Watershed

February 2020

Lower Minnesota River Watershed Total Maximum Daily Load Report

Part III—Northern Watersheds: Carver County Six Lakes

MINNESOTA POLLUTION CONTROL AGENCY

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CLEAN WATER LAND & LEGACY AMENDMENT

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List of Tables

List of Figures

Acronyms

ac-ft/yr	acre feet per year
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CAMP	Citizens Assisted Monitoring Program
CCWMO	Carver County Watershed Management Organization
Chl-*a*	chlorophyll-*a*
DNR	Minnesota Department of Natural Resources
EPA	U.S. Environmental Protection Agency
ft	feet
HSPF	Hydrologic Simulation Program-Fortran
km^2	square kilometer
LA	load allocation
lb	pound
lb/day	pounds per day
lb/yr	pounds per year
m	meter
MCES	Metropolitan Council Environmental Services
mg/L	milligrams per liter
mg/m^2-day	milligrams per square meter per day
MnDOT	Minnesota Department of Transportation
MOS	margin of safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NCHF	North Central Hardwood Forest
NPDES	National Pollutant Discharge Elimination System
P	phosphorus
RC	reserve capacity
RO	reverse osmosis
SSTS	Subsurface Sewage Treatment System
SWPPP	Stormwater Pollution Prevention Plan
TMDL	total maximum daily load
TP	total phosphorus
µg/L	micrograms per liter

WLA	wasteload allocation
WMO	Watershed Management Organization
WRAPS	Watershed Restoration and Protection Strategy

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.

Lake	Lake ID	Year Added to 303(d) List
Gaystock	10-0031	2004
Maria	10-0058	2004
Hazeltine	10-0014	2004
McKnight	10-0216	2014
Jonathan	10-0217	2014
Unnamed (Grace)	10-0218	2006

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.

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

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-*a* (Chl-*a*), and Secchi depth. P is typically the limiting nutrient in Minnesota lakes, meaning that algal growth will increase with increased P. Chl-*a* 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-*a* 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-*a* 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-*a* and Secchi transparency. Based on these relationships it is expected that by meeting the P target in each lake, the Chl-*a* and Secchi standards will likewise be met.

Table 2.1 MPCA lake water quality standards for NCHF Ecoregion.

Lake depth category	TP concentration (µg/L)	Chl-*a* conc. (µg/L)	Minimum Secchi depth (meters)
Deep	40	14	1.4
Shallow	60	20	1.0

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 morphometry

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

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.

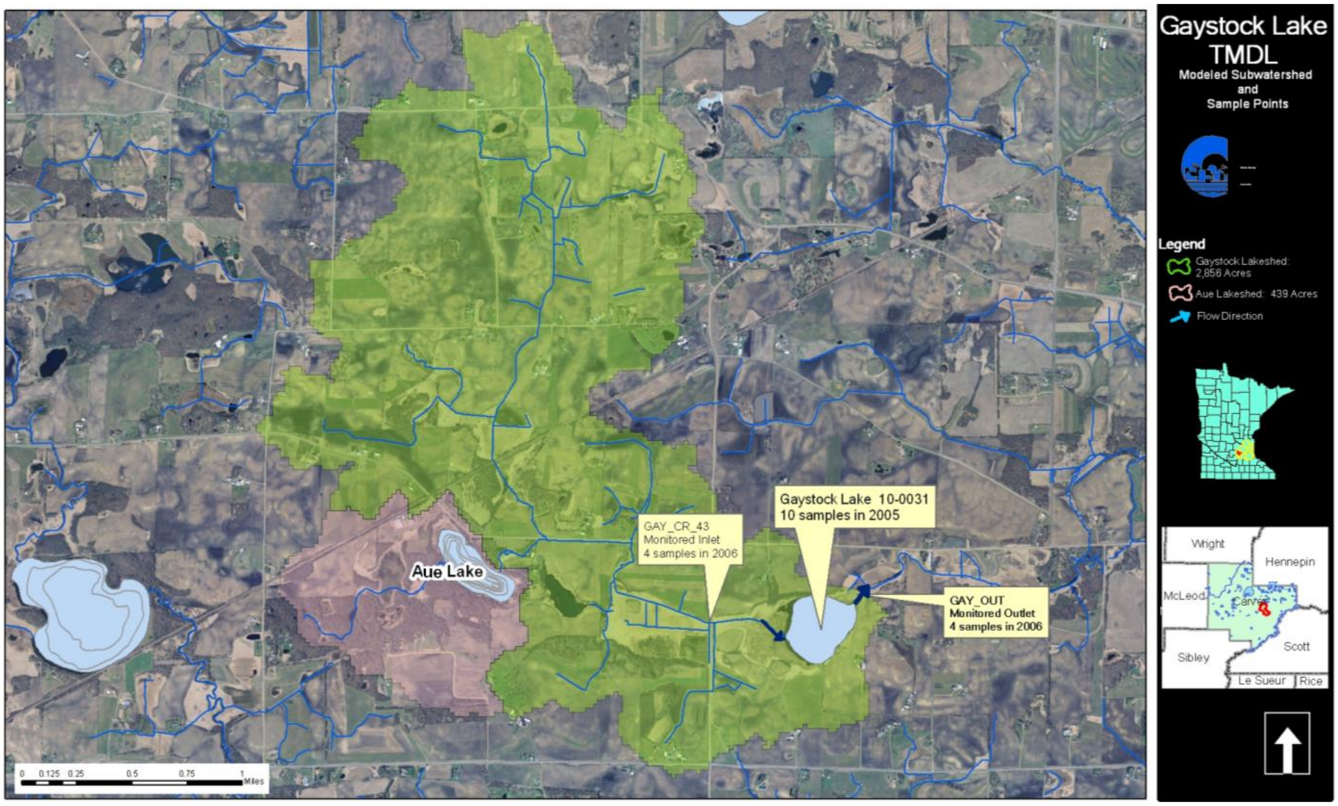

Figure 3.1 Gaystock Lake lakeshed, upstream lakeshed, and sample points.

