1998-2010 (Figure 1). The current actual load (157 kg/yr) was used to represent the Detroit Lakes WWTP. Nonpoint source TP contributions were estimated as described above. Internal loading was left at default levels, and as such, was implicitly represented by the model. For all scenarios the Canfield and Bachman (1981) TP model was chosen because results most closely match observations. For all models, it is assumed that by reaching the applicable TP standard, significant progress will be made towards achieving the Chl-a and secchi depth response variables.

**Figure 1: Observed (blue) and predicted (red) summer average TP in St. Clair Lake (Lake ID# 03-0382). The current average model (Scenario 1) incorporates the average of input values from the full range of years (1998-2010). The applicable north central hardwood forest ecoregion lake eutrophication TP standard is displayed in green.**




Scenarios 2, 3, and 4 were developed to examine the outcome of TP load reductions from nonpoint sources, point sources, and both simultaneously. Scenario 2, an NPDES weighted approach, was designed to examine if aggressive point source reductions, alone, could achieve water quality standards (TP = 60 µg/L). No changes were made to nonpoint load sources. Flow from the Detroit Lakes WWTP was set at AWWDF (2.02 mgd) to represent the future growth potential of the community while the TP concentration was incrementally reduced to 80 µg/L, at which point the summer average in-lake TP concentration was estimated to be 60 µg/L.

Scenario 3, a nonpoint source weighted approach, was designed to test if nonpoint source reductions alone could achieve standards. Summer mean runoff TP concentrations were set to background levels resulting in an estimated 66% reduction from current levels. Although the current WWTP discharges at a fraction of its full capacity, the facility was represented at full permitted capacity given the possibility that some or all of the wastewater sent to RIBs could be sent to surface water in the future. Therefore, the WWTP was set at AWWDF (2.02 mgd) and 1.0 mg/L TP which equates to the full current permitted load (2,792 kg/yr).

Scenario 4, a balanced approach, tests a combination of both point and nonpoint source reductions. Other regional lake assessment studies were used to determine the percent of nonpoint source reductions (MPCA 2002; PRWD 2005). Nonpoint source TP loads from urban and agriculture were reduced by 50%. Loading from pasture was reduced by 33%. Overall, this amounted to a 42% TP load reduction from all estimated nonpoint sources, collectively. The Detroit Lakes WWTP was reduced to a TP concentration of 0.4 mg/L at 0.357 mgd; a flow value which represents the average annual discharge from 2002 through 2010. This equates to an annual TP load of 196 kg/yr which is a 93% reduction from current permitted levels.

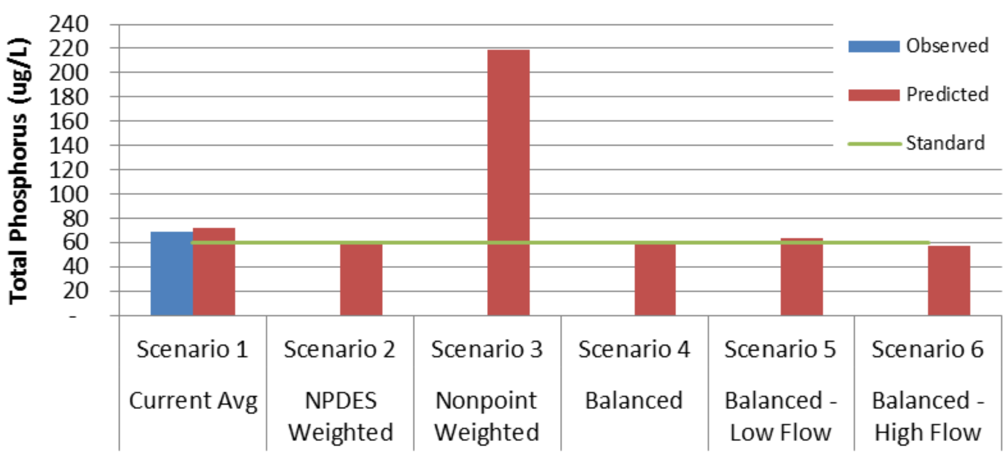
Scenarios 5 and 6 were designed to test if a fixed mass limit of 196 kg/yr would be sufficient to achieve standards in-lake if either flow or concentration values were substantially modified. In scenario 5 the facility flow was reduced from current actual levels by one half to 0.177 mgd while the concentration was allowed to double to 0.8 mg/L. In scenario 6 the flow was doubled from current actual maximum levels to 0.708 mgd and the concentration was reduced to 0.2 mg/L.

***Results***

In Scenario 1, the simulation of current actual conditions, model predictions closely matched observations. Predicted summer average TP was 71 µg/L; observed TP was 69 µg/L (Figure 2, Appendix B). Additional calibration was not necessary. Under average conditions, annual loading from all major sources to St. Clair Lake is estimated to be 534 kg/yr. Currently, the Detroit Lakes WWTP is estimated to be only 10% of the lake water budget. Nonpoint source runoff and precipitation amount to 78% and 12% of the water budget, respectively. Nonetheless, at current actual performance, the Detroit Lakes WWTP amounts to 29% of the annual lake TP load on average. Urban and agricultural runoff from the direct drainage watershed is estimated to contribute 27 and 10% of the annual TP load, respectively.

Scenario 2 demonstrates that it may actually be possible to achieve standards in St. Clair Lake by implementing significant reductions from the Detroit Lakes WWTP, with no further reductions from other nonpoint sources (Figure 2). By reducing WWTP effluent to 80 µg/L, summer average in-lake TP achieved the water quality standard (60 µg/L). On a technical basis, it may be possible to meet a TP limit on the order of 80 µg/L but would require a significant investment to build a new more advanced facility and to operate and maintain it. It should be noted that implementation of such a limit would place the full responsibility of meeting water quality standards on only one source where there are many, and therefore, may not be an equitable solution to a multi-faceted problem.

**Figure 2: St. Clair Lake (Lake ID# 03-0382) observed and modeled summer average TP.**




Scenario 3 demonstrates that significant reductions in nonpoint sources, alone, are insufficient to achieve standards, so long as the facility is capable of discharging at current full permitted load. Predicted summer average TP was 219 µg/L, and as such, was far in exceedance of standards. Nonpoint source TP loading was reduced by 66%. Specific landcovers like agriculture, urban and pasture were reduced by 75%, 75%, and 67%, respectively, to runoff concentrations associated with natural background conditions (Table 3).

Scenario 4 demonstrates that a balanced combination of both point and nonpoint source limits and reductions can achieve standards (Figure 2). Predicted summer average in-lake TP was 61 µg/L; a level equivalent to meeting the water quality standard, in consideration of the variability typically associated with the model. Again, TP loading from the Detroit Lakes WWTP was reduced from current permitted levels (2,792 kg/yr) by 93% to 196 kg/yr. The point source mass load was derived from current average actual annual flow (0.354 mgd) at 0.4 mg/L TP. Nonpoint source loading was reduced by 42%, which was achieved by reducing urban and agriculture runoff concentrations by 50% and pasture concentrations by 33% (Table 3). Other regional lake studies have also recommended nonpoint source load reductions on the order of 50% (MPCA 2002).

