Benton Lake Excess Nutrients TMDL Report

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<tr><th colspan="4">TMDL Summary Table</th></tr>
<tr><th>EPA/MPCA Required Elements</th><th colspan="2">Summary</th><th>TMDL Page #</th></tr>
<tr><td>Waterbody Name & DNR ID</td><td colspan="2">Benton Lake – 10-0069</td><td>1</td></tr>
<tr><td>Location</td><td colspan="2">Carver County, West Metro, drains to Minnesota River via Carver Creek</td><td>4</td></tr>
<tr><td>303(d) Listing Information</td><td colspan="2">Describe the waterbody as it is identified on the State/Tribe’s 303(d) list:
· Benton Lake, Lake, 10-0069-00
· Aquatic recreation (swimming)
· Excess nutrients
· Target Start Date: 2005, Target Completion Date: 2010, Listed in 2002</td><td>1</td></tr>
<tr><td rowspan="4">Applicable Water Quality Standards/ Numeric Targets</td><td>Parameter</td><td>Concentration (μg/L)</td><td rowspan="4">3</td></tr>
<tr><td>Total Phosphorous</td><td>60</td></tr>
<tr><td>Chlorophyll-a</td><td>20</td></tr>
<tr><td>Secchi Depth</td><td>1.0</td></tr>
<tr><td rowspan="2">Loading Capacity (expressed as daily load)</td><td colspan="2">Identify the waterbody’s loading capacity for the applicable pollutant. Identify the critical condition.
For each pollutant: LC = X/day; and Critical Condition Summary</td><td rowspan="2">28</td></tr>
<tr><td>Benton</td><td>See Table 6.1</td></tr>
<tr><td rowspan="3">Wasteload Allocation</td><td colspan="2">Portion of the loading capacity allocated to existing and future point sources [40 CFR §130.2(h)].
Total WLA = X/day, for each pollutant</td><td rowspan="2">28</td></tr>
<tr><td>Benton</td><td>See Table 6.1</td></tr>
<tr><td>Reserve Capacity (and related discussion in report)</td><td>NA</td><td>28</td></tr>
<tr><td rowspan="2">Load Allocation</td><td colspan="2">Identify the portion of the loading capacity allocated to existing and future nonpoint sources and to natural background if possible [40 CFR §130.2(g)].
Total LA = X/day, for each pollutant</td><td rowspan="2">28</td></tr>
<tr><td>Benton</td><td>See Table 6.1</td></tr>
<tr><td>Margin of Safety</td><td colspan="2">Include a MOS to account for any lack of knowledge concerning the relationship between load</td><td>25</td></tr>
</table>

<table>
<tr><td></td><td colspan="2">and wasteload allocations and water quality [CWA §303(d)(1)(C), 40 CFR §130.7(c)(1)].
Identify <u>and explain</u> the implicit or explicit MOS for each pollutant

An implicit MOS was used based on conservative modeling assumptions.</td><td></td></tr>
<tr><td>**Seasonal Variation**</td><td colspan="2">Seasonal variation is accounted for by developing targets for the summer critical period where the frequency and severity of nuisance algal growth is greatest. Although the critical period is the summer, lakes are not sensitive to short-term changes but rather respond to long-term changes in annual load.</td><td>26</td></tr>
<tr><td rowspan="9">**Reasonable Assurance**</td><td colspan="2">**Summarize Reasonable Assurance**

Note: In a water impaired by both point and nonpoint sources, where a point source is given a less stringent WLA based on an assumption that NPS load reductions will occur, reasonable assurance that the NPS reductions will happen must be explained.

In a water impaired solely by NPS, reasonable assurances that load reductions will be achieved are not required (by EPA) in order for a TMDL to be approved.</td><td rowspan="9">37</td></tr>
<tr><td>**Approach**</td><td>**Specific Approach**</td></tr>
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<tr><td>NPDES Phase II Stormwater Permits</td></tr>
<tr><td>NPDES Permits</td></tr>
<tr><td>Feedlot Permitting</td></tr>
<tr><td>County ISTS Ordinance</td></tr>
<tr><td rowspan="2">Non-regulatory</td><td>Education</td></tr>
<tr><td>Incentives</td></tr>
<tr><td>**Monitoring**</td><td colspan="2">**Monitoring Plan included?** Yes

Note: EPA does not approve effectiveness</td><td>46</td></tr>
</table>

	monitoring plans but providing a general plan is helpful to meet reasonable assurance requirements for nonpoint source reductions. A monitoring plan should describe the additional data to be collected to determine if the load reductions provided for in the TMDL are occurring and leading to attainment of water quality standards.	
Implementation	**1. Implementation Strategy included?** The MPCA requires a general implementation strategy/framework in the TMDL. Note: Projects are required to submit a separate, more detailed implementation plan to MPCA within one year of the TMDLs approval by EPA. **2. Cost estimate included?** The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL [MN Statutes 2007, section 114D.25]. Cost Estimate: $550,000 to $1,475,000 Note: EPA is not required to and does not approve TMDL implementation plans.	32
Public Participation	· Public Comment period: February 25 to March 27, 2013 · Summary of other key elements of public participation process Note: EPA regulations require public review [40 CFR §130.7(c)(1)(ii), 40 CFR §25] consistent with State or Tribe's own continuing planning process and public participation requirements.	30

Executive Summary

This Total Maximum Daily Load (TMDL) study addresses a nutrient impairment for Benton Lake in the Carver Creek watershed. The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards.

Benton Lake is located within the city limits of Cologne in Carver County, west of the Twin Cities Metropolitan Area. The western suburbs of the Twin Cities Metropolitan Area are experiencing moderate to high levels of development and there is increasing awareness of water quality issues by the public. This lake is not currently used for recreation beyond its aesthetic values, fishing, and some boating, although there is pressure from local citizens to improve the lake for swimming.

The entire Carver Creek watershed area is 55,076 acres, roughly 54 percent is agricultural land and 10 percent being developed acreage. The watershed contains several lakes which are connected by channels and Carver Creek, which has been identified by the Minnesota Pollution Control Agency (MPCA) as turbidity impaired and is part of a separate approved TMDL study. Six of the watershed's lakes—Burandt, Reitz, Goose, Hydes, Miller and Winkler—have approved TMDL studies. The lake system and Carver Creek flow to the southeast, ultimately discharging into the Minnesota River.

Water quality in Benton Lake is considered poor with frequent algal blooms. Significant sources of phosphorus appear to be from both internal loading and runoff from the landscape. Also contributing to phosphorus loading is Meuwissen Lake, which flows directly into Benton Lake.

Wasteload and load allocations for Benton Lake to meet State standards for the North Central Hardwood Forest ecoregion translate to phosphorus load reductions ranging from 74 to 79 percent. Various activities and strategies are outlined within this TMDL to meet these reduction goals. Activities are in two categories: external load reduction strategies and internal load reduction strategies. External load reduction activities include, but are not limited to, lower phosphorus discharge limits for the Cologne wastewater treatment plant, installation of BMPs throughout each subwatershed, landowner education, wetland restoration, installation of buffer strips, incorporating rain gardens into residential landscapes, and impervious disconnection. Internal load reduction strategies include, but are not limited to, alum treatments, aquatic plant management, and landowner education.

1.0 Target Identification and Determination of Endpoints

1.1 Purpose

This Total Maximum Daily Load (TMDL) study addresses a nutrient impairment in Benton Lake in the Carver Creek watershed in Carver County, Minnesota. The goal of this TMDL is to provide wasteload allocations (WLAs) and load allocations (LAs) and quantify the pollutant reductions needed to meet the state water quality standards. The Benton Lake TMDL for nutrients is being established in accordance with section 303(d) of the Clean Water Act, because the State of Minnesota has determined this water body in the Carver Creek watershed exceeds the state established standards for nutrients.

1.2 Impaired Waters

The MPCA included Benton Lake on the 2002 State of Minnesota 303(d) list of impaired waters (Table 1.1). The lake is impaired for excess nutrients, which inhibit the beneficial use of aquatic recreation.

Table 1.1 Impaired waters in the Carver Creek chain of lakes.

LAKE	DNR LAKE #	AFFECTED USE	YEAR LISTED	POLLUTANT OR STRESSOR
Benton	10-0069	Aquatic recreation	2002	Excess nutrients

The MPCA projected schedule for TMDL report completion, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. This TMDL was scheduled to begin in 2005 and be complete in 2010. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the water body; technical capability and willingness locally to assist with each TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

1.3 Defining Minnesota Water Quality Standards

Water quality in Minnesota lakes is evaluated using three parameters: TP, chlorophyll-a, and Secchi depth. Phosphorus is typically the limiting nutrient in Minnesota lakes, meaning that algal growth will increase with increased phosphorus. Chlorophyll-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 disk until it can no longer be seen from the surface. Greater Secchi depths indicate less light-refracting particulates in the water column and better water quality; conversely, high TP and chlorophyll-a concentrations point to poor water quality.

The protected beneficial use for all lakes is aquatic recreation. Table 1.2 outlines the previous state standards that were used to determine that Benton Lake should be placed on the 303(d) list of impaired waters in Minnesota. In May 2008, the MPCA approved new numerical thresholds based on ecoregion and lake morphometry. The new standards take into account geographic differences across the state and nutrient cycling differences between shallow and deep lakes (MPCA 2005).

Table 1.2 Previous state standards for lakes (NCHF ecoregion).

Impairment Designation	TP (mg/L)	Chlorophyll-a (mg/L)	Secchi Depth (m)
Full Use	<40	<15	≥1.6
Review	40 – 45	NA	NA
Impaired	>45	>18	<1.1

According to the MPCA, Benton Lake is considered a "shallow" lake. Because Carver County falls within the North Central Hardwood Forest (NCHF) ecoregion (Figure 1.1), those standards were used to determine appropriate TMDL goals (Table 1.3).

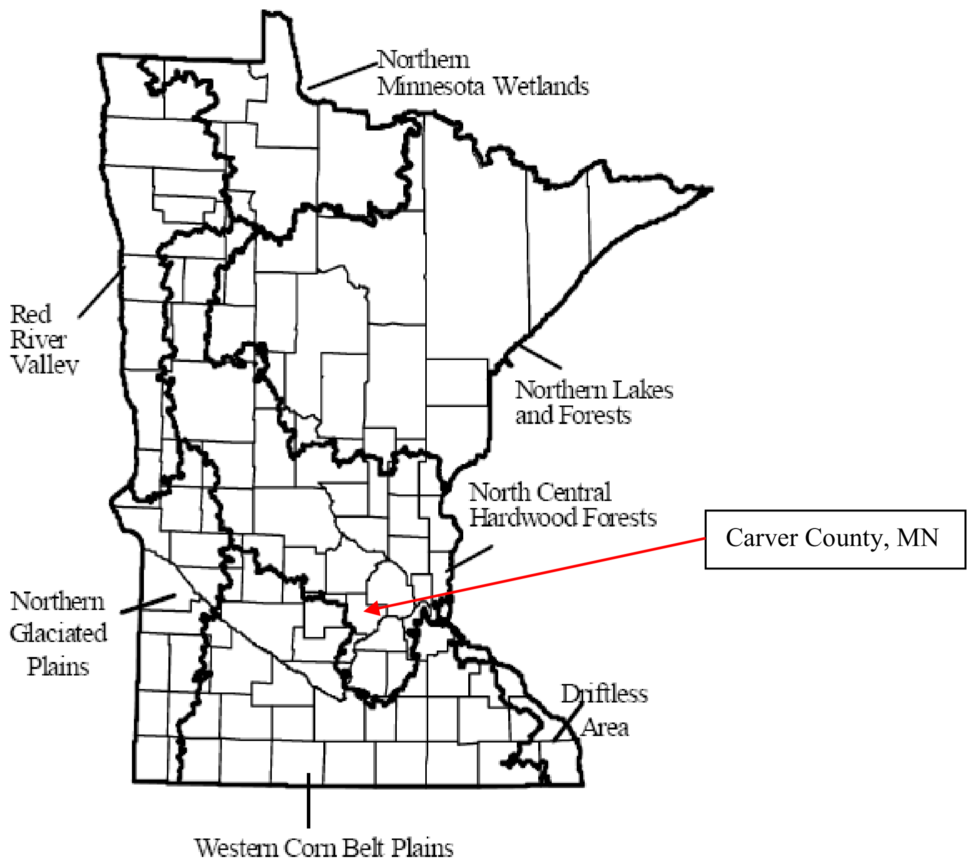


Figure 1.1 Map of Minnesota's ecoregions.

Table 1.3 MPCA lake water quality standards for North Central Hardwood Forest Ecoregion. Values are summer averages (June 1 through September 30).

	NORTH CENTRAL HARDWOOD FORESTS	
Parameters	**Shallow[1]**	**Deep**
TP concentration (µg/L)	60	40
Chl-a concentration (µg/L)	20	14
Secchi disk transparency (meters)	>1.0	>1.4

[1]Shallow lakes are defined as lakes with a maximum depth of 15 feet or less, or with 80 percent or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

This TMDL has been established with the intent to implement all the appropriate activities that are not considered greater than extraordinary efforts. But these proposed goals will require aggressive action. Upon initial implementation, subsequent monitoring will determine the feasibility in moving to the next level. If all appropriate BMPs and activities have been implemented and the lake still does not meet its goals, Carver County staff will reevaluate the TMDL and work with the MPCA to evaluate whether more appropriate site-specific standards for the lake could be pursued and developed.

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). A shift from the algae/invasive macrophyte dominated state to the clear water, native macrophyte dominated state should be a qualitative goal for Benton Lake.

2.0 Watershed and Lake Characterization

2.1 Carver Creek Lakes Watershed Description

Carver Creek watershed is located in central Carver County, encompassing 55,076 acres and parts of three cities (Figure 2.1). Land use in the watershed is predominately agriculture (54 percent), with small portions of developed and natural areas scattered throughout (10 percent and 18 percent, respectively) (Table 2.1).