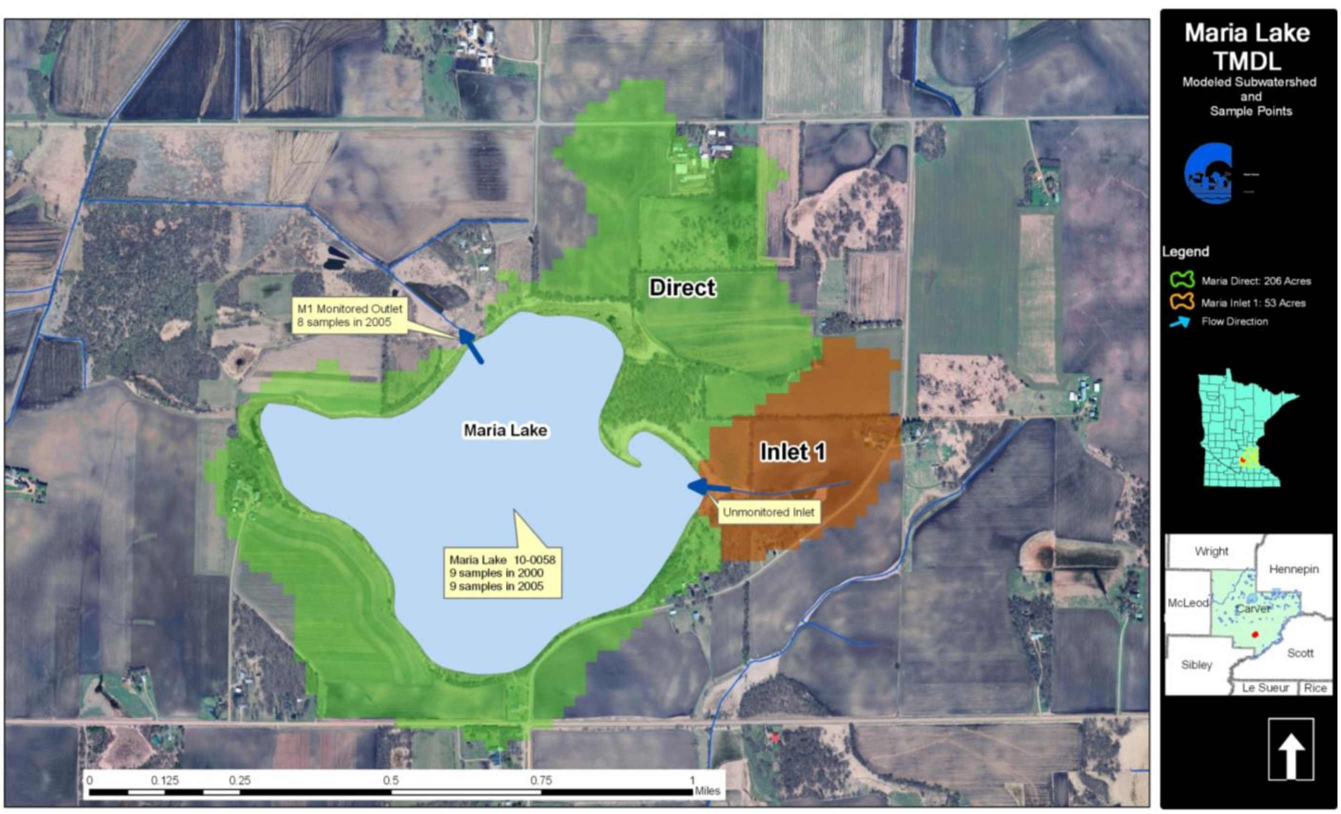

Figure 3.2 Maria Lake Lakeshed and sample points

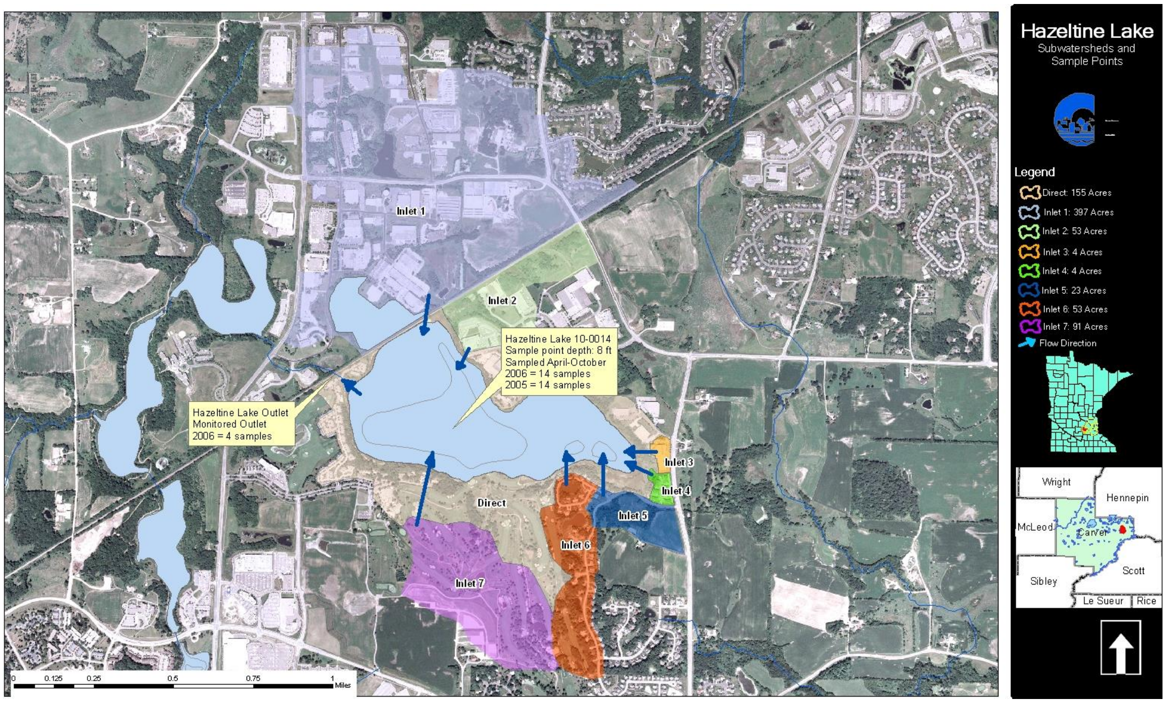

Figure 3.3 Hazeltine Lake lakeshed and sample points

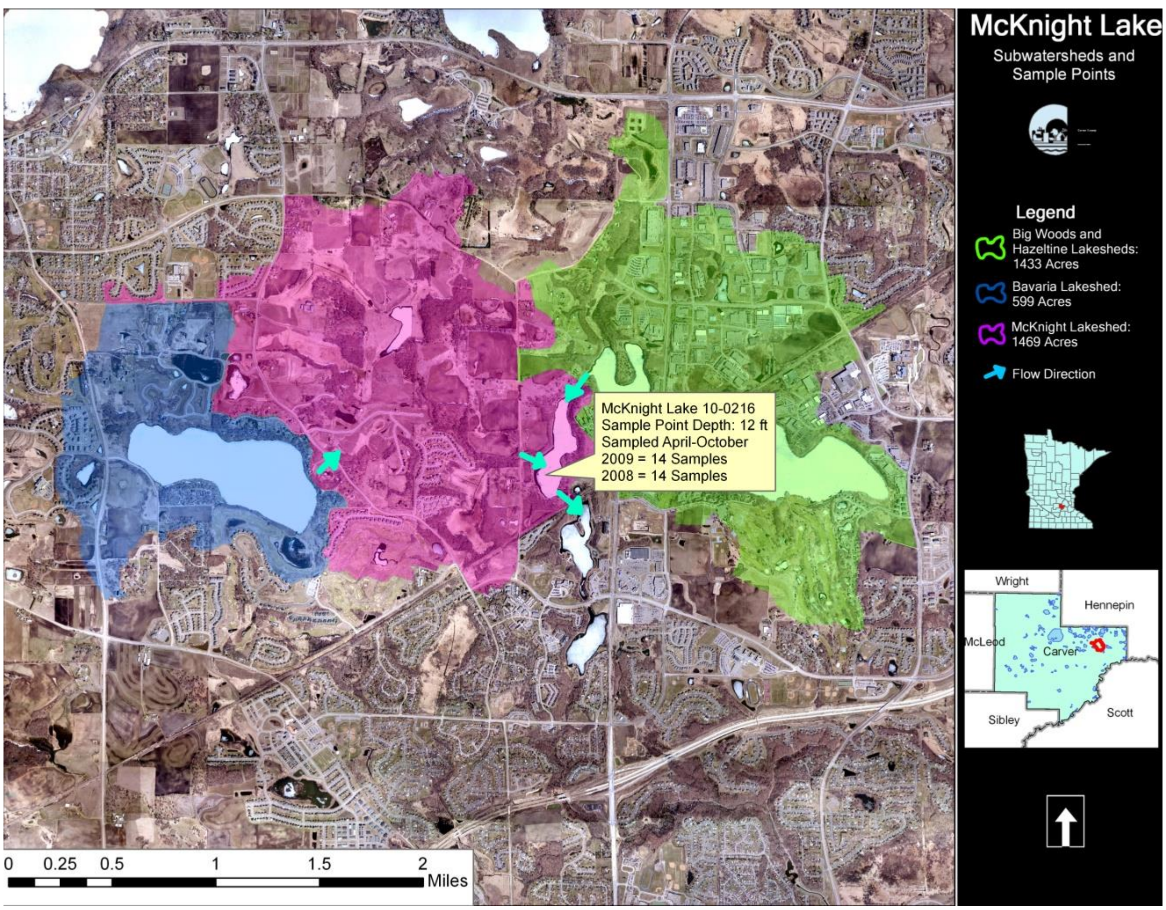

Figure 3.4 McKnight Lake lakeshed, upstream lakesheds, and sample points

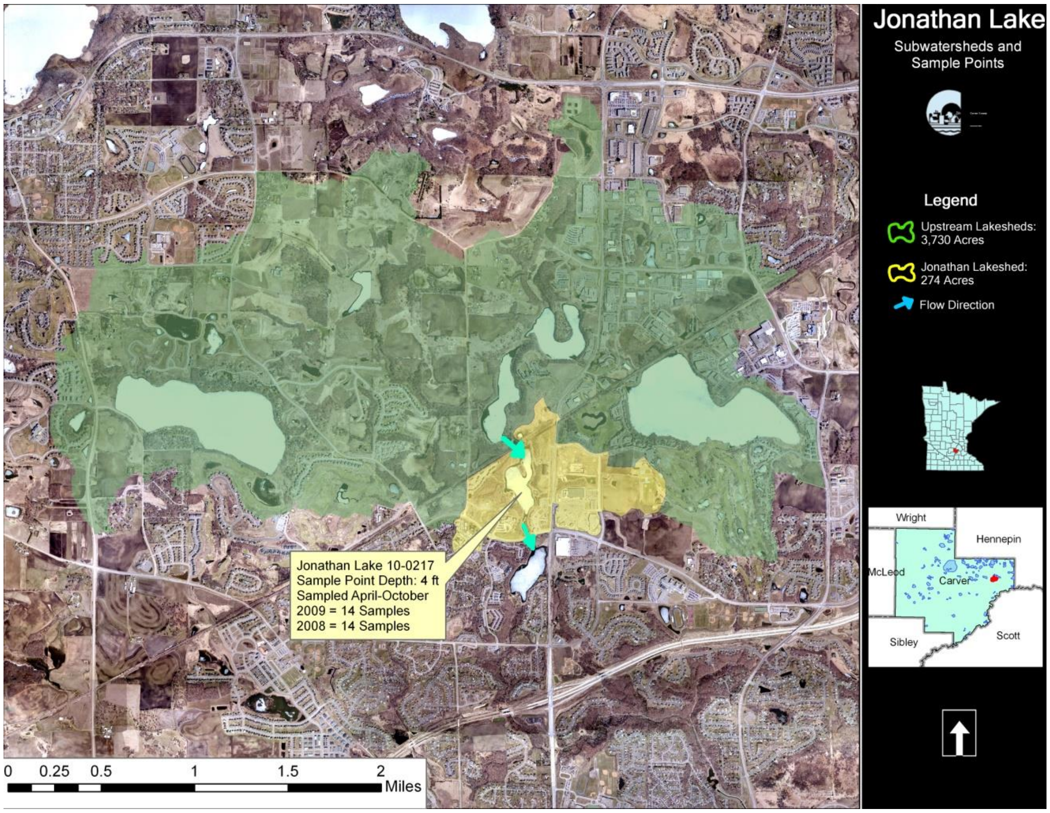

Figure 3.5 Jonathan Lake lakeshed, upstream lakesheds, and sample points

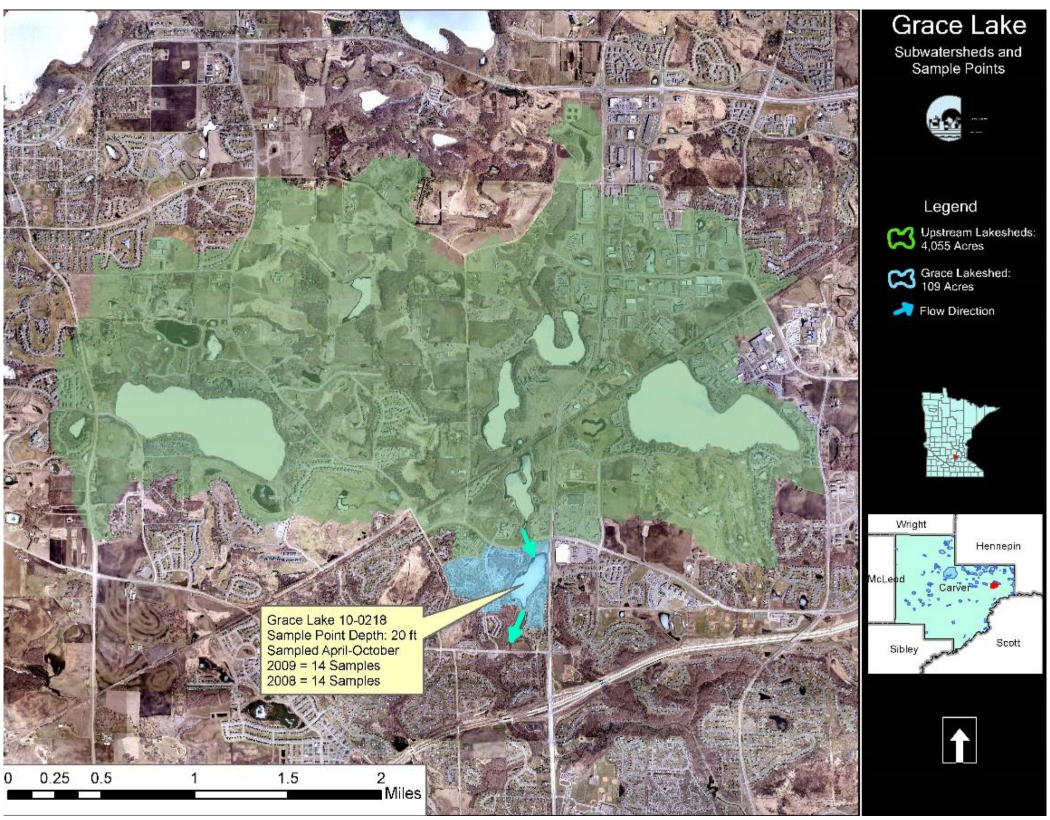

Figure 3.6 Lake Grace lakeshed, upstream lakesheds, and sample points

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 3.2 Base-line lakeshed land use‡

	Land Use Areas, acres					
Lake	**Agriculture**	**Developed**	**Natural**	**Wetland**	**Water***	**Lakeshed Total***
Aue	191	18	178	33	19	**439**
Gaystock	2,153	131	339	217	16	**2,856**
Maria	200	13	30	15	0.4	**259**
Hazeltine	31	463	106	159	14	**773**
Big Woods	69	150	215	52	0.8	**486**
Bavaria	210	238	73	68	9	**599**
McKnight	477	180	656	147	17	**1,477**
Jonathan	47	148	70	9	1.3	**274**
Grace	0.0	71	16	2	0.4	**89**
	Land Use Areas as Percent of Lakeshed Total Area					
Lake	**Agriculture**	**Developed**	**Natural**	**Wetland**	**Water***	**Lakeshed Total**
Aue	43%	4%	41%	7%	4%	**100%**
Gaystock	75%	5%	12%	8%	1%	**100%**
Maria	77%	5%	12%	6%	0.2%	**100%**
Hazeltine	4%	60%	14%	21%	2%	**100%**
Big Woods	14%	31%	44%	11%	0.2%	**100%**
Bavaria	35%	40%	12%	11%	1%	**100%**
McKnight	32%	12%	44%	10%	1%	**100%**
Jonathan	17%	54%	25%	3%	0.5%	**100%**
Grace	0.0%	79%	18%	2%	0.5%	**100%**

‡ 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.

