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### Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ac-ft/yr</td>
<td>acre feet per year</td>
</tr>
<tr>
<td>BMP</td>
<td>best management practice</td>
</tr>
<tr>
<td>CAFO</td>
<td>Concentrated Animal Feeding Operation</td>
</tr>
<tr>
<td>CAMP</td>
<td>Citizens Assisted Monitoring Program</td>
</tr>
<tr>
<td>CCWMO</td>
<td>Carver County Watershed Management Organization</td>
</tr>
<tr>
<td>Chl-a</td>
<td>chlorophyll-a</td>
</tr>
<tr>
<td>DNR</td>
<td>Minnesota Department of Natural Resources</td>
</tr>
<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>ft</td>
<td>feet</td>
</tr>
<tr>
<td>HSPF</td>
<td>Hydrologic Simulation Program-Fortran</td>
</tr>
<tr>
<td>km²</td>
<td>square kilometer</td>
</tr>
<tr>
<td>LA</td>
<td>load allocation</td>
</tr>
<tr>
<td>lb</td>
<td>pound</td>
</tr>
<tr>
<td>lb/day</td>
<td>pounds per day</td>
</tr>
<tr>
<td>lb/yr</td>
<td>pounds per year</td>
</tr>
<tr>
<td>m</td>
<td>meter</td>
</tr>
<tr>
<td>MCES</td>
<td>Metropolitan Council Environmental Services</td>
</tr>
<tr>
<td>mg/L</td>
<td>milligrams per liter</td>
</tr>
<tr>
<td>mg/m²-day</td>
<td>milligrams per square meter per day</td>
</tr>
<tr>
<td>MnDOT</td>
<td>Minnesota Department of Transportation</td>
</tr>
<tr>
<td>MOS</td>
<td>margin of safety</td>
</tr>
<tr>
<td>MPCA</td>
<td>Minnesota Pollution Control Agency</td>
</tr>
<tr>
<td>MS4</td>
<td>Municipal Separate Storm Sewer Systems</td>
</tr>
<tr>
<td>NCHF</td>
<td>North Central Hardwood Forest</td>
</tr>
<tr>
<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
</tr>
<tr>
<td>P</td>
<td>phosphorus</td>
</tr>
<tr>
<td>RC</td>
<td>reserve capacity</td>
</tr>
<tr>
<td>RO</td>
<td>reverse osmosis</td>
</tr>
<tr>
<td>SSTS</td>
<td>Subsurface Sewage Treatment System</td>
</tr>
<tr>
<td>SWPPP</td>
<td>Stormwater Pollution Prevention Plan</td>
</tr>
<tr>
<td>TMDL</td>
<td>total maximum daily load</td>
</tr>
<tr>
<td>TP</td>
<td>total phosphorus</td>
</tr>
<tr>
<td>µg/L</td>
<td>micrograms per liter</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>WLA</td>
<td>wasteload allocation</td>
</tr>
<tr>
<td>WMO</td>
<td>Watershed Management Organization</td>
</tr>
<tr>
<td>WRAPS</td>
<td>Watershed Restoration and Protection Strategy</td>
</tr>
</tbody>
</table>
Executive Summary

This total maximum daily load (TMDL) report is a part of a larger effort addressing impaired waters in the Lower Minnesota River Watershed. The focus of this report is on six impaired lakes in the western suburbs of the Twin Cities Metropolitan Area in Carver County. Water quality in all of these lakes is considered poor, with frequent algal blooms occurring. The goal of this report is to quantify the pollutant reductions needed to meet state water quality standards for nutrients, and spur action to address the impairment. This part of the metro area is experiencing moderate to high levels of development and there is increasing awareness of water quality issues by the public.

Gaystock Lake

Gaystock Lake (10-0031) is located west of the Twin Cities Metro, just south of the city limits of Victoria in the West Chaska Creek Watershed. The lake is not currently used for recreation beyond its aesthetic values, such as observing wildlife. The drainage area of the lake is 2,856 acres; roughly 76% is agricultural land and 5% being developed acreage.

Significant sources of phosphorus (P) appear to be from both internal loading and agricultural runoff. Also contributing to P loading is Aue Lake, which flows into Gaystock Lake. An overall P loading reduction of 88% is needed to meet state standards. Main emphases to reduce these loads includes landowner best management practices (BMPs), rough fish management, and in-lake P management.

Maria Lake

Maria Lake (10-0058) is located east of Gotha. The lake is not currently used for recreation beyond its aesthetic values, such as observing wildlife. The drainage area of the lake is 259 acres, excluding the lake, with roughly 77% of that as agricultural land.

A significant source of P appears to be from internal loading and a small load from the surrounding agricultural lands.

An overall P loading reduction of 85% is needed to meet state standards. Main emphases to reduce these loads includes landowner BMPs, rough fish management, and in-lake P management.

Grace Chain of Lakes

The Grace Chain of Lakes are located in the East Chaska Creek Watershed of Carver County in primarily urban landscapes. The lakes included are Hazeltine (10-0014), McKnight (10-0216), Unnamed (Grace) (10-0218), and Jonathan Lake (10-0217). Except for Lake Grace, which is used for fishing and swimming, these lakes are not currently used for recreation beyond their aesthetic values, such as observing wildlife. The entire East Chaska Creek Watershed area is 6,559 acres; roughly 38% is identified as “natural” and 28% being developed acreage.

P loading sources for the lakes include upstream lake loading, internal loading, and watershed runoff.

Overall needed P loading reductions range from 67% to 91% to meet state standards. Main emphases to reduce these loads includes landowner BMPs, rough fish management, and urban stormwater management.
1. Project Overview

1.1 Purpose

This TMDL study addresses nutrient impairments in six Carver County lakes. The goal of this TMDL is to provide wasteload allocations (WLAs) and load allocations (LAs) to sources, and quantify the pollutant reductions needed to meet the state water quality standards for nutrients in the lakes of Gaystock, Maria, Hazeltine, McKnight, Jonathan, and Grace. These nutrient TMDLs are being established in accordance with section 303(d) of the Clean Water Act.

1.2 Identification of Waterbodies

The lakes for this project are provided in Table 1.1, which includes the year each lake was added to the state of Minnesota 303(d) list of impaired waters. All lakes are impaired by excess nutrients, which inhibit the beneficial use of aquatic recreation, and are class 2B, 3C, 4A, 4B, 5, and 6 waters.

Table 1.1 Impaired waters (lakes) addressed in this project.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Lake ID</th>
<th>Year Added to 303(d) List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaystock</td>
<td>10-0031</td>
<td>2004</td>
</tr>
<tr>
<td>Maria</td>
<td>10-0058</td>
<td>2004</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>10-0014</td>
<td>2004</td>
</tr>
<tr>
<td>McKnight</td>
<td>10-0216</td>
<td>2014</td>
</tr>
<tr>
<td>Jonathan</td>
<td>10-0217</td>
<td>2014</td>
</tr>
<tr>
<td>Unnamed (Grace)</td>
<td>10-0218</td>
<td>2006</td>
</tr>
</tbody>
</table>

Two non-assessed lakes and one lake that is not listed as having impaired aquatic recreation are included in this project because their outflows directly enter an impaired lake (Table 1.2).

Table 1.2 Non-assessed and non-impaired lakes included in this project.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Lake ID</th>
<th>Eutrophication Assessment Status</th>
<th>Reason for Inclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>10-0028</td>
<td>Not assessed</td>
<td>Provides upstream boundary condition for Gaystock Lake.</td>
</tr>
<tr>
<td>Big Woods</td>
<td>10-0249</td>
<td>Not assessed</td>
<td>Grace chain intermediate lake between Hazeltine and McKnight lakes</td>
</tr>
<tr>
<td>Bavaria</td>
<td>10-0019</td>
<td>Non-impaired</td>
<td>Provides upstream boundary condition for McKnight Lake.</td>
</tr>
</tbody>
</table>

1.3 Priority Ranking

The Minnesota Pollution Control Agency (MPCA’s) schedule for TMDL completions, as indicated on Minnesota’s Section 303(d) impaired waters list, reflects Minnesota’s priority ranking of this TMDL. The MPCA has aligned TMDL priorities with the watershed approach and the Watershed Restoration and Protection Strategy (WRAPS) cycle. The schedule for TMDL completion corresponds to the WRAPS report completion on the 10-year cycle. The MPCA developed a state plan, Minnesota’s TMDL Priority Framework Report, to meet the needs of U.S. Environmental Protection Agency (EPA’s) national measure (WQ-27) under EPA’s Long-Term Vision for Assessment, Restoration and Protection under the Clean Water Act Section 303(d) Program. As part of these efforts, the MPCA identified water quality impaired segments that will be addressed by TMDLs by 2022. The Carver Six Lakes Watershed lakes addressed by this TMDL are part of that MPCA prioritization plan to meet EPA’s national measure.
2. **Applicable Water Quality Standards and Numeric Water Quality Targets**

For aquatic recreation uses, water quality in Minnesota lakes is evaluated using three parameters: total phosphorus (TP), chlorophyll-α (Chl-α), and Secchi depth. P is typically the limiting nutrient in Minnesota lakes, meaning that algal growth will increase with increased P. Chl-α is the primary pigment in aquatic algae and has been shown to have a direct correlation with algal biomass. Secchi depth is a physical measurement of water clarity taken by lowering a white or black-and-white disk until it can no longer be seen from the surface, then noting the depth where this occurs. Greater Secchi depths indicate less light-refracting particulates in the water column and better water quality; conversely, high TP, and Chl-α concentrations point to poor water quality.

The protected beneficial use for all lakes is aquatic recreation, including body-contact activities such as swimming. Minnesota’s lake water quality standards vary primarily by ecoregion, and secondarily by lake depth. Carver County is entirely within the North Central Hardwood Forest (NCHF) ecoregion. All six impaired lakes are categorized as shallow. Gaystock and Grace have maximum depths greater than 15 feet; however, their littoral areas are greater than 80%. The standards define a “shallow” lake as one that has either a maximum depth less than 15 feet or a littoral area greater than 80% of the lake’s total area. The “littoral” area is defined in practice as the portion of the lake that is shallower than 15 feet. Therefore, the standards that apply to these impaired lakes are the NCHF shallow-lake standards.

Two of the upstream and intermediate lakes in this study are deep, Aue, and Bavaria. The third lake, Big Woods, is shallow.

Inherent in the numerical water quality goals for shallow lakes are desired ecological endpoints. Carver County’s management strategies are focused on these endpoints, which are restoring the lakes to a diverse, native aquatic plant (macrophyte) dominated state across much of the lake. This type of lake is characterized by low rough fish populations, clearer water, higher wildlife values and positive feedback mechanisms that maintain the lake in this condition (Scheffer 1998).

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

<table>
<thead>
<tr>
<th>Lake depth category</th>
<th>TP concentration (µg/L)</th>
<th>Chl-α conc. (µg/L)</th>
<th>Minimum Secchi depth (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep</td>
<td>40</td>
<td>14</td>
<td>1.4</td>
</tr>
<tr>
<td>Shallow</td>
<td>60</td>
<td>20</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Note**: Values are summer averages (June 1 through September 30).

This TMDL has been established with the intent to implement all the appropriate activities that are not considered greater than extraordinary efforts. However, meeting the existing lake standards will require...
aggressive action given the current state of these lakes. If all appropriate BMPs and activities are implemented and the lakes still do not meet their goals, Carver County staff has indicated they will reevaluate the TMDLs and work with the MPCA to decide whether more appropriate site-specific standards for these lakes could be pursued and developed.
3. Watershed and Waterbody Characterization

3.1 Lakes

The lakes in this study are small, with areas from 20 to 168 acres. The six impaired lakes are also shallow (average depths from 1.5 to 10 feet). Big Woods Lake, intermediate between Hazeltine and McKnight lakes in the Grace Chain of Lakes, is shallow as well. The upstream lakes, Aue and Bavaria; however, are both deep. See Table 3.1 for morphometric details on all the lakes.

Table 3.1 Lake morphology

<table>
<thead>
<tr>
<th>Lake</th>
<th>Surface Area (ac)</th>
<th>Avg Depth (ft)</th>
<th>Max Depth (ft)</th>
<th>Volume (ac-ft)</th>
<th>Littoral Area (ac)</th>
<th>Res. Time (All approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>34</td>
<td>13.9</td>
<td>27</td>
<td>477</td>
<td>24</td>
<td>3 yr</td>
</tr>
<tr>
<td>Gaystock</td>
<td>46</td>
<td>6.9</td>
<td>18</td>
<td>317</td>
<td>42 est.</td>
<td>12 weeks</td>
</tr>
<tr>
<td>Maria</td>
<td>168</td>
<td>3.5</td>
<td>Approx. 4</td>
<td>590</td>
<td>168</td>
<td>5 yr</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>161</td>
<td>3.63</td>
<td>7</td>
<td>584</td>
<td>161</td>
<td>9 months</td>
</tr>
<tr>
<td>Big Woods</td>
<td>32</td>
<td>1.6</td>
<td>--</td>
<td>53</td>
<td>32 est.</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Bavaria</td>
<td>166</td>
<td>17.6</td>
<td>60</td>
<td>2,920</td>
<td>--</td>
<td>6 yr</td>
</tr>
<tr>
<td>McKnight</td>
<td>23</td>
<td>Approx. 3</td>
<td>14</td>
<td>Approx. 69</td>
<td>23</td>
<td>1 week</td>
</tr>
<tr>
<td>Jonathan</td>
<td>23</td>
<td>1.5</td>
<td>Approx. 4</td>
<td>35</td>
<td>23</td>
<td>4 days</td>
</tr>
<tr>
<td>Grace</td>
<td>20</td>
<td>10.0</td>
<td>22</td>
<td>199</td>
<td>18 est.</td>
<td>3 weeks</td>
</tr>
</tbody>
</table>

For map views of the lakes, including lake sampling points, see Figures 3.1 – 3.6. Big Woods is the horseshoe-shaped lake in Figures 3.3 – 3.6 between Hazeltine and McKnight lakes. Lake Bavaria is one mile west of McKnight Lake and is similar in size and shape to Hazeltine (Figures 3.4 – 3.6). There are no tribal lands within the lakesheds of the six lakes.
Figure 3.1 Gaystock Lake lakeshed, upstream lakeshed, and sample points.

Figure 3.2 Maria Lake Lakeshed and sample points
Figure 3.3 Hazeltine Lake lakeshed and sample points

Figure 3.4 McKnight Lake lakeshed, upstream lakesheds, and sample points
Figure 3.5 Jonathan Lake lakeshed, upstream lakesheds, and sample points

Figure 3.6 Lake Grace lakeshed, upstream lakesheds, and sample points
3.2 Subwatersheds

The watersheds of three Minnesota River tributaries contain all of the lakes in this study. In the northeast part of Carver County, the East Chaska Creek Watershed consists of the Grace Chain (Hazeltine – Big Woods – McKnight – Jonathan – Grace, plus Lake Bavaria, an off-chain tributary to McKnight Lake).

In the western and southwestern portions of the county, respectively, the West Chaska Creek Watershed contains Gaystock Lake and its tributary Aue Lake; the Bevens Creek Watershed contains Maria Lake.

In this TMDL, the specific subwatersheds of interest correspond to the study lakes’ lakesheds. A lakeshed is the portion of a lake’s whole watershed that excludes significant upstream lakes and their watersheds (see again Figures 3.1 through 3.6 above). The lakeshed for each study lake in this TMDL also excludes the area of the study lake itself. Lakesheds that are notably large relative to the lake’s area are those of Gaystock Lake (Figure 3.1) and McKnight (Figure 3.4).

