Part I
Pearl Lake
Total Maximum Daily Load Report

Part II
Mill Creek
Bacterial Total Maximum Daily Load Report: Headwaters to Sauk River

Prepared for
Sauk River Watershed District and Minnesota Pollution Control Agency

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Part 1 and Part II

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Part I
Pearl Lake

Total Maximum Daily Load Report

TMDL Summary Table		
EPA/MPCA Required Elements	Summary	TMDL Page #
Location	Stearns County	I-1
303(d) Listing Information	Waterbody: Pearl Lake MDNR ID 73-0037 Impaired Beneficial Use: Aquatic Recreation Impairment/TMDL Pollutant of Concern: Excessive Nutrients (Phosphorus) Priority Ranking: 2008 Target Start, 2019 Target Completion Original Listing Year: 2008	I-1
Applicable Water Quality Standards/Numeric Targets	MPCA Lake Eutrophication Standards (North Central Hardwood Forest): 40 µg/L Total Phosphorus 14 µg/L Chlorophyll *a* 1.4 m Secchi disc transparency Source: Minnesota Rule 7050.0222 Subp. 4. Class 2B Waters	I-4
Loading Capacity (expressed as daily load)	Total Phosphorus Loading Capacity for critical condition Critical condition summary: MPCA eutrophication standard is compared to the growing season (June through September) average. Daily loading capacity for critical condition is based on the total load during the growing season. Pearl Lake (kg/day) 3.86	I-25
Margin of Safety	The margin of safety for this TMDL is set at five percent (5%) of the total load capacity for each	I-25

TMDL Summary Table			
EPA/MPCA Required Elements	Summary		TMDL Page #
	lake.		
Seasonal Variation	TP concentrations in the lakes vary significantly during the growing season, generally worsening in mid- to late-summer. The TMDL guideline for TP is defined as the growing season mean concentration (MPCA, 2004). Accordingly, water quality scenarios (under different management options) were evaluated in terms of the mean growing season TP.		I-25
Wasteload Allocation (WLA)	Source	Pearl Lake WLA (kg/day) WLA (kg/day)	I-25
	Permitted Dischargers	0	
	Reserve Capacity	0	
Load Allocation (LA)	Source	Pearl Lake LA (kg/day)	I-25
	Internal	1.75	
	Watershed	1.77	
	Atmospheric	0.14	
Margin of Safety (MOS)	Explicit: Five Percent of Total Pollutant Allocations	0.19	
Monitoring	The monitoring plan to track TMDL effectiveness is described in Section 4.0 of this TMDL report.		I-26
Implementation	The implementation strategies to achieve the load reductions described in this TMDL are summarized in Section 5.0 of this TMDL report. The total cost to implement this TMDL is estimated to be approximately		I-28

TMDL Summary Table		
EPA/MPCA Required Elements	Summary	TMDL Page #
	$2,300,000.	
Reasonable Assurance	The overall implementation planning (Section 5.0) is multifaceted, with various projects put into place over the course of many years, allowing for monitoring and reflection on project successes and the chance to change course if progress is exceeding expectations or is unsatisfactory.	I-34
Public Participation	Public meetings, announcements, and meetings regarding this TMDL have been conducted and additional public meetings will be scheduled for 2010 to discuss the results of this TMDL.	I-35

Executive Summary

Pearl Lake (DNR ID 73-0037) is currently listed on the Minnesota Pollution Control Agency's (MPCA) 2010 303(d) Impaired Waters List due to excessive nutrients (phosphorus). Pearl Lake is located in Stearns County, Minnesota and is within the North Central Hardwood Forest (NCHF) ecoregion. Pearl Lake is a relatively shallow, eutrophic lake approximately 750 acres in size, with a maximum depth of 18.2 feet and a mean depth of 8.2 feet. The littoral area (area with a depth of 15 feet or less) is approximately 510 acres. Pearl Lake currently supports a healthy fish community, and is managed for walleye and northern pike. The watershed is generally dominated by agricultural land use.

The MPCA projected schedule for Total Maximum Daily Load (TMDL) report completion, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. The Pearl Lake TMDL was scheduled to begin in 2008 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 waterbody; technical capability and willingness locally to assist with each TMDL; and appropriate sequencing of TMDLs within a watershed or basin. The historical growing season water quality for each lake is compared to the MPCA lake eutrophication standards for the NCHF ecoregion below (Table EX-1).

Table EX-1 MPCA Lake Eutrophication Standards for North Central Hardwood Forest Ecoregion

Water Quality Parameter	MPCA Lake Eutrophication Standards (NCHF Ecoregion)	Pearl Lake Summer-Mean Water Quality in 2008	Pearl Lake Summer-Mean Water Quality 2000-2009
Total Phosphorus (µg/L)	40	51	43
Chlorophyll *a* (µg/L)	14	15	17
Secchi disc (m)	1.4	2.3	2.0

The TMDL equation is defined as follows:

TMDL = Wasteload Allocation (WLA) + Load Allocation (LA) + Margin of Safety (MOS) + Reserve Capacity.

For Pearl Lake, the Load Capacity is 1,410 kilograms (kg) of total phosphorus (TP) per water year.

The TMDL equation used to derive this Load Capacity for Pearl Lake is:

Expressed as water year (October 1 through September 30) totals:

TMDL = 0 kg TP (WLA) + 1,339 kg TP (LA) + 71 kg TP (MOS) + 0 kg (Reserve Capacity) = 1,410 kg per water year

Expressed in daily terms (water year)

TMDL = 0.0 kg/d (WLA) + 3.67 kg/d (LA) + 0.19 kg/d (MOS) + 0.0 kg/d (Reserve Capacity) = 3.86 kg/d, on average

To meet the overall load capacity of the lake (i.e., achieve an average summer total phosphorus concentration of less than 40 µg/L), a 25% decrease in phosphorus load (based on 2008 existing conditions) will be required. This will be achieved through a combination of external and internal phosphorus load reductions: (1) a 31% reduction of internal phosphorus load in Pearl Lake through management of Curlyleaf pondweed and sediment phosphorus loading, and (2) loading from the tributary watershed will be reduced by 20% through best management practices (BMPs). There is zero Wasteload Allocation for Pearl Lake.

The Explicit Margin of Safety is set at five percent (5%) of the overall loading capacity. An implicit margin of safety is also included in that internal load reduction efforts are typically all-or-none activities (e.g., alum treatment to reduce all internal loading) and likely will achieve reductions greater than that prescribed in this TMDL.

Phosphorus load reductions to Pearl Lake will be achieved by targeting multiple nonpoint sources. The following summarizes phosphorus reductions that will be targeted in the watershed:

20% reduction of phosphorus load from the watershed, including full compliance for all Subsurface Sewage Treatment Systems (SSTS) adjacent to Pearl Lake.

31% reduction of internal phosphorus loading from lake sediments and Curlyleaf pondweed.

1.0 Introduction

Pearl Lake (DNR ID 73-0037) is located in Stearns County (Figure 1-1), and is within the Upper Mississippi River Basin. The lake is within the North Central Hardwood Forest (NCHF) Ecoregion (Figure 1-2). Pearl Lake is a shallow, eutrophic lake approximately 750 acres in size, with a maximum depth of 18.2 feet and a mean depth of 8.2 feet. The littoral area (area with a depth of 15 feet or less) is approximately 510 acres. Pearl Lake currently supports a healthy fish community, and is managed for walleye and northern pike.

Pearl Lake is currently listed on the Minnesota Pollution Control Agency’s (MPCA) 2008 303(d) Impaired Waters List due to excessive nutrients (phosphorus) and requires a Total Maximum Daily Load (TMDL) report. Pearl Lake was first placed on the MPCA’s 303(d) list in 2008. The target start date for the TMDL report is 2008, and the target completion date is 2010.

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

Current monitoring and study of Pearl Lake is being conducted by the Sauk River Watershed District, the Minnesota Pollution Control Agency (MPCA), and the Minnesota Department of Natural Resources (MDNR).

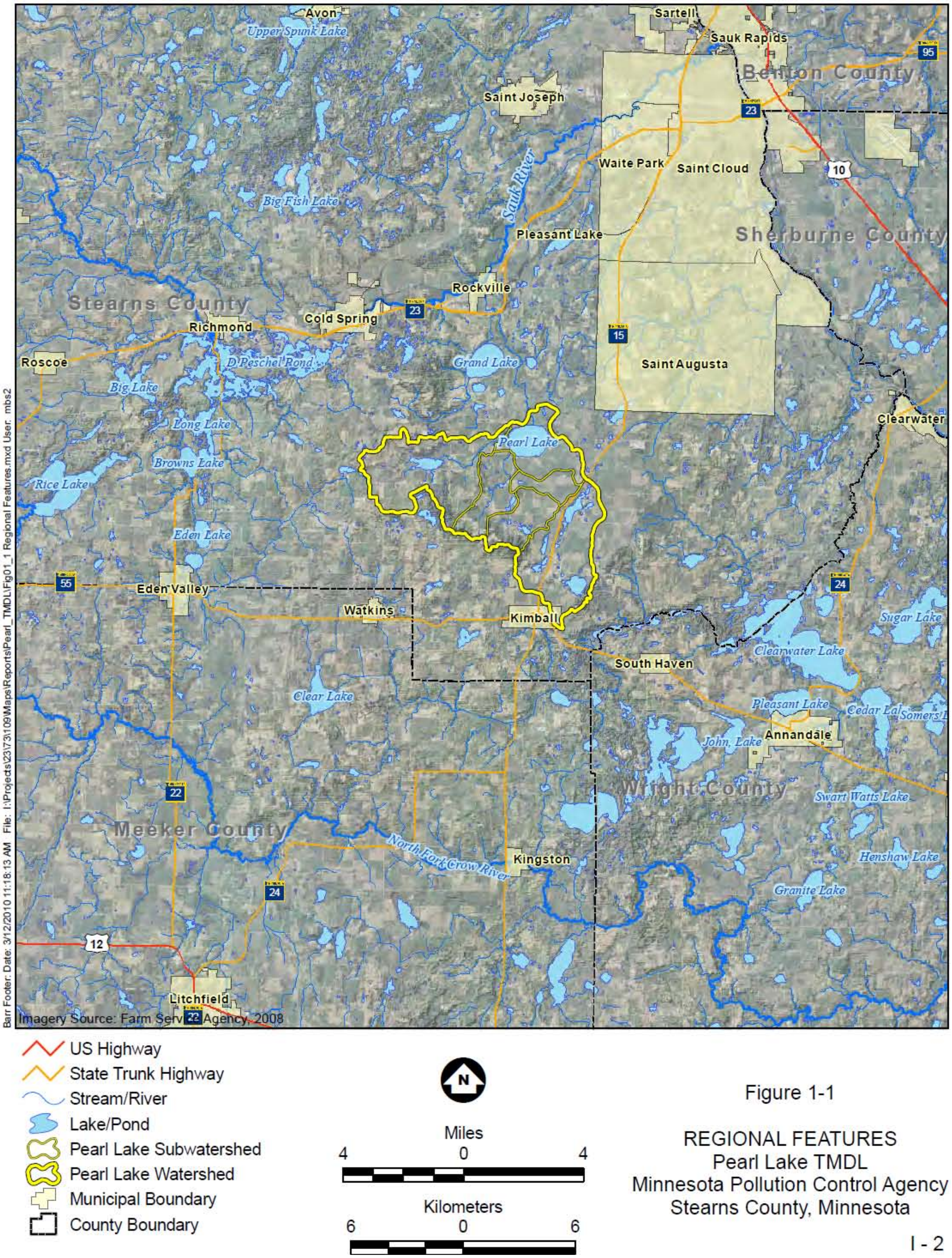

Figure 1-1 Regional Features

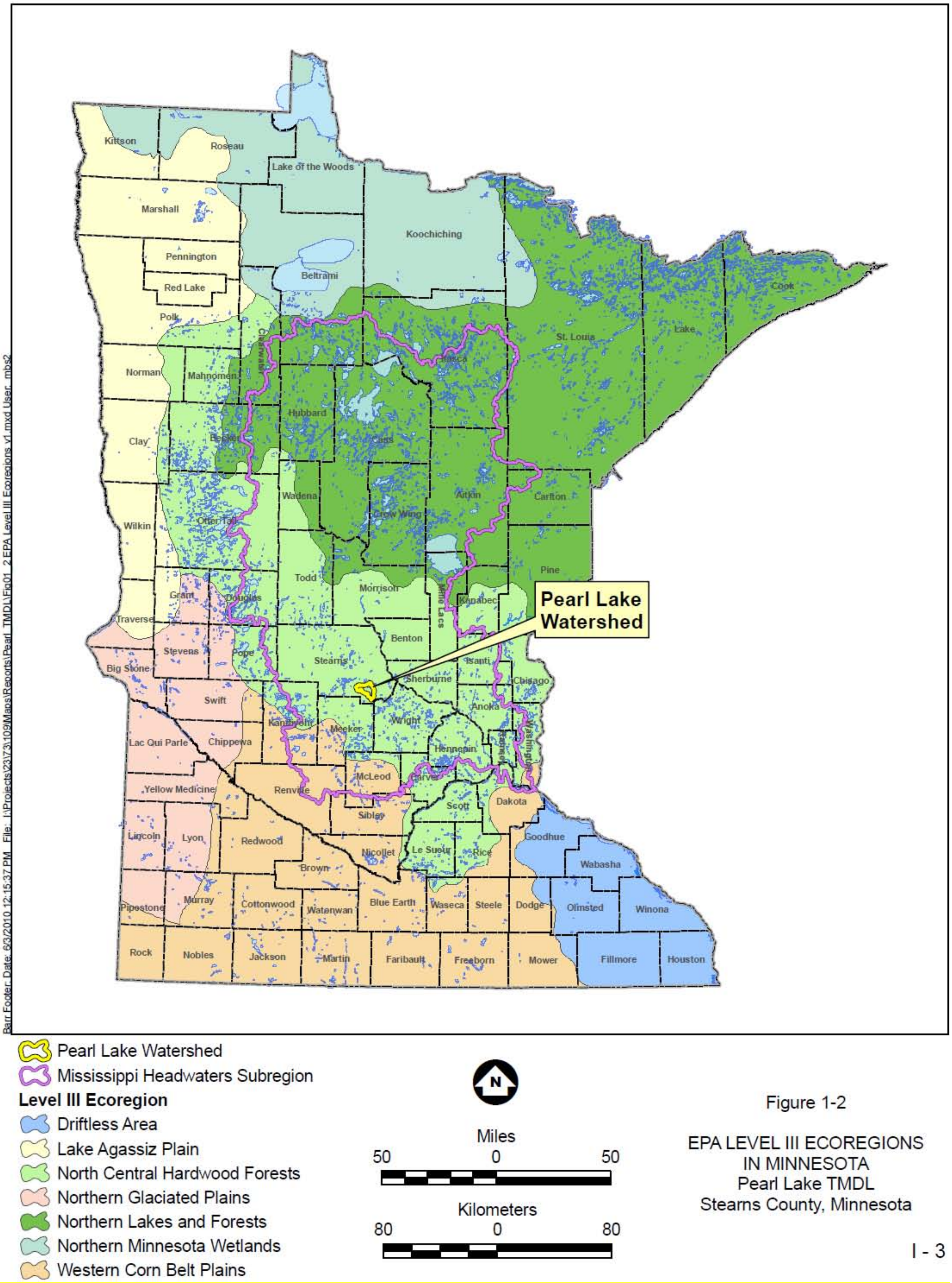

Figure 1-2 EPA Level III Ecoregions in Minnesota

2.0 Background Information

The following sections describe the water quality standards that are applicable to Pearl Lake, as well as the general characteristics of the lake and its watershed.

2.1 Applicable Water Quality Standards

Impaired waters are listed and reported to the citizens of Minnesota and to the EPA in the 305(b) report and the 303(d) list, named after relevant sections of the Clean Water Act. Assessment of waters for the 305(b) report identifies candidates for listing on the 303(d) list of impaired waters. The purpose of the 303(d) list is to identify impaired water bodies for which a plan (the TMDL – this document) will be developed to remedy the pollution problem(s).

The basis for assessing Minnesota lakes for impairment due to eutrophication includes the narrative water quality standard and assessment factors in Minnesota Rules 7050.0150. The MPCA has completed extensive planning and research efforts to develop quantitative lake eutrophication standards for lakes in different ecoregions of Minnesota that would result in achievement of the goals described by the narrative water quality standards. To be listed as impaired by the MPCA, the monitoring data must show that the standards for both total phosphorus (the causal factor), and either chlorophyll *a* or Secchi disc depth (the response factors) are not met (MPCA, 2007a). Pearl Lake is listed based on the eutrophication criteria for the North Central Hardwood Forest (NCHF) ecoregion (Table 2-1).

Table 2-1 MPCA Lake Eutrophication Standards for Total Phosphorus, Chlorophyll *a*, and Secchi Disc in NCHF Ecoregion.

Water Quality Parameter	MPCA Lake Eutrophication Standard (NCHF Ecoregion)
Total Phosphorus (µg/L)	40
Chlorophyll-a (µg/L)	14
Secchi disc (m)	1.4

Source: Minnesota Rule 7050.0222 Subp. 4. Class 2B Waters

2.2 General Lake Characteristics

Pearl Lake is a relatively shallow, eutrophic lake with residences established along most of the shoreline (a total of 118 residences). The watershed is predominantly agricultural. The lake is polymictic, meaning the water column does not typically experience strong thermal stratification and the lake will partially or fully mix several times a year. Pearl Lake is approximately 750 acres in size, with a maximum depth of 18.2 feet and a mean depth of 8.2 feet. The littoral area (area with a depth of 15 feet or less) is approximately 510 acres (Figure 2-1). The outlet of Pearl Lake is Mill Creek, on the northern shore of the lake. Mill Creek is also the only named tributary to Pearl Lake, and enters on the western shore. Pearl Lake currently supports a healthy fish community described by the MDNR as being more diverse than other lakes of similar productivity (MPCA 2009). Pearl Lake is managed for walleye, primarily through stocking of walleye fingerlings. The lake is also managed for northern pike. The MDNR is concerned about extirpation of blackchin shiners, blacknose shiners, banded killifish, and Iowa darter, species that are currently present in Pearl Lake but have difficulty tolerating eutrophic conditions. Common carp, an exotic species, are known to be in Pearl Lake, but the density of carp is not known. Carp can have a negative impact on water quality due to their feeding habits, which can disturb lake sediments and increase internal loading within the lake.

The DNR have conducted aquatic plant surveys of Pearl Lake in 2008 and 2009 as part of the SLICE program. In 2008, 53% of the littoral area of the lake was covered with aquatic vegetation. The two most abundant aquatic plants in Pearl Lake are muskgrass (*Chara* spp.) and Curlyleaf pondweed (*Potamogeton crispus*). Curlyleaf pondweed is an exotic species that has invaded many Minnesota lakes, and is known to have a significant negative impact on water quality when it grows in abundance. Curlyleaf pondweed’s seasonal life cycle is different from native plant species in that it experiences significant die off in early summer. Muskgrass is a native macro-algae that resembles a higher plant. It begins growing in spring when the water warms and continues growing through the fall. Muskgrass is also a favorite food for waterfowl. Due to curly-leaf pondweed’s ability to grow to nuisance levels at the water surface and its potential impacts on water quality, Curlyleaf pondweed is considered a very undesirable aquatic plant. By comparison, muskgrass is a much more desirable aquatic plant.

2.3 General Watershed Characteristics

The size of the Pearl Lake watershed is approximately 18,237 acres (28.5 square miles). Land use percentages of the Pearl Lake watershed, based on the 2001 National Land Cover Database (NLCD), are summarized as follows:

53% cultivated agriculture
21% pasture and grassland
13% forest
7% open water and wetland
6% developed

The 2001 NLCD classifications for the watershed are shown in Figure 2-1.
Mill Creek and an unnamed creek are the primary sources of surface water inflows to Pear Lake. A large portion of the Pearl Lake watershed is landlocked and does not contribute surface flow to Pearl Lake. These watersheds are located to the south and southeast of Pearl Lake, and are identified in Figure 2-1. It is assumed that these areas do not contribute phosphorus to Pearl Lake.

The land use percentages for watershed areas contributing surface flow (i.e., drain to either Mill Creek or and unnamed creek) are summarized as follows:

46% cultivated agriculture
25% pasture and grassland
17% forest
7% open water and wetland
5% developed

Much of the shoreline of Pearl Lake is developed with lakeshore homes, which have subsurface sewage treatment systems (SSTS). There are no municipal wastewater treatment plants or other permitted dischargers in the watershed. There are approximately 34 feedlots within the portion of the Pearl Lake watershed that contributes surface water runoff to the lake.

Pearl Lake has two main tributaries: Mill Creek is the largest, and drains an area of approximately 5,758 acres to the west of Pearl Lake. An unnamed creek drains an area of approximately 2,108 acres to the south of Pearl Lake. The combined area of the Mill Creek and unnamed creek watersheds accounts for 81% of the watershed that contributes surface flow to Pearl Lake, the remaining 19% of the watershed drains directly to the lake.