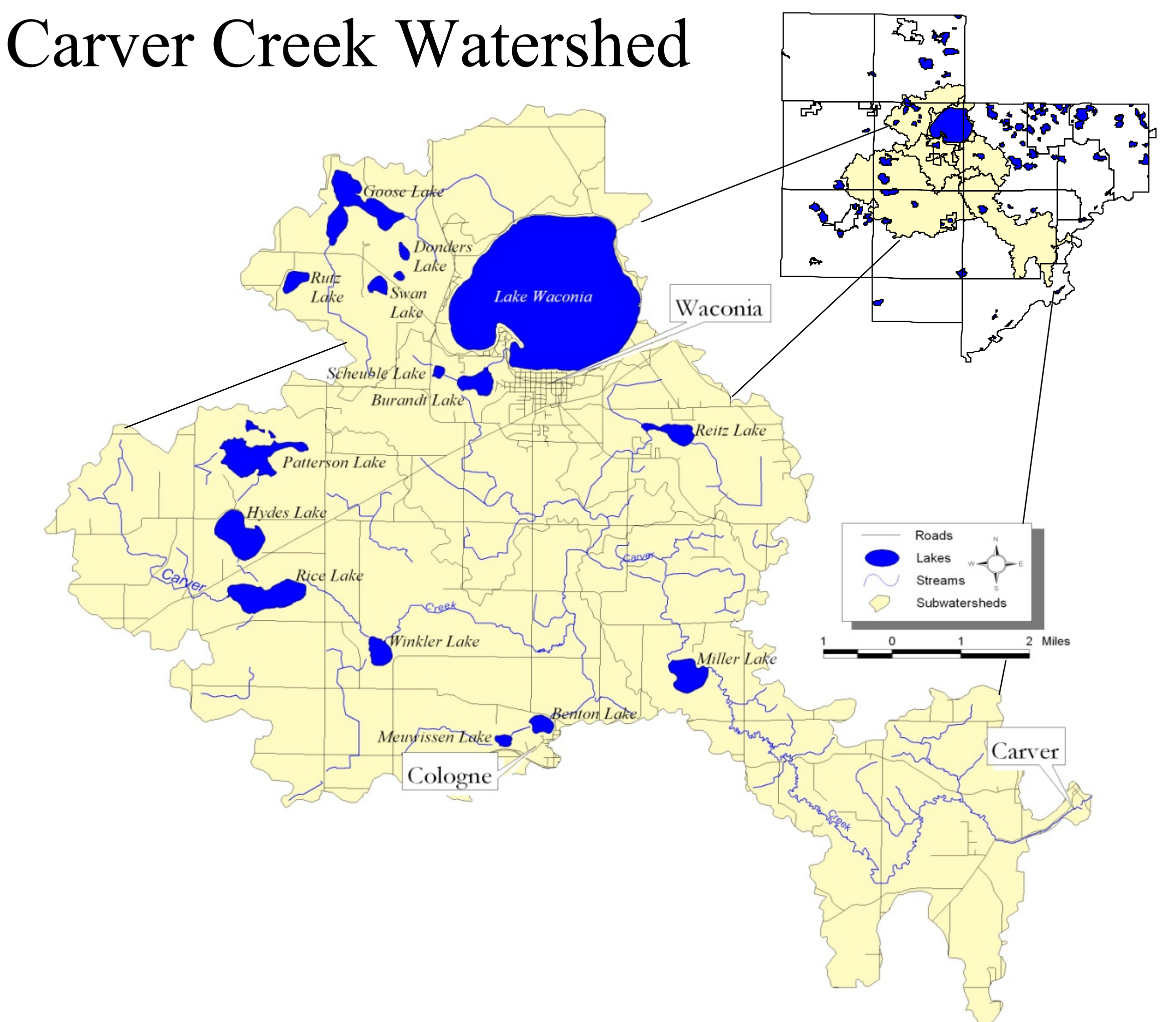


Figure 2.1 Carver Creek lakes and watershed.

Table 2.1 2005 Carver Creek Watershed Land Use.

Land Use	Carver Creek Watershed	
	Acres	Percent
Agriculture	29,880	54%
Developed	5,291	10%
Natural	9,699	18%
Wetland	5,122	9%
Water	5,084	9%
Total	**55,076**	**100%**

The Benton Lake subwatershed can be found in south-central Carver Creek Watershed. Benton Lake is completely surrounded by the City of Cologne.

Table 2.2 Lake characteristics of Benton Lake.

Parameter	**Benton Lake**
Surface Area (ac)	49
Average Depth (ft)	2 (est.)
Maximum Depth (ft)	7 (est.)
Volume (ac-ft)	95
Residence Time (days)	40 – 73
Littoral Area (%)	100
Direct Watershed (excluding lake)(ac)	436
Lake Area:Lakeshed	1:9

The Benton Lake watershed is 436 acres excluding the lake. The indirect watershed (Meuwissen Lake watershed) consists of 1,757 acres flowing in from the northwest, through Meuwissen Lake, and into Benton Lake via inlet B2. With the exception of approximately 16 acres, the Benton Lake drainage area is within the city of Cologne. Benton Lake discharges into Carver Creek which flows southeast into the Minnesota River.

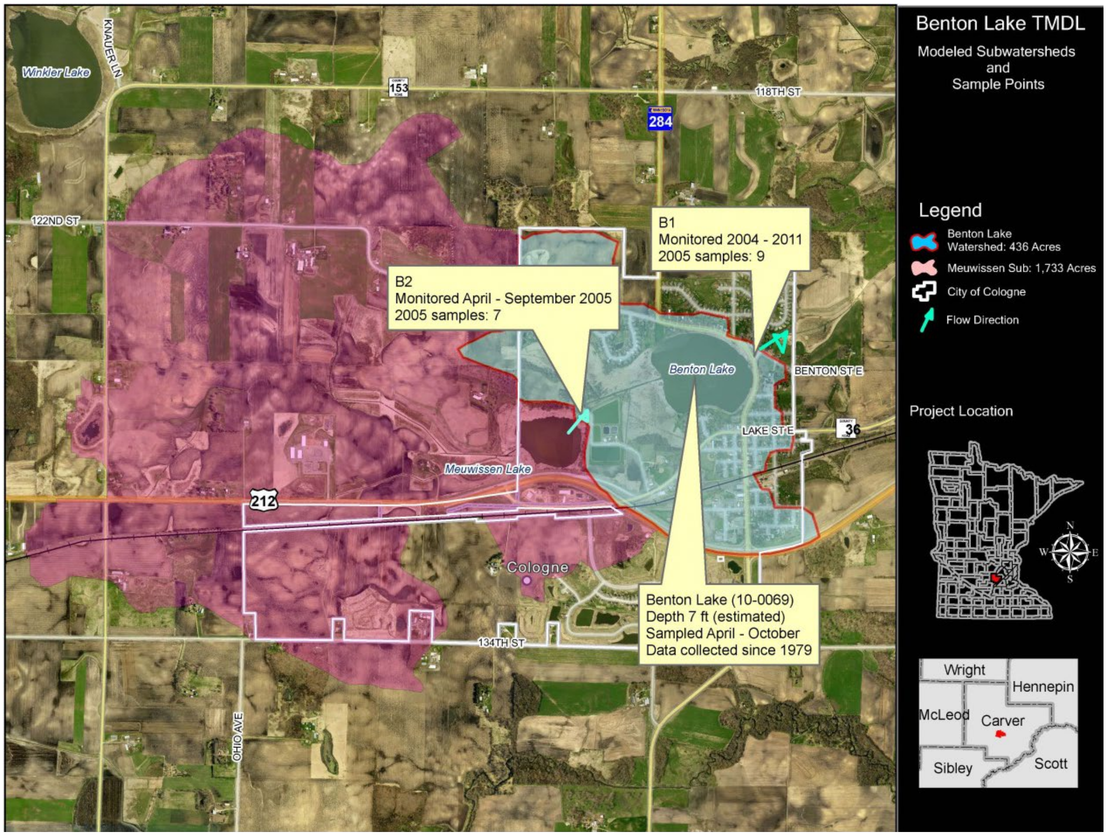


Figure 2.2 Map of Benton Lake watershed, upstream watershed, and sample points.

2.2 Land Use

Based on 2005 land use estimates conducted by the Metropolitan Council (2005) the Benton Lake watershed is predominantly (38 percent) developed (Figure 2.3, Table 2.3). Land use patterns within the watershed have shifted over the past 20-30 years as development has continually displaced the once predominantly agricultural watershed (based on 1984 Met Council land use information). In fact, prior to 1985 nearly 70 percent of the land within the Benton Lake watershed was agricultural. The remaining agricultural land is likely to be developed as the city continues to grow, and is highlighted in Table 2.4 for 2020 land use conducted by Carver County and various LGUs within the County (2001). According to GIS analysis, there are approximately 225 homes in the watershed. All are connected to public sewer systems associated with the city of Cologne. There are no feedlots within the watershed.

Land use in the Meuwissen Lake watershed, which is quite different than that of Benton Lake's direct watershed, is presented in Table 2.3 below. Approximately 77 percent of the indirect watershed remains agricultural and there are no plans for future development, according to the 2020 Comprehensive Plan (Table 2.4). There are approximately 30 homes in the Meuwissen watershed, all with on-site septic systems. According to feedlot inventories conducted in 2000, there are five feedlots with a total of 1057 animal units.

Table 2.3 Benton Lake Watershed 2005 Land Use.

Land Use	Benton Lake		Meuwissen Lake	
	Acres	Percent	Acres	Percent
Agriculture	75	15%	1,353	77%
Developed	186	38%	144	8%
Natural	94	19%	132	8%
Wetland	79	16%	99	6%
Water	52	11%	29	2%
Total	**485**	**100%**	**1,756**	**100%**

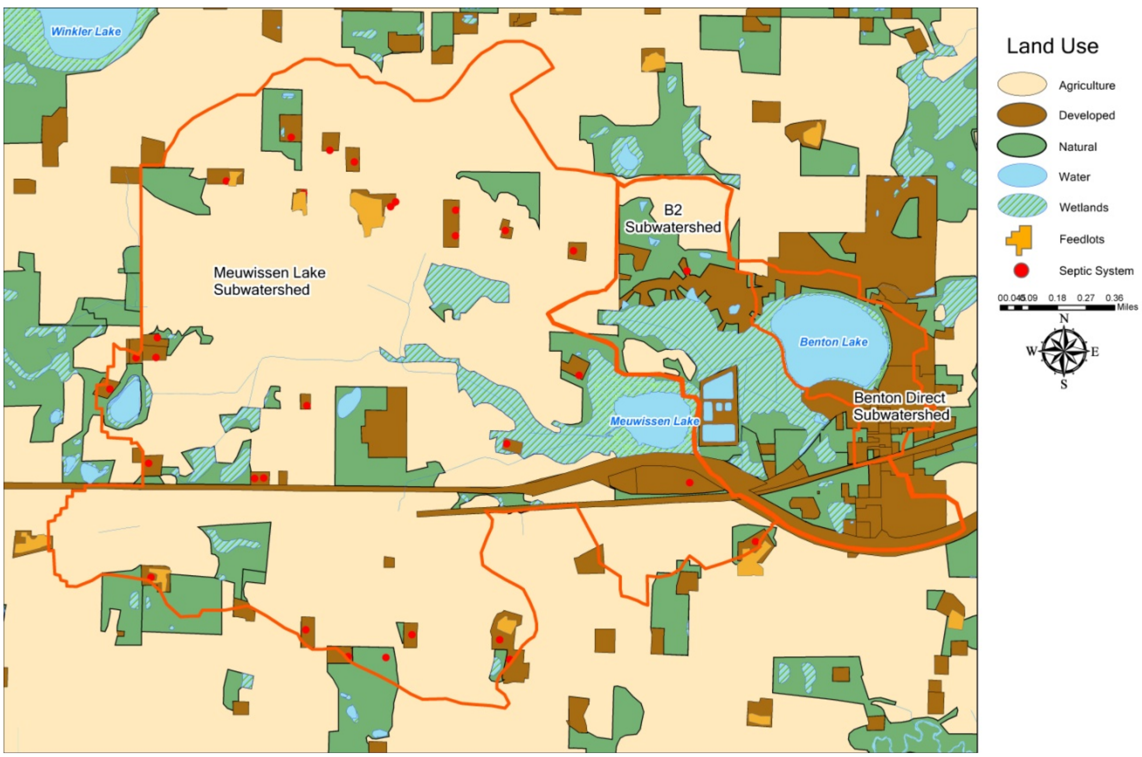


Figure 2.3 Benton Lake watershed 2005 land use and watershed size in relation to Benton Lake.

Table 2.4 Benton Lake Watershed 2020 Land Use.