3.3 Land Use, Runoff, and Lakeshed Loads

Lakeshed land use data (Table 3.2) were derived from the Metropolitan Council’s “Generalized Land Use 2005 for the Twin Cities Metropolitan Area”. Land use is displayed graphically in Figures 3.7 through 3.12. The 2005 land use data serve for both baseline years 2001 (westerly lakes) and 2009 (easterly lakes). Land use is predominantly agricultural in the westerly lakesheds (Aue, Gaystock, and Maria) and developed in the easterly lakesheds of the Grace Chain (Table 3.2). “Human-altered landscapes”, defined as the sum of agriculture plus developed land use, account for approximately 40% to 80% of all lakesheds in this study and represent 66% as an overall, area-weighted average. Based on a study of 1,330 Minnesota lakes that included TP sampling and lakeshed land use analysis, Minnesota Department of Natural Resources (DNR) researchers Cross and Jacobson (2013) found “a critical benchmark of anthropogenic land use disturbance at 40%, that once exceeded could significantly alter TP levels” and fish populations. Thus, it is especially significant that human-altered landscapes exceed 40% of all the study lakesheds.
<table>
<thead>
<tr>
<th>Lake</th>
<th>Agriculture</th>
<th>Developed</th>
<th>Natural</th>
<th>Wetland</th>
<th>Water*</th>
<th>Lakeshed Total*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>191</td>
<td>18</td>
<td>178</td>
<td>33</td>
<td>19</td>
<td>439</td>
</tr>
<tr>
<td>Gaystock</td>
<td>2,153</td>
<td>131</td>
<td>339</td>
<td>217</td>
<td>16</td>
<td>2,856</td>
</tr>
<tr>
<td>Maria</td>
<td>200</td>
<td>13</td>
<td>30</td>
<td>15</td>
<td>0.4</td>
<td>259</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>31</td>
<td>463</td>
<td>106</td>
<td>159</td>
<td>14</td>
<td>773</td>
</tr>
<tr>
<td>Big Woods</td>
<td>69</td>
<td>150</td>
<td>215</td>
<td>52</td>
<td>0.8</td>
<td>486</td>
</tr>
<tr>
<td>Bavaria</td>
<td>210</td>
<td>238</td>
<td>73</td>
<td>68</td>
<td>9</td>
<td>599</td>
</tr>
<tr>
<td>McKnight</td>
<td>477</td>
<td>180</td>
<td>656</td>
<td>147</td>
<td>17</td>
<td>1,477</td>
</tr>
<tr>
<td>Jonathan</td>
<td>47</td>
<td>148</td>
<td>70</td>
<td>9</td>
<td>1.3</td>
<td>274</td>
</tr>
<tr>
<td>Grace</td>
<td>0.0</td>
<td>71</td>
<td>16</td>
<td>2</td>
<td>0.4</td>
<td>89</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lake</th>
<th>Agriculture</th>
<th>Developed</th>
<th>Natural</th>
<th>Wetland</th>
<th>Water*</th>
<th>Lakeshed Total*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>43%</td>
<td>4%</td>
<td>41%</td>
<td>7%</td>
<td>4%</td>
<td>100%</td>
</tr>
<tr>
<td>Gaystock</td>
<td>75%</td>
<td>5%</td>
<td>12%</td>
<td>8%</td>
<td>1%</td>
<td>100%</td>
</tr>
<tr>
<td>Maria</td>
<td>77%</td>
<td>5%</td>
<td>12%</td>
<td>6%</td>
<td>0.2%</td>
<td>100%</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>4%</td>
<td>60%</td>
<td>14%</td>
<td>21%</td>
<td>2%</td>
<td>100%</td>
</tr>
<tr>
<td>Big Woods</td>
<td>14%</td>
<td>31%</td>
<td>44%</td>
<td>11%</td>
<td>0.2%</td>
<td>100%</td>
</tr>
<tr>
<td>Bavaria</td>
<td>35%</td>
<td>40%</td>
<td>12%</td>
<td>11%</td>
<td>1%</td>
<td>100%</td>
</tr>
<tr>
<td>McKnight</td>
<td>32%</td>
<td>12%</td>
<td>44%</td>
<td>10%</td>
<td>1%</td>
<td>100%</td>
</tr>
<tr>
<td>Jonathan</td>
<td>17%</td>
<td>54%</td>
<td>25%</td>
<td>3%</td>
<td>0.5%</td>
<td>100%</td>
</tr>
<tr>
<td>Grace</td>
<td>0.0%</td>
<td>79%</td>
<td>18%</td>
<td>2%</td>
<td>0.5%</td>
<td>100%</td>
</tr>
</tbody>
</table>

‡ Land use data are for 2005 and serve for both base-line years 2001 (westerly lakes) and 2009 (easterly lakes).
* Water area and total area exclude the area of the study lake itself. Land use totals may not tally exactly due to rounding.
Figure 3.7 Gaystock Lake Watershed 2005 land use map
Figure 3.8 Maria Lake Watershed 2005 land use
Figure 3.9 Hazeltine Lake Watershed 2005 land use map
Figure 3.10 McKnight Lake Watershed 2005 land use map

Figure 3.11 Jonathan Lake Watershed 2005 land use map
The depth of precipitation on a watershed is the primary determinant of the depth of runoff the watershed produces. However, the ratio of runoff depth to precipitation depth, or runoff coefficient, largely depends on the watershed’s land use. Carver County developed annual runoff coefficients for West Chaska, Bevens, and East Chaska Creek watersheds that were applied to the lakes in these watersheds for this TMDL. To develop the runoff coefficients, a set of literature values (Ward and Elliot 1995) – with assumed average watershed slopes of less than 2% for Gaystock and Maria lakes and 2% to 6% for the Grace Chain – were applied initially, and then adjusted for the best match to continuous flow records near each creek’s mouth.

The resulting runoff coefficients for land areas were consistently around 0.25 for agricultural land but varied significantly for developed and natural (forest/grassland) land uses (Table 3.3). East Chaska Creek, the most easterly of these watersheds – and the one with the least agriculture and most developed land – had the highest runoff coefficients. Table 3.3 omits the wetland and water land uses because runoff from those land uses was estimated as zero since precipitation and evaporation are approximately equal in this region. The nine study lakes are exceptions, as their models (see Section 4) account for precipitation and evaporation separately and explicitly.

### Table 3.3 Runoff coefficients by watershed and land use

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Lakes</th>
<th>Runoff Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agriculture</td>
<td>Developed</td>
</tr>
<tr>
<td>West Chaska Creek</td>
<td>Gaystock-Aue</td>
<td>0.22</td>
</tr>
<tr>
<td>Bevens Creek</td>
<td>Maria</td>
<td>0.25</td>
</tr>
<tr>
<td>East Chaska Creek</td>
<td>Grace chain</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Note:** Continuous flow record stations used in calibration – West Chaska Creek, CH 1.0 (county station), ~ 1 mile upstream from Minnesota River confluence; – Bevens Creek, BE 2 (MCES WOMP station), ~ 2 miles upstream from confluence; and – East Chaska Creek, EC 2 (county station), ~ 3 miles upstream.
Precipitation for the TMDL baseline years yielded runoff depths ranging from approximately 2 to 8 inches per year for land uses in the 2 westerly watersheds, and approximately 7 to 15 inches per year for land uses in East Chaska Creek Watershed (Table 3.4).

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Lakes</th>
<th>TMDL Baseline Year</th>
<th>Precipitation (inches/yr)</th>
<th>Runoff depth (inches/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Chaska Creek</td>
<td>Gaystock-Aue</td>
<td>2001</td>
<td>29.11</td>
<td>Agriculture: 6.40, Developed: 4.37, Natural: 2.04</td>
</tr>
<tr>
<td>Bevens Creek</td>
<td>Maria</td>
<td>2001</td>
<td>29.11</td>
<td>Agriculture: 7.28, Developed: 8.44, Natural: 2.04</td>
</tr>
<tr>
<td>East Chaska Creek</td>
<td>Grace chain</td>
<td>2009</td>
<td>31.56</td>
<td>Agriculture: 7.89, Developed: 15.46, Natural: 7.26</td>
</tr>
</tbody>
</table>

Runoff averaged over each lakeshed amounted to approximately 4 to 6 inches per year for lakes in the 2 westerly watersheds, and approximately 8 to 14 inches per year for the easterly lakes (Table 3.5).

<table>
<thead>
<tr>
<th>Lake</th>
<th>Agriculture (ac-ft/yr)</th>
<th>Developed (ac-ft/yr)</th>
<th>Natural (ac-ft/yr)</th>
<th>Lakeshed Total Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>102</td>
<td>7</td>
<td>30</td>
<td>Volume (ac-ft/yr): 139, Depth (inches/yr): 3.79</td>
</tr>
<tr>
<td>Gaystock</td>
<td>1,149</td>
<td>48</td>
<td>58</td>
<td>Volume (ac-ft/yr): 1,254, Depth (inches/yr): 5.27</td>
</tr>
<tr>
<td>Maria</td>
<td>121</td>
<td>9</td>
<td>5</td>
<td>Volume (ac-ft/yr): 136, Depth (inches/yr): 6.29</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>20</td>
<td>597</td>
<td>64</td>
<td>Volume (ac-ft/yr): 681, Depth (inches/yr): 10.58</td>
</tr>
<tr>
<td>Big Woods</td>
<td>45</td>
<td>193</td>
<td>130</td>
<td>Volume (ac-ft/yr): 368, Depth (inches/yr): 9.09</td>
</tr>
<tr>
<td>McKnight</td>
<td>314</td>
<td>232</td>
<td>397</td>
<td>Volume (ac-ft/yr): 942, Depth (inches/yr): 7.65</td>
</tr>
<tr>
<td>Jonathan</td>
<td>31</td>
<td>190</td>
<td>42</td>
<td>Volume (ac-ft/yr): 263, Depth (inches/yr): 11.50</td>
</tr>
<tr>
<td>Grace</td>
<td>0</td>
<td>91</td>
<td>10</td>
<td>Volume (ac-ft/yr): 101, Depth (inches/yr): 13.54</td>
</tr>
</tbody>
</table>

The P export – i.e., the P loading rate per unit area from a lakeshed or watershed – varies substantially with land use. For natural land areas such as forest or grassland, P export generally is around 0.10 lb/ac-yr or lower, whereas agricultural and urban landscapes typically export around 0.5 to 1.0 lb/ac-yr. The P export values used in this TMDL (Table 3.6) were developed as follows:

- **Agriculture:** Agricultural P export was derived in two steps. First, P export not including drain-tile contributions (Barr 2004; Table 8, Appendix C – Cropland and Pasture Runoff) for the Minnesota River and Lower Mississippi were averaged, yielding a no-drain tile P export of 0.535 lb/ac-yr (with units converted). The Lower Mississippi was included to reflect the lakesheds' extreme easterly location within the Minnesota basin. The second step was to divide the first value by the 0.6 (derived from King et al. 2014) to account for drain tile contributions, the resulting tile-inclusive (final) P export value being 0.892 lb/ac-yr.

- **Developed:** Runoff P export for developed, or urban, land use was estimated as 0.834 lb/ac-yr, based on a recent and extremely detailed mass balance analysis for a number of urban watersheds in St. Paul (Hobbie et al. 2017). Runoff P exports for seven watersheds within the Capitol Region Watershed District ranged up to 1.15 lb/ac-yr (Hobbie et al. 2017; Table S3, Supplemental Material). For this TMDL, two of these watersheds were excluded: one whose data were not independent (main-stem location downstream from two monitored branch locations), and one that had extremely low P export (about half the mean of all data) and was
known to have large-impact infiltration BMPs. The adopted export value is the area-weighted mean for the five remaining watersheds. The median export for these five watersheds (0.830 lb/ac-yr) was approximately the same as their area-weighted mean.

- **Natural**: The adopted P export value was 0.114 lb/ac-yr, the overall average for grassland, shrubland, and all forest types in the Minnesota River Basin (including both Level III Aggregate Ecoregions: Mostly Glaciated Dairy Region, and Corn Belt and Northern Great Plains) from Barr (2004; Table 8, Appendix I – Non-Agricultural Rural Runoff).

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Lake</th>
<th>Phosphorus export, lb/ac-yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>All</td>
<td>Agriculture Developed Natural</td>
</tr>
<tr>
<td>All</td>
<td>All</td>
<td>0.892 0.834 0.114</td>
</tr>
</tbody>
</table>

Wetlands and open water areas (excluding the study lakes) were assumed to yield zero P export. This is consistent with the earlier assumption of zero runoff and is equivalent to assuming that these areas retain their direct atmospheric P loads.

Lakeshed runoff P loads (Table 3.7) were estimated by multiplying the above P export values by the corresponding land use areas in Table 3.2. Total loads ranged from 26 pounds per year (lb/yr) (Lake Grace) to 1,019 lb/yr (Gaystock). Average lakeshed P export ranged from 0.19 lb/ac-yr (Big Woods) to 0.37 lb/ac-yr (Maria). Calculations of average export used the whole lakeshed area, which excludes the study lake but includes all other wetlands and waterbodies.

### Table 3.7 Baseline-year lakeshed runoff P loads

<table>
<thead>
<tr>
<th>Lake</th>
<th>Agriculture (lb/yr)</th>
<th>Developed (lb/yr)</th>
<th>Natural (lb/yr)</th>
<th>Total (lb/yr)</th>
<th>Overall Export (lb/ac-yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>170</td>
<td>15</td>
<td>20</td>
<td>205</td>
<td>0.47</td>
</tr>
<tr>
<td>Gaystock</td>
<td>1,920</td>
<td>109</td>
<td>39</td>
<td>2,068</td>
<td>0.72</td>
</tr>
<tr>
<td>Maria</td>
<td>179</td>
<td>11</td>
<td>3</td>
<td>193</td>
<td>0.74</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>28</td>
<td>386</td>
<td>12</td>
<td>426</td>
<td>0.55</td>
</tr>
<tr>
<td>Big Woods</td>
<td>61</td>
<td>125</td>
<td>24</td>
<td>211</td>
<td>0.43</td>
</tr>
<tr>
<td>Bavaria</td>
<td>188</td>
<td>198</td>
<td>8</td>
<td>394</td>
<td>0.66</td>
</tr>
<tr>
<td>McKnight</td>
<td>425</td>
<td>150</td>
<td>75</td>
<td>650</td>
<td>0.44</td>
</tr>
<tr>
<td>Jonathan</td>
<td>42</td>
<td>123</td>
<td>8</td>
<td>173</td>
<td>0.63</td>
</tr>
<tr>
<td>Grace</td>
<td>0</td>
<td>59</td>
<td>2</td>
<td>61</td>
<td>0.68</td>
</tr>
</tbody>
</table>

### 3.4 Current/Historical Water Quality

Carver County set up a network of lake and stream monitoring sites in the 1990s to assess water quality and observe trends. The county coordinates its sampling with the Metropolitan Council Environmental Services (MCES) and the MCES’s Citizens Assisted Monitoring Program (CAMP) program. Carver County follows the methods set up by MCES for the CAMP program, which for lakes entails bi-weekly sampling from April to October for TP, Chl-α, and total Kjeldahl nitrogen, as well as field measurements of Secchi depth. The six impaired lakes each have four to six years of summer-season (June through September) monitoring records (see Appendix A).
For the six lakes in their TMDL baseline years, summer-average TP concentrations exceeded the 60 micrograms per liter (µg/L) shallow-lake standard by factors ranging from two to five (Table 3.8). Lake Bavaria, not one of the impaired lakes but upstream from McKnight Lake, met its applicable deep-lake standard of 40 µg/L in McKnight’s baseline year.

Table 3.8 Summer (June-September) mean lake water quality for TMDL baseline years

<table>
<thead>
<tr>
<th>Lake</th>
<th>TMDL Baseline Year</th>
<th>Total Phosphorus (µg/L)</th>
<th>Chl-α (µg/L)</th>
<th>Secchi disk (m)</th>
<th>Number of TP Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue*</td>
<td>2001</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Gaystock</td>
<td>2001</td>
<td>320</td>
<td>98</td>
<td>0.70</td>
<td>9</td>
</tr>
<tr>
<td>Maria</td>
<td>2001</td>
<td>188</td>
<td>36</td>
<td>0.78</td>
<td>8</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>2009</td>
<td>296</td>
<td>328</td>
<td>0.20</td>
<td>9</td>
</tr>
<tr>
<td>Big Woods*</td>
<td>2009</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Bavaria†</td>
<td>2009</td>
<td>39.6</td>
<td>11</td>
<td>1.95</td>
<td>10</td>
</tr>
<tr>
<td>McKnight</td>
<td>2009</td>
<td>231</td>
<td>115</td>
<td>0.30</td>
<td>8</td>
</tr>
<tr>
<td>Jonathan</td>
<td>2009</td>
<td>202</td>
<td>104</td>
<td>0.30</td>
<td>9</td>
</tr>
<tr>
<td>Grace</td>
<td>2009</td>
<td>118</td>
<td>67</td>
<td>0.60</td>
<td>9</td>
</tr>
</tbody>
</table>

* No monitoring data available for downstream lake’s (McKnight’s) baseline year.
† Lake Bavaria is non-impaired; base year shown is for downstream lake (McKnight). Bavaria Chl-α results were not corrected for phaeophytin and may thus be overestimated.

3.5 Phosphorus Source Summary

P enters the Carver lakes from regulated sources, such as industrial and community wastewater, and nonregulated sources, including precipitation and internal loading. Watershed runoff also contributes substantial P; this source is divided into a portion from regulated Municipal Separate Storm Sewer Systems (MS4s) as well as construction stormwater and industrial stormwater, and the remainder, which is not regulated. The mechanism for regulating wastewater and stormwater discharges is the National Pollutant Discharge Elimination System (NPDES), which has permitting and permit enforcement provisions under the Clean Water Act.

3.5.1 Permitted

Five wastewater sources discharged into waters immediately upstream of the Carver lakes (Table 3.9) in the lakes’ baseline years. Three of these directly enter the impaired lakes Gaystock and Hazeltine, whereas the other two enter the Grace-chain intermediate Big Woods Lake.

The Laketown community wastewater treatment plant (Laketown CWWTP) serves a residential cluster located two miles northwest of the city of Carver and discharges to a small tributary of Gaystock Lake. Apex International Manufacturing (Apex) discharges a mix of reverse osmosis (RO) reject water and noncontact cooling water into a wetland north of, and draining into, Hazeltine Lake. McLaughlin Gormley King Company (MGK) has a total of four noncontact cooling and blowdown water discharges that enter a wetland roughly a half mile north of Hazeltine Lake that also drains into that lake.

TEL FSI Inc. is located about a quarter mile north of Big Woods Lake and formerly discharged a mixture of RO reject water and stormwater into a small tributary of that lake. TEL FSI Inc. ceased discharging to Big Woods Lake on November 14, 2017, at which time its wastewater was rerouted to the sanitary
sewer. LifeCore Biomedical LLC (LifeCore Bio) is located close by and discharges into the same tributary stream. LifeCore Bio’s discharge is a mix of RO reject water and vapor-compressor-still flush water.

### Table 3.9 Wastewater sources

<table>
<thead>
<tr>
<th>Discharge</th>
<th>NPDES Permit</th>
<th>Receiving Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laketown community wastewater treatment plant</td>
<td>MN0054399</td>
<td>Gaystock</td>
</tr>
<tr>
<td>Apex International Manufacturing (Apex)</td>
<td>MN0067016</td>
<td>Hazeltine</td>
</tr>
<tr>
<td>McLaughlin Gormley King Company (MGK)</td>
<td>MN0058033</td>
<td>Hazeltine</td>
</tr>
<tr>
<td>TEL FSI Inc</td>
<td>MN0068781</td>
<td>Big Woods</td>
</tr>
<tr>
<td>LifeCore Biomedical LLC (LifeCore Bio)</td>
<td>MN0060747</td>
<td>Big Woods</td>
</tr>
</tbody>
</table>

In addition to the wastewater sources, six MS4s discharge to one or more of the impaired lakes (Table 3.10). The MS4s include: the three cities of Chanhassen, Chaska, and Victoria; Laketown Township; and two transportation authorities, Carver County and Minnesota Department of Transportation (MnDOT)/Metro District. Runoff from urban areas contains P in the form of organic remains (primarily leaves, seeds, grass clippings, and other organic debris), lawn and garden fertilizer (where not P-restricted), and eroded soil particles, as well as atmospheric dry deposition and precipitation. TP concentrations of around 300 µg/L or higher typify urban runoff.