**Table 3: Summary of direct drainage watershed nonpoint source loads and reductions.**

| | Flow | Current Average** Scenario 1 | | NPDES Weighted Scenario 2 | | Nonpoint Weighted Scenario 3 | | Balanced Scenario 4 | |
|---|---|---|---|---|---|---|---|---|---|
| Landcover* | hm3/yr | % ↓ | kg/yr | % ↓ | kg/yr | % ↓ | kg/yr | % ↓ | kg/yr |
| Water | 0.33 | 0% | 16 | 0% | 16 | 0% | 16 | 0% | 16 |
| Urban | 0.84 | 0% | 169 | 0% | 169 | 75% | 42 | 50% | 85 |
| Forest | 0.30 | 0% | 15 | 0% | 15 | 0% | 15 | 0% | 15 |
| Grassland | 0.05 | 0% | 2 | 0% | 2 | 0% | 2 | 0% | 2 |
| Pasture | 0.34 | 0% | 52 | 0% | 52 | 67% | 17 | 33% | 34 |
| Agriculture | 0.32 | 0% | 65 | 0% | 65 | 75% | 16 | 50% | 32 |
| Total | 2.18 | 0% | 319 | 0% | 319 | 66% | 109 | 42% | 185 |

*Derived from NLCD 2006

** same loading estimates used for separate year models (1998-2010)

(% ↓) Percent reduction from current estimate

Often, questions arise as to whether a mass limit, concentration limit, or both should be implemented. Scenario 4 demonstrates that if discharging at 0.354 mgd (129 MG/yr), either a 196 kg/yr or a 0.4 mg/L TP limit is sufficient to meet standards. Assuming the designated flow, these limits are essentially identical. Given the likelihood that the flow from this facility may not remain at or near 0.354 mgd, it is appropriate to explore how changes in flow and concentration, with a fixed mass limit (196 kg/yr), would affect lake TP. The following scenarios (5 and 6) estimate lake TP after cutting flow in half to 0.177 mgd (Scenario 5) and doubling flow to 0.708 (Scenario 6). In order to maintain a facility TP load of 196 kg/yr concentrations were doubled to 0.8 mg/L in Scenario 5 and cut in half to 0.2 mg/L in Scenario 6. The type of limit implemented may determine the necessary treatment technology or operational flexibility available to the city. Ultimately, the most appropriate limit is determined by the change in estimated lake TP, or a lack thereof.

Scenario 5 predicted in-lake TP to be 63 µg/L. In consideration of the uncertainty typically associated with empirical lake models (CV~20%), a predicted 3 µg/L increase in TP would be both insignificant from a modeling perspective and immeasurable on a summer average basis. Therefore, this scenario suggests that lake eutrophication standards could be met if facility flow was significantly reduced below current levels, and if concentrations were allowed to rise near the current maximum allowed level (1.0 mg/L).

Scenario 6 predicted in-lake TP to be 57 µg/L. If actual flow is doubled, but the concentration is commensurately cut in half to keep load at or below 198 kg/yr, standards could be met. It is important to recognize that if the Detroit Lakes WWTP receives a 198 kg/yr and increases its surface water discharge rate; they will need to reduce their concentration by a commensurate amount in order to remain in compliance with the limit.

***Summary***

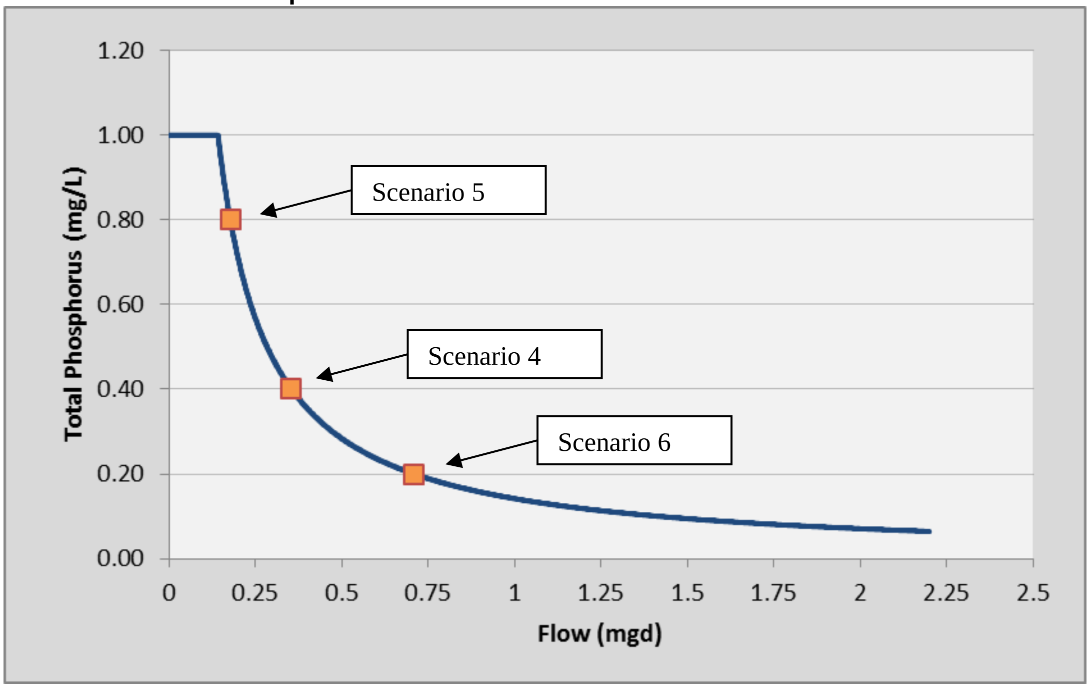
Given that the Detroit Lakes WWTP is found to have the reasonable potential to cause or contribute to the excess nutrient impairment in St. Clair Lake, they are required by federal law to receive a WQBEL. Eventually a TMDL study will also develop a WLA for this facility using a similar analytical process, with potentially more resources to examine specific load sources in greater detail. Optimally, the recommended WQBEL and WLA will be very similar if not identical. Nonetheless, the permittee should be aware of the possibility that the TMDL could eventually require a WLA that is more restrictive than the recommended WQBEL, in which case, the new limit would be implemented during the next permit cycle following the completion of the TMDL study.

The results of this analysis demonstrate that water quality standards in St. Clair Lake can be met in two ways. First, Scenario 2 demonstrates that an 80 µg/L TP limit for the WWTP can achieve lake eutrophication standards with no other nonpoint source reductions necessary. This approach would place the full burden of responsibility to meet lake standards on one source, the WWTP, and in doing so may impart undue hardship upon the municipality and users.

Second, Scenario 4 also meets lake eutrophication standard, but uses a combination of point source limits and nonpoint source reductions. Previous regional lake studies were used as references when determining the appropriate percent of nonpoint source reductions from urban stormwater and agricultural runoff (MPCA 2002, PRWD 2005). The approach used for Scenario 4 more closely reflects the process used with other similar restoration plans. Therefore, it is recommended that the Detroit Lakes WWTP receive a 198 kg/yr TP WQBEL which was derived from Scenario 4 model results.

Scenarios 5 and 6 demonstrate that should the facility reduce their discharge rate to St. Clair Lake, it may be possible to discharge at TP concentrations up to 1.0 mg/L and still meet standards in-lake (Figure 3). However, if flow increases over current actual levels, the facility will be required to reduce effluent TP concentrations below 0.4 mg/L to remain in compliance with the 198 kg/yr WQBEL. Finally, the permittee should be reminded that the upcoming TMDL study may call for a more restrictive WLA limit, with which the Detroit Lakes WWTP will need to comply. It is strongly recommended that the city participate in future TMDL stakeholder meetings in order to better understand the process and provide valuable input.