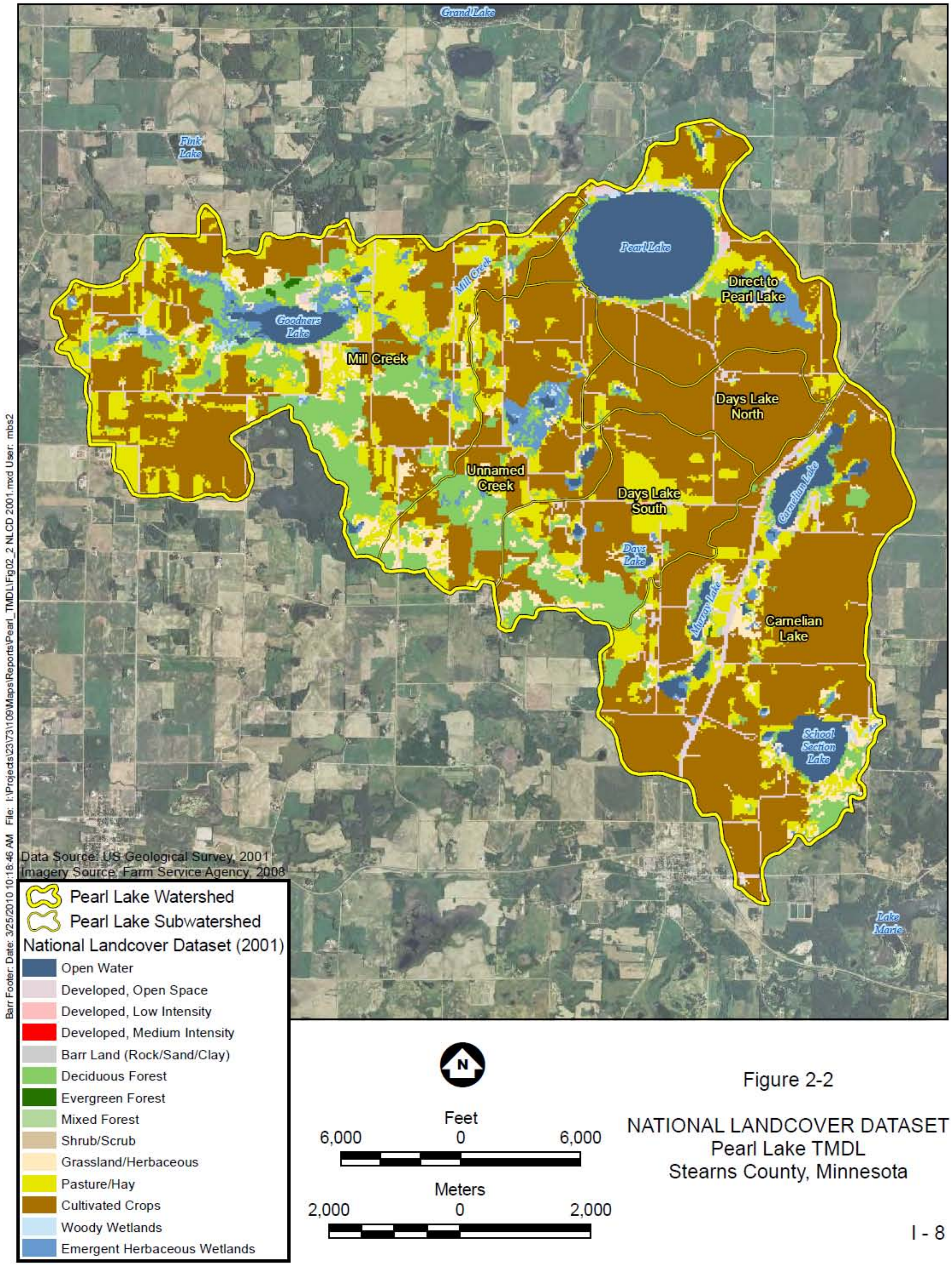

Figure 2-1 National Landcover Dataset

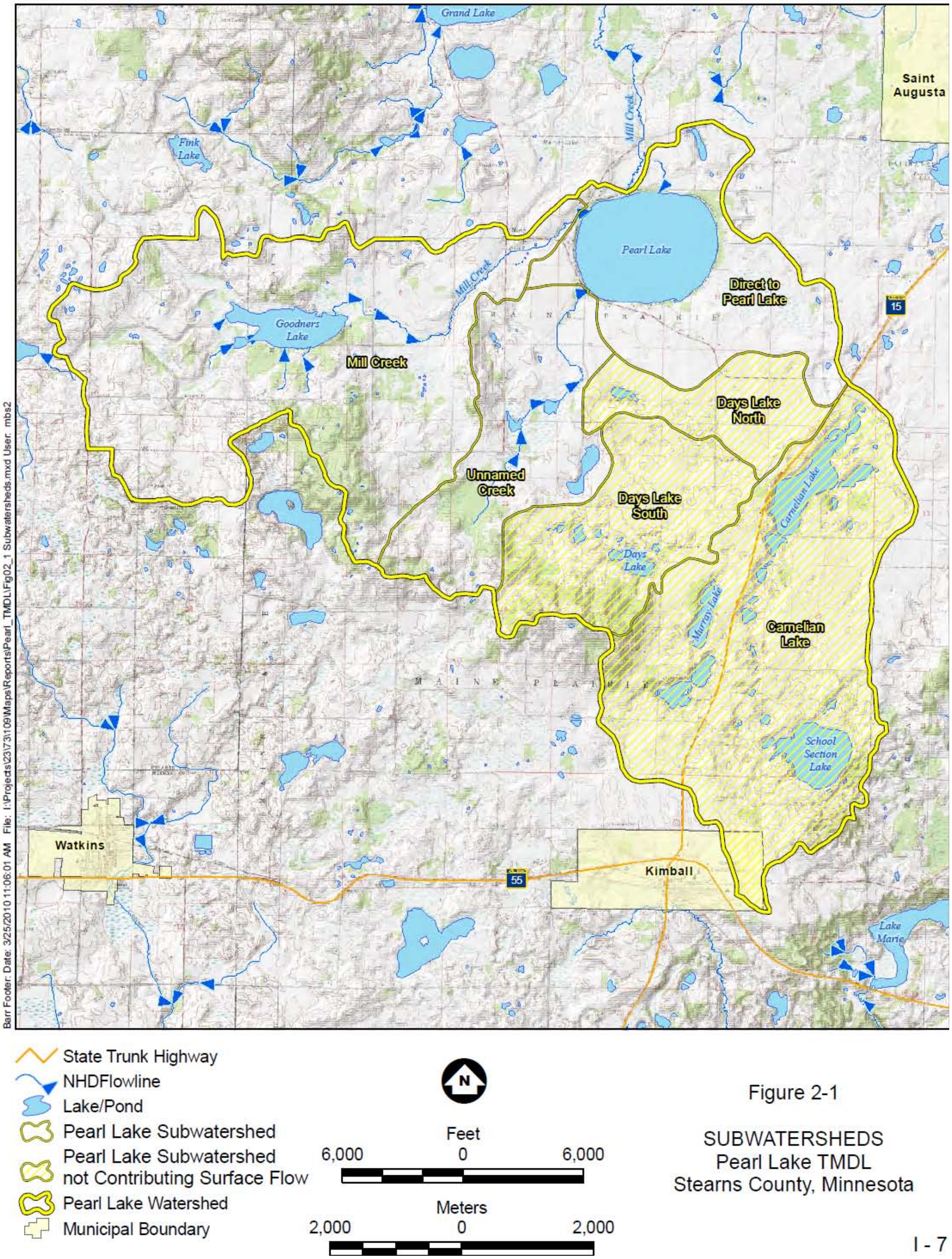

Figure 2-2 Pearl Lake Subwatersheds

2.4 Previous and Ongoing Studies and Reports

Pearl Lake is a Sentinel Lake in the MDNR's SLICE program (Sustaining Lakes in a Changing Environment). The mission of SLICE is to monitor the condition of Minnesota lake habitats and fish populations using key status indicators and respond appropriately to threats to lake habitats and fish populations such that the MDNR is successful at providing sustainable fishing opportunities for the citizens of Minnesota. The SLICE program website is http://www.dnr.state.mn.us/fisheries/slice/index.html. The MDNR has completed a four page lake summary report for Pearl Lake as part of the SLICE program (MPCA 2009). The report summarizes the status of water quality, aquatic vegetation, and the fisheries of Pearl Lake up to year 2008. The MNDR collected additional data in 2009, and plans to publish a more extensive lake assessment report for Pearl Lake.

The data provided by the SLICE program provide important insights into how aquatic plants affect annual changes in the water quality and ecology of Pearl Lake. The aquatic plant surveys conducted in 2008 and 2009 by the MDNR demonstrate that curly-leaf pondweed growth can vary significantly each year and understanding pondweed dynamics is complicated. Factors often attributed to observed pondweed growth differences include water temperature, ice cover thickness, snow cover thickness, and when ice-off occurs in the spring. Curlyleaf biomass observed in a lake, to a large degree, is a function of how early and vigorously the plant grows in the spring and when and to what extent the plant emerges through the lake surface (known as "topping out"). When and to what degree (i.e., coverage) pondweed tops out is a reasonable indicator of biomass. The extent of curly-leaf pondweed that is "topped-out" (i.e. growing at the lake surface) in Pearl Lake in the first week of June in 2008 and 2009 is shown in Figure 2-3. The extent of topped-out curly-leaf pondweed in 2009 (5.6 acres) is only a fraction of that observed in 2008 (170 acres). It should be noted that there have been no lake-wide management activities conducted in Pearl Lake for the control of curly-leaf pondweed.

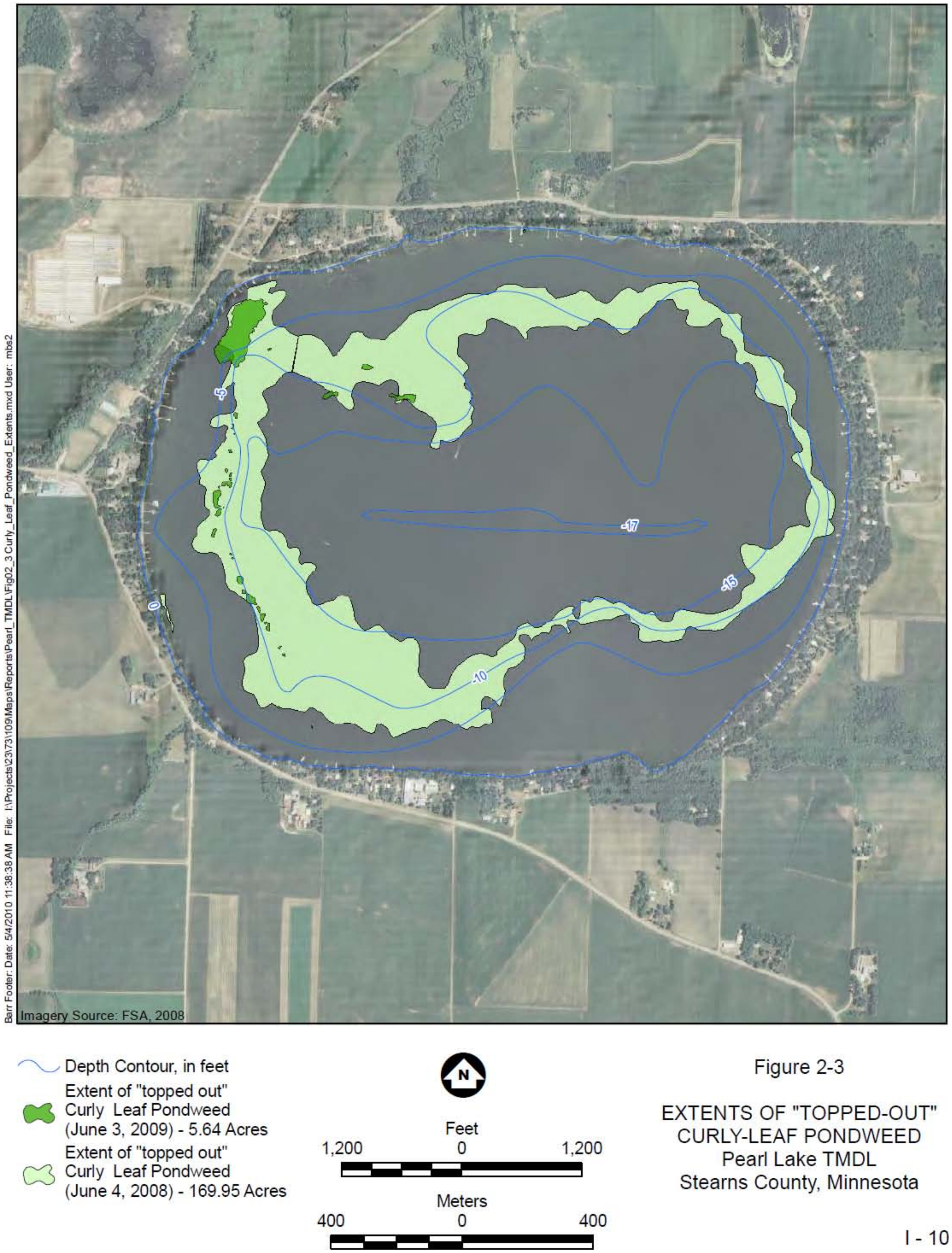

Figure 2-3 Extents of "Topped-Out" Curly-leaf Pondweed

3.0 Excess Nutrient Impairments

The following sections summarize the water quality data for Pearl Lake, efforts to model water quality of the lake, and development of the phosphorus load and wasteload TMDL allocations.

3.1 Pearl Lake Water Quality

Pearl Lake was assessed for nutrient impairment in 2007, and was listed as impaired in 2008. At that time, both total phosphorus and chlorophyll *a* exceeded the full support thresholds, while Secchi disc depth indicated full support; however, the summer mean Secchi disc transparency had declined from 2000 to 2006, and Pearl Lake was proposed and subsequently approved for listing (MPCA 2008). Additional data were collected in Pearl Lake in 2008 and 2009. Summer mean Secchi disc transparency met the water quality standard in 2000,2001, 2008 and 2009, but not in 2006 (Figure 3-1). In the last ten years (2000-2009), summer mean total phosphorus concentrations have exceeded the water quality standard three of the four years data were collected (Figure 3-2). Similar to total phosphorus, summer-average concentrations of chlorophyll *a* exceeded the water quality standard three of the four years data were collected (Figure 3-3). Most recently, 2009 had summer-averages below the total phosphorus and chlorophyll *a* standards.

The concentration of total phosphorus in Pearl Lake can vary greatly in a given season. Typically, concentrations of total phosphorus in late spring are in the range of 24-29 µg/L, and concentrations hold steady into early summer. In July, concentrations of total phosphorus begin to rise, peaking in August or September (Figure 3-4). Concentrations of total phosphorus peaked as high as 82 µg/L and 76 µg/L in 2006 and 2008, respectively. The summer of 2009 was different than other recent years in that total phosphorus concentrations declined during early summer, reaching a low of 15 µg/L on June 25, 2009. Concentrations of total phosphorus began to increase in July, and continued to increase in August, just as in previous years, but the summer mean total phosphorus concentration was 32 µg/L. By comparison, the summer mean total phosphorus concentration in 2008 was 51 µg/L, 65% greater than in 2009.

The effect of external phosphorus loads on the differences observed in 2008 and 2009 is somewhat difficult to determine because water quality data collected from Mill Creek and unnamed creek in 2008 did not meet quality assurance standards. As a result, phosphorus concentration data are only available for the tributaries to Pearl Lake for 2009. However, the rainfall data suggest that external loads were likely similar for 2008 and 2009. Rainfall totals for water year 2008 (10/1/2007-9/30/2008) and water year 2009 (10/1/2008-9/30/2009) were similar, at 22.0 inches and 27.9 inches, respectively.

One major difference observed in 2009 when compared to 2008 was that coverage of curly-leaf pondweed was markedly lower. Curly-leaf pondweed is a nonnative submerged aquatic plant that has been introduced to many Minnesota lakes, and can grow to dominate and out-compete native aquatic plant communities. Studies have shown curly-leaf pondweed can also have negative impacts on water quality of North American lakes by enhancing eutrophication. Curly-leaf pondweed grows earlier and dies earlier in the year than native plants. When the curly-leaf pondweed dies in early summer, phosphorus that is stored in the plant is released. A potential secondary effect of curly-leaf pondweed die off is that bacteria and other organisms feed on the dead plant matter, and consume oxygen as part of their metabolic processes. With the deposition of decaying plant matter to the bottom of a lake, oxygen levels may be reduced at the sediment interface. This may trigger internal phosphorus loading.

3.2 TMDL Modeling Methodology

Watershed loadings and in-lake concentrations of phosphorus were used to calibrate an in-lake model to determine source load impacts on water quality and potential reductions in loading needed to meet the water quality standard in Pearl Lake. The modeling methodology is detailed below.

3.2.1 Watershed, In-Lake, and Climate Data

Water quality data, including total and dissolved phosphorus concentrations, were collected in the two main tributaries to Pearl Lake in 2008 and 2009. The two tributaries that were monitored are Mill Creek (upstream of Pearl Lake) and the unnamed creek to the south of Pearl Lake. Water quality data was collected near the outlets to Pearl Lake for both creeks. Water quality data collected in 2008 and sent for laboratory analyses did not meet quality control requirements. Therefore, 2009 water quality data for Mill Creek and unnamed creek were used to estimate phosphorus concentrations in these creeks for 2008.

Local precipitation was measured during the summer months of 2008 and 2009 with a weather station placed on the western shore of Pearl Lake. Additional climate data (precipitation, air temperature, relative humidity, and wind speed) were obtained from the St. Cloud Regional Airport weather station, 16 miles to the northeast.

Pearl Lake was monitored for the following parameters either in the field or through laboratory analyses:

Dissolved oxygen, specific conductance, temperature, pH, and Secchi disc transparency

Total phosphorus, total dissolved phosphorus, chlorophyll *a*

3.2.2 In-Lake Mass Balance Modeling

The following sections detail the in-lake mass balance modeling for phosphorus. The methods for estimating the external phosphorus loading for water year 2008 are described, as are the methods of estimating the internal phosphorus loading and in-lake water quality modeling.

3.2.2.1 Subsurface Sewage Treatment Systems (SSTS) Loading

The total phosphorus loading from SSTS to Pearl Lake was estimated by using the number of shoreline residences on Pearl Lake along with ecoregion averages for seasonal versus permanent structures, population per household type, percent conforming and failing systems, and an untreated phosphorus load of 0.8845 kg/cap/year from *The Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (Barr, 2004).

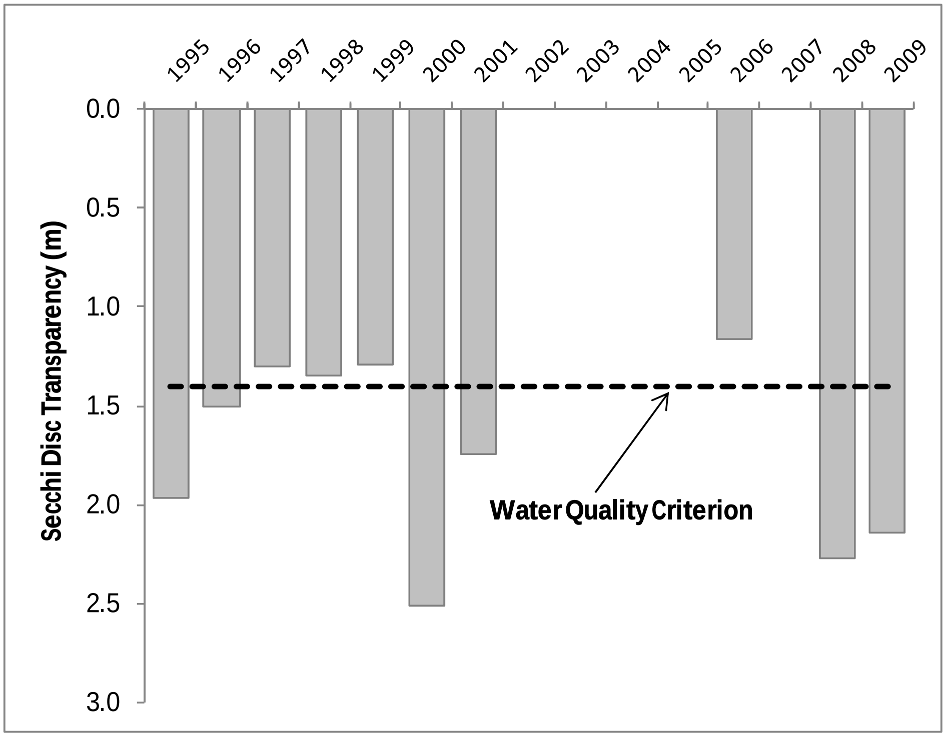

Figure 3-1 Pearl Lake Summer Mean Secchi Disc Transparency

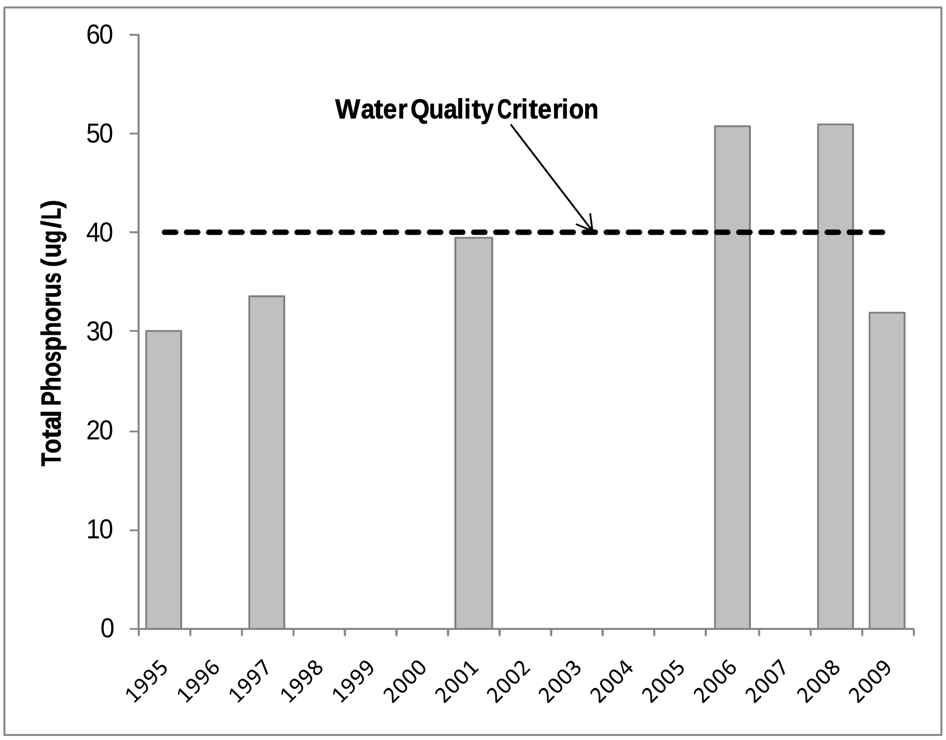

Figure 3-2 Pearl Lake Summer Mean Total Phosphorus

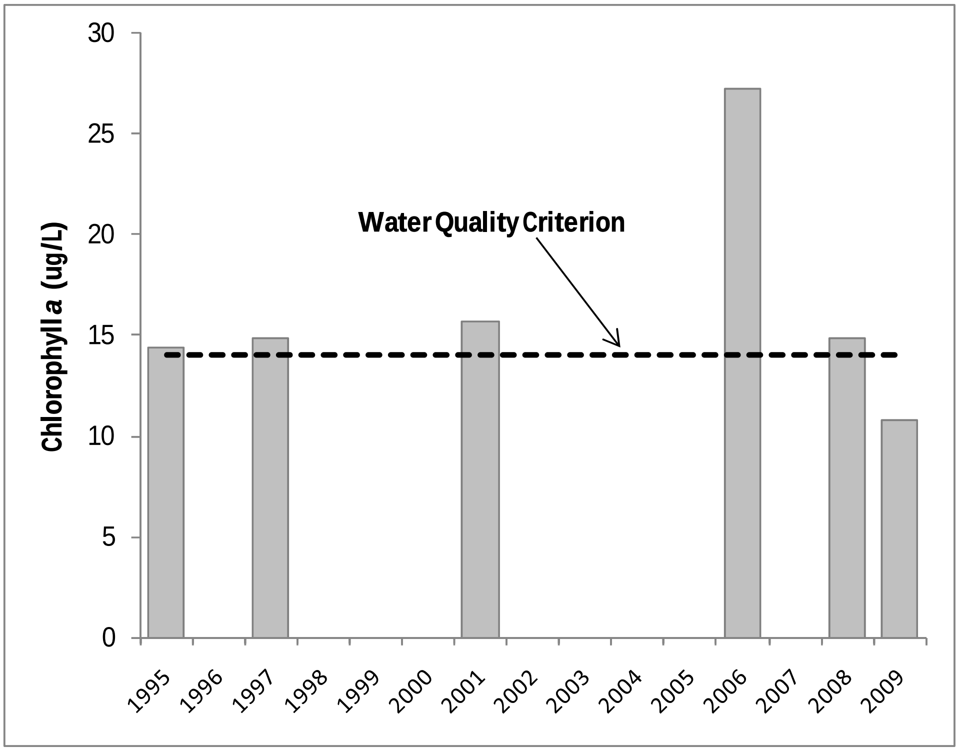

Figure 3-3 Pearl Lake Summer Mean Chlorophyll a

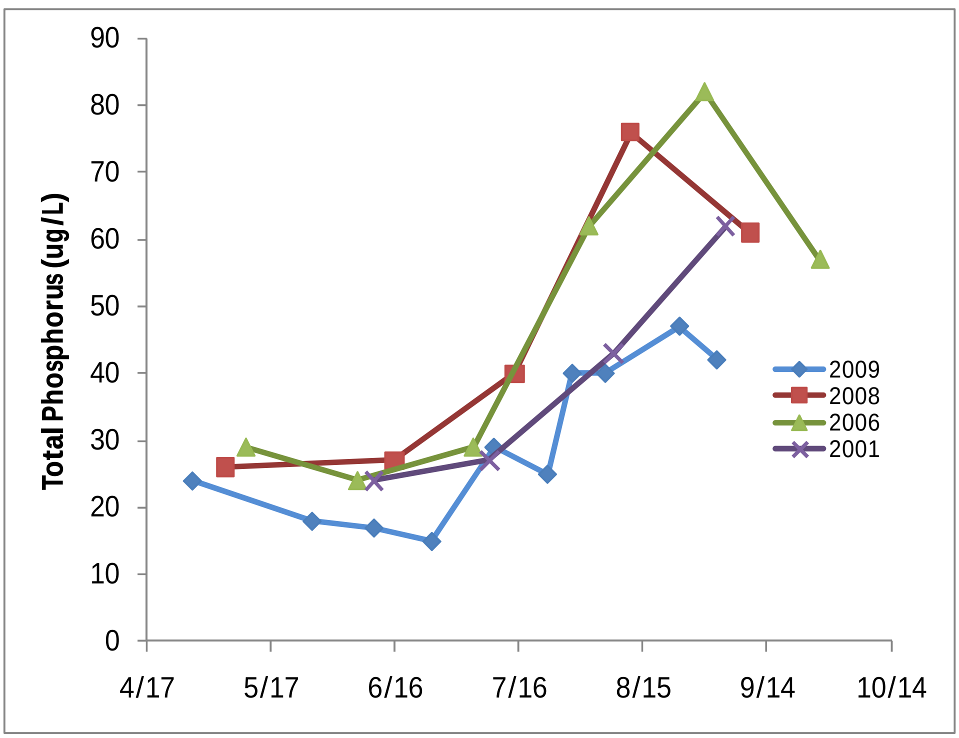

Figure 3-4 Pearl Lake Total Phosphorus Concentrations at Lake Surface

3.2.2.2 Direct Atmospheric Loading

The phosphorus load from direct precipitation and atmospheric deposition to the surface of Pearl Lake was estimated by multiplying the lake surface area by an atmospheric loading rate of 0.0696 kg P/ac/yr, the rate for the Upper Mississippi Watershed in an average precipitation year (Barr 2004).