### Table 3.10 Regulated MS4s

<table>
<thead>
<tr>
<th>MS4</th>
<th>Permit Number</th>
<th>Impacted lakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carver County</td>
<td>MS4000070</td>
<td>Hazeltine, McKnight, Jonathan</td>
</tr>
<tr>
<td>City of Chanhassen</td>
<td>MS4000079</td>
<td>Hazeltine, McKnight</td>
</tr>
<tr>
<td>City of Chaska</td>
<td>MS4000080</td>
<td>Hazeltine, McKnight, Jonathan,  Grace</td>
</tr>
<tr>
<td>City of Victoria</td>
<td>MS400126</td>
<td>Gaystock, McKnight</td>
</tr>
<tr>
<td>Laketown Township</td>
<td>MS400142</td>
<td>Gaystock</td>
</tr>
<tr>
<td>MnDOT/Metro District</td>
<td>MS400170</td>
<td>Hazeltine, Jonathan</td>
</tr>
</tbody>
</table>

Permitted sources also include construction stormwater and industrial stormwater. These are expected to be small sources when operating in compliance with permit conditions and since they make up a very small portion of the watershed.

#### 3.5.2 Non-permitted

Watershed runoff from areas outside MS4s are more variable in their P concentrations and ultimate sources. Runoff from smaller urban areas that are not within regulated MS4s will nonetheless be similar to MS4 runoff. Runoff from cropland, which dominates the two westerly lakesheds of Gaystock and Maria, has TP concentrations similar to those in urban runoff. P-containing fertilizer, in chemical form or as applied manure, may increase the TP in cropland runoff. Runoff from natural areas (forest and/or grassland) contains P in the form of organic remains and little else, as fertilizer use and soil erosion are generally absent; and runoff TP concentrations are about one-tenth the concentrations in urban and agricultural runoff.

Three of the six impaired lakes and all three upstream and intermediate lakes have at least one septic system within 1,000 feet (ft) of their shoreline (Table 3.11). Although shown in Table 3.11 as having no septic systems in its lakeshed, McKnight Lake actually has a number of systems in its lakeshed, but all of them are near the lakeshed boundary and are well over 1,000 ft from McKnight Lake (see Figure 3.10) so should not be sources.
Table 3.11 Septic system counts

<table>
<thead>
<tr>
<th>Lake</th>
<th>Number of Septic Systems*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>9</td>
</tr>
<tr>
<td>Gaystock</td>
<td>2</td>
</tr>
<tr>
<td>Maria</td>
<td>4</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>1</td>
</tr>
<tr>
<td>Big Woods</td>
<td>3</td>
</tr>
<tr>
<td>Bavaria</td>
<td>6</td>
</tr>
<tr>
<td>McKnight</td>
<td>0</td>
</tr>
<tr>
<td>Jonathan</td>
<td>0</td>
</tr>
<tr>
<td>Grace</td>
<td>0</td>
</tr>
</tbody>
</table>

* Septic systems within 1,000 ft of lakeshore.

The lakesheds of the two westerly impaired lakes contain eleven feedlots in all, hosting 1,300 animal units (AUs; steer/stock cow or equivalent) overall (Table 3.12). None of the feedlots in these lakesheds is large enough to be classified as a Concentrated Animal Feeding Operation (CAFO).

Table 3.12 Feedlots and Animal Units

<table>
<thead>
<tr>
<th>Lakeshed</th>
<th>Number of feedlots</th>
<th>Number of animal units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaystock</td>
<td>9</td>
<td>1,031</td>
</tr>
<tr>
<td>Maria</td>
<td>2</td>
<td>272</td>
</tr>
</tbody>
</table>

The atmosphere contributes P directly to the lake surface through both precipitation and the settling of dust particles (“dryfall”). The total atmospheric P loading rate was set at 42 kg/km²-yr (~0.37 lb/ac-yr), typical of the Metro and southern Minnesota areas (Barr 2007).

Internal loading is the recycling of P stored in lake-bottom sediments back into the water column. Internal loading commonly results from oxygen depletion, which changes sediment-bound P into dissolved, and thus diffusible, form. Other causes include wind mixing and sediment resuspension in shallow lakes, activities of bottom-feeding fish such as carp and bullhead, and mid-summer curly-leaf pondweed die-off. Carp especially affect water quality adversely in the Grace Lake Chain. Internal loading is a natural phenomenon, but a history of long-term, excessive loading from watershed runoff, wastewater discharges, or other sources tends to magnify it.
4 TMDL Development

A TMDL is a calculation of the largest loading of an impairment-causing pollutant that a waterbody can receive while still meeting water quality standards. A “loading” (or “load”) is measured as a time-rate of mass transfer or flux, with common units being pounds (lb) or kilograms (kg) per day or per year. Lake TMDLs generally consider the time unit to be a year, so their natural units are lb/yr or kg/yr. Dividing the annual load by the number of days in a year (or season, where used as the primary basis) gives the expression specified by the Clean Water Act of the TMDL as a “daily load”. The TMDL for a waterbody is also termed the “loading capacity”, emphasizing that the core meaning is an overall limit. But the TMDL must also allocate, or subdivide, the loading capacity among the various pollutant sources (and certain set-aside portions, often), as follows:

\[ \text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} [+ \text{MOS} + \text{RC}] \]

Here the two summations represent the total of all WLAs, which are sources subject to regulation under the NPDES, and the total of all LAs, covering all nonregulated sources. The WLAs include wastewater discharges (with treatment as required) from industrial and municipal facilities, as well as stormwater runoff from regulated “MS4s”. LAs include runoff from natural areas, agricultural lands, and urban areas outside regulated MS4s; plus atmospheric loading and internal loading. The TMDL may also explicitly set aside a portion of the loading capacity as a “margin of safety” (MOS); alternatively (as in this study), the TMDL may have an “implicit MOS”, reflecting conservative aspects inherent in the calculation procedures. Another possible set-aside is a “reserve capacity” (RC), meant to accommodate future growth. As is common for Minnesota TMDLs in general, the TMDLs in this study do not include explicit RCs. Subsections 4.1 through 4.5 below outline the development of the six lake TMDLs. Subsection 4.6 presents a summary of the results.

4.1 Loading Capacity

The P loading capacity, or TMDL, for each impaired lake was developed by quantifying all of the lake’s existing P loadings, then using the loadings to calibrate a lake water quality model that incorporates the known lake characteristics and hydrology. After simulating conditions for the TMDL baseline-year, further simulations were conducted for the same conditions but with reduced P loads. These further simulations ultimately arrived at the total loading that results in attainment of the lake’s water quality standard – a TP concentration of 60 µg/L for all the impaired lakes in this study. This total loading is the lake’s P loading capacity. The modeling was done on an annual basis, so the loading capacity is also an annual value. The TMDL is simply the annual loading capacity restated as an average daily equivalent.

This TMDL made use of the lake water quality model BATHTUB (BATHTUB for Windows Version 6.20) developed by Dr. William W. Walker (1999) for the U.S. Army Corps of Engineers. BATHTUB calculates a steady-state P mass balance for an ideal, well-mixed lake. The P mass balance includes inputs of watershed load, municipal and industrial wastewater discharges, septic systems, feedlots, atmospheric deposition, and internal loading; as well as two outputs, the outflow load (lake TP concentration multiplied by the outflow water volume) and its complement, the “retained load” (portion of the total load that settles and remains in the lake’s bottom sediments). The retained load prediction is the critical
part of the P mass balance. BATHTUB has several optional submodels for calculating the retained load; the option used for all lakes in this study is the Canfield-Bachmann “lake” option.

The Canfield-Bachmann formulation predicts the retained P load from a statistical relationship between retention and total load, based on data for 704 lakes and reservoirs (626 in the U.S). Whenever a Canfield-Bachmann model application has an explicit internal load specified that load actually represents a deviation from a “normal” internal load reflected in the 704 lakes used in the original model development. Conversely, a “zero” internal load in a Canfield-Bachmann model application actually implies a “normal” internal load.

Baseline-year P loadings were determined as follows:

- **Wastewater loads:** There were five wastewater dischargers in the study lakesheds in their baseline years (Table 4.1):

<table>
<thead>
<tr>
<th>Discharge</th>
<th>NPDES Permit #</th>
<th>Receiving Lake</th>
<th>Baseline Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laketown CWWTP</td>
<td>MN0054399</td>
<td>Gaystock</td>
<td>2001</td>
</tr>
<tr>
<td>Apex</td>
<td>MN0067016</td>
<td>Hazeltine</td>
<td>2009</td>
</tr>
<tr>
<td>MGK</td>
<td>MN0058033</td>
<td>Hazeltine</td>
<td>2009</td>
</tr>
<tr>
<td>LifeCore Bio</td>
<td>MN0060747</td>
<td>Big Woods/McKnight</td>
<td>2009</td>
</tr>
<tr>
<td>TEL FSI Inc</td>
<td>MN0068781</td>
<td>Big Woods/McKnight</td>
<td>2009</td>
</tr>
</tbody>
</table>

  Their discharge characteristics were based on Discharge Monitoring Reports (Table 4.2):

<table>
<thead>
<tr>
<th>Discharge</th>
<th>Average Flow gallons/day</th>
<th>TP Conc mg/L</th>
<th>P Load lb/yr</th>
<th>DMR Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laketown CWWTP</td>
<td>2,500</td>
<td>2.3</td>
<td>17.5</td>
<td>2004&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Apex</td>
<td>16,273</td>
<td>0.0266</td>
<td>1.3</td>
<td>2009</td>
</tr>
<tr>
<td>MGK</td>
<td>31,537</td>
<td>0.5167</td>
<td>49.7</td>
<td>2009&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LifeCore Biomedical LLC</td>
<td>6,797</td>
<td>0.585</td>
<td>12.1</td>
<td>2009</td>
</tr>
<tr>
<td>TEL FSI Inc</td>
<td>10,000</td>
<td>1.000</td>
<td>30.5</td>
<td>2010 - 2015&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Laketown CWWTP data based on 2004 DMR values because TP was not monitored in 2001, and flows during 2001-2002 and part of 2003 evidently were misreported (extremely under-reported). The 2004 values (flow 2,546 gallons/day and flow-weighted mean TP 2.267 mg/L) were rounded in this table.

<sup>b</sup> MGK TP concentration from sampling in 2013 (only available data).

<sup>c</sup> TEL FSI Inc TP concentration assumed (no data available).

- **Lakeshed runoff loads:** see Table 3.7 for the baseline year lakeshed runoff P loads. These loads capture both rural and urban (including MS4-permitted) loads.

- **Septic systems:** Loading rates per septic system (Table 4.3) were derived for conforming systems, failing systems, and as a weighted average, based on an overall average system failure rate of 47% for Carver County (MPCA 2011):
Table 4.3 Estimated septic-system P loading rates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per capita P load</td>
<td>lb/cap-yr</td>
<td>2.30</td>
</tr>
<tr>
<td>Average system size</td>
<td>capita/system</td>
<td>2.90</td>
</tr>
<tr>
<td>P load to system</td>
<td>lb/system-yr</td>
<td>6.67</td>
</tr>
</tbody>
</table>

**Conforming systems (53% of all systems):**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil P retention</td>
<td>%</td>
<td>90%</td>
</tr>
<tr>
<td>Net P load to lake</td>
<td>lb/system-yr</td>
<td>0.67</td>
</tr>
</tbody>
</table>

**Failing systems (47% of all systems):**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil P retention</td>
<td>%</td>
<td>70%</td>
</tr>
<tr>
<td>Net P load to lake</td>
<td>lb/system-yr</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Weighted average values:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil P retention</td>
<td>%</td>
<td>81%</td>
</tr>
<tr>
<td>Net P load to lake</td>
<td>lb/system-yr</td>
<td>1.29</td>
</tr>
</tbody>
</table>

In Table 4.3, the per-capita P loading rate is from MPCA (2014), and the average system size is from the Metropolitan Council’s 2014 Population Estimates for Cities, Townships and Counties. Each lake’s overall P load from septic systems was calculated by multiplying the number of systems times the appropriate loading rate per system. Baseline conditions used the weighted average system-loading rate; the conforming system rate was applied for the all-conforming case. The results are in Table 4.4:

Table 4.4 Estimated septic-system P loads

<table>
<thead>
<tr>
<th>Lake</th>
<th>Number of Septic Systems*</th>
<th>Septic-System P Load, lb/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Existing</td>
</tr>
<tr>
<td>Aue</td>
<td>9</td>
<td>11.6</td>
</tr>
<tr>
<td>Gaystock</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td>Maria</td>
<td>4</td>
<td>5.2</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Big Woods</td>
<td>3</td>
<td>3.9</td>
</tr>
<tr>
<td>Bavaria</td>
<td>6</td>
<td>7.8</td>
</tr>
<tr>
<td>McKnight</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jonathan</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grace</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Septic systems within 1,000 ft of lakeshore.

- **Feedlots:** A per-AU loading of 0.29 lb/yr, accounting for soil attenuation, was estimated (Table 4.5):

Table 4.5 Estimated livestock P loading rate

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure-P production rate*</td>
<td>lb P/AU-yr</td>
<td>29.1</td>
</tr>
<tr>
<td>Soil/land cover retention</td>
<td>percent</td>
<td>99%</td>
</tr>
<tr>
<td>Net P load to lakes</td>
<td>lb P/AU-yr</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Note: AU = Animal Unit, approximately equivalent to a 1,000-lb cow (Minnesota Dept of Agriculture 2017).

* Median for livestock categories (converted to AU basis) assembled for The Minnesota Nutrient Reduction Strategy (State of Minnesota 2014).
This load per AU was multiplied by lakeshed AU counts from the county, resulting in the P loads in Table 4.6:

<table>
<thead>
<tr>
<th>Lake</th>
<th>Number of Feedlots</th>
<th>Total Number of Animal Units</th>
<th>P Load to Lake lb/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaystock</td>
<td>9</td>
<td>1,031</td>
<td>300</td>
</tr>
<tr>
<td>Maria</td>
<td>2</td>
<td>272</td>
<td>79</td>
</tr>
</tbody>
</table>

- **Atmospheric loading**: the MPCA study “Detailed Assessment of Phosphorus Sources to Minnesota Watersheds” (Barr Engineering 2004) and its update (Barr Engineering 2007) provided a Metro-southern Minnesota value of 0.37 lb/ac-yr for the average atmospheric P loading rate.

- **Upstream lakes**: upstream lakes, whether impaired or not, were modeled with BATHTUB in the same general manner as the six impaired lakes (see below).

- **Internal loading and calibration**: Five of the Carver lakes were calibrated straightforwardly by initial modeling using the known and estimated P loads described above and then, where the initial model under-predicted the lake TP, adding a suitable internal loading rate; or, where the initial model over-predicted the lake TP, adjusting the rate of P retention through a calibration factor. Maria, Hazeltine, and Jonathan lakes all required internal loads for calibration. Lakes Bavaria and Grace instead needed their P-retention-rate calibration factors increased above one (the no-effect default value), with zero internal load. Lake Bavaria is non-impaired, and Lake Grace benefits from P retention in its upstream lake chain. The fitted internal loading rates for Maria, Hazeltine, and Jonathan were between 0.6 and 4.7 milligrams per square meter per day (mg/m²-day), and the calibration factors for Bavaria and Grace were between 1.2 and 1.7 (see Table 4.6). The four remaining lakes consist of two upstream-downstream pairs (Big Woods-McKnight, and Aue-Gaystock) in which the upstream lakes have no observed TP for calibration. The general approach to model calibration for these lakes was to assign appropriate internal loading rates to the upstream lakes, thereby estimating their outflow TP concentrations and P loads, then using the latter results as inputs for completing the usual calibration of the downstream lakes. The detailed procedure was as follows:

1. The average internal loading rate for the five calibrated lakes above (1.3 mg/m²-day) was initially assigned to Big Woods lake, which tentatively determined its outflow TP concentration as 228 µg/L

2. McKnight Lake was then provisionally calibrated using Big Woods’ outflow data as above, which resulted in an internal loading rate for McKnight of 9.8 mg/m²-day

3. A new average internal loading rate was calculated by including McKnight Lake’s provisionally calibrated value with the rates for the first five lakes; the newly resulting average was 2.7 mg/m²-day (about double the initial average)

4. Steps 1 – 3 above were repeated, beginning with assigning the new average internal loading rate to Big Woods Lake; Big Woods’ resulting outflow TP concentration was 255 µg/L (12%
greater than the tentative first estimate), and McKnight Lake’s recalibrated internal loading rate was 8.34 mg/m²-day (15% decrease from the provisional first value)

(5) The same internal loading rate that was assigned to Big Woods Lake in step 3 was assigned to Aue Lake, which gave it an estimated outflow TP concentration of 146 µg/L and resulted in a calibrated internal loading rate for Gaystock Lake of 3.97 mg/m²-day (see again Table 4.7):

Table 4.6 Baseline-year calibration parameters

<table>
<thead>
<tr>
<th>Lake</th>
<th>Internal P Load Rate (mg/m²-day)</th>
<th>Calibration Factor (P sedimentation rate)</th>
<th>Observed Lake TP* (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>2.82</td>
<td>1</td>
<td>146</td>
</tr>
<tr>
<td>Gaystock</td>
<td>4.48</td>
<td>1</td>
<td>320</td>
</tr>
<tr>
<td>Maria</td>
<td>1.241</td>
<td>1</td>
<td>188</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>4.68</td>
<td>1</td>
<td>296</td>
</tr>
<tr>
<td>Big Woods</td>
<td>2.70</td>
<td>1</td>
<td>255</td>
</tr>
<tr>
<td>Bavaria</td>
<td>0</td>
<td>1.254</td>
<td>39.6</td>
</tr>
<tr>
<td>McKnight</td>
<td>8.20</td>
<td>1</td>
<td>231</td>
</tr>
<tr>
<td>Jonathan</td>
<td>0.620</td>
<td>1</td>
<td>202</td>
</tr>
<tr>
<td>Table 4.7</td>
<td>0</td>
<td>1.680</td>
<td>118</td>
</tr>
</tbody>
</table>

* Lake TP concentrations for Aue and Big Woods lakes (bold-italic) were determined by assigning them internal P loading rates (see text). These two upstream/intermediate lakes have no monitoring data for their downstream lake's baseline year.