**Figure 4: The dark blue line represents all combinations of facility flow and concentration sufficient to remain in compliance with the recommended 198 kg/yr TP WQBEL and the existing 1.0 mg/L TP concentration limit. Under very low flows the facility could operate up to 1.0 mg/L and remain in compliance with the WQBEL. Conversely, if facility flow increases over current actual levels, the TP concentration will need to be adequately reduced to remain in compliance with the mass limit.**




### *References*


Canfield, D. E. J. and W. Bachmann (1981). "Prediction of total Phosphorus Concentrations, Chlorophyll *a*, and Secchi Depths in Natural and Artificial Lakes." Can. J. Fish. Aquat. Sci. **38**: 414 - 423.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J.,

2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Heiskary, S.A. and B. Wilson. “Minnesota’s Approach to Lake Nutrient Criteria Development”, Lake and Reservoir Management, Vol. 24, Pp. 282-297, 2008.

Lin, J.P.(2004). “Review of published export coefficient and event mean concentration (EMC) data,” WRAP Technical Notes Collection (ERDC TN-WRAP-04-3). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/wrap

Minnesota Pollution Control Agency, “Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria”, 2005.

Minnesota Pollution Control Agency, “Water Quality Assessment of the Upper Pelican River Watershed (North Floyd, Floyd, Little Floyd, Rice Wetland, Detroit Lake, Little Detroit Lake) Becker County, Minnesota” Clean Water Partnership Program Working Paper, 2002.

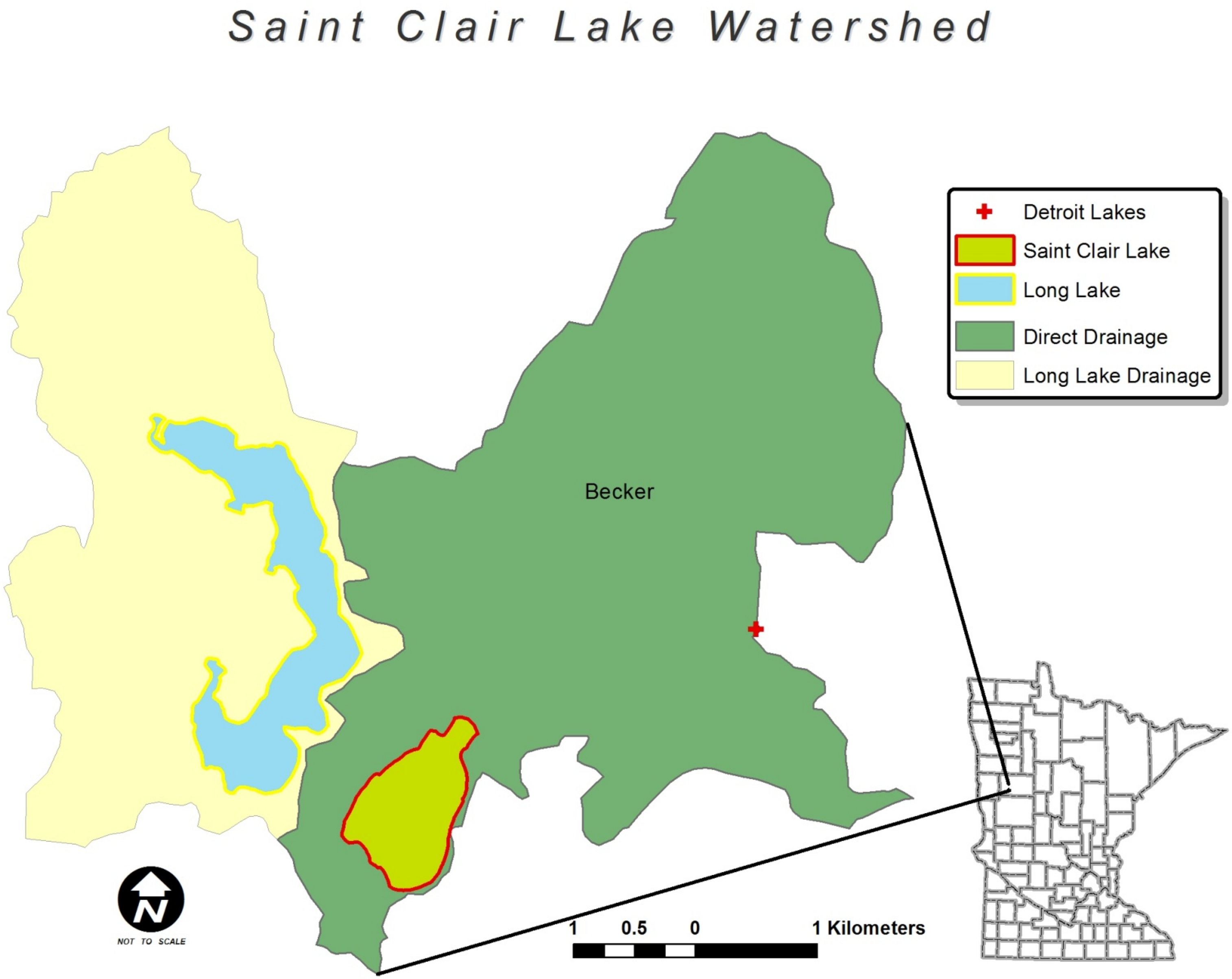
Pelican River Watershed District, Revised Management Plan. 2005. http://www.prwd.org/files/PRWD%20-%20RMP.pdf

Vaughn, S.R., (2010). *DNR Watershed Delineation: Project History, Methodology, Terminology & Data Attribution*. Unpublished manuscript. Minnesota Department of Natural Resources - Waters.

Walker, W. W., 1985. *Empirical Methods for Predicting Eutrophication in Impoundments; Report 3, Phase III: Model Refinements*. Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Walker, W. W., 1986. *Empirical Methods for Predicting Eutrophication in Impoundments; Report 3, Phase III: Applications Manual*. Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

***Appendix A: Map***




***Appendix B: Model scenario results***

| Scenario Modifications | | | Detroit Lakes WWTP Input | | | | Model Estimates |
|---|---|---|---|---|---|---|---|
| | | Flow | Flow | | Concentration | Mass | TP |
| **Scenario Description** | **Scenario** | **Multiplier** | **mgd** | **hm3/yr** | **mg/L** | **kg/yr** | **mg/L** |
| **Current Actual *** | 1 | na | 0.357 | 0.494 | 0.32 | 157 | 71 |
| **NPDES-Weighted** | 2 | AWWDF | 2.02 | 2.792 | 0.08 | 223 | 60 |
| **Nonpoint Weighted** | 3 | na | 2.02 | 2.792 | 1.00 | 2792 | 219 |
| **Balanced** | 4 | na | 0.36 | 0.494 | 0.40 | 198 | 61 |
| **Balanced - low flow** | 5 | 0.5 | 0.18 | 0.247 | 0.80 | 198 | 63 |
| **Balanced - high flow** | 6 | 2 | 0.71 | 0.988 | 0.20 | 198 | 57 |

*129 MG /365 days = 0.357mgd (actual average flow 2002-2010)