3.2.2.3 Watershed Loading (Water and Phosphorus)

The first step in modeling Pearl Lake water quality was to create a water balance. A daily time-step water balance was generated for the late-spring and summer months (May-September) of 2008 and 2009:

Change in lake volume = Watershed Inflow + Direct Precipitation – Evaporation – Outflow

The outflow of Pearl Lake was determined with a hydrologic rating curve that relates lake elevation near the outlet with flow in Mill Creek immediately downstream of Pearl Lake. The elevation of Pearl Lake was measured daily during summer months with an electronic pressure transducer that logs water level. Average daily outflow (Figure 3-5) was then calculated from lake elevation by using the hydrologic rating curve. The daily direct precipitation to the surface of Pearl Lake was determined by multiplying the daily precipitation measured with a weather station on the western shore of Pearl Lake by the surface area of Pearl Lake. Daily evaporation was estimated using the Meyer evaporation model (Meyer, 1944) and available climate data. The change in lake volume was determined by measuring the change in lake elevation from one day to the next.

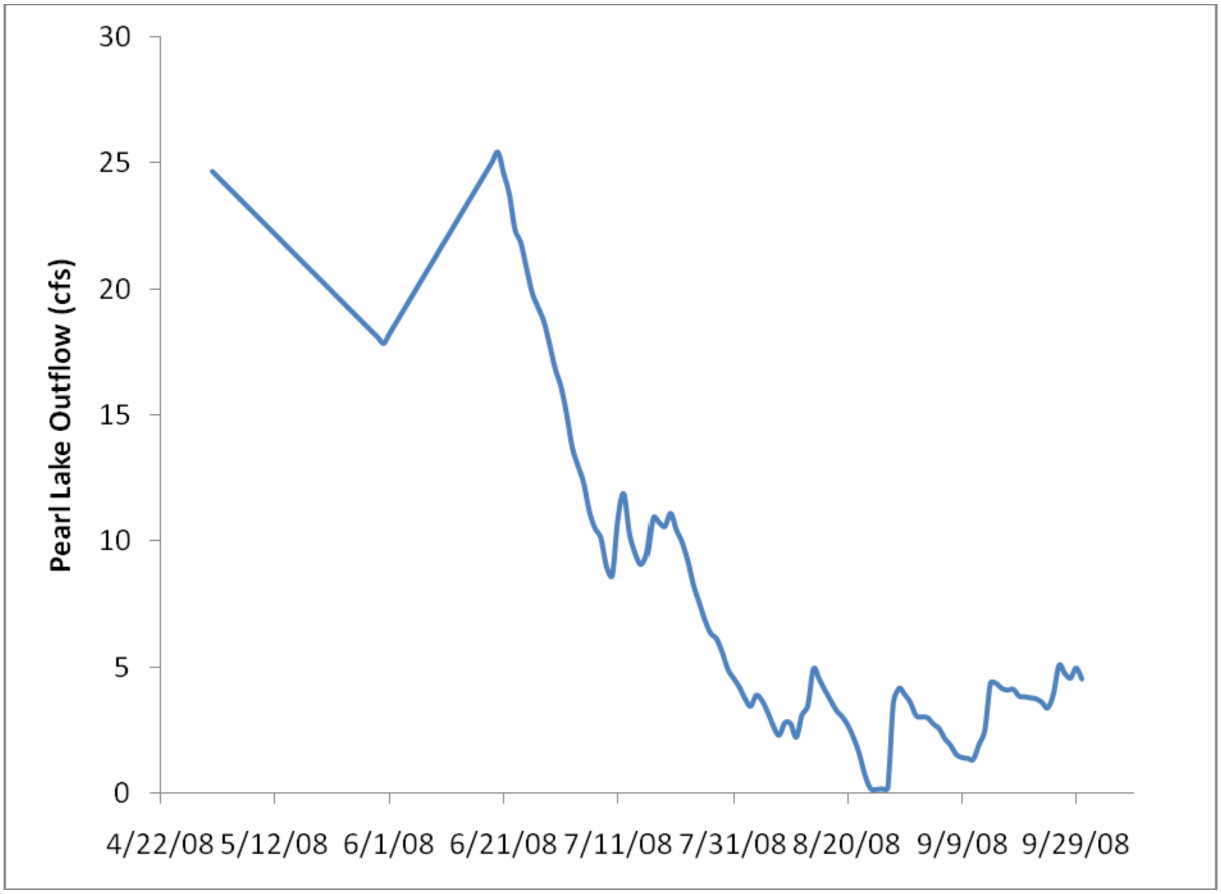

Figure 3-5 Measured Flow at Pearl Lake Outlet

Flow was not measured in the tributaries to Pearl Lake (Mill Creek, an unnamed creek, and direct watershed); therefore, the total watershed inflow was determined by balancing the above water balance equation. By dividing the total summer inflow in 2009 by the estimate of the total volume of precipitation that fell on the watershed that contributes flow to Pearl Lake, it was determined that the water yield for the contributing watershed is approximately 29%. By comparison, the water yield for the Upper Mississippi watershed in an average precipitation year is approximately 26% (Barr 2004). The water yield determined from the spring-summer 2009 water balance was used to estimate the amount of precipitation that becomes surface runoff in the watershed during the months of the year when daily lake elevation monitoring data was unavailable (October-April).

Total phosphorus concentrations were measured in Mill Creek and unnamed creek in the spring and summer months of 2008 and 2009. The data collected in Mill Creek and unnamed creek in 2008 did not meet quality control criteria; therefore, 2009 total phosphorus data from Mill Creek and unnamed creek (Table 3-1) was used as a substitute for 2008. The dissolved phosphorus concentrations were a large percentage of the total phosphorus concentration for much of the year. At times, the dissolved phosphorus fraction was as high as 84% of the total phosphorus fraction. The direct watershed to Pearl Lake is similar in size and land use to unnamed creek, and was assumed to have the same total phosphorus concentration in runoff as unnamed creek for the purpose of modeling water quality in Pearl Lake.

Table 3-1 Total and Dissolved Phosphorus Concentrations (µg/L) in Mill Creek and Unnamed Creek.

Sample Date	Mill Creek Total	Mill Creek Dissolved	Unnamed Creek Total	Unnamed Creek Dissolved
3/17/2009	310	245	437	365
3/23/2009	500	235	2,150	1,150
4/16/2009	39	28	43	31
4/29/2009	43	30	49	29
5/12/2009	47	29	63	37
5/27/2009	80	59	30	12
6/11/2009	59	48	30	10
7/10/2009	113	95	32	11
7/15/2009	115	92	--	12
8/6/2009	83	69	23	12
9/2/2009	87	58	24	14

3.2.2.4 Lake Modeling

Lake modeling to determine the concentration of phosphorus in the lake water column with a given hydrologic and phosphorus load was conducted using a finite difference model and the assumption that the lake is completely mixed. The finite difference model (Pilgrim et. al., 2007) used is described by the following equation:

$$C = Co + \frac{(W*t - Qout*C - K*V*Co)*\Delta T}{V}$$

Where: C = phosphorus concentration in the lake, Co = initial phosphorus concentration or concentration of previous time step, or phosphorus concentration from the previous time step, W = phosphorus loading from external sources, internal sources, and dry or wet deposition directly on the lake, Qout = flow out of the lake, which is assumed to be equal to the seven day running average inflow rate, K = net apparent settling velocity (units of 1/y, and KVCo=phosphorus mass loss by settling). The net apparent settling velocity (K) can also be expressed in units of m/y if the average lake depth is used in the settling loss equation.

Using the water balance developed for water year 2008, the lake model was built using measured and estimated phosphorus inflow concentrations, estimates of direct deposition of phosphorus to the lake surface, initial estimates of net apparent settling velocities, and initial estimates of internal loading rates.

Net apparent settling rate and internal loading rates were the primary calibration parameters for the model. The net apparent settling rate was calibrated by selecting different values to match the phosphorus decline rate in Pearl Lake in the spring or following a storm event. The calibrated phosphorus settling rate was 5.2/y (or 13.0 m/y) for 2008 and 2009. Observed water quality data indicated year 2009 had less internal loading in Pearl Lake than other recent years, and was therefore selected to calibrate the settling rate of phosphorus.

The internal load rate was then changed to improve the fit between the modeled and observed concentrations of phosphorus in Pear Lake. The internal load rate changed throughout the growing season and it is suspected that the change was a function of curlyleaf growth and die-off. The rate of internal load change, suspected to be curlyleaf die-off and decay, followed a consistent relationship which could be described by a third order polynomial (Figure 3-6). Although internal loading from sediments can change during year, the change observed in Figure 3-6 is not characteristic of phosphorus release from sediments. The relationship described in Figure 3-6 should not be applied to different years because the coverage of curlyleaf changes annually. The lake wide average summer internal load rate was 2.7 $mg/m^2/day$ for 2008. Internal loading occurred for a total of 89 days in 2008, roughly starting on June 1 and ending August 31. In 2009, internal loading occurred for 61 days and the rate was 2.6 $mg/m^2/d$. Internal loading occurred at a nearly constant rate in 2009, suggesting that internal loading in 2009 was more indicative of phosphorus release from sediments.

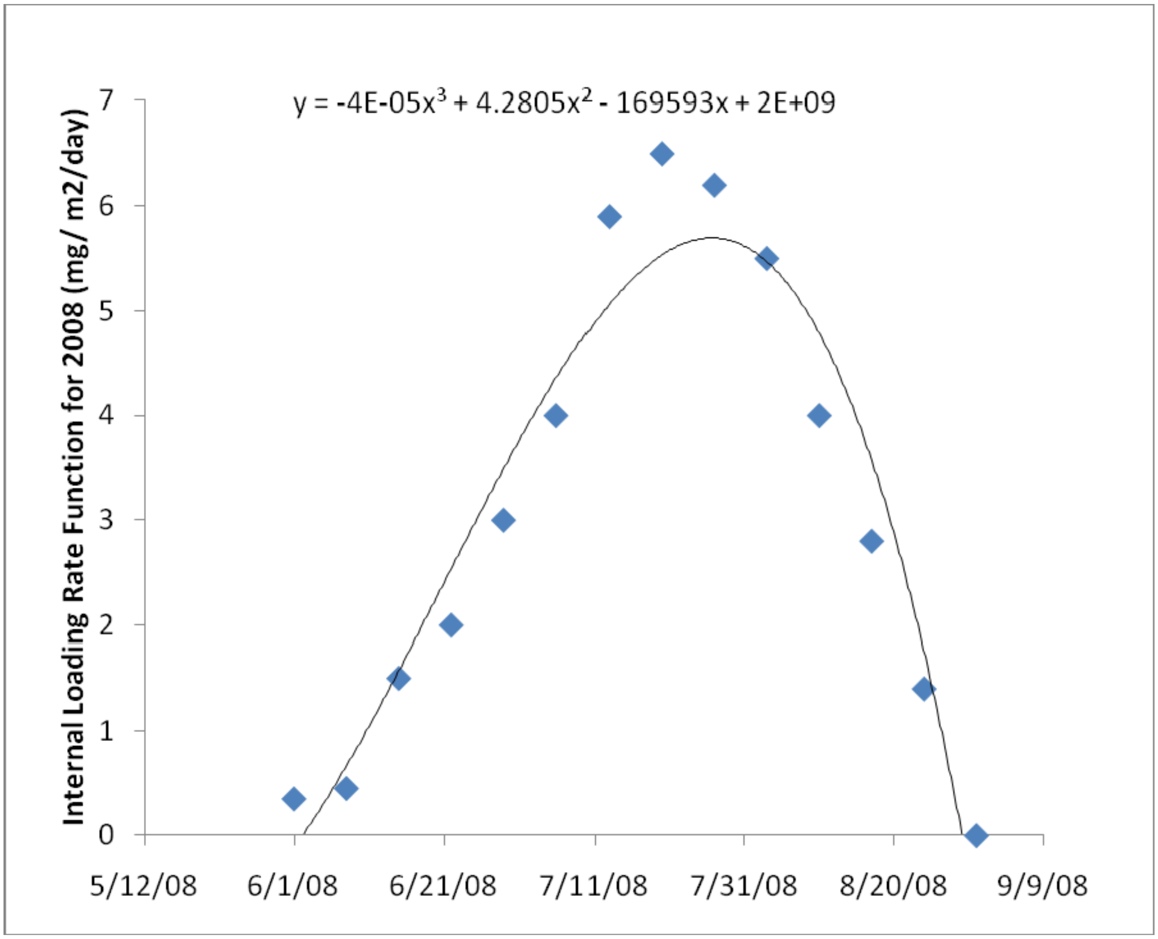

Figure 3-6 Internal Loading Function Describing Internal Loading in Pearl Lake in 2008

3.3 Modeling Results

The results of model calibration (for phosphorus only) are shown Figure 3-7. As described in the previous section, the model includes estimates of atmospheric, internal, and watershed loads for phosphorus and the corresponding water loads. These inputs were applied to the water quality model to predict phosphorus concentrations in Pearl Lake observed during the 2008 growing season. The year 2008 was selected because it represents an average climate year with a summer-mean total phosphorus concentration that exceeds the water quality criterion.

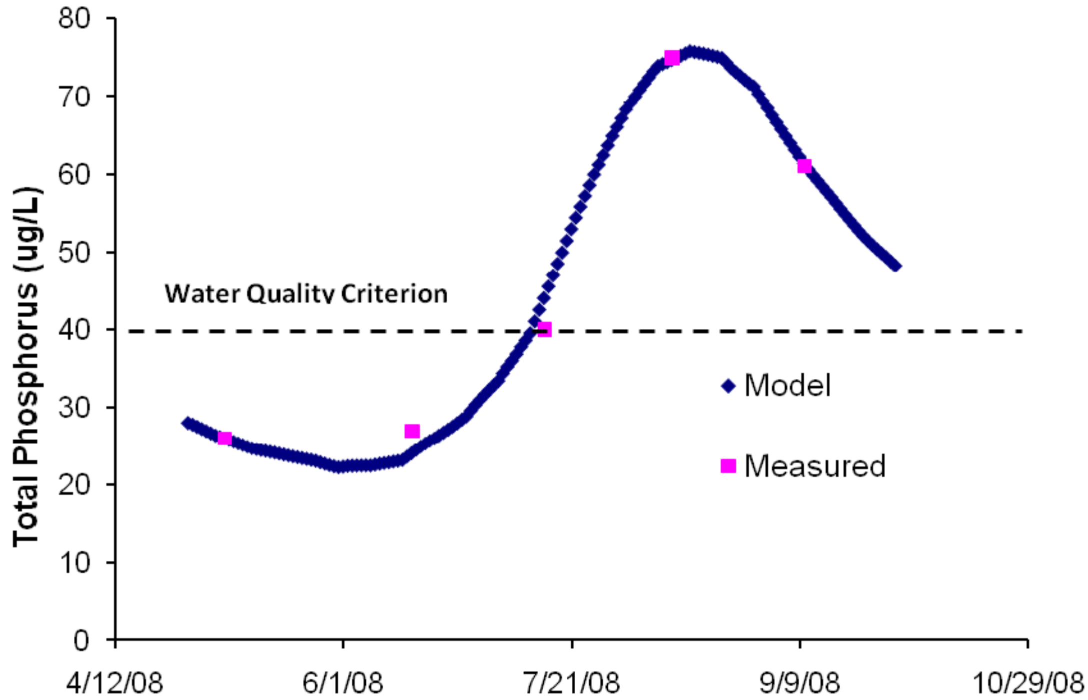

Figure 3-7 Pearl Lake Modeled and Measured Phosphorus for 2008 Growing Season

Water and total phosphorus loads for the 2008 water year for Pearl Lake are shown in Table 3-2.

Table 3-2Water, Total Phosphorus, and Net Internal Load Budgets in Pearl Lake during the 2008 Water Year

Calibration Year	External Water Load (AF)	External Total Phosphorus Load (kg)	Internal Total Phosphorus Load (kg)
2008	14,538	809	923

With the use of the calibrated water quality model, the magnitude (e.g., loading) of different phosphorus sources contributing to Pearl Lake were determined and are summarized in Figure 3-8.

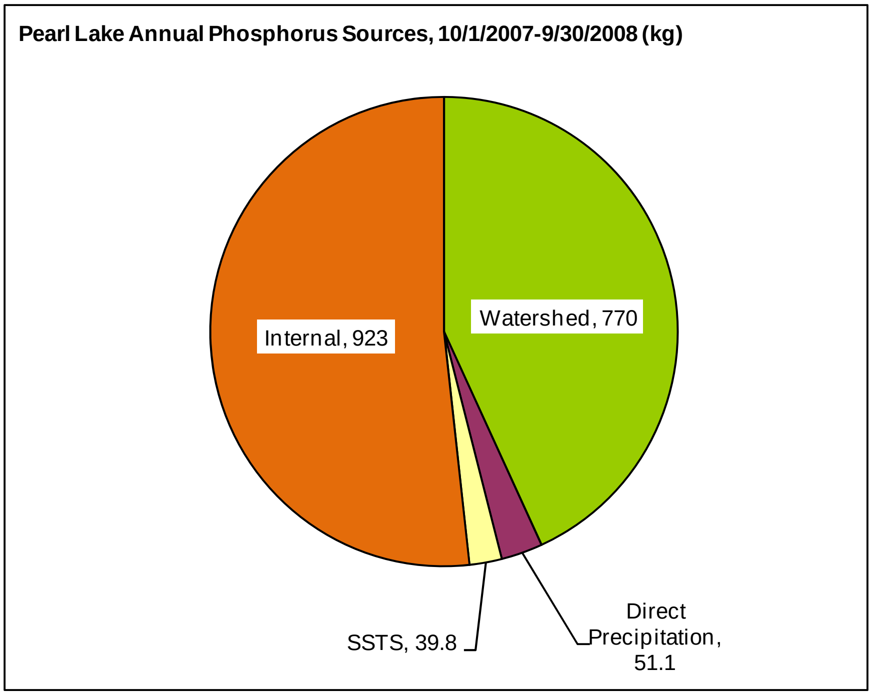

Figure 3-8 Phosphorus Sources (kg) to Pearl Lake for Water Year 2008

The 2008 observed summer-mean total phosphorus concentration of 51 µg/L is 11 µg/L above the 40 µg/L total phosphorus standard. According to the calibrated water quality model, a reduction of approximately 22% in the total phosphorus loading would be required to achieve the 40 µg/L standard in Pearl Lake for 2008.

3.4 Methodology for Load Allocations, Wasteload Allocations, and Margin of Safety

A TMDL is defined as follows (EPA, 1999):

TMDL = WLA + LA + MOS + Reserve Capacity

Where:

WLA	=	Wasteload Allocation to Point Sources
LA	=	Load Allocation to NonPoint Sources
MOS	=	Margin of Safety
Reserve Capacity	=	Load set aside for future allocations from growth or changes

This section will define each of the terms in this equation for Pearl Lake, and will discuss seasonal variation and reasonable assurances.

The water quality standard requires compliance with the phosphorus criteria during the growing season (June through September), which represents the critical condition and the time of the year when the water quality criteria are not being met. As a result, this TMDL study presents annual waste-load and load allocations that are based on the requirement of keeping the growing-season-average total-phosphorus concentration in Pearl Lake at or below 40 µg/L under average climate conditions. The TMDL was developed using the 2008 monitoring and climatic data and calibrated model for the following reasons:

Precipitation and hence watershed runoff was average in 2008;
External phosphorus loading is representative of average conditions; and
Overall, 2008 was a poor water quality year for Pearl Lake and as such represents a more conservative year upon which to derive load allocations.

It should be noted that watershed hydrologic load data were only available for 2008 and 2009 and as a result accurate load allocations could only be derived for those years.

3.4.1 Wasteload Allocations

No permitted dischargers are within the tributary watershed for Pearl Lake, and none are currently anticipated in the future. Therefore, the total phosphorus wasteload allocation for Pearl Lake is zero.

3.4.2 Load Allocations to Nonpoint Sources

The phosphorus load allocations for Pearl are attributable to the internal, atmospheric, and nonpoint source (watershed) loads to the lake. The following summarizes reductions in phosphorus loads from nonpoint sources and internal sources in order to achieve water quality standards for Pearl Lake:

20% reduction from nonpoint external (watershed) sources; and

31% reduction in internal loading, reductions strategies are outlined in section 5.0

3.4.3 Margin of Safety

Under Section 303(d) of the Clean Water Act, a margin of safety is required as part of a TMDL. The MOS accounts for the uncertainty that the allocations set in the TMDL will result in the water body meeting the water quality standard. Thus, an explicit MOS of 5 percent of the total loading capacity for Pearl lake was used to account for uncertainty in the TMDL allocation process.