To determine the loading capacity for the impaired lakes, the BATHTUB input data files for the baseline years were copied and then modified by reducing the overall P load sufficiently for the predicted lake TP concentration to meet the water quality TP standard (Table 4.7).

Load reductions were also determined for the unassessed lakes Aue and Big Woods, so the modeled outflow from Aue (deep lake) to Gaystock had a TP concentration of 40 µg/L, and the outflow from Big Woods (shallow) to McKnight Lake had a concentration of 60 µg/L. The reduced overall loads for Aue and Big Woods lakes are not TMDLs for these lakes because the lakes have not been assessed for impairment. However, the load limit for one industrial source discharging to Big Woods Lake, LifeCore Biomedical LLC, is a WLA with respect to McKnight Lake, immediately downstream.

Appendix C contains the BATHTUB input data and mass-balance outputs for the loading-capacity BATHTUB models.

Large P load reductions will be needed to achieve the loading capacities of the impaired lakes (Table 4.8). Baseline loads exceeded loading capacities by factors of 3 to 10; conversely, the required overall load reductions range from 67% to 91%.
Tables 4.12 through 4.17 in Subsection 4.6 give the baseline and loading capacity data for the impaired lakes in detail.

Natural background conditions refer to inputs that would be expected under natural, undisturbed conditions outside of human influence. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment and therefore natural background is accounted for and addressed through the MPCA’s waterbody assessment process. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, wastewater, failing Subsurface Sewage Treatment Systems (SSTSs), and other anthropogenic sources.

Based on the MPCA’s waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the waterbodies’ ability to meet state water quality standards. For all impairments addressed in this TMDL study, natural background sources are implicitly included in the LA portion of the TMDL allocation tables and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment.

### 4.2 Load Allocation Methodology

LAs for nonregulated P sources include septic systems, feedlots, upstream lakes, internal loading, watershed runoff load from non-permitted MS4 areas in the lakeshed, and atmospheric deposition directly on the lake. All septic systems are assumed to be conforming under the TMDL scenario and, hence, retaining 90% of their system loads (see Table 4.3). Feedlot P loads in the Gaystock and Maria lakesheds were reduced substantially from their baseline estimates. Gaystock lakeshed’s feedlot P load was reduced 88%, essentially the same as for the two MS4s in the lakeshed. Maria’s feedlot P load was reduced 63%, a little less than, but close to, the reduction for the lakeshed runoff P load. There are no wastewater discharges and no regulated MS4s in Maria’s lakeshed.

Upstream lakes affect over half of the lakes in this study. Under the TMDL scenario, the effects are positive. For Grace Lake, the TP concentration decrease in its upstream lake (Jonathan) from baseline

<table>
<thead>
<tr>
<th>Lake</th>
<th>Overall P Load, lb/yr</th>
<th>Overall P load % reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline Load</td>
<td>Loading Capacity</td>
</tr>
<tr>
<td>Aue</td>
<td>546</td>
<td>66.6</td>
</tr>
<tr>
<td>Gaystock</td>
<td>3,132</td>
<td>363</td>
</tr>
<tr>
<td>Maria</td>
<td>1,020</td>
<td>151</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>2,996</td>
<td>276</td>
</tr>
<tr>
<td>Big Woods</td>
<td>1,143</td>
<td>222</td>
</tr>
<tr>
<td>Bavaria</td>
<td>464</td>
<td>460</td>
</tr>
<tr>
<td>McKnight</td>
<td>2,107</td>
<td>482</td>
</tr>
<tr>
<td>Jonathan</td>
<td>1,833</td>
<td>506</td>
</tr>
<tr>
<td>Grace</td>
<td>1,617</td>
<td>527</td>
</tr>
</tbody>
</table>
(202 µg/L) to the TMDL scenario (60 µg/L) was sufficient by itself to restore Grace Lake to full support of its designated uses. In fact, under the TMDL scenario the modeled TP for Grace Lake is 46 µg/L, well below the applicable standard of 60 µg/L. Jonathan, McKnight, Big Woods, and Gaystock lakes also benefit from upstream lake load reductions, but all these other lakes need additional load reductions as well to meet their standards.

All of the study lakes except Bavaria and Grace exhibited baseline internal loads. The baseline internal load for Jonathan Lake equaled just 9% of its loading capacity, but in all of the remaining lakes the baseline internal load exceeded the lake’s entire loading capacity (by up to 8-fold for Hazeltine Lake).

For the TMDL scenario, all internal loads, including Jonathan’s, were cut to zero. However, even with all internal loads at zero, the TP concentration in lakeshed runoff needs large reductions to allow the lakes (excluding Bavaria and Grace) to meet their water quality standards (Table 4.9).

Table 4.8 Lakeshed runoff TP concentration for TMDL and baseline

<table>
<thead>
<tr>
<th>Lake</th>
<th>Baseline TP, µg/L</th>
<th>TMDL TP, µg/L</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aue</td>
<td>545</td>
<td>126.5</td>
<td>77%</td>
</tr>
<tr>
<td>Gaystock</td>
<td>606</td>
<td>70.7</td>
<td>88%</td>
</tr>
<tr>
<td>Maria</td>
<td>523</td>
<td>150.0</td>
<td>71%</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>230</td>
<td>108.5</td>
<td>53%</td>
</tr>
<tr>
<td>Big Woods</td>
<td>210</td>
<td>49.8</td>
<td>76%</td>
</tr>
<tr>
<td>Bavaria</td>
<td>296</td>
<td>296.0</td>
<td>0%</td>
</tr>
<tr>
<td>McKnight</td>
<td>254</td>
<td>93.4</td>
<td>63%</td>
</tr>
<tr>
<td>Jonathan</td>
<td>241</td>
<td>113.9</td>
<td>53%</td>
</tr>
<tr>
<td>Grace</td>
<td>221</td>
<td>221</td>
<td>0%</td>
</tr>
</tbody>
</table>

The percentage reductions for lakeshed runoff P loads that the TMDLs require are approximately the same as the TP concentration percent reductions above because the lake water budgets for baseline and TMDL scenarios were approximately the same (affected only by wastewater flow changes). (The net effect of wastewater flow changes was between 3% and 4% of Big Woods’ and Hazeltine’ total inflows and < 1 for the other lakes.) The same percentage load reductions also apply to both lakeshed runoff LAs for nonregulated areas and WLAs for the regulated MS4s; that is because the lakeshed P loads were apportioned by area in the TMDLs. This is the simplest apportioning method and is equivalent to assuming that each lakeshed’s average P export is uniform throughout its extent.

Atmospheric P deposition remained unchanged from the baseline to the TMDL scenario.

4.3 Wasteload Allocation Methodology

WLAs in these TMDLs include wastewater discharges, MS4s, construction stormwater, and industrial stormwater. Of the five original wastewater sources (Table 4.1), two, TEL FSI Inc. and APEX, no longer discharge to any study lake. The other three have allowable P loads ranging from 14 to 51 pounds per day (lb/day) (Table 4.10). LifeCore Biomedical LLC’s WLA equals its NPDES-permitted flow at a TP concentration of 300 µg/L (reduced by 49% from its baseline value of 585 µg/L). Laketown CWWTP’s and MGK’s WLAs are consistent with their current NPDES limits.
Table 4.10 Wastewater P loads for TMDL condition

<table>
<thead>
<tr>
<th>Discharge</th>
<th>NPDES Permit #</th>
<th>Receiving Lake</th>
<th>Average Flow gallons/day</th>
<th>TP Conc mg/L</th>
<th>P Load lb/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laketown CWWTP</td>
<td>MN0054399</td>
<td>Gaystock</td>
<td>5,800</td>
<td>2.868</td>
<td>50.7</td>
</tr>
<tr>
<td>MGK</td>
<td>MN0058033</td>
<td>Hazeltine</td>
<td>7,000</td>
<td>0.651</td>
<td>13.9</td>
</tr>
<tr>
<td>LifeCore Biomedical LLC</td>
<td>MN0060747</td>
<td>Big Woods/McKnight</td>
<td>50,000</td>
<td>0.300</td>
<td>45.7</td>
</tr>
</tbody>
</table>

Discharges terminated after baseline year:

<table>
<thead>
<tr>
<th>Discharge</th>
<th>NPDES Permit #</th>
<th>Receiving Lake</th>
<th>Average Flow gallons/day</th>
<th>TP Conc mg/L</th>
<th>P Load lb/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>APEX</td>
<td>MN0067016</td>
<td>Hazeltine</td>
<td>0</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>TEL FSI Inc</td>
<td>MN0068781</td>
<td>Big Woods/McKnight</td>
<td>0</td>
<td>--</td>
<td>0</td>
</tr>
</tbody>
</table>

For each lakeshed, the runoff P load split between WLAs (for regulated MS4 areas) and LAs (nonpermitted MS4 areas) was proportional to area (with minor exception – see below). Maria Lake has no MS4 areas within its lakeshed. MS4 area maps for the lakesheds of the other five impaired lakes are in Appendix D. Considering that load is proportional to area is equivalent to assuming that P export is uniform throughout the lakeshed. The exception mentioned above is for transportation-authority MS4s, in this case the MnDOT and Carver County. Because the right-of-way areas these authorities manage are relatively small and, thus, have small loads, the larger municipalities absorb their load reductions. MnDOT and the county continue to implement water quality-impact mitigation measures, as they have done, but are freed from reporting requirements for myriad small load reductions. Table 4.11 presents the MS4 baseline P loads and WLAs. (See Table 3.8 for baseline years to be used to indicate crediting for any load-reducing BMP towards the meeting of an MS4’s WLA.) The MS4 load reduction percentages in Table 4.11 are virtually the same as the corresponding runoff TP concentration reductions in Table 4.9 because of the general assumption of load proportionality to area.

WLAs for construction and industrial stormwater combined were conservatively set at 0.1% of the total allowable runoff loading from each lakeshed. The construction portion of this value is based on past Carver County TMDL project estimates of areas under construction at any one time. This value was then doubled to account for any current and future industrial stormwater sources.
Table 4.9 MS4 Wasteload Allocations

<table>
<thead>
<tr>
<th>Lake</th>
<th>Permit Number</th>
<th>MS4 Area (acres)</th>
<th>Existing Load (lb/yr)</th>
<th>MS4 WLA (lb/yr)</th>
<th>Reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaystock</td>
<td>MS400142</td>
<td>33</td>
<td>24</td>
<td>2.8</td>
<td>88%</td>
</tr>
<tr>
<td></td>
<td>MS400126</td>
<td>34</td>
<td>25</td>
<td>2.9</td>
<td>88%</td>
</tr>
<tr>
<td>Maria</td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>City of Chaska</td>
<td>MS400080</td>
<td>358</td>
<td>197</td>
<td>54%</td>
</tr>
<tr>
<td></td>
<td>City of Chanhassen</td>
<td>MS400079</td>
<td>77</td>
<td>42</td>
<td>54%</td>
</tr>
<tr>
<td></td>
<td>Carver County</td>
<td>MS400070</td>
<td>11</td>
<td>6.1</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>MnDOT</td>
<td>MS400170</td>
<td>2.0</td>
<td>1.1</td>
<td>--</td>
</tr>
<tr>
<td>McKnight</td>
<td>City of Chaska</td>
<td>MS400080</td>
<td>367</td>
<td>162</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>City of Chanhassen</td>
<td>MS400079</td>
<td>45</td>
<td>20</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>City of Victoria</td>
<td>MS400126</td>
<td>79</td>
<td>35</td>
<td>63%</td>
</tr>
<tr>
<td>Jonathan</td>
<td>City of Chaska</td>
<td>MS400080</td>
<td>130</td>
<td>82</td>
<td>54%</td>
</tr>
<tr>
<td></td>
<td>MnDOT/Metro District</td>
<td>MS400170</td>
<td>3.8</td>
<td>2.4</td>
<td>--</td>
</tr>
<tr>
<td>Grace</td>
<td>City of Chaska</td>
<td>MS400080</td>
<td>87</td>
<td>59</td>
<td>0%</td>
</tr>
</tbody>
</table>

4.4 Margin of Safety

A MOS has been incorporated into this TMDL by using a conservative modeling approach to account for an inherently imperfect understanding of the lakes’ systems, and to ultimately ensure that the nutrient reduction strategy is protective of the water quality standard. Conservative modeling includes using the summer average (June through September) of in-lake samples to account for the highest algal growth potential of the lake. During this time period, average air temperatures and water temperatures are in the optimal range for high productivity of the lake.

The lake response model for TP used for this TMDL uses the rate of lake sedimentation, or the loss of P from the water column as a result of settling, to predict TP concentration. Sedimentation can occur as algae die and settle, as organic material settles, or as algae are grazed by zooplankton. Sedimentation rates in shallow lakes can be higher than rates for deep lakes. Shallow lakes differ from deep lakes in that they tend to exist in one of two states: turbid water and clear water. Lake response models assume that even when TP concentration in the lake is at or better than the state water quality standard the lake will continue to be in that turbid state. However, as nutrient load is reduced and other internal load management activities such as fish community management occur to provide a more balanced lake system, shallow lakes will tend to “flip” to a clear water condition. In that balanced, clear water condition, light penetration allows rooted aquatic vegetation to grow and stabilize the sediments, and zooplankton to thrive and graze on algae at a much higher rate than is experienced in turbid waters. Thus in a clear water state more P will be removed from the water column through settling than the model would predict.

The TMDL is set to achieve water quality standards while still in a turbid water state. To achieve the beneficial use, the lake must flip to a clear water state, which can support the response variables at higher TP concentrations due to increased zooplankton grazing, reduced sediment resuspension, etc. Therefore, this TMDL is inherently conservative by setting allocations for the turbid water state.
4.5 Seasonal Variation

Seasonal variation is accounted for through the utilization of annual loads, and developing targets for the summer period where the frequency and severity nuisance algal growth will be the greatest. Although the critical period is the summer, lake water quality responds mainly to long-term changes such as changes in the annual load. Therefore, seasonal variation is accounted for in the annual loads. Additionally, by setting the TMDL to meet targets established for the most critical period (summer), the TMDL will inherently be protective of water quality during all other seasons.

4.6 Reserve Capacity

RC is that portion of the TMDL that accommodates future loads. No RC is allocated in this TMDL. Any growth will need to occur within the allocations established in this TMDL and no additional load will be added to accommodate future growth.

4.7 TMDL Summary

Tables 4.12 – 4.17 below summarize the overall allocations of existing and allowable loads for the impaired lakes in this study.