## *Appendix C: Scenario 1 Model Inputs*

| | | |
|---|---|---|
| PROBLEM TITLE | St. Clair Lake (03-0382) | |
| | | |
| NON-POINT SOURCE P MODEL... | | |
| Drainage Area | km2 | 0 |
| Precipitation | m/yr | 0.61 |
| Evaporation | m/yr | 0.61 |
| Atmospheric Total P Load | kg/km2-yr | 30 |
| Atmospheric Ortho P Load | kg/km2-yr | |
| | | |
| INTERNAL LOAD | | |
| Total P Release Rate | mg/m2-day | 0 |
| Time of Release | days/yr | 122 |
| Total P Load | kg/yr | 0 |
| | | |
| POINT SOURCE INFLOWS... | | |
| Inflow | mgd | 0.36 |
| Inflow | hm3/yr | 0.49 |
| Total P Conc | ppm | 0.32 |
| Total P Load | kg/yr | 157 |
| Ortho P Load | kg/yr | 0 |
| | | |
| LAKE or RESERVOIR CHARACTERISTICS... | | |
| Surface Area | acres | 242 |
| | km2 | 1.0 |
| Mean Depth | m | 1.2 |
| Mean Depth of Mixed Layer | m | 1.2 |
| | | |
| Mean Depth of Hypolimnion | m | 0 |
| Observed Phosphorus | ppb | 69 |
| Observed Chl-a | ppb | 0 |
| Observed Secchi | meters | 0 |

MODEL PARAMETERS. (See Documentation for Windows Version of BATHTUB)...

| | | |
|---|---|---|
| BATHTUB Total P Model Number | (1-9) | 8 |
| BATHTUB Total P Model Name | | CB-LAKES |
| Consider Ortho P Loads (1=yes, 0=no-recommended) | | 0 |
| P Decay Calibration (normally =1) | | 1 |
| | | |
| BATHTUB Chl-a Model Number | (2,4,5 or 6) | 4 |
| BATHTUB Chl-a Model Name | | P-LIN |
| Include Flushing Term in Chla Model (0 or 1) | | 1 |
| Chlorophyll-a Calib (normally = 1) | | 0.3 |
| Chla Temporal Coef. of Variation | | 1 |
| Chla Nuisance Criterion | ppb | 20 |
| | | |
| BATHTUB Secchi Model Number | (2,4,5) | 4 |
| BATHTUB Secchi Model Name | | Carlson |
| Alpha = Non-Algal Turbidity | 1/m | 0.08 |
| Beta = 1/S vs. Chla Slope | m2/mg | 0.025 |
| Secchi Calib (normally = 1) | | 1 |

NONPOINT ESTIMATOR
Direct Drainage Watershed only

| | | |
|---|---|---|
| Runoff | in | 4.974149966 |
| Runoff | m | 0.13 |
| Transport | | 1 |

| | | Area | | Volume | | Concentration |
|---|---|---|---|---|---|---|
| Water | km2 | 2.6 | hm3/yr | 0.3 | ppb | 50 |
| Urban | km2 | 6.7 | hm3/yr | 0.8 | ppb | 200 |
| Forest | km2 | 2.4 | hm3/yr | 0.3 | ppb | 50 |
| Grassland | km2 | 0.4 | hm3/yr | 0.0 | ppb | 50 |
| Pasture | km2 | 2.7 | hm3/yr | 0.3 | ppb | 150 |
| Agriculture | km2 | 2.6 | hm3/yr | 0.3 | ppb | 200 |
| | | | | | | |
| Total | km2 | 17.3 | hm3/yr | 2.2 | | |

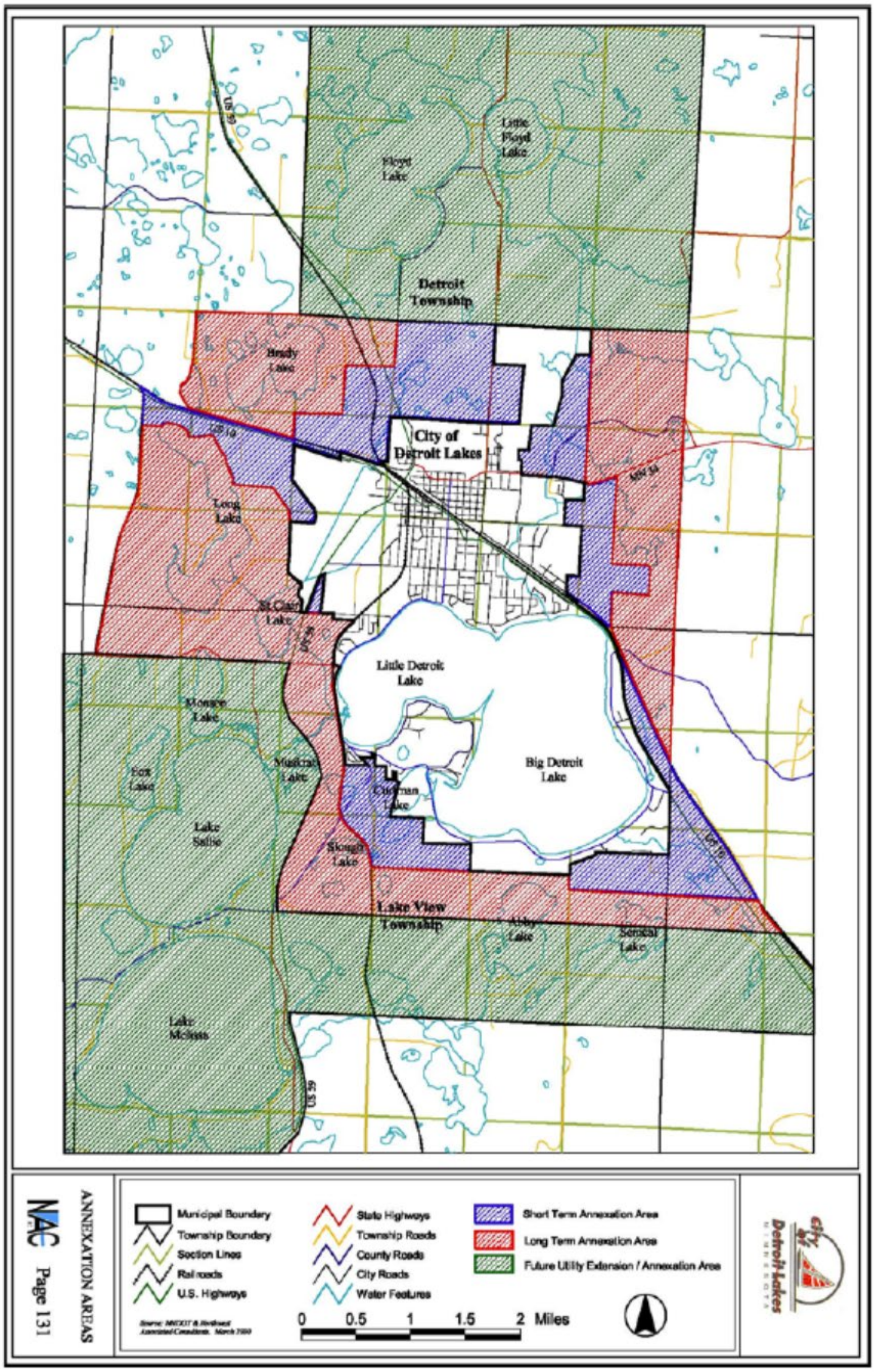
NONPOINT ESTIMATOR
Long Lake Drainage

| | | |
|---|---|---|
| flow | hm3/yr | 1.65 |
| concentration | ug/L | 17 |
| load | kg/yr | 28 |

# 12 APPENDIX C – DETROIT LAKES ANNEXATION PLAN

**Figure 13. City of Detroit Lakes Short- and Long-term Annexation Areas**

From: Exhibit 2: Land Use Plan and Annexation Exhibit, p. 27 *in:* Minnesota Department of Transportation – District 4, City of Detroit Lakes, and Becker County. June 2011. *Transportation Planning Study, Detroit Lakes, Minnesota.*



# 13 APPENDIX D – LAKE HISTORY

## 13.1 Lake History, Management, and Uses

In 1915, the lake was drained from approximately 600 acres to its current size of approximately 160 acres. The city of Detroit Lakes' original WWTF was constructed in 1929; biological treatment was added in 1942; trickling filter, stabilization ponds, and irrigation upgrades were added in 1962; and RIBS and chemical treatment were added in 1976. The city of Detroit Lakes WWTF still discharges to St. Clair Lake today. Eighty acres of the lake was treated with alum in the fall of 1998 in order to suppress P release from the nutrient-enriched sediments (refer to Section 13.2 Existing Studies: St. Clair Alum Treatment for more information).