Land Use	Benton Lake		Meuwissen Lake	
	Acres	Percent	Acres	Percent
Agriculture	19	4%	1,290	73%
Developed	291	60%	77	4%
Natural	20	4%	111	6%
Wetland	98	20%	250	14%
Water	57	12%	29	2%
Total	**485**	**100%**	**1,757**	**100%**

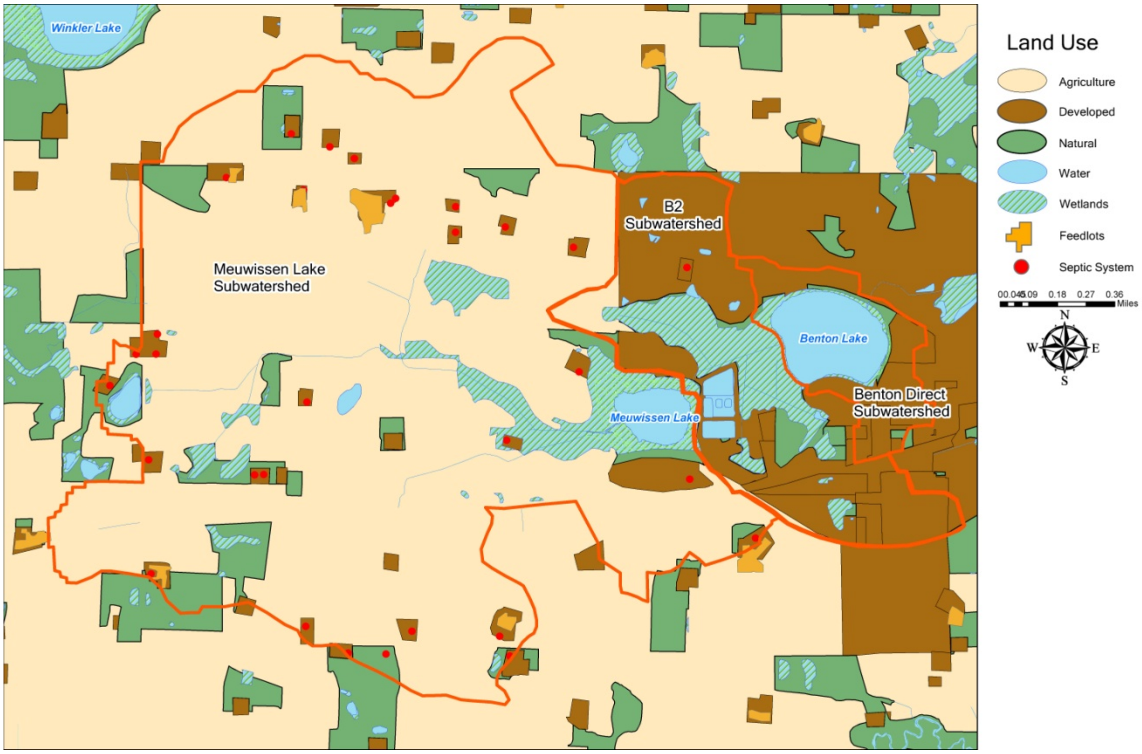


Figure 2.4 Benton Lake watershed 2020 land use and watershed size in relation to Benton Lake.

Differences in land use between the 2005 and 2020 estimates are partly due to the different methodology used to determine each classification. Any changes seen in wetland land use or developed land are largely a reflection of this difference in methodology. Developed land use does not include farmsteads, which were classified as agricultural land use for the 2020 Land Use data.

The largest increase in land uses for Benton Lake will projected to be developed land uses. This is mainly due to the city expanding to the north, changing current agricultural lands to residential (Figure 2.4). Meuwissen Lake watershed sees a four percent reduction in developed land uses. This could be due to the differences in the methodology of how land uses were classified.

2.3 Fish Populations and Fish Health

Benton Lake has experienced fish kills over the years, primarily in the winter. Fish kills occur when dissolved oxygen (DO) levels are so low that fish begin to die from the lack of oxygen. Fish kills commonly occur during the summer or winter. Summer kills are the result of high productivity of algae and macrophytes that eventually die back and are subsequently broken down by bacteria. The breakdown by bacteria demands oxygen, which depletes it from the water column. Winter fish kills are the result of snow-covered ice that shades out photosynthesis under the ice. These conditions, coupled with a high sediment oxygen demand can deplete the DO under the ice and result in a fish kill. Sediment oxygen demand is defined as the biological, biochemical, and chemical processes that occur at the sediment-water juncture that uses oxygen. More detailed summaries are available from the county upon request.

No complete fish population surveys have been conducted on Benton Lake; however, in 2003 the MDNR conducted a survey to assess its potential as a walleye rearing pond. During the survey black bullhead and carp were determined to be very abundant, particularly in the west side of the lake. The high rough fish population, in addition to low oxygen levels made the lake an unlikely candidate for use as a walleye pond. In addition to the 2003 survey, a historical survey was conducted in 1980 to gain insight into potential game species present in the lake. During the investigation it was documented that there were various minnow species and carp present and noted that the lake likely experienced frequent winterkills. It is interesting to note that a landowner indicated to the MDNR that 30-40 years prior, anglers fished the lake for northern pike.

2.4 Aquatic Plants

Native aquatic plants are beneficial to lake ecosystems providing spawning and cover for fish, habitat for macroinvertebrates, refuge for prey, and stabilization of sediments. Broadleaf plants present in the lake provide cover for fish, food for waterfowl, and support invertebrates and other small animals that both waterfowl and fish eat. In addition to the mentioned benefits, studies have shown that both emergent and submersed aquatic plants reduce the wind mixing activity that promotes sediment re-suspension in shallow lakes (James, W.F and J.W. Barko, 1994). However, in excess they limit recreation activities such as boating and swimming as well as aesthetic appreciation.

Excess nutrients in lakes can create an environment primed for the takeover by invasive exotic plants. Some exotics can lead to special problems in lakes. For example, Eurasian water milfoil can reduce plant biodiversity in a lake because it grows in great densities and squeezes other plants out. Ultimately, this can lead to a shift in the fish community because these high plant densities favor panfish over larger game fish. Species such as curlyleaf pondweed can cause very specific problems by changing the dynamics of internal phosphorus loading. All in all, there is a delicate balance in the aquatic plant community in any lake ecosystem.

Carver County staff conducted simplified macrophyte surveys of all lakes during the 2005 monitoring season. During the macrophyte survey, it was documented that nearly the entire lake was bare of aquatic plants. Sago pondweed, was present very sparsely at the shoreline and a cattail fringe was documented along nearly all of the shoreline. The lake bottom consisted mostly of loose, unconsolidated mud.

The lake survey conducted in 1980 by the MNDNR was similar to the current survey. It was indicated that coontail was the only species of submerged vegetation in the lake and was found in moderate density throughout the lake with cattails present around much of the lake fringe. A filamentous alga was also recorded to be present along the south and west parts of lake.

2.5 Shoreline and Habitat Conditions

Naturally vegetated shorelines with abundant amounts of vegetation provide numerous benefits to both lakeshore owners and users. The shoreline areas as defined in this report are areas adjacent to the lake's edge with hydrophytic vegetation and water up to 1.5 feet deep or a water table within 1.5 feet from the surface. Water quality is often improved, plant and animal biodiversity increases, they provide habitat for aquatic and terrestrial species, shorelines are more stable and erosion is decreased, there is a significant reduction in required maintenance, and an increase in aesthetic value. Therefore, identifying projects where natural shoreline habits can be restored or protected will enhance the overall lake ecosystem.

Carver County staff conducted a shoreline survey in June 2005 utilizing a Trimble GPS unit and ArcPad program. Staff circumnavigated the lake, mapping and recording shoreline type such as natural vegetation, sand beach, turf grass to shoreline, pasture, and/or retaining wall. Results from this survey indicate that nearly 94 percent of the shorelines is "natural vegetation". The rest of the shoreline is "Lawn". More detailed shoreline and habitat reports are available from the county.

3.0 Assessment of Water Quality Data

3.1 Data Sources and Methodology

3.1.1 Carver County Environmental Services

Carver County and its Water Plan act to coordinate monitoring of county lakes and streams. Monitoring of lakes follows the Water Plan management goal of creating and maintaining a comprehensive, accurate assessment of surface and groundwater quality trends over the long term. In order to establish baseline water quality, Carver County set up a network of sampling sites in the 1990s. In accordance with the County Water Plan, watersheds were given a priority (high, medium, low) based on funding available, need for monitoring data, current water quality conditions, current land use, and staff availability. In addition, Carver County promotes volunteer monitoring efforts in an attempt to broaden the public's awareness and expand our monitoring network. Benton Lake has been given a high priority and has been monitored by both volunteer and county staff annually since 1999.

Carver County follows the monitoring techniques set up by the Metropolitan Council Environmental Services (MCES) for the Citizens Assisted Monitoring Program (CAMP) program. This program includes bi-weekly in-lake samples that are analyzed for TP, chlorophyll-a, and total Kjeldahl nitrogen (TKN). Additionally, Secchi depth measurements are taken and user perception surveys are filled out during each monitoring event. Monitoring takes place from April to October each year.

3.1.2 Metropolitan Council Environmental Services

Carver Creek Lakes are also periodically monitored by the volunteer program CAMP. Citizen volunteers collect a water sample to be submitted to MCES for analysis of total phosphorous, total Kjeldahl nitrogen, and chlorophyll-a. Also collected is a Secchi disk reading and general user perceptions of the lake. Each lake is sampled bi-weekly from April to October for a total of 14 samples.

3.2 Phosphorus, Chlorophyll-a, and Secchi Depth

Monitoring conducted has depicted in-lake conditions which are hypereutrophic. A summary of all TP, chlorophyll-a, TKN, and Secchi depth data collected are presented in Table 3.1 below. Over the monitoring history, the growing season mean TP has averaged four times higher than the shallow lake standard (60 µg/L). Likewise, chlorophyll-a has remained high and Secchi transparency has remained low since 1999. Furthermore, TKN has remained above 2.0 mg/L, or the threshold which marks a negative response in water quality (MPCA 2005).

Table 3.1 Growing season (June 1 – September 30) mean lake water quality for Benton Lake.

Year	TP Concentration (µg/L)(n)	Chlorophyll-a Concentration (µg/L)(n)	Secchi disk transparency (meters)(n)	TKN (mg/L)(n)
1979	246 (4)	14 (4)	1.7 (3)	2.8 (4)
1994	(N/A)	(N/A)	2.0 (1)	(N/A)
1999	194 (13)	205 (N/A)	0.4 (13)	4.0 (13)
2000	235 (14)	181 (14)	0.3 (14)	4.5 (14)
2001	241 (14)	201 (14)	0.5 (14)	4.9 (14)
2003	274 (14)	233 (14)	0.4 (14)	4.5 (14)
2005	235 (14)	91 (14)	0.3 (14)	4.0 (14)
2007	332 (13)	227 (13)	0.4 (13)	10.0 (13)
Average	252	190	0.4	5.3

n is the number of samples collected each season

During each sampling event staff fills out a survey indicating their opinion of the lake's physical and recreational conditions ranked on a 1 to 5 scale. Recent average user perception rankings were 3.8 (between 3 = "definite algae present" and 4 = "high algal color") and 4.0 for recreational suitability (4 = "no swimming, boating ok"). Extreme nuisance algae blooms can be seen in the high chlorophyll-a concentrations the lake has experienced.

The following discussion of Benton Lake water quality focuses on the 2005 data. TP concentrations in Benton Lake ranged from 115 to 357 µg/L with a growing season average of 235 µg/L.

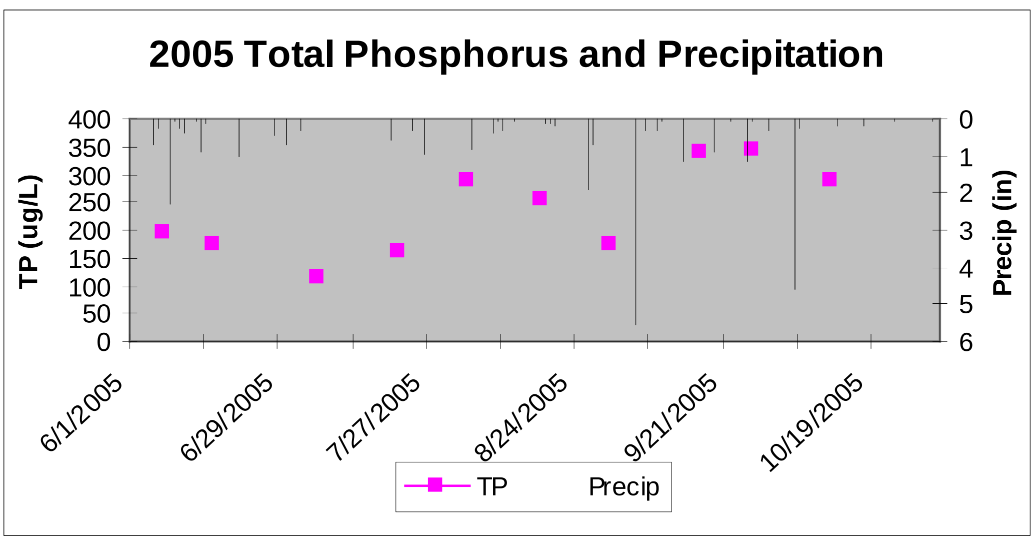


Figure 3.1 Benton Lake TP concentrations during the 2005 summer sampling season.

Increases in TP over the growing season suggest that internal loads of phosphorus play a role in water quality since inflow is naturally low later in the season (Welch & Cooke

1995). Clearer detection of between-year changes in TP can be seen in Figure 3.2. During years of below-average precipitation (2000) TP typically increases while years of above-average precipitation (2005) does not show correspondingly increased phosphorus, although it is still very high.

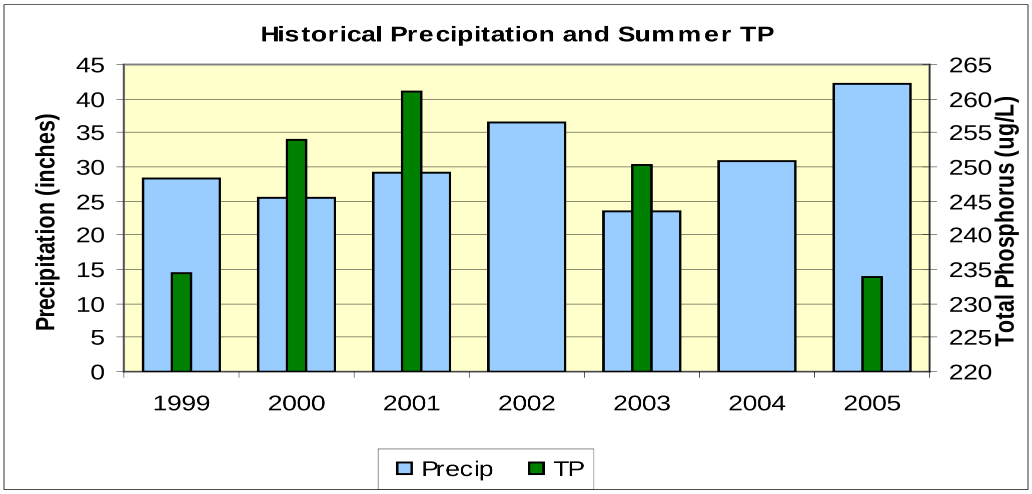
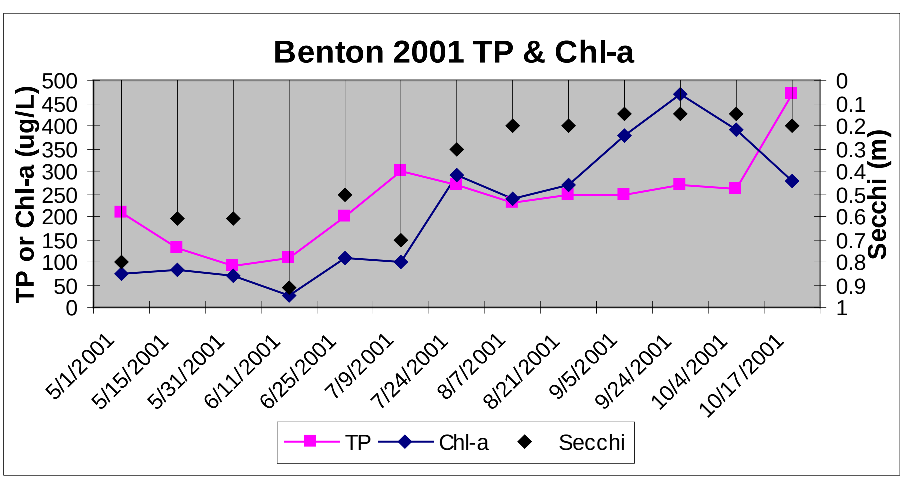


Figure 3.2 Benton in-lake TP and annual precipitation.