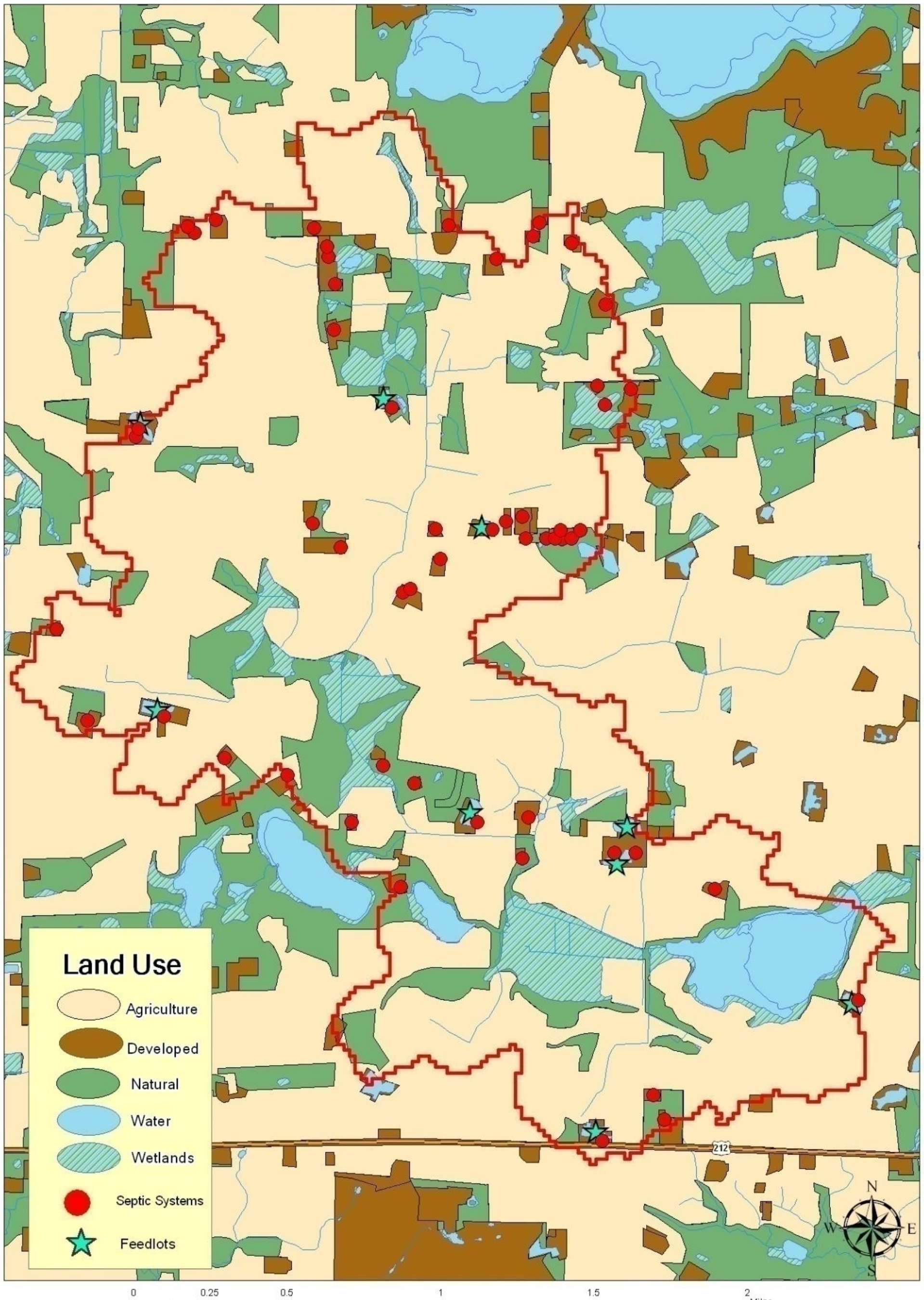

Figure 3.7 Gaystock Lake Watershed 2005 land use map

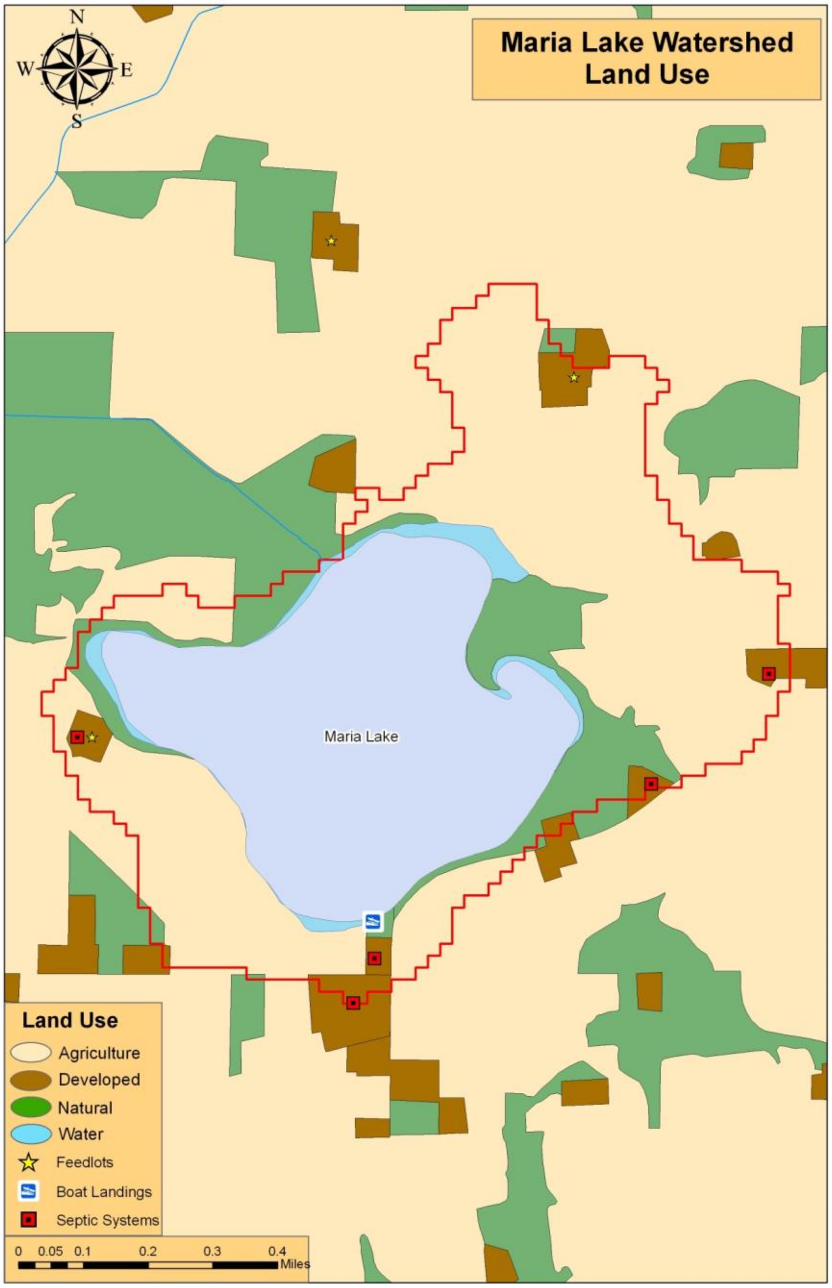

Figure 3.8 Maria Lake Watershed 2005 land use

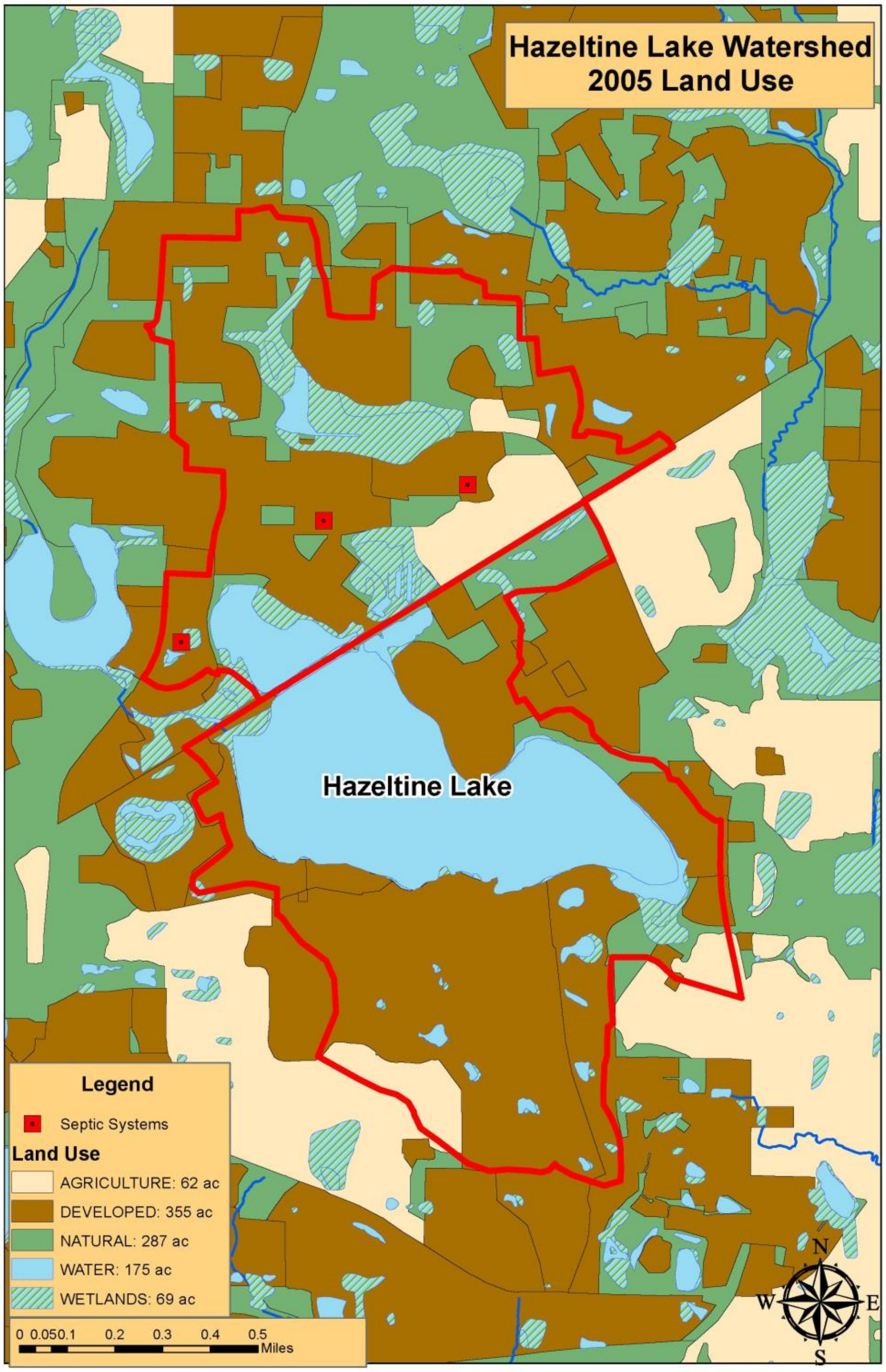

Figure 3.9 Hazeltine Lake Watershed 2005 land use map

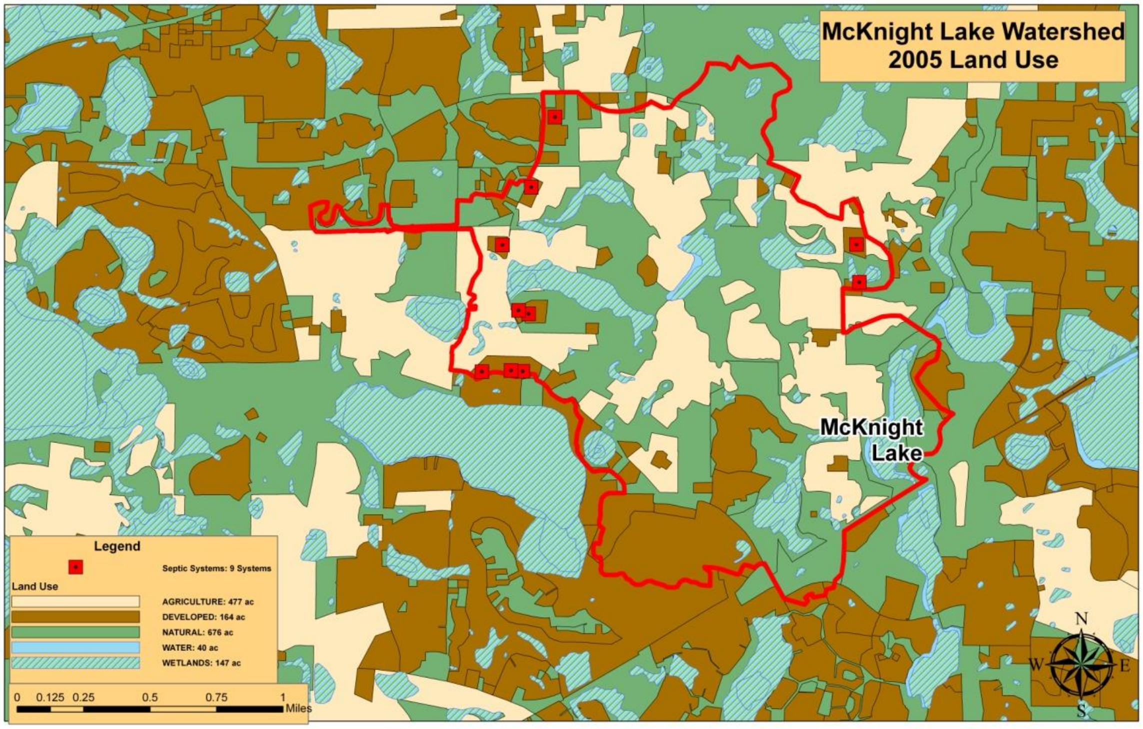

Figure 3.10 McKnight Lake Watershed 2005 land use map

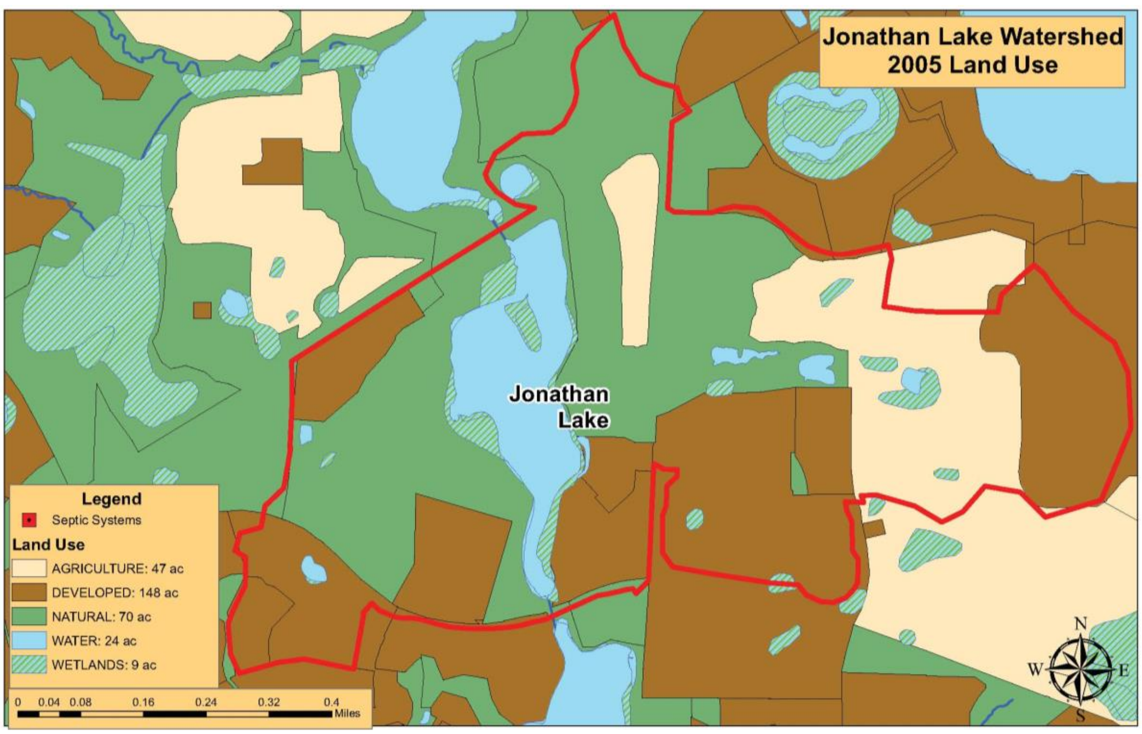

Figure 3.11 Jonathan Lake Watershed 2005 land use map

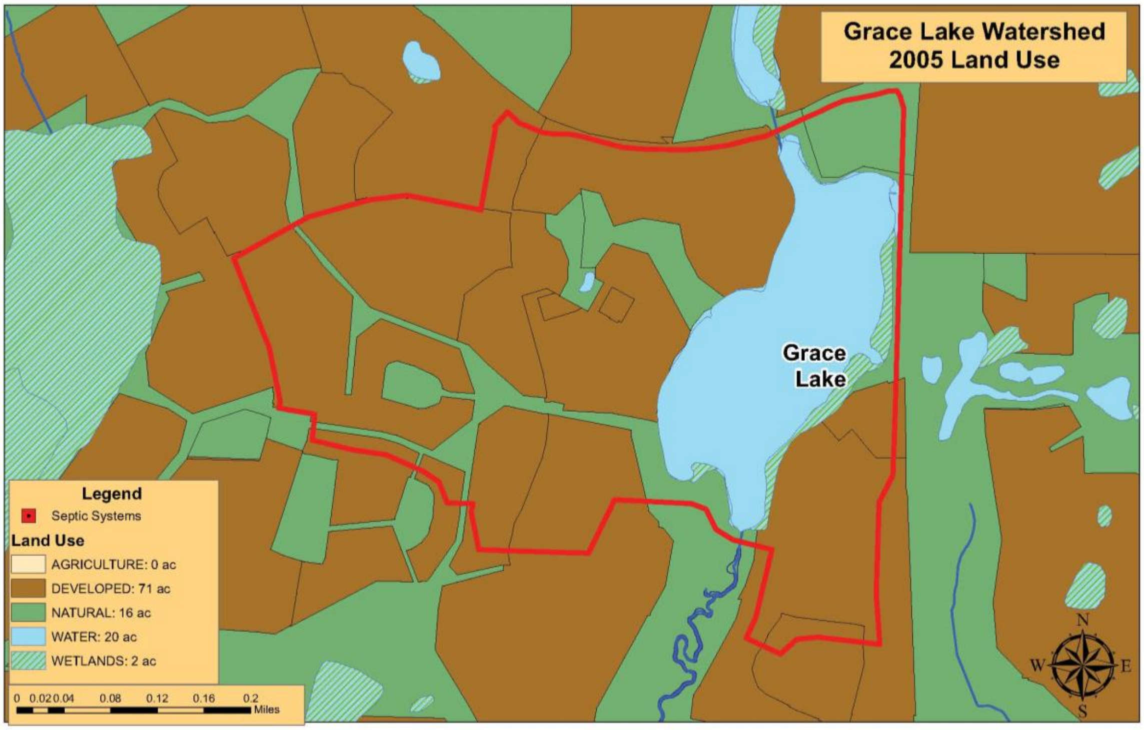

Figure 3.12 Grace Lake Watershed 2005 land use map

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

Watershed	Lakes	Runoff Coefficient		
		Agriculture	Developed	Natural
West Chaska Creek	Gaystock-Aue	0.22	0.15	0.07
Bevens Creek	Maria	0.25	0.29	0.07
East Chaska Creek	Grace chain	0.25	0.49	0.23