3.4.4 Reserve Capacity

Significant future development is not expected in the watershed area in this study. Existing land use/land cover conditions can be considered representative of the future land use/land cover and population conditions for the purposes of setting the TMDL load allocations, and no reserve capacity has been set aside for Pearl Lake nonpoint source load allocations.

3.5 Phosphorus TMDL Allocations for Pearl Lake

Load allocations were set so that Pearl Lake will meet the total phosphorus criterion of 40 µg/L for the NCHF Ecoregion. Phosphorus load estimates for the entire 2008 water year were used to determine the daily load and wasteload allocations for Pearl Lake (Table 3-3). The entire water year was used to develop annual and daily load allocations to avoid underestimating phosphorus load contributions from the tributary watersheds. The highest phosphorus concentrations were observed in the spring, and hence, load allocations developed only for June through September would have underestimated the contribution of external loads to the impairment status of Pearl Lake.

3.6 Seasonal Variation

Total phosphorus concentrations in the lakes can vary significantly during the growing season. The TMDL guideline for total phosphorus is defined as the growing season (June through September) mean concentration (MPCA, 2007b). Accordingly, water quality scenarios (under different management options) were evaluated in terms of the growing season mean total phosphorus concentration.

Table 3-3Pearl Lake Total Phosphorus Wasteload and Load Allocations

Phosphorus Sources	Existing TP Load (kg/year)	TMDL Wasteload Allocation		Percent Reduction of Existing TP Load (Percent)
		Annual (kg/year)	Daily (kg/day)	
Permitted Dischargers	0	0	0	0
Total Wasteload Sources	0	0	0	0
Internal and Nonpoint Sources	Existing TP Load (kg)	TMDL Load Allocation	Daily TMDL Load Allocation	Percent Reduction of Existing TP Load (Percent)
		(LA)	(LA)	

Phosphorus Sources	Existing TP Load (kg/year)	TMDL Wasteload Allocation		Percent Reduction of Existing TP Load (Percent)
		Annual (kg/year)	Daily (kg/day)	
		(kg)	(kg/day)	
Internal Sources	923	640	1.75	31
Non-point watershed sources	810	648	1.77	20
Atmospheric Sources	51.1	51.1	0.14	0
Total Load Sources	1,784	1,339	3.67	25
Margin of Safety (MOS)	0	71	0.19	0
Overall Source Total	1,784	1,410	3.86	25

4.0 Monitoring Plan to Track TMDL Effectiveness

The water quality of Pearl Lake has been monitored infrequently over the past three decades. Water quality data (phosphorus and TSS) were collected in 2009 for Mill Creek and the unnamed creek. The Sauk River Watershed District will coordinate continued monitoring of water quality in Pearl Lake, as well as Mill Creek and the unnamed creek. For the years in which monitoring is conducted (e.g., just prior to and after implementation) and with consideration of fund availability, water quality measurements should be collected monthly in Pearl Lake from May through September.

Secchi disc transparency

Dissolved oxygen (1-meter depth intervals)

Temperature (1-meter depth intervals)

pH (1-meter depth intervals)

Total phosphorus (surface, mid-depth, and near bottom)

Dissolved phosphorus (surface, mid-depth, and near bottom)

Chlorophyll *a* (surface only)

For years in which monitoring is conducted (e.g., just prior to and after implementation) watershed monitoring (Mill Creek and the unnamed creek) should be conducted at a frequency of once every two weeks for the period of April through November. The following parameters should be collected from the watershed monitoring locations:

Total phosphorus

Dissolved phosphorus

Total suspended solids

Flow

Curly-leaf pondweed, which is known to increase eutrophication in North American lakes, is prevalent in Pearl Lake, but the extent and total biomass can vary from one year to the next. Curly-leaf pondweed is unique compared to native aquatic plants in that it grows under the ice and during the spring when water temperatures are still cold. Ice thickness and snow depth may affect the growth of curly-leaf pondweed by limiting the amount of light reaching the curly-leaf pondweed. Curly-leaf pondweed monitoring should be conducted as part of the implementation plan to document the coverage and density of curly-leaf prior to and after implementation.

For the years in which curly-leaf pondweed monitoring is conducted, a curly-leaf pondweed survey should be conducted during the first half of June each year to monitor the growth of curly-leaf pondweed. At a minimum, surveys would utilize GPS to record the extent of where curly-leaf pondweed is observed “topping out”, or growing at the surface of Pearl Lake. More detailed aquatic plant surveys could include density ratings or stem counts. To better define the growth and die-off of curly-leaf, surveys could be conducted in late July and early September in addition to the June survey. If feasible, the pondweed surveys should be conducted the same year that water quality monitoring is conducted.

5.0 TMDL Implementation Strategies

The following sections summarize implementation strategies that should be implemented in order to achieve reductions in phosphorus loading necessary to achieve water quality targets in Pearl Lake. Overall, the implementation strategy should be adaptive. Implementation strategies should be reevaluated and updated as new data becomes available. Consideration should be given on how implementation of upstream phosphorus reduction strategies may affect downstream phosphorus sources (e.g. reductions in external loading may lead to a reduction in internal phosphorus in the long term).

5.1 Annual Load Reductions

The TMDL implementation plan focuses on reducing external sources of phosphorus to the watershed with additional work to better estimate internal sources of phosphorus loading. Annual overall total load reductions of 444 kg (25 %) in phosphorus loading in Pearl Lake is required to meet the total phosphorus growing-season average of 40 µg/L. Load-reduction projects should be implemented following a priority ranking system for the available nutrient reduction strategies. It is anticipated that it will take more than 20 years to implement all of the projects required to achieve the annual load reduction. Additional monitoring is also recommended to help ascertain the removal efficiency of planned watershed measures to reduce phosphorus loading to the lake.

5.2 Sector-Specific Strategies

Nonpoint source pollution has and remains a difficult item to quantify to a absolute number. The data relied on for the TMDL is not in a fine enough scale to allow the assigning absolute numbers for a specific water quality concern, for example a particular management practice which has been changed. Many implantation measures are therefore based upon an expected amount of participants to achieve the desired result. The following sections provide detailed implementation strategies associated with each of the significant phosphorus loading sources within Pearl Lake and its watershed.

5.2.1 Public Education for Water Quality Protection

An extensive public education program should be developed to inform watershed residents of the issues facing Pearl Lake and their roles in addressing these issues and to engage them in taking action. A public education program should promote a community-to-community awareness and clearly identify the contribution that all communities, such as waterfront property owners and agricultural producers. An educational program should be developed that integrates public relations advertising, marketing, civic engagement, public involvement, technical assistance, and training to optimize nutrient reductions from all phosphorus loading sectors within the overall watershed.

5.2.2 Environmental Planning for Urban, Rural and/or Seasonal Development

State and local governments should establish an integrated land and water resource planning process that is environmentally conscientious while ensuring planned and orderly growth with respect to land drainage and sewer and water services. "Low-impact development" concepts need to be considered for future land use planning. All new development, redevelopment, industrial, and construction projects should be designed to maintain or improve existing developed hydrology and pollutant loadings and fully comply with the local watershed and government authorities, National Pollutant Discharge Elimination System (NPDES), and anti-degradation requirements.

All rural residential, commercial, industrial, and urban development projects should be comprehensively reviewed with respect to water and wastewater treatment requirements to protect the environment. Developers should be required to include the full cost-recovery expense of installing the required water and wastewater treatment services for new developments and ensure that these are built into the costs of the development.

Developers should be responsible for land drainage issues for new residential developments that consider the nutrient impacts of the development and should build low-impact, environmentally conscientious concepts into the design of the project, with the aim of reducing environmental service costs to minimize pollution loads. The state and/or local government should establish regulations, such as minimum set-back distances from shorelines for new developments, to prevent significant disturbances which would result in increased erosion along lakes and waterways.

5.2.3 Treatment of Existing Stormwater Sources

Unmanaged stormwater can adversely affect water quality. In addition, unmanaged stormwater can overwhelm streams and cause streambank scouring. It is expected that the MPCA will continue to administer the requirements of the federal Clean Water Act which call for better management of stormwater through programs such as the Construction Stormwater Permit and the Industrial Stormwater Permit.

For existing sources of stormwater that are not subject to these permit programs, it is recommended (when feasible) that low-impact design principles be incorporated into all plans for redevelopment or expansion and infrastructure or street replacement projects. Where it is not feasible or cost-effective to improve the existing developed hydrology and pollutant loadings, government entities should pursue other options for providing regional management of stormwater runoff.

5.2.4 Ditch Cleaning

Routine maintenance, cleaning, restoring of ditches to original design characteristics of Judicial, private and roadside ditches has the potential to contribute loadings but are generally exempted from construction stormwater permitting. There are several exceptions; new work improving, expanding or otherwise doing work beyond restoring to original design conditions, as well as work exceeding 1 acre in size of disturbance in the case of private ditches or greater than 5 acres in size in Judicial and roadside ditches would be subject to a construction stormwater permit. The permitting process for construction stormwater permitting would define the work and best management practices to be completed as part of the work.

5.2.5 Livestock Access to Riparian Areas and Waterways

Drainage from confined livestock areas should be directed to retention basins, grassed buffer strips, constructed wetlands, or another generally recommended nutrient-reduction feature. This may be particularly relevant to the Pearl Lake drainage because of the fairly high number of livestock operations in the watershed. Manure accumulated in confined holding areas should be regularly removed and applied to crop or pasture lands during appropriate seasons and at appropriate agronomic rates. Livestock producers should be encouraged through enhanced incentives, education, and (when required) regulations to implement measures to protect riparian areas and waterways, such as managing livestock access in riparian areas and providing off-site watering structures.

Agriculture extension programs, as well as other partnership programs, should be used to help agricultural producers assess the environmental risk of their operations. The programs should also be used to provide advice on how to prevent the contamination of groundwater and surface water.

5.2.6 Soil Fertility and Manure Testing

Additional strategies that promote and support annual soil testing should be developed to provide agricultural producers with the tools necessary to make sound agronomic, economic, and environmental decisions. Incentives for agricultural producers conducting soil testing and manure testing should be considered. Enhanced education on the economic and environmental benefits of soil and manure testing is recommended.

5.2.7 Agricultural Drainage

A review of agricultural land drainage networks on a watershed basis should be undertaken. This review should explore the feasibility of reducing the velocity of flow in agricultural drains and ditches to allow particulate nutrients an opportunity to settle out. The use of nutrient traps or settling basins along drains should be explored to determine their effectiveness in reducing nutrient loading. This work would include a review of the feasibility of acquiring marginal land and constructing new wetlands, or restoring existing wetland areas that could serve as natural filters for drainage water.

5.2.8 Septic Field Maintenance and Alternatives to Septic Fields

A focused educational campaign should be undertaken to provide guidance to homeowners on how to properly maintain septic fields and how to recognize when they are failing. The appropriate local government authority should require mandatory inspection of private sewage treatment systems at the time of sale. The sale of the property would be conditional on a properly functioning system. Both states and/or local governments should explore the funding options to recover the costs of conducting an ongoing comprehensive septic field inspection program and maintaining a septic field database.

5.2.9 Stream Channel Erosion

All new development, redevelopment, industrial, and construction activity projects should be designed to maintain or improve the existing hydrology (i.e. reduce peak flows). In addition, opportunities for correcting existing channel and shoreline erosion sources should be investigated. A protocol should be developed and followed to ensure that all assessments of erosion in the watershed are comparable and can be prioritized.

5.2.10 Silviculture

Silviculture operations should implement BMPs that are appropriate for each site and process, based on the recommendations in *Water Quality in Forest Management: Best Management Practices in Minnesota* or another state-approved forestry BMP guidebook.

5.2.11 Internal Load Reduction

Internal load reduction should be investigated as a means to reduce phosphorus levels in Pearl Lake. Internal loading is a substantial portion of the total phosphorus load to Pearl Lake. Reductions of external loading of phosphorus has the potential to lead to a long term reduction of internal loading in Pearl Lake, however, it is not clear how long this process will take or what the new long-term equilibrium phosphorus level would be. Hence, internal load control is needed to meet in-lake water quality standards for phosphorus. Internal loading should also be reevaluated periodically as part of the overall adaptive management strategy. Additionally, the longevity of internal load reduction technologies can be increased substantially if external loads are reduced.

Internal load reduction can include reduction of phosphorus loading due to Curlyleaf pondweed, as well as reduction of phosphorus that is released from lake sediments. The most common management strategy for Curlyleaf pondweed is application of a chemical herbicide. Before the MDNR will issue a permit for the large scale treatment of a lake for Curlyleaf pondweed, aquatic plant management plans are required and must be developed in conjunction with the MDNR. These plans detail the current status of the aquatic plant community, along with specific treatment objectives and activities.

Reduction of phosphorus that is released from lake sediments can be achieved through inactivation or removal. Inactivation can be accomplished by the addition of a chemical such as alum, which will bind with phosphorus in the sediment and prevent its release back into the water column. Removal of phosphorus can be accomplished with dredging of the sediment.

Management of biological factors can also lead to a reduction of internal phosphorus loading from the sediment. Carp and bullhead are bottom feeding fish that disturb the lake sediment, causing phosphorus to be recycled back into the water column. If carp are present in high numbers, they can cause a significant increase in eutrophication in a shallow lake system.

Additional attention should be given to measuring the amount of carp present in Pearl Lake during the next fisheries survey.

5.3 Evaluation of BMP Effectiveness and Priority Ranking for Nutrient Reduction Strategies

SRWD will coordinate efforts to determine what best management practices would be practical, economically feasible, and environmentally effective in reducing nutrient loading in Pearl Lake and its watersheds. As a first step, the TMDL Implementation Plan should include a review of the cost-effectiveness of best management practices that should be undertaken, based on existing applicable knowledge. BMP cost-effectiveness, combined with information about local water quality impairments and nutrient delivery to Pearl Lake and leveraged funding from outside sources, should be used to finalize a priority ranking system for implementing individual nutrient reduction strategies throughout the watershed.

5.4 Implementation Cost

The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL [Minn. Statutes 2007, section 114D.25]. The cost to implement the TMDL includes both external load and internal load control. The total cost to implement this TMDL is estimated to be approximately $2,300,000. This estimate will be refined when the detailed implementation plan is developed, following approval of the TMDL study. Some detail regarding this preliminary cost estimate is provided below.

External load control could involve several best management practices to control erosion and sediment transport with runoff events, stream bank stabilization, and agricultural best management practices. Another approach is to construct a pond or wetland to remove particulate phosphorus from lake inflows. The cost to settle particulate phosphorus from Mill Creek and the unnamed creek is dependent upon the watershed size and the desired retention time and removal requirements. A very approximate estimate is that a pond with a 60 acre-foot wet detention volume will be required to achieve adequate suspended sediment and phosphorus removal from the Mill Creek and unnamed creek inflows (total watershed area of 7,866 acres). The cost to design and construct the 60 acre-foot pond is approximated from the following equation (Brown and Schuler, 1997): C (in thousands) = $24.5V^{0.705}$, where = construction, design and permitting cost and V = volume in the pond (cubic feet). Using this equation and adjusting for inflation (4% annually), it is estimated that the cost to design and construct this pond would be approximately $800,000. This does not include land acquisition cost. This cost estimate should be used as a planning level estimate only.

The cost to treat the lake sediments with an alum treatment to inhibit phosphorus from the lake sediments is estimated to be approximately $1,000,000 ($1,300/ac for 750 acres). The cost to treat curly-leaf pondweed is estimated to be $500,000 (treatment for 5 years for 150 acres of the lake).

This implementation cost estimate will be refined when the detailed implementation plan is developed, following approval of the TMDL study.

6.0 Reasonable Assurances

The following should be considered as reasonable assurance that implementation will occur and result in nutrient load reductions in Pearl Lake toward meeting their designated uses.

The Sauk River Watershed District is the water management authority for Pearl Lake and is qualified to implement corrective actions and achieve TMDL goals.

Watershed wide the SRWD & SWCD pursue grants to help offset the cost to install BMPs. The district works cooperatively with the local Soil Water Conservation Districts and the National Resource Conservation Service to help landowners receive up to 75% cost share for their projects. The cost share funds are also available to local municipalities for stormwater mitigation and other BMPs.

> The BMPs and other strategies outlined in Section 5.0 have all been demonstrated to be effective in reducing transport of pollutants to surface waters.

Monitoring will be conducted to track progress and guide adjustments in the implementation approach.

The Construction and Industrial Activities NPDES Permits requires permittees to provide reasonable assurances that if an EPA-approved TMDL has been developed, they must review the adequacy of their stormwater pollution prevention plans (SWPPP) to meet the TMDL's WLA set for stormwater sources. If the SWPPP is not meeting the applicable requirements, schedules and objectives of the TMDL, they must modify their SWPPP, as appropriate, within 18 months after the TMDL is approved.

All significant development, redevelopment, industrial, and construction projects need to be designed to maintain or improve existing developed hydrology and pollutant loadings to fully comply with the local watershed and government authorities, NPDES, and anti-degradation requirements.

An implementation plan will be finalized within one year following EPA approval of the TMDL, which will identify specific BMP opportunities sufficient to achieve the sector-specific load reduction and associated adoption schedule. Individual SWPPPs will be modified accordingly following the recommendations of the implementation plan.

7.0 Public Participation

In April 2008 the SRWD held a meeting with the Pearl Lake Association to discuss impaired waters, the TMDL and process to complete the TDML. In December 2008, the SRWD held a public meeting in Waite Park to inform the general public about the TMDL study. The public meeting was listed on the SRWD website and in the local papers for two consecutive weeks. In addition, the SRWD has discussed the five TMDL studies occurring within the District in annual newsletters. The SRWD's Board of managers has discussed the TMDL's with the residents within their watershed area. Other stakeholders such as the Stearns SWCD have discussed this TMDL with local landowners during education events and their newsletter. A public meeting will be scheduled in the summer to fall 2010 timeframe to discuss the outcome of this TMDL with the residents of Pearl Lake and tributary watersheds.

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Part II
Draft Mill Creek
Bacterial Total Maximum Daily Load Report:
Headwaters to Sauk River

TMDL Summary Table

<table>
<tr><td colspan="7">TMDL Summary Table</td></tr>
<tr><td>EPA/MPCA Required Elements</td><td colspan="6">Summary</td><td>TMDL Report Section</td></tr>
<tr><td>Location</td><td colspan="6">Southeastern portion of the Sauk River Watershed District in Stearns County, Minnesota, in the Upper Mississippi River Basin. See Figure 2-1.</td><td>Section 2</td></tr>
<tr><td>303(d) Listing Information</td><td colspan="6">Mill Creek, Headwaters to Sauk River (07010202-537).

Mill Creek was added to the 303(d) list in 2006 due to excess bacteria concentrations that impair aquatic recreation, as defined by Minnesota Rules 7050.0150. The TMDL for Mill Creek was originally prioritized to start in 2004 and be completed by 2009.</td><td>Section 1</td></tr>
<tr><td>Applicable Water Quality Standards and

Numeric Targets</td><td colspan="6">Criteria are defined in Minnesota Rules 7050.0222 for Class 2B surface waters: The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. The numeric target for the reach is in terms of E. coli: Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.</td><td>Section 3</td></tr>
<tr><td rowspan="3">Loading Capacity expressed as daily

geometric mean</td><td colspan="6">The loading capacity (the total maximum daily load) is provided across five flow regimes:</td><td rowspan="3">Section 5</td></tr>
<tr><td>Reach</td><td>Flow Interval</td><td>Waste Load (10^9 org. E. coli per day)</td><td>Load (10^9 org. E. coli per day)</td><td>Margin of Safety (10^9 org. E. coli per day)</td><td>TMDL (10^9 org. E. coli per day)</td></tr>
<tr><td>Mill Creek</td><td>High Flow</td><td>0</td><td>158</td><td>40</td><td>198</td></tr>
</table>

TMDL Summary Table							
EPA/MPCA Required Elements	Summary						TMDL Report Section
		Wet	0	54.8	37.8	92.6	
		Mid-Range	0	29.2	12.0	41.2	
		Dry	0	8.51	7.39	15.9	
		Low Flow	0	1.06	4.51	5.57	

Wasteload Allocation	There are no permitted sources in the watershed allowed to discharge to surface waters. The Wasteload Allocation represents the NPDES Construction Permit.			Section 5
	Source	Permit #	Gross WLA (organisms/month)	
	NPDES Construction	MNR100001	Construction storm water activities are considered in compliance with provisions of the TMDL if: (1) they obtain a Construction General Permit under the NPDES program, (2) properly select, install and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, (3) or meet local construction storm water requirements if they are more restrictive than requirements of the State General Permit.	
Load Allocation	The majority of the loading capacity is allocated to existing non-permitted sources. Proportional loads were derived by using the estimated percentage contribution of each source, excluding illegal and non-permitted sources (e.g., feedlots without runoff controls and failing SSTS). Wet condition proportions were applied to the High Flow and Wet regimes, dry condition proportions were applied to Dry and Low Flow regimes and the average of wet and dry			Section 5

TMDL Summary Table		
EPA/MPCA Required Elements	Summary	TMDL Report Section
	condition proportions were applied to the Mid-Range regime.	

Source	Load Allocation (10^9 organisms *E. coli*/day)				
	High Flow	Wet	Mid-Range	Dry	Low Flow
Riparian pastures	76	26	17	5.7	0.71
Non-riparian pastures	26	9.1	4.7	1.3	0.16
Feedlots w/o runoff controls	0	0	0	0	0
Applied Manure	31	11	5.5	1.5	0.19
Incorporated Manure	25	8.7	2.3	0	0
Septic systems (SSTS)	0	0	0	0	0
Urban runoff	0.16	0.054	0.014	0	0
Wildlife	0.023	0.008	0.006	0.002	0.0003
Total	158	54.8	29.2	8.51	1.06

Margin of Safety	The explicit MOS is the difference between the median and minimum loading values in each of the defined flow regimes. This accounts for the variation in flow for each regime.	Section 5.3
Seasonal Variation	Seasonal variation is accounted for by the use of a load duration curve to set TMDLs over seasonal flow regimes. The in-stream data used for the source assessment and the calculation of required load reductions represents observations across the range of seasonal and annual flow variation and loading conditions.	Section 5.4

TMDL Summary Table		
EPA/MPCA Required Elements	Summary	TMDL Report Section
Reasonable Assurance	Reasonable assurance is provided by the cooperative efforts of the Sauk River Watershed District, a watershed-based organization with statutory responsibility to protect and improve water quality of the water resources in the Sauk River watershed, which contains the listed reach and its tributary watershed. The source reduction strategies detailed in the implementation section have been shown to be effective in reducing pathogen transport and survival.	Section 8
Monitoring	A detailed monitoring plan will be included in the Implementation Plan to be completed. Current monitoring in the watershed is performed by the Sauk River Watershed District.	Section 6
Implementation	This TMDL sets forth a summary of potential management measures and load reduction strategies. More detail will be provided in the Implementation Plan to be completed. The estimated cost for the recommended implementation activities is $700,000 to address loading from livestock and $950,000 to address failing or illegal septic systems.	Section 7
Public Participation	A public meeting was held in Waite Park in December 2008 to inform the general public about the TMDL study. In addition, discussion of this TMDL study has been included in the SRWD newsletter and in the Stearns SWCD newsletter. A public meeting will be scheduled with the residents of the Mill Creek watershed to discuss the findings of this TMDL (when approved) and to review the complimentary implementation plan.	Section 9

1.0 Executive Summary

Section 303(d) of the Clean Water Act requires that every two years all states publish a list of streams and lakes that do not meet water quality standards. Waters placed on the list are considered impaired. States are required to set Total Maximum Daily Loads (TMDLs) for impaired waters in order to define the maximum amount of pollutant a water can receive while maintaining water quality standards and to determine the load reductions necessary to achieve water quality standards. A TMDL is divided into a wasteload allocation for point sources, a load allocation for nonpoint sources and natural background and a margin of safety.