Internal release is not the sole cause of water quality fluctuations. During the initial monitoring period in mid-April of 2005, total phosphorus results were very high (283 µg/L). Past years have demonstrated similar variations in phosphorus over the summer. In addition to internal loading and watershed runoff, monitoring data indicates that Meuwissen Lake negatively impacts Benton Lake during high flows, mainly during the early portion of the monitoring season.

Two years of seasonal data are shown in Figure 3.3. Both years show more sustained high TP later in the season, likely corresponding to warm water temperatures influencing increased release of TP from sediment. Chlorophyll-a concentrations increase and Secchi depths decline as the season progresses, though chlorophyll-a levels exhibit much higher levels in 2001.



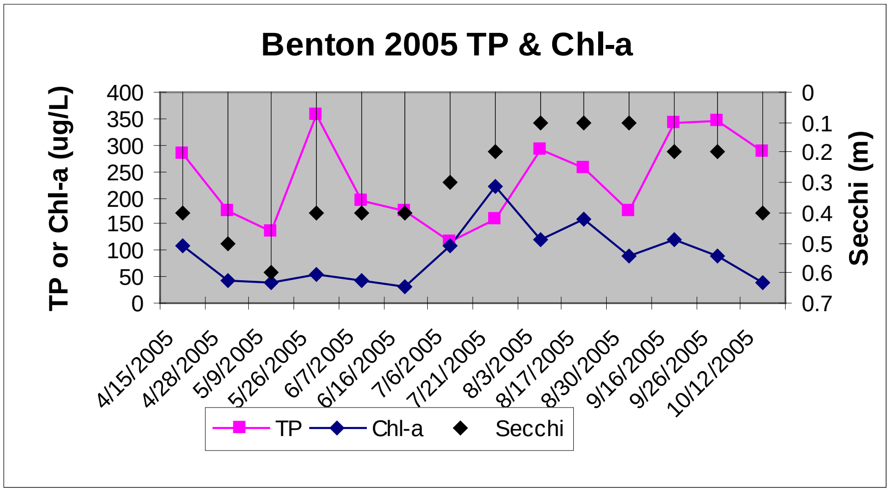


Figure 3.3 2001 and 2005 summer TP, chlorophyll-a, and Secchi depth in Benton Lake.

4.0 Phosphorus Source Assessment

4.1 Introduction

Understanding the sources of nutrients is a key component in developing a TMDL. This section provides only a general overview of the potential sources of phosphorus to Benton Lake. Section 5.0 provides further analysis of relative contributions of the basic source categories. However, it is acknowledged that we currently lack a detailed understanding of contributions from some of the source categories, particularly nonpoint.

4.2 Point Sources

The city of Cologne has a wastewater treatment Class B facility currently permitted under MPCA permit number MN0023108 to continuously discharge into the ditch between Meuwissen and Benton Lakes 0.2 miles upstream of Benton Lake (Figure 2.2).

Carver County staff believes that high levels of phosphorus are likely present in the lake sediments due to historical land use, point source discharges, and surrounding inflows.

Until recently the Cologne WWTP permit allowed for the facility to discharge up to 1.2 kg of phosphorus/day at a maximum concentration of 1.0 mg/L. The facility is designed to treat a 30-day average wet weather flow (AWW) of 0.325 million gallons per day (mgd), and annual dry weather flow (ADW) of 0.185 mgd and an annual average flow of 0.285 mgd. Actual discharges have been reported annually to the MPCA and are given in Table 4.1 below. The data below were used as model inputs.

Table 4.1 Cologne WWTP flow and TP load.

Year	SD001* (effluent)		
	Avg Flow (mgd)	Avg TP Conc. (mg/L)	Ann. TP Load (kg/yr)
2006	0.096	0.28	38
2005	0.087	0.26	31
2004	0.082	0.42	47
2003	0.072	0.29	29
2002	0.092	0.39	50
2001	0.084	0.11	13
2000	0.056	0.05	4.1
Month (year 2005)	**Avg Flow (mgd)**	**Avg TP Conc. (mg/L)**	**Daily TP Load (kg/day)**
Jan	0.06	0.84	0.20
Feb	0.07	0.45	0.12
Mar	0.07	0.22	0.06
Apr	0.10	0.20	0.07
May	0.10	0.12	0.04
Jun	0.11	0.20	0.08
Jul	0.08	0.20	0.06
Aug	0.08	0.02	0.01
Sep	0.10	0.30	0.11
Oct	0.12	0.15	0.07
Nov	0.08	0.20	0.06
Dec	0.09	0.19	0.06

*Permitted daily load (1.2 kg/day) is equivalent to 438 kg/yr.

Prior to 1980, the Cologne WWTP discharged into Meuwissen Lake. In 1980 the WWTP moved the discharge point to the stream between Meuwissen and Benton Lake therefore bypassing Meuwissen Lake. This change did not require a variance hearing because the discharge was not directly into a lake. As such, the WWTP has discharged phosphorus upstream of Benton Lake for nearly 30 years. Since 2001, the WWTP has continuously discharged into this ditch year round.

4.3 Nonpoint Sources

The following section provides a general overview of nonpoint source contributions. Because of the complexity of this part of the process for better understanding these sources and how to address them will need to occur through adaptive management (discussed in general terms in Section 8.5). This will be done post-TMDL during the implementation phase.

4.3.1 Internal Phosphorus Release

Internal phosphorus loading has been demonstrated to be an important aspect of the phosphorus budgets of lakes, especially when lakes are shallow and well-mixed. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year. Various factors that contribute to the recycling of internal phosphorus for Benton Lake include: frequent wind mixing that entrains P-rich sediments back into the water column, lack of aquatic macrophytes, bioturbation from benthivorous fish such as carp and bullhead, increased temperatures that promote bacterial decomposition, and internal phosphorus release when sediment anoxia releases poorly bound phosphorus in a form readily available for phytoplankton production (MPCA 2006).

4.3.2 Urban/Development Runoff

The development of stormwater sewer systems has increased the speed and efficiency of transporting urban runoff to local water bodies. This runoff carries materials like grass clippings, fertilizers, leaves, car wash wastewater, soil, oil and grease and animal waste; all of which contain phosphorous. These materials may add to increased internal loads through the breakdown of organics and subsequent release from the sediments. The addition of organic material into the lakes increases the sediment oxygen demand, further exacerbating the duration and intensity of sediment phosphorus release from lake sediments.

4.3.3 Agricultural Runoff

Agricultural runoff can contribute phosphorus to surface waters by transporting eroded soil particles and excess fertilizers.

Nutrients such as phosphorus, nitrogen, and potassium in the form of fertilizers, manure, sludge, irrigation water, legumes, and crop residues are applied to enhance production. When they are applied in excess of plant needs, nutrients can be available for runoff.

Animal agriculture can affect water quality, especially nutrients. Animal manure, which contains large amounts of both phosphorus and nitrogen, is often applied to agricultural fields as fertilizer. A regional Minnesota study suggests that the applied manure represents a 74 percent greater amount of phosphorus than the University of Minnesota recommended amounts (Mulla et al. 2001). This can average an extra 35 pounds per acre of phosphorus, which will ultimately be available for runoff. It is generally believed, however, that in more recent years more efficient use of manure is being achieved in Minnesota due to both economic and environmental concerns. In addition, properly applied manure can improve soil's ability to infiltrate water, thus reducing the potential for runoff (MPCA, 2005). Additionally, runoff from some feedlots can transport animal manure to surface waters.

4.3.4 Septic Systems

Failing or nonconforming direct discharge SSTS can be a significant source of phosphorus to surface waters. Septic systems, also called onsite wastewater disposal systems, can act as sources of nitrogen, phosphorus, organic matter, and bacterial and viral pathogens for reasons related to inadequate design, inappropriate installation, neglectful operation, and/or exhausted lifetime. Inappropriate installation often involves improper sighting, including locating in areas with inadequate separation distances to groundwater, inadequate absorption area, fractured bedrock, sandy soils (especially in coastal areas), inadequate soil permeability, or other conditions that prevent or do not allow adequate treatment of wastewater if not accounted for. Inappropriate installation can also include smearing of trench bottoms during construction, compaction of the soil bed by heavy equipment, and improperly performed percolation tests (Gordon, 1989; USEPA, 1993). In terms of system operation, as many as 75 percent of all system failures have been attributed to hydraulic overloading (Jarrett et al., 1985). Also, regular inspection and maintenance is necessary and often does not occur. Finally, conventional septic systems are designed to operate over a specified period of time. At the end of the expected life span, replacement is generally necessary. Homeowners may be unaware of this issue or unable to afford a replacement. Based on Carver County survey data, approximately 45 to 65 percent of the systems in the county are likely failing (Carver County 2005).

4.3.5 Atmospheric Deposition

Precipitation contains phosphorus that can ultimately end up in the lakes as a result of direct input on the lake surface or as a part of stormwater runoff from the watershed. Although atmospheric inputs must be accounted for in development of a nutrient budget, direct inputs to the lake surface are very difficult if not impossible to control and are consequently considered part of the background load.

4.3.6 Wetlands

Wetlands have the ability to remove pollutants from runoff passing through the wetland or riparian area by slowing the water and allowing sediments to settle out, acting as a sink for phosphorus, and converting nitrate to nitrogen gas through denitrification (EPA Web). However, wetlands can become contaminated with agricultural and/or urban runoff, thus becoming another source of excess phosphorus that may end up in the lake when large rain events flush through the wetland system resuspending nutrients and sediments. No data has been collected regarding the phosphorus concentrations in the wetlands of Carver Creek watershed.

5.0 Linking Water Quality Targets and Sources

5.1 Modeling Introduction

A detailed nutrient budget can be a useful tool for identifying management options and their potential effects on water quality. Additionally, lake response models can be developed to understand how different lake variables respond to changes in nutrient loads. With this information, managers can make educated decisions about how to allocate restoration dollars and efforts, as well as predict the resultant effect of such efforts.

5.2 Selection of Models and Tools

Modeling was completed in order to translate the target in-lake phosphorus concentration into load allocations, responses, and reductions goals. The models used throughout the process included a Reckhow-Simpson spreadsheet and the BATHTUB V6.1 (Walker 1999) model.

The major inflows to the lakes were monitored for flow and phosphorus loading; however, for unmonitored subwatersheds, the Reckhow-Simpson model was used to develop runoff volumes and phosphorus loads. This model relies on phosphorus export and runoff coefficients based on land uses to estimate phosphorus loading and runoff. Development of runoff and export coefficients is described in section 5.3. Outputs from the Reckhow-Simpson model were then utilized as inputs to the BATHTUB model.

BATHTUB is a publicly available model developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). BATHTUB has been used successfully in many lake studies in Minnesota and throughout the United States. It is a steady-state annual or seasonal model that predicts a lake's summer (June – September) mean surface water quality. BATHTUB's time-scales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and (if appropriate) groundwater; and outputs through the lake outlet, groundwater (if appropriate), water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments. BATHTUB allows choice among several different mass-balance phosphorus models. For deep lakes in Minnesota, the option of the Canfield-Bachmann lake formulation has proven to be appropriate in most cases. For shallow Minnesota lakes, other options have often been more useful. BATHTUB's in-lake water quality predictions include two response variables, chlorophyll-a concentration and Secchi depth, in addition to TP concentration. Empirical relationships between in-lake TP, chlorophyll-a, and Secchi depth form the basis for predicting the two response variables. Among the key empirical model parameters is the ratio of the inverse of Secchi depth (the inverse being proportional to the light extinction coefficient) to the chlorophyll-a concentration. The ratio's default value in the model is

0.025 meters squared per milligram (m^2/mg); however, the experience of MPCA staff supports a lower value, as low as 0.015 m^2/mg, as typical of Minnesota lakes in general.

BATHTUB was used to estimate nutrient inflows from each of the major subwatersheds within Benton Lake. Monitored lake and subwatershed data was used to calibrate models. Unmonitored subwatershed loads estimated via the Reckhow-Simpson Model were input into BATHTUB. After running the BATHTUB model for two years for validation, a phosphorus budget was developed for current conditions. The final BATHTUB model allowed us to estimate the relative contributions of each subwatershed and within the lake. Thus, the development of a benchmark budget allows managers to begin to assess the sources of nutrient loads and target areas for load reductions.

Several models (subroutines) are available for use within the BATHTUB model. The selection of the subroutines is based on past experience in modeling lakes in Minnesota, and is focused on subroutines that were developed based on data from natural lakes. Table 5.1 depicts the model subroutines that were chosen for all lakes modeled within this TMDL. Selection of models is also dependant on data availability. For instance, you cannot reliably use models that require orthophosphorus data if you do not have that data. For more information on these model equations, see the BATHTUB model documentation (Walker 1999).