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 3.4 Baseline-year precipitation and runoff depth by watershed and land use

Watershed	Lakes	TMDL Baseline Year	Precipitation (inches/yr)	Runoff depth (inches/yr)		
				Agriculture	Developed	Natural
West Chaska Creek	Gaystock-Aue	2001	29.11	6.40	4.37	2.04
Bevens Creek	Maria	2001	29.11	7.28	8.44	2.04
East Chaska Creek	Grace chain	2009	31.56	7.89	15.46	7.26

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 3.5 Lakeshed baseline-year runoff volume and depth

Lake	Agriculture (ac-ft/yr)	Developed (ac-ft/yr)	Natural (ac-ft/yr)	Lakeshed Total Runoff	
				Volume (ac-ft/yr)	Depth (inches/yr)
Aue	102	7	30	**139**	**3.79**
Gaystock	1,149	48	58	**1,254**	**5.27**
Maria	121	9	5	**136**	**6.29**
Hazeltine	20	597	64	**681**	**10.58**
Big Woods	45	193	130	**368**	**9.09**
Bavaria	138	307	44	**490**	**9.81**
McKnight	314	232	397	**942**	**7.65**
Jonathan	31	190	42	**263**	**11.50**
Grace	0	91	10	**101**	**13.54**

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 0.10lb/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 3.6 Baseline-year lakeshed P export by land use

Watershed	Lake	Phosphorus export, lb/ac-yr			
		Agriculture	Developed	Natural	
All	All	0.892	0.834	0.114	

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

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

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-*a*, 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

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

* 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-*a* results were not corrected for pheophytin 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

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

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

MS4	Permit Number	Impacted lakes
Carver County	MS400070	Hazeltine, McKnight, Jonathan
City of Chanhassen	MS400079	Hazeltine, McKnight
City of Chaska	MS400080	Hazeltine, McKnight, Jonathan, Grace
City of Victoria	MS400126	Gaystock, McKnight
Laketown Township	MS400142	Gaystock
MnDOT/Metro District	MS400170	Hazeltine, Jonathan

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

Lake	Number of Septic Systems*
Aue	9
Gaystock	2
Maria	4
Hazeltine	1
Big Woods	3
Bavaria	6
McKnight	0
Jonathan	0
Grace	0

* 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

Lakeshed	Number of feedlots	Number of animal units
Gaystock	9	1,031
Maria	2	272

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/km^2-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:

$$\text{TMDL} = \Sigma \text{ WLAs} + \Sigma \text{ LAs} \; [+ \text{ MOS} + \text{RC}]$$

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 4.1 Carver lakes wastewater dischargers

Discharge	NPDES Permit #	Receiving Lake	Baseline Year
Laketown CWWTP	MN0054399	Gaystock	2001
Apex	MN0067016	Hazeltine	2009
MGK	MN0058033	Hazeltine	2009
LifeCore Bio	MN0060747	Big Woods/McKnight	2009
TEL FSI Inc	MN0068781	Big Woods/McKnight	2009

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

Table 4.2 Baseline-year wastewater effluent characteristics

Discharge	Average Flow gallons/day	TP Conc mg/L	P Load lb/yr	DMR Years
Laketown CWWTP	2,500	2.3	17.5	2004[a]
Apex	16,273	0.0266	1.3	2009
MGK	31,537	0.5167	49.7	2009[b]
LifeCore Biomedical LLC	6,797	0.585	12.1	2009
TEL FSI Inc	10,000	1.000	30.5	2010 - 2015[c]

[a] 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.

[b] MGK TP concentration from sampling in 2013 (only available data).

[c] 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

Parameter	Units	Value
Per capita P load	lb/cap-yr	2.30
Average system size	capita/system	2.90
P load to system	lb/system-yr	6.67
Conforming systems (53% of all systems):		
Soil P retention	%	90%
Net P load to lake	**lb/system-yr**	**0.67**
Failing systems (47% of all systems):		
Soil P retention	%	70%
Net P load to lake	**lb/system-yr**	**2.00**
Weighted average values:		
Soil P retention	%	81%
Net P load to lake	**lb/system-yr**	**1.29**

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

Lake	Number of Septic Systems*	Septic-System P Load, lb/yr	
		Existing	**All Conforming**
Aue	9	11.6	6.0
Gaystock	2	2.6	1.3
Maria	4	5.2	2.7
Hazeltine	1	1.3	0.7
Big Woods	3	3.9	2.0
Bavaria	6	7.8	4.0
McKnight	0	0	0
Jonathan	0	0	0
Grace	0	0	0

* 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 4.4 Estimated livestock P loading rate

Parameter	Units	Value
Manure-P production rate*	lb P/AU-yr	29.1
Soil/land cover retention	percent	99%
Net P load to lakes	**lb P/AU-yr**	**0.29**

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 4.5 Baseline-Year livestock P loads for Gaystock and Maria Lakes

Lake	Number of Feedlots	Total Number of Animal Units	P Load to Lake lb/yr
Gaystock	9	1,031	300
Maria	2	272	79

- **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/m^2-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/m^2-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/m^2-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/m^2-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/m^2-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/m^2-day (see again Table 4.7):

Table 4.6 Baseline-year calibration parameters

Lake	Internal P Load Rate mg/m^2-day	Calibration Factor (P sedimentation rate)	Observed Lake TP* ug/L
Aue	2.82	1	***146***
Gaystock	4.48	1	320
Maria	1.241	1	188
Hazeltine	4.68	1	296
Big Woods	2.70	1	***255***
Bavaria	0	1.254	39.6
McKnight	8.20	1	231
Jonathan	0.620	1	202
Table 4.7 Baseline-year calibration parameters	0	1.680	118

* 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%.

Table 4.7 Carver lakes baseline load and loading capacity

Lake	Overall P Load, lb/yr		Overall P load % reduction
	Baseline Load	Loading Capacity	
Aue	546	66.6	88%
Gaystock	3,132	363	88%
Maria	1,020	151	85%
Hazeltine	2,996	276	91%
Big Woods	1,143	222	81%
Bavaria	464	460	1%
McKnight	2,107	482	77%
Jonathan	1,833	506	72%
Grace	1,617	527	67%

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

(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

Lake	Lakeshed Runoff TP, ug/L		TP concentration % reduction
	Baseline	TMDL	
Aue	545	126.5	77%
Gaystock	606	70.7	88%
Maria	523	150.0	71%
Hazeltine	230	108.5	53%
Big Woods	210	49.8	76%
Bavaria	296	296.0	0%
McKnight	254	93.4	63%
Jonathan	241	113.9	53%
Grace	221	221	0%

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

Discharge	NPDES Permit #	Receiving Lake	Average Flow gallons/day	TP Conc mg/L	P Load lb/yr
Laketown CWWTP	MN0054399	Gaystock	5,800	2.868	50.7
MGK	MN0058033	Hazeltine	7,000	0.651	13.9
LifeCore Biomedical LLC	MN0060747	Big Woods/McKnight	50,000	0.300	45.7
Discharges terminated after baseline year:					
APEX	MN0067016	Hazeltine	0	--	0
TEL FSI Inc	MN0068781	Big Woods/McKnight	0	--	0

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

Lake	MS4	Permit Number	MS4 Area acres	Existing Load lb/yr	MS4 WLA lb/yr	Reduction %
Gaystock	Laketown Township	MS400142	33	24	2.8	88%
	City of Victoria	MS400126	34	25	2.9	88%
Maria	None	--	0	0	0	--
Hazeltine	City of Chaska	MS400080	358	197	91	54%
	City of Chanhassen	MS400079	77	42	20	54%
	Carver County	MS400070	11	6.1	6.1	--
	MnDOT	MS400170	2.0	1.1	1.1	--
McKnight	City of Chaska	MS400080	367	162	59	63%
	City of Chanhassen	MS400079	45	20	7.3	63%
	City of Victoria	MS400126	79	35	13	63%
Jonathan	City of Chaska	MS400080	130	82	38	54%
	MnDOT/Metro District	MS400170	3.8	2.4	2.4	--
Grace	City of Chaska	MS400080	87	59	59	0%

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

Load Category	Load Component	Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	%
	TOTAL LOAD	**3,132**	**8.57**	**363**	**1.00**	**2,768**	**88%**
Wasteload	**Total WLA**	**66**	**0.18**	**57**	**0.15**	**43**	**65%**
	Laketown CWWTP* (MN0054399)	18	0.048	51	0.14	--	--
	Construction/Industrial SW	0.24	0.00066	0.24	0.00066	--	--
	Laketown Twp (MS400142)	24	0.065	2.8	0.0076	21	88%
	Victoria (MS400126)	25	0.067	2.9	0.0079	22	88%
Load	**Total LA**	**3,066**	**8.39**	**307**	**0.84**	**2,759**	**90%**
	Non-MS4 runoff	2,018	5.53	235	0.64	1,783	88%
	Upstream lake - Aue	57	0.16	16	0.043	41	73%
	Atmospheric deposition	17	0.047	17	0.047	0.0	0%
	Internal load	671	1.8	0	0	671	100%
	SSTS	2.6	0.0071	1.3	0.0037	1.3	48%
	Feedlots	300	0.82	37	0.10	262	88%

* 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

Load Category	Load Component	Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	%
TOTAL LOAD		**1,020**	**2.79**	**151**	**0.41**	**869**	**85%**
Wasteload	**Total WLA**	**0.055**	**0.00015**	**0.055**	**0.00015**	**0**	**0%**
	Construction/Industrial SW	0.055	0.00015	0.055	0.00015	0	0%
Load	**Total LA**	**1,020**	**2.79**	**151**	**0.41**	**869**	**85%**
	Non-MS4 runoff	192	0.53	55	0.15	137	71%
	Atmospheric deposition	63	0.17	63	0.17	--	--
	Internal load	680	1.86	0	0	680	100%
	SSTS	5.2	0.014	2.7	0.0073	2.5	48%
	Feedlots	79	0.22	30	0.081	50	63%

Table 4.12 Hazeltine Lake (10-0014) TMDL Allocation

Load Category	Load Component	Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	%
TOTAL LOAD		**2,996**	**8.20**	**276**	**0.76**	**2,720**	**91%**
Wasteload	**Total WLA**	**298**	**0.82**	**132**	**0.36**	**166**	**56%**
	Apex* (MN0067016)	1.3	0.0037	0	0	1.3	100%
	MGK‡ (MN0058033)	50	0.14	14	0.038	36	72%
	Construction/Industrial SW	0.20	0.00055	0.20	0.00055	--	--
	Chaska (MS400080)	197	0.54	91	0.25	106	54%
	Chanhassen (MS400079)	42	0.12	20	0.054	23	54%
	Carver County (MS400070)	6.1	0.017	6.1	0.017	--	--
	MNDOT Metro Dist (MS400170)	1.10	0.0030	1.10	0.0030	--	--
Load	**Total LA**	**2,698**	**7.39**	**144**	**0.39**	**2,554**	**95%**
	Non-MS4 runoff	179	0.49	83	0.23	96	54%
	Atmospheric deposition	60	0.17	60	0.17	--	--
	Internal load	2,457	6.7	0	0	2,457	100%
	SSTS	1.29	0.0035	0.67	0.0018	0.63	48%