The Minnesota Pollution Control Agency (MPCA) has determined that Mill Creek from its headwaters to the Sauk River (reach ID 07010202-537) is impaired and does not meet Minnesota water quality standards for pathogen indicator bacteria *Escherichia coli* (*E. coli*). This reach was placed on the 303(d) list in 2006 because monitoring data indicate that *E. coli* levels typically exceed the monthly geometric mean standard of 126 *E. coli* organisms per 100 mL. *E. coli* bacteria is used in water quality monitoring as an indicator organism to identify water that is contaminated with human or animal waste and the accompanying disease-causing organisms. Bacterial abundance in excess of the water quality standards can pose a health risk to swimmers and bathers and can limit other recreational uses.

Mill Creek is a tributary to the Sauk River, located in the southeastern portion of the Sauk River watershed in central Minnesota. The creek flows into the Sauk River in the city of Rockville, 16 miles upstream of the confluence of the Sauk River and the Mississippi River at Sauk Rapids. The Mill Creek watershed is approximately 48 square miles in size, and land use in the watershed is predominantly agricultural.

This TMDL study uses a population source inventory and assumed bacteria availability and delivery ratios to estimate the sources of bacteria that contribute to the observed load in Mill Creek. This analysis indicates that riparian pastures, surface applied manure, and feedlots without runoff controls are likely the primary sources of *E. coli* contamination.

This TMDL study uses a load duration curve approach to determine the bacteria loading capacity of Mill Creek under a variety of flow regimes. The duration curve is used to determine the general allocations necessary to meet water quality standards. These allocations are then proportioned between the legal sources based on the proportional loading determined from the source inventory. Overall *E. coli* load reductions of between 59% and 93% are required in order to meet water quality standards, depending on the flow conditions. The primary implementation strategies recommended to address the *E. coli* loading from primarily agricultural sources are agricultural best management practices such as riparian pasture management, manure management, and feedlot runoff protection.

2.0 Background

2.1 Watershed Description

Mill Creek is a tributary to the Sauk River, located in the southeastern portion of the Sauk River watershed in central Minnesota (see Figure 2-1). Mill Creek flows into the Sauk River in the city of Rockville, 16 miles upstream of the confluence of the Sauk River and the Mississippi River at Sauk Rapids. The Mill Creek watershed makes up 48 square miles of the approximately 1050-square mile Sauk River watershed, and includes Pearl Lake and Grand Lake. Land use in the watershed is predominantly agricultural.

The Mill Creek watershed is administered by the Sauk River Watershed District (SRWD), which is working to identify impaired waters and improve the water quality throughout the greater Sauk River watershed. Monitoring data for the last ten years shows that the entire length of Mill Creek, from the headwaters to the Sauk River at Rockville (ID 07010202-537) does not meet water quality standards for *E. coli* bacteria. The impaired reach and its tributary watersheds are shown in Figure 2-1.

A portion of the Mill Creek watershed, located to the south of Pearl Lake, does not contribute surface flow to the creek during normal conditions. This subwatershed is approximately 12.1 square miles in size, or 25% of the entire Mill Creek watershed area, and includes several small landlocked lakes. The characteristics of this noncontributing area are similar to that of the Mill Creek watershed as a whole. The remainder of this document will discuss the characteristics of the *entire* Mill Creek watershed (including the noncontributing subwatershed) unless it is clearly stated otherwise.

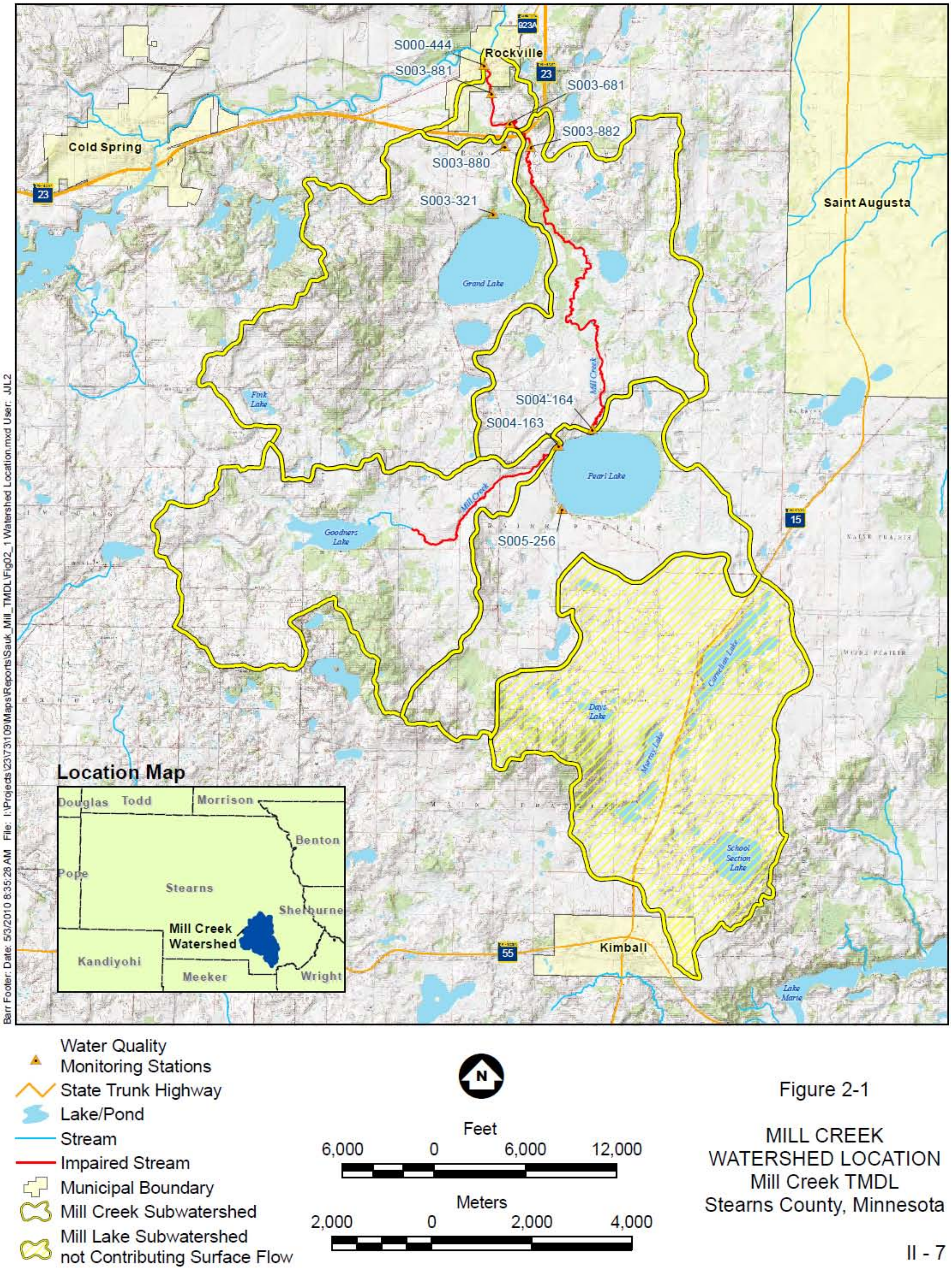

Figure 2-1 Mill Creek Watershed Location

2.2 Land Use

Land use in the Mill Creek watershed is primarily agricultural. Land use data from the National Land Cover Database (2001) was used to determine land use within the sub-watersheds that are tributary to Mill Creek, including the subwatershed that does not contribute surface flow to Mill Creek. This land use data set was developed by the USGS land use/land cover classification system, and describes the predominant types of land use in the area. The major land use categories in the Mill Creek watershed are shown in Figure 2-2 and Figure 2-3.

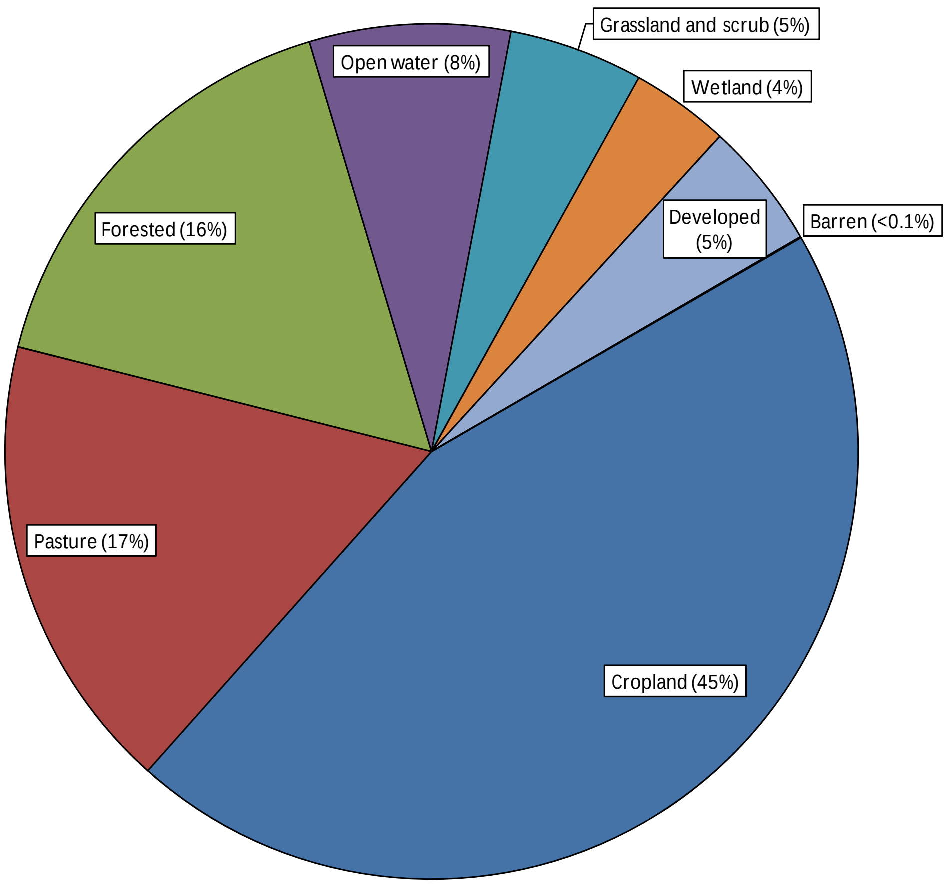

Figure 2-2 Mill Creek Watershed Proportional Land Use

The major land use categories (with the exception of developed land) are well-distributed across the Mill Creek watershed. The majority of the developed land is located in and around the city of Rockville, on the northern and downstream end of the watershed, and on the shores of Grand and Pearl Lakes. Agricultural land uses occupy the bulk of the watershed, with cropland and pasture together accounting for over 60% of the watershed area.

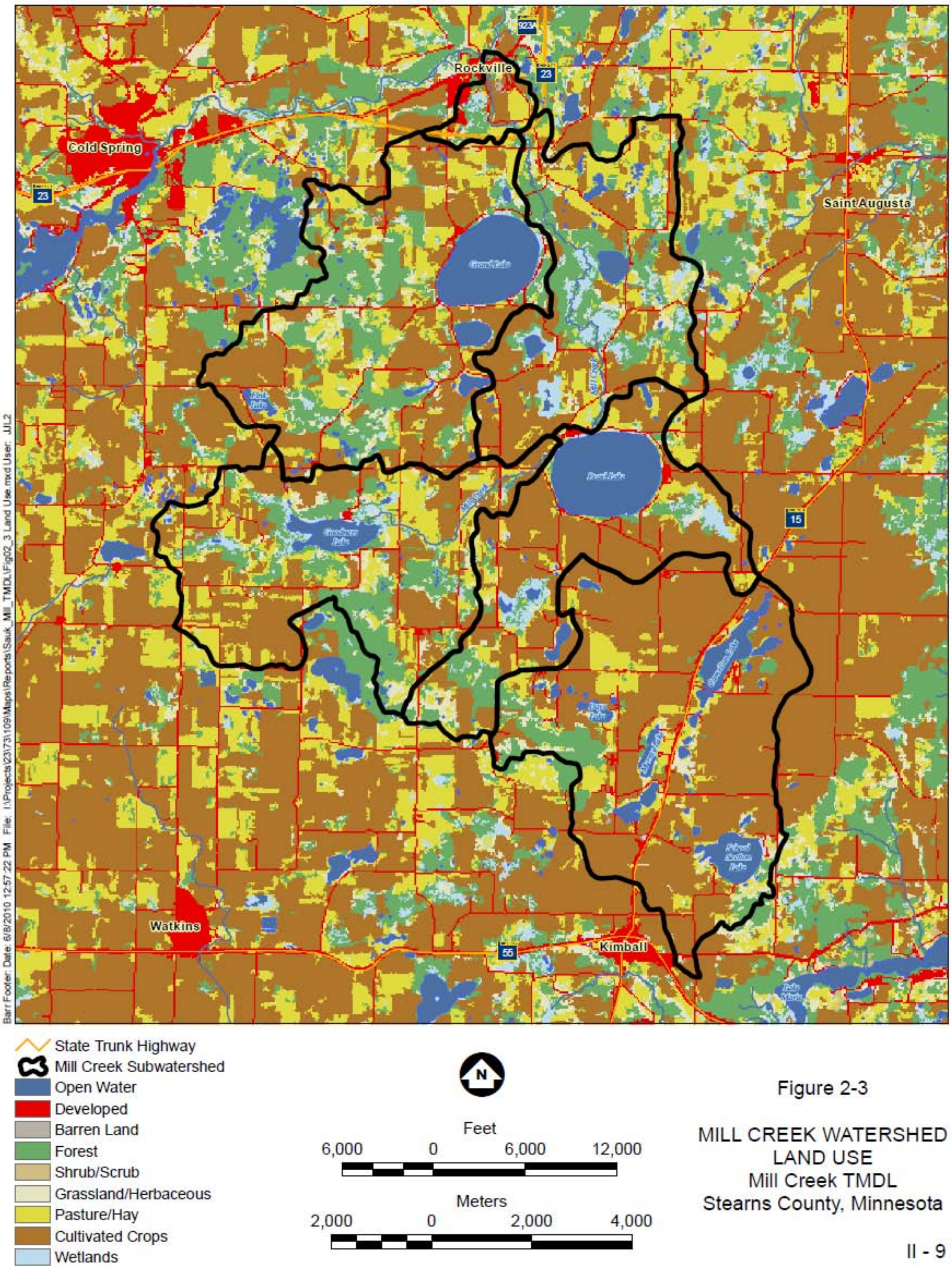

Figure 2-3 Mill Creek Watershed Land Use

2.3 Stream Physical Characteristics

The headwaters of Mill Creek are approximately 2.9 miles west-southwest of Pearl Lake, where Mill Creek originates from the wetland complex surrounding Goodners Lake. Downstream of Pearl Lake, Mill Creek flows for 7.5 miles though primarily agricultural areas before entering the Sauk River at Rockville. Grand Lake, which is similar in size to Pearl Lake with a larger contributing watershed, drains to Mill Creek through an unnamed tributary 1.5 miles upstream of the confluence with the Sauk River.

The riparian areas bordering Mill Creek are generally pasture or grassland upstream of Pearl Lake and downstream of the tributary from Grand Lake. These riparian grasslands range in width from 50 to 200 feet on either side of the stream, and are generally either used for grazing cattle or are set aside as buffer zones. Although in several locations Mill Creek is restricted to a relatively narrow riparian corridor, there is no evidence that Mill Creek itself has been ditched.

In the central segment of the stream reach (between Pearl Lake and Grand Lake) Mill Creek flows through several large wetlands and forests that provide significant buffering and protection of the creek from direct overland flow from cropland or developed areas. In this middle reach of the creek there are few residences or farms located near the creek.

2.4 Field Monitoring

The SRWD has undertaken water quality monitoring of Mill Creek since 2003 as part of an initial diagnostic study and in support of the current TMDL study. Field data collection has included monthly or weekly water quality sampling, both continuous and discrete flow measurements, and field measurements of water clarity using turbidimeters and transparency tubes. This study will focus only on measurements of flow and bacteria abundance (fecal coliform and *E. coli*); a more thorough presentation of the data for Mill Creek is included in the Lower Sauk River Diagnostic Study (Barr, 2006).

The stream monitoring locations with measurements of bacteria abundance within the Mill Creek watershed are summarized in Table 2-1 and shown in Figure 2-1. Bacteria data have been collected in units of both fecal coliform and *E. coli* at various points along Mill Creek and the tributary stream from Grand Lake. The monitoring location with the longest period of record, spanning the widest range of stream flow and climatic conditions, is at the mouth of Mill Creek in Rockville (station ID S000-444).

Because there is not a sufficient data set for fecal coliform or *E. coli* data when considered separately, measurements in both units are expressed here in terms of *E. coli* by using the conversion suggested by the MPCA, as discussed in Section 3.2 (126 organisms *E. coli* equals 200 organisms fecal coliform).

Table 2-1 Monitoring Locations in the Mill Creek Watershed (upstream to downstream)

Station ID	Location	Bacteria abundance as *E. coli* (organisms per 100 mL)			
		Observation Frequency & Dates	Num. Obs.	Range	Geomean
S005-256	Unnamed inlet to Pearl Lake at CSAH 8	Weekly in 2008	16	1 - 894	49
S004-163	Mill Creek inlet to Pearl Lake at CR-141	Weekly in 2008	22	1 - 540	67
S004-164	Mill Creek outlet from Pearl Lake at CR-146	Biweekly in 2007, weekly in 2008	23	1 - 1296	29
S003-321	Unnamed outlet from Grand Lake at Hubbert Ln.	Occasional in 2005 and 2007	6	17 – 540	124
S003-880	Unnamed trib. from Grand Lake at 230th St.	Occasional in 2005 and 2007	8	57 – 21,700	**387**
S003-882	Mill Creek at 230th St.	Biweekly in 2005 and 2007	14	22 – 1,130	**163**
S003-681*	Mill Creek ¾ mile south of Rockville*	Weekly in 2004	2	82 – 315	**161**
S003-881	Mill Creek at Mill St.	Weekly in Sept-Oct 2005	5	630 – 7,340	**2,030**
S000-444	Mill Creek at MN-23	Biweekly in 2003 and 2004, weekly in 2005, 2007 and 2008	58	8 – 10,580	**330**

Bold values are in exceedance of the chronic *E. coli* standard of 126 org. per 100 mL (see Section 3).
* Location S003-681 is identified as being 100 feet upstream of a manure release in 2004.

Paired measurements of stream flow and water quality (i.e., fecal coliform or *E. coli*) do not exist for the majority of the data collected for Mill Creek after 2004 and at any of the monitoring locations shown in Table 2-1. The Lower Sauk River Diagnostic Study (Barr, 2006), however, used continuous and discrete flow measurements collected during 2004 and 2005 on Mill Creek to develop a regression relationship between flow in the Sauk River (measured continuously at USGS station 05270500 near St. Cloud) and flow in Mill Creek (at location S000-444 in Rockville). This relationship was used to estimate the flow-duration curve for Mill Creek (see Section 5) and to estimate daily flows for days without instantaneous measurements of stream flow.

3.0 Applicable Water Quality Standards and Impairment Assessment

3.1 Significance of Fecal Coliform and *E. coli*

Fecal coliform bacteria are a group of bacteria found in the intestines and waste of warm-blooded animals including human sources. *E. coli* is a sub-group of fecal coliform and is virtually always present along with fecal coliform (MPCA, 2008). These bacteria are used in water quality monitoring as indicator organisms to identify water that is contaminated with human or animal waste and the accompanying disease-causing organisms.

Fecal coliform and *E. coli* bacteria can enter surface water bodies through discharges of poorly or untreated human waste, runoff from feedlots, agricultural lands and urban stormwater systems, and direct deposition by wildlife or grazing animals. Proper sewage treatment (both in municipal and septic systems) and manure management practices tend to reduce bacterial contamination of surface and groundwater.

Two Minnesota studies describe the presence and growth of “naturalized” or “indigenous” strains of E. coli in watershed soils (Ishii et al., 2006), and ditch sediment and water (Sadowsky et al., 2010). The latter study, supported with Clean Water Land and Legacy funding, was conducted in the Seven Mile Creek watershed, an agricultural landscape approximately 30 miles to the east of the mouth of the Cottonwood River. DNA fingerprinting of E. coli from sediment and water samples collected in Seven Mile Creek from 2008-2010 resulted in the identification of 1568 isolates comprised of 452 different E. coli strains. Of these strains, 63.5 percent were represented by a single isolate, suggesting new or transient sources of E. coli. The remaining 36.5 percent of strains were represented by multiple isolates, suggesting persistence of specific E. coli. Discussions with the primary author of the Seven Mile Creek study suggest that while 36 percent might be used as a rough indicator of “background” levels of bacteria at this site during the study period, this percentage is not directly transferable to the concentration and count data of E. coli used in water quality standards and TMDLs. Additionally, because the study is not definitive as to the ultimate origins of this bacteria, it would not be appropriate to consider it as “natural” background. Finally, the author cautioned about extrapolating results from the Seven Mile Creek watershed to other watersheds without further studies.

From a pragmatic standpoint, this study suggests that there is a fraction of bacteria that may exist regardless of most traditional implementation strategies that are employed to control the sources of E. coli.

3.2 Applicable Water Quality Standards

Mill Creek is classified as a Class 2B, 3C, 4A, 4B, 5, and 6 water. The narrative standard for Class 2B (the most stringent classification that applies to Mill Creek) is defined in *Minnesota Rules* 7050.0222:

> *The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable.*

The numeric standard for Class 2B is in terms of *E. coli*:

> *Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.*

Prior to 2008 the bacteria standard for Class 2B was expressed in terms of fecal coliform bacteria:

> *Not to exceed 200 organisms per 100 milliliters as a geometric mean of not less than five samples within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 2,000 organisms per 100 milliliters. The standard applies only between April 1 and October 31.*

The change in the standard from fecal coliform to *E. coli* was driven by guidance from the US EPA that *E. coli* is a better indicator of the presence of waterborne pathogens than is fecal coliform (MPCA, 2009). This conversion assumes that, on average, 126/200 or 63% of fecal coliforms are *E. coli*. The in-stream water quality data for this TMDL study are in terms of both fecal coliform (data collected in 2006 and earlier) and *E. coli* (data collected in 2007 and later). Because there is not a sufficient data set of either fecal coliform or *E. coli* data considered separately, measurements in both units are expressed here in terms of *E. coli* by using the conversion suggested by the change in the water quality standard (126 organisms *E. coli* equals 200 organisms fecal coliform). Although this method is not preferred for analysis of bacteria data (MPCA, 2009), it is necessary for the assessment of impairment in this case.