Table 4.10 Gaystock Lake (10-0031) TMDL Allocation

<table>
<thead>
<tr>
<th>Load Category</th>
<th>Load Component</th>
<th>Existing TP Load</th>
<th>Allowable TP Load</th>
<th>Estimated Load Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Total WLA</strong></td>
<td>lb/yr</td>
<td>lb/day</td>
<td>lb/yr</td>
</tr>
<tr>
<td>Wasteload</td>
<td>Laketown CWTP* (MN0054399)</td>
<td>66</td>
<td>0.18</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>Construction/Industrial SW</td>
<td>0.24</td>
<td>0.00066</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>Laketown Twp (MS400142)</td>
<td>24</td>
<td>0.065</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Victoria (MS400126)</td>
<td>25</td>
<td>0.067</td>
<td>2.9</td>
</tr>
<tr>
<td>Load</td>
<td><strong>Total LA</strong></td>
<td>3,066</td>
<td>8.39</td>
<td>307</td>
</tr>
<tr>
<td></td>
<td>Non-MS4 runoff</td>
<td>2,018</td>
<td>5.53</td>
<td>235</td>
</tr>
<tr>
<td></td>
<td>Upstream lake - Aue</td>
<td>57</td>
<td>0.16</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Atmospheric deposition</td>
<td>17</td>
<td>0.047</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Internal load</td>
<td>671</td>
<td>1.8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>SSTS</td>
<td>2.6</td>
<td>0.0071</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Feedlots</td>
<td>300</td>
<td>0.82</td>
<td>37</td>
</tr>
</tbody>
</table>

* Laketown Community Wastewater Treatment Plant; allowable load > existing load because of substantial flow increase due to an increase in the number of homes over the intervening period since the “existing load” was calculated.
### Table 4.11 Maria Lake (10-0058) TMDL Allocation

<table>
<thead>
<tr>
<th>Load Category</th>
<th>Load Component</th>
<th>Existing TP Load</th>
<th>Allowable TP Load</th>
<th>Estimated Load Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>lb/yr</td>
<td>lb/day</td>
<td>lb/yr</td>
</tr>
<tr>
<td><strong>TOTAL LOAD</strong></td>
<td></td>
<td>1,020</td>
<td>2.79</td>
<td>151</td>
</tr>
<tr>
<td><strong>Wasteload</strong></td>
<td>Total WLA</td>
<td>0.055</td>
<td>0.00015</td>
<td>0.055</td>
</tr>
<tr>
<td></td>
<td>Construction/Industrial SW</td>
<td>0.055</td>
<td>0.00015</td>
<td>0.055</td>
</tr>
<tr>
<td><strong>Load</strong></td>
<td>Total LA</td>
<td>1,020</td>
<td>2.79</td>
<td>151</td>
</tr>
<tr>
<td></td>
<td>Non-MS4 runoff</td>
<td>192</td>
<td>0.53</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Atmospheric deposition</td>
<td>63</td>
<td>0.17</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Internal load</td>
<td>680</td>
<td>1.86</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>SSTS</td>
<td>5.2</td>
<td>0.014</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Feedlots</td>
<td>79</td>
<td>0.22</td>
<td>30</td>
</tr>
</tbody>
</table>

### Table 4.12 Hazeltine Lake (10-0014) TMDL Allocation

<table>
<thead>
<tr>
<th>Load Category</th>
<th>Load Component</th>
<th>Existing TP Load</th>
<th>Allowable TP Load</th>
<th>Estimated Load Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>lb/yr</td>
<td>lb/day</td>
<td>lb/yr</td>
</tr>
<tr>
<td><strong>TOTAL LOAD</strong></td>
<td></td>
<td>2,996</td>
<td>8.20</td>
<td>276</td>
</tr>
<tr>
<td><strong>Wasteload</strong></td>
<td>Total WLA</td>
<td>298</td>
<td>0.82</td>
<td>132</td>
</tr>
<tr>
<td></td>
<td>Apex* (MN0067016)</td>
<td>1.3</td>
<td>0.0037</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>MGK‡ (MN0058033)</td>
<td>50</td>
<td>0.14</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Construction/Industrial SW</td>
<td>0.20</td>
<td>0.00055</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Chaska (MS400080)</td>
<td>197</td>
<td>0.54</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>Chanhassen (MS400079)</td>
<td>42</td>
<td>0.12</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Carver County (MS400070)</td>
<td>6.1</td>
<td>0.017</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>MNDOT Metro Dist (MS400170)</td>
<td>1.10</td>
<td>0.0030</td>
<td>1.10</td>
</tr>
<tr>
<td><strong>Load</strong></td>
<td>Total LA</td>
<td>2,698</td>
<td>7.39</td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>Non-MS4 runoff</td>
<td>179</td>
<td>0.49</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>Atmospheric deposition</td>
<td>60</td>
<td>0.17</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Internal load</td>
<td>2,457</td>
<td>6.7</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>SSTS</td>
<td>1.29</td>
<td>0.0035</td>
<td>0.67</td>
</tr>
</tbody>
</table>

* Apex International Manufacturing; no longer discharges to Hazeltine Lake
‡ McLaughlin Gormley King Company
Table 4.13 McKnight Lake (10-0216) TMDL Allocation

<table>
<thead>
<tr>
<th>Load Category</th>
<th>Load Component</th>
<th>Existing TP Load</th>
<th>Allowable TP Load</th>
<th>Estimated Load Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>lb/yr</td>
<td>lb/day</td>
<td>lb/yr</td>
</tr>
<tr>
<td>TOTAL LOAD</td>
<td></td>
<td>2,107</td>
<td>5.77</td>
<td>482</td>
</tr>
<tr>
<td>Wasteload</td>
<td>Total WLA</td>
<td>225</td>
<td>0.62</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td>LifeCore Biomedical LLC*</td>
<td>8.3</td>
<td>0.023</td>
<td>37.4</td>
</tr>
<tr>
<td></td>
<td>Construction/Industrial SW</td>
<td>0.24</td>
<td>0.00066</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>Chaska (MS400080)</td>
<td>162</td>
<td>0.44</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Chanhassen (MS400079)</td>
<td>20</td>
<td>0.054</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>Victoria (MS400126)</td>
<td>35</td>
<td>0.095</td>
<td>13</td>
</tr>
<tr>
<td>Load</td>
<td>Total LA</td>
<td>1,882</td>
<td>5.15</td>
<td>365</td>
</tr>
<tr>
<td></td>
<td>Non-MS4 runoff</td>
<td>434</td>
<td>1.19</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>Big Woods Outflow excl LifeCore**</td>
<td>772</td>
<td>2.11</td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>Upstream lake - Bavaria</td>
<td>53</td>
<td>0.14</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Atmospheric deposition</td>
<td>8.6</td>
<td>0.024</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>Internal load</td>
<td>615</td>
<td>1.68</td>
<td>0</td>
</tr>
</tbody>
</table>

* LifeCore Biomedical LLC’s load here reflects P retention in Big Woods Lake, 32% and 18% for existing and TMDL conditions, respectively. The P retention percentages here are for Big Woods Lake in general. The retention is greater for the existing condition because, in the Canfield-Bachmann model, retention is an increasing function of total load; and the lake’s total load is of course larger under the existing condition. LifeCore’s WLA corresponds to its P discharge directly into Big Woods Lake. LifeCore discharged 12 lb/yr into Big Woods Lake under the existing condition, and its allowable load (WLA) under the TMDL is 45.7 lb/yr, reflecting an increase in production capacity.

‡ Big Wood Lake’s outflow load is reduced here by the load from LifeCore Biomedical LLC (listed separately in table).

Table 4.14 Jonathan Lake (10-0217) TMDL Allocation

<table>
<thead>
<tr>
<th>Load Category</th>
<th>Load Component</th>
<th>Existing TP Load</th>
<th>Allowable TP Load</th>
<th>Estimated Load Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>lb/yr</td>
<td>lb/day</td>
<td>lb/yr</td>
</tr>
<tr>
<td>TOTAL LOAD</td>
<td></td>
<td>1,833</td>
<td>5.02</td>
<td>506</td>
</tr>
<tr>
<td>Wasteload</td>
<td>Total WLA</td>
<td>84</td>
<td>0.23</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Construction/Industrial SW</td>
<td>0.082</td>
<td>0.00022</td>
<td>0.082</td>
</tr>
<tr>
<td></td>
<td>Chaska (MS400080)</td>
<td>82</td>
<td>0.22</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>MNDOT Metro Dist (MS400170)</td>
<td>2.4</td>
<td>0.0065</td>
<td>2.4</td>
</tr>
<tr>
<td>Load</td>
<td>Total LA</td>
<td>1,749</td>
<td>4.79</td>
<td>465</td>
</tr>
<tr>
<td></td>
<td>Non-MS4 runoff</td>
<td>88</td>
<td>0.24</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Upstream lake - McKnight</td>
<td>1,606</td>
<td>4.40</td>
<td>416</td>
</tr>
<tr>
<td></td>
<td>Atmospheric deposition</td>
<td>8.6</td>
<td>0.024</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>Internal load</td>
<td>46</td>
<td>0.13</td>
<td>0</td>
</tr>
<tr>
<td>Load Category</td>
<td>Load Component</td>
<td>Existing TP Load</td>
<td>Allowable TP Load</td>
<td>Estimated Load Reduction</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------------</td>
<td>------------------</td>
<td>-------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lb/yr</td>
<td>lb/day</td>
<td>lb/yr</td>
</tr>
<tr>
<td>TOTAL LOAD</td>
<td></td>
<td>1,617</td>
<td>4.43</td>
<td>527</td>
</tr>
<tr>
<td>Wasteload</td>
<td>Total WLA</td>
<td>59</td>
<td>0.16</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Construction/Industrial SW</td>
<td>0.060</td>
<td>0.00017</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>Chaska (MS400080)</td>
<td>59</td>
<td>0.16</td>
<td>59</td>
</tr>
<tr>
<td>Load</td>
<td>Total LA</td>
<td>1,558</td>
<td>4.27</td>
<td>468</td>
</tr>
<tr>
<td></td>
<td>Non-MS4 runoff</td>
<td>1.5</td>
<td>0.0041</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Upstream lake - Jonathan</td>
<td>1,549</td>
<td>4.24</td>
<td>459</td>
</tr>
<tr>
<td></td>
<td>Atmospheric deposition</td>
<td>7.5</td>
<td>0.021</td>
<td>7.5</td>
</tr>
</tbody>
</table>
5 Future Growth Considerations

This part of the metro area is experiencing moderate to high levels of development and so the provisions below will apply.

5.1 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 nonregulated 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 and is covered under a NPDES Permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL. 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.
6 Reasonable Assurance

Needed elements are in place for both point sources and nonpoint sources to make progress toward needed pollutant reductions in this TMDL. A range of local partners are involved in water resource management and implementation for these lakes, including Carver County Land and Water Services Division, Carver County Extension, the Carver Soil and Water Conservation District, and cities.

6.1 Regulatory approaches

**NPDES permitted sources.** All municipal and industrial NPDES Wastewater Permits in the watershed will reflect limits derived from WLAs described herein. Discharge monitoring is conducted by permittees and routinely submitted to the MPCA for review.

The MPCA oversees stormwater management accounting activities for all MS4 entities previously listed in this TMDL study. The Small MS4 General Permit requires regulated municipalities to implement BMPs that reduce pollutants in stormwater to the maximum extent practicable. A critical component of permit compliance is the requirement for the owners or operators of a regulated MS4 conveyance to develop a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP addresses all permit requirements, including the following six measures:

- Public education and outreach
- Public participation
- Illicit Discharge Detection and Elimination Program
- Construction site runoff controls
- Post-construction runoff controls
- Pollution prevention and municipal good housekeeping measures

A SWPPP is a management plan that describes the MS4 permittees’ activities for managing stormwater within their regulated area. In the event of a completed TMDL study, MS4 permittees must document the WLA in their future NPDES/SDS Permit application and provide an outline of the BMPs to be implemented that address any needed reductions. The MPCA requires MS4 owners or operators to submit their application and corresponding SWPPP document to the MPCA for review. Once the application and SWPPP are deemed adequate by the MPCA, all application materials are placed on 30-day public notice, allowing the public an opportunity to review and comment on the prospective program. Once NPDES/SDS Permit coverage is granted, permittees must implement the activities described within their SWPPP, and submit an annual report to the MPCA documenting the implementation activities completed within the previous year, along with an estimate of the cumulative pollutant reduction achieved by those activities. For information on all requirements for annual reporting, please see the Minnesota Stormwater Manual.

This TMDL assigns TP WLAs to permitted MS4s. The Small MS4 General Permit requires permittees to develop compliance schedules for EPA approved TMDL WLAs not already being met at the time of permit application. A compliance schedule includes BMPs that will be implemented over the permit term, a timeline for their implementation, and a long-term strategy for continuing progress towards
assigned WLAs. For WLAs being met at the time of permit application, the same level of treatment must be maintained in the future. Regardless of WLA attainment, all permitted MS4s are still required to reduce pollutant loadings to the maximum extent practicable.

The MPCA’s stormwater program and its NPDES Permit program are regulatory activities providing reasonable assurance that implementation activities are initiated, maintained, and consistent with WLAs assigned in this study.

Regulated construction stormwater was given a categorical TMDL in this study (combined with industrial stormwater). However, construction activities disturbing one-acre or more in size are still required to obtain NPDES Permit coverage through the MPCA. Compliance with TMDL requirements are assumed when a construction site owner/operator meets the conditions of the Construction General Permit, and properly selects, installs, and maintains all BMPs required under the permit. This includes any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or compliance with local construction stormwater requirements if they are more restrictive than those in the State General Permit.

Industrial stormwater was combined into a categorical stormwater WLA in this study (with construction stormwater). Industrial activities still require permit coverage under 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, their discharges are considered compliant with WLAs set in this study.

**County water rules.** Carver County water rules establish standards and specifications for the common elements relating to watershed resource management including: Water Quantity, Water Quality, Natural Resource Protection, Erosion and Sediment Control, Wetland Protection, Shoreland Management, and Floodplain Management. The complete water management rules are contained in the Carver County Code, Section 153.

**County feedlot program.** The Carver County Feedlot Management Program includes the feedlot registration process. The permit process ensures that the feedlot meets State pollution control standards and locally adopted standards. The County has had a locally operated permitting process under delegation from the MPCA since 1980. The County adopted a Feedlot Ordinance in 1996. The Feedlot Ordinance incorporates State standards plus additional standards and procedures deemed necessary to appropriately manage feedlots in Carver County.

**County SSTS ordinance.** The Carver County SSTS ordinance regulates the design, location, installation, construction, alteration, extension, repair, and maintenance of SSTSs. The County currently enforces the ordinance in unincorporated areas; cities are responsible in their jurisdiction. The law gives responsibility to the County throughout the county unless a city specifically develops and implements its own program and SSTS ordinance.

### 6.2 Nonregulatory approaches

**Nonpoint prioritization/targeting.** The Lower Minnesota River WRAPS Report details a number of tools that provide means for identifying priority pollutant sources and focusing implementation work in the
watershed. These include but are not limited to the Hydrologic Simulation Program-FORTRAN (HSPF)-SAM modeling, Environmental Benefits Index analysis, and Restorable Wetlands Inventory. County targeting efforts include producing a Grace Chain of Lakes Subwatershed Assessment Report highlighting the cost benefit projects to pursue in the area. In addition to the subwatershed assessment, Carver County Water Management Organization has a landowner cost share program that has targeted the Grace Chain of Lakes through a mailing project.

**Strategy development and local planning.** The WRAPS and the implementation strategies outlined in this TMDL report (Section 8) demonstrate a scenario that can attain the pollutant reduction goals. The Carver County Watershed Management Organization (CCWMO) completed a Water Management Plan in 2010, as required under Minn. Stat. 103B.231. This plan includes goals for several “major issues/program areas” including surface water management, impaired waters and TMDLs, urban stormwater management, wetland management, agricultural practices and education. A major part of the plan is for implementation, which provides a range of activities and strategies for all of the major issues/program areas above. The plan further outlines specific planned projects to be done over the 10-year timeframe of the plan, detailing the project type, partners, timeframe and costs. Examples projects include stormwater treatment or retrofits, wetland restorations, and lake management. The next 10-year plan revision is underway and will more fully address the lakes in this TMDL project.

**Funding availability.** Carver County has established a stable source of funding through a watershed levy in the Carver County Water Resource Management Area taxing district. This levy allows for consistent funding for staff, monitoring, and engineering costs, as well as on the ground projects. The County has also been very successful in obtaining grant funding from local, state and federal sources. These funds include grants from Clean Water, Land and Legacy funds, EPA Clean Water Act Section 319 grants, and various NRCS programs.

**Tracking and monitoring progress.** Monitoring components outlined in Section 7 constitute a sufficient means for tracking progress and supporting adaptive management.
7 Monitoring Overview

Monitoring will continue for TMDL lakes as prioritized by the Surface Water Implementation Strategies within Section K of the Water Management Organization (WMO) Water Management Plan. These strategies outline that established lake sampling sites will be maintained, lake sampling sites that are needed will be established, and any lake sampling sites as dictated by TMDL Studies or TMDL Implementation Plans will be established. Table 7.1 outlines monitoring commitments for the lakes within this TMDL. Monitoring frequency will be bi-weekly from April through October.

Table 7.1 Monitoring commitment for lakes within this TMDL.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Strategy</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaystock</td>
<td>Not established, implementation based</td>
<td>Establish during targeted implementation efforts</td>
</tr>
<tr>
<td>Maria</td>
<td>Not established, implementation based</td>
<td>Establish during targeted implementation efforts</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>Established, continue to monitor</td>
<td>Minimum every other year</td>
</tr>
<tr>
<td>McKnight</td>
<td>Established, continue to monitor</td>
<td>Minimum every other year</td>
</tr>
<tr>
<td>Jonathan</td>
<td>Established, continue to monitor</td>
<td>Minimum every other year</td>
</tr>
<tr>
<td>Grace</td>
<td>Established, continue to monitor</td>
<td>Minimum every other year</td>
</tr>
</tbody>
</table>

Adaptive management relies on the County conducting additional monitoring as BMPs are implemented in order to determine if the implementation measures are effective and how effective they are. This monitoring will assist in evaluating the success of projects and identify changes needed in management strategies. Revision of management and monitoring strategies will occur as needed.

Additional anticipated monitoring for each of the lakes includes the following:

**Gaystock.** Additional areas that may need to be monitored include Aue Lake in-lake sampling, sampling and flow measurements taken at the inlet to Gaystock Lake, sediment samples to further account for internal loading, and land use change monitoring.

**Maria.** Additional monitoring for Maria Lake may include detailed inlet and outlet monitoring. This will refine loading estimates and help pinpoint areas for projects within the watershed.

**Hazeltine.** Additional areas that may need to be monitored sampling and flow measurements taken at the inlet and outlet of Hazeltine Lake, sediment samples to further account for internal loading, land use change monitoring, and BMP performance monitoring. Furthermore, assessment of the stormwater discharge may be monitored to better grasp the nutrient loads caused by runoff from surrounding land.

**McKnight.** Additional monitoring may include more detailed monitoring at the inlet and outlet to refine loading estimates, and monitoring of Big Woods Lake to identify its role in nutrient loading to McKnight Lake, as well as in-lake monitoring of Big Woods Lake.

**Jonathan.** Monitoring of the storm sewer system might lead to a more accurate account of loadings into Jonathan Lake. This will allow for a more refined picture of the Jonathan Lake system.

**Grace.** As with Jonathan Lake, additional monitoring of the storm sewer system discharging to Grace Lake will allow for a more precise model of the whole lake system.
8 Implementation Strategy Summary

The Lower Minnesota River WRAPS Report and WMO water plan will further outline implementation strategies and actions to address the subject lakes. Below is a summary of the proposed strategies at this time.

8.1 Permitted Sources

8.1.1 Construction Stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre 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 Minnesota’s NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS 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. Construction activity must also meet all local government construction stormwater requirements.

8.1.2 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 Minnesota’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. Industrial activity must also meet all local government construction stormwater requirements.

8.1.3 MS4s

MS4s are subject to the NPDES Municipal Stormwater Permit requirements. This permit provides conditions for compliance with approved TMDLs and associated WLAs. Compliance includes progress towards needed loading reductions and annual reporting requirements.

