Deer Creek Watershed

Total Maximum Daily Load Implementation Plan: Turbidity Impairment

For Submission to:

Minnesota Pollution Control Agency
Northeast Region Watershed Unit

December, 2013

wq-iw10-04c

Deer Creek Watershed Total Maximum Daily Load Implementation Plan: Turbidity Impairment

Prepared for Minnesota Pollution Control Agency

December, 2013

BARR

4700 West 77th Street
Minneapolis, MN 55435-4803
Phone: (952) 832-2600
Fax: (952) 832-2601

Deer Creek Watershed

Total Maximum Daily Load Implementation Plan: Turbidity Impairment

Table of Contents

List of Acronyms/Abbreviations iv

Executive Summary v

1.0 Introduction 1
- 1.1 Impairment Listing 1
- 1.2 Geographic Extent and Watershed Characteristics 1

2.0 Turbidity TMDL Summary 5
- 2.1 Existing Water Quality and Standards 5
- 2.2 Turbidity Sources 6
- 2.3 TMDL Results Summary 11
  - 2.3.1 TMDL Allocations 11
  - 2.3.2 Load and Water Quality Duration Curves 13
  - 2.3.3 Field Turbidity and Transparency Tube Station Comparison 15
  - 2.3.4 Loading Reductions 19
- 2.4 Overall Conclusions from Turbidity-Related Monitoring and Sediment Sources Requiring Load Reductions 19

3.0 Implementation Objectives and Priority Management 21
- 3.1 Implementation Objectives 21
  - 3.1.1 Hydrology 21
  - 3.1.2 Connectivity 23
  - 3.1.3 Biology 24
  - 3.1.4 Geomorphology 24
  - 3.1.5 Water Quality 25
- 3.2 Evaluation of BMP Effectiveness and Priority Ranking for Sediment Reduction Strategies 26
  - 3.2.1 Streambank Slumping 26
  - 3.2.2 Sediment Volcanoes 27
- 3.3 Monitoring 31
  - 3.3.1 Turbidity specific monitoring 31
  - 3.3.2 Geomorphology 31
- 3.4 Adaptive Management 32
- 3.5 Reasonable Assurance 33
- 3.6 Education and Outreach 33
- 3.7 Public and Stakeholder Participation 34
- 3.8 Interim Milestones 34

References 36

List of Tables

Table EX.1 Total suspended solids loading capacities and allocations (AUID: 04010301-531) vi
Table 1.1 Deer Creek watershed 303(d) impairments addressed in this report 1
Table 1.2 2006 NLCD land use classification found in the Deer Creek watershed 3
Table 2.1 Total suspended solids loading capacities and allocations (AUID: 04010301-531) 12
Table 2.2 Median field turbidity at each sampling location 16
Table 3.1 Modeled and estimated sediment yield components (simulated for June, 2008 through October, 2010) 21
Table 3.2 Proposed implementation activities, estimated costs and prioritization for Deer Creek restoration 28

List of Figures

Figure EX.1 TSS load duration curve for Lower Deer Creek (2008-2010) vii
Figure 1.1 Deer Creek Watershed and Sampling Locations 2
Figure 2.1 Simplified turbidity conceptual model of candidate sources and potential pathways 7
Figure 2.2 TSS Load duration curve for Lower Deer Creek (2008-2010) 14
Figure 2.3 TSS water quality duration curve for Lower Deer Creek (2008-2010) 15
Figure 2.4 Field turbidity duration curve for Lower Deer Creek at CSAH 23 station (2008-2010) 16
Figure 2.5 Field turbidity duration curve for Upper Deer Creek at CSAH 3 station (2008-2010) 17
Figure 2.6 Field turbidity duration curve for Tributary to Deer Creek at CSAH 3 17
Figure 2.7 Field turbidity duration curve for Tributary to Deer Creek at CSAH 6 18
Figure 2.8 Field turbidity duration curve for Deer Creek at CSAH 6 18
Figure 2.9 Transparency tube readings for Deer Creek monitoring stations 19
Figure 3.1 Streambank slumping and terrain analysis for Deer Creek 29
Figure 3.2 Streambank slumping along Deer Creek and primary tributary profiles 30
Figure 3.3 Deer Creek stream survey locations and significant features 32

Appendices

Appendix A Watershed and Groundwater Modeling

Appendix B Carlton County Zoning Ordinance Information

Contributing Reviewers:

Brad Matlack, Neva Widner, H.M.Loy, Mark Thell Carlton Soil And Water Conservation District
Greg Bernu, Karola Dalen, David Banta, Carlton County
Michael Dahl, Deserae Hendrickson, Karl S. Koller, Kirstin Stutzman, MN DNR
Michele Micke, MN DOT
Karen Evens, Gregory Johnson, MN Pollution Control Agency
Gary Erickson, Sappi Fine Paper NA Inc.

List of Acronyms/Abbreviations

AUID	assessment unit identification number
BMP(s)	best management practice(s)
CSAH	County State Aid Highway
EPA	U.S. Environmental Protection Agency
FMGs	Forest Management Guidelines
FNU	formazin nephelometric units
LA	load allocation
mg/L	milligrams per liter
MOS	margin of safety
MDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NLCD	National Land Cover Dataset
NRBP	Nemadji River Basin Project
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
SWCD	Soil and Water Conservation District
TMDL	total maximum daily load
TSS	total suspended solids
USGS	United States Geological Survey
WLA	wasteload allocation

Executive Summary

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to develop TMDLs for water bodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and instream conditions. By following the TMDL process, states can establish water quality-based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources.

Once a TMDL is established, an Implementation Plan must be developed. The Implementation Plan is designed to ensure that the management actions identified by the TMDL will be carried out. The Implementation Plan provides information on management measures and regulatory controls; timelines for implementation of management measures and attainment of water quality standards; a monitoring plan designed to determine the effectiveness of implementation actions; and description of adaptive management procedures.

In 2004 Deer Creek was listed by the Minnesota Pollution Control Agency (MPCA) as an impaired stream for turbidity (a measure of cloudiness of water that affects aquatic life). Deer Creek has been identified as a significant sediment loading tributary within the Nemadji River basin and ultimately to Lake Superior (NRCS, 1996). Deer Creek is a small perennial tributary to the Nemadji River located entirely in Carlton County, Minnesota with a drainage area of 5,063 acres. A majority of the watershed (> 90%) is privately owned with the remainder in a state owned wildlife management area. Most of the watershed is undeveloped with 52.9% of the watershed classified as forested, 22.3% as wetlands, 13.4% as agricultural, 10.0% as grassland or scrubland and only 1.1% of the watershed as low intensity development.

A sampling station located directly downstream of Highway 23 and 0.84 miles upstream from the North Fork of the Nemadji River was used for the TMDL analysis. At the Hwy 23 sampling location a total suspended solids (TSS) concentration of 4 mg/L corresponds to the 10 NTU turbidity standard. Continuous flow measurements were combined with periodic sampling throughout the ice free months between 2008 and 2010. Median TSS concentrations for the three year period were recorded as 78.5 mg/L for high flow events (0-10% flow duration), 31.0 mg/L for moist conditions (10-40% flow duration), 9.0 mg/L for mid-range flows (40-60% flow duration), 20.0 mg/L for dry conditions (60-90% flow durations) and 23.5 mg/L for low flows (90-100% flow durations). The 4 mg/L TSS concentration has been applied to determine TMDL loading capacities, since it is the most conservative surrogate concentration for the turbidity standard and the Hwy 23 sampling station is most representative of the overall watershed.

The five flow rate categories were used to calculate the total suspended solid loading capacities and allocations for Deer Creek (Table EX.1), based on the mid-point flow rate for each of the flow zones and the 4 mg/L TSS concentration that corresponds to the 10 NTU standard. To meet the TMDL, total daily loads at the Highway 23 station would have to be equal to or lower than 429 lbs/day for high flows, 73 lbs/day for moist conditions, 40 lbs/day for mid-range flows, 40 lbs/day for dry conditions, and 27 lbs/day for low flows. This translates to corresponding daily load reductions of 99, 95, 56, 95 and 89 percent for the high, moist, mid, dry and low flow zones, respectively, to meet the requirements of the TMDL.

Table EX.1 Total suspended solids loading capacities and allocations (AUID: 04010301-531)

	Flow Zone				
	High	**Moist**	**Mid**	**Dry**	**Low**
	lbs/day				
TOTAL DAILY LOADING CAPACITY	429	73	40	40	27
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0	0	0	0	0
Communities Subject to MS4 NPDES Requirements	0	0	0	0	0
Construction and Industrial Stormwater	0.43	0.07	0.04	0.04	0.03
Load Allocation	385.8	65.8	35.8	35.8	24.4
Margin of Safety	42.9	7.3	4.0	4.0	2.7

Duration curves are a helpful visual tool to envision where the current data is plotting relative to the target limit (4 mg/L) and how that relates to streamflow. The duration curve plots each flow observation based on its percentile rank. A flow duration interval of 10% represents a value where only 10% of the flow rates are higher represented on the graphic as "high flows". A 90% interval represents a low flow rate where 90% of measurements are higher, represented on the graphic as "low flows". A load duration curve was created for three years of combined data (2008-2010) at the Lower Deer Creek station located near Hwy 23 (Figure EX.1), which shows that all recorded measurements were above the turbidity standard and the higher loads in the moist and high flow zones are the result of both increased flows and elevated TSS concentrations.

Major sources of turbidity in Deer Creek include failing "Red Clay Dam" structures and knickpoint migration of stream channels and streambank slumping induced by adjustments in hydrology caused by past watershed wide land use changes and possibly climate change. Destabilization of stream banks from livestock grazing in riparian zones can have localized effects on water quality and the presence of sediment volcanoes in the middle of the Deer Creek main stem providing a steady influx of sediment from groundwater discharge points that are still contributing to the turbidity impairment under low flow conditions. Silviculture activities are also expected to contribute to some of the watershed land cover changes that affect hydrology and sediment loading in the Deer Creek watershed. Watershed modeling indicates that significant water quality and stream channel changes could result from changes to the current land use and land management within the watershed. Simulation of an all forested land cover scenario for the Deer Creek watershed indicated there would be reduction in total cumulative sediment yield of 16 to 20 percent from existing conditions, while simulation of a non-forested (or complete conversion to open space) scenario indicate an increase in total cumulative sediment yield from existing conditions of 20 percent for Deer Creek at Hwy. 23 and an increase of more than 60 percent for Deer Creek at CSAH 3.

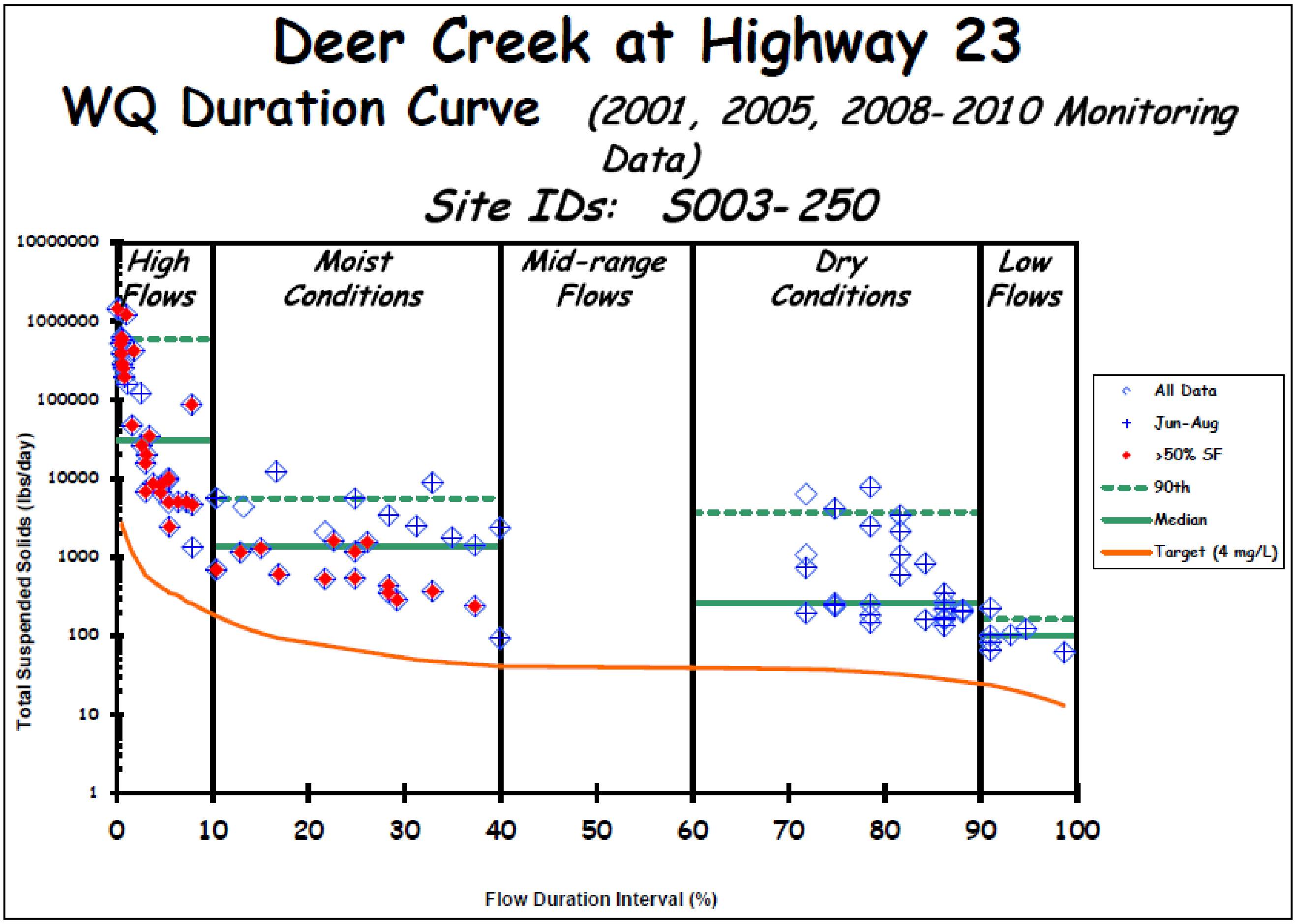


Figure EX.1 TSS load duration curve for Lower Deer Creek (2008-2010)

1.0 Introduction

This document presents the Implementation Plan for the Bluff Creek Total Maximum Daily Load (TMDL). Deer Creek is listed on the 2004 Minnesota Section 303(d) List of Impaired Waters due to impairment for turbidity. A TMDL for Deer Creek has been developed and approved.

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to develop TMDLs for water bodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and instream conditions. By following the TMDL process, states can establish water quality-based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources.

Once a TMDL is established, an Implementation Plan must be developed. The Implementation Plan is designed to ensure that the management actions identified by the TMDL will be carried out. The Implementation Plan provides information on management measures and regulatory controls; timelines for implementation of management measures and attainment of water quality standards; a monitoring plan designed to determine the effectiveness of implementation actions; and description of adaptive management procedures.

1.1 Impairment Listing

Section 303(d) of the Clean Water Act provides authority for completing TMDLs to achieve state water quality standards and/or designated uses. In 2004, Deer Creek was placed on the 303(d) list of impaired waters for elevated turbidity levels (Table 1.1).

Table 1.1 Deer Creek watershed 303(d) impairments addressed in this report

Reach	Description	Year listed	Assessment Unit ID	Affected Use	Pollutant or Stressor
Deer Creek	Headwaters to Nemadji River	2004	04010301-531	Aquatic life	Turbidity

Turbidity in water is caused by suspended sediment; organic material, dissolved salts, and stains that scatter light in the water column making the water appear cloudy. Excess turbidity can degrade aesthetic qualities of water bodies, increase the cost of treatment for drinking or food processing uses, and can harm aquatic life. Aquatic organisms may have trouble finding food, gill function may be affected, and spawning beds may be covered. In addition, greater thermal impacts may result from increased sediment deposition in the stream.

1.2 Geographic Extent and Watershed Characteristics

Deer Creek is a small perennial tributary to the Nemadji River located entirely in Carlton County Minnesota with a drainage area of 5,063 acres (Figure 1.1). Based on field investigations and review of LIDAR data, the subwatersheds in the far northern portion of the watershed were determined to be non-contributing under typical flow conditions. A majority of the land, (> 90%) is privately owned land with the remainder in a state owned wildlife management area. No tribal lands are located in the watershed. Deer Creek has been identified as a significant sediment loading tributary within the Nemadji River basin and ultimately to Lake Superior (NRCS, 1996).

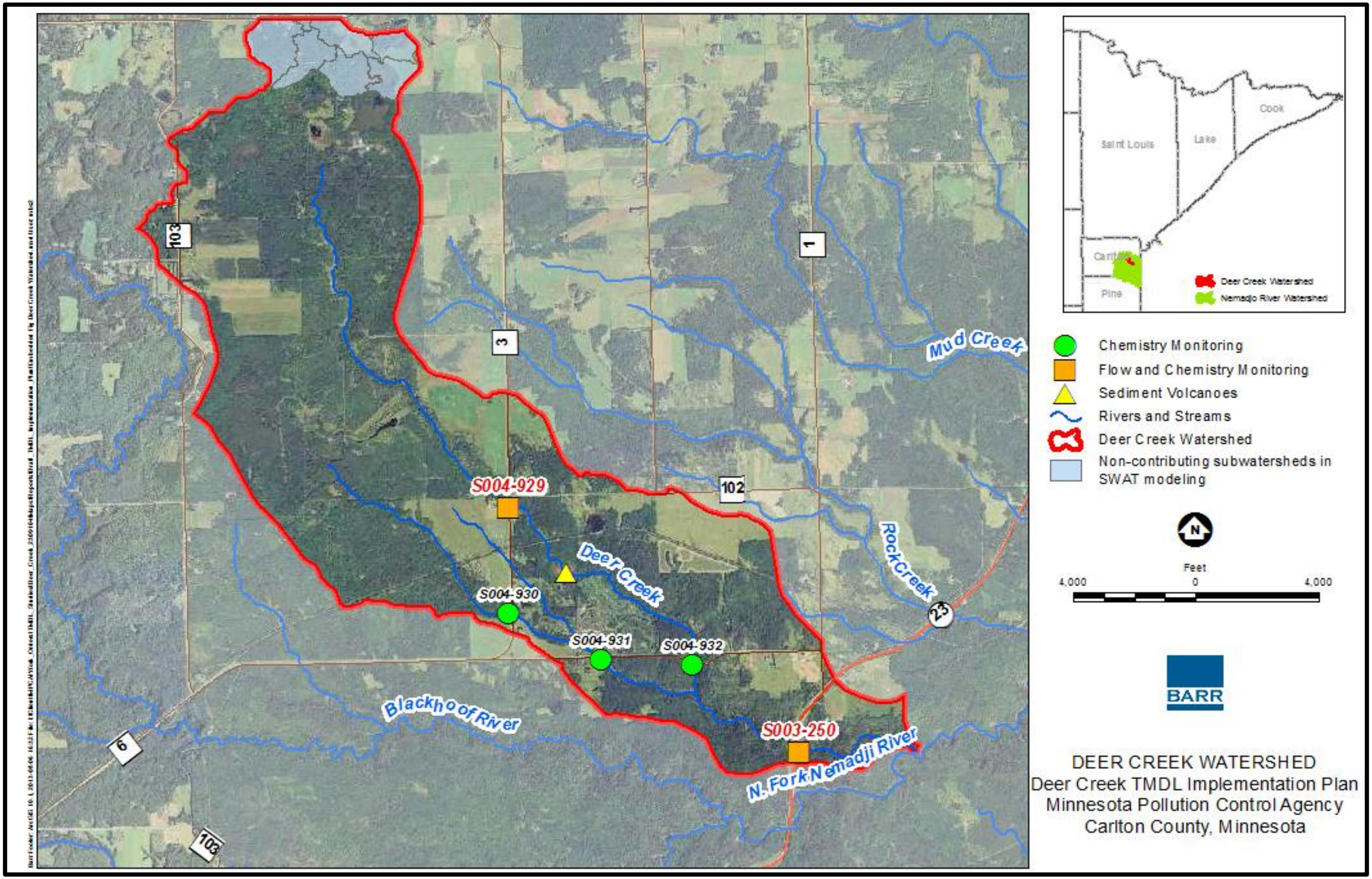


Figure 1.1 Deer Creek Watershed and Sampling Locations

Sediment carried into the Nemadji River from its tributaries is carried downstream to Superior Harbor and eventually out into Lake Superior. From previous studies, the average annual sediment load of the Nemadji River is well over 100,000 tons. Of that, 14 percent of all the silt and clay is trapped in Superior Bay. About 74 percent is carried out into Lake Superior (NRCS, 1998b). It has been estimated that 89 percent of the fines (silt- and clay- sized particles) eroded come from stream bank and bluff erosion along tributary streams. The remaining 11 percent of fines originated from watershed sources like roadside erosion and sheet and rill erosion. The majority (about 92 percent) of all stream bank and bluff erosion occurs in the red-clay portion of the basin which included Deer Creek (NRCS, 1998b).