The TMDL allocations presented here are based upon the "chronic" monthly geometric mean standard of 126 organisms per 100 mL. It is assumed that achieving the necessary reductions to meet the chronic standard will also reduce exceedances of the "acute" standard of 1,260 organisms per 100 mL (MPCA, 2002).

3.3 Impairment Assessment

Observations of bacteria abundance have been collected on varying schedules at the different monitoring locations in the Mill Creek watershed, as shown in Table 2-1. Note from Table 2-1 that the geometric mean and maximum observed *E. coli* abundance generally increases in

Mill Creek moving downstream from Pearl Lake. This indicates that bacteria loading to the stream is ongoing throughout the watershed rather than concentrated at particular reach locations. In order to capture the loading from the entire watershed in this analysis, and because of the limited number of bacteria data at other monitoring locations, this TMDL will use only the fecal coliform and *E. coli* data (expressed in terms of *E. coli*) from the monitoring location at the mouth of Mill Creek in Rockville (station ID S000-444). The period of record used to determine this TMDL is October 1, 1998 to September 30, 2008.

During the period of record, the monthly geometric mean *E. coli* abundance exceeded the chronic standard of 126 organisms per 100 mL for all months except April. These data are shown in Figure 3-1. Note that for the months of April and October there are fewer than five observations (the minimum number of observations required to indicate impairment) within the period of record. *E. coli* levels in Mill Creek are consistently above the chronic standard throughout the period of record, especially for the warm-weather months of June through September where the majority of the observations are in excess of 126 organisms per 100 mL.

In addition to *E. coli* levels consistently above the chronic standard, there are regular exceedances of the acute standard of 1,260 organisms per 100 mL in Mill Creek. For the entire data set (n = 58), 14% of the observations (n = 8) were above this higher standard. These extreme bacteria levels are typically caused by heavy precipitation events; however, extreme bacterial levels also result from spills or other releases from treatment systems or containment facilities.

Bacteria data can also be interpreted based on the total load of bacteria in the stream, which is the product of concentration times flow. The most commonly used method for this type of analysis is the load-duration curve, which relates bacteria loading at a given flow to how often a particular flow is exceeded in the stream. The load-duration curve is useful to assess whether loading conditions are a function of stream flow or are independent from flow, as well as whether high bacteria loading typically occurs during high or low flow conditions. The load-duration data for Mill Creek are presented in Section 5 (Figure 5.2) and show that the majority of the observed bacteria loading values for Mill Creek in Rockville are above the chronic standard of 126 organisms per 100 mL for all flow conditions, and that extremely high loading typically occurs during the higher flow conditions. Further discussion on the development of load-duration curves is given in Section 5.

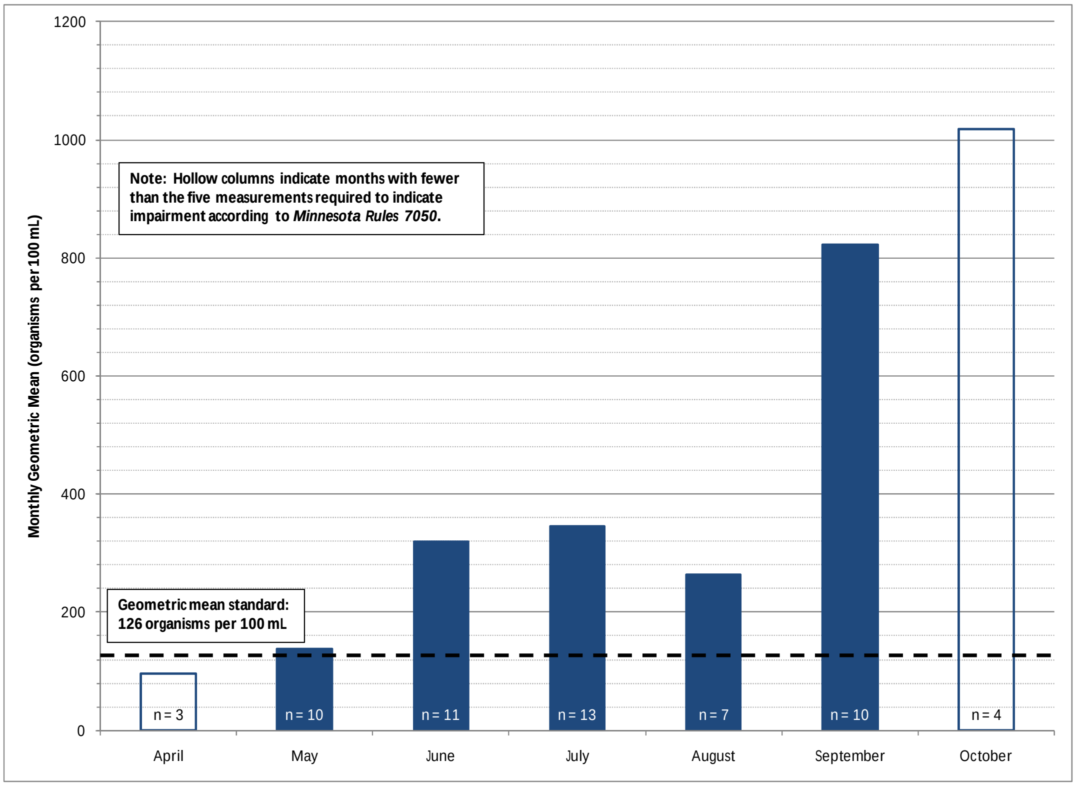

Figure 3-1 Mill Creek Monthly E. coli Geometric Mean

4.0 Source Assessment

4.1 Source Inventory

This section provides an inventory of the sources of bacteria within the Mill Creek watershed. These sources are non-point in nature; there are no known point sources of bacteria within the entire tributary watershed of Mill Creek. The sources of bacteria in the watershed include livestock and associated agricultural practices such as manure spreading and pasturing, runoff from the City of Rockville, septic systems, pets, and natural wildlife.

Although the Minnesota surface water quality standards and numeric targets are in terms of *E. coli* and the available water quality data has been discussed here in terms of *E. coli,* this source assessment uses fecal coliform production and transport rates found in the literature. It is assumed that *E. coli* loading from a range of sources can be estimated from loading data supplied in units of fecal coliform. An empirical relationship between *E. coli* and fecal coliform (200 fecal coliform units per 126 *E. coli* units) abundance observed by the MPCA (MPCA, 2007) can be used to convert the fecal coliform loads to *E. coli* loads. The relative percent of the total fecal coliform loading from a given source is assumed to be equal to the percent of the total *E. coli* loading from that source.

The methodology for this source inventory and assessment is based on that found in the Bacterial TMDL for the Clearwater River (Wenck, 2009). The Clearwater River watershed is immediately adjacent to the Mill Creek watershed to the south and has similar land use and agricultural practices.

4.1.1 Septic Systems and Human Waste

Human waste can be a significant source of bacteria loading to surface waters, especially during dry and low flow periods when human waste sources continue and there is little runoff to convey other sources to surface water bodies. Septic systems (subsurface sewage treatment systems or SSTS) that are not properly designed or maintained can allow untreated or partially treated sewage to flow into surface waters. Emergency bypasses from wastewater treatment facilities can also contribute bacteria loading to streams and rivers during extreme high flow conditions.

There are no permitted surface water discharges from municipal or industrial wastewater treatment facilities in the Mill Creek watershed. The wastewater treatment facility for the City of Rockville discharges to the Sauk River and is outside of the area considered for this study.

Census data (2000) indicate that the Mill Creek watershed has an estimated total population of 2,163 residing in 818 households (see Figure 4-1). When the portion of the watershed that does not contribute surface flow to Mill Creek is excluded, the estimated population is 1,713 in 626 households. Population density is highest near the City of Rockville.

According to data collected by Stearns County Environmental Services, approximately 2% of the septic systems in the county are allowing inadequately treated wastewater into county waterways (Stearns, 2009). These systems are often referred to as “straight pipe” systems, and are typically connected directly into county tile drains or ditches. Straight pipe systems are illegal, un-permitted systems according to *Minnesota Rules* 7080 and constitute an imminent public health threat (IPHT). When these systems are discovered as part of the county’s regular SSTS inspection program, they must be upgraded to acceptable status within 90 days. An additional 17% of the septic systems in the county are estimated to be failing, which means that fecal coliform bacteria is detectable in the soil 50 feet from the system. Failing SSTS must be upgraded within 10 months of discovery.

Based on this population and SSTS data, there are an estimated 13 “straight pipe” systems and 106 failing systems in the contributing watershed of Mill Creek. For this analysis, inadequately treated wastewater will be assumed to represent the bacteria loading from 19% of the population in the contributing watershed or 325 people. This is a conservative estimate since a portion of the households in the watershed do not have SSTS but are connected to the City of Rockville wastewater treatment system and most failing septic systems (as opposed to “straight pipe” systems) do not directly contribute bacteria to surface waters.

4.1.2 Urban Stormwater Runoff and Pets

Untreated urban stormwater can have bacteria concentrations as high as or higher than runoff from pastures and cropland (USEPA, 2001), primarily from pet waste. Although only a small portion (3%) of the Mill Creek watershed is developed (see Figure 2-2 and Figure 2-3), the City of Rockville directs much of its stormwater into Mill Creek. The tributary area for the storm sewer system likely includes areas that are outside of the surface watershed of Mill Creek.

The total number of pets in the contributing watershed of Mill Creek is estimated from the American Veterinary Medical Association values of 0.66 cats and 0.58 dogs per household. For the 626 households in the contributing watershed, there are an estimated 413 cats and 363 dogs. Waste from these animals is conservatively assumed to be conveyed to surface waters with equal likelihood, regardless of the location of the household within the watershed.

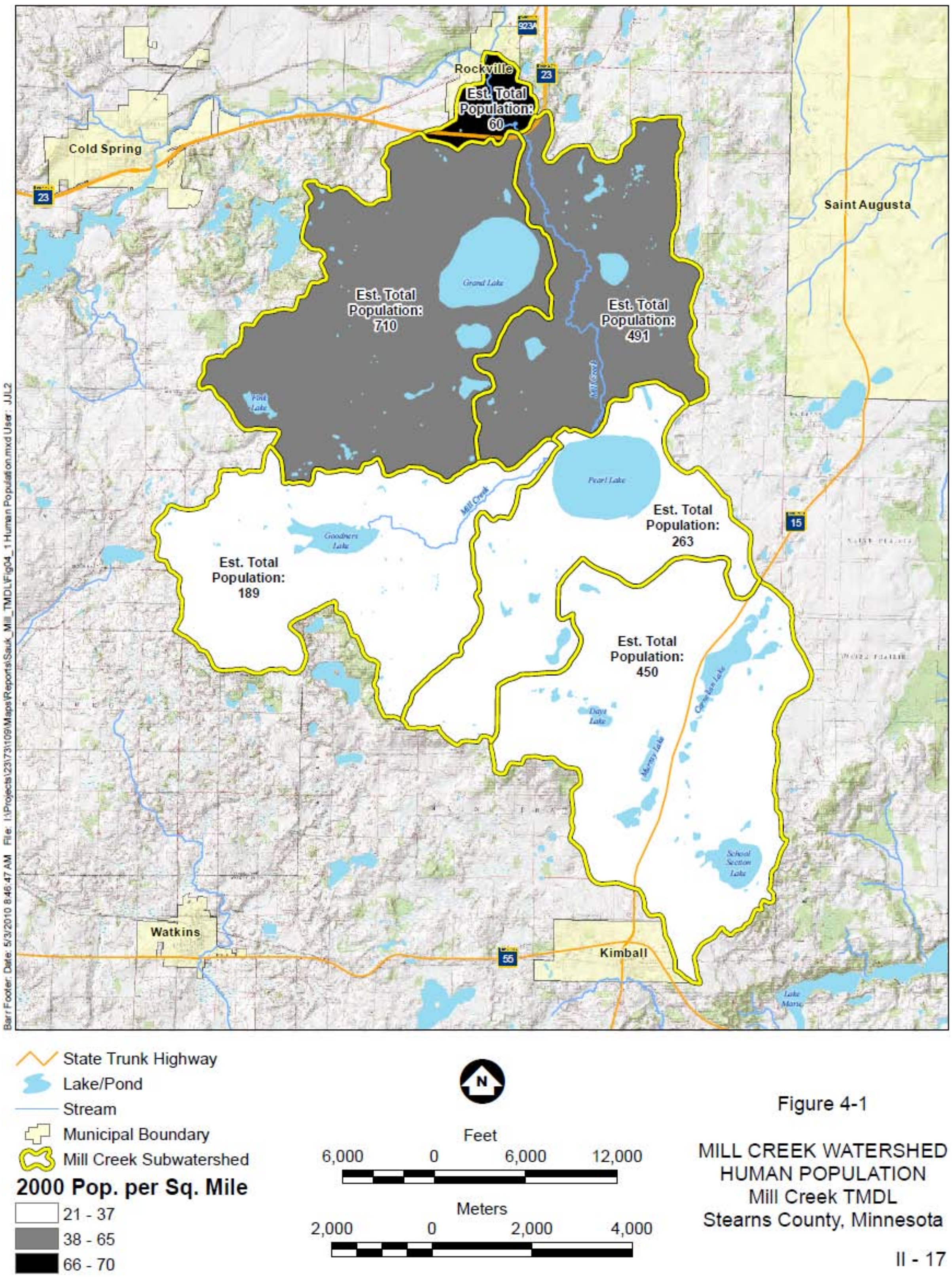

Figure 4-1 Mill Creek Watershed Human Population

4.1.3 Livestock

In agricultural areas livestock are typically the primary source of bacteria loading, and runoff from feedlots, pastures and cropland that has received manure application has the potential to be a significant contributor of bacteria to surface water bodies.

According to GIS data obtained from Stearns County Environmental Services, there are 78 feedlots in the Mill Creek watershed with a total of 9,174 animal units. One animal unit represents one 1,000-lb animal, the typical weight of a beef steer, stock cow or horse. Of this total, 68 feedlots with a total of 8,105 animal units are in the portion of the watershed that contributes surface flow to Mill Creek. See Figure 4-2 for the locations and relative sizes of the permitted feedlots in the Mill Creek watershed. Beef and dairy cattle together account for the majority of the total animal units in the contributing watershed.

Stearns County feedlot permitting records (Von Holdt, 2010b) indicate that the majority of the feedlots in the Mill Creek watershed are in compliance with the conditions of their permits and manage manure adequately to avoid runoff problems. In the current permit cycle there have been 6 feedlots listed as noncompliant for having open lots with inadequate runoff controls. These recently-noncompliant feedlots account for 10.5% of the total animal units in the entire Mill Creek watershed (contributing and non-contributing area). For this analysis the feedlot compliance data has been further broken down to identify the fraction of each by animal type residing on feedlots with inadequate runoff controls.

Pastured livestock can deposit manure in or immediately adjacent to surface water bodies if the pastures are not separated from streams and wetlands by fencing. Livestock management practices in the Mill Creek watershed suggest that livestock have frequent access to Mill Creek and its tributaries in some locations, likely contributing to the bacteria impairment. Analysis of landuse data shown in figure 2-2 indicates that pasture makes up 17% of the land, 42% of which is within 300ft of a stream or 1,000ft of a lake and therefore a potential source of bacterial loading via surface runoff.This analysis assumes that 25% of all dairy cattle and 50% of all beef cattle, horses and sheep are pastured, with 42% of all pastured animals in riparian areas.

4.1.4 Cropland Manure Application

Manure from livestock feedlots is applied to croplands either by surface application or liquid incorporation. Large swine and dairy feedlots typically collect liquid manure in containment structures and use liquid incorporation to apply the manure to cropland, while smaller feedlots typically apply manure to field surfaces where it is worked into the soil with tillage equipment. Stearns County feedlot permitting records (Von Holdt, 2010b) provide estimates of the percentage of livestock manure that is stored as liquid manure and incorporated, based on the permitted liquid manure storage facilities. According to county staff (Von Holdt, 2010b), smaller feedlots in the area either stockpile manure until it can be applied and potentially incorporated or surface apply manure directly following harvest and throughout the winter, with tillage either immediately after application or in the spring just prior to planting. This analysis uses assumed distributions of surface applied and incorporated manure based on these observations.

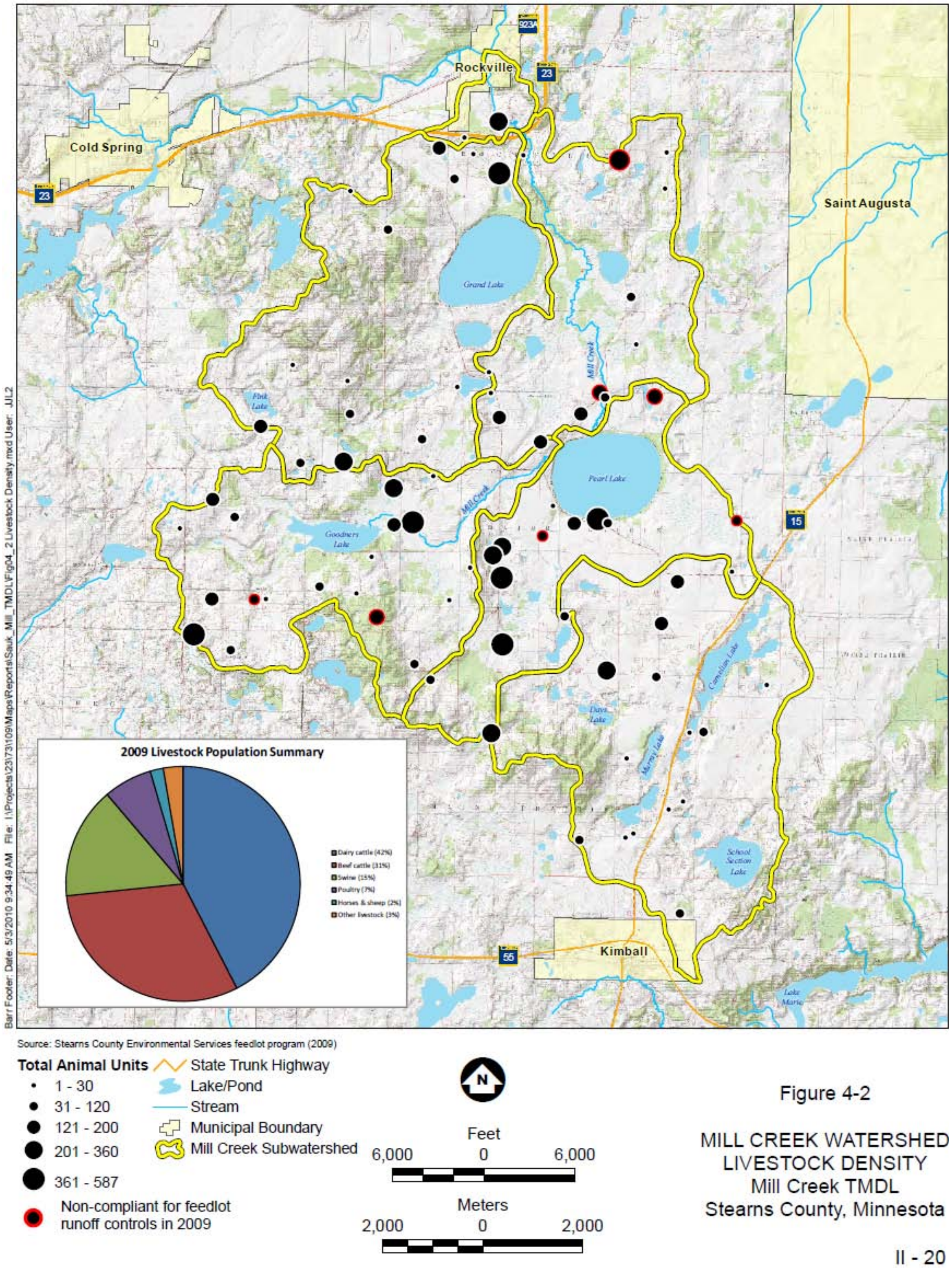

Figure 4-2 Mill Creek Watershed Livestock Density

4.1.5 Wildlife

The Minnesota Department of Natural Resources (DNR) compiles population estimates for various native wildlife species at locations throughout Minnesota. The 2009 Farmland Wildlife Populations estimate (DNR, 2009a) indicated that deer populations in the management unit that includes the Mill Creek watershed were 6 deer per square mile. The 2009 Migratory Bird Populations estimate (DNR, 2009b) indicated that breeding populations of ducks and Canada geese in areas with similar wetland density as the Mill Creek watershed were 7.1 ducks and 2.8 geese per square mile. This breeding population estimate is representative of resident waterfowl populations in spring and early summer, before juveniles reach maturity.

Mill Creek is closely connected with several wetland complexes and forested areas, as shown in the land use map for the watershed (Figure 2-2). Wildlife are expected to be most concentrated in these areas, and therefore their contributions to the overall bacteria loading in the watershed will likely be transported relatively quickly into the surface water. However, because of the relatively low numbers of deer and waterfowl compared to the livestock in the watershed, the proportional bacteria loading from wildlife is low.

4.2 Bacteria Source Loading

The TMDL for Mill Creek was developed using the load duration approach, as described in Section 5. In order to develop the linkage between watershed sources of bacteria and water quality targets, this study will follow an approach that was initially developed for the southeast Minnesota regional fecal coliform TMDL (MPCA, 2002). This approach was also used to develop the Clearwater River TMDL (Wenck, 2009). In this approach it is necessary to; (1) estimate the amount of bacteria potentially available for runoff from each source, and (2) assess the potential for the bacteria to reach surface waters under wet and dry conditions. This analysis results in the partitioning of the stream load by source based on the total load estimated to reach surface waters under the given conditions.

4.2.1 Bacteria Available for Runoff

The data and assumptions discussed in Section 4.1 resulted in total populations corresponding to potential sources and estimates of total bacteria production. Because the available literature values for bacteria production for various sources are in terms of fecal coliform rather than *E. coli*, total fecal coliform loading will be used throughout these calculations. The resulting proportional loads, however, are assumed to be equally applicable to *E. coli* loading.

The total source-population inventory for the contributing watershed is shown in Table 4-1, along with the estimated quantity of fecal coliform bacteria produced monthly. The results are summarized in Figure 4-3. Livestock sources account for 98.9% of the bacteria produced in the watershed.

Once produced, fecal coliform bacteria is made available or applied on the land surface by several different methods, especially for livestock sources. Table 4-2 shows the fraction of bacteria generated by different sources and application types that are available to runoff into

Mill Creek and its tributaries (for method used to calculate actual delivery, see Section 4.2.2). The methodology used here was recently applied in the Bacterial TMDL for the Clearwater River (Wenck, 2009), a neighboring watershed in central Minnesota. The assumed availability and distribution between various application methods represent the characteristics of the Mill Creek watershed, as discussed in Section 4.1. The total fecal coliform produced in the watershed is divided by application method according to the assumptions in Table 4-2; the results are summarized in Figure 4-4.