In addition to MS4-initiated projects, Carver County partners with cities to take on stormwater treatment projects that benefit water resources. The county carries this out through the CCWMO. Requirements set forth in the County Water Management Plan and rules are designed to address pollutant and volume reduction associated with for development and redevelopment of land. In addition, both the cities and the county encourage urban landowners to reduce nutrient runoff from their properties.
8.1.4 Wastewater
The MPCA oversees NPDES Wastewater Permits for all dischargers cited in this TMDL. Discharge limits are provided that are designed to meet all associated WLAs.

8.2 Non-Permitted Sources

8.2.1 Agriculture
Agricultural land is the major land use within the Carver Creek Watershed, thus producing the highest amounts of P loads entering each lake. Improved farming practices have over time greatly reduced the runoff generated from fields. However, new and innovative BMPs are becoming more available for farmers. With these new BMPs and including proven techniques, further reductions in both volume and nutrients are still possible for the agricultural land uses. In general, needed efforts will be a combination of soil erosion protection, fertilizer efficiency and increased living cover on cultivated lands.

8.2.2 Feedlots
Feedlots without runoff controls may contribute to nutrient loading during wet conditions. Surface water concerns include contamination by open lot runoff into a waterbody, ditch or open tile inlet. In order to address this pollution, the County will rely on goals and policies set forth in the County Water Management Plan and utilize existing regulations and rules (County Feedlot Management Ordinance Chapter 54, and Minn. R. ch. 7020) to ensure compliance.

8.2.3 SSTS
Failing and/or direct discharge septic systems are potentially contributing nutrients to all waterbodies throughout Carver County. These failing and improperly maintained SSTS present a substantial threat to the quality of surface and groundwater resources within Carver County. Actions to ensure that direct discharge systems are eliminated have been taken as part of the Carver and Bevens Fecal Coliform TMDL Implementation Plan. This implementation action will be extended to include East and West Chaska Creek watersheds to ensure SSTS in and around Gaystock, Hazeltine, McKnight, Jonathan, and Grace Lakes are properly functioning.

8.2.4 Internal Loading
Aquatic plant management. Curly-leaf pondweed grows under the ice but dies back during late June or early July, releasing nutrients to the water column in summer, possibly leading to algal blooms. For these reasons, it is of importance to control populations of curly-leaf pondweed and establish a native aquatic plant community. While Eurasian water milfoil, which out-competes native plants, is the current dominant aquatic plant, curly-leaf pondweed can quickly take its place if given the chance.

Aquatic plants stabilize banks and sediment, oxygenate water, protect small fish, create spawning habitats, act as refuges for zooplankton and serve as food sources for waterfowl and wildlife. For these reasons, it is of importance to restore native aquatic plant populations within each lake. Strategies to accomplish this include: lake drawdown; manual, chemical, or mechanical removal of curly-leaf pondweed; and monitoring to ensure that non-native invasive species are not introduced into the plant community.

Rough fish management and biomanipulation. Species such as black bullhead and carp increase the mixing of sediments releasing P into the water column, and reducing the clarity of water, thereby
minimizing the amount of light filtering to aquatic macrophytes. Carp are a particular issue in the easterly lakes of the Grace chain. Potential management practices and approaches include: investigate partnership with University of Minnesota in research of effective carp removal methods, stocking of pan fish to assist in reducing carp reproduction through predation of carp eggs, increased surveys to monitor the results of management efforts and installation of fish barriers paired with intensified efforts for removal of carp and black bullheads. Reintroduction of other specific species for long-term function of the lake systems may be considered as well.

**Alum treatment.** Aluminum sulfate (alum) is a chemical addition that forms a nontoxic precipitate with P. It removes P from the lake system so that is not released from the sediments and made available for algal growth. Efforts for these lakes would need to include feasibility studies and determination of treatment areas, dosing rates and costs.

### 8.3 Cost

Lake restoration activities can be grouped into two main categories: those aimed at reducing external nutrient loads and those aimed at reducing internal loads.

Carver County staff has provided a preliminary range of estimated costs to implement TMDL goals for this TMDL (excluding wastewater treatment plant-related costs). The overall total for all lakes ranges from $2,093,000 to $5,832,000. CCWMO’s watershed management plan includes a section on prioritizing waterbodies for improvement projects considering several factors. Individual strategies and costs associated with them are provided in the tables below.

**Table 8.1 Cost breakdown for external strategies for each lake. Numbers in thousands.**

<table>
<thead>
<tr>
<th>Lake</th>
<th>SSTS Low</th>
<th>SSTS High</th>
<th>Feedlots Low</th>
<th>Feedlots High</th>
<th>Landowner Practices Low</th>
<th>Landowner Practices High</th>
<th>Stormwater Mgmt Low</th>
<th>Stormwater Mgmt High</th>
<th>Ag BMPs Low</th>
<th>Ag BMPs High</th>
<th>Total Low</th>
<th>Total High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaystock</td>
<td>17</td>
<td>150</td>
<td>40</td>
<td>100</td>
<td>10</td>
<td>50</td>
<td>25</td>
<td>75</td>
<td>100</td>
<td>250</td>
<td>192</td>
<td>625</td>
</tr>
<tr>
<td>Maria</td>
<td>2</td>
<td>10</td>
<td>15</td>
<td>50</td>
<td>2</td>
<td>10</td>
<td>200</td>
<td>500</td>
<td>219</td>
<td>570</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazeltine</td>
<td>6</td>
<td>42</td>
<td>50</td>
<td>150</td>
<td>150</td>
<td>250</td>
<td>206</td>
<td>542</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McKnight</td>
<td>56</td>
<td>420</td>
<td>50</td>
<td>150</td>
<td>150</td>
<td>300</td>
<td>256</td>
<td>870</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jonathan</td>
<td>25</td>
<td>100</td>
<td>100</td>
<td>175</td>
<td>100</td>
<td>175</td>
<td>150</td>
<td>275</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grace</td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>175</td>
<td>100</td>
<td>175</td>
<td>150</td>
<td>275</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>81</strong></td>
<td><strong>622</strong></td>
<td><strong>55</strong></td>
<td><strong>150</strong></td>
<td><strong>212</strong></td>
<td><strong>660</strong></td>
<td><strong>525</strong></td>
<td><strong>975</strong></td>
<td><strong>300</strong></td>
<td><strong>750</strong></td>
<td><strong>1173</strong></td>
<td><strong>3157</strong></td>
</tr>
</tbody>
</table>

**Table 8.2 Cost breakdown for internal strategies for each lake. Numbers in thousands**

<table>
<thead>
<tr>
<th>Lake</th>
<th>Aquatic Plant Mgmt Low</th>
<th>Aquatic Plant Mgmt High</th>
<th>Rough Fish Mgmt Low</th>
<th>Rough Fish Mgmt High</th>
<th>Alum Treatment Low</th>
<th>Alum Treatment High</th>
<th>Total Low</th>
<th>Total High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaystock</td>
<td>50</td>
<td>250</td>
<td>100</td>
<td>175</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>425</td>
</tr>
<tr>
<td>Maria</td>
<td>10</td>
<td>100</td>
<td>25</td>
<td>100</td>
<td>50</td>
<td>100</td>
<td>85</td>
<td>300</td>
</tr>
<tr>
<td>Hazeltine</td>
<td>75</td>
<td>450</td>
<td>110</td>
<td>250</td>
<td>100</td>
<td>150</td>
<td>185</td>
<td>700</td>
</tr>
<tr>
<td>McKnight</td>
<td>15</td>
<td>50</td>
<td>85</td>
<td>225</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>425</td>
</tr>
<tr>
<td>Jonathan</td>
<td>15</td>
<td>50</td>
<td>85</td>
<td>250</td>
<td>100</td>
<td>150</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>Grace</td>
<td>15</td>
<td>75</td>
<td>85</td>
<td>250</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>475</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>180</strong></td>
<td><strong>975</strong></td>
<td><strong>490</strong></td>
<td><strong>1250</strong></td>
<td><strong>250</strong></td>
<td><strong>400</strong></td>
<td><strong>920</strong></td>
<td><strong>2625</strong></td>
</tr>
</tbody>
</table>
8.4 Adaptive Management

The WLAs and LAs for all lakes within this TMDL represent aggressive goals. Consequently, implementation will be conducted using adaptive management principles (Figure 8.1). The County will continue to monitor each lake to identify improvements and adapt implementation strategies accordingly. It is difficult to predict the nutrient reduction that would occur from implemented strategies because we do not know the exact contribution of each pollutant source to the lake, and many of the strategies affect more than one source. Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL.

Figure 8.1 Adaptive Management
9 Public Participation

The County has an excellent track record with inclusive participation of its citizens, as evidenced through the public participation in completion of the Carver County Water Management Plan. The County has utilized stakeholder meetings, citizen surveys, workshops and permanent citizen advisory committees to gather input from the public and help guide implementation activities. The use of this public participation structure has aided in the development of this and other TMDLs in the County.

The CCWMO Advisory Committee was established as a permanent advisory committee. The Committee is operated under the County’s standard procedures for advisory committees and works with staff to make recommendations to the County Board on matters relating to watershed planning.

The make-up of the CCWMO Advisory Committee is as follows.

- Five citizen representatives from Commissioner Districts: one from each district.
- One representative from the Soil and Water Conservation Board.
- Four citizen representatives from watersheds. One from each watershed.
- One representative from the Technical Advisory Committee

The Committee has received updates on Excess Nutrient TMDL processes since its inception in 2004.

TMDL progress, methods, data results and implementation procedures were presented and analyzed at various Committee meetings since 2008. Committee members commented on carp removal possibilities, sources, internal loading rates, and future monitoring plans. All issues commented on were considered in the development of the draft TMDL.

Early in the development of this TMDL, an MS4 stakeholder group was organized to discuss the TMDL. Representatives were present from the MnDOT, the City of Chaska, the City of Chanhassen, the City of Victoria, and Laketown Township. Two meetings were held on August 8, 2013, and February 12, 2014. In addition, opportunity for informal review of a draft TMDL was provided to these stakeholders and other regulated entities.

The Carver Six Lakes TMDL subsequently was made a part of the Lower Minnesota River (HUC-8) TMDL/WRAPS project, which addresses dozens of additional impaired lakes and stream reaches. The MPCA conducted stakeholder meetings for the Lower Minnesota River project – including coverage of the Carver Six Lakes TMDL – on August 27, 2017, and December 12, 2018. An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from July 22, 2019, through September 20, 2019. There were 12 comment letters received and responded to as a result of the public comment period.
10 Literature Cited


Carver County and Wenck Associates, Inc. 2005. Carver County Bacteria TMDL. Report to the MPCA.


http://www.mda.state.mn.us/animals/feedlots/feedlot-dmt/animalunitcalcwksht.aspx


MPCA, 2005. MPCA Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) and 303(d) List.
http://www.pca.state.mn.us/publications/wq-lw1-06.pdf

MPCA, 2006. Lake TMDL Protocols and Submittal Requirements Draft report 9/18/06.


Appendices

Appendix A - Lake Water Quality Summer Mean Data

Note: The base year for each lake’s TMDL (or downstream lake’s TMDL in the case of Big Woods and Bavaria lakes) is highlighted and bolded. Aue Lake has no monitoring data for the project period. A summary of biological data for the impaired lakes follows Table A.8.

### Table A.1 Gaystock Lake summer mean lake water quality.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Phosphorus Concentration (ug/L)</th>
<th>Chlorophyll-α Concentration (ug/L)</th>
<th>Secchi disk transparency (m)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Number of Observations^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>228</td>
<td>262</td>
<td>0.60</td>
<td>2.15</td>
<td>2</td>
</tr>
<tr>
<td>2000</td>
<td>498</td>
<td>245</td>
<td>0.40</td>
<td>2.94</td>
<td>8</td>
</tr>
<tr>
<td>2001</td>
<td>320</td>
<td>98</td>
<td>0.70</td>
<td>2.39</td>
<td>9</td>
</tr>
<tr>
<td>2005</td>
<td>232</td>
<td>212</td>
<td>0.20</td>
<td>3.79</td>
<td>9</td>
</tr>
<tr>
<td>2006</td>
<td>209</td>
<td>94</td>
<td>0.40</td>
<td>3.14</td>
<td>8</td>
</tr>
</tbody>
</table>

^a In 1999 there were no chlorophyll-α observations.

### Table A.2 Maria Lake summer mean lake water quality.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Phosphorus Concentration (ug/L)</th>
<th>Chlorophyll-α Concentration (ug/L)</th>
<th>Secchi disk transparency (m)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Number of Observations^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>155</td>
<td>69</td>
<td>0.90</td>
<td>2.15</td>
<td>2</td>
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<td>2000</td>
<td>411</td>
<td>222</td>
<td>0.54</td>
<td>5.04</td>
<td>9</td>
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<tr>
<td>2001</td>
<td>188</td>
<td>36</td>
<td>0.78</td>
<td>2.38</td>
<td>8</td>
</tr>
<tr>
<td>2005</td>
<td>186</td>
<td>92</td>
<td>0.62</td>
<td>2.94</td>
<td>9</td>
</tr>
</tbody>
</table>

^a In 2000 there were 12 Secchi disk observations.

### Table A.3 Hazeltine Lake summer mean lake water quality.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Phosphorus Concentration (ug/L)</th>
<th>Chlorophyll-α Concentration (ug/L)</th>
<th>Secchi disk transparency (m)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Number of Observations^a</th>
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</thead>
<tbody>
<tr>
<td>1999</td>
<td>150</td>
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<td>2.80</td>
<td>1</td>
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<tr>
<td>2000</td>
<td>186</td>
<td>152</td>
<td>0.30</td>
<td>3.30</td>
<td>9</td>
</tr>
<tr>
<td>2001</td>
<td>207</td>
<td>134</td>
<td>0.30</td>
<td>3.90</td>
<td>9</td>
</tr>
<tr>
<td>2005</td>
<td>173</td>
<td>232</td>
<td>0.30</td>
<td>4.30</td>
<td>9</td>
</tr>
<tr>
<td>2006</td>
<td>230</td>
<td>98</td>
<td>0.30</td>
<td>4.90</td>
<td>9</td>
</tr>
<tr>
<td>2009</td>
<td>296</td>
<td>328</td>
<td>0.20</td>
<td>5.90</td>
<td>9</td>
</tr>
<tr>
<td>2010</td>
<td>162</td>
<td>244</td>
<td>0.30</td>
<td>4.10</td>
<td>9</td>
</tr>
</tbody>
</table>

^a In 2010 there were 8 chlorophyll-α observations.
Table A.4 McKnight Lake summer mean lake water quality.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Phosphorus Concentration (ug/L)</th>
<th>Chlorophyll-α Concentration (ug/L)</th>
<th>Secchi disk transparency (m)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>171</td>
<td>77</td>
<td>0.40</td>
<td>1.90</td>
<td>9</td>
</tr>
<tr>
<td>2008</td>
<td>177</td>
<td>91</td>
<td>0.40</td>
<td>3.00</td>
<td>9</td>
</tr>
<tr>
<td>2009</td>
<td>231</td>
<td>115</td>
<td>0.30</td>
<td>3.40</td>
<td>9</td>
</tr>
<tr>
<td>2010</td>
<td>160</td>
<td>111</td>
<td>0.50</td>
<td>2.40</td>
<td>9</td>
</tr>
</tbody>
</table>

* In 2009 there were 8 total P and 8 TKN observations.

Table A.5 Lake Jonathan summer mean lake water quality.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Phosphorus Concentration (ug/L)</th>
<th>Chlorophyll-α Concentration (ug/L)</th>
<th>Secchi disk transparency (m)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>176</td>
<td>40</td>
<td>0.50</td>
<td>2.00</td>
<td>8</td>
</tr>
<tr>
<td>2006</td>
<td>184</td>
<td>70</td>
<td>0.40</td>
<td>2.10</td>
<td>9</td>
</tr>
<tr>
<td>2008</td>
<td>191</td>
<td>84</td>
<td>0.50</td>
<td>2.90</td>
<td>9</td>
</tr>
<tr>
<td>2009</td>
<td>202</td>
<td>104</td>
<td>0.30</td>
<td>2.70</td>
<td>9</td>
</tr>
<tr>
<td>2010</td>
<td>167</td>
<td>124</td>
<td>0.50</td>
<td>2.10</td>
<td>8</td>
</tr>
</tbody>
</table>

* In 2010 there were 9 chlorophyll-α observations.

Table A.6 Lake Grace summer mean lake water quality.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Phosphorus Concentration (ug/L)</th>
<th>Chlorophyll-α Concentration (ug/L)</th>
<th>Secchi disk transparency (m)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>203</td>
<td>35</td>
<td>0.70</td>
<td>2.00</td>
<td>8</td>
</tr>
<tr>
<td>2003</td>
<td>123</td>
<td>62</td>
<td>1.00</td>
<td>1.60</td>
<td>9</td>
</tr>
<tr>
<td>2004</td>
<td>91</td>
<td>20</td>
<td>1.00</td>
<td>1.40</td>
<td>8</td>
</tr>
<tr>
<td>2006</td>
<td>96</td>
<td>44</td>
<td>1.10</td>
<td>1.70</td>
<td>9</td>
</tr>
<tr>
<td>2008</td>
<td>90</td>
<td>44</td>
<td>0.90</td>
<td>2.40</td>
<td>9</td>
</tr>
<tr>
<td>2009</td>
<td>118</td>
<td>67</td>
<td>0.60</td>
<td>2.20</td>
<td>9</td>
</tr>
<tr>
<td>2010</td>
<td>124</td>
<td>63</td>
<td>1.10</td>
<td>1.90</td>
<td>9</td>
</tr>
</tbody>
</table>

* In 2004 there were 9 chlorophyll-α observations.

Table A.7 Big Woods Lake (non-assessed) summer mean water quality.