Table 5.1 BATHTUB model options.

Model Options	**Code**	**Description**
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	P, N, LIGHT, T
Secchi Depth	0	VS. CHLA & TURBIDITY
Dispersion	0	None
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

5.3 Watershed Model Coefficients

The Reckhow-Simpson model estimates phosphorus loads for a watershed using land-use areas derived from available GIS data, along with runoff coefficients and phosphorus export values (loading rates per unit area) corresponding to the land use classes. These values were used when monitoring was not completed in specific subwatersheds.

5.3.1 Watershed Runoff

Watershed runoff was estimated using runoff coefficients assuming average watershed slopes of less than 2 percent (Ward And Elliott 1995). Runoff coefficients used are presented in Table 5.2, which are the adjusted literature values.

Table 5.2 Runoff Coefficients to estimate runoff.

Land Use	Watershed Runoff Coefficients
	Benton
Developed	0.25
Natural	0.07
Water	0
Agriculture	0.25
Wetland	0

Runoff coefficients were developed by applying literature values to the entire 55,076 acre Carver Creek watershed, and then adjusting the values to better predict monitored annual runoff volumes. Actual watershed runoff was monitored at Carver Creek site CA 1.7, which is monitored continuously by the Metropolitan Council Environmental Services Watershed Outlet Monitoring Program (WOMP). Predicted and monitored annual runoff volumes are presented in Table 5.3. Monitored runoff was very low in 2000 due to low precipitation (25.39 inches) and the timing of precipitation events. Most of the precipitation occurred mid-summer at which time vegetation was present and absorbed the majority of rainfall. Most years had a runoff difference of less than 20 percent and were deemed to be reasonable to apply to the Carver Creek watershed.

Table 5.3 Predicted and monitored annual runoff for the Carver Creek watershed.

	1998	1999	2000	2001	2002	2003	2004	2005
Predicted Runoff (ac-ft)	25,632	24,234	21,650	24,822	31,047	20,064	26,400	35,976
Monitored Runoff (ac-ft)	26,680	23,190	3,772	28,451	38,155	17,489	20,695	28,704
Percent Difference	-4%	4%	83%	-15%	-23%	13%	22%	20%

The five calendar years 2001 – 2005 included two average-precipitation years, 2001 and 2004. 2001 was used to determine the TMDL for the lake (Table 5.4). For implementation planning, Benton Lake and its watershed were also modeled for a wet year (2005) and a dry year (2003).

Table 5.4 Wet, dry, and average annual precipitation amount and year.

	Year	Amount (in)
Wet	2005	42.18
Average	2001	29.11
Dry	2003	23.53

5.3.2 Watershed Phosphorus Export

To determine phosphorus export, both for concentrations and total loads, export coefficients were utilized and are outlined in Table 5.5. Calculated concentrations and loads are used within the BATHTUB model to represent subwatersheds that do not have actual monitored sample data. Land use areas and precipitation depths for each year were needed to calculate runoff phosphorus concentrations. Land use areas were based on GIS files provided by the Metropolitan Council (2005). Land use loading rates (Table 5.5) were applied to the watershed land use to estimate watershed phosphorus loads. Phosphorus export coefficients are based upon literature values that best represented conditions in the Carver Creek Lakes watershed (EPA 1980). Runoff TP concentrations were computed from runoff depths calculated using runoff coefficients outlined in Section 5.3.1 and the resulting land use phosphorus loads derived from export values (Table 5.6). When considering loading rates for the developed areas, it was assumed that no BMPs were in place within the watershed.

Table 5.5 Phosphorus export coefficients by land use.

Loading Rate (kg/ha/yr)	Low	Average	High
Developed	0.3	0.4	0.6
Forest/Grassland	0.01	0.04	0.08
Water (Atmospheric)	0	0	0
Agriculture	0.2	0.5	1.0
Septic (kg/capital)	0.7	1.5	3.0
Wetland	0	0	0

Based on average precipitation (29.11 inches).

Table 5.6 Runoff phosphorus concentrations.

TP Concentration (µg/L)	Low	Average	High
Developed	135.2	216.3	324.5
Forest/Grassland	19.3	77.3	154.5
Agriculture	108.2	270.4	540.8

Based on average precipitation (29.11 inches).

5.3.3 Internal Load

Internal load terms were determined based on a residual process utilizing the BATHTUB model. After accounting for and entering land use and nutrient loads corresponding to the segment and tributaries using a 1.0 $mg/m^2/day$ of internal loading, the model was run. Predicted and observed values were evaluated. At this point, if the in-lake predicted phosphorus values remained below that of the observed, additional internal loading was added until the predicted and observed nutrients were within 10 percent of each other. This process suggests that the internal load is the load remaining after all external sources have been accounted for.

5.3.4 Atmospheric Load
Atmospheric loading rates were set at a rate of 20 mg/m^2/yr based on conversations with the MPCA and literature values (Bruce Wilson personal communication).

5.4 Phosphorus Budget Components
5.4.1 Internal Load
Using the process outlined in Section 5.3.3, final internal loading terms were determined to be 2.3 and 3.25 mg/m^2/day for 2005 and 2001, respectively.

5.4.2 Atmospheric Load
Using rates determined in Section 5.3.4 and the area of the lake, the atmospheric loading for Benton Lake is set at 4 kg/yr.

5.4.3 Upstream Lakes
Monitoring at Meuwissen Outlet during the 2005 monitoring season depicted the quality of the water moving out of Meuwissen Lake (Appendix A). Results from the 2005 monitoring season were used instead of the Reckhow-Simpson model for calculating inputs from Meuwissen Lake. Because of this, Reckhow-Simpson modeled flow and phosphorus concentrations were used in the BATHTUB models for only 2001.

Table 5.7 BATHTUB model inputs to Benton Lake from Meuwissen Lake.

Year	Lake	Watershed Area (km^2)	P Concentration (µg/L)	Outflow (hm^3/yr)	Load (kg/yr)
2005	Meuwissen	7.11	292	2.24	654
2001	Meuwissen	7.11	291	1.15	334

5.4.4 Tributary or Watershed Load
Table 5.8 outlines the inputs used within the BATHTUB model for both the 2001 and 2005 modeled years. These values are calculated using methods as described in Section 5.3.

Table 5.8 BATHTUB model inputs for Benton Lake.

Year	Watershed Area (km^2)	P Concentration (µg/L)	Outflow (hm^3/yr)	Load (kg/yr)
2005	2.0	150.2	0.31	47
	0.6			
2001	2.0	217.7	0.21	47
	0.6		0.05	

5.4.5 Municipal Wastewater Load
Data reported to the MPCA was used as input into the BATHTUB model as point sources. The data input into the models is shown below in Table 5.9. In 2005 the treatment facility reported discharging 31 kg of phosphorus, which is a small portion of its current permitted load.

Table 5.9 Cologne WWTP reported values for 2005 and 2001.

Year	SD001-effluent to surface water		
	Average flow (mgd)	**Average P Load (kg/yr)**	**Permitted Load (kg/yr) @ 1.2 kg/day**
2005	0.0874	31.9	438
2001	0.0841	30.7	438

5.5 Model Validation and Benchmark Phosphorus Budgets

5.5.1 Model Validation

Model results from 2001 (average year) and 2005 (wet year) are presented as the predicted and observed values and a coefficient of variation (standard error of the mean) within Table 5.10. Predicted phosphorus concentrations best reflected the observed values only after the internal loading was accounted for, suggesting that internal loading is a critical component to water quality in Benton Lake.

Table 5.10 Observed and predicted in-lake water quality for Benton Lake in 2001 and 2005 (June – September).

Year	Predicted		Observed	
	Mean	**CV**	**Mean**	**CV**
2005	233.3	0.18	234.0	0.35
2001	259.8	0.20	261.0	0.34

The model represents reasonable agreement among predicted and observed TP in both 2005 and 2001.

5.5.2 Benchmark Phosphorus Budgets

One of the key aspects of developing TMDLs is an estimate of the nutrient budget for the current loading to the water body. Monitoring data and modeling were used to estimate the current sources of phosphorus to Benton Lake. Nutrient and water budgets are presented below. These budgets do not account for any groundwater exchange; and it is assumed that the lake acts as both a groundwater discharge and recharge area so the net effect on the water or nutrient budgets is very small.

External loads, particularly from the Meuwissen Lake subwatershed, make up the greatest portion of the current nutrient budget (Table 5.11). However, Meuwissen Lake only contributes to the overall load during high flows particularly in the spring. Internal loads appear to be a substantial source of phosphorus to Benton Lake as well. The WWTP currently discharges below the set limits resulting in a rather low portion of the load to Benton Lake.

Table 5.11 Summary of current TP and water budget for Benton Lake based on 2001 data and BATHTUB modeling.

Subwatershed	Area km^2	Water Inflow hm^3/yr	TP Load kg/yr	Percent of Total Load
Meuwissen Lake subwatershed	7.1	1.15	334	53%
Benton Lake Subwatershed	2.0	0.21	47	7%
Cologne WWTP	--	0.1	13	2%
Atmospheric Deposition	0.2	0.1	4	0.6%
Total External		**2.3**	**398**	**63%**
Total Internal			**237**	**37%**
TOTAL P LOADING			**635**	**100%**

In-lake water quality monitoring of Meuwissen Lake indicates that phosphorus concentrations are similar to that of Benton Lake. The high load stemming from Meuwissen Lake can be attributed to its large watershed and the high percent of agricultural land use in the watershed. In addition to this, the WWTP historically discharged directly to the lake causing a buildup of nutrients in the sediment thereby resulting in a high internal load.

6.0 TMDL Allocations

TMDL = WLA + LA + MOS + RC

Where:

TMDL = Total Maximum Daily Load
WLA = Wasteload Allocation (for permitted sources)
LA = Load Allocation (for nonpermitted sources)
MOS = Margin of Safety
RC = Reserve Capacity

6.1 TMDL Allocations Introduction

The TMDL presented here is developed to be protective of aquatic recreation beneficial uses in lakes, as embodied in the Minnesota lake water quality standards. Loads are expressed both as annual and daily loads; however, an annual load is more relevant to this TMDL study because the growth of phytoplankton is more responsive to changes in the annual load than the daily load.

6.1.1 Loading Capacity Determinations

The loading capacity of Benton Lake was determined by fitting the lake's phosphorus load to the shallow lake state standard, using the BATHTUB model. The loading capacity is the same as the TMDL. Section 6.3 presents the TMDL and TMDL allocations.

6.1.2 Critical Condition

The Minnesota lake standards consider the summer growing season (June-September) as the critical condition. Minnesota lakes typically demonstrate impacts from excessive nutrients during the summer, including excessive algal blooms and fish kills. Consequently, the lake response models have focused on the summer growing season as the critical condition. Additionally, this lake tends to have relatively short residence times and therefore respond to summer growing season loads.

6.1.3 Margin of Safety (MOS)

A margin of safety has been incorporated into this TMDL by using a conservative modeling approach to account for an inherently imperfect understanding of the lake system and to ultimately ensure that the nutrient reduction strategy is protective of the water quality standard.

The lake response model for total phosphorus used for this TMDL uses the rate of lake sedimentation, or the loss of phosphorus from the water column as a result of settling, to predict total phosphorus 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 or clear water. Lake response models assume that even when total phosphorus 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 phosphorus 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 total phosphorus concentrations due to increased zooplankton grazing, reduced sediment resuspension, etc. Therefore, this TMDL is inherently conservative by setting allocations for the turbid water state.

6.1.4 Reserve Capacity (RC)

Reserve Capacity (RC) is that portion of the TMDL that accommodates future loads (MPCA lake protocol report 2006). No reserve capacity is allocated in this TMDL. Any growth will need to occur within the allocations established in this TMDL.

6.1.5 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.

6.2 TMDL Allocation Approach

The TMDL was allocated to a combination of load allocation and wasteload allocation. The approach to making these allocations is described in the following two sections and is the same as was done for other lake TMDLs completed in the Carver Creek watershed.

6.2.1 Load Allocations (LAs)

Load allocations (LAs) include watershed runoff loading from the direct watershed (which contains no regulated Municipal Separate Storm Sewer Systems covered by an NPDES permit), as well as atmospheric and internal loadings. For load allocations, the direct watershed includes both B2 and direct subwatershed as outlined in Section 2.1. The loading from Meuwissen Lake is also placed in the LA category since there is no regulated MS4 or wastewater discharge within its subwatershed. A future TMDL will consider Meuwissen Lake’s phosphorus balance in greater detail.

The LA for the direct watershed was estimated using the export coefficients as outlined in Table 5.5 multiplied by 2020 land use areas as shown in Section 2.2 to produce 2020 loading results. (2020 land use is used for allocations to provide capacity for estimated future growth.) This product is then reduced by the required reduction percentage for external loads as outlined by Section 5.5.2 for the benchmark-year (2001) hydrology. The reduction percentage for 2001 is 79 percent. Applying this reduction to the estimated 2020 loading results in an LA value of 11.0 kg/yr. (Note: a very small fraction of this—0.1 percent or 0.01 kg/yr—is actually set aside for construction/industrial stormwater. See section 6.2.2.3.)

The atmospheric loading was set equal to that in the benchmark phosphorus budget (Section 5.3.4) as this is not a load that can be reduced. This load is 4.0 kg/yr.
The LA for internal loading was calculated by assuming a very low rate of phosphorus release from the lake sediment, representing a mesotrophic shallow lake condition. Mesotrophic lakes demonstrate internal phosphorus release rates ranging from 0 to 12 mg/m^2/day with a median release rate around 4 mg/m^2/day (Nurnberg 1997). A rate of 0.0975 mg/m^2/day was selected, which represents a 97% reduction and provides an internal load allocation of 7.12 kg/yr. Benton Lake is entirely littoral and can be expected to release little or no phosphorus when maintained in a healthy state.

The allowable loading from Meuwissen Lake was calculated assuming that the water discharging from it meets the state shallow lake standard of 60 µg/L. Volume discharge rates were determined using the runoff coefficients outlined in Section 5.3. From these, total yearly phosphorus loads were calculated. This load is 68.8 kg/yr.