Note that this analysis makes the simplifying assumption that all bacteria produced in the watershed remains in the watershed. For some sources (e.g., dairy cattle) all bacteria produced is assumed to be available for runoff, whether via pastures or via manure applied to cropland. For some sources (e.g., humans), a portion of the bacteria produced is assumed to not be available for runoff under any circumstances, such as in adequately treated rural wastewater.

Table 4-1Estimated Population and Monthly Fecal Coliform Production by Source

Category	Source	Animal Units or Population	Fecal Coliform Organisms per Unit per Month (10^9 organisms)**	Total Fecal Coliform Organisms Available per Month (10^9 organisms)
Human	Total population	1713	61.0	104,000
Urban Runoff	Cats	413	153	63,000
	Dogs	363	153	55,400
Livestock	Dairy cattle	3438 AU	2200	7,550,000
	Beef cattle	2510 AU	3970	9,950,000
	Swine	1248 AU	2440	3,040,000
	Poultry	543 AU	1040	563,000
	Horses & sheep	147 AU	12.8	1,880
	Other livestock	220 AU	1040	228,000
Wildlife	Deer	217	15.3	3,310
	Canada geese	102	0.317	32.4
	Ducks	257	0.159	40.8
	Other wildlife	Unknown	Unknown	3,310*

* Unknown, estimated as equivalent to deer fecal coliform loading.
** Derived from literature values in Mulla et. al. (2001), USEPA (2001), and Alderisio and DeLuca (1999).

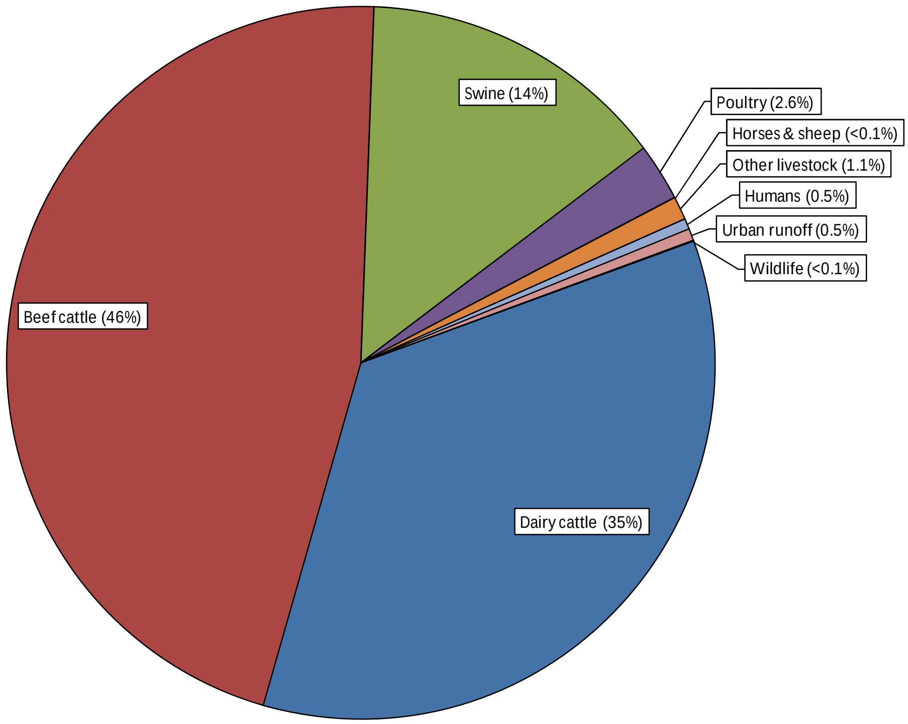

Figure 4-3 Fecal Coliform Production by Source

Table 4-2 Assumed Fecal Coliform Availability by Application Method

Category	Application Method	Assumed Availability*	Notes
Human	Adequately treated rural wastewater	81% of humans	Not available for runoff
	Inadequately treated rural wastewater	19% of humans	
Urban Runoff	Properly managed pet waste	90% of pets	Not available for runoff
	Improperly managed pet waste	10% of pets	
Livestock	Riparian pastures (42%)	10.5% of dairy cattle 21% of beef cattle 21% of horses/sheep	Total 25% dairy cattle pastured Total 50% beef cattle pastured Total 50% horses/sheep pastured
	Non-riparian pastures (58%)	14.5% of dairy cattle 29% of beef cattle 29% of horses/sheep	Total 25% dairy cattle pastured Total 50% beef cattle pastured Total 50% horses/sheep pastured
	Feedlots without adequate runoff controls	15% of dairy cattle 9.5% of beef cattle 1.5% of swine 40.5% of horses/sheep	Based on Stearns County feedlot records for noncompliant operations in 2009
	Surface applied manure	14.5% of dairy cattle 26% of beef cattle 28% of swine 10% of poultry 2.5% of horses/sheep 50% of other livestock	Remainder of available manure
	Incorporated manure	45.5% of dairy cattle 14.5% of beef cattle 70.5% of swine 90% of poultry 7% of horses/sheep 50% of other livestock	Based on Stearns County Environmental Services feedlot records for liquid manure storage, poultry and other livestock values adjusted based on known watershed conditions (Von Holdt, 2010b)
Wildlife	Wildlife waste	100% of deer 100% of Canada geese 100% of ducks 100% of other wildlife	All bacteria available for runoff

* Based on SSTS and feedlot records from Stearns County Environmental Services (SSTS, 2009; Von Holdt, 2010b).

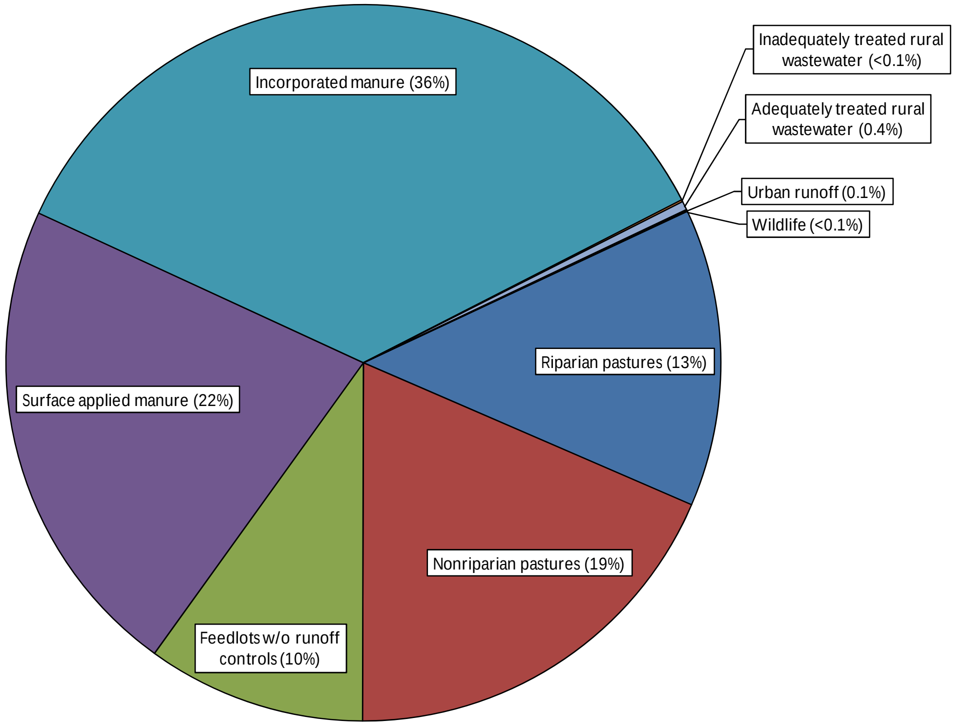

Figure 4-4 Fecal Coliform Availability by Application Method

4.2.2 Bacteria Delivery Potential

Once the estimated total bacteria produced in the contributing portion of the Mill Creek watershed is calculated and assigned to various application methods, final assumptions must be made on the potential for each application method to deliver bacteria to surface waters. This analysis is adapted from that used in the TMDL for the Clearwater River (Wenck, 2009). The Clearwater River analysis ranked each application method according to its risk of bacteria delivery and assigned a corresponding delivery percentage (see Table 4-3). The delivery percentage represents the fraction of the total available bacteria that is assumed to be transported to Mill Creek and its tributaries for a given condition (wet or dry).

This analysis procedure reflects the conditions in the primarily agricultural watersheds in and surrounding Mill Creek. The assumed dry weather application methods are inadequately treated wastewater, livestock in riparian pastures, feedlots without runoff controls and wildlife (especially geese and ducks). All application methods are assumed to contribute bacteria to the stream in wet weather, especially livestock in riparian pastures and feedlots without runoff controls.

Table 4-3Assumed Fecal Coliform Delivery Potential by Application Method

Application Method	Assumed Delivery Potential*	
	Wet Conditions	Dry Conditions
Inadequately treated wastewater	Moderate (4%)	Moderate (4%)
Improperly managed pet waste	Moderate (4%)	None
Riparian pastures (42%)	Very high (8%)	High (6%)
Non-riparian pastures (58%)	Low (2%)	Very low (1%)
Feedlots without runoff controls	High (6%)	Moderate (4%)
Surface applied manure	Low (2%)	Very low (1%)
Incorporated manure	Very low (1%)	None
Wildlife waste	Moderate (4%) for waterfowl Very low (1%) for all other	Moderate (4%) for waterfowl Very low (1%) for all other

* Adapted from values used in Wenck (2009).

4.2.3 Estimated Source Load Proportions

Total bacteria loading in the contributing Mill Creek watershed was estimated by multiplying the total number of fecal coliform organisms available per month for each source by its corresponding availability and delivery potential. A comparison of sources contributing to wet weather and dry weather loading is shown in Figure 4-5 and Figure 4-6, respectively.

Bacteria loading to Mill Creek is dominated by loading from riparian pastures during both wet and dry weather conditions, but especially during dry weather conditions when bacteria are not transported by surface runoff from most other sources but can be deposited directly in surface water by livestock in riparian pastures. Feedlots without runoff controls are also a significant source of bacteria loading to Mill Creek during all weather conditions. For all conditions the loading from inadequately treated wastewater, urban runoff, and the resident wildlife population are negligible.

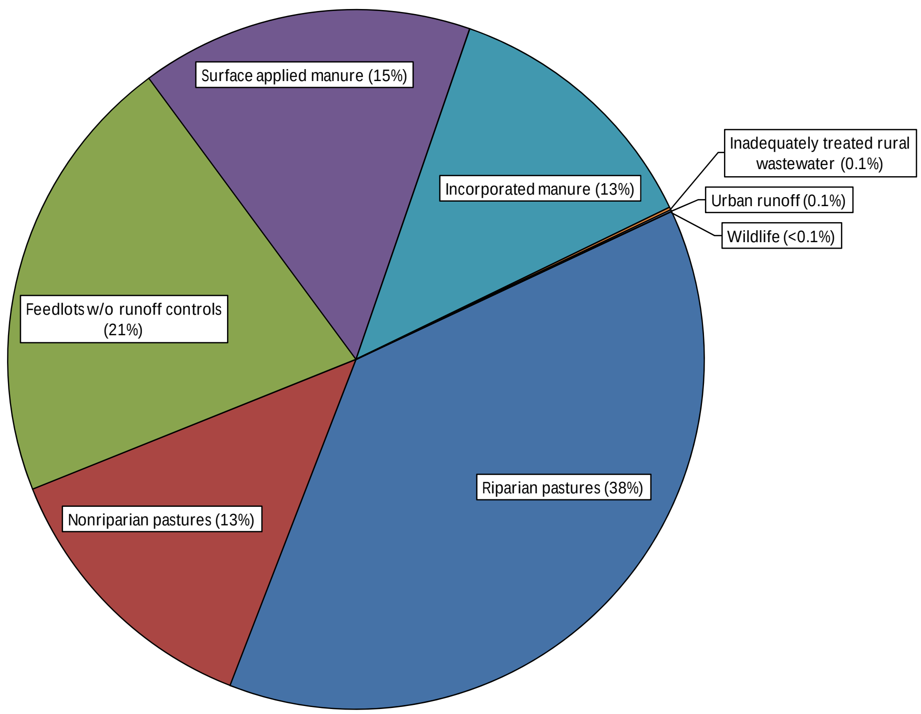

Figure 4-5 Bacteria Loading by Source for Wet Weather Conditions

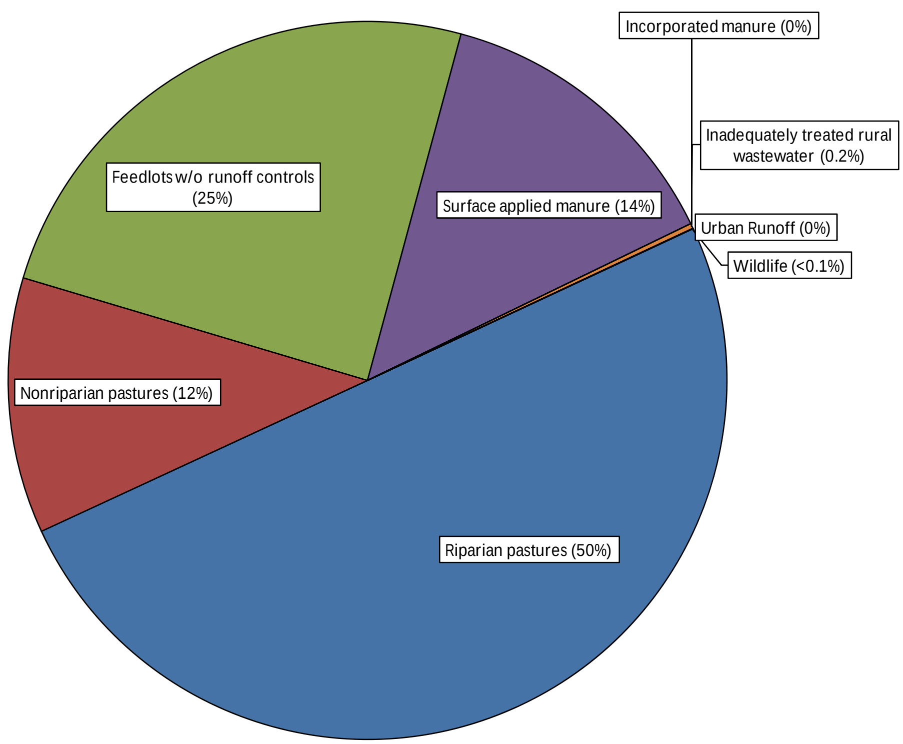

Figure 4-6 Bacteria Loading by Source for Dry Weather Conditions

5.0 Bacterial TMDL

5.1 Flow-Duration Curve

As discussed in Section 2, flow measurements for Mill Creek were not available for an extended period of record. To overcome this data limitation, the Lower Sauk Diagnostic Study (Barr, 2006) developed a regression relationship between flow in the Sauk River (at USGS station 05270500 near St. Cloud) and flow in Mill Creek (at location S000-444 in Rockville). This relationship was used to estimate flow in Mill Creek for the period of record available for the Sauk River (1909 to 2009). These flow estimates were used to develop a flow-duration curve for Mill Creek.

Because the applicable water quality standard for bacteria is applied monthly between April and October, an April through October monthly flow duration curve was used in the development of this TMDL. This curve was developed by calculating the average monthly flow in Mill Creek for the months of April through October (based on the Sauk River USGS data) and ranking the resulting values from highest to lowest. This curve depicts the percentage of time that the average flow in any given month between April and October exceeds a particular value. For example, 40% of the months in the April-October data set had average flows higher than 18 cfs. The resulting flow-duration curve for Mill Creek is shown in Figure 5-1.

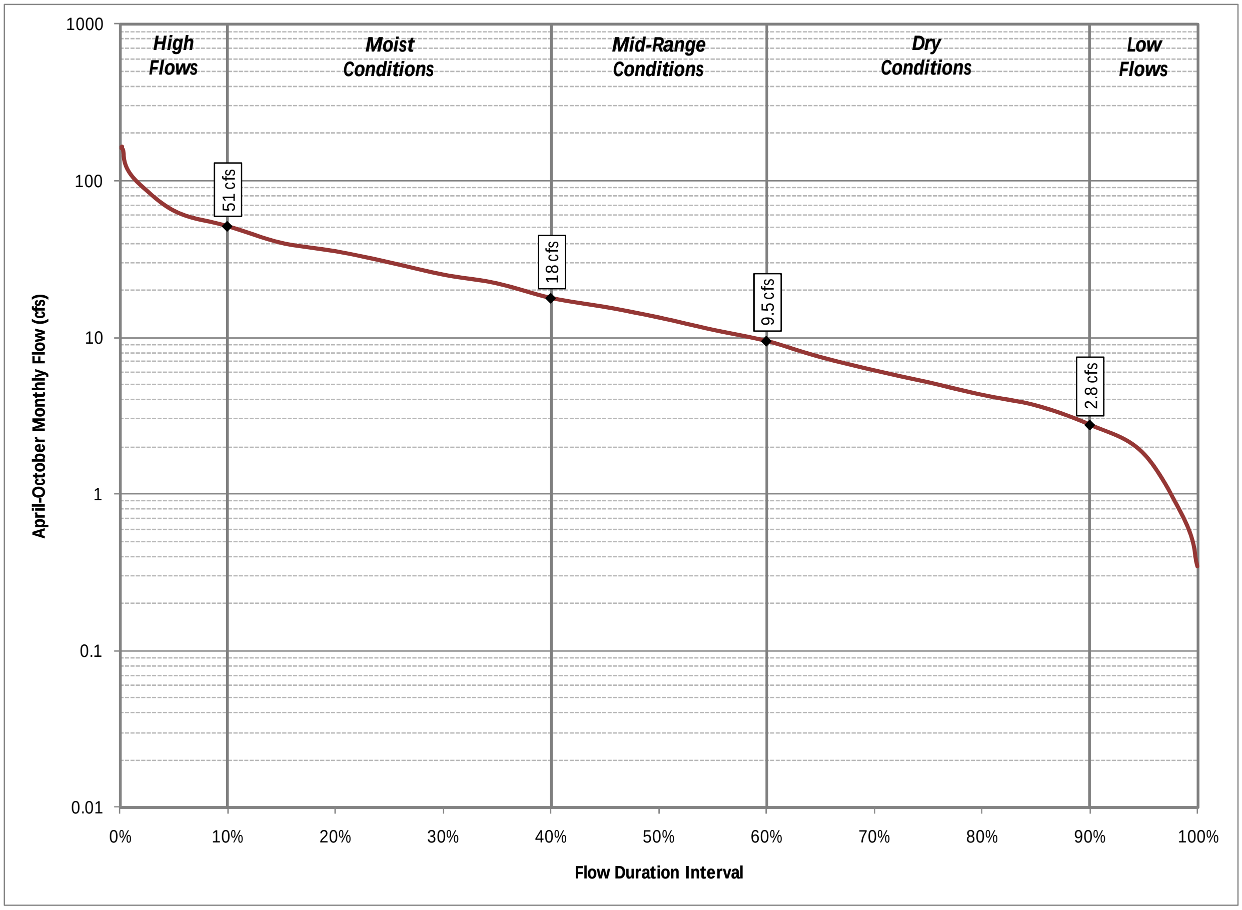

Figure 5-1 Estimated April-October Monthly Flow Duration Curve for Mill Creek

5.2 Observed Load-Duration Data

Similar to the flow-duration curve, the load-duration curve relates bacteria loading at a given flow to how often that flow value is exceeded in the stream. The load-duration curve is developed by calculating the total bacteria loading (in terms of organisms per month) associated with a given observation by multiplying the observed bacteria abundance by the flow. An example calculation is shown below. Observed flow (in units of cubic feet per second) is multiplied by the observed *E. coli* abundance (in units of organisms per 100 mL). The additional factors are needed to convert units for water volume (from 100 mL to cubic feet) and time (from seconds to days). The resulting loading is expressed in terms of organisms per day.

Observed flow and bacteria abundance:

9.5 (cfs) and 199 (*E. coli* organisms per 100 mL), data for August 5, 2003 converted to units of *E. coli* from measurement of fecal coliform

E. coli load for interval:

9.5 (cfs) 199 (org/100mL) · 283.17 (100mL/ft^3) 86,400 (sec/day) = **46.2 x 10^{10} (org/day)**

The resulting bacteria load is then plotted relative to the percentage of time that the monthly average flow exceeds the observed flow. In the example shown above, the observed flow of 9.5 cfs is exceeded 60% of the time in Mill Creek. The entire set of load-duration data for Mill Creek is shown in Figure 5-2. Load-duration curves are also shown for the chronic and acute *E. coli* water quality standards, as discussed in Section 5.3.

From Figure 5-2 it is clear that *E. coli* loading in Mill Creek is typically above the loading permitted by the chronic water quality standard of 126 organisms per 100 mL. For all flow duration intervals (i.e. High Flow, Wet, etc.), the geometric mean of the observed *E. coli* loading is above the loading permitted by the water quality standard.

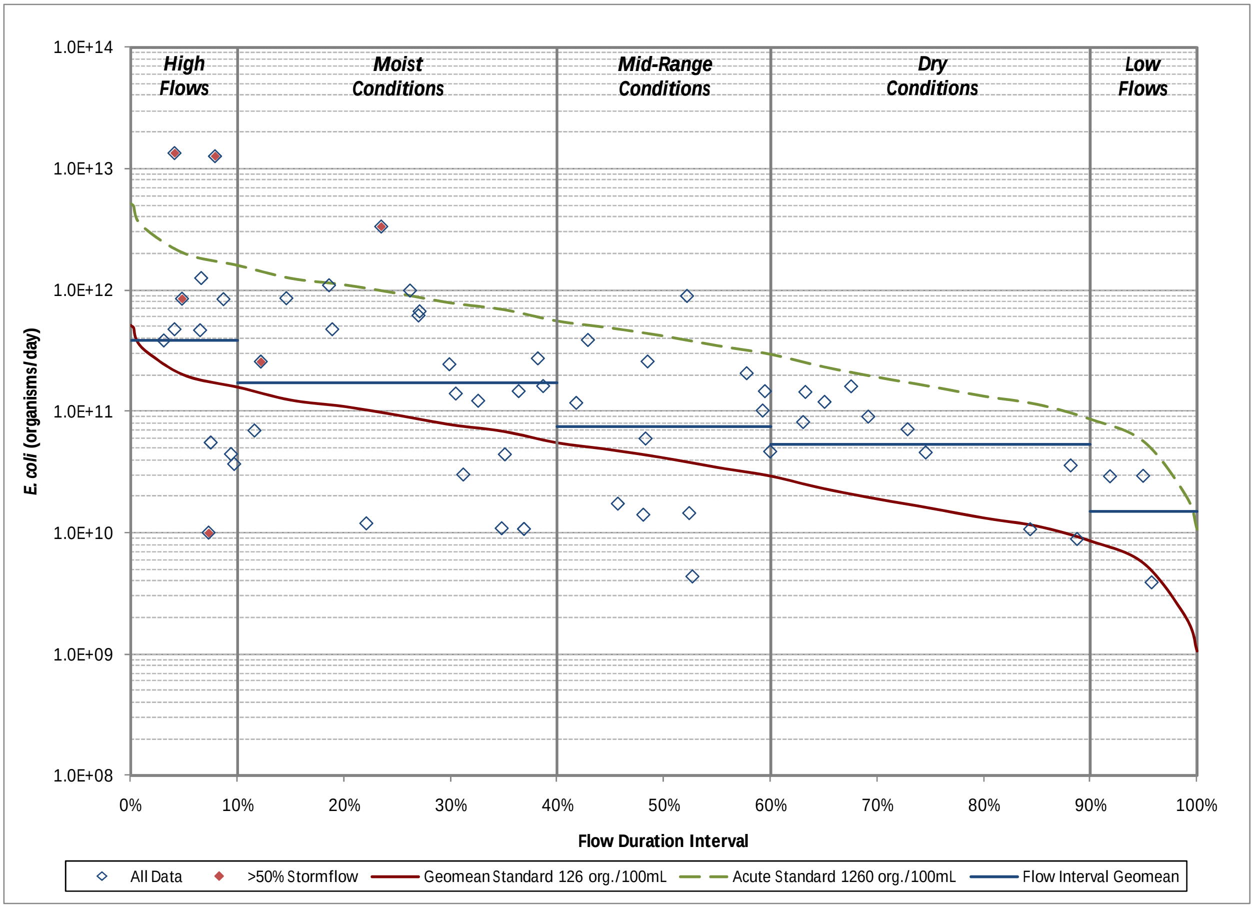

Figure 5-2 Mill Creek E. coli Load Duration Data

5.3 Loading Capacity

As shown in the Source Assessment in Section 4.0, bacterial loading to Mill Creek is entirely from nonpoint sources. The allowable bacteria load is highly dependent upon daily flow conditions, and therefore is highly dynamic. The focus of this analysis is on the "chronic" *E. coli* standard of 126 organisms per 100 mL (applied to the monthly geometric mean) rather than the "acute" standard of 1,260 organisms per 100 mL, although allowable loading for both standards is shown on the accompanying figures. It is assumed that achieving the necessary reductions to meet the chronic standard will also reduce exceedances of the acute standard to within acceptable limits.