<table>
<thead>
<tr>
<th>Year*</th>
<th>Total Phosphorus Concentration (ug/L)</th>
<th>Chlorophyll-α** Concentration (ug/L)</th>
<th>Secchi disk transparency (m)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>119</td>
<td>100</td>
<td>0.51</td>
<td>2.0</td>
<td>8</td>
</tr>
<tr>
<td>2015</td>
<td>360</td>
<td>269</td>
<td>0.11</td>
<td>4.5</td>
<td>10</td>
</tr>
</tbody>
</table>

* Base year for downstream lake 2009.
 ** Chlorophyll-α is not corrected for phaeophytin.
Table A.8 Lake Bavaria (non-impaired) summer mean water quality.

<table>
<thead>
<tr>
<th>Year*</th>
<th>Total Phosphorus Concentration (ug/L)</th>
<th>Chlorophyll-α** Concentration (ug/L)</th>
<th>Secchi disk transparency (m)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Number of Observations a–d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>42.5</td>
<td>35.5</td>
<td>1.63</td>
<td>1.95</td>
<td>4</td>
</tr>
<tr>
<td>1986</td>
<td>33.9</td>
<td>24.9</td>
<td>2.00</td>
<td>1.19</td>
<td>9</td>
</tr>
<tr>
<td>1987</td>
<td>35.0</td>
<td>23.8</td>
<td>2.06</td>
<td>1.11</td>
<td>9</td>
</tr>
<tr>
<td>1994</td>
<td>30.0</td>
<td>10.9</td>
<td>2.24</td>
<td>1.04</td>
<td>8</td>
</tr>
<tr>
<td>1996</td>
<td>32.5</td>
<td>9.0</td>
<td>2.13</td>
<td>1.10</td>
<td>8</td>
</tr>
<tr>
<td>1997a</td>
<td>15.0</td>
<td>8.0</td>
<td>2.47</td>
<td>0.95</td>
<td>10</td>
</tr>
<tr>
<td>1998</td>
<td>22.2</td>
<td>15.0</td>
<td>2.55</td>
<td>0.90</td>
<td>9</td>
</tr>
<tr>
<td>1999</td>
<td>22.5</td>
<td>10.1</td>
<td>2.10</td>
<td>0.91</td>
<td>10</td>
</tr>
<tr>
<td>2000</td>
<td>26.0</td>
<td>13.2</td>
<td>2.03</td>
<td>0.89</td>
<td>10</td>
</tr>
<tr>
<td>2001</td>
<td>25.2</td>
<td>10.8</td>
<td>1.95</td>
<td>1.06</td>
<td>9</td>
</tr>
<tr>
<td>2002</td>
<td>29.5</td>
<td>9.3</td>
<td>1.85</td>
<td>0.99</td>
<td>12</td>
</tr>
<tr>
<td>2003b</td>
<td>21.9</td>
<td>16.1</td>
<td>1.49</td>
<td>1.47</td>
<td>11</td>
</tr>
<tr>
<td>2006</td>
<td>24.6</td>
<td>14.3</td>
<td>1.73</td>
<td>1.16</td>
<td>10</td>
</tr>
<tr>
<td>2007</td>
<td>39.6</td>
<td>10.9</td>
<td>1.95</td>
<td>1.38</td>
<td>10</td>
</tr>
<tr>
<td>2010d</td>
<td>30.5</td>
<td>17.3</td>
<td>1.20</td>
<td>1.36</td>
<td>10</td>
</tr>
</tbody>
</table>

Notes:

* Base year for downstream lake 2009.
** Chlorophyll-α is not corrected for phaeophytin.
a In 1997 there were 9 chlorophyll-α observations.
b In 2003 there were 11 chlorophyll-α observations.
c In 2005 there were 9 chlorophyll-α observations.
d In 2010 there were 8 chlorophyll-α observations.

Biological Data for Impaired lakes

Fish Populations and Fish Health

The DNR conducts fish surveys on lakes in the region and around the state on a periodic basis. The DNR usually uses either trap, effective for bluegills, nets or gill nets, better for walleyes and northern pike. The DNR also sometimes uses electrofishing, which is better for evaluating bass abundances and population size structures; however, this requires extra field effort and different equipment. The DNR’s LakeFinder website (www.dnr.state.mn.us/lakefind/index.html) highlights recent surveys on most lakes. Detailed information on the lakes discussed below also can be requested through the Carver County Water Management Organization.

The DNR does not provide fisheries information for Gaystock Lake, as it lacks a public access. Maria Lake has had fish kills (mainly winterkills), the latest of which occurred during the winter of 2000-2001. Fish kills occur because of asphyxiation when dissolved oxygen drops to very low levels. However, different fish species have different oxygen requirements. Hardier fish such as carp and bullheads, for example, can survive low dissolved oxygen when most or all other fish species die off.
The DNR conducted a fish survey for Hazeltine Lake in 2000, in which they identified three species: black bullhead, bluegill, and green sunfish. DNR publications indicate that Hazeltine Lake suffers periodic winterkills, and these have probably reduced the diversity of Hazeltine Lake’s fishery. Fisheries information is unavailable for McKnight or Jonathan lakes. A DNR full fish survey of Grace Lake in 1998 identified nine species. There appears to be no evidence of winterkills in Grace Lake.

**Aquatic Plants**

Aquatic plants benefit lakes by providing spawning and cover for fish, habitat for macroinvertebrates, refuge for prey, and stabilization of sediments. However, in excess they limit recreational activities such as boating and swimming as well as aesthetic appreciation.

Carver County staff conducted simplified macrophyte surveys in 2006 on Gaystock Lake (fall), Maria (spring), and Hazeltine (spring and fall). In Gaystock Lake, county staff found macrophytes only in low abundance. Staff characterized the lake bottom as largely sandy and rocky. Maria Lake exhibited low aquatic-plant diversity. Hazeltine Lake had low macrophyte abundance except for curly-leaf pondweed, an invasive exotic. County staff found much of the lake bottom to be mucky.

**Shoreline Habitat**

In addition to providing fish habitat – including spawning areas and refuges – and wildlife habitat, natural shorelines stabilize erosion and improve runoff water quality. Restoring and protecting natural shoreline habitat can enhance a lake’s overall ecological health. CCWMO staff classified shoreline land use for the impaired lakes in this study using aerial images, GPS-based field investigations, and local knowledge of shorelines.

Gaystock and Maria lakes, in the west and southwest parts of the county, both have 100% natural shorelines featuring cattail fringes. However, both lakes have nearby agricultural areas.

The shorelines of the impaired lakes in the Grace chain have mostly natural vegetation, ranging from 51% (Grace Lake) to 64% (Hazeltine Lake). Hazeltine National Golf Club borders 14% of Hazeltine Lake’s shoreline, and lawn turf occupies another 14%. A bike path borders all or most of the remaining shorelines of McKnight, Jonathan, and Grace lakes.
Appendix B - Lake Phosphorus BATHTUB Models for Baseline Conditions

Note: BATHTUB outputs here omit unnecessary items and are compactly reformatted.

**Universal input values**

The six impaired Carver County lakes plus three upstream/intermediate lakes all have the following input values in common:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Model Options</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Averaging Period (yrs)</td>
<td>1</td>
<td>Phosphorus Balance</td>
<td>8</td>
<td>CANF &amp; BACH, LAKES</td>
</tr>
<tr>
<td>Storage Increase (m)</td>
<td>0</td>
<td>Phosphorus Calibration</td>
<td>1</td>
<td>DECAY RATES</td>
</tr>
<tr>
<td>Atmos. P Load (kg/km²-yr)</td>
<td>42</td>
<td>Mass-Balance Tables</td>
<td>1</td>
<td>USE ESTIMATED CONCS</td>
</tr>
</tbody>
</table>

Annual precipitation and evaporation vary by subwatershed:

<table>
<thead>
<tr>
<th>Subwatershed</th>
<th>Precipitation</th>
<th>Evaporation</th>
<th>Included lakes (parentheses mark upstream/intermediate lakes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Chaska Ck</td>
<td>0.7394</td>
<td>0.7000</td>
<td>(Aue) &amp; Gaystock</td>
</tr>
<tr>
<td>Bevens Ck</td>
<td>0.7394</td>
<td>0.7000</td>
<td>Maria</td>
</tr>
<tr>
<td>East Chaska Ck</td>
<td>0.8016</td>
<td>0.8000</td>
<td>Hazeltine, McKnight, (Big Woods), (Bavaria), Jonathan, &amp; Grace</td>
</tr>
</tbody>
</table>

Bathtub accommodates five tributary types, but the models here use only two of these:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>catchment or upstream waterbody - concentration and flow/outflow specified</td>
</tr>
<tr>
<td>3</td>
<td>wastewater discharge - concentration and flow specified</td>
</tr>
</tbody>
</table>
**West Chaska Creek Lakes**

**Aue 2001**

C:\Users\jerdman\Desktop\BATHTUB models 2018\Aue cal 2001_JBE_2018-01-09.btb

**Aue 2001 Input Data**

<table>
<thead>
<tr>
<th>Seg</th>
<th>Name</th>
<th>Area (km²)</th>
<th>Depth (m)</th>
<th>Length (km)</th>
<th>Mixed Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aue</td>
<td>0.139</td>
<td>4.23</td>
<td>0.70</td>
<td>4.00</td>
</tr>
</tbody>
</table>

**Calibration Data**

<table>
<thead>
<tr>
<th>Seg</th>
<th>TP Calibration Factor</th>
<th>Internal P Load (mg/m²-day)</th>
<th>Observed TP (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2.82</td>
<td>--</td>
</tr>
</tbody>
</table>

**Tributary Data**

<table>
<thead>
<tr>
<th>Trib</th>
<th>Trib Name</th>
<th>Type</th>
<th>Dr Area (km²)</th>
<th>Flow (hm³/yr)</th>
<th>Total P (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lakeshed runoff</td>
<td>1</td>
<td>1.773</td>
<td>0.171</td>
<td>545</td>
</tr>
<tr>
<td>2</td>
<td>Septics</td>
<td>3</td>
<td>0</td>
<td>0.0001</td>
<td>52,825</td>
</tr>
</tbody>
</table>

**Aue 2001 Mass Balance Results**

<table>
<thead>
<tr>
<th>Name</th>
<th>Area (km²)</th>
<th>Flow (hm³/yr)</th>
<th>Conc (mg/m³)</th>
<th>Load (kg/yr)</th>
<th>Runoff (m/yr)</th>
<th>Export (kg/km²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakeshed runoff</td>
<td>1.773</td>
<td>0.171</td>
<td>545.0</td>
<td>93.2</td>
<td>0.10</td>
<td>52.6</td>
</tr>
<tr>
<td>Septics</td>
<td>0.00010</td>
<td></td>
<td>52,825</td>
<td>5.3</td>
<td></td>
<td>42.0</td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.139</td>
<td>0.103</td>
<td>56.8</td>
<td>5.8</td>
<td>0.74</td>
<td>42.0</td>
</tr>
<tr>
<td>Internal Load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>143.2</td>
</tr>
<tr>
<td><strong>Total Inflow</strong></td>
<td><strong>1.912</strong></td>
<td><strong>0.274</strong></td>
<td><strong>903.6</strong></td>
<td><strong>247.5</strong></td>
<td><strong>0.14</strong></td>
<td><strong>129.4</strong></td>
</tr>
<tr>
<td>Outflow</td>
<td>1.912</td>
<td>0.177</td>
<td>146.2</td>
<td>25.8</td>
<td>0.09</td>
<td>13.5</td>
</tr>
<tr>
<td>Evaporation</td>
<td></td>
<td>0.097</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>221.7</td>
</tr>
</tbody>
</table>
Gaystock 2001

Gaystock 2001 Input Data

<table>
<thead>
<tr>
<th>Segment Morphometry</th>
<th>Area</th>
<th>Depth</th>
<th>Length</th>
<th>Mixed Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seg</strong></td>
<td><strong>Name</strong></td>
<td><strong>km²</strong></td>
<td><strong>m</strong></td>
<td><strong>km</strong></td>
</tr>
<tr>
<td>1</td>
<td>Gaystock</td>
<td>0.186</td>
<td>2.10</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Calibration Data

<table>
<thead>
<tr>
<th>Seg</th>
<th>TP Calibration Factor</th>
<th>Internal P Load mg/m²-day</th>
<th>Observed TP ug/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>4.48</td>
<td>320</td>
</tr>
</tbody>
</table>

Tributary Data

<table>
<thead>
<tr>
<th>Trib</th>
<th>Trib Name</th>
<th>Type</th>
<th>Dr Area</th>
<th>Flow</th>
<th>Total P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lakeshed runoff</td>
<td>1</td>
<td>11.558</td>
<td>1.547</td>
<td>606</td>
</tr>
<tr>
<td>2</td>
<td>Aue Lake outflow</td>
<td>1</td>
<td>1.912</td>
<td>0.177</td>
<td>146</td>
</tr>
<tr>
<td>3</td>
<td>Laketown CWWTP</td>
<td>3</td>
<td>0</td>
<td>0.00346</td>
<td>2,300</td>
</tr>
<tr>
<td>4</td>
<td>Septics</td>
<td>3</td>
<td>0</td>
<td>0.00010</td>
<td>11,739</td>
</tr>
<tr>
<td>5</td>
<td>Feedlots</td>
<td>3</td>
<td>0</td>
<td>0.00017</td>
<td>800,000</td>
</tr>
</tbody>
</table>

Gaystock 2001 Mass Balance Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Area</th>
<th>Flow</th>
<th>Conc</th>
<th>Load</th>
<th>Runoff</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakeshed runoff</td>
<td>11.558</td>
<td>1.547</td>
<td>606</td>
<td>937</td>
<td>0.13</td>
<td>81.1</td>
</tr>
<tr>
<td>Aue Lake outflow</td>
<td>1.912</td>
<td>0.177</td>
<td>146</td>
<td>26</td>
<td>0.09</td>
<td>13.5</td>
</tr>
<tr>
<td>Laketown CWWTP</td>
<td>0.00346</td>
<td>2,300</td>
<td>8.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septics</td>
<td>0.00010</td>
<td>11,739</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedlots</td>
<td>0.00017</td>
<td>800,000</td>
<td>136</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.186</td>
<td>0.138</td>
<td>57</td>
<td>7.8</td>
<td>0.74</td>
<td>42.0</td>
</tr>
<tr>
<td>Internal Load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>304</td>
<td></td>
</tr>
<tr>
<td><strong>Total Inflow</strong></td>
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Bevens Creek Lake

Maria 2001

Maria 2001 Input Data

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Calibration Data

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### East Chaska Creek Lakes

**Hazeltine 2009**

C:\Users\jerdman\Desktop\BATHTUB models 2018\Hazeltine cal 2009_JBE_2018-05-22.btb

**Hazeltine 2009 Input Data**

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**Calibration Data**

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<th>Observed TP (ug/L)</th>
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**Tributary Data**

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<th>Flow (hm³/yr)</th>
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**Hazeltine 2009 Mass Balance Results**

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<th>Runoff (m/yr)</th>
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### Big Woods 2009

**C:\Users\jerdman\Desktop\BATHTUB models 2018\Big Woods cal 2009_JBE_2018-01-10.btb**

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#### Tributary Data

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#### Big Woods 2009 Mass Balance Results

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### Bavaria 2009

**C:\Users\jerdman\Desktop\BATHTUB models 2018\Bavaria cal 2009_JBE_2018-01-09.btb**

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Lower Minnesota River Watershed TMDLs: Part III

Minnesota Pollution Control Agency

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### Bavaria 2009 Mass Balance Results

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### McKnight 2009 Input Data

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#### Calibration Data

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#### Tributary Data

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<th>Trib Name</th>
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<td>0.605</td>
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### McKnight 2009 Mass Balance Results

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<td>3.153</td>
<td>231.0</td>
<td>728.3</td>
<td>0.21</td>
<td>48.4</td>
</tr>
<tr>
<td>Evaporation</td>
<td></td>
<td>0.074</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td></td>
<td></td>
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<td></td>
<td>227.5</td>
</tr>
</tbody>
</table>
Jonathan 2009

C:\Users\jerdman\Desktop\BATHTUB models 2018\Jonathan cal 2009_JBE_2018-06-22.btb

Jonathan 2009 Input Data

<table>
<thead>
<tr>
<th>Seg Name</th>
<th>Area (km²)</th>
<th>Depth (m)</th>
<th>Length (km)</th>
<th>Mixed Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Jonathan</td>
<td>0.093</td>
<td>0.46</td>
<td>0.7</td>
<td>0.45</td>
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Calibration Data

<table>
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<th>TP Calibration Factor</th>
<th>Internal P Load (mg/m²-day)</th>
<th>Observed TP (ug/L)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>0.62</td>
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Tributary Data

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<th>Dr Area (km²)</th>
<th>Flow (hm³/yr)</th>
<th>Total P (ug/L)</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>McKnight Outflow</td>
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<td>15.042</td>
<td>231</td>
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Jonathan 2009 Mass Balance Results

<table>
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<th>Area (km²)</th>
<th>Flow (hm³/yr)</th>
<th>Conc (mg/m³)</th>
<th>Load (kg/yr)</th>
<th>Runoff (m/yr)</th>
<th>Export (kg/km²/yr)</th>
</tr>
</thead>
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<td>70.5</td>
</tr>
<tr>
<td>McKnight Outflow</td>
<td>15.042</td>
<td>3.153</td>
<td>231.0</td>
<td>728.3</td>
<td>0.21</td>
<td>48.4</td>
</tr>
<tr>
<td>Precipation</td>
<td>0.093</td>
<td>0.075</td>
<td>52.4</td>
<td>3.9</td>
<td>0.80</td>
<td>42.0</td>
</tr>
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<td>Total Inflow</td>
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<td>51.2</td>
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<tr>
<td>Outflow</td>
<td>16.246</td>
<td>3.478</td>
<td>202.0</td>
<td>702.7</td>
<td>0.21</td>
<td>43.3</td>
</tr>
<tr>
<td>Evaporation</td>
<td></td>
<td>0.074</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
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Grace 2009