From various investigations to date, the high sediment yield of the Nemadji River Basin appears to be a result of changes in the hydrologic system and, possibly, climate change. Hydrologic changes caused by human activities have resulted in increased volumes and rates of runoff and stream-flow. These changes have resulted in higher stream-flow regimes that, in turn, have increased stream bank and bluff erosion and slumping. The major human activities that have had a significant impact on the hydrology of the basin are the early logging practices dating back to the mid 1800's.

In the Mid 1800s, the Nemadji Basin was dominated by vast stands of White Pine and Red Pine. Following logging, deciduous forests dominated by quaking aspen replaced the pine forests, a change that would be expected to increase water yield (Koch et al., 1977). In the early 1900s forested areas were replaced by agricultural lands peaking in the 1950s after which some agricultural lands were converted to deciduous forest. Currently the three main land uses in the Deer Creek watershed are deciduous forest, woody wetlands and pasture/hay (Table 1.2) representing 74% of the total area according to land use data from the United States Geological Survey (USGS) 2006 National Land Cover Database (2006NLCD; Fry et al., 2011). Overall 52.9% of the watershed is forested, 22.3% is covered in wetlands, 13.4% is agricultural, 10.0% is grassland or scrubland and only 1.1% of the watershed has low intensity development.

Table 1.2 2006 NLCD land use classification found in the Deer Creek watershed

Land Use	Percent of watershed
Deciduous Forest	41.6%
Woody Wetlands	20.6%
Pasture/Hay	11.4%
Evergreen Forest	9.2%
Shrub/Scrub	7.1%
Mixed Forest	2.1%
Cultivated Crops	2.0%
Grassland/Herbaceous	1.7%
Emergent Herbaceous Wetlands	1.7%
Developed, Open Space	1.2%
Developed, Low Intensity	1.1%
Open Water	0.3%

The evolution of rivers and streams in the Nemadji Basin creates a certain amount of natural erosion and sedimentation. Additionally, confined aquifer discharge through the lacustrine sediments along the streams adds suspended sediment to the system. This has been documented in the Deer Creek and

Mud Creek subwatersheds.

Monitoring conducted by Nemadji River Basin Project (NRBP) staff in 2004 showed that total suspended solids in Nemadji streams typically have total suspended solids (TSS) concentration less than 40 mg/L, whereas Deer Creek was above 600 mg/L, a fifteen-fold difference (CCSWCD, 2005).

The root cause of turbidity in the upper Nemadji River is driven by erosion of inorganic cohesive-sediment banks consisting of lacustrine clays and mixed clay till (clay-silt-very fine sands). Soils mass movement, bluff and streambank erosion contribute the largest load of sediment to the Nemadji River and Lake Superior harbor (Andrews et al., 1980; Banks and Brooks, 1996).

2.0 Turbidity TMDL Summary

2.1 Existing Water Quality and Standards

Turbidity standards in the state of Minnesota are defined based on an assigned water class. All waters of Minnesota are allocated classes based on their suitability for the following beneficial uses:

1. Domestic consumption
2. Aquatic life and recreation
3. Industrial consumption
4. Agriculture and wildlife
5. Aesthetic enjoyment and navigation
6. Other uses
7. Limited resource value

Deer Creek is listed in the Minn. Rules Ch. 7050.0470 classification as a 1B, 2A, 3B water body. A turbidity standard is associated with each of the three classifications. Assessments of water quality are usually based on Class 2 beneficial uses (aquatic life and recreation) given that other uses will largely be protected if Class 2 standards are met. Class 2A waters are defined as:

> **Class 2A waters**. The quality of Class 2A surface waters shall be such as to permit the propagation and maintenance of a healthy community of cold 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. This class of surface waters is also protected as a source of drinking water.

The turbidity standard for Class 2A waters is defined as:

> **Minn. Rules Ch. 7050.0222, turbidity water quality standard for Class 2A waters** is 10 nephelometric turbidity units (NTUs). The designated use that this standard protects is aquatic life. Impairment assessment procedures for turbidity are provided in the guidance manual for determination of impairment (MPCA, 2007a). Essentially, impairment listings occur when greater than ten percent of data points collected within the previous ten-year period exceed the 10 NTU standard (or equivalent values for total suspended solids or transparency tube data).

Turbidity, recorded using the optical properties of a water sample, is derived from suspended sediments, organic material, dissolved salts and stains. This analysis focused primarily on the suspended sediment and organic material components, as they appear to be the primary factors of turbidity in this watershed. In order to evaluate and establish loads the surrogate measure of total suspended solids (TSS) was used. This parameter shows a good correlation with turbidity, based on regressions done on the monitoring data.

The Carlton County SWCD staff collected water quality information at five sites within the Deer Creek watershed with continuous flow measurements recorded at two of those five sites (Figure 1.1). Grab samples were also collected for TSS and turbidity lab measurements at the time of Sonde field readings at the two flow gage stations. Continuous flow measurements were made using a hydraulic pressure transducer recording continuous stream stage data. The five sites (shown in Figure 1.1) include:

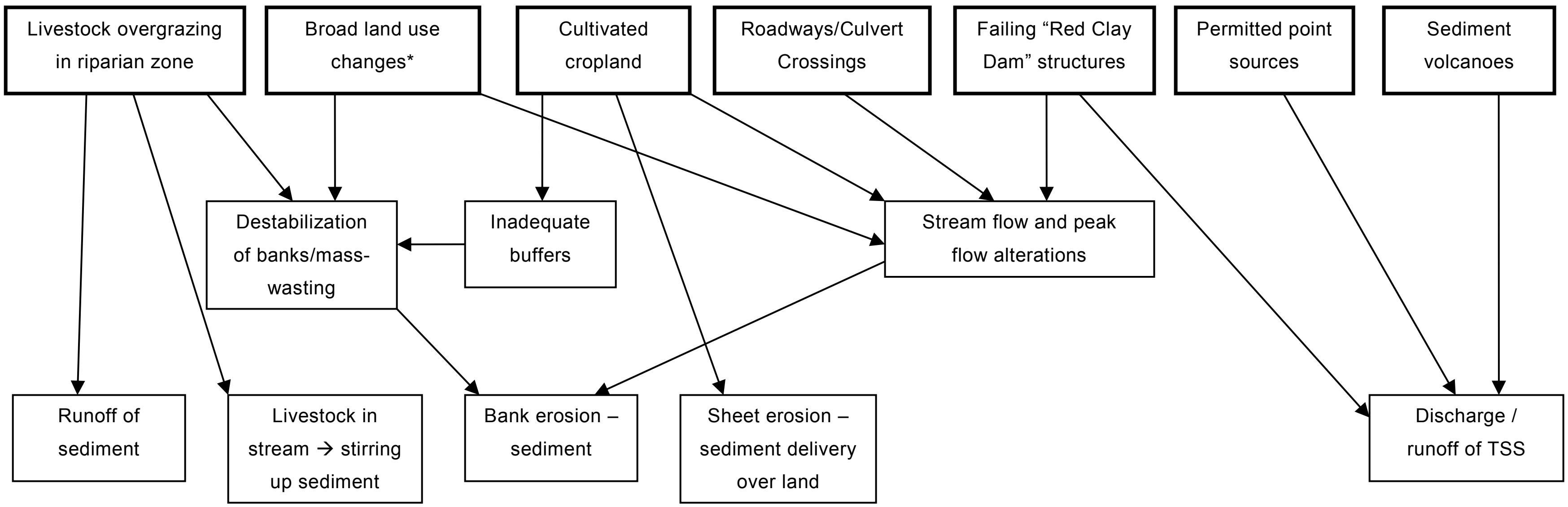
- **Lower Deer Creek** at State Highway 23 (S003-250) – Located 1 mile upstream from the confluence with the Nemadji River and downstream of the sediment volcanoes. A USGS streamflow station was operational near this location until 2001. In 2005 a continuous stream stage recorder was installed and chemistry data was collected starting in 2008.
- **Upper Deer Creek** at CSAH 3 (S004-929) – Located upstream of the sediment volcanoes. A continuous stream stage recorder was installed and chemistry data collection began in 2008.
- **Tributary at CSAH 3** (S004-930) – The first of two sampling locations located on an unnamed tributary to Deer Creek. Chemistry data collection began in 2008.
- **Tributary at CSAH 6** (S004-931) – The second sampling location on the unnamed tributary. Chemistry data collection began in 2008.
- **Deer Creek at CSAH 6** (S004-932). – Lies midway between the upper and lower Deer Creek sites and also downstream from the sediment volcanoes. Chemistry monitoring began at this site in 2008.

Lab turbidity and TSS measurements were recorded from grab samples at the Upper and Lower Deer Creek sites. The measurements were used to develop a NTU to TSS relationship. At the Lower Hwy 23 site (S003-250), grab sample data were available for years 2004 to 2010. At the upstream Hwy 3 site (S004-929), grab samples were available for years 2008 to 2010.

The NTU to TSS relationship was used to convert the 10 NTU standard to a TSS measurement for the water quality duration curves. For the Hwy 3 sampling location the 10 NTU standard is converted to a TSS concentration of 5 mg/L. At the Hwy 23 sampling location a concentration of 4 mg/L TSS represents the 10 NTU standard. The 4 mg/L standard was used to determine TMDL loading capacities since it is the most conservative surrogate concentration for the turbidity standard and the Hwy 23 sampling station is most representative of the overall watershed.

2.2 Turbidity Sources

Conclusions regarding turbidity sources and current loading for the TMDL study were based largely on previous research conducted on both Deer Creek and also the entire Nemadji River watershed. Some of the research conducted is highlighted in this section. A simplified turbidity conceptual model is presented in Figure 2.1 that shows several possible candidate sources in the Deer Creek watershed. This figure illustrates both “external” and “internal” sources. Most nonpoint sources are typically considered external in that they are located in the watershed outside of the stream channel yet contribute TSS. Internal sources of TSS typically encompass processes that occur within the channel (including the bed, banks and slumps) or the floodplain of a waterway or stream. Such processes include channel and floodplain erosion or scour, bank slumping, and the presence of sediment volcanoes. The components of this conceptual model, as they pertain to this watershed, are evaluated below in a general way. The relative amounts of sediment loading from each of the primary sources has been considered in more detail as a part of an evaluation of watershed modeling, GIS terrain analysis and comparisons of the available water quality and quantity monitoring data (see Section 3.0).



* Broad land use changes can also cause sediment delivery via:

- bank erosion/mass-wasting or slumping as meandering watercourses attempt to attain new equilibrium
- incision and higher stream power can cause headward erosion and downcutting (knickpoints may form; channel erodes knickpoint resulting in upstream scour)

Figure 2.1 Simplified turbidity conceptual model of candidate sources and potential pathways

Livestock in Riparian Zone

Livestock grazing in riparian areas can contribute to excess turbidity via soil runoff directly from devegetated areas, resuspending of sediments by walking in the stream, and by destabilizing the banks leading to increased bank erosion or slumping. Based on 2006 land use data, pasture or hay covered areas encompass 11.4% of the Deer Creek watershed (Table 1.2). A recent study concluded that grazing in the riparian areas of Deer Creek significantly reduced stream bank stability (Riedel et al., 2006). Stream bank materials in the analyzed sections of Deer Creek were generally stable. Instabilities were found in areas with reduced riparian vegetation and subsequent bank erosion caused by cattle traffic. The introduction of hoof shear from cattle traffic resulted in the largest decrease in stream bank stability even when compared to the loss of riparian vegetation (Riedel et al., 2006). No confined animal feeding operations (CAFOs) that would require a permit are located in the watershed.

Estimated water quality impact:

Due to the limited presence of livestock throughout the watershed, the overall sediment load contribution from this source is minor or limited, but where present livestock impact to streambanks can be significant.

Watershed wide land use changes

Land-cover condition within a watershed—specifically the amount and distribution of open lands within a watershed—influence surface water quality within a watershed through effects on stream peak flows, loss of base flow, sedimentation, erosion, turbidity, nutrient levels, and water temperatures. These effects in turn can negatively impact stream biotic integrity, including the health and distribution of fish and invertebrates and human benefits derived from streams. Stream channel stability is dependent on stable flow regimes which match the capacity of the stream channel. In addition to impairment of aquatic ecosystems, stream channel instability caused by increased peak flows can also create societal costs in the form of increased culvert failure and maintenance needs along with bank stabilization measures required to protect threatened structures.

Changes in vegetative cover from forestland, greater than 15 years old, to open land causes snow to melt faster and higher rainfall runoff velocities. These have an impact on smaller peak flow events as well as annual peak flows. These impacts begin to appear as the percentage of open land within a watershed rises above 60 percent (Verry, 2000).

The Nemadji River basin as a whole has seen significant land use changes over the past two centuries including timber harvesting in the 1800s, forest fires and the conversion of wooded coniferous forest land to hay and pasture during the early 1900s. Land use changes between 2008 and 2010 in an area of Deer Creek indicate that silviculture activities occur in the area, and depending on BMP implementation, would be expected to change surface runoff and the resulting sediment contributions to the streams during a period of time.

Broad land use changes have altered stream flows causing the channel base elevations to down cut which in turn induced an array of knickpoint migrations throughout the basin resulting in mass wasting and associated channel incision (Riedel et al., 2005; Magner, 2004). A full assessment of the influence of incision in terms of turbidity is difficult. There is no specific monitoring data that provides a breakdown of contributions for upland erosion versus these near-channel sources. Headwater ditches are shorter than the natural channel and, thus, steeper in gradient. As such they generally exhibit higher velocities and higher peak flows. Also, their geometry is such that there is limited access to the floodplain. Therefore, the energy is confined to the channel. The net result is increased potential for bank erosion. The land use changes have resulted in estimated increased sedimentation rates into Lake Superior from 0.89 mm/year during pre-historic post glacial period to 2.00 mm/year from 1890 to 1955 (Kemp et al., 1978).

Estimated water quality impact from channel incision:

Nearly all of the stream reaches in the Deer Creek system are experiencing high levels of channel incision and limited floodplain access so the overall sediment load contribution from this effect is significant, especially in the lower reaches of the watershed.

The Deer Creek watershed is sparsely populated with the majority of the land cover and use in the watershed associated with wooded areas. Changes to the existing land use/cover from wooded areas would result in increased surface runoff contributing to the stream bank erosion currently present. Examination of land use data provided by the USGS (NLCD2001 and NLCD2006) and the USDA (2006-2010) showed no significant land use changes since 2001. It is not expected that urbanization, and any associated MS4 permit requirements, will occur in the foreseeable future.

Estimated water quality impact from land use conversion:

Development is generally occurring in the upper watershed with limited single family household homes throughout the watershed. In general, it is expected that land use conversion to open space and/or developed conditions will significantly increase the sediment loadings in the Deer Creek system.

Land cover changes were observed in the watershed through a comparison of aerial photographs between the years 2008 and 2010. The removal of trees over a large, previously forested area was incorporated into the watershed modeling to simulate how this land cover change would produce exposed soils capable of contributing TSS to Deer Creek as well as changes to the watershed hydrology. The timber harvest at this site followed the Minnesota Forest Resources Council (MFRC) Forest Management Guidelines that are intended to protect water quality of nearby water bodies (Bernu, 2012).

It is important to note that timber harvest does not represent a change in land use rather it is a temporary land cover condition of a long term rotation of a forest. As a result, the impacts are expected to be short term (5 to 15 years in a 40-year or longer rotation; Verry, 2000). Depending on where the forest products are going, forest product certification can also drive this adherence to the site level guidelines (currently estimated at 90% compliance). The collective forest product resources on private land are substantial and will need to be used in a sustainable manner for the good of forest industries and regional forest economics.

Estimated watershed impact:

Private timber harvests will continue driven by pulp prices, and landowner economics, and likely in a random way without government coordination. Education for adherence to the voluntary site level guidelines may be the best BMP for this source. Planting of "vacant land" can be a BMP that will result in more of the watershed in a forested state to realize the hydrologic benefit of mature forest. Updates of open land maps last updated in 2004 can be critical to targeting this BMP.

Through the implementation of this TMDL, recommendations to landowners on how to best manage land use and/or land cover changes will be made to minimize the impact on TSS loads.

Sediment Volcanoes

The sediment volcanoes in Deer Creek occur at the toe of 10 meter high slumps in the south-central portion of the watershed (see Figure 1.1). Groundwater flow discharged at the surface expression of the slump faults transport coarse sediments which are deposited near the discharge point, forming a volcano-shape structure, and finer sediment which becomes suspended causing excess turbidity in the creek (Mooers and Wattrus, 2005). Approximately 10 volcanoes have been observed between 2006 and 2008 discharging approximately 100 gallons per minute of groundwater to the creek (Mooers and Wattrus, 2005). It is hypothesized that the sediment volcanoes formed in the Deer Creek watershed in the early 1990s after the formation of a large beaver dam which ponded water up to 3 meters. The beaver dam was built and washed out a number of times between the early 1990's to 2001 when it was removed by the Minnesota Department of Natural Resources. The elevated pore water pressure could have increased the shear stress and/or decreased the shear strength along the lower boundary of the clay. In a positive feedback process the dewatering of the aquifer caused subsidence which leads to more slumping and more sediment being transported through the volcano. The pond drainage could have also led to fracturing of a glacio-lacustrine clay confining layer over a locally extensive aquifer (Mossberger, 2010).

Estimated water quality impact:

While the estimated sediment volcano loading represents a much smaller portion of the observed sediment load, the water quality monitoring data indicates that the sediment volcanoes are still contributing to the turbidity impairment under low flow conditions.

Failing "Red Clay Dam" Structures

The Red Clay Project was a 1970's era project that encompassed watersheds in Northeast Minnesota and Northern Wisconsin draining to Lake Superior. In Minnesota, efforts focused on sediment retention structures in two subwatersheds of the Nemadji River Basin in Carlton County. Four structures were constructed in the Deer Creek Watershed. The design life of these structures was 10-25 years depending on the specific project and the design life has now been exceeded. Three of the four structure sites in the Deer Creek watershed were assessed by a multi-agency team which found failed metal pipes and, in one case, a breached structure (Site 4, Figure 3.1). Soil loss from this breached structure site is approximately 8775 tons, and will continue to increase as the channel seeks to stabilize itself. Potential soil loss from 2 other sites where the metal pipes are rusted out is 3,900 tons.

Estimated water quality impact:

These potential soil losses will result in significant additional sediment delivered to the watershed stream system until the sites are stabilized. The SWCD has received funding for sites in Deer Creek and Skunk Creek simultaneously to plan and implement stabilization projects. This source is fixable but will require large amounts of funding and staff resources to complete.

Cultivated Cropland

Cultivated cropland can contribute to excess turbidity via sheet/rill erosion of soil; destabilization of banks (if inadequate buffers) leading to increased bank erosion; and also drainage alterations on cropped land leading to increased flows causing bank/bed erosion. Based on the land use data from 2006, areas covered with cultivated crops represent only 2% of the watershed (Table 1.2).

Estimated water quality impact:

While land use coverage indicates the presence of cultivated croplands the dominant agricultural classification is pasture/hay management representing 11.4% of the watershed resulting in minimal turbidity contributions from current row cropland.