6.2.2 Wasteload Allocations (WLAs)

Wasteload allocations (WLAs) are required for regulated MS4 discharges, municipal and industrial wastewater discharges, and stormwater runoff from both industrial and construction sites.

6.2.2.1 Municipal Separate Storm Sewer Systems (MS4s)

Currently there are no regulated discharges from MS4s and, thus, no allocation is provided for this category. If in the future the Census Bureau-defined Urban Area expands into this watershed and/or additional stormwater discharges come under NPDES permit coverage within the watershed, WLA will be transferred to these entities. The transfer will be on a one-to-one areal basis from LA currently assigned to watershed runoff. MS4s will be notified and will have an opportunity to comment on the reallocation.

6.2.2.2 Municipal and Industrial Wastewater Discharges

The only NPDES-permitted wastewater facility within the Benton Lake watershed is the City of Cologne WWTP. The WLA for this facility is essentially the loading capacity remaining after the LA components of section 6.2.1 (plus the WLA for construction and industrial stormwater, section 6.2.2.3) are accounted for. The resulting WLA for this facility is 46.4 kg/yr.

6.2.2.3 Construction Stormwater and Industrial Stormwater

The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites $\geq$ 1 acre expected to be active in the watershed at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS 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. It should be noted that all local construction stormwater requirements must also be met.

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

The land area representing construction and industrial stormwater would be expected to make up a very small portion of the watersheds at any one time. Therefore, WLAs for construction and industrial stormwater combined were conservatively set at 0.1% of the allowable loading from the direct watershed. This equates to 0.01 kg/yr.

6.3 Summary of TMDL Allocations and Reductions

The Benton Lake TMDL is set for a shallow lake in the NCHF ecoregion of Minnesota with a standard of 60 µg/L phosphorus as a final goal. The selected average precipitation year for the Benton Lake TMDL is 2001. Table 6.2 presents the TMDL and its components.

Table 6.1 TMDL allocations for Benton Lake. Allowable loads to meet the NCHF shallow lake standard of 60 µg/l. MOS is implicit and RC is zero.

Load Units	TMDL	WLA Cologne WWTP	WLA Construction/ Industrial	LA Atmospheric	LA Internal	LA Non-MS4	LA Upstream Lakes
kg/yr	137.4	46.4	0.01	4.0	7.1	11.0	68.8
kg/day	0.38	0.13	0.00003	0.011	0.02	0.03	0.19

Pollutant load modeling was conducted and analyzed on an annual basis to establish this TMDL at a level necessary to attain and maintain applicable water quality standards.

Daily wasteload allocations were derived from this analysis. A baseline year of 2005 is to be used for evaluating and crediting loading reductions for this TMDL.

6.3.1 Load Response

In addition to meeting a phosphorus limit of 60 µg/L, chlorophyll-a and Secchi depth standards must also be met. In developing the lake nutrient standards for Minnesota lakes (Minn. Rule 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 total phosphorus and the response variables chlorophyll-a and Secchi disk. Based on these relationships it is expected that by meeting the phosphorus target of 60 µg/L for Benton Lake the chlorophyll-a and Secchi standards (20 µg/L and 1.0 m, respectively) will likewise be met.

6.3.2 Modeled Historic Loads

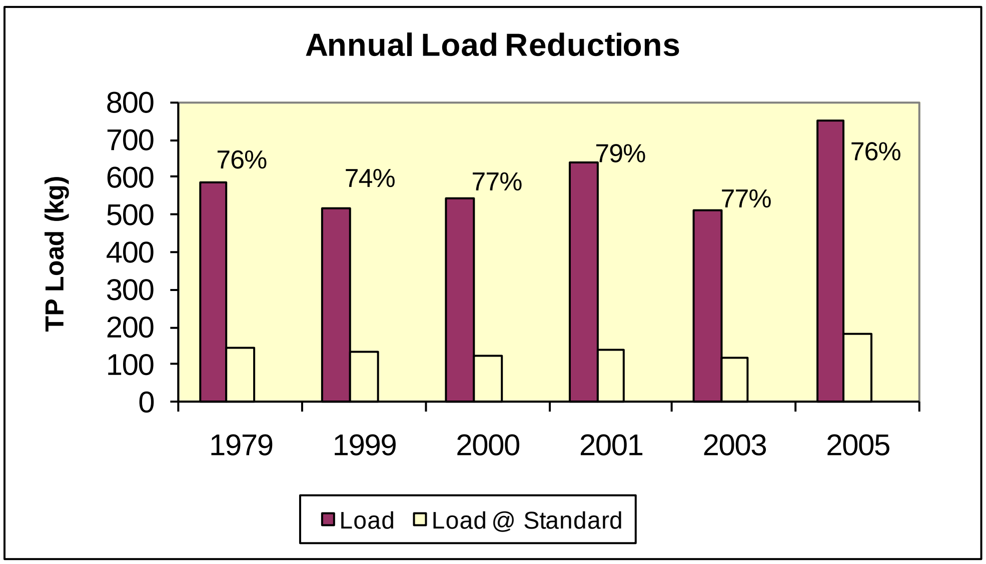


Figure 6.1 Predicted annual loads for monitored conditions at Benton Lake and for the 60 µg/L TP standard over the last 10 years. Percentages represent the necessary load reduction to meet the standard.

Using the Canfield-Bachmann equation, historic loads and load reductions were calculated for each monitored year (Figure 6.1). In order to meet the NCHF shallow lake water quality standard of 60 µg/L TP, the phosphorus load must be reduced by 74 percent to 79 percent based on water quality and precipitation. Over the last ten years the lowest allowable load was 118 kilograms of phosphorus and the maximum allowable load was 182 kilograms of phosphorus.

7.0 Public Participation

7.1 Introduction

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, approved in 2001. 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 will aid in the development of this and other TMDLs in the County.

7.2 Technical Advisory Committee

The Water, Environment, & Natural Resource Committee (WENR) was established as a permanent advisory committee. The WENR is operated under the County's standard procedures for advisory committees. The WENR works with staff to make recommendations to the County Board on matters relating to watershed planning.

The make-up of the WENR is as follows:

1 County Board Member
1 Soil and Water Conservation District Member
5 citizens – (1 appointed from each commissioner district)
1 City of Chanhassen (appointed by city)
1 City of Chaska (appointed by city)
1 City of Waconia (appointed by city)
1 appointment from all other cities (County Board will appoint)
2 township appointments (County Board will appoint– must be on existing township board.)
4 other County residents (1 from each physical watershed area – County Board will appoint)

The full WENR committee received updates on the TMDL process from its conception in 2004.

As part of the WENR committee, two sub-committees are in place and have held specific discussions on Excess Nutrient TMDLs. These are the Technical sub-committee and the Policy/Finance sub-committee.

TMDL progress, methods, data results and implementation procedures were presented and analyzed at the WENR meetings mentioned above. 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.

7.3 Public Comments

Stakeholder involvement involved the following components: public survey, public meeting, and personal meetings. The following are general discussions of stakeholder involvement.

Landowners within the Benton Lake watershed were invited to an open house that was held on January 22nd, 2008. During that meeting, 47 were present to learn about the history of Benton Lake, how the City of Cologne's WWTP interacts with the lake, and the impacts of carp on the lake. Leading up to the open house, 350 surveys were mailed to landowners. Of those 350, 53 were filled out and returned. The following is a summary of the user survey and comments received during the meeting:

- Sources that respondents were concerned about were the City of Cologne's WWTP, lawn fertilizers, and rough fish.
- Group has active leaders that want to see improvement of water quality within the lake and are eager to help.
- Respondents would like to see the lake return to a state that allows for swimming, fishing, and boating activities.
- Survey responses indicate the willingness to participate in cost share grants to help with improving water quality.

In addition, an opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from February 25 to March 27, 2013.

8.0 Implementation

8.1 Introduction

Carver County, through their Water Management Plan, has embraced a basin wide goal for protecting water quality in the Carver Creek watershed including Benton Lake. Currently, Carver County has developed detailed action strategies to address several of the issues identified in this TMDL. The Carver SWCD is active in these watersheds and works with landowners to implement BMPs on their land.

This section broadly addresses the course that Carver County will take to incorporate actions and strategies to achieve the TMDL goals set forth within this document. An Implementation Plan that will lay out specific goals, actions and strategies will be published within one year of the final EPA approval of this TMDL. Any action items pertinent to this TMDL that are not included in the Carver County Water Plan will be identified and amended to the Implementation Plan.

8.2 Carver County Water Management Plan

To respond to the County's established goals for Natural Resource Management, the Carver County Water Management Plan describes the set of issues requiring implementation action. MN Rule 8410 describes a list of required plan elements. Carver County has determined the following issues to be of higher priority. Items not covered in this plan will be addressed as necessary to accomplish the higher priority goals. Each issue is summarized in the Carver County Water Management Plan followed by background information, a specific goal, and implementation steps. The issues included in the plan which addresses nutrient TMDL sources and reductions are:

- SSTS
- Feedlots
- Stormwater Management
- Construction Site Erosion & Sediment Control
- Land Use Practices for Rural & Urban Areas
- Water Quality

8.3 Source Reduction Strategies

To reach the reduction goals Carver County will rely largely on its current Water Management Plan which identifies the Carver SWCD as the local agency for implementing BMPs. It will list suggested BMPs to be applied in the watershed and the order of importance for which they should be applied. An important aspect of the implementation plan will be public input.

The strategies listed below will be utilized to assist in reducing pollutant loads. It is difficult to predict nutrient reductions that would occur from each strategy. Because of this, an iterative management approach will be applied to the monitoring strategy after implementation of the BMPs.

8.4 SWAT Modeling

Although the modeling conducted for this TMDL estimates pollutant sources, we have determined that this lake is much more complex than the models chosen can handle. The MCES developed a SWAT model for the Carver Creek watershed for a Turbidity TMDL for total suspended solid (TSS) loading. As part of the Implementation Plan for the Carver Creek Lakes, phosphorus was added to the SWAT model development. This model is much more complex than what was used here and allows for differentiating and prioritizing phosphorus sources. Implementation of BMPs to reduce external loads will utilize SWAT modeling to predict source loads to effectively locate these practices.

8.5 Adaptive Management

The WLAs and LAs for Benton Lake represent aggressive goals. Consequently, implementation will be conducted using adaptive management principals. The County will continue to monitor Benton 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.

8.6 Lake Strategies

Lake restoration activities can be grouped into two main categories: those aimed at reducing external nutrient loads, and those practices aimed at reducing internal loads. Focus of lake strategies will depend upon the lake characteristics and nutrient balances of Benton Lake.

Total costs to implement this TMDL, which encompasses internal and external load reduction strategies for Benton Lake have been estimated from $550,000 to $1,475,000. Individual strategies and costs associated with them are broken out in the following sections.

8.6.1 External Load Reduction Strategies

8.6.1.1 Cologne WWTP

The Cologne WWTP has an established NPDES permit MN0023108 that limits the amount of flow and phosphorus loading as well as the phosphorus concentration limit. A reduction in one or all three will be needed to meet the required WLA.

8.6.1.2 Landowner Practices

Runoff from urban landscapes is potentially a major source of nutrients, particularly phosphorus, entering lakes and streams. These sources include runoff generated from driveways, rooftops, decks, lawn maintenance activities, and washing of cars. Several cost-effective practices are available for landowners to reduce or eliminate phosphorus and nutrient loads.

Goals:
- Landscaping to reduce runoff and promote infiltration, such as vegetated swales or rain gardens.
- Minimizing the amount of impervious surface, either through innovative BMPs, such as porous pavement, or reduction of actual impervious surface.
- Proper application of lawn and garden fertilizers and chemical herbicides.
- Planting and maintaining native vegetation to help water quality by soaking up rainfall, reducing runoff, and retaining sediment.
- Creating/maintaining buffers of at least 50 feet at waterways, with the goal of creating 100 foot buffers to maximize water quality benefits.
- Removal of leaf litter from lakeshore lawns
- Mulching or bagging of grass clippings
- Car washing on lawns instead of on driveways

Total Cost for Implementation: $50,000 to $150,000

8.6.1.3 Stormwater Management
Construction activity in growth areas can deliver phosphorus laden sediment if not controlled properly. In the incidence of unforeseen development, the requirements set forth in the County Water Management Plan and rules should ensure that anticipated increases in urban stormwater runoff do not contribute to nutrient loading.

Goals:
- Attenuate stormwater and minimize degradation of Carver County's water resources by reducing the amount and rate of surface water runoff from agricultural and urban land uses.
- Ensure proper erosion control practices are properly installed onsite during construction.

Cost for Implementation: $100,000 to $150,000

8.6.1.4 Feedlots
Feedlots without runoff controls may contribute to nutrient loading during wet conditions. Surface water concerns include contamination by open lot runoff into a water body, ditch or open tile inlet. Rules addressing proper feedlot management are included in the water management plan and will be addressed here. In order to address this pollution, the County will rely on goals and policies set forth in the County Water Management Plan. Properly managed feedlots will assist in meeting nutrient standards during wet conditions.

Goals:
- Proper management of feedlots to insure that water quality of surface water and groundwater is not impaired.
- Utilize existing regulations and rules (County Feedlot Management Ordinance Chapter 54, and MPCA Rule-Chapter 7020) to ensure compliance.

Cost for Implementation: $40,000 to $100,000

8.6.1.5 SSTS

Failing and/or direct discharge septic systems are potentially contributing nutrients to Meuwissen Lake, the upstream lake to Benton Lake. 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. Should any non-conforming systems remain at the time TMDL implementation, action will be taken to ensure of their elimination.

Goals:
- Elimination of all non-conforming systems that are or are likely to become a pollution or health hazard.
- Ensure that all SSTS repairs, replacements, and new systems are properly designed and installed.
- Ensure that all SSTS are properly managed, operated and maintained.

Cost for Implementation: $10,000 to $150,000

8.5.1.6 Agricultural BMPs

Agricultural land is the major land use for Meuwissen Lake, which has an impact on the water quality of Benton Lake. Farming practices have 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.