* Apex International Manufacturing; no longer discharges to Hazeltine Lake

‡ McLaughlin Gormley King Company

Table 4.13 McKnight Lake (10-0216) TMDL Allocation

Load Category	Load Component	Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	%
TOTAL LOAD		**2,107**	**5.77**	**482**	**1.32**	**1,625**	**77%**
Wasteload	**Total WLA**	**225**	**0.62**	**117**	**0.32**	**137**	**61%**
	LifeCore Biomedical LLC*	8.3	0.023	37.4	0.102	--	--
	Construction/Industrial SW	0.24	0.00066	0.24	0.00066	--	--
	Chaska (MS400080)	162	0.44	59	0.16	102	63%
	Chanhassen (MS400079)	20	0.054	7.3	0.020	13	63%
	Victoria (MS400126)	35	0.095	13	0.035	22.0	63%
Load	**Total LA**	**1,882**	**5.15**	**365**	**1.00**	**1,517**	**81%**
	Non-MS4 runoff	434	1.19	160	0.44	275	63%
	Big Woods Outflow excl LifeCore**	772	2.11	144	0.40	627	81%
	Upstream lake - Bavaria	53	0.14	53	0.14	0.27	1%
	Atmospheric deposition	8.6	0.024	8.6	0.024	--	--
	Internal load	615	1.68	0	0	615	100%

* 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

Load Category	Load Component	Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	%
TOTAL LOAD		**1,833**	**5.02**	**506**	**1.38**	**1,328**	**72%**
Wasteload	**Total WLA**	**84**	**0.23**	**40**	**0.11**	**44**	**52%**
	Construction/Industrial SW	0.082	0.00022	0.082	0.00022	--	--
	Chaska (MS400080)	82	0.22	38	0.10	44	54%
	MNDOT Metro Dist (MS400170)	2.4	0.0065	2.4	0.0065	--	--
Load	**Total LA**	**1,749**	**4.79**	**465**	**1.27**	**1,284**	**73%**
	Non-MS4 runoff	88	0.24	41	0.11	47	54%
	Upstream lake - McKnight	1,606	4.40	416	1.14	1190	74%
	Atmospheric deposition	8.6	0.024	8.6	0.024	--	--
	Internal load	46	0.13	0	0	46	100%

Table 4.15 Grace Lake (10-0218) TMDL Allocation

Load Category	Load Component	Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	%
TOTAL LOAD		**1,617**	**4.43**	**527**	**1.44**	**1,090**	**67%**
Wasteload	**Total WLA**	**59**	**0.16**	**59**	**0.16**	**0**	**0%**
	Construction/Industrial SW	0.060	0.00017	0.060	0.00017	--	--
	Chaska (MS400080)	59	0.16	59	0.16	--	--
Load	**Total LA**	**1,558**	**4.27**	**468**	**1.28**	**1,090**	**70%**
	Non-MS4 runoff	1.5	0.0041	1.5	0.0041	--	--
	Upstream lake - Jonathan	1,549	4.24	459	1.26	1,090	70%
	Atmospheric deposition	7.5	0.021	7.5	0.021	--	--

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 their 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 is 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.

Lake	Strategy	Schedule
Gaystock	Not established, implementation based	Establish during targeted implementation efforts
Maria	Not established, implementation based	Establish during targeted implementation efforts
Hazeltine	Established, continue to monitor	Minimum every other year
McKnight	Established, continue to monitor	Minimum every other year
Jonathan	Established, continue to monitor	Minimum every other year
Grace	Established, continue to monitor	Minimum every other year

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-initated 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.

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

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

Lake	Aquatic Plant Mgmt		Rough Fish Mgmt		Alum Treatment		Total	
	Low	High	Low	High	Low	High	**Low**	**High**
Gaystock	50	250	100	175			**150**	**425**
Maria	10	100	25	100	50	100	**85**	**300**
Hazeltine	75	450	110	250			**185**	**700**
McKnight	15	50	85	225	100	150	**200**	**425**
Jonathan	15	50	85	250			**100**	**300**
Grace	15	75	85	250	100	150	**200**	**475**
Total	**180**	**975**	**490**	**1250**	**250**	**400**	**920**	**2625**

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.

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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.

Year	Total Phosphorus Concentration (ug/L)	Chlorophyll-*a* Concentration (ug/L)	Secchi disk transparency (m)	Total Kjeldahl Nitrogen (mg/L)	Number of Observations[a] (--)
1999[a]	228	--	0.70	2.60	2
2000	498	245	0.40	2.94	8
2001	**320**	**98**	**0.70**	**2.39**	**9**
2005	232	212	0.20	3.79	9
2006	209	94	0.40	3.14	8

[a] In 1999 there were no chlorophyll-*a* observations.

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

Year	Total Phosphorus Concentration (ug/L)	Chlorophyll-*a* Concentration (ug/L)	Secchi disk transparency (m)	Total Kjeldahl Nitrogen (mg/L)	Number of Observations[a] (--)
1999	155	69	0.90	2.15	2
2000[a]	411	222	0.54	5.04	9
2001	**188**	**36**	**0.78**	**2.38**	**8**
2005	186	92	0.62	2.94	9

[a] In 2000 there were 12 Secchi disk observations.

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

Year	Total Phosphorus Concentration (ug/L)	Chlorophyll-*a* Concentration (ug/L)	Secchi disk transparency (m)	Total Kjeldahl Nitrogen (mg/L)	Number of Observations[a] (--)
1999	150	78	0.50	2.80	1
2000	186	152	0.30	3.30	9
2001	207	134	0.30	3.90	9
2005	173	232	0.30	4.30	9
2006	230	98	0.30	4.90	9
2009	**296**	**328**	**0.20**	**5.90**	**9**
2010[a]	162	244	0.30	4.10	9

[a] In 2010 there were 8 chlorophyll-*a* observations.

Table A.4 McKnight Lake summer mean lake water quality.

Year	Total Phosphorus Concentration (ug/L)	Chlorophyll-*a* Concentration (ug/L)	Secchi disk transparency (m)	Total Kjeldahl Nitrogen (mg/L)	Number of Observations[a] (--)
2006	171	77	0.40	1.90	9
2008	177	91	0.40	3.00	9
2009[a]	**231**	**115**	**0.30**	**3.40**	**9**
2010	160	111	0.50	2.40	9

[a] In 2009 there were 8 total P and 8 TKN observations.

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

Year	Total Phosphorus Concentration (ug/L)	Chlorophyll-*a* Concentration (ug/L)	Secchi disk transparency (m)	Total Kjeldahl Nitrogen (mg/L)	Number of Observations[a] (--)
2002	176	40	0.50	2.00	8
2006	184	70	0.40	2.10	9
2008	191	84	0.50	2.90	9
2009	**202**	**104**	**0.30**	**2.70**	**9**
2010[a]	167	124	0.50	2.10	8

[a] In 2010 there were 9 chlorophyll-*a* observations.

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

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

[a] In 2004 there were 9 chlorophyll-*a* observations.

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

Year*	Total Phosphorus Concentration (ug/L)	Chlorophyll-*a*** Concentration (ug/L)	Secchi disk transparency (m)	Total Kjeldahl Nitrogen (mg/L)	Number of Observations (--)
2014	119	100	0.51	2.0	8
2015	360	269	0.11	4.5	10

* Base year for downstream lake 2009.

** Chlorophyll-*a* is not corrected for phaeophytin.

Table A.8 Lake Bavaria (non-impaired) summer mean water quality.

Year*	Total Phosphorus Concentration (ug/L)	Chlorophyll-*a*** Concentration (ug/L)	Secchi disk transparency (m)	Total Kjeldahl Nitrogen (mg/L)	Number of Observations [a - d] (--)
1983	42.5	35.5	1.63	1.95	4
1986	33.9	24.9	2.00	1.19	9
1987	35.0	23.8	2.06	1.11	9
1994	30.0	10.9	2.24	1.04	8
1996	32.5	9.0	2.13	1.10	8
1997[a]	15.0	8.0	2.47	0.95	10
1998	22.2	8.9	3.08	0.95	9
1999	22.5	15.0	2.55	0.90	10
2000	33.0	10.1	2.10	0.91	10
2001	26.0	13.2	2.03	0.89	10
2002	25.2	10.8	1.95	1.06	9
2003[b]	37.1	9.3	1.85	0.99	12
2004	29.5	21.9	1.73	1.05	10
2005[c]	38.0	16.1	1.49	1.47	11
2006	24.6	6.0	2.56	1.03	9
2007	55.4	7.4	2.23	1.11	10
2008	28.1	14.3	1.73	1.16	10
2009*	**39.6**	**10.9**	**1.95**	**1.38**	**10**
2010[d]	30.5	17.3	1.20	1.36	10

__Notes:__

* Base year for downstream lake 2009.

** Chlorophyll-*a* is not corrected for phaeophytin.

[a] In 1997 there were 9 chlorophyll-*a* observations.

[b] In 2003 there were 11 chlorophyll-*a* observations.

[c] In 2005 there were 9 chlorophyll-*a* observations.

[d] In 2010 there were 8 chlorophyll-*a* 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:

Parameter	Value	Model Options	Code	Description
Averaging Period (yrs)	1	Phosphorus Balance	8	CANF & BACH, LAKES
Storage Increase (m)	0	Phosphorus Calibration	1	DECAY RATES
Atmos. P Load (kg/km^2-yr)	42	Mass-Balance Tables	1	USE ESTIMATED CONCS

Annual precipitation and evaporation vary by subwatershed:

Subwatershed	Precipitation meter/yr	Evaporation meter/yr	Included lakes (*parentheses mark upstream/intermediate lakes*)
West Chaska Ck	0.7394	0.7000	(Aue) & Gaystock
Bevens Ck	0.7394	0.7000	Maria
East Chaska Ck	0.8016	0.8000	Hazeltine, McKnight, (Big Woods), (Bavaria), Jonathan, & Grace

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

Type	Description
1	catchment or upstream waterbody - concentration and flow/outflow specified
3	wastewater discharge - concentration and flow specified

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

	Segment Morphometry	Area	Depth	Length	Mixed Depth
Seg	Name	km^2	m	km	m
1	Aue	0.139	4.23	0.70	4.00

	Calbration Data	TP Calibration	Internal P Load	Observed TP
Seg		Factor	mg/m^2-day	ug/L
1		1	2.82	--

	Tributary Data		Dr Area	Flow	Total P
Trib	Trib Name	Type	km^2	hm^3/yr	ug/L
1	Lakeshed runoff	1	1.773	0.171	545
2	Septics	3	0	0.0001	52,825

Aue 2001 Mass Balance Results

	Area	Flow	Conc	Load	Runoff	Export
Name	km^2	hm^3/yr	mg/m^3	kg/yr	m/yr	$kg/km^2/yr$
Lakeshed runoff	1.773	0.171	545.0	93.2	0.10	52.6
Septics		0.00010	52,825	5.3		
Precipitation	0.139	0.103	56.8	5.8	0.74	42.0
Internal Load				143.2		
Total Inflow	***1.912***	***0.274***	***903.6***	***247.5***	***0.14***	***129.4***
Outflow	1.912	0.177	146.2	25.8	0.09	13.5
Evaporation		0.097				
Retention				221.7		

Gaystock 2001

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Gaystock 2001 Input Data

Seg	Segment Morphometry Name	Area km²	Depth m	Length km	Mixed Depth m
1	Gaystock	0.186	2.10	0.50	2.10

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m²-day	Observed TP ug/L
1		1	4.48	320

Trib	Tributary Data Trib Name	Type	Dr Area km²	Flow hm³/yr	Total P ug/L
1	Lakeshed runoff	1	11.558	1.547	606
2	Aue Lake outflow	1	1.912	0.177	146
3	Laketown CWWTP	3	0	0.00346	2,300
4	Septics	3	0	0.00010	11,739
5	Feedlots	3	0	0.00017	800,000

Gaystock 2001 Mass Balance Results

Name	Area km²	Flow hm³/yr	Conc mg/m³	Load kg/yr	Runoff m/yr	Export kg/km²/yr
Lakeshed runoff	11.558	1.547	606	937	0.13	81.1
Aue Lake outflow	1.912	0.177	146	26	0.09	13.5
Laketown CWWTP		0.00346	2,300	8.0		
Septics		0.00010	11,739	1.2		
Feedlots		0.00017	800,000	136		
Precipitation	0.186	0.138	57	7.8	0.74	42.0
Internal Load				304		
Total Inflow	***13.656***	***1.865***	***762***	***1,421***	***0.14***	***104.0***
Outflow	13.656	1.735	320	555	0.13	40.7
Evaporation		0.130				
Retention				865		

Bevens Creek Lake

Maria 2001

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Maria 2001 Input Data

Seg	Segment Morphometry Name	Area km²	Depth m	Length km	Mixed Depth m
1	Maria Lake	0.680	1.07	1.0	1.07

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m²-day	Observed TP ug/L
1		1	1.24	188

Trib	Tributary Data Trib Name	Type	Dr Area km²	Flow hm³/yr	Total P ug/L
1	Lakeshed runoff	1	1.047	0.167	523
2	Septics	3	0	0.0001	23,478
3	Feedlots	3	0	0.000045	800,000

Maria 2001 Mass Balance Results

Name	Area km^2	Flow hm^3/yr	Conc mg/m^3	Load kg/yr	Runoff m/yr	Export kg/km^2/yr
Lakeshed runoff	1.047	0.167	523.0	87.3	0.16	83.4
Septics		0.00010	23,478	2.3		
Feedlots		0.000	800,000	36.0		
Precipitation	0.680	0.503	56.8	28.6	0.74	42.0
Internal Load				308.2		
Total Inflow	***1.727***	***0.670***	***690.3***	***462.5***	***0.39***	***267.8***
Outflow	1.727	0.194	188.0	36.5	0.11	21.1
Evaporation		0.476				
Retention				426.0		

East Chaska Creek Lakes

Hazeltine 2009

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Hazeltine 2009 Input Data

Seg	Segment Morphometry Name	Area km^2	Depth m	Length km	Mixed Depth m
1	Hazeltine	0.652	1.10	1.55	1.1