Roadways/Culvert Crossings

Using the 30 m NLCD impervious surface dataset a total impervious area of 7.25 acres was calculated representing only 0.1% of the total Deer Creek watershed. Impervious surfaces are mostly identified as the county and state roads that cross within the watershed boundaries. Roadways can contribute to excess turbidity directly via sediment delivery and indirectly via adaptations in watershed boundaries leading to changes in runoff volumes that could cause increased bank/bed erosion. Culvert crossings can increase erosion through slope changes and increased water velocities.

Estimated water quality impact:

Carlton County SWCD recently completed a culvert inventory to identify stream crossings and culverts that block fish passage and/or contribute sediment or channel instability to the stream. Results of the inventory have yet to be quantified, but some measure of impact is expected. For example, a large channel bank slump is located downstream of the State Highway 23 crossing that is a chronic source of sediment to the stream.

Permitted Point Sources

Point sources, for the purpose of this TMDL, are those facilities/entities that discharge or potentially discharge solids to surface water or otherwise contribute to excess turbidity and require a National Pollutant Discharge Elimination System (NPDES) permit from the MPCA. Typical point source categories are: wastewater treatment facilities, construction activities, municipal and industrial stormwater sources.

The only point sources that may apply to this watershed are construction and industrial stormwater sources. No industrial or wastewater treatment plants discharge into Deer Creek and no municipalities are subject to Municipal Separate Storm Sewer Systems (MS4) permit requirements.

Regarding construction, the MPCA issues construction permits for any construction activities disturbing: one acre or more of soil; less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre; or less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources.

Estimated water quality impact:

Although stormwater runoff at construction sites that do not have adequate runoff controls can be significant on a per acre basis (MPCA Stormwater web page, 2006), the source appears to be a minor turbidity source in the Deer Creek watershed. Industrial stormwater sources are not currently present in the watershed but, for the purpose of the TMDL, are treated similarly to construction sources.

2.3 TMDL Results Summary

2.3.1 TMDL Allocations

A TMDL is a calculation of the maximum amount of pollutant that a waterbody can receive and still meet water quality standards and/or designated uses. It is the sum of the loads of a single pollutant from all contributing point and nonpoint sources. TMDLs consist of three main components: WLA, LA, and MOS. In this case, the WLA includes two regulated stormwater sources combined into the construction and industrial permitted stormwater category. There are no permitted wastewater facilities or municipalities subject to an MS4 Permit in the Deer Creek watershed. The LA, reported as a single category, includes both watershed runoff and other sources. The third component, MOS, is the part of the allocation that accounts for uncertainty in the development of the loads.

The three components (WLA, LA, and MOS) were calculated as a total maximum daily load of TSS. As described in Section 2.1, TSS is used as a surrogate for turbidity based on a correlation between the two. The methodology used to derive and express the TSS load components was based on the duration curve approach. For each flow condition within the impaired reach, the total loading capacity or "TMDL" was divided into its component WLA, LA, and MOS. The allocations were distributed to the stormwater WLA category, as well as the LA, based on an even distribution of load that corresponded with the contributing watershed area. It should be noted that this method implicitly assumes that observed stream flows and flow regimes must remain constant over time.

Flow duration curves were developed for the Lower Deer Creek station for years 2008-2010. The flow duration curves rank each flow based on its percentile rank. A flow duration interval of 10% represents a value where only 10% of the flow rates are higher. A 90% interval represents a low flow rate where 90% of measurements are higher. For development of the TMDL rates were divided into five categories: high flows (0-10%), moist conditions (10-40%), mid-range flows (40-60%), dry conditions (60-90%) and low flows 90-100%).

The five flow rate categories were used to calculate the total suspended solid loading capacities and allocations for Deer Creek (Table 2.1). The total daily loading capacity was calculated using the mid-point flow rate for each of the flow zones and the 4 mg/L TSS concentration which corresponds to the 10 NTU standard, as described in Section 2.1. This analysis results in total daily load capacities for the high, moist, mid, dry and low flow zones at the monitoring location. The monitoring location represents 7.7 mi^2 of the total 7.9 mi^2 of watershed area therefore the loading capacities were adjusted to the entire watershed. Using this adjustment the total daily load capacities for the entire Deer Creek watershed were 429, 73, 40, 40 and 27 lbs/day for the high, moist, mid, dry and low flow zones respectively. This loading capacity was then divided between MOS, WLA, and LA components. In this analysis only MOS, LA, and construction and industrial stormwater activity requirements were apportioned, resulting in 89.9% of the capacity allocated to non-point sources as a load allocation requirements, 0.1% allocated to construction and industrial stormwater and 10% applied to the MOS.

Table 2.1 Total suspended solids loading capacities and allocations (AUID: 04010301-531)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	lbs/day				
TOTAL DAILY LOADING CAPACITY	429	73	40	40	27
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0	0	0	0	0
Communities Subject to MS4 NPDES Requirements	0	0	0	0	0
Construction and Industrial Stormwater	0.43	0.07	0.04	0.04	0.03
Load Allocation	385.8	65.8	35.8	35.8	24.4
Margin of Safety	42.9	7.3	4.0	4.0	2.7

	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Communities Subject to MS4 NPDES Requirements	0%	0%	0%	0%	0%
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	0.1%
Load Allocation	89.9%	89.9%	89.9%	89.9%	89.9%
Margin of Safety	10%	10%	10%	10%	10%

2.3.2 Load and Water Quality Duration Curves

A load duration curve was created for three years of combined data (2008-2010) at the Lower Deer Creek station located near Hwy 23 (Figure 2.2). Load duration curves plot the corresponding TSS load (lbs/day) calculated using the 15 minute interval flow rate (cfs) and TSS concentration (mg/L), converted from the NTU turbidity measurement, against the flow percent rank (%) for each measurement. At the Deer Creek Highway 23 station the highest TSS loads occurred during the high and moist flow zones. Median loads over the three year period were calculated as 13314, 810, 94, 228, and 128 lbs/day for the high, moist, mid, dry and low flow zones respectively. The 10 NTU standard was calculated by taking the product of the 4 mg/L TSS equivalent and the flow rate at various percentages. This curve is displayed with an orange line in Figure 2.2. Also present on Figure 2.2 are the 90th percentile and median loads for the 5 flow zones. All measurements recorded between 2008 and 2010, at the lower Deer Creek station, were above the turbidity standard.

The higher loads in the moist and high flow zones are the result of both increased flows and elevated TSS concentrations (see Figure 2.3). Median concentrations for the three year period were recorded as 79, 31, 9, 20 and 24 mg/L for the high moist, mid, dry and low flow zones, respectively. The 90 percentile TSS concentrations were 604, 74, 9, 78 and 38 mg/L for the high moist, mid, dry and low flow zones respectively. Figure 2.3 also shows that the TSS observations in the three lower flow zones were significantly higher than the TSS concentration that corresponds to the turbidity standard, resulting in TSS loads that were also higher than the loading capacity (as shown in Figure 2.2) for the mid-range to low flow conditions.

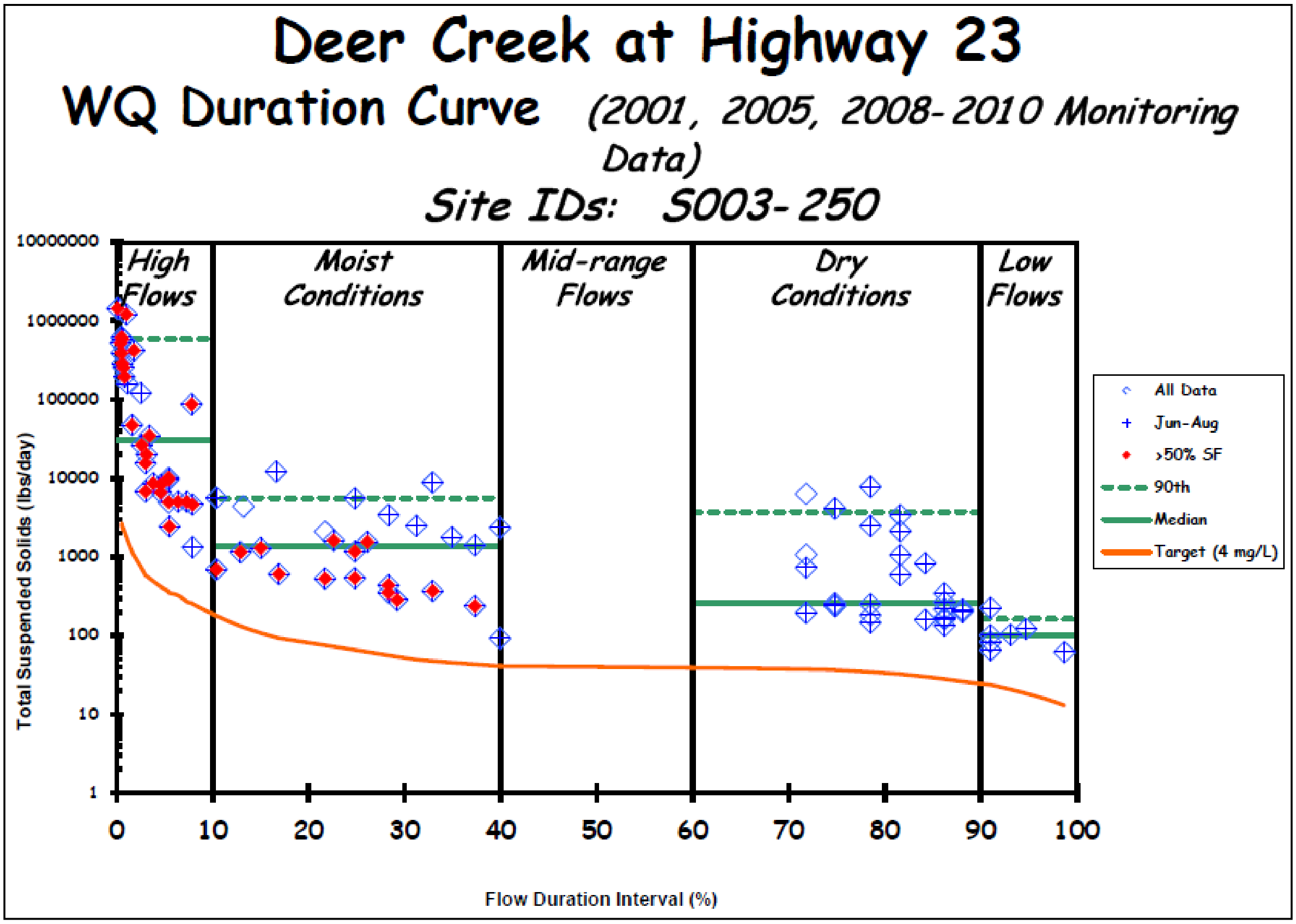


Figure 2.2 **TSS Load duration curve for Lower Deer Creek (2008-2010)**

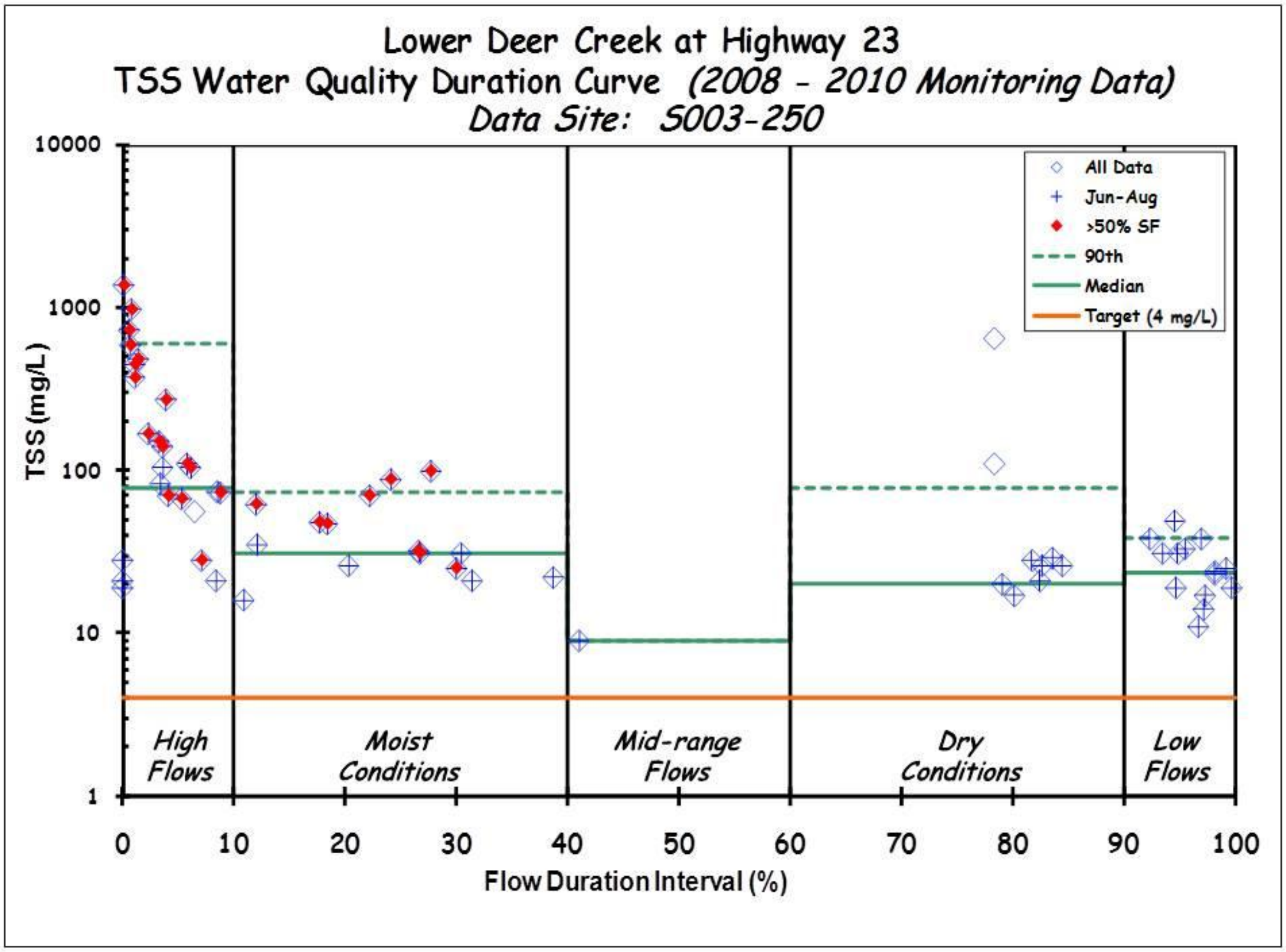


Figure 2.3 TSS water quality duration curve for Lower Deer Creek (2008-2010)

2.3.3 Field Turbidity and Transparency Tube Station Comparison

Field turbidity measurements were made at all sampling locations displayed in Figure 1.1 between 2008 and 2010. Field turbidity duration curves in units of formazin nephelometric units (FNU) for each site are shown in Figures 2.4 through 2.8. Median values for each flow regime at the various locations are summarized in Table 2.2. Median turbidity values increase by at least 100% for four of the five flow regimes between CSAH 3 and CSAH 6 on the Deer Creek main stem. This section of Deer Creek contains sediment volcanoes which are a significant source of sediment in the watershed. Values at all other locations are comparable to the CSAH 6 site. The downstream tributary site experienced higher turbidity readings than the upstream site under most of the lower flow conditions (see Table 2.2). Turbidity under high flow conditions is significantly higher at five of the monitoring stations. No comparison was made between the field turbidity data and the turbidity standard given that the field FNUs are not equal to the NTUs of the turbidity standard; however, the preponderance of values well above 10 indicate high turbidity levels.

Figure 2.9 shows how the transparency tube readings varied at each site between 2008 and 2012. The results compare well with the conclusions of the field turbidity monitoring and confirm that the sediment volcanoes significantly increase turbidity in the main stem. Figure 2.9 also shows that other sources of sediment are significantly increasing turbidity from the upstream to downstream direction on both the main stem and tributary to Deer Creek. In addition, higher flow conditions appeared to exacerbate the turbidity levels at all of the sites, except for Deer Creek at CSAH 3, as the lowest transparency levels shown in Figure 2.9 appeared to correlate with the years (2011 and 2012) that experienced higher flow.

Table 2.2 Median field turbidity at each sampling location

	Median Field Turbidity measurements (FNU)				
	High Flow	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Deer Creek at CSAH 3	57	14	25	14	21
Deer Creek at CSAH 6	113	51	40	59	42
Deer Creek at Highway 23	125	63	30	56	51
Tributary at CSAH 3	102	38	--	50	13
Tributary at CSAH 6	114	90	83	49	42

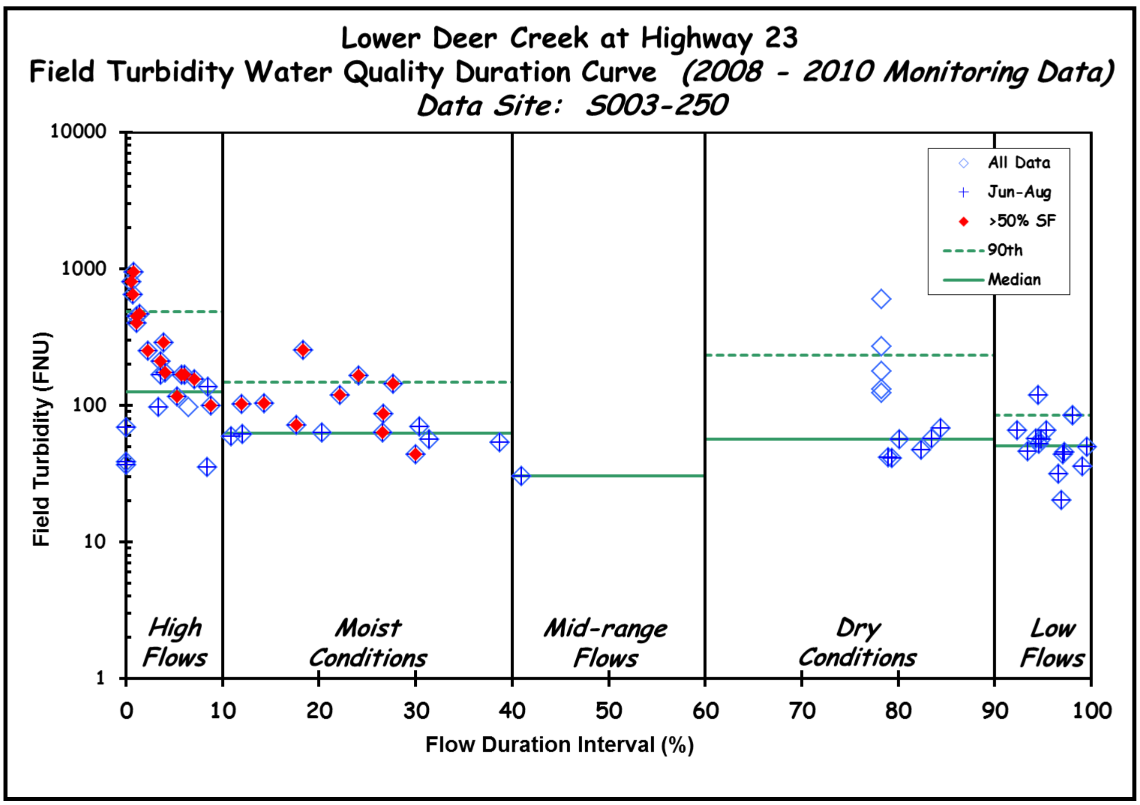


Figure 2.4 Field turbidity duration curve for Lower Deer Creek at CSAH 23 station (2008-2010)