C:\Users\jerdman\Desktop\BATHTUB models 2018\Grace cal 2009_JBE_2018-06-22.btb

Grace 2009 Input Data

<table>
<thead>
<tr>
<th>Seg Name</th>
<th>Area (km²)</th>
<th>Depth (m)</th>
<th>Length (km)</th>
<th>Mixed Depth (m)</th>
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</thead>
<tbody>
<tr>
<td>1 Grace</td>
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<td>0.550</td>
<td>3.00</td>
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</table>

Calibration Data

<table>
<thead>
<tr>
<th>Seg</th>
<th>TP Calibration Factor</th>
<th>Internal P Load (mg/m²-day)</th>
<th>Observed TP (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0</td>
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</table>

Tributary Data

<table>
<thead>
<tr>
<th>Trib Name</th>
<th>Dr Area (km²)</th>
<th>Flow (hm³/yr)</th>
<th>Total P (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakeshed runoff</td>
<td>1</td>
<td>0.124</td>
<td>221</td>
</tr>
<tr>
<td>Jonathan Outflow</td>
<td>1</td>
<td>16.246</td>
<td>202</td>
</tr>
</tbody>
</table>

Grace 2009 Mass Balance Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Area (km²)</th>
<th>Flow (hm³/yr)</th>
<th>Conc (mg/m³)</th>
<th>Load (kg/yr)</th>
<th>Runoff (m/yr)</th>
<th>Export (kg/km²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakeshed runoff</td>
<td>0.361</td>
<td>0.124</td>
<td>221.0</td>
<td>27.4</td>
<td>0.34</td>
<td>75.9</td>
</tr>
<tr>
<td>Jonathan Outflow</td>
<td>16.246</td>
<td>3.478</td>
<td>202.0</td>
<td>702.6</td>
<td>0.21</td>
<td>43.2</td>
</tr>
<tr>
<td>Precipitation</td>
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<td>0.0648</td>
<td>52.4</td>
<td>3.4</td>
<td>0.80</td>
<td>42.0</td>
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<td>Total Inflow</td>
<td>16.688</td>
<td>3.667</td>
<td>200.0</td>
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<td>3.602</td>
<td>118.0</td>
<td>425.1</td>
<td>0.22</td>
<td>25.5</td>
</tr>
<tr>
<td>Evaporation</td>
<td></td>
<td>0.0647</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Retention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>308.3</td>
</tr>
</tbody>
</table>
Appendix C – Lake Phosphorus BATHTUB Models for TMDL Conditions

Note: BATHTUB outputs here omit unnecessary items and are compactly reformatted.

**Universal input values**

The six impaired Carver County lakes plus three upstream/intermediate lakes all have the following input values in common:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Model Options</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Averaging Period (yrs)</td>
<td>1</td>
<td>Phosphorus Balance</td>
<td>8</td>
<td>CANF &amp; BACH, LAKES</td>
</tr>
<tr>
<td>Storage Increase (m)</td>
<td>0</td>
<td>Phosphorus Calibration</td>
<td>1</td>
<td>DECAY RATES</td>
</tr>
<tr>
<td>Atmos. P Load (kg/km²-yr)</td>
<td>42</td>
<td>Mass-Balance Tables</td>
<td>1</td>
<td>USE ESTIMATED CONCS</td>
</tr>
</tbody>
</table>

Annual precipitation and evaporation vary by subwatershed:

<table>
<thead>
<tr>
<th>Subwatershed</th>
<th>Precipitation meter/yr</th>
<th>Evaporation meter/yr</th>
<th>Included lakes (parentheses mark upstream/intermediate lakes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Chaska Ck</td>
<td>0.7394</td>
<td>0.7000</td>
<td>(Aue) &amp; Gaystock</td>
</tr>
<tr>
<td>Bevens Ck</td>
<td>0.7394</td>
<td>0.7000</td>
<td>Maria</td>
</tr>
<tr>
<td>East Chaska Ck</td>
<td>0.8016</td>
<td>0.8000</td>
<td>Hazeltine, McKnight, (Big Woods), (Bavaria), Jonathan, &amp; Grace</td>
</tr>
</tbody>
</table>

Bathtub accommodates five tributary types, but the models here use only two of these:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>catchment or upstream waterbody - concentration and flow/outflow specified</td>
</tr>
<tr>
<td>3</td>
<td>wastewater discharge - concentration and flow specified</td>
</tr>
</tbody>
</table>

**West Chaska Creek Lakes**

Aue at standard

C:\Users\jerdman\Desktop\BATHTUB models 2018\Aue at standard_JBE_2018-01-16.btb

Aue at standard Input Data

<table>
<thead>
<tr>
<th>Seg</th>
<th>Segment Morphometry</th>
<th>Area</th>
<th>Depth</th>
<th>Length</th>
<th>Mixed Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Name</td>
<td>km²</td>
<td>m</td>
<td>km</td>
<td>m</td>
</tr>
<tr>
<td>1</td>
<td>Aue</td>
<td>0.139</td>
<td>4.23</td>
<td>0.70</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Calibration Data

<table>
<thead>
<tr>
<th>Seg</th>
<th>TP Calibration Factor</th>
<th>Internal P Load mg/m²-day</th>
<th>TP Standard ug/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>40</td>
</tr>
</tbody>
</table>

Tributary Data

<table>
<thead>
<tr>
<th>Trib</th>
<th>Trib Name</th>
<th>Type</th>
<th>Dr Area</th>
<th>Flow</th>
<th>Total P ug/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lakeshed runoff</td>
<td>1</td>
<td>1.773</td>
<td>0.171</td>
<td>126.5</td>
</tr>
<tr>
<td>2</td>
<td>Septics</td>
<td>3</td>
<td>0</td>
<td>0.0001</td>
<td>27,229</td>
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</tbody>
</table>

Aue at standard Mass Balance Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Area</th>
<th>Flow</th>
<th>Conc</th>
<th>Load</th>
<th>Runoff</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakeshed runoff</td>
<td>1.773</td>
<td>0.171</td>
<td>126.5</td>
<td>21.6</td>
<td>0.10</td>
<td>12.2</td>
</tr>
<tr>
<td>Septics</td>
<td>0.0001</td>
<td>27,229</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.139</td>
<td>0.103</td>
<td>56.8</td>
<td>5.8</td>
<td>0.74</td>
<td>42.0</td>
</tr>
<tr>
<td>Internal Load</td>
<td>0.097</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Inflow</strong></td>
<td>1.912</td>
<td>0.274</td>
<td>110.2</td>
<td>30.2</td>
<td>0.14</td>
<td>15.8</td>
</tr>
<tr>
<td>Outflow</td>
<td>1.912</td>
<td>0.177</td>
<td>40.0</td>
<td>7.1</td>
<td>0.09</td>
<td>3.7</td>
</tr>
<tr>
<td>Evaporation</td>
<td>0.097</td>
<td>0</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Retention</strong></td>
<td>23.1</td>
<td></td>
<td></td>
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</tr>
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</table>
Gaystock TMDL

C:\Users\jerdman\Desktop\BATHTUB models 2018\Gaystock cal 2001_JBE_2018-05-23.btb

Gaystock TMDL Input Data

<table>
<thead>
<tr>
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<th>Name</th>
<th>Area (km²)</th>
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<th>Length (km)</th>
<th>Mixed Depth (m)</th>
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<tbody>
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<td>1</td>
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<td>0.50</td>
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Calibration Data

<table>
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<th>Seg</th>
<th>TP Calibration Factor</th>
<th>Internal P Load (mg/m²-day)</th>
<th>TP Standard (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>60</td>
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Tributary Data

<table>
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<tr>
<th>Trib</th>
<th>Trib Name</th>
<th>Type</th>
<th>Dr Area (km²)</th>
<th>Flow (hm³/yr)</th>
<th>Total P (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lakeshed runoff</td>
<td>1</td>
<td>11.558</td>
<td>1.547</td>
<td>70.7</td>
</tr>
<tr>
<td>2</td>
<td>Aue Lake outflow</td>
<td>1</td>
<td>1.912</td>
<td>0.177</td>
<td>40</td>
</tr>
<tr>
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<td>Laketown CWWTP</td>
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<td>0.00802</td>
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<tr>
<td>4</td>
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<td>6,051</td>
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<tr>
<td>5</td>
<td>Feedlots</td>
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<td>0.000170</td>
<td>100,000</td>
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Gaystock TMDL Mass Balance Results

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<th>Conc (mg/m³)</th>
<th>Load (kg/yr)</th>
<th>Runoff (kg/yr)</th>
<th>Export (kg/km²/yr)</th>
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</thead>
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<td>Lakeshed runoff</td>
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<td>1.547</td>
<td>71</td>
<td>109</td>
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<td>9.5</td>
</tr>
<tr>
<td>Aue Lake outflow</td>
<td>1.912</td>
<td>0.177</td>
<td>40</td>
<td>7.1</td>
<td>0.09</td>
<td>3.7</td>
</tr>
<tr>
<td>Laketown CWWTP</td>
<td>0.00802</td>
<td>2,868</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septics</td>
<td>0.00010</td>
<td>6,051</td>
<td>0.6</td>
<td></td>
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<td></td>
</tr>
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</tr>
<tr>
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<td>57</td>
<td>7.8</td>
<td>0.74</td>
<td>42.0</td>
</tr>
<tr>
<td>Internal Load</td>
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</tr>
<tr>
<td>Total Inflow</td>
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<td>12.1</td>
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<td>Outflow</td>
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<td>104</td>
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<td>7.6</td>
</tr>
<tr>
<td>Evaporation</td>
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<tr>
<td>Retention</td>
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<td>61</td>
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</tbody>
</table>

Bevens Creek Lake

Maria TMDL

C:\Users\jerdman\Desktop\BATHTUB models 2018\Maria TMDL_JBE_2018-01-12.btb

Maria TMDL Input Data

<table>
<thead>
<tr>
<th>Seg</th>
<th>Name</th>
<th>Area (km²)</th>
<th>Depth (m)</th>
<th>Length (km)</th>
<th>Mixed Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maria Lake</td>
<td>0.680</td>
<td>1.07</td>
<td>1.00</td>
<td>1.07</td>
</tr>
</tbody>
</table>

Calibration Data

<table>
<thead>
<tr>
<th>Seg</th>
<th>TP Calibration Factor</th>
<th>Internal P Load (mg/m²-day)</th>
<th>TP Standard (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>60</td>
</tr>
</tbody>
</table>

Tributary Data

<table>
<thead>
<tr>
<th>Trib</th>
<th>Trib Name</th>
<th>Type</th>
<th>Dr Area (km²)</th>
<th>Flow (hm³/yr)</th>
<th>Total P (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lakeshed runoff</td>
<td>1</td>
<td>1.047</td>
<td>0.167</td>
<td>150.0</td>
</tr>
<tr>
<td>2</td>
<td>Septics</td>
<td>3</td>
<td>0</td>
<td>0.00010</td>
<td>12,102</td>
</tr>
<tr>
<td>3</td>
<td>Feedlots</td>
<td>3</td>
<td>0</td>
<td>0.000045</td>
<td>300,000</td>
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</tbody>
</table>
Maria TMDL Mass Balance Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Area</th>
<th>Flow</th>
<th>Conc</th>
<th>Load</th>
<th>Runoff</th>
<th>Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakeshed runoff</td>
<td>1.047</td>
<td>0.167</td>
<td>150.0</td>
<td>25.0</td>
<td>0.16</td>
<td>23.9</td>
</tr>
<tr>
<td>Septics</td>
<td>0.00010</td>
<td>12,102</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedlots</td>
<td>0.000045</td>
<td>300,000</td>
<td>13.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.680</td>
<td>0.503</td>
<td>56.8</td>
<td>28.6</td>
<td>0.74</td>
<td>42.0</td>
</tr>
<tr>
<td>Internal Load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Total Inflow</strong></td>
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*East Chaska Creek Lakes*

Hazeltine TMDL

C:\Users\jerdman\Desktop\BATHTUB models 2018\Hazeltine TMDL_JBE_2018-05-23.btb

Hazeltine TMDL Input Data

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Hazeltine 2009 Mass Balance Results

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Big Woods at standard
C:\Users\jerdman\Desktop\BATHTUB models 2018\Big Woods at standard_JBE_2018-02-20.btb

Big Woods at standard Input Data

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Calibration Data

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Tributary Data

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Big Woods at standard Mass Balance Results

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Bavaria for TMDL
C:\Users\jerdman\Desktop\BATHTUB models 2018\Bavaria for TMDL_JBE_2018-01-12.btb

Bavaria for TMDL Input Data

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Calibration Data

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Tributary Data

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### Bavaria for TMDL Mass Balance Results

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### McKnight TMDL

C:\Users\jerdman\Desktop\BATHTUB models 2018\McKnight TMDL_JBE_2018-05-29.btb

### McKnight TMDL Input Data

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### Calibration Data

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### Tributary Data

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### McKnight TMDL Mass Balance Results

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<th>Load (kg/yr)</th>
<th>Runoff (m/yr)</th>
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<td>5.977</td>
<td>1.162</td>
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<td>108.5</td>
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<td>14.0</td>
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<tr>
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<td>0.605</td>
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Jonathan TMDL
C:\Users\jerdman\Desktop\BATHTUB models 2018\Jonathan TMDL_JBE_2018-05-30.btb

Jonathan TMDL Input Data

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Tributary Data

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Jonathan TMDL Mass Balance Results

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<td>60.0</td>
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Grace TMDL
C:\Users\jerdman\Desktop\BATHTUB models 2018\Grace TMDL_JBE_2018-06-25.btb

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Calibration Data

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Tributary Data

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<th>Trib Name</th>
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Grace TMDL Mass Balance Results

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<th>Conc (mg/m³)</th>
<th>Load (kg/yr)</th>
<th>Runoff (m/yr)</th>
<th>Export (kg/km²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakeshed runoff</td>
<td>0.361</td>
<td>0.124</td>
<td>221.0</td>
<td>27.4</td>
<td>0.34</td>
<td>75.9</td>
</tr>
<tr>
<td>Jonathan Outflow</td>
<td>16.246</td>
<td>3.467</td>
<td>60.0</td>
<td>208.0</td>
<td>0.21</td>
<td>12.8</td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.081</td>
<td>0.065</td>
<td>52.4</td>
<td>3.4</td>
<td>0.80</td>
<td>42.0</td>
</tr>
<tr>
<td><strong>Total Inflow</strong></td>
<td><strong>16.688</strong></td>
<td><strong>3.656</strong></td>
<td><strong>65.3</strong></td>
<td><strong>238.8</strong></td>
<td><strong>0.22</strong></td>
<td><strong>14.3</strong></td>
</tr>
<tr>
<td>Outflow</td>
<td>16.688</td>
<td>3.591</td>
<td>46.3</td>
<td>166.4</td>
<td>0.22</td>
<td>10.0</td>
</tr>
<tr>
<td>Evaporation</td>
<td></td>
<td>0.065</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>72.4</td>
</tr>
</tbody>
</table>
Appendix D – MS4 Area Maps
Figure D.1 Gaystock Lake MS4 Areas
Figure D.3 McKnight Lake MS4 Areas [See Figure D.6 for updates in northwest part of lakeshed]
Figure D.4 Jonathan Lake MS4 Areas
Figure D.5 Lake Grace MS4 Areas
Figure D.6 McKnight Lake Area Updates – Extreme West of Lakeshed and Victoria MS4

Note: Pale purple area conforms to Figure D.3 lakeshed boundary (yellow Line). Green area updates local Victoria MS4 boundary and lakeshed boundary.
### Table D-1. City of Victoria Updates for Victoria MS4 Area in McKnight Lakeshed

<table>
<thead>
<tr>
<th>Description</th>
<th>Portion of Victoria MS4 area/Reference</th>
<th>McKnight Lakeshed Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W 86th St - Bavaria Rd vicinity</td>
<td>North side of W 82nd St</td>
</tr>
<tr>
<td></td>
<td>Figure D-6 green area</td>
<td>Figure D-3</td>
</tr>
<tr>
<td>Carver County 2014</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Updated MS4 area</td>
<td>75</td>
<td>4</td>
</tr>
</tbody>
</table>

### Table D-2. McKnight Lakeshed Area Update

<table>
<thead>
<tr>
<th>Description</th>
<th>Lake shed Area, ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Figure 3.10, Legend*</td>
<td>1,504</td>
</tr>
</tbody>
</table>

*City of Victoria updates, Apr 2018:*

<table>
<thead>
<tr>
<th>Additions</th>
<th>Subtractions</th>
<th>Net change</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-37</td>
<td>-27</td>
</tr>
</tbody>
</table>

Updated current area 1,477

* Sum of land use subtotals (1,527 ac), less lake area (23 ac).

### Table D-3. McKnight Lakeshed 2005 Land Use Updated

<table>
<thead>
<tr>
<th>Description</th>
<th>Land Use Areas, acres</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Agriculture</td>
</tr>
<tr>
<td>Per Figure 3.10 Legend</td>
<td>477</td>
</tr>
<tr>
<td>McKnight Lake area</td>
<td>23</td>
</tr>
<tr>
<td>Water, lakeshed area less lake area</td>
<td>477</td>
</tr>
</tbody>
</table>

*City of Victoria updates, Apr 2018:*

<table>
<thead>
<tr>
<th>Additions</th>
<th>Subtractions</th>
<th>Net change</th>
</tr>
</thead>
<tbody>
<tr>
<td>-9</td>
<td>-29</td>
<td>-37</td>
</tr>
</tbody>
</table>

Updated McKnight lakeshed 477 180 656 147 17 1,477