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m^2-day	Observed TP ug/L
1		1	4.68	296

Trib	Tributary Data Trib Name	Type	Dr Area km^2	Flow hm^3/yr	Total P ug/L
1	Lakeshed runoff	1	3.127	0.841	230
2	APEX	3	0	0.0225	27
3	MGK	3	0	0.0436	517
4	Septics	3	0	0.00010	5,869

Hazeltine 2009 Mass Balance Results

Name	Area km^2	Flow hm^3/yr	Conc mg/m^3	Load kg/yr	Runoff m/yr	Export kg/km^2/yr
Lakeshed runoff	3.127	0.841	230	193	0.27	62
APEX		0.0225	27	0.6		
MGK		0.0436	517	23		
Septics		0.00010	5,869	0.6		
Precipitation	0.652	0.523	52	27	0.80	42
Internal Load				1,115		
Total Inflow	***3.779***	***1.430***	***950***	***1,359***	***0.38***	***360***
Outflow	3.779	0.908	296	269	0.24	71
Evaporation		0.522				
Retention				1,090		

Big Woods 2009

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Big Woods 2009 Input Data

Seg	Segment Morphometry Name	Area km²	Depth m	Length km	Mixed Depth m
1	Big Woods	0.130	0.50	0.56	0.50

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m²-day	Observed TP ug/L
1		1	2.70	--

Trib	Tributary Data Trib Name	Type	Dr Area km²	Flow hm³/yr	Total P ug/L
1	Lakeshed runoff	1	1.967	0.454	210
2	Hazeltine Outflow	1	3.779	0.908	296
3	TEL FSI Inc	3	0	0.0138	1,000
4	LifeCore Biomedical LLC	3	0	0.0094	585
5	Septics	3	0	0.0001	17,608

Big Woods 2009 Mass Balance Results

Name	Area km²	Flow hm³/yr	Conc mg/m³	Load kg/yr	Runoff m/yr	Export kg/km²/yr
Lakeshed runoff	1.967	0.454	210.0	95.3	0.23	48.5
Hazeltine Outflow	3.779	0.908	295.7	268.5	0.24	71.0
TEL FSI Inc		0.014	1,000	13.8		
LifeCore Biomedical LLC		0.009	585.0	5.5		
Septics		0.00010	17,608	1.8		
Precipitation	0.130	0.104	52.4	5.5	0.80	42.0
Internal Load				128.2		
Total Inflow	***5.876***	***1.490***	***348.1***	***518.6***	***0.25***	***88.3***
Outflow	5.876	1.386	255.4	353.9	0.24	60.2
Evaporation		0.104				
Retention				164.7		

Bavaria 2009

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Bavaria 2009 Input Data

Seg	Segment Morphometry Name	Area km²	Depth m	Length km	Mixed Depth m
1	Bavaria	0.673	5.35	1.5	4.80

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m²-day	Observed TP ug/L
1		1.254	0	39.6

Trib	Tributary Data Trib Name	Type	Dr Area km²	Flow hm³/yr	Total P ug/L
1	Lakeshed runoff	1	2.423	0.604	296
2	Septics	3	0	0.0001	35,216

Bavaria 2009 Mass Balance Results

Name	Area km²	Flow hm³/yr	Conc mg/m³	Load kg/yr	Runoff m/yr	Export kg/km²/yr
Lakeshed runoff	2.423	0.604	296.0	178.8	0.25	73.8
Septics		0.00010	35,216	3.5		
Precipitation	0.673	0.539	52.4	28.3	0.80	42.0
Total Inflow	***3.096***	***1.144***	***184.1***	***210.6***	***0.37***	***68.0***
Outflow	3.096	0.605	39.6	24.0	0.20	7.7
Evaporation		0.538				
Retention				186.6		

McKnight 2009

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McKnight 2009 Input Data

Seg	Segment Morphometry Name	Area km²	Depth m	Length km	Mixed Depth m
1	McKnight	0.0931	0.91	0.955	0.90

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m²-day	Observed TP ug/L
1		1	8.20	231

Trib	Tributary Data Trib Name	Type	Dr Area km²	Flow (hm³/yr) Mean	Total P (ppb) Mean
1	Lakeshed runoff	1	5.977	1.162	254.0
2	Big Woods Outflow	1	5.876	1.386	255.4
3	Bavaria Outflow	1	3.096	0.605	39.6

McKnight 2009 Mass Balance Results

Name	Area km²	Flow hm³/yr	Conc mg/m³	Load kg/yr	Runoff m/yr	Export kg/km²/yr
Lakeshed runoff	5.977	1.162	254.0	295.1	0.19	49.4
Big Woods Outflow	5.876	1.386	255.4	354.0	0.24	60.2
Bavaria Outflow	3.096	0.605	39.6	24.0	0.20	7.7
Precipitation	0.093	0.075	52.4	3.9	0.80	42.0
Internal Load				278.8		
Total Inflow	***15.042***	***3.228***	***296.1***	***955.8***	***0.21***	***63.5***
Outflow	15.042	3.153	231.0	728.3	0.21	48.4
Evaporation		0.074				
Retention				227.5		

Jonathan 2009

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

Jonathan 2009 Input Data

	Segment Morphometry	Area	Depth	Length	Mixed Depth
Seg	Name	km^2	m	km	m
1	Jonathan	0.093	0.46	0.7	0.45

	Calbration Data	TP Calibration	Internal P Load	Observed TP
Seg		Factor	mg/m^2-day	ug/L
1		1	0.62	202

	Tributary Data		Dr Area	Flow	Total P
Trib	Trib Name	Type	km^2	hm^3/yr	ug/L
1	Lakeshed runoff	1	1.111	0.325	241
2	McKnight Outflow	1	15.042	3.153	231

Jonathan 2009 Mass Balance Results

	Area	Flow	Conc	Load	Runoff	Export
Name	km^2	hm^3/yr	mg/m^3	kg/yr	m/yr	$kg/km^2/yr$
Lakeshed runoff	1.111	0.325	241.0	78.3	0.29	70.5
McKnight Outflow	15.042	3.153	231.0	728.3	0.21	48.4
Precipitation	0.093	0.075	52.4	3.9	0.80	42.0
Internal Load				21.1		
Total Inflow	***16.246***	***3.553***	***234.1***	***831.7***	***0.22***	***51.2***
Outflow	16.246	3.478	202.0	702.7	0.21	43.3
Evaporation		0.074				
Retention				129.0		

Grace 2009

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

Grace 2009 Input Data

	Segment Morphometry	Area	Depth	Length	Mixed Depth
Seg	Name	km^2	m	km	m
1	Grace	0.0809	3.04	0.550	3.00

	Calbration Data	TP Calibration	Internal P Load	Observed TP
Seg		Factor	mg/m^2-day	ug/L
1		1.680	0	118.0

	Tributary Data		Dr Area	Flow	Total P
Trib	Trib Name	Type	km2	hm3/yr	ug/L
1	Lakeshed runoff	1	0.361	0.124	221
2	Jonathan Outflow	1	16.246	3.478	202

Grace 2009 Mass Balance Results

	Area	Flow	Conc	Load	Runoff	Export
Name	km^2	hm^3/yr	mg/m^3	kg/yr	m/yr	$kg/km^2/yr$
Lakeshed runoff	0.361	0.124	221.0	27.4	0.34	75.9
Jonathan Outflow	16.246	3.478	202.0	702.6	0.21	43.2
Precipitation	0.081	0.0648	52.4	3.4	0.80	42.0
Total Inflow	***16.688***	***3.667***	***200.0***	***733.4***	***0.22***	***43.9***
Outflow	16.688	3.602	118.0	425.1	0.22	25.5
Evaporation		0.0647				
Retention				308.3		

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:

Parameter	Value	Model Options	Code	Description
Averaging Period (yrs)	1	Phosphorus Balance	8	CANF & BACH, LAKES
Storage Increase (m)	0	Phosphorus Calibration	1	DECAY RATES
Atmos. P Load (kg/km^2-yr)	42	Mass-Balance Tables	1	USE ESTIMATED CONCS

Annual precipitation and evaporation vary by subwatershed:

Subwatershed	Precipitation meter/yr	Evaporation meter/yr	Included lakes (*parentheses mark upstream/intermediate lakes*)
West Chaska Ck	0.7394	0.7000	(Aue) & Gaystock
Bevens Ck	0.7394	0.7000	Maria
East Chaska Ck	0.8016	0.8000	Hazeltine, McKnight, (Big Woods), (Bavaria), Jonathan, & Grace

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

Type	Description
1	catchment or upstream waterbody - concentration and flow/outflow specified
3	wastewater discharge - concentration and flow specified

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

Seg	Segment Morphometry Name	Area km^2	Depth m	Length km	Mixed Depth m
1	Aue	0.139	4.23	0.70	4.00

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m^2-day	TP Standard ug/L
1		1	0	40

Trib	Tributary Data Trib Name	Type	Dr Area km^2	Flow hm^3/yr	Total P ug/L
1	Lakeshed runoff	1	1.773	0.171	126.5
2	Septics	3	0	0.0001	27,229

Aue at standard Mass Balance Results

Name	Area km^2	Flow hm^3/yr	Conc mg/m^3	Load kg/yr	Runoff m/yr	Export kg/km^2/yr
Lakeshed runoff	1.773	0.171	126.5	21.6	0.10	12.2
Septics		0.00010	27,229	2.7		
Precipitation	0.139	0.103	56.8	5.8	0.74	42.0
Internal Load				0		
Total Inflow	***1.912***	***0.274***	***110.2***	***30.2***	***0.14***	***15.8***
Outflow	1.912	0.177	40.0	7.1	0.09	3.7
Evaporation		0.097				
Retention				23.1		

Gaystock TMDL

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

Gaystock TMDL Input Data

Seg	Segment Morphome Name	Area km2	Depth m	Length km	Mixed Depth m
1	Gaystock	0.186	2.10	0.50	2.10

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m2-day	TP Standard ug/L
1		1	0	60

Trib	Tributary Data Trib Name	Type	Dr Area km2	Flow hm3/yr	Total P ug/L
1	Lakeshed runoff	1	11.558	1.547	70.7
2	Aue Lake outflow	1	1.912	0.177	40
3	Laketown CWWTP	3	0	0.00802	2,868
4	Septics	3	0	0.00010	6,051
5	Feedlots	3	0	0.000170	100,000

Gaystock TMDL Mass Balance Results

Name	Area km^2	Flow hm^3/yr	Conc mg/m^3	Load kg/yr	Runoff m/yr	Export $kg/km^2/yr$
Lakeshed runoff	11.558	1.547	71	109	0.13	9.5
Aue Lake outflow	1.912	0.177	40	7.1	0.09	3.7
Laketown CWWTP		0.00802	2,868	23		
Septics		0.00010	6,051	0.6		
Feedlots		0.00017	100,000	17		
Precipitation	0.186	0.138	57	7.8	0.74	42.0
Internal Load				0		
Total Inflow	***13.656***	***1.869***	***88***	***165***	***0.14***	***12.1***
Outflow	13.656	1.739	60	104	0.13	7.6
Evaporation		0.130				
Retention				61		

Bevens Creek Lake

Maria TMDL

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

Maria TMDL Input Data

Seg	Segment Morphome Name	Area km^2	Depth m	Length km	Mixed Depth m
1	Maria Lake	0.680	1.07	1.00	1.07

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m^2-day	TP Standard ug/L
1		1	0	60

Trib	Tributary Data Trib Name	Type	Dr Area km^2	Flow hm^3/yr	Total P ug/L
1	Lakeshed runoff	1	1.047	0.167	150.0
2	Septics	3	0	0.0001	12,102
3	Feedlots	3	0	0.000045	300,000

Maria TMDL Mass Balance Results

Name	Area km²	Flow hm³/yr	Conc mg/m³	Load kg/yr	Runoff m/yr	Export kg/km²/yr
Lakeshed runoff	1.047	0.167	150.0	25.0	0.16	23.9
Septics		0.00010	12,102	1.2		
Feedlots		0.000045	300,000	13.5		
Precipitation	0.680	0.503	56.8	28.6	0.74	42.0
Internal Load				0		
Total Inflow	***1.727***	***0.670***	***102.0***	***68.3***	***0.39***	***39.6***
Outflow	1.727	0.194	60.0	11.6	0.11	6.7
Evaporation		0.476				
Retention				56.7		

East Chaska Creek Lakes

Hazeltine TMDL

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

Hazeltine TMDL Input Data

Seg	Segment Morphome Name	Area km2	Depth m	Length km	Mixed Depth m
1	Hazeltine	0.652	1.10	1.55	1.1

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m2-day	TP Standard ug/L
1		1	0	60

Trib	Tributary Data Trib Name	Type	Dr Area km2	Flow hm3/yr	Total P ug/L
1	Lakeshed runoff	1	3.127	0.841	109
2	APEX	3	0	0.0000	0
3	MGK	3	0	0.0097	651
4	Septics	3	0	0.00010	3,025

Hazeltine 2009 Mass Balance Results

Name	Area km²	Flow hm³/yr	Conc mg/m³	Load kg/yr	Runoff m/yr	Export kg/km²/yr
Lakeshed runoff	3.127	0.841	108.5	91.2	0.27	29.2
APEX		0.000	0.0	0.0		
MGK		0.010	650.9	6.3		
Septics		0.00010	3025.0	0.3		
Precipitation	0.652	0.523	52.4	27.4	0.80	42.0
Internal Load				0		
Total Inflow	***3.779***	***1.373***	***91.2***	***125.2***	***0.36***	***33.1***
Outflow	3.779	0.852	60.0	51.1	0.23	13.5
Evaporation		0.522				
Retention				74.1		