Goals:
- Identify and prioritize key erosion and restoration areas
- Educate land owners on new and innovative BMPs and well as proven techniques
- Design and implement cropland BMPs
- Installation of buffer strips in locations identified.

Cost for Implementation: $200,000 to $500,000

8.5.2 Internal Load Reduction Strategies

8.5.2.1 Aquatic Plant Management

Macrophyte surveys and monitoring efforts have shown that aquatic plants have not established a community within Benton Lake. 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 water fowl and wildlife. For these reasons, it is of importance to restore native aquatic plant populations within Benton Lake.

Goals:
- Establish a native plant community
- Draw-down to aid in establishing native aquatic plants

- Manual, chemical, or mechanical removal of curl leaf pondweed.
- Monitor the lake to ensure that non-native invasive species are not introduced into the plant community.

Cost for Implementation: $50,000 to $250,000

8.5.2.2 Rough Fish Management

Species such as black bullhead and carp increase the mixing of sediments releasing phosphorus into the water column, and reducing the clarity of water, thereby minimizing the amount of light filtering to aquatic macrophytes. Implementation plans must include the management of rough fish species by following management practices set forth below.

Goals:

- Investigate partnership with U of M 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.
- Installation of fish barriers paired with intensified efforts for removal of carp and black bullheads

Cost for Implementation: $50,000 to $100,000

8.5.2.3 Bio-manipulation

For shallow lake ecosystems, switching a lake from algae dominated to a clear water state requires a reverse switch which typically consists of bio-manipulation. This process consists of the complete restructuring of the fish community and works best if nutrient levels (both internal and external) are reduced prior to manipulation. Upon removal of fish, zooplankton such as daphnia populations will increase and graze away phytoplankton thereby allowing for clear water. Clear water will then allow for the growth of aquatic plants, return of healthy zooplankton populations, and the return of a more stable clear-water lake.

Goals:

- External nutrient reductions as indicated by implementation plan.
- Internal nutrient reductions as indicated by implementation plan.
- Manipulation of fish community- and reintroduction following zooplankton and aquatic plant establishment.

Total cost for implementation: $50,000 to $75,000

9.0 Reasonable Assurance

9.1 Introduction

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control such reasonable assurances, including a thorough knowledge of the ability to implement BMPs in an overall effective manner. Carver County is in a position to implement the TMDL and ultimately achieve water quality standards.

9.2 Carver County

The Carver County Board of Commissioners (County Board), acting as the water management authority for the former Bevens Creek (includes Silver Creek), Carver Creek, Chaska Creek, East Chaska Creek, and South Fork Crow River watershed management organization areas, has established the "Carver County Water Resource Management Area" (CCWRMA). The purpose of establishing the CCWRMA is to fulfill the County's water management responsibilities under Minnesota Statute and Rule. This structure was chosen because it will provide a framework for water resource management as follows:

- Provides a sufficient economic base to operate a viable program;
- Avoids duplication of effort by government agencies;
- Avoids creation of a new bureaucracy by integrating water management into existing County departments and related agencies;
- Establishes a framework for cooperation and coordination of water management efforts among all of the affected governments, agencies, and other interested parties; and
- Establishes consistent water resource management goals and standards for at least 80 percent of the county.

The County Board is the governing body of the CCWRMA for surface water management and for groundwater management. In function and responsibility, the County Board is equivalent to a joint powers board or a watershed district board of managers. All lakes within the Carver Creek Watershed are part of the CCWRMA.

The County is uniquely qualified through its zoning and land use powers to implement corrective actions to achieve TMDL goals. The County has stable funding for water management each year, but will likely need assistance for full TMDL implementation in a reasonable time frame, and will continue its baseline-monitoring program. Carver County has established a stable source of funding through a watershed levy in the CCWRMA taxing district (adopted 2001). This levy allows for consistent funding for staff, monitoring, engineering costs and also for on the ground projects. The County has also been very successful in obtaining grant funding from local, state and federal sources due to its organizational structure.

Carver County recognizes the importance of the natural resources within its boundaries, and seeks to manage those resources to attain the following goals:

1. Protect, preserve, and manage natural surface and groundwater storage and retention systems;
2. Effectively and efficiently manage public capital expenditures needed to correct flooding and water quality problems;
3. Identify and plan for measures to effectively protect and improve surface and groundwater quality;
4. Establish more uniform local policies and official controls for surface and groundwater management;
5. Prevent erosion of soil into surface water systems;
6. Promote groundwater recharge;
7. Protect and enhance fish and wildlife habitat and water recreational facilities; and
8. Secure additional benefits associated with the proper management of surface and groundwater.

Water management involves the following County agencies: Carver County Land and Water Services Division, Carver County Extension, and the Carver Soil and Water Conservation District (SWCD). The County Land and Water Services Division is responsible for administration of the water plan and coordinating implementation. Other departments and agencies will be called upon to perform water management duties that fall within their area of responsibility. These responsibilities may change as the need arises. The key entities meet regularly as part of the Joint Agency Meeting (JAM) process to coordinate priorities, activities, and funding.

9.3 Regulatory Approach

9.3.1 Watershed Rules

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. Of particular benefit to Nutrient TMDL reduction strategies are the stormwater management and infiltration standards which are required of new development in the CCWRMA. The complete water management rules are contained in the Carver County Code, Section 153.

9.3.2 NPDES Permits for Municipal and Industrial Wastewater

The MPCA issues NPDES permits for any discharge into waters of the state. These permits have both general and specific limits on pollutants that are based on water quality standards. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. One such permit is held by a facility within the Benton Lakeshed: permit numbers MN0023108 (City of Cologne's WWTP).

9.3.3 Feedlot Permitting

The County Feedlot Management Program includes the feedlot permitting 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.

9.3.4 County SSTS Ordinance

The 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.

9.4 Non-Regulatory Approach

9.4.1 Education

Implementation relies on three overall categories of activities: 1) Regulation, 2) Incentives, and 3) Education. All three categories must be part of an implementation program. The County has taken the approach that regulation is only a supplement to a strong education and incentive based program to create an environment of low risk. Understanding the risk through education can go a long way in preventing problems. In addition, education can be a simpler, less costly and a more community friendly way of achieving goals and policies. It can provide the framework for more of a "grass roots" implementation rather than a "top-down" approach of regulation and incentives. However, education by itself will not always meet intended goals, has certain limitations, and is more of a long-term approach.

Carver County created the Environmental Education Coordinator position in 2000 with the responsibility for development and implementation of the water education work plan. Several issues associated with the water plan were identified as having a higher priority for education efforts. These issues were identified through discussions with the advisory committees, and include ease of immediate implementation, knowledge of current problem areas, and existing programs. The higher priority objectives are not organized in any particular order. The approach to implement the TMDL will mimic the education strategy of the water plan. Each source reduction strategy will need an educational component and will be prioritized based on the number of landowners, type of source, and coordination with existing programs.

9.4.2 Incentives

Many of the existing programs, on which the water management plan relies, are incentive based offered through the County and the Carver and Sibley SWCDs. Some examples include state and federal cost share funds directed at conservation tillage, crop nutrient management, rock inlets, conservation buffers, and low interest loan programs for SSTS upgrades. Reducing nutrient sources will depend upon a similar strategy of incorporating incentives into implementation practices. After the approval of the TMDL by the EPA, and following the County's entrance into the implementation phase, it is anticipated that the County will apply for funding to assist landowners in the application of BMPs identified in the Implementation Plan.

10.0 Monitoring

Monitoring will continue for Benton Lake as prioritized by the Water Plan (Table 10.1). However, after implementation of nutrient reduction strategies a stepped-up approach of monitoring will be conducted.

Table 10.1 Monitoring commitment for Carver Creek Lakes.

Lake	Priority	Frequency	Schedule	
Benton	Moderate	Bi-Weekly	Rotating	April - October

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 areas that may need to be monitored include Meuwissen Lake in-lake sampling, sampling and flow measurements taken at the inlet to Benton Lake, sediment samples to further account for internal loading, and land use change monitoring. Furthermore, assessment of the stormwater discharge may be monitored to better grasp the nutrient loads caused by runoff from surrounding land.

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Appendix A Tributary Monitoring

Water quality parameters such as temperature, transparency, and DO were measured in the field with a hand-held electronic meter. Nutrient grab samples and composite samples were analyzed for TP, total suspended solids, nitrate + nitrite, total ammonia nitrogen, volatile suspended solids, turbidity, dissolved phosphorus, alkalinity and chemical oxygen demand by the Metropolitan Council Laboratory in St. Paul, MN. Flow was also monitored during water quality sampling events utilizing a hand-held SonTec Flow Tracker.

A.1 Benton Lake

Water quality and flow were monitored in 2005 at the outflow of Meuwissen Lake, site B2, which flows into Benton Lake (Figure 4.1). B2 is located upstream of the Cologne WWTP discharge point and approximately 0.4 miles above the stream entry into Benton Lake. Thus, B2 accounts for inflow from the entire 1,757 acres draining from the Meuwissen Lake subwatershed. Consequently, a rather large portion of the land that contributes to the inflow of water into Benton Lake is captured at this location. Because the sample point is located at the outflow of Meuwissen Lake it reflects the in-lake water quality.

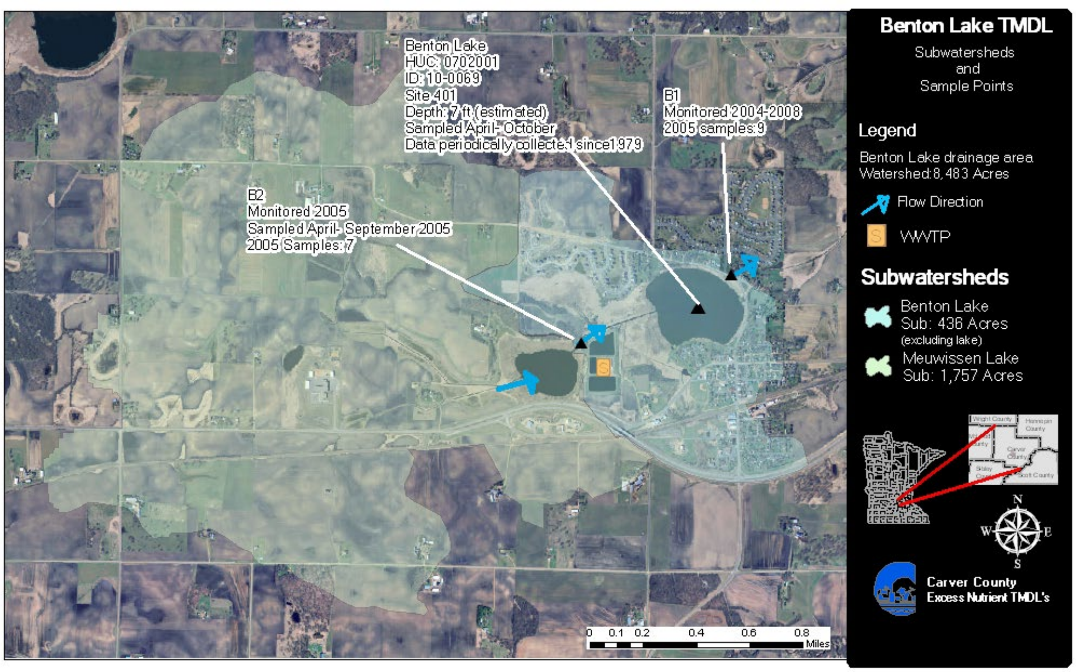

Figure A.1 Benton Lake subwatersheds and sampling points.

Grab samples and flow were collected from April 1st to September 30th to target an array of flow conditions. Stage was not monitored continuously to develop a daily discharge record. B2 experienced minimal flow throughout the 2005 summer season and samples were collected only if it was determined that the stream was flowing. All grab samples and flow data from 2005 are shown in Table 4.1.

Table A.1 Benton Lake inlet monitored phosphorus concentrations and flow.

DATE	B2 TP (μ/L)	B2 DP (μ/L)	B2 OP(μ/L)	DATE	FLOW (CFS)
4/20/05	229	45	~5	4/28/05	5.2
5/5/05	358	28	<5	5/6/05	0.2
6/1/05	326	52	13	6/3/05	0.6
6/14/05	214	28	12	6/15/05	2.4
6/28/05	1450	56	~5	7/26/05	0.5
7/13/05	230	22	<5	9/20/05	0.3
10/7/05	458	352	305		

High TP concentrations were prevalent during much of the 2005 summer season coupled with minimal flow. Observation tells us that B2 experiences flow during spring runoff and after extended periods of precipitation, particularly when there is no crop cover. Although flow is minimal at the Meuwissen Lake outlet (B2), flow from this subwatershed is estimated to represent approximately 50 percent of the water inflow into Benton Lake. Orthophosphorus and dissolved phosphorus generally tracked with phosphorus concentrations. However, they represented a rather minimal fraction of TP for most samples. During the last sample period on October 7, 2005, dissolved and orthophosphorus represented a rather large percentage of TP. This occurrence corresponds with increased precipitation. These results suggest that precipitation late in the season resulted in agricultural runoff in the watershed and may have acted to flush nutrients out of Meuwissen Lake.

Thus, the water quality of Meuwissen Lake negatively impacts that of Benton Lake early in the season when flows are high and late in the season if precipitation is enough to cause the lake to rise to the point that it overflows into the outlet (B2).

In addition to data gathered at the inlet, there is a grab sample site located at the outflow of Benton Lake (B1). Water quality grab samples and flow data have been collected at B1 since 2004 as part of the Carver Creek Turbidity TMDL (Draft 2009) and monitoring will continue through the 2008 season. TP concentrations at this site are above the expected average concentration (75^{th} percentile) for streams in the NCHF ecoregion. The average summer TP at B1 is 235 μg/L and concentrations range from 230-1450 μg/L. The data collected at this site is and can be used for comparison to lake model outputs. However, the data will be better utilized during the implementation phase of the TMDL to aid in determining actual phosphorus reductions.