Figure 5-3 shows the TMDL in terms of TMLC for both the chronic and acute water quality standards. The load duration curves were developed by multiplying the flow duration intervals from Figure 5-1 by the applicable bacteria abundance from the water quality standard, using the calculation method described above for the observed data.

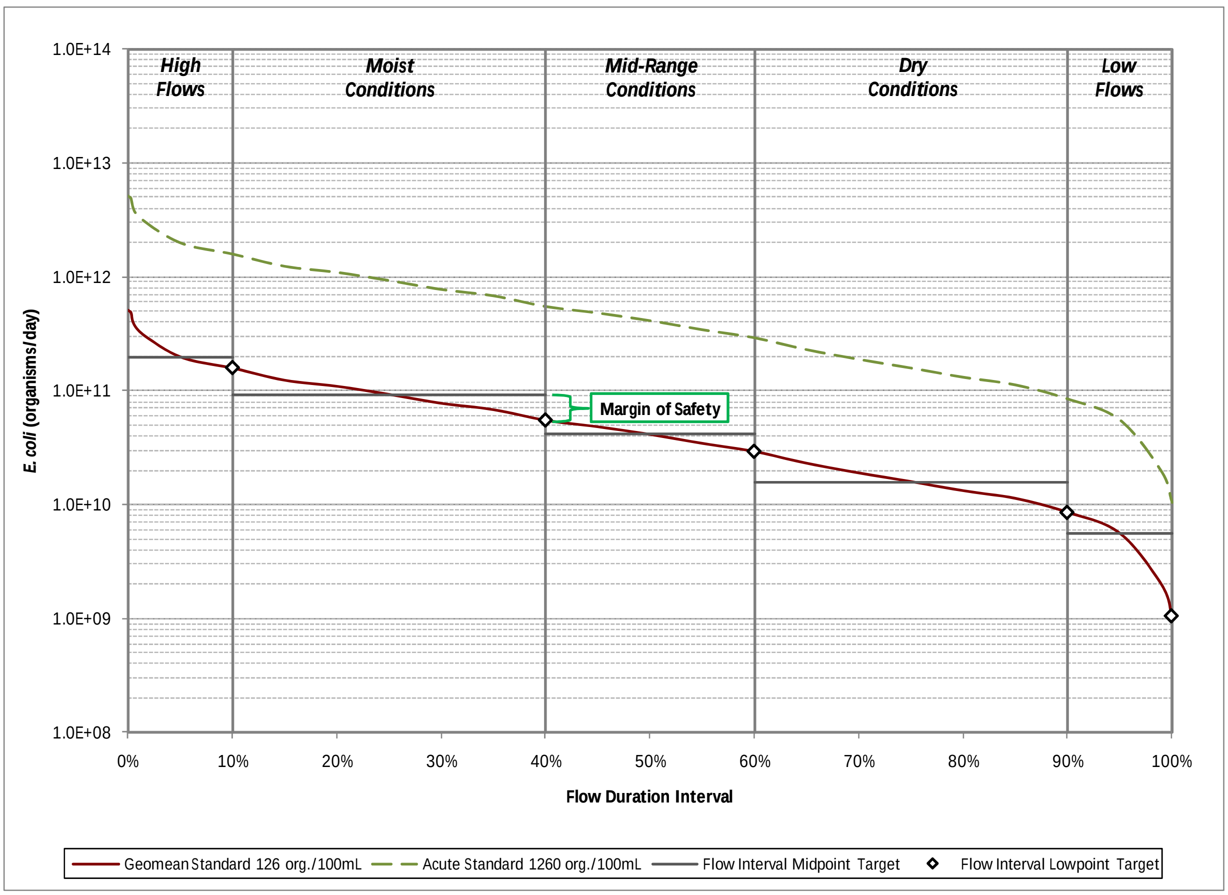

Figure 5-3 TMDL for Mill Creek - Total Monthly Loading Capacity

To develop the TMDL equation, the midpoint monthly flow for each of the five flow intervals (i.e. High Flow, Wet, etc., see Figure 5.3) was multiplied by the standard of 126 organisms per 100 mL. The load allocation (LA), which includes all nonpoint pollution sources that are not subject to NPDES permit requirements, was established by taking the minimum monthly flow for each of the five flow intervals and multiplying it by the water quality standard. Since there are no permitted discharges in the Mill Creek watershed, there is no wasteload allocation (WLA). The difference between the allowable bacteria load at the midpoint of each flow interval (i.e. 5% exceedance, 25% exceedance, 50% exceedance, etc.) and at the minimum flow for each flow interval (i.e. 10% exceedance, 40% exceedance, 60% exceedance, etc) is established as the margin of safety (MOS). These values are shown in Table 5-1, expressed as monthly loading of *E. coli*.

Table 5-1TMDL for E. coli in Mill Creek (daily loading capacity)

Reach	Flow Interval	Wasteload Allocation* (10^9 org. *E. coli* / day)	Load Allocation (10^9 org. *E. coli* / day)	Margin of Safety (10^9 org. *E. coli* / day)	TMDL (10^9 org. *E. coli* / day)
Mill Creek	High Flow	0	158	40	198
	Wet	0	54.8	37.8	92.6
	Mid-Range	0	29.2	12.0	41.2
	Dry	0	8.51	7.39	15.9
	Low Flow	0	1.06	4.51	5.57

* There are no permitted point discharges from industries, municipalities or waste water treatment plants or individually permitted sources within the Mill Creek watershed. Therefore the wasteload allocation is zero.

Example calculations for the high flow interval are shown below. Flow (in units of cubic feet per second) is multiplied by the *E. coli* standard abundance (in units of organisms per 100 mL). The additional factors are needed to convert units for volume (from 100 mL to cubic feet) and time (from seconds to days). The resulting loading is expressed in terms of organisms per day.

Flow at interval midpoint: 64.3 (cfs) (from flow-duration curve at 5% exceedance)
TMDL for interval:
64.3 (cfs) · 126 (org/100mL) · 283.17 (100mL/ft^3) · 86,400 (sec/day) = **198 x 10^9 (org/day)**
Flow at interval minimum:
51.2 (cfs) (from flow duration curve at 10% exceedance)
Load allocation for interval:
51.2 (cfs) · 126 (org/100mL) · 283.17 (100mL/ft^3) · 86,400 (sec/day) = **158 x 10^9 (org/day)**
MOS for interval:
198 x 10^9 (org/day) - 158 x 10^9 (org/day) = **40 x 10^9 (org/day)**

5.4 Reductions Necessary to Meet Allocations

Figure 5-3 shows the load-duration curve developed from observations of bacteria abundance (expressed in terms of *E. coli*) for Mill Creek at Rockville (station ID S000-444). By comparing measured bacteria data with the load allocations from the TMDL for Mill Creek (Table 5-1), the percent reduction in *E. coli* loading necessary to comply with the provisions of the TMDL can be determined. This information is presented in Table 5-2.

Table 5-2Required Load Reductions for E. coli in Mill Creek (daily loading)

Reach	Flow Interval	Observed Geometric Mean (10^9 org. *E. coli* / day)	Load Allocation (10^9 org. *E. coli* / day)	Reduction Required (10^9 org. *E. coli* / day)	Reduction Required (%)
Mill Creek	High Flow	384	158	226	59%
	Wet	171	54.8	116	68%
	Mid-Range	73.8	29.2	44.7	61%
	Dry	53.1	8.51	44.6	84%
	Low Flow	14.8	1.06	13.8	93%

The calculated reductions in *E. coli* loading that are required for Mill Creek to achieve compliance with the water quality standards can be compared to the estimated proportional source loading determined in Section 4. This information will be used to guide the implementation plan to be developed to complement this TMDL study.

Because the bacterial loading to Mill Creek is primarily in the form of nonpoint sources, the load allocation can be divided among the sources discussed in Section 4. No load allocation will be assigned to inadequately treated wastewater or to feedlots without runoff controls because both of these sources are illegal and are regulated by existing permit programs. The remainder of the estimated existing load is used to determine load allocations by source (Table 5-3). Wet condition proportions are applied to the High Flow and Wet intervals, dry condition proportions are applied to Dry and Low Flow intervals and the average of wet and dry condition proportions are applied to the Mid-Range interval.

Table 5-3Observed and Required Load Allocations by Source (daily loading)

Source	Estimated Existing "Wet" Loading	Estimated Existing "Dry" Loading	Load Allocation (10^9 organisms *E. coli* per day)				
			High Flow	Wet	Mid-Range	Dry	Low Flow
Riparian pastures	48%	67%	76	26	17	5.7	0.71
Non-riparian pastures	17%	15%	26	9.1	4.7	1.3	0.16
Feedlots w/o runoff controls	--*	--*	0	0	0	0	0
Applied Manure	20%	18%	31	11	5.5	1.5	0.19
Incorporated Manure	16%	0%	25	8.7	2.3	0	0
Septic systems (SSTS)	--*	--*	0	0	0	0	0
Urban runoff	0.1%	0%	0.16	0.054	0.014	0	0
Wildlife	0.01%	0.03%	0.023	0.008	0.006	0.002	0.0003
Total	100%	100%	158	54.8	29.2	8.51	1.06

* The estimated existing loading from feedlots without runoff controls and inadequately treated rural wastewater (SSTS) was excluded from this analysis because these sources are illegal and are regulated by existing permit programs. Zero load allocation was assigned to each of these sources.

5.5 Margin of Safety

A reasonable margin of safety is necessary in order to account for natural variability and uncertainty in the effect that the calculated load allocations will have on observed water quality. The MOS can be defined either explicitly, through quantification of variability, or implicitly, through the use of conservative assumptions. In this TMDL, an explicit MOS has been defined as the difference between the midpoint and minimum allowable loading in each of the defined flow regimes (see Figure 5-3). This accounts for the variation in flow for each regime.

5.6 Seasonal Variation

Seasonal variation is accounted for by the use of a load duration curve to set TMDLs over seasonal flow regimes. The in-stream data used for the source assessment and the calculation of required load reductions represents observations across the range of seasonal and annual flow variation and loading conditions. Because the *E. coli* water quality standard only applies from April 1 through October 31, flow and loading data for the winter months were excluded from this analysis.

5.7 Annual Variability

Annual variability is accounted for in this TMDL by the use of the 100-year flow record for the USGS gauge on the Sauk River (#05270500) to develop the flow duration curve for Mill Creek. This lengthy dataset spans the full range of high and low flows in the creek and wet and dry precipitation conditions. The resulting load allocation and TMDL values are therefore representative of typical conditions in Mill Creek.

Field observations of bacteria abundance were collected between 2003 and 2008 at Mill Creek in Rockville (ID S000-444). Data were collected during wet, average, and dry months and during high and low flows. Table 5-4 shows the observed departure from normal precipitation for the months included in this study, and demonstrates that the bacteria data was collected during a range of conditions. The required load reductions calculated above area therefore are representative of typical conditions in the watershed.

Annual variability will be further addressed in the implementation plan that is complementary to this TMDL, since load reduction strategies such as riparian pasture management will function regardless of annual flow variability.

Table 5-4Departure from Normal Precipitation (inches), 2003-2008

Year	April	May	June	July	Aug.	Sept.	Oct.
1971-2000 Average	2.1	3.5	4.7	3.6	3.8	3.2	2.5
2003	+1.7	-0.1	+1.1	+1.7	-3.7	+0.4	-1.1
2004	-1.1	+3.9	-0.3	N/A	-2.3	+3.3	+0.7
2005	+0.6	+0.2	+2.4	-2.0	-0.9	+3.1	+2.8
2006	+2.4	-2.0	-1.2	-2.5	+1.8	+1.1	-1.8
2007	+0.6	-1.7	-2.6	-2.5	+2.3	0.0	+2.7
2008	+1.9	+0.3	+1.2	-1.9	-0.4	-0.3	+0.9
	weekly or biweekly data				monthly data		

Data source: NWS station #211691, Collegeville MN (St. John's University)

5.8 Future Growth

The population and land use practices within the Mill Creek watershed are not anticipated to change significantly in the future. The City of Rockville is the only urban area within the watershed, and its wastewater treatment facility does not discharge to Mill Creek. An increase in population in Rockville will therefore have no effect on the bacteria loading from human sources to Mill Creek. Increases in the urban stormwater system as a result of population growth have the potential to increase bacteria loading from pet waste, but this source was shown in Section 4 to be a negligible contributor to the overall bacteria loading in Mill Creek.

Population growth in the rural areas of the watershed will result in the installation of new SSTS, which will effectively treat human waste and will not contribute bacteria load to Mill Creek. Since bacteria loading from SSTS is illegal under current law, changes in the human population will not alter the load allocations provided in this TMDL.

Livestock is estimated to be the major source of bacteria loading to Mill Creek, both through riparian pasture and through surface applied manure. Livestock facilities are permitted with respect to feedlot runoff controls and manure storage systems, and changes in feedlot facilities or animal numbers will be associated with permits designed to minimize export of bacteria to surface waters. Any potential increases in bacteria loading to Mill Creek or its tributaries from changes in livestock and manure management practices should be mitigated, but no significant changes are expected. A provision for an increase in livestock waste generation in the Mill Creek watershed is not needed at this time.

The MPCA will monitor population growth, urban expansion, and changes in agriculture and will reopen this TMDL if adjustments to load allocations are required.

6.0 Monitoring Plan

The SRWD measures lake and stream water quality, stream flow, and weather conditions at multiple locations throughout the greater Sauk River watershed. For the purposes of this TMDL, the most important data is that from the monitoring station on Mill Creek in Rockville (ID S000-444). The continued collection of monthly or weekly *E. coli* data will be essential to track water quality trends, assess progress towards implementation goals and make adaptive management decisions.

In addition to its regular monitoring program, the SRWD implements special monitoring projects to track the outcome of specific actions or to investigate water quality concerns. An example of this type of project is the Lower Sauk River Diagnostic Study (Barr, 2006) discussed previously. Supplemental monitoring of this nature will occur throughout the course of TMDL implementation. The following recommendations are made to supplement the regular monitoring program:

- Continue monthly or bi-weekly water quality monitoring on Mill Creek and coordinate sampling at monitoring locations S003-880 (Unnamed tributary from Grand Lake at 230th St.) and S003-882 (Mill Creek at 230th St.) to separate out *E. coli* loading from the unnamed tributary and the main stem of Mill Creek.

- Perform instantaneous flow measurements when water quality samples are collected to aid in the determination of total *E. coli* loading.

7.0 Implementation Activities

Following the approval of the Mill Creek TMDL study a more detailed implementation plan will be developed. This section provides general implementation strategies designed to reduce *E. coli* loading to surface waters within the watershed.

The findings of this study indicate that the primary *E. coli* sources to Mill Creek are riparian pastures, surface applied manure, and runoff from feedlots without runoff controls. Bacteria load reductions from these sources will be the most effective towards meeting water quality goals. A less significant source of bacteria loading is failing SSTS, which must be repaired under Minnesota's permitting system. Given the severe bacteria load reductions that are required in the Mill Creek watershed, all stakeholders in the drainage area must be empowered to participate in a variety of load reduction strategies.

7.1 Riparian Pasture Management

The most significant measure that can be taken to reduce *E. coli* loading in Mill Creek is to improve riparian pasture management, with a special emphasis on excluding livestock from streams and stream banks. Livestock with access to streams and stream banks contaminate surface waters through direct deposition of fecal matter and through erosion of bank soil material. Excluding livestock from these areas by installing adequate fencing is an essential tool for reducing *E. coli* concentrations in Mill Creek. Typical pasture management projects that include fencing and alternative water sources for livestock cost between $1,000 and $6,500 each.

Rotational grazing can also be used to reduce grazing pressure on pastures and to minimize the subsequent erosion of soil and fecal material into surface waters. Pastures are subdivided into paddocks and livestock are moved between paddocks frequently. Consequently, forage plants do not become overgrazed and they continue to slow overland flow of water and to hold soil (and fecal matter) in place and minimize erosion.

7.2 Manure Management

Manure management plans are required as part of feedlot operation permits. Effective manure management requires that the manure be applied to fields in such a way as to maximize the nutrients delivered to crops without providing excessive nutrients or manure that is likely to wash off croplands. Because surface applied manure (along with the similar non-riparian pastures) is estimated to be a major contributor of *E. coli* loading to Mill Creek, better manure management practices are necessary in order to reduce in-stream *E. coli* concentrations. Improvements in manure management could include installation of runoff controls such as filter strips or adequate buffer zones separating manure stockpiles from surface waters or drainage systems, installation of liquid manure storage facilities, and increased use of manure incorporation. The costs of installing filter and buffer strips can range widely, from as little as $1,500 to as much as $25,000 depending on the width of the strip and the amount of grading necessary. Injecting manure spreaders (for manure incorporation) cost approximately $50,000 each.

In addition, vegetative practices such as wetland restorations, riparian buffers, filter strips and grassed waterways can help to reduce the amount of pollution that is transported from croplands to surface waters through erosion and overland flow. Cost share programs are available at the state and federal levels to assist landowners with installation of these practices, and the use of such programs should be encouraged.

7.3 Feedlot Runoff Reduction

Feedlots without adequate runoff controls account for an estimated 14% to 15% of the total bacteria loading to Mill Creek. Based on conversations with the Stearns County Environmental Services, ongoing feedlot permit administration typically leads to the identification and resolution of permit compliance issues on area feedlots within a period of weeks to months. Continued vigilance and administration of this program will be essential to further reducing the *E. coli* load from these sources.

Cost share programs are available through the Environmental Quality Incentive Program (EQIP) and through funds from the Board of Water and Soil Resources (BWSR). This funding is typically used to install both high cost solutions such as liquid manure storage facilities (average cost of approximately $60,000) and low cost solutions such as gutters and filter strips. Feedlot operators within the Mill Creek watershed should be encouraged and assisted in applying for cost share funding to make needed upgrades to their operations.

7.4 SSTS Repair

As discussed in Section 4, an estimated 19% of the residential septic systems in the Mill Creek watershed are estimated to be either “straight pipe” or failing systems. Although the portion of the total bacteria loading to Mill Creek attributed to this source is small (less than 0.5% of the total loading), the potential for impacts to human health is high. Repair of out of compliance SSTS is enforced through the Stearns County Environmental Services division, and funding for construction projects is available through the Minnesota revolving loan program. Replacement of a typical SSTS costs approximately $8,000.

7.5 Total Estimated Costs

A planning-level cost estimate for the recommended implantation activities is required as part of the TMDL submittal. This cost estimate will be refined in conjunction with the development of the detailed implementation plan following approval of this TMDL.

The most significant source of bacteria loading to Mill Creek is livestock manure, which reaches the stream from riparian pastures and runoff from croplands, feedlots, and storage areas. The total estimated cost to bring feedlots without adequate runoff controls into compliance and to reduce bacteria transport from the remainder of the feedlots and pastures in the watershed is $700,000 (Nelson, 2010).

Additional bacteria load reduction and protection of human health will be accomplished by bringing all septic systems in the watershed into compliance with Minnesota regulations. The total estimated cost for SSTS replacement and repair is $950,000.

8.0 Reasonable Assurance

The following should be considered as reasonable assurance that implementation will occur and result in nutrient load reductions in Pearl Lake toward meeting their designated uses.

- The Sauk River Watershed District is the water management authority for the Mill Creek watershed and is qualified to implement corrective actions and achieve TMDL goals.
  Watershed wide the SRWD pursues grants to help offset the cost to install BMPs. The district works cooperatively with the local Soil Water Conservation Districts and the National Resource Conservation Service to help landowners receive up to 75% cost share for their projects. The SRWD's cost share funds are also available to local municipalities for stormwater mitigation and other BMPs.
  The BMPs and other strategies outlined in Section 5.0 have all been demonstrated to be effective in reducing transport of pollutants to surface waters.

Monitoring will be conducted to track progress and guide adjustments in the implementation approach.

The Construction and Industrial Activities NPDES Permits requires permittees to provide reasonable assurances that if an EPA-approved TMDL has been developed, they must review the adequacy of their stormwater pollution prevention plans (SWPPP) to meet the TMDL's WLA set for stormwater sources. If the SWPPP is not meeting the applicable requirements, schedules and objectives of the TMDL, they must modify their SWPPP, as appropriate, within 18 months after the TMDL is approved.

All significant development, redevelopment, industrial, and construction projects need to be designed to maintain or improve existing developed hydrology and pollutant loadings to fully comply with the local watershed and government authorities, NPDES, and anti-degradation requirements.

An implementation plan will be finalized within one year following EPA approval of the TMDL, which will identify specific BMP opportunities sufficient to achieve the sector-specific load reduction and associated adoption schedule. Individual SWPPPs will be modified accordingly following the recommendations of the implementation plan.

9.0 Public Participation

In December 2008, the SRWD held a public meeting in Waite Park to inform the general public about the TMDL study. The public meeting was listed on the SRWD website and in the local papers for two consecutive weeks. In addition, the SRWD has discussed the five TMDL studies occurring within the District in our annual newsletters. The SRWD's Managers have each discussed the ongoing TMDL studies with the residents within their watershed area. Other stakeholders such as the Stearns SWCD have discussed this TMDL with local landowners during education events and in their newsletter.

A public meeting will be scheduled with the residents of the Mill Creek watershed to discuss the findings of this TMDL (when approved) and to review the corresponding implementation plan.

10.0 References

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