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

Seg	Segment Morphome Name	Area km2	Depth m	Length km	Mixed Depth m
1	Big Woods	0.130	0.50	0.56	0.50

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m2-day	TP Standard ug/L
1		1	0	60

Trib	Tributary Data Trib Name	Type	Dr Area km2	Flow hm3/yr	Total P ug/L
1	Lakeshed runoff	1	1.967	0.454	50
2	Hazeltine Outflow	1	3.779	0.852	60
3	TEL FSI Inc	3	0	0.0000	0
4	LifeCore Biomedical I	3	0	0.0691	300
5	Septics	3	0	0.0001	9,076

Big Woods at standard Mass Balance Results

Name	Area km^2	Flow hm^3/yr	Conc mg/m^3	Load kg/yr	Runoff m/yr	Export $kg/km^2/yr$
Lakeshed runoff	1.967	0.454	49.8	22.6	0.23	11.5
Hazeltine Outflow	3.779	0.852	60.0	51.1	0.23	13.5
TEL FSI Inc		0.000	0.0	0.0		
LifeCore Biomedical LLC		0.069	300.0	20.7		
Septics		0.00010	9076.0	0.9		
Precipitation	0.130	0.104	52.4	5.5	0.80	42.0
Internal Load				0		
Total Inflow	***5.876***	***1.479***	***68.2***	***100.8***	***0.25***	***17.2***
Outflow	5.876	1.375	60.0	82.6	0.23	14.0
Evaporation		0.104				
Retention				18.3		

Bavaria for TMDL

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

Bavaria for TMDL Input Data

Seg	Segment Morphome Name	Area km2	Depth m	Length km	Mixed Depth m
1	Bavaria	0.673	5.35	1.5	4.80

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m2-day	TP Standard ug/L
1		1.254	0	40.0

Trib	Tributary Data Trib Name	Type	Dr Area km2	Flow hm3/yr	Total P ug/L
1	Lakeshed runoff	1	2.423	0.604	296
2	Septics	3	0	0.0001	18,153

Bavaria for TMDL Mass Balance Results

Name	Area km²	Flow hm³/yr	Conc mg/m³	Load kg/yr	Runoff m/yr	Export kg/km²/yr
Lakeshed runoff	2.423	0.604	296.0	178.8	0.25	73.8
Septics		0.00010	18153.0	1.8		
PRECIPITATION	0.673	0.539	52.4	28.3	0.80	42.0
******TOTAL INFLOW***	***3.096***	***1.144***	***182.6***	***208.9***	***0.37***	***67.5***
ADVECTIVE OUTFLOW	3.096	0.605	39.4	23.8	0.20	7.7
***EVAPORATION		0.538				
***RETENTION				185.0		

McKnight TMDL

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

McKnight TMDL Input Data

Seg	Segment Morphome Name	Area km2	Depth m	Length km	Mixed Depth m
1	McKnight	0.0931	0.91	0.955	0.90

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m2-day	TP Standard ug/L
1		1	0.00	60

Trib	Tributary Data Trib Name	Type	Dr Area km2	Flow hm3/yr	Total P ug/L
1	Lakeshed runoff	1	5.977	1.162	93.4
2	Big Woods Outflow	1	5.876	1.375	60.0
3	Bavaria Outflow	1	3.096	0.605	39.4

McKnight TMDL Mass Balance Results

Name	Area km²	Flow hm³/yr	Conc mg/m³	Load kg/yr	Runoff m/yr	Export kg/km²/yr
Lakeshed runoff	5.977	1.162	93.4	108.5	0.19	18.2
Big Woods Outflow	5.876	1.375	60.0	82.5	0.23	14.0
Bavaria Outflow	3.096	0.605	39.4	23.8	0.20	7.7
Precipitation	0.093	0.075	52.4	3.9	0.80	42.0
Internal Load				0		
Total Inflow	***15.042***	***3.217***	***68.0***	***218.8***	***0.21***	***14.5***
Outflow	15.042	3.142	60.0	188.7	0.21	12.5
Evaporation		0.074				
Retention				30.1		

Jonathan TMDL

C:\Users\jerdman\Desktop\BATHTUB models 2018\Jonathan TMDL_JBE_2018-05-30.btb

Jonathan TMDL Input Data

Seg	Segment Morphome Name	Area km2	Depth m	Length km	Mixed Depth m
1	Jonathan	0.093	0.46	0.7	0.45

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m2-day	TP Standard ug/L
1		1	0.00	60

Trib	Tributary Data Trib Name	Type	Dr Area km2	Flow hm3/yr	Total P ug/L
1	Lakeshed runoff	1	1.111	0.325	114
2	McKnight Outflow	1	15.042	3.142	60

Jonathan TMDL Mass Balance Results

Name	Area km^2	Flow hm^3/yr	Conc mg/m^3	Load kg/yr	Runoff m/yr	Export $kg/km^2/yr$
Lakeshed runoff	1.111	0.325	113.9	37.0	0.29	33.3
McKnight Outflow	15.042	3.142	60.0	188.5	0.21	12.5
Precipitation	0.093	0.075	52.4	3.9	0.80	42.0
Internal Load				0		
Total Inflow	***16.246***	***3.542***	***64.8***	***229.4***	***0.22***	***14.1***
Outflow	16.246	3.467	60.0	208.2	0.21	12.8
Evaporation		0.074				
Retention				21.3		

Grace TMDL

C:\Users\jerdman\Desktop\BATHTUB models 2018\Grace TMDL_JBE_2018-06-25.btb

Grace TMDL Input Data

Seg	Segment Morphome Name	Area km2	Depth m	Length km	Mixed Depth m
1	Grace	0.0809	3.04	0.550	3.00

Seg	Calbration Data	TP Calibration Factor	Internal P Load mg/m2-day	TP Standard ug/L
1		1.680	0	60.0

Trib	Tributary Data Trib Name	Type	Dr Area km2	Flow hm3/yr	Total P ug/L
1	Lakeshed runoff	1	0.361	0.124	221
2	Jonathan Outflow	1	16.246	3.467	60

Grace TMDL Mass Balance Results

Name	Area km^2	Flow hm^3/yr	Conc mg/m^3	Load kg/yr	Runoff m/yr	Export $kg/km^2/yr$
Lakeshed runoff	0.361	0.124	221.0	27.4	0.34	75.9
Jonathan Outflow	16.246	3.467	60.0	208.0	0.21	12.8
Precipitation	0.081	0.065	52.4	3.4	0.80	42.0
Total Inflow	***16.688***	***3.656***	***65.3***	***238.8***	***0.22***	***14.3***
Outflow	16.688	3.591	46.3	166.4	0.22	10.0
Evaporation		0.065				
Retention				72.4		