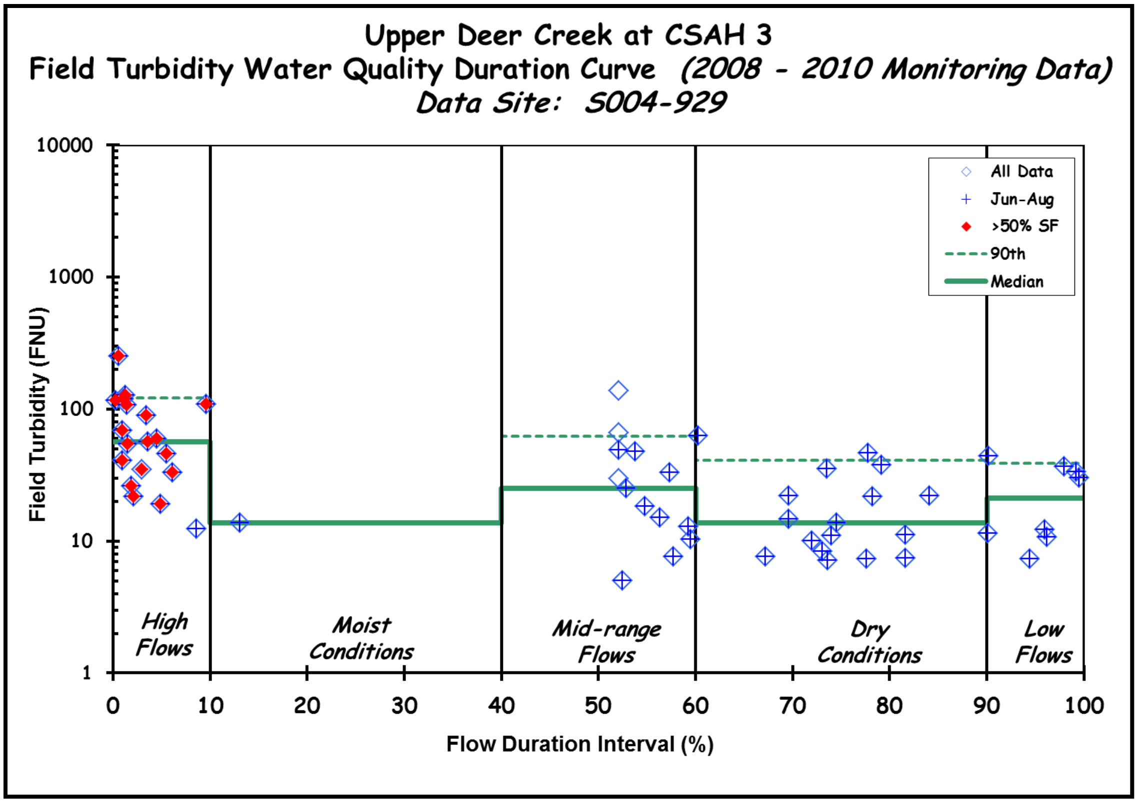


Figure 2.5 Field turbidity duration curve for Upper Deer Creek at CSAH 3 station (2008-2010)

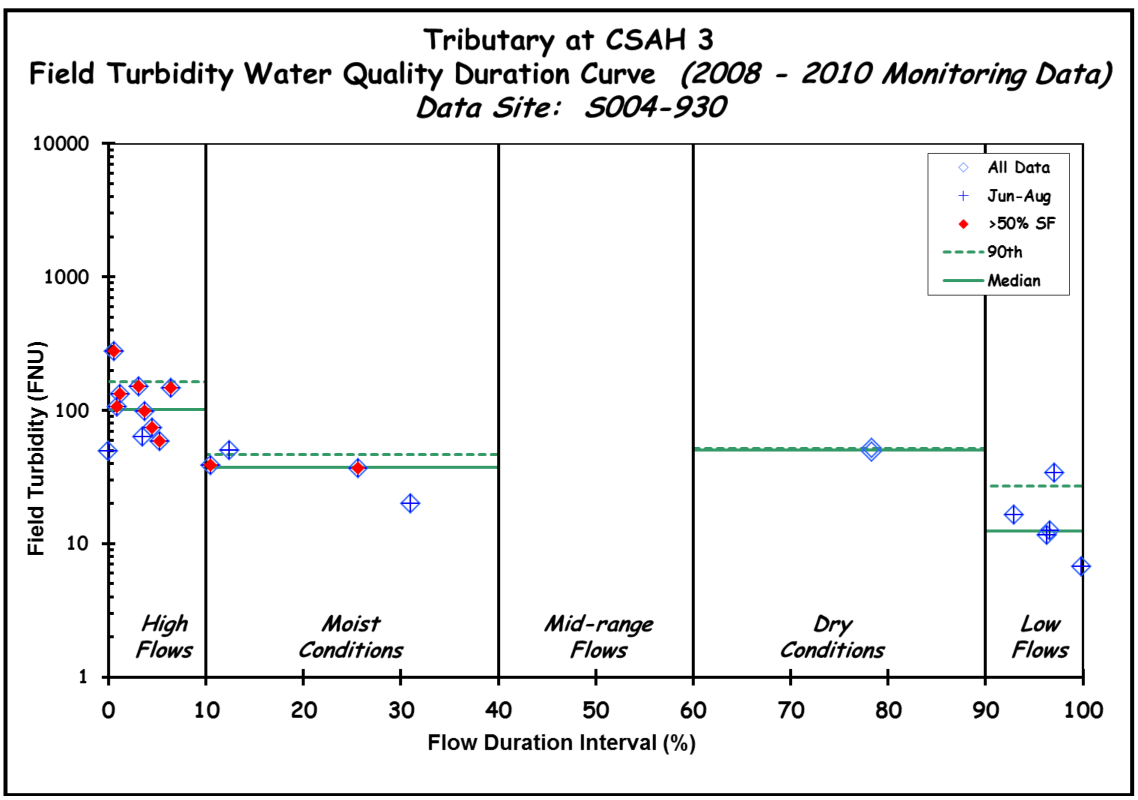


Figure 2.6 Field turbidity duration curve for Tributary to Deer Creek at CSAH 3

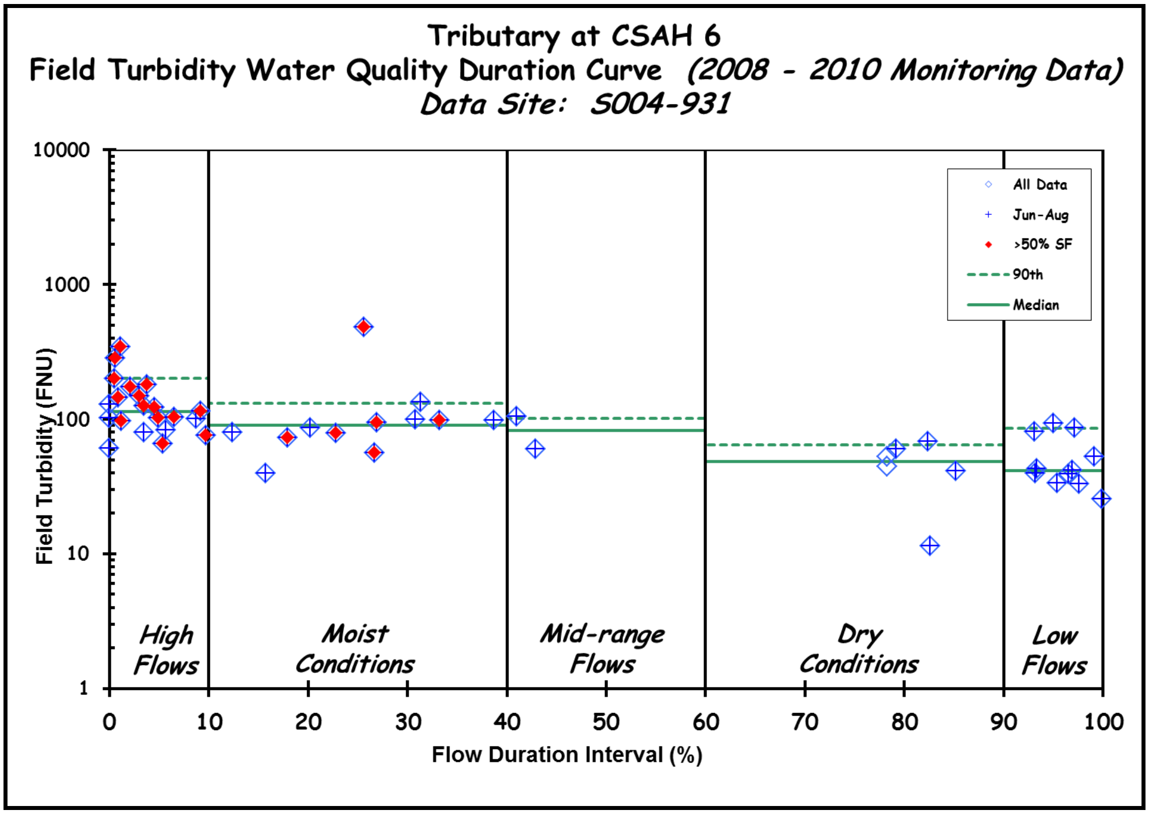


Figure 2.7 Field turbidity duration curve for Tributary to Deer Creek at CSAH 6

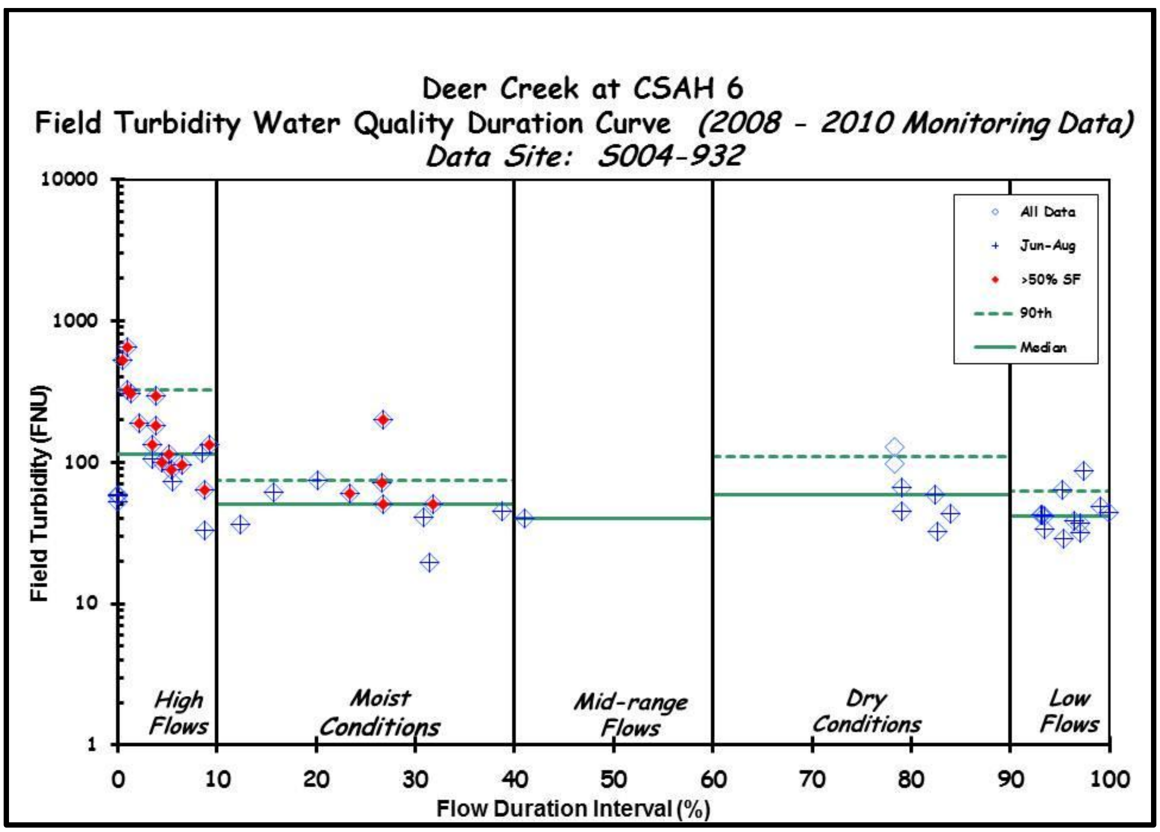


Figure 2.8 Field turbidity duration curve for Deer Creek at CSAH 6

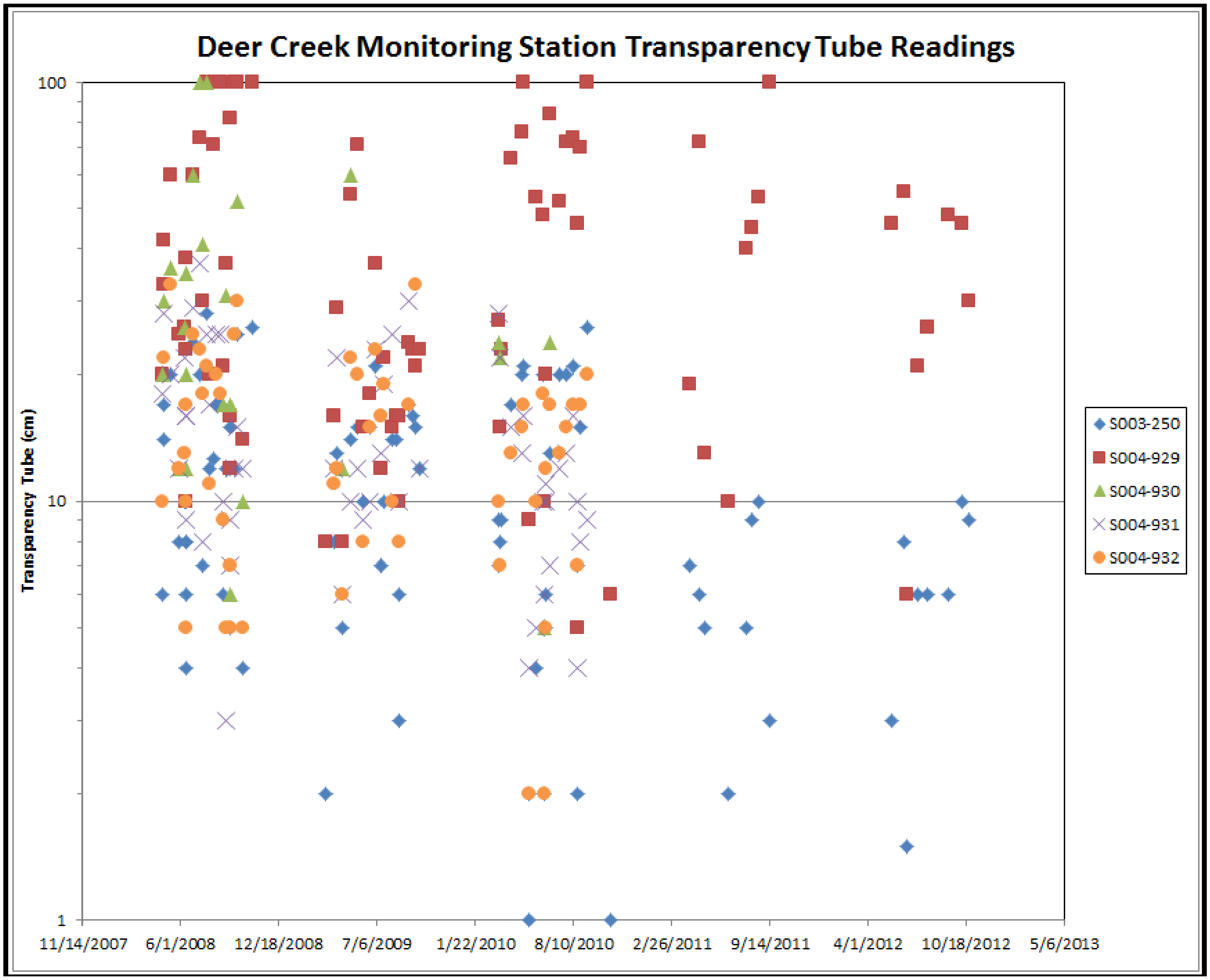


Figure 2.9 Transparency tube readings for Deer Creek monitoring stations

2.3.4 Loading Reductions

As indicated in Figures 2.2 and 2.3, the monitored 90th percentile TSS loading and water quality concentrations are above the NTU standard to varying degrees for all of the combined years under all flow conditions. As a result, varying levels of loading reductions are needed under each of five flow conditions, which are being equally applied to all of the load allocation components. To meet the requirements of the TMDL, daily load reductions of 99, 95, 56, 95 and 89 percent for the high, moist, mid, dry and low flow zones respectively are required.

2.4 Overall Conclusions from Turbidity-Related Monitoring and Sediment Sources Requiring Load Reductions

Some of the conclusions to be drawn from the project monitoring experience, data and assessments discussed in Sections 2.1 through 2.3 are the following:

- Based on the available data, the turbidity impairments in the watershed are significant when viewed across the entire sampling season. Turbidity readings at the Deer Creek outflow station (at Highway 23) are significantly higher than the 10 NTU standard for all parts of the flow regime.

- Median TSS loads at the Highway 23 station were recorded at 13314, 810, 94, 228, and 128 lbs/day for the high moist, mid, dry and low flow zones respectively. To meet the requirements of the TMDL, daily loads of 429, 73, 40, 40 and 27 lbs/day for the high, moist, mid, dry and low flow zones respectively are required. To meet the requirements of the TMDL, daily load reductions of 99, 95, 56, 95 and 89 percent for the high, moist, mid, dry and low flow zones respectively are required.

- The calculated Total Maximum Daily Load (TMDL) of TSS that serves as the loading capacity for each reach is based on the TSS concentration equivalent to the 10 NTU standard. For implementation planning purposes, an overall load reduction percentage can be made by comparing the existing dataset to the listing/delisting criteria for turbidity. To meet the requirements of the TMDL, daily load reductions between 56 and 99 percent will be needed, depending on the flow condition.

- Increased turbidity values were observed in all flow regimes between CSAH3 and CSAH6. This section of Deer Creek contains the sediment volcanoes which are a significant source of turbidity under low flow. As shown in Table 2.2, field turbidity was twice as high downstream of the sediment volcanoes under low flows.

- Primary sources contributing TSS within this watershed are mass-wasting and erosion of slumping stream banks, headcut erosion at migrating knickpoints, watershed-wide land use changes, and sediment volcanoes. Failing "Red Clay Dam" structures and livestock grazing in riparian areas have also been previously identified as TSS sources. The relative amounts of sediment loading from each of the primary sources has been considered in more detail as a part of an evaluation of watershed modeling, GIS terrain analysis and comparisons of the available water quality and quantity monitoring data (see Section 3.0). The watershed modeling indicates that a significant portion of the increased sediment loading estimated for the Deer Creek system can be attributed to near-channel sources of sediment.

3.0 Implementation Objectives and Priority Management

3.1 Implementation Objectives

A number of recommendations are made below to provide implementation strategies associated with each of the significant sediment loading sources within the Deer Creek watershed. Detailed watershed and groundwater modeling (presented in Table 3.1 and discussed in detail in Appendix A) has also been completed in conjunction with the TMDL implementation planning effort to identify and prioritize, more specifically, the types of BMPs that should be put into practice. Table 3.1 shows that approximately one third of the increase in sediment loading estimated for the Deer Creek system between the two monitoring stations can be attributed to near-channel sources of sediment. While the estimated sediment volcano loading represents a much smaller portion of the cumulative sediment load, as shown in Table 3.1, the water quality monitoring data discussed in Section 2.3.2 indicates that the sediment volcanoes are still contributing to the turbidity impairment under low flow conditions.

Table 3.1 Modeled and estimated sediment yield components (simulated for June, 2008 through October, 2010).

Monitoring Station	Total Contributing Drainage Area (acres)	Monitored Total Cumulative Sediment Yield (tons)	Simulated Near-Channel Sediment Yield (tons)	Estimated Sediment Volcano Loading (tons)
Deer Creek at CSAH 3	901	297	7	7
Deer Creek at Hwy. 23	5,063	2,626	732	35

The recommended implementation objectives are defined following a five-component framework for evaluating the health of a stream system that has been adopted by the Minnesota Department of Natural Resources (DNR) in their *Watershed Assessment Tool* (http://www.dnr.state.mn.us/watershed_tool/index.html). The five components are hydrology, connectivity, biology, geomorphology, and water quality.

3.1.1 Hydrology

The objective is to attain a hydrologic regime that better supports geomorphic stability and ecological function. To improve hydrological function in the watershed we plan on focusing on possible land cover changes associated with silviculture and assure future land use planning considers hydrology impacts. Increasing stream base flows and reducing storm event flows are specific recommendations.