Aquatic recreation is the designated use for St. Clair Lake, which incorporates swimming, wading, aesthetics, and other related uses. Currently the lake is used primarily by waterfowl. The lake is subject to winterkill (loss of oxygen under ice cover) and is not supportive of permanent game fish populations. Also, there is no public access and algae blooms in the late summer discourage recreational use. Motor boat access is restricted to the Minnesota DNR and PRWD for data gathering purposes.

Worth noting is that the city of Detroit Lakes utilizes polyphosphates to treat drinking water. Monitoring of drinking water quality conducted by the Minnesota Department of Health in 2009-2010 indicated a median concentration of about 1.5 mg PO4/liter (or about 480 ug P/L) (MDH, 2012). Polyphosphate, as a dissolved form of P, is especially mobile in the environment and may be available for biological uptake, for example, by algae in the water column. Losses of polyphosphate treated drinking water via irrigation overspray/losses, car washing, street and driveway cleaning, fire hydrant flushing and pipe leakage can be funneled into the stormwater conveyance system. Polyphosphate enriched domestic water applied to residential and commercial lawn areas can enrich urban soils and may influence seasonal P loss rates. Hence, this may be a significant source of ortho P to lakes (Wilson and Olson, 2012).

## 13.2 Existing Studies

St. Clair Lake has been the focus of a few studies in the past two decades. It has also been included in studies for downstream lakes such as Lake Sallie and Lake Melissa. Summarized here are those more current studies found relevant and useful to this TMDL study.

*2012 - Total Phosphorus Water Quality Based Effluent Limit Analysis: City of Detroit Lakes WWTP to St. Clair Lake*

Federal law [40CFR 122.44(d)] restricts mass increases in pollutant loading upstream of impaired waters and requires that at all NPDES dischargers have a WQBEL if they have the reasonable potential to cause or contribute to downstream impaired waters. Triggered by this law, MPCA developed a WQBEL for the Detroit Lakes WWTF (Weiss 2012). The WQBEL analysis found that the Detroit Lakes WWTP contributes roughly 29% of the annual TP load to St. Clair Lake. Nonpoint sources account for roughly 65%. The analysis explored the combination of point and nonpoint source load reductions and recommends a WQBEL of 198 kg/yr (437 lb/yr) for the city of Detroit Lakes WWTP in order to meet the water quality target in St. Clair Lake. The WQBEL target is a mass loading, which is affected by concentration and flow. The facility could operate with up to the permitted 1 mg/L TP under very low flows; conversely, the facility could operate with very high flows if very low concentrations are achieved. The WQBEL Report conclusions alert the reader to the possibility that a future TMDL could require a WLA that is more restrictive than the recommended WQBEL, in which case, the new limit would be implemented during the next permit cycle following the completion of the TMDL study.

*2001 - St. Clair Alum Treatment: An Evaluation*

The PRWD evaluates the effects of the 1998 St. Clair Lake alum treatment (80 acres treated) (Hecock 2001). According to a study in 1984, St. Clair Lake is filled with a layer of sediments up to 16 feet thick, which are thought to have originated from historic partially-treated wastewater discharged into the lake by the city of Detroit Lakes. Low oxygen levels in the late winter and early spring (February through April) were found to correspond with high P levels as a result of P release from the sediments. Alum treatment was undertaken in 1998 to cap the sediments (suppress internal P loading) as one of many projects prescribed in a Clean Water Partnership Project for the restoration of downstream Lake Sallie. Specifics of the data collection and alum treatment are provided. Average TP concentrations in the discharge from St. Clair Lake decreased 58% (121 to 51 µg/L for the period from fall 1998 through 1999) pre- and post-alum treatment. TP in the discharge from St. Clair Lake no longer peaks in the late winter and has a reduced peak in the mid-summer. This study also documents an average sediment P concentration of 0.4 grams of P per kilogram sediment (dry weight).

*1998 - A Study of the Contribution of Groundwater to Phosphorous Loadings for Selected Lakes in the Pelican River Watershed*

Prepared for the PRWD, the groundwater model was used to carefully examine where infiltrated water at the Detroit Lakes Waste Water Treatment Facility goes to (p.1) (PRWD 1998). According to this study, groundwater P from RIBs and spray irrigation fields operated by the Detroit Lakes WWTF discharge naturally to Ditch 14, which discharges to St. Clair Lake. At the time of the report (1998), external P sources to St. Clair Lake were found to be from the following sources: 70% WWTF, 27% direct watershed runoff, 1.6% groundwater, 1.2% atmospheric deposition, 0.23% Long Lake discharge.

### 13.3 Effectiveness of Alum Treatment

The effectiveness of alum treatment in the fall of 1998 was evaluated using a weight-of-evidence approach. Findings are inconclusive, but they shed some light on the possible effectiveness of alum treatment. The following information was used:

- Historical annual P discharge from St. Clair Lake estimated based on monitored P loads in Ditch 14 immediately downstream of St. Clair Lake and, alternatively, in-lake P data with annual depths of runoff
- Annual WWTF loading based on monthly discharge monitoring reports
- Atmospheric deposition (average annual value as calculated for the overall P source assessment)
- Historical annual direct watershed load based on calibration of the Simple Method model for individual years and corresponding runoff (see in Section 3.5.2, *Direct Watershed Runoff* for Simple Method modeling methods)
- Historical annual Long Lake discharge based on annual in-lake concentrations and depths of runoff.
- Sediment P measurement (Hecock 2001) and internal loading regression equations (Nürnberg 1988)

In late 1998, substantial improvements in lake water quality occurred due to actions by the city of Detroit Lakes and by the PRWD. The Detroit Lakes WWTF made significant changes in their operations resulting in a ~44% reduction (or 933 lbs/year) in TP loading.  About this same time, the PRWD sponsored an alum (aluminum sulfate) treatment of St. Clair Lake. Alum is a common lake chemical treatment, also employed by many drinking water treatment facilities, that strips lake water P and forms a P-trapping layer along the lake sediments. Table 23 summarizes the WWTF P discharge reductions based on monthly permit required discharge monitoring reports.

There are several methods that can be employed to assess the success of alum treatments over time. However, given the nature of simultaneous reductions resulting from the Detroit Lakes WWTF upgrade and PRWD sponsored alum treatments; it is difficult to identify specific reductions for each effort as they mask each other's effectiveness. Nonetheless, it is clear that substantial reductions occurred as a result of the combined reduction strategies and present water quality continues to reflect these actions – they worked.