Appendix D – MS4 Area Maps

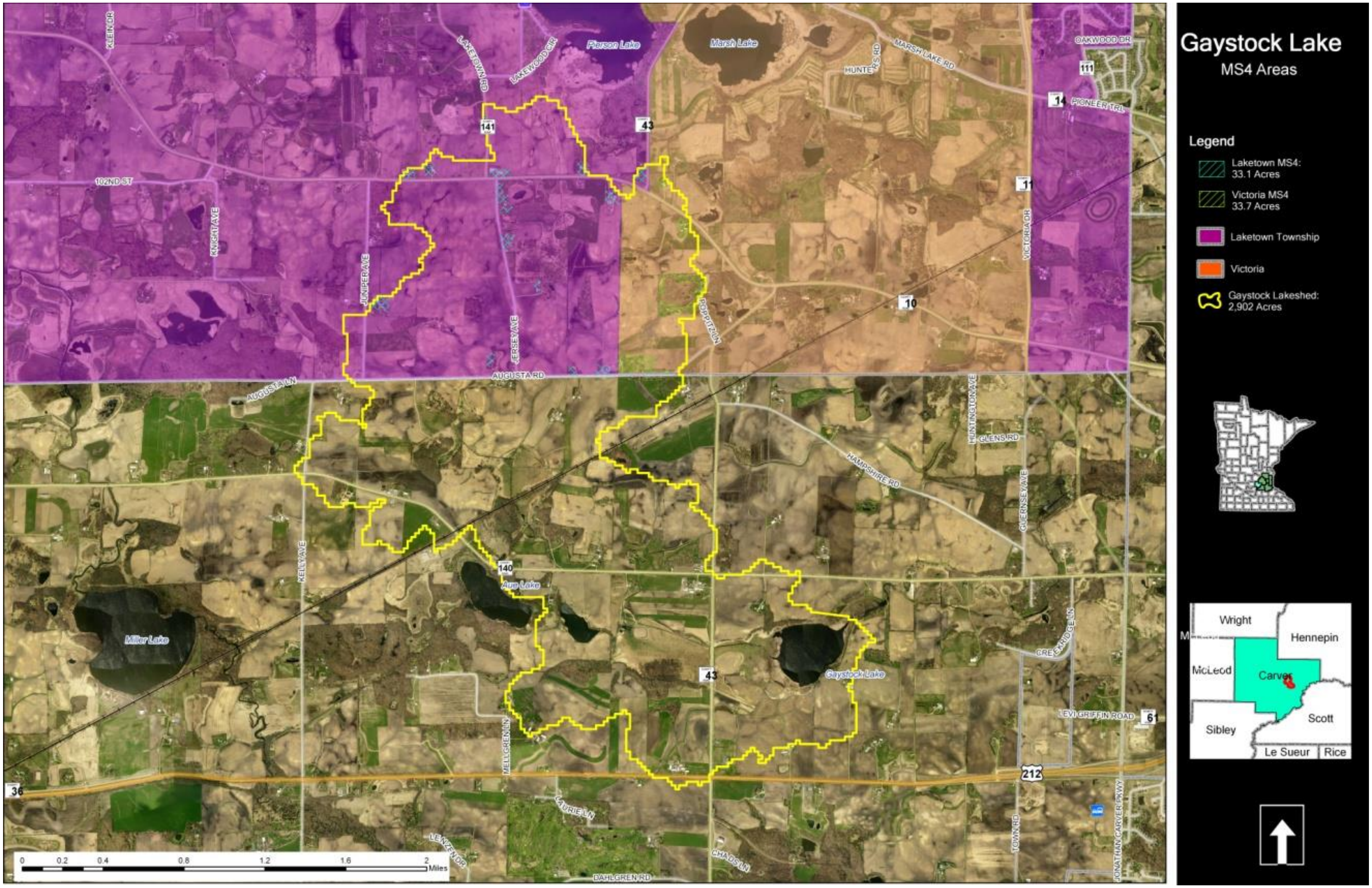

Figure D.1 Gaystock Lake MS4 Areas

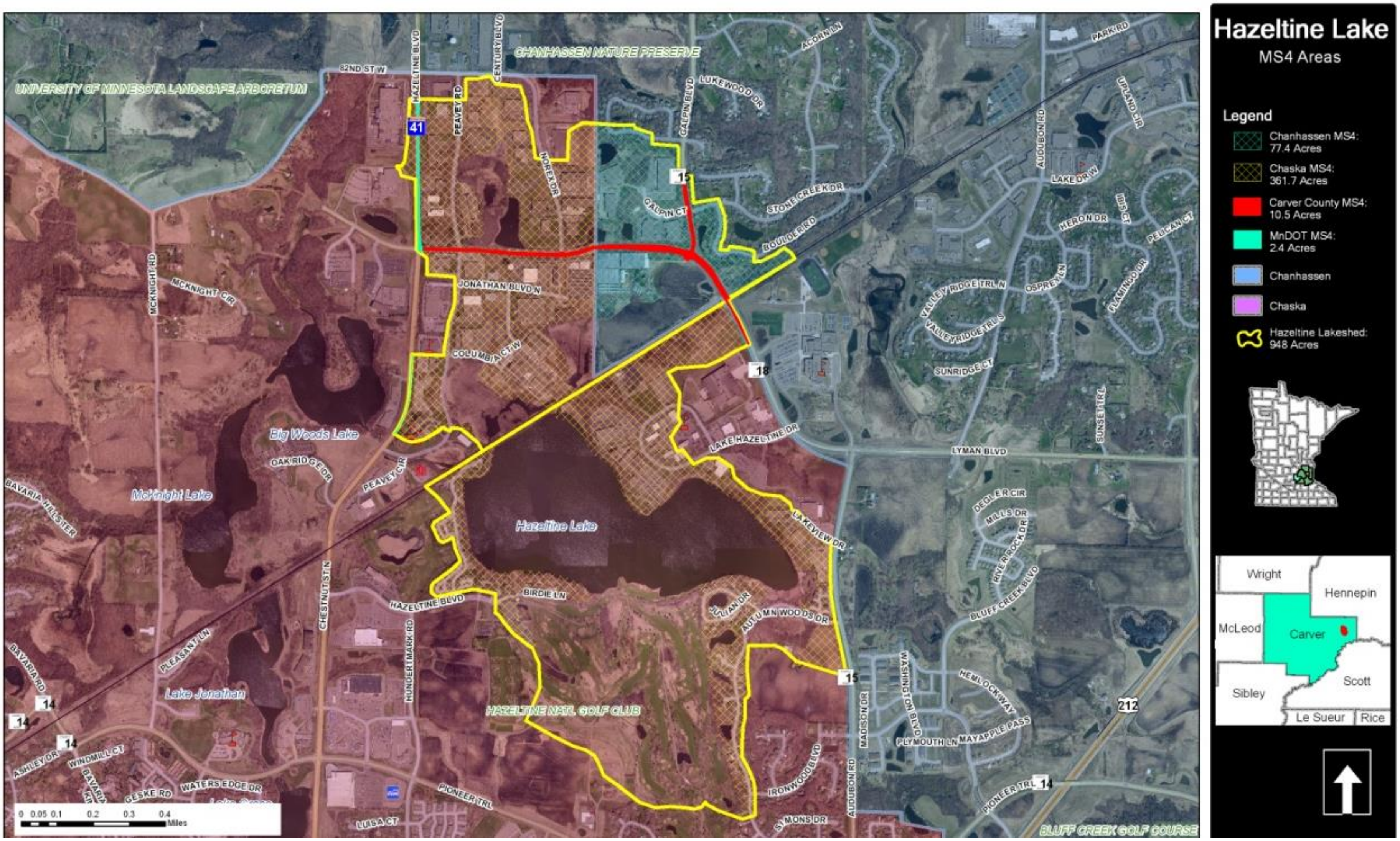

Figure D.2 Hazeltine Lake MS4 Areas

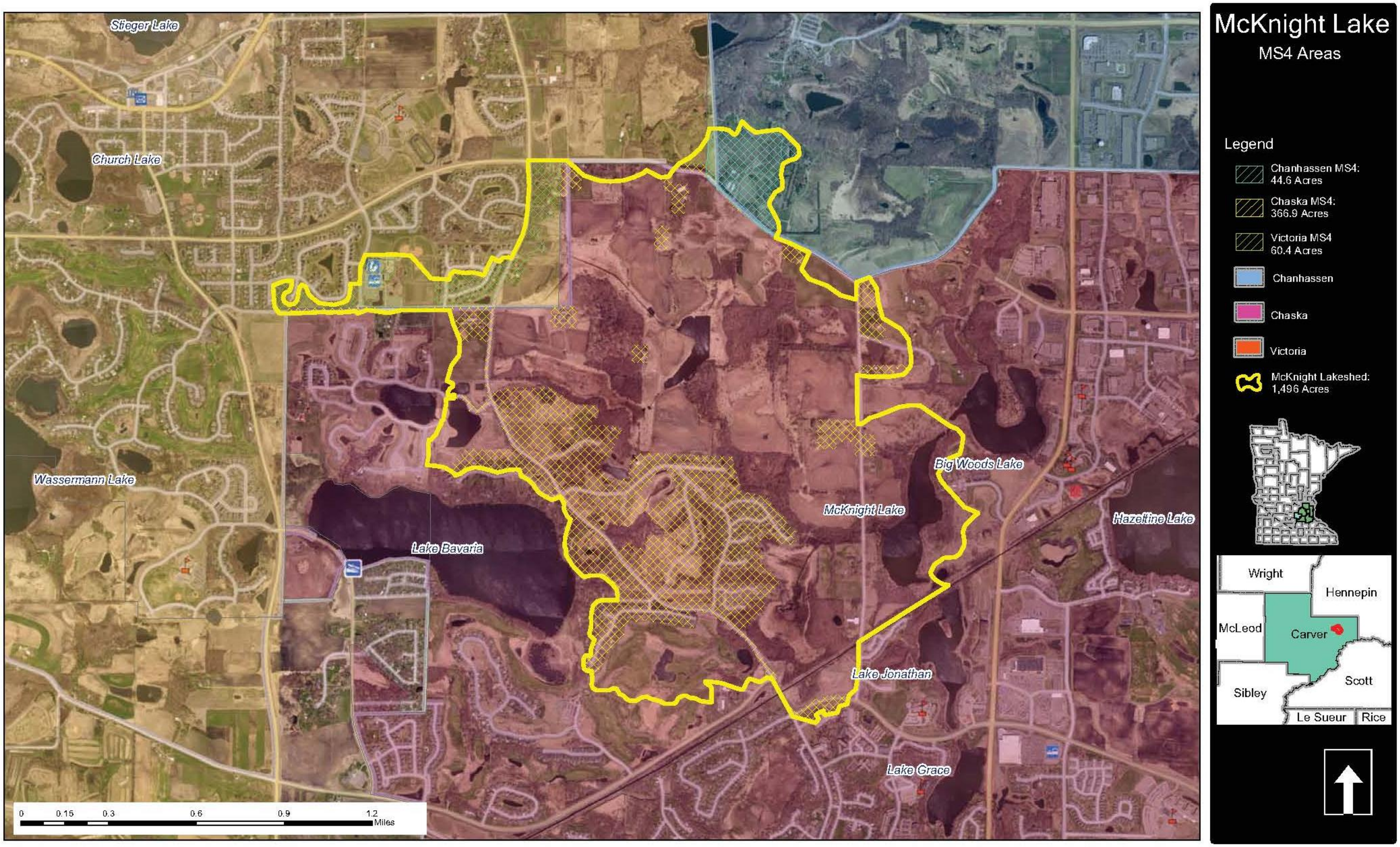

Figure D.3 McKnight Lake MS4 Areas [See Figure D.6 for updates in northwest part of lakeshed]

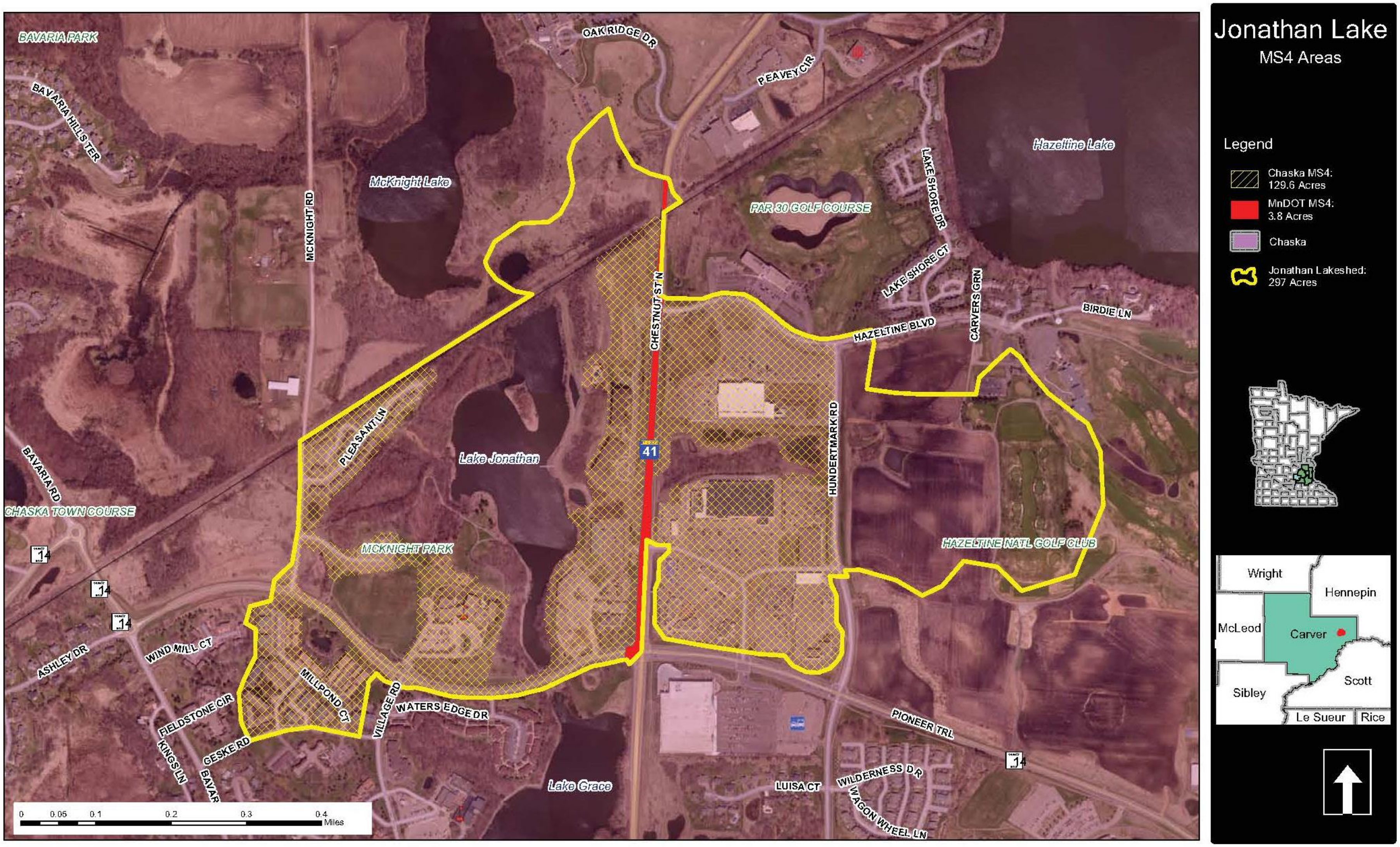

Figure D.4 Jonathan Lake MS4 Areas

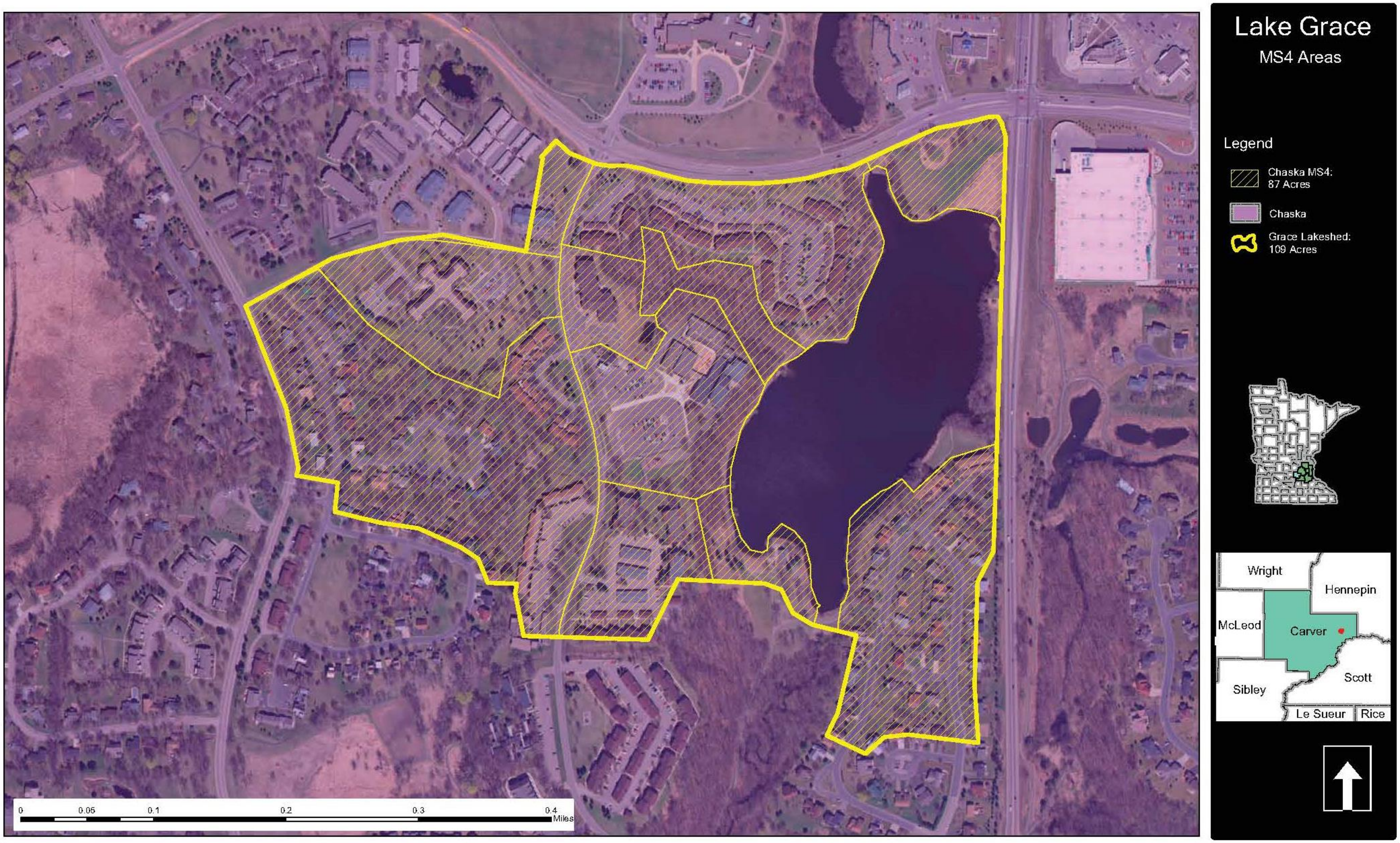

Figure D.5 Lake Grace MS4 Areas

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

	Portion of Victoria MS4 area/Reference		
	W 86th St - Bavaria Rd vicinity	**North side of W 82nd Street***	**McKnight Lakeshed Total**
Description	**Figure D-6 green area**	**Figure D-3**	**Figures D-3 & D-6**
Carver County 2014	--	--	60
Updated MS4 area	75	4	79

Table D-2. McKnight Lakeshed Area Update

Description	Lake shed Area, ac
Per Figure 3.10, Legend*	1,504
City of Victoria updates, Apr 2018:	
Additions	10
Subtractions	-37
Net change	***-27***
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

	Land Use Areas, acres					
Description	**Agriculture**	**Developed**	**Natural**	**Wetland**	**Water**	**Lakeshed Total**
Per Figure 3.10 Legend	*477*	*178*	*685*	*147*	*40*	***1,527***
McKnight Lake area					23	23
Water, lakeshed area less lake area	*477*	*178*	*685*	*147*	*17*	***1,504***
City of Victoria updates, Apr 2018:						
Additions	--	10	0	--	--	10
Subtractions	--	-8	-29	--	--	-37
Net change	0	2	-29	0	0	-27
Updated McKnight lakeshed	**477**	**180**	**656**	**147**	**17**	**1,477**