Silviculture

Land cover changes between 2008 and 2010 in an area of Deer Creek point to the presence of silviculture in the area. During silviculture operations it is recommended that appropriate BMPs are implemented for each site and process. Carlton County SWCD is developing a logging BMP fact sheet with input from the forestry committee of the Nemadji River Basin Project. Carlton County has also zoned portions of the Deer Creek watershed to support forest management and minimize higher-density development (see Appendix B). The Red Clay Overlay District requirements apply to the entire Deer Creek watershed.

Carlton County implements all recommendations of the MN Forest Resources Council Forest Management Guidelines (FMGs), where applicable, for harvesting public lands in the Nemadji River basin. Past recommendations to private landowners in the watershed have been made to carry no more than 15% of ownership in forested cover types less than 15 years of age. This recommendation has been difficult to follow for some private land owners that may have to subject the entire property to harvesting due to economies of scale. In general, annual State Guideline Monitoring results in the Nemadji basin have shown greater than 90 percent compliance with the implementation of the FMGs for water quality and soil stabilization. Other projects within the watershed include Carlton County's pursuit of reestablishing long lived tree species. In addition, the NRCS Great Lakes Restoration Initiative (GLRI) project to re-vegetate private land open areas, and scrublands, has specifically targeted the Deer Creek watershed as an area for grants.

Watershed modeling completed for this study (and discussed in detail in Appendix A) has been used to assess the relative impacts on surface runoff and sediment contributions under a range of land use conditions. The results show that significant water quality and stream channel changes could result from changes to the current land use and land management within the watershed. Simulation of an all forested land cover scenario for the Deer Creek watershed indicated there would be reduction in total cumulative sediment yield of 16 to 20 percent from existing conditions. Results from the non-forested (or complete conversion to open space) simulation scenario indicate an increase in total cumulative sediment yield from existing conditions of 20 percent for Deer Creek at Hwy. 23 and an increase of more than 60 percent for Deer Creek at CSAH 3. Most of the elevated levels of changes in predicted erosion rates for the five years of simulated land cover change corresponded with higher runoff events that occurred each year during 2010, 2011 and 2012.

Watershed land use changes

Administered by the Zoning & Environmental Services office, Carlton County Zoning Ordinance #27 regulates a variety of shoreland activities to protect the integrity of the county's water resources. These activities include vegetation removal, grading and filling, and limiting impervious surfaces within shoreland areas. Shoreland properties also have specific setbacks from the OHWL for structures, sewer systems, and minimum lot area requirements for development.

Shoreland is defined by the Shoreland Management Overlay District which is comprised of the surface waters listed on the Carlton County Public Waters Inventory Map of 1985.

The Shoreland Management Overlay District includes the Red Clay Overlay District which is comprised of the entire basins of the St. Louis and Nemadji Rivers. The purpose is intended to establish additional setback requirements that reflect the unstable and highly erodible soil characteristics of several clayey soil associations within these basins. For example, a structure is required to have a 30 foot setback from the top of a bluff in shoreland areas of the Nemadji River watershed. Also, the allowed amount of cleared vegetation in a shoreland area is smaller within the basins of the St. Louis and Nemadji Rivers, compared to the other basins in the county.

Carlton County Zoning Ordinance #27 regulation of clearing vegetation also applies to defined shoreland being used for livestock watering. For example, if a shoreland stream is being used for livestock watering in the Nemadji basin, a maximum of 40 feet of woody vegetation can be cleared along the OHWL. The woody vegetation can be cleared and mowed or grazed, but no bare dirt may exist.

Carlton County Zoning Ordinance #30 requires compliance inspections for individual sewage treatment systems in shoreland areas anytime a zoning permit application is submitted to the Zoning & Environmental services office.

Development projects with nonconformities, such as lots and structures not meeting current ordinance standards, in the Shoreland Overlay District require an approved Shoreland Mitigation Plan when completing the variance application process. A mitigation plan often includes planting native vegetation buffers, controlling erosion and stormwater runoff.

Details on these activities are summarized in Appendix B or for more information contact the Carlton County Zoning & Environmental Services Office.

The Carlton County Zoning and Environmental Services Office is responsible for the implementation of the Carlton County Comprehensive Local Water Management Plan 2010-2020. The purpose of the plan is to provide the citizens of Carlton County, local government, state agencies and federal agencies with a strategic framework to manage its water and land resources.

3.1.2 Connectivity

The objective is to evaluate and restore the connectivity in the watershed system including fish passage, sediment transport in the stream and overall stream stability. Connectivity includes issues of vertical connectivity to groundwater and lateral connectivity to a stream's floodplain.

Any replacement or addition of a stream crossing should be done in a manner that does not disrupt aquatic passage and allows for sediment and wood debris transport. This can be achieved through proper design that includes burying of culverts. In the Deer Creek watershed and much of the greater Nemadji Watershed, special consideration should be made for rock grade control structure installation where the culvert is currently acting as the grade control. Any replacement or addition of a stream crossing on public waters is required to be authorized through a DNR Public Waters Work Permit. MDNR's design criteria for culvert crossings that allow for aquatic passage and maintain stream stability should be followed. Typically, the best replacement for a stream crossing is a span bridge. If that is not possible, the Stream Simulation (USFS, 2008) method is the next best option.

Culvert Inventory

A culvert inventory was recently completed to identify stream crossings and culverts that block fish passage and/or contribute sediment or channel instability to the stream. The culvert inventory was a USFWS Fish Passage Project, which targeted streams that a DNR Specialist identified as higher value trout habitat, then extended the data collection to include other perennial stream/road crossings in the Nemadji Watershed. Data was obtained from the top priority streams as well as a large majority of the perennial streams in the Nemadji River watershed, including specific culverts within the Deer Creek system. The data collected in the inventory includes culvert condition, stream condition, and culvert-stream relationship (i.e. if the culvert is perched above the stream bed). Results of the culvert inventory will be used to prioritize those structures that are in need of replacement or repair.

Culvert Design Training

Develop and host workshop events on the inter-related topics of culvert design, fish passage/ biologic connectivity and stream geomorphology impacts, specifically grade control and a shared understanding of the design criteria that are being used by the road authorities to ensure that these conveyances do not mobilize more sediment in the watershed.

3.1.3 Biology

The biological objective is to improve the ecological function of the stream ecosystem through the support of aquatic life use for cold water fish designated by Minnesota's water quality standards (MN R. 7050). This will be completed through the implementation of the objective of the four other watershed system components, while also evaluating the ecological condition of the stream and identifying functional needs for the ecosystem (pools, riffles, habitat, channel and bank stability, etc.). Some natural channel design stream restoration which targets sediment reduction will also improve habitat conditions.

3.1.4 Geomorphology

The objective is to restore and maintain channel stability of Deer Creek where necessary and feasible. Stability is defined as maintaining the dimensions, pattern and profile of stream channels so that the channel neither aggrades or degrades over time and is able to transport its water and sediment. Deer Creek stability issues include areas of excess incision and deposition. Incised stream reaches cannot access a floodplain during bankfull events. As a result, the banks, bed and bluff areas continue to erode. Four areas are highlighted as necessary to restore geomorphological features including livestock access to riparian areas and waterways, streambank destabilization and mass wasting, failing dam structures and the presence of sediment volcanoes.

Livestock Access to Riparian Areas and Waterways

Livestock producers should continue to implement measures to protect riparian areas and waterways, such as managing livestock access in riparian areas and providing off-site watering structures. Previous studies have shown hoof stresses in the riparian areas as a significant source of stream bank erosion in the Deer Creek watershed. Continuing the current practices of limiting livestock access to these areas can reduce stresses and stabilize the banks. It is recommended that an update to the last animal registration and county feedlot inventory conducted in 1996 be completed as a part of the implementation phase.

Stream Channel Destabilization and Mass Wasting

Several streambank erosion and slumping features have been inventoried in the watershed and documented with GIS terrain analysis and stream channel metrics. In addition, significant knickpoint features were indicated with the LiDAR data (but were not field-verified) in the main stem and primary tributary to Deer Creek that may have experienced significant erosion and are expected to be subject to ongoing migration in the future. While the severity of these sites will continue to be monitored in the future, the modeling completed for this study (see Appendix A) has been used to assess the relative magnitude of the sediment contributions from each source area and LiDAR GIS terrain analysis has also been used to prioritize areas for implementation. Activities intended to address these sources of sediment are a high priority for the watershed and are discussed in more detail in Section 3.2. As projects are developed to address the issue, a careful evaluation of flood plain connectivity and potential for bluff stabilization should be incorporated into the design plans. Natural Channel Restoration Design is a tool appropriate for these evaluations and also aid in stream channel re-design to mitigate bank destabilization.

Failing Dam Structures

As discussed in Section 2.2, at least 3 out of the 4 Red Clay Dam structures are failing and in need of repair in the Deer Creek watershed. The Carlton SWCD successfully obtained Clean Water Funds to address these failing structures. Engineering plans will be developed for erosion control measures on the three structures in the Deer Creek watershed in phase three of a three phase project. This activity is a high priority for the watershed.

Sediment Volcanoes

While several sediment volcanoes have been documented in the Deer Creek watershed, the monitoring data indicates that the sediment volcano features shown in Figure 1.1 are likely a smaller contribution to the turbidity impairment in this reach (see Table 3.1). The water quality and quantity monitoring data, combined with the watershed and groundwater modeling completed for this study, has been used to assess the relative contributions from the sediment volcanoes in the watershed and evaluate whether there are feasible options to improve their influence over stream water quality. Activities intended to address these sources of sediment are a high priority for the watershed and are discussed in more detail in Section 3.2.

3.1.5 Water Quality

The water quality objective is to support aquatic life in a cold-water ecosystem by reducing sediment concentration in Deer Creek to meet TMDL targets. This objective will be met through integrating water quality activities with riparian and stream channel and bluff management for sediment control, implementing and maintaining silviculture practices to limit the water quality effects of land use changes in the watershed, and implementing construction and industrial stormwater management practices.

Construction Stormwater Implementation

The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites $\geq$ 1 acre expected to be active in the watershed at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

Industrial Stormwater Implementation

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

3.2 Evaluation of BMP Effectiveness and Priority Ranking for Sediment Reduction Strategies

With limited time, staff and funding opportunities for restoration efforts, an attempt has been made to determine what best management practices would be practical, economically feasible, and environmentally effective in reducing turbidity loading in the Deer Creek watershed. This includes consideration of the expected cost-effectiveness of best management practices that should be undertaken, based on existing applicable knowledge. Table 3.2 provides a summary of the proposed implementation activities and estimated costs for restoration in the Deer Creek watershed. In addition to these implementation activities, it is expected that the Deer Creek Watershed Technical Team will continue to meet and Carlton County will maintain educational and outreach information on their website and conduct annual meetings with lake and stream groups. The following sections provide more detail about considerations for addressing erosion from streambank slumping and sediment volcano discharges to the stream.

3.2.1 Streambank Slumping

A GIS terrain analysis was conducted to evaluate the potential for streambank slumping in the Deer Creek watershed and compared with information collected to field-verify the predictive capabilities of the GIS analysis. The results of this analysis (shown in Figure 3.1) show the sites that possess steep slopes combined with the highest percentiles for plan and profile curvatures. Figure 3.2 shows how the streambank slumping sites correspond to the profiles of Deer Creek and the primary tributary. In general, the slumps identified and located in the GIS analysis correspond with the stream reaches that have higher gradient and would likely be undergoing more incision and active degradation.

After incorporating stream channel metrics for near-bank stress with the slump characteristics, the erosion potential from the streambank slumping source areas identified in GIS were subdivided into three categories: high, medium and lower. It should be noted that the "lower" category of erosion potential represents a high risk for erosion (because it corresponds with the highest percentiles in the terrain analysis), but the volume of sediment erosion may not be as great as the higher risk categories. Table 3.2 indicates corresponding implementation activities for each one of these three categories of erosion potential, but in practice, it is anticipated that attempts to address each erosion category will be more economical on a reach-by-reach basis.

Figure 3.1 also shows the locations of the red clay dam sites. There is an active migrating knickpoint and significant channel degradation immediately downstream of Dam4 that will also need to be addressed.

Figure 3.2 also shows that both Deer Creek and the primary tributary have the high potential for significant knickpoints (at uncontrolled changes in grade) that are downstream of the area where sediment volcanoes are located. Implementation of constructed rock riffles to control the grade and address headcut erosion at both of the migrating knickpoints is a high priority (see Table 3.2).

Access to each of the slumps that were identified and prioritized in GIS will likely be difficult, which may not warrant construction activities with heavy equipment. Several stream reaches are more likely to self-stabilize if vegetation is managed. Trees may need to be thinned at locations that have already slumped to provide greater sunlight to ground vegetation. Drainage patterns of failure areas should be reviewed to store and/or redirect local drainage around eroding slopes as needed to reduce concentrated flow over the bank. Grade control and energy dissipation is recommended for ravines that are adjacent to slumps.

In the lower portion of the watershed, control of groundwater seepage should also be considered. Large slumps or slope failures adjacent to the creek should be stabilized and the creek redirected away from the bank toe. The stabilized bank should be revegetated with native vegetation and provided with erosion control. Erosion should be monitored to determine whether conditions are worsening at each site.

3.2.2 Sediment Volcanoes

The discharge of water and sediment associated with the sediment volcanoes is a complex issue with several confounding variables. Groundwater modeling has been completed to evaluate whether restoring an impoundment at the site of the sediment volcanoes should be considered as a way of reducing groundwater flow and entrainment of clay particles in the downstream flow.

Since access to the site of the sediment volcanoes is difficult, and there is a high potential for significant land disturbance adjacent to the stream, it is recommended that the initial study of feasible options to control sediment begin with the installation of drive point piezometers at the site. Four of these piezometers would be installed in the stream bed near the sediment volcano, with two nests of two. At each nest location, one piezometer would be installed at about 3 feet and one as deep as possible. Head measurements would be collected to better understand the depth that would be required for an impoundment at the site. These piezometers can also be sampled, if necessary, but are only temporary and would likely need to be replaced if long-term evaluations are desired. The costs associated with this field work are largely going to be driven by the need for planning and consideration of safety issues. The estimated cost for completing this monitoring and the development of a feasibility study is included in Table 3.2.

If drive point piezometers alone are inconclusive, piezometers and geologic borings could be installed with a tripod drilling rig. This larger effort allows for going deeper and the ability to log the geology in much greater detail than what currently exists. Two nests of two borings would again be installed, similar to the drive point piezometers. Sediment from cores could also be sampled for isotopes to compare sources. The same issues with planning and safety costs will need to be considered for this option, as well.

Other options that could be considered to address the sediment volcanoes include larger, more permanent wells that would flow or be pumped to reduce head at depth and in turn reduce upward pressures at the stream bed that is suspending sediment or a French drain system that would collect groundwater inflow at the stream bed in the area of the sediment volcanoes and discharge to a location where it can be controlled or treated. Both of these options may not be feasible or worth the costs unless data from one of the aforementioned options (above) indicate otherwise.

Table 3.2 Proposed implementation activities, estimated costs and prioritization for Deer Creek restoration.

Priority/ Scheduling[1]	Activity	Estimated Cost[2]	Project Lead and Partners	Labeled Location(s) Indicated on Figure 3.1
High-Ongoing	Corrective Actions for Red Clay Dam Failures	$1,000,000	Carlton SWCD, NRCS, BWSR	Dam2 through Dam4
High	Staff (1 FTE) to Oversee Red Clay Dam Restoration and Stream Channel Stabilization Projects	$60,000-$80,000 per year	Carlton SWCD, NRCS	--
High-Ongoing	Culvert Prioritization and Repair/Replacement	$50,000-$200,000	Carlton SWCD, MnDOT, MDNR	--
High	Constructed Rock Riffles for Stabilization of Migrating Knickpoints	$50,000-$150,000	Carlton SWCD, MDNR, MPCA, BWSR	KP1 and KP2
High	High Priority Streambank Slump Stabilization	$100,000-$500,000	Carlton SWCD, MDNR, MPCA, BWSR	H1 through H30
High-Ongoing	Shoreland Ordinance Revisions/Possible Development of Conservation Overlay Districts and Forestry Education	$	Carlton County	--
Medium	Update to County Feedlot Inventory/Livestock Exclusion	$50,000	Carlton SWCD, MPCA	--
Medium	Medium Priority Streambank Slump Stabilization	$100,000-$500,000	Carlton SWCD, MDNR, MPCA, BWSR	M1 through M24
Medium	Sediment Volcano Monitoring/Feasibility Study	$30,000-$100,000	Carlton SWCD, MDNR, MPCA, BWSR	SV1
Lower	Sediment Volcano Impoundment	$100,000-$500,000	Carlton SWCD, MDNR, MPCA, BWSR	SV1
Lower	Lower Priority Streambank Slump Stabilization	$100,000-$500,000	Carlton SWCD, MDNR, MPCA, BWSR	L1 through L20
Lower	Biennial Ordinance Workshop for Contractors/Developers	$	Carlton County	--
Lower	Ordinance Workshops for Lake Associations/Shoreland Owners	$	Carlton County	--
Lower	Educate Board of Adjust Committee Members	$	Carlton County	--
GRAND TOTAL		**$1,590,000-$3,580,000**		

[1]High priority items are scheduled for completion during the first five years, medium for the second five years and lower priorities for ten to 30 years after plan approval; some activities are ongoing
[2]Order of magnitude cost estimates including planning/implementation (mobilization, engineering/design, contingencies); easement costs not included

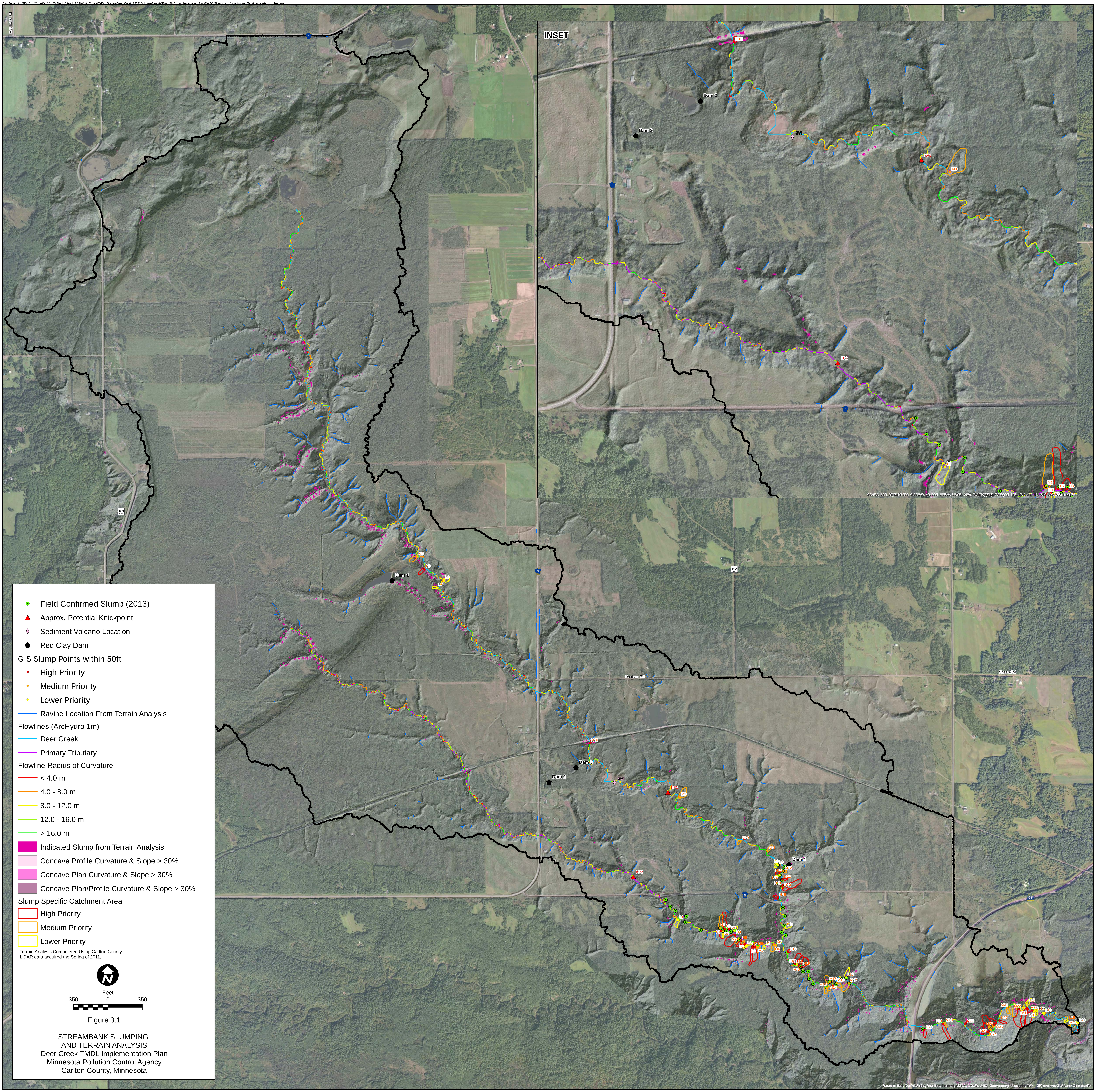


Figure 3.1

STREAMBANK SLUMPING
AND TERRAIN ANALYSIS
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota

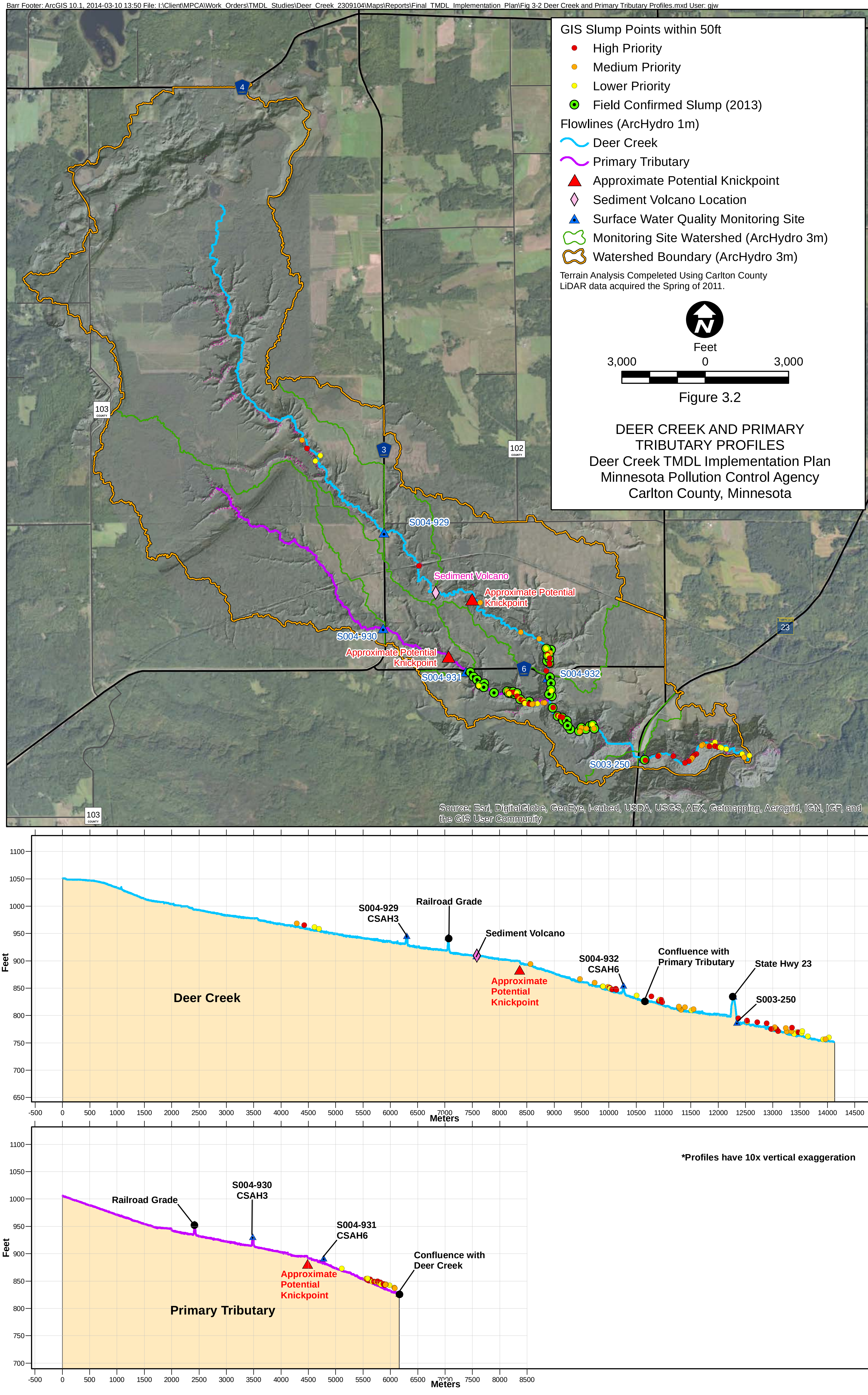


Figure 3.2

DEER CREEK AND PRIMARY TRIBUTARY PROFILES
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota

3.3 Monitoring

The goals of follow-up monitoring are generally to both evaluate progress toward the water quality targets provided in the TMDL and to inform and guide implementation activities. The MPCA has recently begun implementation of a 10-year rotation for watershed work. MPCA employs an intensive watershed monitoring schedule that provides comprehensive assessments of all of the major watersheds (HUC 8 digit) on a ten-year cycle. This schedule provides intensive biological monitoring of streams and lakes within each major watershed to determine overall health of the water resources, to identify impaired waters, and to identify those waters in need of additional protection to prevent future impairments. The Nemadji watershed began this rotational cycle in 2011. Monitoring at this intensive level will occur again in 2021. More specific monitoring plan(s) will be developed as part of implementation efforts. The impaired water body will remain listed until water quality standards are met. Additional monitoring will primarily be conducted by local staff, citizen volunteers, MPCA and DNR staff.

For the purposes of this TMDL, 2008-2010 represents the baseline condition that future implementation activities should be measured against. As previously discussed, increases in runoff volume and peak flow associated with conversion of natural land cover and increased density of development lead to a shift in the flow duration characteristics, which in turn, correspond with higher rates of sediment delivery capacity in the stream that contributes to streambank slumping, ravine and gully erosion and represents a significant stressor to aquatic life in Deer Creek.

3.3.1 Turbidity specific monitoring

At a minimum, monitoring will be continued at the Deer Creek downstream site at Highway 23 for assessment/study purposes. This monitoring will occur during the open water season and at a frequency and timing similar to previous turbidity assessment monitoring.

Additional monitoring sites may be needed to further investigate the sediment sources from the sediment volcanoes. Stations directly upstream and downstream of the sediment volcanoes can be used to determine how sediment loads at the outflow are impacted by the sediment volcanoes.

3.3.2 Geomorphology

Slumping, erosion, and the relation to land use practices has been studied extensively in the Nemadji River watershed, including Deer Creek. Watershed characteristics that influence the slumping and stream erosion have been documented. This data includes streambank erosion and vegetation analysis, stream metric data, roadside erosion and slump inventories, as well as slump and land use mapping and analysis. Figure 3.3 shows several of the significant features that have been identified throughout the Deer Creek watershed, including the stream survey locations from 2011.

If stabilization of the erosion sites is not undertaken, they should be monitored to determine the rate of erosion. This could be accomplished by establishing benchmarks and performing high-definition laser scanning of the erosion sites, which would be difficult to survey using traditional methods. The survey should be repeated every 2 to 3 years and following severe runoff events. Monitoring the sites over a period of years will provide a better picture of which erosion sites are most active. In addition, a geotechnical investigation should be performed to gain insight into the role soils and groundwater play in the mass-wasting processes. Finally, a more detailed investigation of local sources of runoff to the eroding areas should be performed to determine if upland best management practices can be implemented to reduce the rate and volume of runoff, as well as the likelihood of erosion in the headwater channels.

Down cutting and bank erosion were observed in some reaches of the stream. It is recommended that a more detailed survey of the stream be repeated, with a survey of the thalweg profile and periodic cross-sections. Several cross-sections have been surveyed in the past and those cross-sections should be re-surveyed for comparison. This survey should be performed during leaf-off season so that GPS readings can be recorded.

3.4 Adaptive Management

An adaptive management approach will be implemented to assess the impact each of the implementation actions are having on the turbidity levels in Deer Creek. An adaptive management plan includes continued water quality monitoring as each of the improvements are implemented. Items will be conducted based on the priority outlined in Section 3.2. If water quality is shown to improve it is suggested that the approach is working and the implementation will continue. However if water quality is not shown to improve the approach will be evaluated and adjusted in order to meet the required water quality levels.

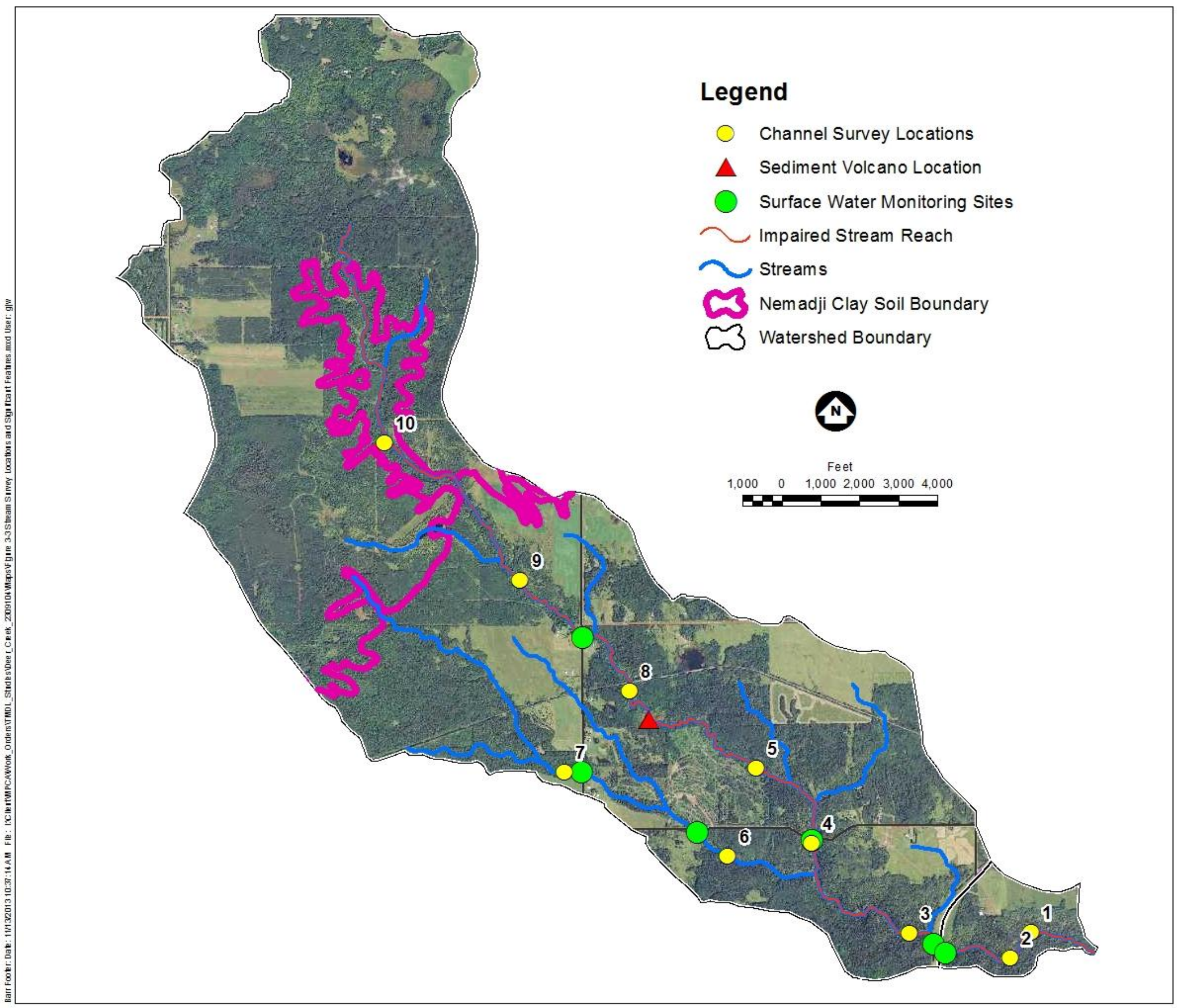


Figure 3.3 Deer Creek stream survey locations and significant features

3.5 Reasonable Assurance

The following should be considered as reasonable assurance that implementation will occur and result in sediment load reductions in the listed waters toward meeting their designated uses:

- Monitoring will be conducted to track progress and suggest adjustment in the implementation approach.

- The Nemadji River basin is a focus area for water quality work in the county. The Nemadji River, including the Deer Creek watershed, is part of the Carlton County water plan and SWCD annual plan of work. Inclusion of the watershed in county work plans makes project work in the watershed eligible for state funding resources from the Clean Water, Land, and Legacy Act and other state generated funding sources. In addition, two federal organizations, the Natural Resources Conservation Service and Great Lakes Commission Erosion and Sediment Control Program list the Nemadji Basin as a target area for their funding programs.

- The Nemadji River is part of the St. Louis River Area of Concern (AOC), which was designated by the Great Lakes Water Quality Agreement (WQA) between the United States and Canada in 1972. Nine beneficial use impairments have been recognized: 1) Restrictions on fish and wildlife consumption; 2) Degradation of fish and wildlife populations; 3) Fish tumors or other deformities; 4) Degradation of benthos; 5) Restrictions on dredging activities; 6) Eutrophication or undesirable algae; 7) Beach closings; 8) Degradation of aesthetics; and 9) Loss of fish and wildlife habitat. A Remedial Action Plan (RAP) was developed in 1987. The goal of the RAP is to define problems and their causes, and then recommend actions and timetables to restore all beneficial uses of AOCs. Restoring uses is to be achieved through implementation of programs and measures to control pollution sources and remediate environmental problems. Governments within the boundaries of the AOC, and an area citizen organization participate in furthering the goals of the RAP and evaluate progress toward those goals.

- The local community has invested 30 years of effort in this watershed. As projects evolved, more citizens have come forward as citizen volunteers. Project work in the watershed has been continuous over the past 10 years with large acreage tree plantings, culvert repairs, road repairs, sediment control structure assessments and repair.

3.6 Education and Outreach

Carlton County and the Carlton SWCD provide educational and outreach opportunities to various audiences on a wide variety of runoff management and water quality issues. Current opportunities include BMPs for silviculture, livestock access and shoreland activities.

Additional outreach activities include education on stream and watershed health, which may include specific targeted training for proper stream crossing design and education about the proper design of culverts installed on private property.

The MN DNR in cooperation with EPA have developed methods to identify locations within watersheds (i.e. the subwatershed and catchment scales) that are at risk due to impacts related to the amount of open land within the watershed. This work can be utilized to inform forest management decisions within impacted watersheds, subwatersheds and catchments. Possible applications of this effort may include education and outreach efforts designed to inform landowners of open land impacts to watersheds, reforestation efforts in targeted locations where such work can reduce the percentage of open land below the impact threshold, and coordination of timber sale activity across land ownerships to effectively maintain open land amounts below threshold.

3.7 Public and Stakeholder Participation

A number of opportunities were made for both public and stakeholder participation in the Deer Creek TMDL process during the last two years. These opportunities included:

- Updates in the SWCD newsletter distributed to 2600 landowners,
- Distribution of draft reports for review and comments to Stewardship committee members,
- Dialog at meetings of the Nemadji Stewardship committee and SWCD board, both ongoing venues for public and watershed residents to participate,
- Continued and timely postings to the Nemadji River and Deer Creek web pages hosted by the SWCD, and
- An open house meeting to benefit public review of the final draft during the public notice period.

An "open house" style event was held to highlight the Deer Creek Turbidity TMDL report and to provide discussion of likely Best Management Practices to improve water quality. The event was titled "Deer Creek TMDL Open House Event, Improving the Deer Creek Watershed" and held on Wednesday, April 17th, 6pm to 7:30pm, at the Carlton County Transportation building.

Outreach to advertise the event included a press release and informational flyer sent to the following local organizations: the Pine Journal newspaper, the Moose Lake Star Gazette newspaper, the clerks of Blackhoof Township and Wrenshall Township, the Nemadji Watershed Stewardship Committee, and the Carlton County Soil and Water Conservation District (SWCD) Board of elected officials. Personal invitations were extended to: Carlton County Land Department – Greg Bernu, Carlton County Transportation Department – Mike Tardy and Milt Hagen, Natural Resources Conservation Service – Dan Weber, Boreal Natives – Jeff West, Carlton County Commissioners and the county Zoning & Environmental Services staff. All who were invited by personal invitation attended the event.

In addition, notices were posted at the following community bulletin boards: the local grocery store, post office, barber shop, and well frequented town diner. The SWCD social media page, (Facebook), announced the open house. The Nemadji watershed newsletter, reaching 2,576 landowners, included an announcement for the open house. The newsletter generated 6 responses from citizens interested in stream/rain gage monitoring and membership in the stewardship committee. One individual stopped at the SWCD office to discuss how the TMDL report might affect local cattle producers or farmers. However, no official statement/comment was received on that subject. The open house meeting was sparsely attended. Weather reports for that evening indicated a significant snowfall was expected, and that might have been a deterrent to attendance.

The TMDL was public noticed from March 25 to April 23, 2013 via the State Register. Five responses were received via email. Two responders requested extensions to the comment period. Three submitted comments on various aspects of the TMDL report.

3.8 Interim Milestones

It can take many years for stream systems to respond to sediment load reduction and runoff control activities in the watershed. Interim measures will need to be implemented to assess the progress toward achieving the water quality standards and restoration of biotic integrity. These activities could include:

- Tracking of new BMPs retrofit into the watershed, including the number, types, and estimated load reduction for each

- Tracking of the participation of private property owners in existing programs to implement runoff and erosion controls, native creek buffers, etc. including their location and type of project implemented
- Documentation of new or modified educational materials and activities that address sediment management and control of surface runoff

These milestones will provide information that documents the progress being made to achieve the TMDL even when water quality improvement is not yet observed in the creek. The water quality monitoring program for this *TMDL Implementation Plan* is discussed in Section 3.3.

References

Andrews, S. C., Christensen, R.G., Wilson, C.D. 1980. Impact of nonpoint pollution control on western Lake Superior. Red clay project final report part III. USEPA report 905/9-76-002, Washington, D.C.

Banks, G., Brooks, K. 1996. Erosion–sedimentation and nonpoint pollution in the Nemadji Watershed: status of our knowledge. University of Minnesota, Department of Forest Resources, St Paul.

Bernu, G. 2012. Personal communication.

Carlton County Soil and Water Conservation District (CCSWCD). 2005. Nemadji River Basin Project Newsletter. Summer.

Duan, N. 1983. Smearing estimate: A nonparametric retransformation method. J. of the American Statistical Association. 78 (383), 605–610.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

Kemp, A.L.W., Dell, C.I., Harper, N.S., 1978. Sedimentation rates and a sediment budget for Lake Superior. J. Great Lakes Res. 4 (3–4), 276–287.

Koch, R.G., Kapustka, L.A., Koch, L.M., 1977. Presettlement vegetation of the Nemadji River Basin. J. Minn. Academy Sci. 43, 19–23.

Magner, J. 2004. Channel Stability Monitoring in the Nemadji River Basin.

Minnesota Pollution Control Agency (MPCA). 2007a. *The Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment.* http://www.pca.state.mn.us/publications/manuals/tmdl-guidancemanual04.pdf

MPCA. 2007b. Turbidity TMDL Protocols and Submittal Requirements. Accessed December 13, 2007 at http://www.pca.state.mn.us/publications/wq-iw1-07.pdf.

Mooers, H.D., and Wattrus, N.L., 2005. Results of Deer Creek Groundwater Seepage Investigation Report to Carlton County Planning and Zoning Department, 29p.

Mossberger, I.G. 2010. Potential for Slumps, Sediment Volcanoes, and Excess Turbidity in the Nemadji River Basin. M.S. Thesis. University of Minnesota.

Natural Resources Conservation Service (NRCS), 1996. Memorandum.

NRCS, 1998a. Nemadji River Basin Project Report. USDA Natural Resources Conservation Service, St Paul, MN.