For present day conditions, the Nürnberg (1988) internal loading equation (based on sediment P (refer to *Internal Loading* in Section 3.5.2)) was used to estimate St. Clair Lake's internal P loading, Pre-alum treatment sediment had a measured P value of 0.4 g TP per kg, dry weight (Hecock 2001). Using this value, the Nurnberg equation estimates an internal loading rate of approximately 336 lb/yr, or 14% of the average overall P load to St. Clair Lake (1992 and 1998).

Internal recycling of sediment P can be increased in a positive loop manner, by excessive watershed P loading generating more algae that in turn deplete oxygen and cause liberation of sediment bound P (that produce more algae etc.) The opposite can also be true, in that reduced P loading from watershed sources can result in reduced internal loading over time. Hence, the primary lake management strategy is to reduce watershed loading.

The Nürnberg (1988) internal loading equation also illustrates how a reduction in water column TP results in suppressed internal loading. Assuming a hypothetical constant sediment TP value (0.4 g TP per kg, dry weight as measured in St. Clair Lake) and actual annual in-lake P concentrations – as the in-lake water quality improves, the internal loading goes down (Table 24). Reductions in internal loading can improve lake quality, but if in-lake P concentrations improve as a result of a significant reduction in external P loads, internal loading can be desirably affected (e.g. suppressed).

These analyses illustrate two important points, though inconclusive:

- The Detroit Lakes WWTF has a capacity to significantly affect the P loading to St. Clair Lake, and St. Clair Lake appears to have responded to WWTF operational changes in 1998/1999.
- The coincidence of the alum treatment and WWTF operational changes confounds (and precludes) analysis of the effectiveness of the 1998 alum treatment.

**Table 23. Historic Changes in WWTF Phosphorus Load to St. Clair Lake**

| Time Period | Average Annual WWTF Phosphorus Load (lb/yr) | Decrease in Phosphorus Discharge between Initial and Final Time Periods (lb/yr) | Percentage Decrease in Overall Phosphorus Load to St. Clair Lake due to WWTF Operational Changes (%) |
|---|---|---|---|
| 1995-1998 | 1,379 | 933 (68%) | 44% (933 of 2,137) |
| 1999-2006 | 446 | | |

**Table 24. Hypothetical Changes to Internal Loading in St. Clair Lake with a Constant Sediment Phosphorus Concentration**

| Time Period | Average Annual Internal Load with a Constant Sediment TP Concentration of 0.4 g TP per kg dry (lb/yr) | Decrease in Internal Load between Initial and Final Time Periods (lb/yr) | Percentage Decrease in Overall Phosphorus Load to St. Clair Lake due to WWTF Operational Changes (%) |
|---|---|---|---|
| 1992 & 1998 | 336 | 75 (22%) | 3.5% (75 of 2,137) |
| 1999-2006 | 260 | | |

# 14 APPENDIX E – AREA ANNEXATION SUMMARY

Downloaded from the State Records website on May 19, 2013:

http://www.mba.state.mn.us/Docket.html?County=Becker+County&Status=All&StartDate=&EndDate

| Docket Number | Project Name | Description | Acres | Status |
|---|---|---|---|---|
| A-7795 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 20.5 | •Filed: March 26, 2012<br>•Closed: June 20, 2012 |
| OA-349-1 | Detroit Lakes City / Detroit Township; Becker County | Orderly Annexation | 390 | •Filed: March 27, 1995<br>•Closed: April 7, 1995 |
| OA-410-1 | Detroit Lakes City / Detroit Township; Becker County | Orderly Annexation | 1.06 | •Filed: December 1, 1995<br>•Closed: January 5, 1996 |
| OA-637-1 | Audubon City / Audubon Township; Becker County | Orderly Annexation | 1.38 | •Filed: October 15, 1999<br>•Closed: November 5, 1999 |
| OA-926-1 | Detroit Lakes City / Detroit Township; Becker County | Orderly Annexation | 436 | •Filed: March 28, 2003<br>•Closed: June 16, 2003 |
| A-6552 | Detroit Lakes City / Detroit Township, Lake View Township; Becker County | Annexation by chief administrative law judge's Order | 664 | •Filed: September 13, 2001<br>•Closed: October 29, 2001 |
| A-6600 | Detroit Lakes City / Lake View Township, Detroit Township; Becker County | Annexation by chief administrative law judge's Order | 658.4 | •Filed: November 15, 2001<br>•Closed: June 16, 2003 |
| A-5507 | Frazee City / Burlington Township; Becker County | Annexation by Ordinance | 35.5 | •Filed: April 10, 1995<br>•Closed: May 12, 1995 |
| A-5578 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 41.51 | •Filed: September 18, 1995<br>•Closed: October 6, 1995 |
| A-5579 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 27 | •Filed: September 20, 1995<br>•Closed: October 6, 1995 |
| A-5594 | Audubon City / Audubon Township; Becker County | Annexation by Ordinance | 19.5 | •Filed: October 12, 1995<br>•Closed: November 3, 1995 |
| A-5882 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 3 | •Filed: December 5, 1997<br>•Closed: January 9, 1998 |
| A-5994 | Audubon City / Audubon Township; Becker County | Annexation by Ordinance | 0.84 | •Filed: July 30, 1998<br>•Closed: August 7, 1998 |
| A-6050 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 8.4 | •Filed: December 14, 1998<br>•Closed: May 20, 1999 |
| A-6051 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 15.1 | •Filed: December 14, 1998<br>•Closed: January 18, 2000 |
| A-6052 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 4.43 | •Filed: December 14, 1998<br>•Closed: January 18, 2000 |
| A-6053 | Detroit Lakes City / Detroit Township; | Annexation by Ordinance | 31.3 | •Filed: December 14, 1998 |