Appendix B BATHTUB Benchmark Models

B.1 2001 Inputs

Benton 2001
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Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.74	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	20	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	0.000	0.00
Chl-a Temporal CV	0.720	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Benton Lake	0	1	0.2	0.59	0.5	0.59	0.12	0	0	0.08	0.2	0	0	3.25	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seq	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	261	0	6000	0	201	0	0.35	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seq	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	mewuissen	1	1	7.1	1.1479	0.1	0	0	291.2	0.2	0	0	0	0	0	0
2	Benton watershed	1	1	2	0.2147	0.1	0	0	217.7	0.2	0	0	0	0	0	0
3	Cologen WWTP	1	3	0	0.116191	0	0	0	110	0	0	0	0	0	0	0

B.2 2001 Mass Balance

Benton 2001

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Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	mewuissen	7.1	1.1	1.32E-02	0.10	0.16
2	1	1	Benton watershed	2.0	0.2	4.61E-04	0.10	0.11
3	3	1	Cologen WWTP		0.1	0.00E+00	0.00	
PRECIPITATION				0.2	0.1	8.76E-04	0.20	0.74
TRIBUTARY INFLOW				9.1	1.4	1.36E-02	0.09	0.15
POINT-SOURCE INFLOW					0.1	0.00E+00	0.00	
***TOTAL INFLOW				9.3	1.6	1.45E-02	0.07	0.17
ADVECTIVE OUTFLOW				9.3	1.5	1.68E-02	0.09	0.16
***TOTAL OUTFLOW				9.3	1.5	1.68E-02	0.09	0.16
***EVAPORATION					0.2	2.30E-03	0.30	

Overall Mass Balance Based Upon — **Predicted** — **Outflow & Reservoir Concentrations**

Component: — **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	% Total	Load Variance (kg/yr)^2	% Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	mewuissen	334.3	52.6%	5.59E+03	98.0%	0.22	291.2	47.1
2	1	1	Benton watershed	46.7	7.4%	1.09E+02	1.9%	0.22	217.7	23.4
3	3	1	Cologen WWTP	12.8	2.0%	0.00E+00		0.00	110.0	
PRECIPITATION				4.0	0.6%	4.00E+00	0.1%	0.50	27.0	20.0
INTERNAL LOAD				237.4	37.4%	0.00E+00		0.00		
TRIBUTARY INFLOW				381.0	60.0%	5.70E+03	99.9%	0.20	279.6	41.9
POINT-SOURCE INFLOW				12.8	2.0%	0.00E+00		0.00	110.0	
***TOTAL INFLOW				635.2	100.0%	5.70E+03	100.0%	0.12	390.5	68.3
ADVECTIVE OUTFLOW				381.1	60.0%	6.54E+03		0.21	259.8	41.0
***TOTAL OUTFLOW				381.1	60.0%	6.54E+03		0.21	259.8	41.0
***RETENTION				254.1	40.0%	5.85E+03		0.30		

Overflow Rate (m/yr)	7.3	Nutrient Resid. Time (yrs)	0.0483
Hydraulic Resid. Time (yrs)	0.0804	Turnover Ratio	20.7
Reservoir Conc (mg/m3)	260	Retention Coef.	0.400

B.3 2001 Predicted vs. Observed

Benton 2001

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Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment:	**1**	**Benton Lake**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	259.8	0.20	97.0%	261.0		97.0%
TOTAL N MG/M3	6000.0		99.7%	6000.0		99.7%
C.NUTRIENT MG/M3	229.3	0.16	99.0%	230.1		99.0%
CHL-A MG/M3				201.0		100.0%
SECCHI M				0.3		6.9%
ANTILOG PC-1				12154.4		99.9%
ANTILOG PC-2				21.3		98.9%
(N - 150) / P	22.5	0.20	66.0%	22.4		65.8%
TURBIDITY 1/M	0.1	0.20	1.1%	0.1	0.20	1.1%
ZMIX * TURBIDITY	0.0	0.23	0.0%	0.0	0.23	0.0%
ZMIX / SECCHI				1.7	0.12	3.7%
CHL-A * SECCHI				70.3		99.7%
CHL-A / TOTAL P				0.8		98.4%
FREQ(CHL-a>10) %				100.0		100.0%
FREQ(CHL-a>20) %				99.8		100.0%
FREQ(CHL-a>30) %				98.9		100.0%
FREQ(CHL-a>40) %				97.0		100.0%
FREQ(CHL-a>50) %				94.2		100.0%
FREQ(CHL-a>60) %				90.6		100.0%
CARLSON TSI-P	84.3	0.03	97.0%	84.4		97.0%
CARLSON TSI-CHLA				82.6		100.0%
CARLSON TSI-SEC				75.1		93.1%

B.4 2005 Inputs

Benton 2005
File: S:\Water\TMDL\TMDLs Lakes\Draft TMDL to MPCA\Benton\BATHTUB Models\benton.05_use this one.btb

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	1.07	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	20	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	0.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Benton Lake	0	1	0.2	0.59	0.5	0.59	0.12	0	0	3.47	0.2	0	0	2.3	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	234	0	4000	0	102	0	0.2	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	mewuissen	1	1	7.1	2.24	0.1	0	0	292	0.2	0	0	0	0	0	0
2	Benton watershed	1	1	2	0.311	0.1	0	0	150.2	0.2	0	0	0	0	0	0
3	Cologen WWTP	1	3	0	0.12	0	0	0	257	0	0	0	0	0	0	0

B.5 2005 Mass Balance

Benton 2005

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Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	mewuissen	7.1	2.24	5.02E-02	0.10	0.32
2	1	1	Benton watershed	2.0	0.31	9.67E-04	0.10	0.16
3	3	1	Cologen WWTP		0.12	0.00E+00	0.00	
PRECIPITATION				0.2	0.21	1.83E-03	0.20	1.07
TRIBUTARY INFLOW				9.1	2.55	5.11E-02	0.09	0.28
POINT-SOURCE INFLOW					0.12	0.00E+00	0.00	
***TOTAL INFLOW				9.3	2.88	5.30E-02	0.08	0.31
ADVECTIVE OUTFLOW				9.3	2.72	5.53E-02	0.09	0.29
***TOTAL OUTFLOW				9.3	2.72	5.53E-02	0.09	0.29
***EVAPORATION					0.16	2.30E-03	0.30	

Overall Mass Balance Based Upon — **Predicted** — **Outflow & Reservoir Concentrations**

Component: — **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	% Total	Load Variance (kg/yr)²	% Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	mewuissen	654.1	72.4%	2.14E+04	99.5%	0.22	292.0	92.1
2	1	1	Benton watershed	46.7	5.2%	1.09E+02	0.5%	0.22	150.2	23.4
3	3	1	Cologen WWTP	30.8	3.4%	0.00E+00		0.00	257.0	
PRECIPITATION				4.0	0.4%	4.00E+00	0.0%	0.50	18.7	20.0
INTERNAL LOAD				168.0	18.6%	0.00E+00		0.00		
TRIBUTARY INFLOW				700.8	77.6%	2.15E+04	100.0%	0.21	274.7	77.0
POINT-SOURCE INFLOW				30.8	3.4%	0.00E+00		0.00	257.0	
***TOTAL INFLOW				903.6	100.0%	2.15E+04	100.0%	0.16	313.2	97.2
ADVECTIVE OUTFLOW				635.6	70.3%	1.65E+04		0.20	233.3	68.3
***TOTAL OUTFLOW				635.6	70.3%	1.65E+04		0.20	233.3	68.3
***RETENTION				268.0	29.7%	9.85E+03		0.37		

Overflow Rate (m/yr)	13.6	Nutrient Resid. Time (yrs)	0.0305
Hydraulic Resid. Time (yrs)	0.0433	Turnover Ratio	32.8
Reservoir Conc (mg/m3)	233	Retention Coef.	0.297

B.6 2005 Predicted vs. Observed

Benton 2005

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Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment:	**1**	**Benton Lake**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	233.3	0.18	96.1%	234.0		96.1%
TOTAL N MG/M3	4000.0		98.5%	4000.0		98.5%
C.NUTRIENT MG/M3	188.7	0.12	98.1%	189.1		98.1%
CHL-A MG/M3				102.0		99.9%
SECCHI M				0.2		1.3%
ANTILOG PC-1				10756.5		99.8%
ANTILOG PC-2				8.7		71.9%
(N - 150) / P	16.5	0.18	48.3%	16.5		48.1%
TURBIDITY 1/M	3.5	0.20	97.6%	3.5	0.20	97.6%
ZMIX * TURBIDITY	2.0	0.23	28.9%	2.0	0.23	28.9%
ZMIX / SECCHI				2.9	0.12	20.4%
CHL-A * SECCHI				20.4		83.6%
CHL-A / TOTAL P				0.4		89.6%
FREQ(CHL-a>10) %				100.0		99.9%
FREQ(CHL-a>20) %				99.0		99.9%
FREQ(CHL-a>30) %				95.2		99.9%
FREQ(CHL-a>40) %				88.5		99.9%
FREQ(CHL-a>50) %				80.0		99.9%
FREQ(CHL-a>60) %				70.7		99.9%
CARLSON TSI-P	82.8	0.03	96.1%	82.8		96.1%
CARLSON TSI-CHLA				76.0		99.9%
CARLSON TSI-SEC				83.2		98.7%

Appendix C BATHTUB TMDL Load Response Models

C.1 TMDL Inputs

Benton TMDL
File: S:\Water\TMDL\TMDLs Lakes\Draft TMDL to MPCA\Benton\BATHTUB Models\Benton TMDL 2.btb
Description:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.739394	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	20	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	0.000	0.00
Chl-a Temporal CV	0.720	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Benton Lake	0	1	0.19789	0.593	0.5	0.593	0.12	0	0	0.08	0.2	0	0	0.0975	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	235	0	48625	0	235.75	0	0.38	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Upstream Lakes	1	1	7.1	1.1474	0.1	0	0	60	0.2	0	0	0	0	0	0
2	External	1	1	1.4	0.21449	0.1	0	0	51.43401	0.2	0	0	0	0	0	0
3	Construction/Industrial	1	1	0	0.000214	0.1	0	0	51.43401	0.2	0	0	0	0	0	0
4	Cologen WWTP	1	3	0	0.44904	0	0	0	103.5518	0	0	0	0	0	0	0

C.2 TMDL Mass Balance

Benton TMDL

File: S:\Water\TMDL\TMDLs Lakes\Draft TMDL to MPCA\Benton\BATHTUB Models\Benton TMDL 2.btb

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seq	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Upstream Lakes	7.1	1.147	1.32E-02	0.10	0.16
2	1	1	External	1.4	0.214	4.60E-04	0.10	0.15
3	1	1	Construction/Industrial		0.0002	4.60E-10	0.10	
4	3	1	Cologen WWTP		0.449	0.00E+00	0.00	
PRECIPITATION				0.2	0.146	8.56E-04	0.20	0.74
TRIBUTARY INFLOW				8.5	1.362	1.36E-02	0.09	0.16
POINT-SOURCE INFLOW					0.449	0.00E+00	0.00	
***TOTAL INFLOW				8.7	1.957	1.45E-02	0.06	0.23
ADVECTIVE OUTFLOW				8.7	1.799	1.67E-02	0.07	0.21
***TOTAL OUTFLOW				8.7	1.799	1.67E-02	0.07	0.21
***EVAPORATION					0.158	2.26E-03	0.30	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Upstream Lakes	68.844	50.1%	2.37E+02	96.0%	0.22	60.0	9.7
2	1	1	External	11.032	8.0%	6.09E+00	2.5%	0.22	51.4	7.9
3	1	1	Construction/Industrial	0.011	0.0%	6.09E-06	0.0%	0.22	51.4	
4	3	1	Cologen WWTP	46.499	33.8%	0.00E+00		0.00	103.6	
PRECIPITATION				3.958	2.9%	3.92E+00	1.6%	0.50	27.0	20.0
INTERNAL LOAD				7.047	5.1%	0.00E+00		0.00		
TRIBUTARY INFLOW				79.887	58.1%	2.43E+02	98.4%	0.20	58.6	9.4
POINT-SOURCE INFLOW				46.499	33.8%	0.00E+00		0.00	103.6	
***TOTAL INFLOW				137.391	100.0%	2.47E+02	100.0%	0.11	70.2	15.8
ADVECTIVE OUTFLOW				108.292	78.8%	2.48E+02		0.15	60.2	12.5
***TOTAL OUTFLOW				108.292	78.8%	2.48E+02		0.15	60.2	12.5
***RETENTION				29.099	21.2%	1.23E+02		0.38		

Overflow Rate (m/yr)	9.1	Nutrient Resid. Time (yrs)	0.0514
Hydraulic Resid. Time (yrs)	0.0652	Turnover Ratio	19.5
Reservoir Conc (mg/m3)	60	Retention Coef.	0.212

C.3 TMDL Predicted

Benton TMDL

File: S:\Water\TMDL\TMDLs Lakes\Draft TMDL to MPCA\Benton\BATHTUB Models\Benton TMDL 2.btb

Predicted Values Ranked Against CE Model Development Dataset

Segment: 1 Benton Lake

	Predicted Values--->		
Variable	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	60.2	0.13	60.0%
TOTAL N MG/M3	48625.0		100.0%
C.NUTRIENT MG/M3	60.2	0.13	74.3%
CHL-A MG/M3			
SECCHI M			
ANTILOG PC-1			
ANTILOG PC-2			
(N - 150) / P	805.4	0.13	100.0%
TURBIDITY 1/M	0.1	0.20	1.1%
ZMIX * TURBIDITY	0.0	0.23	0.0%
ZMIX / SECCHI			
CHL-A * SECCHI			
CHL-A / TOTAL P			
FREQ(CHL-a>10) %			
FREQ(CHL-a>20) %			
FREQ(CHL-a>30) %			
FREQ(CHL-a>40) %			
FREQ(CHL-a>50) %			
FREQ(CHL-a>60) %			
CARLSON TSI-P	63.2	0.03	60.0%
CARLSON TSI-CHLA			
CARLSON TSI-SEC			