NRCS, 1998b. Appendix F—Sediment Budget Process. In: Nemadji River Basin Project Report. USDA Natural Resources Conservation Service, St Paul, MN.

Riedel, M. S., Brooks, K. N., Verry, E. S. 2006. Stream Bank Stability Assessment in Grazed

Riparian Areas. Proceedings of the Eight Federal Interagency Sedimentation Conference (8th FISC), April 2-6, 2006 Reno, NV.

Riedel, M. S., Verry, E. S., Brooks, K. N. 2005. Impacts of lake use conversion on bankfull discharge and mass wasting. Journal of Environmental Management. 76 326-337.

U.S. Environmental Protection Agency. 1999. *Protocol for Developing Sediment TMDLs, First Edition* EPA 841-B-99-004. Washington, D.C.

U.S. Forest Service (USFS). 2008. *Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings.* 0877 1801—SDTDC. National Technology and Development Program. San Dimas, CA. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_054564.pdf

Verry, E. S. 2000. Society of American Foresters. In Society of American Foresters (ed.) *Land Fragmentation and Impacts to Streams and Fish in the Central and Upper Midwest*. pp. 16-20. Washington, DC: SAF Publ 01-02.

Appendix A

Watershed and Groundwater Modeling

Appendix A: Deer Creek Watershed and Groundwater Modeling

Prepared in support of the Deer Creek Watershed Total Maximum Daily Load Implementation Plan

December, 2013

Appendix A: Deer Creek Watershed and Groundwater Modeling

Prepared in support of the Deer Creek Watershed Total Maximum Daily Load Implementation Plan

December, 2013

BARR

4700 West 77th Street
Minneapolis, MN 55435-4803
Phone: (952) 832-2600
Fax: (952) 832-2601

Deer Creek Watershed and Groundwater Modeling

December, 2013

Table of Contents

1.0 Introduction 1
1.1 Historical Nature of the Problem 1
1.2 Model Scope and Objectives 1
2.0 Geology of Project Area 2
2.1 Surficial and Unconsolidated Geology 2
2.2 Bedrock Geology 2
3.0 Model Selection and Development 3
3.1 MODFLOW Groundwater Model 3
3.1.1 Model Domain and Discretization 4
3.1.2 Boundary Conditions and Parameters 5
3.1.3 Solvers and Convergence Criteria 6
3.2 SWAT Surface Water Model 6
3.2.1 Land Use 7
3.2.2 Soils 7
3.2.3 Topography 7
3.2.4 HRUs / Subwatersheds 7
3.3 Description of Model Linkage 8
3.4 Model Optimization 9
3.4.1 Calibration Targets 10
3.4.1.1 Hydraulic Head 10
3.4.1.2 Baseflow 11
3.4.1.3 Surface Water Runoff 11
3.4.1.4 Sediment Yield 11
3.4.2 Optimization Goals 12
3.4.3 Optimization Parameters 12
3.5 Optimization Results 13
3.5.1 Flow and Hydraulic Head 13
3.5.2 Watershed Recharge 14
3.5.3 Sediment Loading 14
4.0 Results of Modeled Land Use Change Scenarios 16
5.0 References 17

List of Figures

Figure A-1 – Surficial Geology
Figure A-2 – Geologic Cross Section A to A'
Figure A-3 – Geologic Cross Section B to B'
Figure A-4 – Bedrock Geology
Figure A-5 – Groundwater Model Domain
Figure A-6 – Hydraulic Conductivity Zones
Figure A-7 – Simulated and Measured Average Monthly Flow, Deer Creek at Hwy. 23 (S003-250)
Figure A-8 – Simulated and Measured Average Monthly Flow, Deer Creek at CSAH 3 (S004-929)
Figure A-9 – Measured vs. Simulated Hydraulic Head, Regional Hydraulic Head Targets
Figure A-10 – Measured vs. Simulated Hydraulic Head, Local Hydraulic Head Targets
Figure A-11 – Groundwater Recharge
Figure A-12 – Cumulative Sediment Yields, All Forest vs. Existing Land Use
Figure A-13 – Cumulative Sediment Yields, Complete Logging vs. Existing Land Use

1.0 Introduction

1.1 Historical Nature of the Problem

Deer Creek, a small perennial tributary to the Nemadji River, located in Carlton County Minnesota, has been identified as a significant source of sediment loading within the Nemadji River basin, which ultimately discharges to Lake Superior. In 2004, Deer Creek was placed on the 303(d) list of impaired waters for elevated turbidity levels. Erosion of stream banks, consisting of silty-clay and glacial till complexes, contribute the largest load of sediment in the upper Nemadji River basin (Andrews et al., 1980, Banks and Brooks, 1996). The erosion of these banks is primarily controlled by cohesiveness of the sediments, the relationship between shear strength and shear stress of the sediments, seepage of groundwater, and stream flow (Mooers and Wattrus, 2005). Some of these controlling factors may have been impacted by changes in land use and/or climate. To assess the relationship between groundwater and surface water, and the influences of land use on that complex relationship, a groundwater-surface water model was constructed as part of this study.

1.2 Model Scope and Objectives

The modeling conducted for this study was designed to assess groundwater-surface water interaction for Deer Creek. In order to assess this relationship, a model capable of simulating both surficial hydrologic processes and groundwater flow is necessary. The coupling of two models, SWAT and MODFLOW, was chosen to accomplish this task. The two models were constructed to:

- Include a simplified, but robust, representation of the essential hydrologic and hydrogeologic features in the study area
- Simulate observed hydraulic heads and stream flows that are consistent with available data
- Allow for assessment of scenarios (i.e. changes in land use) to measure the effects on stream flow and sediment transport to aid in the Deer Creek TMDL process.

2.0 Geology of Project Area

2.1 Surficial and Unconsolidated Geology

Unconsolidated sediments of the Deer Creek watershed consist of a complex sequence of lacustrine silt and clay deposits intermixed with glacial till and coarser grained sand and gravel lenses. Surficial deposits in the northern portion of the watershed consist predominantly of near-shore and deltaic sands, and unsorted glacial till, sand, and gravel of the Thomson Moraine (Figure A-1). Surficial sediments in the southern portion of the watershed consist of a thin, 1 to 20 foot thick, mantle of red to reddish-gray carbonate rich till (Knife River member of the Barnum Formation). Underlying the thin mantle of till is 20 to 200 feet of massive silty-clay (Figures A-2 and A-3), with local silt to fine-grained sand layers (Wrenshall member of the Barnum Formation) (Knaeble and Hobbs, 2009). A large bedrock valley runs southwest to northeast below the Deer Creek watershed (Figure A-4). The depth to bedrock across the Deer Creek watershed ranges from less than 100 feet near where Deer Creek discharges to the Nemadji River, to over 750 feet near the center of the watershed along the axis of the bedrock valley. Sediments at depth within the bedrock valley are generally unknown, or undifferentiated, due to lack of geologic records at these depths (Knaeble and Hobbs, 2009).

Mooers and Wattrus (2005) identified at least two confined sand units near the Deer Creek watershed overlain by up to 42 meters (138 ft) of confining clay. Mooers and Wattrus (2005) hypothesized that these sand bodies are hydraulically connected to larger surficial sand complexes in the far northern part of the watershed (Figure A-1) as well as within the Thomson Moraine north of the watershed.

2.2 Bedrock Geology

Bedrock lithology below the Deer Creek watershed (Figure A-4) consists entirely of the Fond du Lac Formation; a light orange to reddish-brown sandstone, mudstone and conglomerate. To the south is the Hinckley Sandstone; a tan to orange, fine-to medium-grained quartz arenite. To the north are slates and metamorphosed greywacke of the Thompson Formation.

3.0 Model Selection and Development

Model selection is primarily determined by the purpose and objectives of the model and the availability of data. For this study, the industry standard groundwater flow code MODFLOW (Harbaugh, 2005; Niswonger et al., 2011) was used in conjunction with the surface water model code SWAT (Neitsch et al., 2011). MODFLOW is the industry standard finite difference, 3-D, groundwater flow model developed by the USGS. SWAT is a physically based, watershed scale model developed by the USDA to assess the impacts of different land management practices on stream flow along with chemical and sediment loading. These two models were primarily designed to simulate separate spectrums of the hydrologic cycle – SWAT for surface water and MODFLOW for groundwater. SWAT only considers groundwater in a simple "black-box" perfunctory fashion. While in most MODFLOW models, surface-water features are used as boundary conditions acting as either a source or sink for groundwater to help maintain an appropriate water balance, and groundwater recharge is typically estimated using inverse modeling methods, or other non-physically based methods. These two models (SWAT and MODFLOW) were used in tandem, allowing for the strengths of each model to substitute for the weaknesses of the other. Essentially, SWAT was used to calculate surface-water runoff and produce recharge values for MODFLOW. MODFLOW was used to simulate groundwater flow in the aquifer and baseflow to the stream.

3.1 MODFLOW Groundwater Model

MODFLOW simulates three-dimensional, steady-state and transient groundwater flow (saturated) using finite-difference approximations of the following differential equation of groundwater flow:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right)-W = S_s \frac{\partial h}{\partial t}$$

where:

K_x, K_y, and K_z are values of hydraulic conductivity along the x, y, and z coordinate axes

W is volumetric flux from water sources and sinks

S_s is specific storage

h is hydraulic head

t is time

MODFLOW was developed by the USGS and is in the public domain. It is widely used and accepted. The graphical user interface Groundwater Vistas (ver. 6.4) (Environmental Simulations, Inc. 2011) was used to help construct the MODFLOW model for this application. The version of MODFLOW used in this study is MODFLOW-NWT (Niswonger et al., 2011).

3.1.1 Model Domain and Discretization

The groundwater model covers an area of 1,351 mi^2 (3,500 km^2) and is shown on Figure A-5. The primary area of interest for this study was the Deer Creek watershed, located in Carlton County, Minnesota. The size of the model domain was chosen to capture the effect of differing surface-water and groundwater watersheds, and to limit the effects of boundary conditions on the area of interest. The model is divided into four layers to capture groundwater flow in both the unconsolidated and bedrock aquifers. In general, model layers one and two represent unconsolidated Quaternary sediments and model layers three and four represent bedrock. The extent of the active model domain for layers one and two is consistent with physical boundaries (Figure A-5); to the south, west and east, the active domain of layers one and two extends to edge of the Nemadji River watershed; to the north the domain extends beyond the Nemadji River watershed to the St. Louis River and Lake Superior. The extent of the active model domain is greater for layers three and four, in which the bedrock groundwater flow system is simulated (Figure A-5). The boundaries defining the active extent for layers three and four are represented with constant head cells (see Section 3.1.2); these were chosen to limit boundary effects in the area of interest and are not related to physical boundaries.

The model domain is subdivided into rectilinear grid cells to solve the finite-difference approximations. The model grid consists of 695 rows, 759 columns, and 4 layers, for a total of 2,110,020 cells, of which 1,794,432 cells are active during the simulation. The size of the model cells varies throughout the model domain from a maximum size of 234 meters by 234 meters far from the area of interest to a minimum size of 20 meters by 20 meters across the Deer Creek watershed. The length unit of the model is meters and site coordinates are in UTM NAD83, Zone 15N. The X offset of the model grid origin is 519,000 meters and the Y offset of the origin is 5,127,000 meters.

Time is discretized in the model using a unit of days. For model calibration a steady-state solution was used (see Section 3.4), and hence, time is not part of the solution. Post calibration, the model was converted to transient. The transient simulation covers January 2007 to December 2010 using monthly stress periods with a time-step length of two days.

3.1.2 Boundary Conditions and Parameters

Boundary conditions establish the sources and sinks of water for a groundwater flow model (e.g. river, lakes, constant-head cells, and no-flow cells). The geologic and hydrogeologic conceptual model aids in the selection of appropriate boundary conditions. Parameter values define aquifer and boundary properties (e.g. hydraulic conductivity, river bed conductance, and recharge) and are either fixed at some defined value or are adjusted within expected ranges during model calibration. Boundary conditions and model parameters are described in the following sections.

Constant Head Boundaries

A constant head boundary was assigned along the northeast edge of the model domain and represents Lake Superior and the St. Louis Bay, both major groundwater discharge zones in the region. These constant head cells were assigned an elevation of 183.49 meters based on stage elevation from USGS topographic maps. At depth, within the bedrock groundwater flow system, constant head cells were assigned along the perimeter of the model domain in layers three and four. Hydraulic head elevations for these perimeter constant head cells were defined using an interpolated bedrock potentiometric surface using data from Carlton and Pine County hydrogeologic atlases (Berg, 2004; Berg, 2011) and static water levels from wells within Wisconsin.

Rivers

Rivers and streams within the model domain are represented using the river package. Stream stage was estimated based on interpolated values from a digital elevation model and remained fixed throughout the model simulation. Conductance for the river cells was adjusted as an estimated parameter during model calibration and was scaled based on the length and width that each stream intersects a model cell.

No-Flow Boundaries

The southern, western, and eastern edge of the active model domain for layer one and layer two were assigned no-flow boundaries. These boundaries coincide with the boundary of the Nemadji River watershed. Areas outside the active model domain, but within the finite-difference grid, were also assigned as no-flow boundary conditions and were not part of the computation process.

Recharge

Recharge for the groundwater flow model was derived from output of the SWAT model. In areas of the groundwater flow model that exist outside the domain of the SWAT model, recharge was determined using the inverse method during model calibration.

Hydraulic Conductivity

The different hydrostratigraphic units within the model are represented by hydraulic conductivity zones as shown on Figure A-6. The extent of each hydraulic conductivity zone represents simplified lithological units as described by Boerboom (2001), Boerboom (2009), Patterson and Knaeble (2001) and Knaeble and Hobbs (2009). Hydraulic conductivity zones in model layer one generally conform to the surficial geology. The hydrogeologic conductivity zones in model layers three and four generally conform to the major bedrock units.

3.1.3 Solvers and Convergence Criteria

The NWT Solver (Niswonger et al., 2011) was used for this study. A head tolerance of 1.0×10^{-3} m and flux tolerance of 200 m^3/day were used for solver convergence criteria. Maximum outer iterations for the solver were 200. The portion of cell thickness used to smoothly adjust storage and conductance coefficients as the saturated thickness of a cell approaches zero was set at 1.0×10^{-4} m. All other solver settings were set at default values for “complex” problems as defined internally within the solver code.

3.2 SWAT Surface Water Model

SWAT is a basin-scale continuous distributed water quality simulation model capable of predicting long-term effects of alternative land management practices. Major components of the model include hydrology, erosion, nutrients, pesticides, crop growth, and agricultural management. Hydrologic processes include surface runoff, tile drainage, irrigation, snow-melt runoff, infiltration, lateral flow and plant uptake. The SWAT model classifies precipitation as snow when the average air temperature is less than the snowfall temperature and melts it when the maximum temperature exceeds the snowmelt temperature. Melted snow is treated as rainfall for estimating surface runoff and percolation. Daily average soil temperature is simulated at the soil surface and the center of each soil layer. Soil temperature at the surface is calculated as a function of maximum and minimum air temperature, snow cover, plant cover and residue cover for the day being simulated and the preceding four days. The temperature of the soil layers are calculated as a function of soil surface temperature, mean air temperature and the depth of the soil at which variations in the climatic conditions will not affect the soil temperature. The weather input for SWAT consists of daily values of daily precipitation, and maximum/minimum air temperature. The model has the option of generating the air temperature data if they are not available. Solar radiation, wind speed and relative humidity are also generated by the model.

3.2.1 Land Use

Modeled land cover characteristics for the Deer Creek watershed were obtained from the Carlton SWCD in GIS format. Most of the watershed is forest land with some agricultural cropland, all of which typically incorporate hay or alfalfa. There are a number of small wetlands spread throughout the watershed. One class of developed land was included in the land use coverage to ensure that varying amounts of impervious and road surfaces could be modeled. The forest land in the GIS coverage was split into two classes—areas that had been logged in the past (classified as mixed forest) and areas that more closely resembled older growth evergreen forests. The individual NLCD land use classifications were re-categorized in the ArcSWAT interface to distinguish the following land uses: forest, hay and pasture, water/wetlands and residential development.

3.2.2 Soils

A soil map was derived from the Soil Survey Geographic Database SSURGO, a small-scale NRCS soil database for Carlton County. Soil characteristics associated with SSURGO soil map units such as depth of each horizon, particle size distribution, organic matter content, and vertical hydraulic conductivity were developed and pre-processed using the ArcSWAT interface.

3.2.3 Topography

Using the statewide hydrography layer to burn in the known streams and associated channel crossings, each subwatershed was delineated using the available 3-meter LiDAR digital elevation model (DEM) data, cropped to the boundaries of the Deer Creek watershed. Subwatershed divides and slopes were determined in the ArcSWAT interface using the DEM data, but the subwatersheds were not further broken down into separate slope classes in the model. The DEM coverage was used by the ArcSWAT interface to digitally determine the locations of stream and overland channels (flowlines) and the associated morphometric characteristics. The SWAT model had 114 subwatersheds delineated in ArcSWAT and utilized for further model development.

3.2.4 HRUs / Subwatersheds

Input for the SWAT model was derived at two different scales: the subwatershed and the hydrologic response unit (HRU). HRUs are developed by overlaying soil type, slope and land cover. It is noted that HRUs in the version (2009.93.7, Revision 591) of ArcSWAT used for this project are not defined by a flow direction and the spatial location within each subwatershed does not influence pollutant loading to the stream. SWAT was also used to model hay and pasture land, forest land, water and developed land cover HRUs in each subwatershed. The following table shows the distribution of the general SWAT model land uses applied to the Deer Creek watershed.

Land Use	Percentage of Watershed Area
Forested-Evergreen	55.2%
Forested-Mixed	18.9%
Alfalfa/Hay/Pasture	22.0%
Water/Wetlands	2.2%
Residential Development	1.7%

The initial HRUs set up in the ArcSWAT interface were further refined for each subwatershed in the watershed to account for the various land cover classes, including hay and forest land management (discussed below). This resulted in an excessive quantity of HRUs in the watershed, with several of the HRUs resulting from unique combinations of soils and land use that represented negligible areas in each subwatershed. This resulted in 1,833 HRUs generated in ArcSWAT, but none of the remaining smaller HRU areas were eliminated from the modeling to maintain consistency with the groundwater modeling and provide accurate recharge inputs.

However, land cover changes were observed in the watershed through an aerial photographs comparison between the years 2008 and 2010. This land cover change produced exposed soils capable of contributing TSS to Deer Creek and also changes the hydrology of the watershed, however the timber harvest at this site (which likely occurred in the winter of 2009-2010) followed forest management guidelines, so the simulation of the resulting land cover changes (and any changes in sediment and water yield) in the SWAT model involved resetting the applicable forest land cover rotation to the beginning of its growth cycle.

3.3 Description of Model Linkage

The two models, SWAT and MODFLOW, are linked in a sequential manner. The SWAT model is run first, to completion, calculating surface runoff and groundwater recharge. MODFLOW is then run using groundwater recharge values from SWAT, and calculates aquifer water levels and baseflow to streams. The results of both models are then post processed to combine the surface water runoff from SWAT and the baseflow from MODFLOW. Attempts were made early on to completely couple to two models, passing baseflow and recharge values between the models on a daily time step. However, it was determined that this style of coupling would dramatically increase model run time, and hinder any form of model calibration.

The following describes how SWAT and MODFLOW were run.

1. SWAT run with standard daily time steps and output summarized by both HRU and sub-basin on a monthly basis
2. Monthly recharge values per HRU were summarized and mapped to the MODFLOW grid
3. MODFLOW was run with monthly stress period (during calibration MODFLOW was run in steady-state due to long transient runtimes)
4. Results from both models were post processed in the following manner
    a. Monthly surface runoff from SWAT was summarized according to contribution to each of two gauging stations
    b. Monthly baseflow from MODFLOW was summarized according to contribution to each of two gauging station locations
    c. Surface runoff and baseflow combined to produce total flow corresponding to each of two gauging station locations

It should be noted that there is no "routing" of water through the watershed using this linking scheme. The total amount of runoff from a given sub-watershed within SWAT is assumed to reach the gauging station in the same day. This simplification is deemed to be insignificant given that monthly flows were used for model calibration, and actual routing of water through the watershed is less than a month.