| | | | | |
|---|---|---|---|---|
| | Becker County | | | •Closed: January 18, 2000 |
| A-6114 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 40 | •Filed: June 17, 1999<br>•Closed: January 18, 2000 |
| A-6134 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 60 | •Filed: August 6, 1999<br>•Closed: September 3, 1999 |
| A-6183 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 13.36 | •Filed: November 1, 1999<br>•Closed: December 3, 1999 |
| A-6244 | Frazee City / Burlington Township; Becker County | Annexation by Ordinance | 2.22 | •Filed: February 23, 2000<br>•Closed: April 14, 2000 |
| A-6368 | Frazee City / Burlington Township; Becker County | Annexation by Ordinance | 40 | •Filed: September 12, 2000<br>•Closed: October 16, 2000 |
| A-6423 | Audubon City / Audubon Township; Becker County | Annexation by Ordinance | 2 | •Filed: January 24, 2001<br>•Closed: August 17, 2001 |
| A-6437 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 8.4 | •Filed: February 16, 2001<br>•Closed: March 16, 2001 |
| A-6438 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 17.3 | •Filed: February 16, 2001<br>•Closed: March 16, 2001 |
| A-6537 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 57 | •Filed: August 13, 2001<br>•Closed: September 14, 2001 |
| A-6538 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 50 | •Filed: August 13, 2001<br>•Closed: September 14, 2001 |
| A-6586 | Lake Park City / Lake Park Township; Becker County | Annexation by Ordinance | 26.17 | •Filed: October 18, 2001<br>•Closed: November 9, 2001 |
| A-6592 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 0.71 | •Filed: October 23, 2001<br>•Closed: November 9, 2001 |
| A-6774 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0.32 | •Filed: October 28, 2002<br>•Closed: November 21, 2002 |
| A-6775 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 0.407 | •Filed: October 28, 2002<br>•Closed: November 8, 2002 |
| A-6855 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 25 | •Filed: March 31, 2003<br>•Closed: April 10, 2003 |
| A-6897 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 13.2 | •Filed: June 9, 2003<br>•Closed: November 12, 2003 |
| A-6954 | Frazee City / Burlington Township; Becker County | Annexation by Ordinance | 18.5 | •Filed: September 15, 2003<br>•Closed: October 13, 2003 |
| A-7119 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 51.86 | •Filed: July 13, 2004<br>•Closed: August 12, 2004 |
| A-7142 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 10.5 | •Filed: August 16, 2004<br>•Closed: September 9, 2004 |
| A-7143 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 37.52 | •Filed: August 16, 2004<br>•Closed: September 9, 2004 |
| A-7186 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 19.24 | •Filed: October 11, 2004<br>•Closed: November 10, 2004 |
| A-7219 | Wolf Lake City / Wolf Lake Township; Becker County | Annexation by Ordinance | 74.14 | •Filed: January 3, 2005<br>•Closed: January 11, 2005 |
| A-7220 | Wolf Lake City / Wolf Lake Township; Becker County | Annexation by Ordinance | 15.23 | •Filed: January 3, 2005<br>•Closed: January 11, 2005 |
| A-7240 | Audubon City / Audubon Township; Becker County | Annexation by Ordinance | 12 | •Filed: January 31, 2005<br>•Closed: February 11, 2005 |
| OA-926-2 | Detroit Lakes City / Detroit Township; Becker County | Orderly Annexation | 126.4 | •Filed: March 7, 2005<br>•Closed: April 7, 2005 |
| OA-926-3 | Detroit Lakes City / Detroit Township; | Orderly Annexation | 54 | •Filed: March 14, 2005 |

| | | | | |
|---|---|---|---|---|
| | Becker County | | | •Closed: April 7, 2005 |
| OA-934-1 | Detroit Lakes City / Lake View Township; Becker County | Orderly Annexation | 10.79 | •Filed: March 7, 2005<br>•Closed: April 7, 2005 |
| OA-926-4 | Detroit Lakes City / Detroit Township; Becker County | Orderly Annexation | 27 | •Filed: April 25, 2005<br>•Closed: May 12, 2005 |
| A-7339 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 20.05 | •Filed: July 25, 2005<br>•Closed: August 10, 2005 |
| A-7368 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 4.27 | •Filed: October 17, 2005<br>•Closed: November 10, 2005 |
| A-7375 | Wolf Lake City / Wolf Lake Township; Becker County | Annexation by Ordinance | 2.27 | •Filed: October 27, 2005<br>•Closed: November 10, 2005 |
| A-7376 | Wolf Lake City / Wolf Lake Township; Becker County | Annexation by Ordinance | 0.5 | •Filed: October 27, 2005<br>•Closed: November 10, 2005 |
| A-7405 | Frazee City / Burlington Township; Becker County | Annexation by Ordinance | 28.13 | •Filed: February 10, 2006<br>•Closed: March 9, 2006 |
| A-7406 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 58 | •Filed: February 13, 2006<br>•Closed: March 9, 2006 |
| A-7435 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 35.73 | •Filed: May 22, 2006<br>•Closed: June 19, 2006 |
| A-7440 | Audubon City / Audubon Township; Becker County | Annexation by Ordinance | 2 | •Filed: June 2, 2006<br>•Closed: June 19, 2006 |
| A-7483 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 24.1 | •Filed: August 21, 2006<br>•Closed: January 16, 2007 |
| A-7492 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 1.4 | •Filed: October 19, 2006<br>•Closed: April 11, 2007 |
| A-7493 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 1.44 | •Filed: October 23, 2006<br>•Closed: November 16, 2006 |
| A-7494 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 141.74 | •Filed: October 23, 2006<br>•Closed: November 16, 2006 |
| OA-1337-1 | Detroit Lakes City / Detroit Township; Becker County | Orderly Annexation | 226.04 | •Filed: May 14, 2007<br>•Closed: June 14, 2007 |
| A-7585 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 49.81 | •Filed: October 1, 2007<br>•Closed: October 16, 2007 |
| A-7598 | Frazee City / Burlington Township; Becker County | Annexation by Ordinance | 28 | •Filed: December 17, 2007<br>•Closed: March 20, 2008 |
| OA-926-5 | Detroit Lakes City / Detroit Township; Becker County | Orderly Annexation | 167.6 | •Filed: June 16, 2008<br>•Closed: July 23, 2008 |
| OA-934-2 | Detroit Lakes City / Lake View Township; Becker County | Orderly Annexation | 17.21 | •Filed: June 17, 2008<br>•Closed: July 23, 2008 |
| A-7666 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 8.41 | •Filed: December 8, 2008<br>•Closed: December 18, 2008 |
| D-461 | Audubon City / Audubon Township; Becker County | Detachment | 10 | •Filed: January 16, 2009<br>•Closed: January 22, 2009 |
| A-7688 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 7.6 | •Filed: May 26, 2009<br>•Closed: June 18, 2009 |
| D-54 | Wolf Lake City / Spruce Grove Township; Becker County | Detachment | 0 | •Filed: March 12, 1965<br>•Closed: June 22, 1965 |
| A-3243 | Audubon City / Audubon Township; Becker County | Annexation by Ordinance | 31.58 | •Filed: October 13, 1977<br>•Closed: June 4, 1978 |
| A-4502 | Audubon City / Audubon Township; Becker County | Annexation by Ordinance | 0.51 | •Filed: June 30, 1988<br>•Closed: November 2, 1988 |
| A-5300 | Audubon City / Audubon Township; | Annexation by Ordinance | 2 | •Filed: March 25, 1994 |

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| | Becker County | | | •Closed: April 8, 1994 |
| OA-277-1 | Audubon City / Audubon Township; Becker County | Orderly Annexation | 14.25 | •Filed: November 19, 1992<br>•Closed: December 4, 1992 |
| OA-267-1 | Audubon City / Audubon Township; Becker County | Orderly Annexation | 2.87 | •Filed: July 21, 1992<br>•Closed: August 5, 1992 |
| OA-121-1 | Detroit Lakes City / Lake View Township; Becker County | Orderly Annexation | 122 | •Filed: July 14, 1976<br>•Closed: February 13, 1978 |
| A-754 | Becker County / Wolf Lake City; Becker County | Annexation by Ordinance | 0 | •Filed: January 20, 1965<br>•Closed: January 27, 1965 |
| A-4065 | Wolf Lake City / Spruce Grove Township; Becker County | Annexation by Ordinance | 2.84 | •Filed: November 29, 1983<br>•Closed: December 16, 1983 |
| A-5372 | Wolf Lake City / Wolf Lake Township; Becker County | Annexation by Ordinance | 41.75 | •Filed: June 20, 1994<br>•Closed: July 1, 1994 |
| A-72 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: December 9, 1959<br>•Closed: December 10, 1959 |
| A-117 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: May 12, 1960<br>•Closed: June 2, 1960 |
| A-237 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: May 16, 1961<br>•Closed: July 20, 1961 |
| A-653 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: June 8, 1964<br>•Closed: November 5, 1964 |
| A-709 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: October 30, 1964<br>•Closed: January 7, 1965 |
| A-900 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: November 5, 1965<br>•Closed: February 24, 1966 |
| A-1000 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: May 4, 1966<br>•Closed: June 9, 1966 |
| A-1476 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0 | •Filed: December 6, 1968<br>•Closed: June 26, 1969 |
| A-1633 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0 | •Filed: July 24, 1969<br>•Closed: February 13, 1970 |
| A-1665 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: August 29, 1969<br>•Closed: February 13, 1970 |
| A-1829 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: May 8, 1970<br>•Closed: October 7, 1970 |
| A-1910 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: October 13, 1970<br>•Closed: June 11, 1971 |
| A-1922 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: November 3, 1970<br>•Closed: June 11, 1971 |
| A-1951 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 24.94 | •Filed: January 12, 1971<br>•Closed: June 18, 1971 |
| A-2022 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 18.6 | •Filed: June 9, 1971<br>•Closed: December 10, 1971 |
| A-2123 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: December 16, 1971<br>•Closed: February 11, 1972 |
| A-2165 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: March 6, 1972<br>•Closed: August 11, 1972 |
| A-2183 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0 | •Filed: April 24, 1972<br>•Closed: July 14, 1972 |
| A-2231 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: July 27, 1972<br>•Closed: December 14, 1972 |
| A-2294 | Becker County / Detroit Lakes City; Becker | Annexation by Ordinance | 0 | •Filed: October 19, 1972 |

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| | County | | | •Closed: February 1, 1973 |
| A-2365 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0 | •Filed: March 7, 1973<br>•Closed: August 23, 1973 |
| A-2368 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0 | •Filed: March 14, 1973<br>•Closed: August 23, 1973 |
| A-2448 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0 | •Filed: July 12, 1973<br>•Closed: November 16, 1973 |
| A-2454 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0 | •Filed: July 17, 1973<br>•Closed: November 30, 1973 |
| A-2455 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: July 17, 1973<br>•Closed: November 16, 1973 |
| A-2486 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0 | •Filed: September 10, 1973<br>•Closed: November 16, 1973 |
| A-2583 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: March 18, 1974<br>•Closed: July 15, 1974 |
| A-2670 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 0 | •Filed: August 14, 1974<br>•Closed: February 21, 1975 |
| A-2749 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: January 24, 1975<br>•Closed: July 18, 1975 |
| A-2750 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: January 24, 1975<br>•Closed: July 18, 1975 |
| A-2805 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: July 7, 1975<br>•Closed: October 10, 1975 |
| A-2835 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 13.67 | •Filed: August 20, 1975<br>•Closed: March 18, 1976 |
| A-3197 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: August 1, 1977<br>•Closed: January 13, 1978 |
| A-3206 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: August 10, 1977<br>•Closed: January 13, 1978 |
| A-3223 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: September 12, 1977<br>•Closed: January 13, 1978 |
| A-3378 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: June 16, 1978<br>•Closed: January 12, 1979 |
| A-3491 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: February 15, 1979<br>•Closed: June 12, 1979 |
| A-3559 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: July 16, 1979<br>•Closed: January 4, 1980 |
| A-3560 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: July 16, 1979<br>•Closed: November 9, 1979 |
| A-3585 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 0 | •Filed: August 24, 1979<br>•Closed: March 8, 1982 |
| A-3609 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: August 24, 1979<br>•Closed: January 4, 1980 |
| A-3643 | Becker County / Detroit Lakes City; Becker County | Annexation by Ordinance | 0 | •Filed: December 13, 1979<br>•Closed: October 10, 1980 |
| A-4187 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 40.3 | •Filed: February 14, 1985<br>•Closed: October 11, 1985 |
| A-4218 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 70.2 | •Filed: May 15, 1985<br>•Closed: October 11, 1985 |
| A-4346 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 23 | •Filed: October 21, 1986<br>•Closed: February 5, 1987 |
| A-4608 | Detroit Lakes City / Lake View Township, | Annexation by chief administrative | 864 | •Filed: May 26, 1989 |

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| | Detroit Township; Becker County | law judge's Order | | •Closed: May 31, 1991 |
| A-4737 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 96.3 | •Filed: May 21, 1990<br>•Closed: July 2, 1990 |
| A-4758 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 9.3 | •Filed: August 13, 1990<br>•Closed: June 8, 1991 |
| A-4768 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 25.6 | •Filed: August 24, 1990<br>•Closed: September 5, 1990 |
| A-4769 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 1.1 | •Filed: August 24, 1990<br>•Closed: September 5, 1990 |
| A-4855 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 2.19 | •Filed: May 20, 1991<br>•Closed: June 10, 1991 |
| A-4917 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 350 | •Filed: November 13, 1991<br>•Closed: December 10, 1991 |
| A-4943 | Detroit Lakes City / Lake View Township, Detroit Township; Becker County | Annexation by Ordinance | 3000 | •Filed: March 18, 1992<br>•Closed: April 2, 1992 |
| A-5006 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 38 | •Filed: August 17, 1992<br>•Closed: February 2, 1993 |
| A-5089 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 186 | •Filed: March 12, 1993<br>•Closed: March 17, 1993 |
| A-5217 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 31.38 | •Filed: November 1, 1993<br>•Closed: November 8, 1993 |
| A-5244 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 36.78 | •Filed: December 13, 1993<br>•Closed: June 20, 1994 |
| A-5374 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 36.78 | •Filed: June 20, 1994<br>•Closed: July 1, 1994 |
| A-7732 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 86 | •Filed: July 22, 2010<br>•Closed: August 17, 2010 |
| A-2863 | Frazee City / Burlington Township; Becker County | Annexation by Ordinance | 0 | •Filed: October 9, 1975<br>•Closed: November 12, 1976 |
| A-2990 | Frazee City / Burlington Township; Becker County | Annexation by Ordinance | 0 | •Filed: August 3, 1976<br>•Closed: January 13, 1978 |
| A-7747 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 0.92 | •Filed: December 3, 2010<br>•Closed: December 14, 2010 |
| A-1473 | Lake Park City / Lake Park Township; Becker County | Annexation by Ordinance | 0 | •Filed: December 4, 1968<br>•Closed: August 8, 1969 |
| A-2072 | Lake Park City / Lake Park Township; Becker County | Annexation by Ordinance | 10 | •Filed: September 22, 1971<br>•Closed: July 14, 1972 |
| A-3751 | Lake Park City / Lake Park Township; Becker County | Annexation by Ordinance | 0 | •Filed: September 18, 1980<br>•Closed: February 11, 1982 |
| A-4463 | Lake Park City / Lake Park Township; Becker County | Annexation by Ordinance | 18 | •Filed: March 4, 1988<br>•Closed: April 19, 1988 |
| A-7808 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 2.3 | •Filed: May 21, 2012<br>•Closed: July 13, 2012 |
| A-7791 | Detroit Lakes City / Detroit Township; Becker County | Annexation by Ordinance | 12.95 | •Filed: March 14, 2012<br>•Closed: April 17, 2012 |
| OA-926-6 | Detroit Lakes City / Detroit Township; Becker County | Orderly Annexation | 129 | •Filed: October 15, 2012<br>•Closed: November 13, 2012 |
| A-7871 | Detroit Lakes City / Lake View Township; Becker County | Annexation by Ordinance | 7.51 | •Filed: December 18, 2013<br>•Closed: January 14, 2014 |
| A-7882 | Detroit Lakes City / Burlington Township; Becker County | Annexation by Ordinance | 52.7 | •Filed: April 3, 2014<br>•Closed: April 8, 2014 |