3.4 Model Optimization

The combined SWAT and MODFLOW models were calibrated through a series of automated inverse optimization procedures using the model-independent parameter estimating software PEST (Version 13.0) (Watermark Numerical Computing, 2005; 2011). Automated inverse optimization is a method for minimizing the differences, or residuals, between simulated results and observations. The sum of the squared weighted residuals for all targets is the objective function that is to be minimized. The square of the residual is used because some residuals are negative and some are positive. Additional independent checks on calibration were made outside of PEST using techniques such as the Nash-Sutcliffe method on time series data of modeled verses simulated baseflow, surface runoff, and total stream flow.

Using PEST involved making some choices on which parameters (e.g. hydraulic conductivity, river cell conductance, curve numbers, etc.) would be allowed to vary, the maximum and minimum values in which the parameter values could be varied, and initial estimates for the parameter values.

The overall process of the calibration procedure for this study was as follows:

1. The models were constructed

2. Calibration targets were chosen
3. Parameters that were allowed to vary during the optimization process where chosen, as was the range over which the parameters were allowed to vary.
4. The results of the PEST optimization were evaluated and changes were made :
    a. The lower and upper bounds for parameter values were adjusted
    b. Insensitive parameters were tied together or fixed
    c. The observation weights were adjusted so that one type of observation does not influence the calibration too much, or observations that are less certain don't contribute excessively to the objective function
    d. Calibration targets representing periods that the model can't simulate or are not properly constrained to simulate (i.e. snow melt runoff) were reduced in weight or eliminated completely from the optimization.

3.4.1 Calibration Targets

3.4.1.1 Hydraulic Head

A total of 1561 hydraulic head values using static water levels from the County Well Index (CWI). Static water level data from the CWI generally represent water levels measured by drilling contractors during the time of well installation. Sources of error in this data include the following:

- Inaccuracy of water level measurement – drilling contractors may not have used precise measuring devices.
- Inaccuracies in well location – many wells are identified only to the nearest quarter-quarter-quarter section (300 to 600 feet location error).
- Inaccuracy in well elevation – well elevations are typically estimated using 7.5 minute topographic maps and are also subject to errors in location
- Water levels may not have stabilized at the time of measurement – water levels are typically collected during or immediately after well installation or development and may not have reached equilibrium with the aquifer.
- Hydrostratigraphic units misidentified or not correctly assigned in the databases – the well may actually be screened in a different unit or multiple units.

Given sources of unavoidable uncertainty in these target values, head targets derived from CWI data are typically assigned a likely error of at least +/- 20 feet (about +/- 6 meters). It is not uncommon to find two nearby targets in the same aquifer with substantially different head values. Geostatistical cross validation techniques and manual review of the CWI data were used to eliminate obvious outliers from the calibration dataset.

Hydraulic head targets were broken into two groups; (1) near/within Deer Creek watershed (n = 94) and (2) not near/within the Deer Creek Watershed (n = 1,467). This was done to allow for a greater weight to be applied to targets near the area of interest.

3.4.1.2 Baseflow

The MODLFOW model was run in a steady-state condition during calibration due to extremely long run times for a transient model. Steady-state models are not time variant; so, only the mean measured baseflow at two monitoring locations (Hwy. 23 (S003-250) and CSAH 3 (S004-929) stations) were used as baseflow calibration targets. Baseflow separation methods of Arnold et al. (1995) and Arnold and Allen (1999) were used. Due to the nature of the baseflow separation technique, the first and last months prior to a gap in data (e.g. winter when stream gauge stations were not active) were not included for establishing baseflow targets. The mean baseflow was estimated to be 0.6 cfs for Deer Creek at CSAH 3 and 1.5 cfs for Deer Creek at Hwy. 23.

After calibration the MODFLOW model was run in transient mode as a check to see how well monthly baseflow were matched. A total of 45 monthly baseflow values were used; 27 for the Deer Creek at Hwy. 23, and 18 for Deer Creek at CSAH 3.

3.4.1.3 Surface Water Runoff

Monthly surface runoff observations at both monitoring locations (Hwy. 23 and CSAH 3 stations) were used during model calibration. Surface runoff was derived by subtracting monthly baseflow (see section 3.4.1.2 above) from total stream flow. As with the monthly baseflow, the first and last months prior to a gap in data (e.g. winter when stream gauge stations were not active) were not included for calibration. Also, only months with complete records (no missing days) were used.

Based on field investigations and review of LIDAR data, the subwatersheds in the far northern portion of the watershed were determined to be non-contributing under typical flow conditions. To account for the lack of contribution to surface runoff from these subwatersheds the curves numbers were artificially reduced to 25 for all pertinent HRUs in these subwatersheds.

3.4.1.4 Sediment Yield

Total cumulative sediment yields between June, 2008 and October, 2010 were used as calibration targets. Total sediment yield during this period was estimated to be 297 tons for Deer Creek at CSAH 3 and 2,626 tons for Deer Creek at Hwy. 23. Sediment load from the sediment volcanos located upstream of the Hwy. 23 monitoring station was estimated to be 1.2 tons per month, based on an estimated discharge rate of 100 gallons per minute from the volcanoes combined with an estimated TSS concentration of 68 mg/L (which corresponds to the 120 NTU turbidity level typically observed under low flow conditions). It should be noted that suspended sediment concentration (SSC) data were not available for this study, which could have resulted in significantly higher estimates of sediment loading or yield, based on data comparisons from other watershed studies. The

SWAT model is only able to simulate sediment yield from typical erosional sources (overland flow and stream bank or near-channel sources of erosion), so the target sediment yield at the Hwy. 23 station was reduced to 2,591 tons (total sediment yield less input from sediment volcanoes).

3.4.2 Optimization Goals

Model simulated flows were compared to measured flows to determine if the model was adequately calibrated. Both graphical comparisons and quantitative statistical methods were used to evaluate model fit. The primary statistical analysis used to evaluate model fit was the Nash-Sutcliffe efficiency (NSE). NSE is computed as show below (Nash and Sutcliffe, 1970).

$$NSE = 1 - \left[\frac{\sum_{i-1}^{n}(Y_i^{obs} - Y_i^{sim})^2}{\sum_{i-1}^{n}(Y_i^{obs} - Y^{mean})^2}\right]$$

Where Y_i^{obs} is the ith observation for the constituent being evaluated, Y_i^{sim} is the ith simulated value for the constituent being evalutated, Y^{mean} is the mean of the observed data for the constituent being evaluated, and n is the total number of observations.

A NSE of 0.5 or above was set as the optimization goal for surface runoff (Moriasi et al., 2007). Because MODFLOW was calibrated in steady-state, a NSE target goal is not appropriate for baseflow. A goal of simulated average baseflow within 20 percent of measured average baseflow was used.

In addition to stream flow, simulated and measured hydraulic head values were also compared. However, much more emphasis was given to stream flow values compared to hydraulic head. No specific goal was established in regard to hydraulic head, except to minimize the residuals.

3.4.3 Optimization Parameters

Parameters that were allowed to vary during the optimization process were:

- MODFLOW
  - Horizontal hydraulic conductivity
  - Anisotropy (Kx/Kz)
  - Riverbed conductance
  - Regional recharge (outside of SWAT model domain but within MODFLOW model domain)
- SWAT
  - Curve Number (global percent change based on soil group A,B,C or soil group D)
  - Operation Curve Number (CNOP) adjustment factor

- Average slope length (global factor for all HRUs)
- Groundwater “revap” coefficient (global factor for all HRUs)
- Available water capacity (global factor for all HRUs)
- Sediment re-entrainment parameters

The final optimized MODFLOW parameter values for hydraulic conductivity are shown on Figure A-6.

The final optimized SWAT parameters were as follows:

- SCS runoff curve number for moisture condition II (CN2) for A, B, and C soils = 10% global increase from initial parameter estimates
- SCS runoff curve number for moisture condition II (CN2) for D soils in subbasins upstream of monitoring station at CSAH 3 = 10% global decrease
- SCS runoff curve number for moisture condition II (CN2) or D soils in subbasins downstream of monitoring station at CASH 3 = 10 % global increase
- Factor applied to CN2 values to define CNOP values after logging occurred in watershed = 1.006
- Available water capacity of soil (SOL_AWC) = 10 % global decrease from initial parameter estimates
- Factor applied to average slope length (SLSUBBSN) = 3.78
- Groundwater “revap” coefficient (GW_REVAP) = 0.87
- Linear parameter for maximum amount of sediment re-entrained in channel (SPCON) = 8.9e-04
- Exponent parameter for calculating amount of sediment re-entrained in channel sediment routing (SPEXP) = 1.12

3.5 Optimization Results

3.5.1 Flow and Hydraulic Head

Overall, the final optimized model matched transient surface runoff, total flow, and hydraulic head values well. Model fit characteristics with respect to surface runoff, total stream flow and average baseflow for the final optimized model are shown in Table A-1. The NSE values shown Table A-1 represent a satisfactory fit above 0.5, a good fit above 0.65, and a very good fit above 0.75 (per Moriasi et al., 2007). Steady-state (long-term average) targets were used for baseflow; hence NSE values for baseflow are not applicable and are not included in Table A-1. A comparison of average baseflow shows good agreement (within 20 percent). Monthly time series plots of measured versus simulated baseflow, surface runoff, and total stream flow are presented on Figure A-7 to Figure A-8.

Table A-1 Model fit characteristics for surface runoff, total stream flow and baseflow

Monitoring Station	Surface Runoff NSE	Total Flow NSE	Average Baseflow (measured‖simulated) cfs
Deer Creek at CSAH 3	0.66	0.52	0.6‖0.5
Deer Creek at Hwy. 23	0.77	0.67	1.5‖1.4

Model fit characteristics with respect to hydraulic head calibration targets for the final optimized model are shown in Table A-2. Plots comparing simulated heads to measured heads are shown on Figure A-9 and Figure A-10. The results show that the residuals for local targets are within ten to fifteen percent of the absolute value range of hydraulic heads in the area.

Table A-2 Model fit characteristics for hydraulic head calibration targets

Group	Mean Residual (ft)	Absolute Residual Mean (ft)	Residual Standard Deviation (ft)
Local targets (within and near Deer Creek Watershed)	-5.4	26.8	37.0
Regional Targets	0.6	12.0	15.7

3.5.2 Watershed Recharge

For the period 2002-2010, recharge over the Deer Creek watershed, as calculated by SWAT, ranged from less than 1 in/yr to 9.5 in/yr with an annual average of 2.2 in/yr (Figure A-11). Most of the recharge in the watershed occurs in the northern half where the soils are much sandier and topography is not as steep compared to the southern half of the watershed. Results from the SWAT model are slightly less than recharge rates of between 3 in/yr and 11 in/yr estimated by Lorenz and Delin (2007) using a regional regression recharge (RRR) method for the entire state of Minnesota.

3.5.3 Sediment Loading

Total cumulative sediment yield between June, 2008 and October, 2010 for the final optimized model is shown in Table A-3, which shows that the modeled loading estimates are within 3 percent of the measured loadings at each monitoring station. Table A-3 shows that approximately one third of the increase in sediment loading estimated for the Deer Creek system between the two monitoring stations can be attributed to near-channel sources of sediment.

Table A-3 Measured and simulated sediment yield

Monitoring Station	Measured Total Cumulative Sediment Yield (tons)	Simulated Total Cumulative Sediment Yield (tons)	Simulated Near-Channel Sediment Yield (tons)
Deer Creek at CSAH 3	297	305	7
Deer Creek at Hwy. 23	2591	2591	732

4.0 Results of Modeled Land Use Change Scenarios

In order to assess the impacts of different land uses, two scenarios were simulated; an “all forest” simulation and a non-forested simulation. Each simulation was run with the same climate data as the model used for calibration, with output for surface runoff and sediment yields processed from January 2002 to August 2012 of the simulation. For the all forest simulation, all existing land use of pasture or hay was converted back to forest. For the non-forested simulation, all currently existing forest not on state land (Blackhoof River Wildlife Management Area and Blackhoof River Aquatic Management Area) was simulated to have been converted from a forested condition to non-forested condition in January of 2008 and replanted in the spring of 2008. While conversion of the entire watershed to non-forested in one season is unrealistic, it provides a simple and easy to understand land use change for assessing larger scale impacts, particularly in regard to sediment yields.

Results from the all forest simulation indicate a decrease in total cumulative sediment yield over the 10.5 years simulated. For Deer Creek at Hwy. 23, the reduction in total cumulative sediment yield was simulated as 2,700 tons, or 20 percent. For Deer Creek at CSAH 3, a reduction of 290 tons, or 16 percent, was simulated (Figure A-12).

Results from the non-forested simulation indicate an increase in total cumulative sediment yield starting shortly after the simulated logging (January 2008). For Deer Creek at Hwy. 23 an increase in total cumulative sediment yield of 1,450 tons, or 20 percent, was simulated from January 2008 to August, 2012. For Deer Creek at CSAH 3 an increase of 1,580 tons, or 63 percent, was simulated from January 2008 to August, 2012 (Figure A-13). Figure A-13 shows that most of the elevated levels of changes in predicted erosion rates corresponded with higher runoff events that occurred each year during 2010, 2011 and 2012.

5.0 References

Andrews S.C., R.G. Christensen, and C.D. Wilson. 1980. Impact of nonpoint pollution control on western Lake Superior. Red clay project final report part III. USEPA report 905/9-76-002, Washington, D.C.

Arnold, J.G., P.M. Allen, R. Muttiah, and G. Bernhardt. 1995. Automated base flow separation and recession analysis techniques. Ground Water 33(6): 1010-1018.

Arnold, J.G. and P.M. Allen. 1999. Automated methods for estimated baseflow and ground water recharge from streamflow records. Journal of the American Water Resources Association 35(2):411-424.

Banks, G., and K. Brooks. 1996. Erosion-sedimentation and nonpoint pollution in the Nemadji Watershed: status of our knowledge. University of Minnesota, Department of Forest Resources, St. Paul.

Berg, James. 2004. Hydrogeology of the unconsolidated and bedrock aquifer, Plate 8 of Pine County Geologic Atlas, Part B, Minnesota Department of Natural Resources.

Berg, James. 2011. Potentiometric surfaces of buried aquifers, stable isotope geochemistry, and groundwater use, Plate 9 of Carlton County Geologic Atlas, Part B, Minnesota Department of Natural Resources

Boerboom, Terrence. 2009. Bedrock Geology, Plate 2 of Carlton County Geologic Atlas, Part A, Minnesota Geological Survey.

Boerboom, Terrence. 2001. Bedrock Geology, Plate 2 of Pine County Geologic Atlas, Part A, Minnesota Geological Survey.

Environmental Simulations Inc. 2011. Guide to using Groundwater Vistas, Version 6. Environmental Simulations Inc.

Harbaugh, A.W., 2005. MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model – the Ground-Water Flow Process. U.S. Geological Survey Techniques and Methods 6-A16.

Knaeble Alan, Hobbs, H.C., 2009. Surficial Geology, Plate 3 of Carlton County Geologic Atlas, Part A, Minnesota Geological Survey.

Lorenz, D.L. and G.N. Delin, 2007. A regression model to estimate regional ground water recharge. *Ground Water*, v. 45 no. 2, p. 196-208.

McDonald, M.G., and A.W. Harbaugh, 1988. A Modular Three-Dimensional Finite-Difference Groundwater Flow Model, *U.S. Geological Survey Techniques of Water-Resource Investigations*, TWRI 6-A1, 575 p.

Mooers, H. and Wattrus, N. 2005. Results of Deer Creek Groundwater Seepage Investigation. Report to the Carlton County Planning and Zoning.

Nash, J.E., and J.V. Sutcliffe. 1970. River flow forecasting through conceptual models: Part 1. A discussion of principles. *J. Hydrology* 10(3): 282-290.

Neitsch, S.L., Arnold, J.G., Kiniry, J.R., and William, J.R. 2011. Soil and Water Assessment Tool Theoretical Documentation Version 2009. Texas Water Resources Institute.

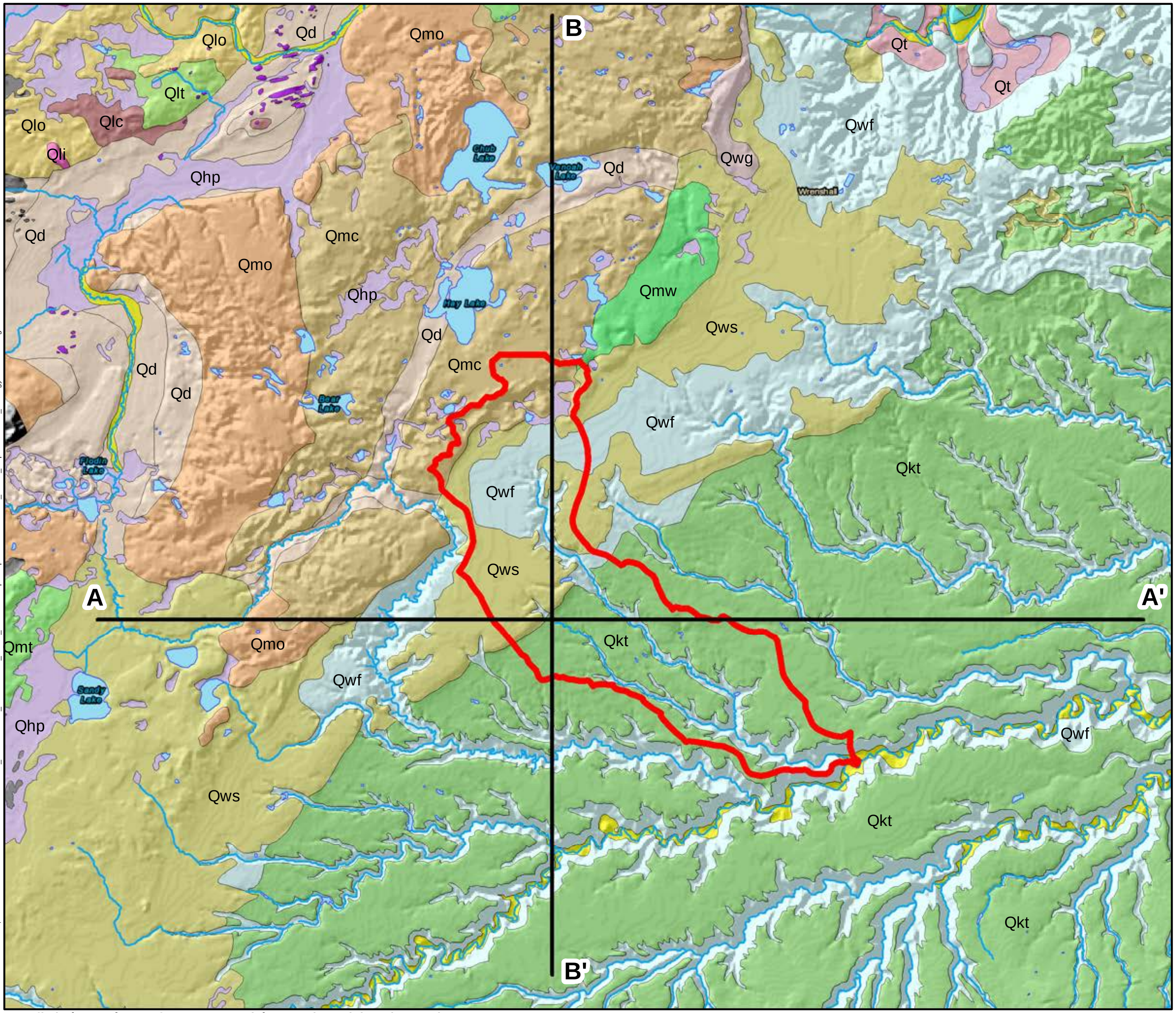
Niswonger, R.G., Panday, S., Ibaraki, M., 2011. MODFLOW-NWT, A Newton formulation for MODFLOW-2005: U.S. Geological Survery Techniques and Methods 6-A37, 44 p.

Patterson, Carrie, and Knaeble A.R., 2001. Surficial Geology, Plate 4 of Pine County Geologic Atlas, Part A, Minnesota Geological Survey.

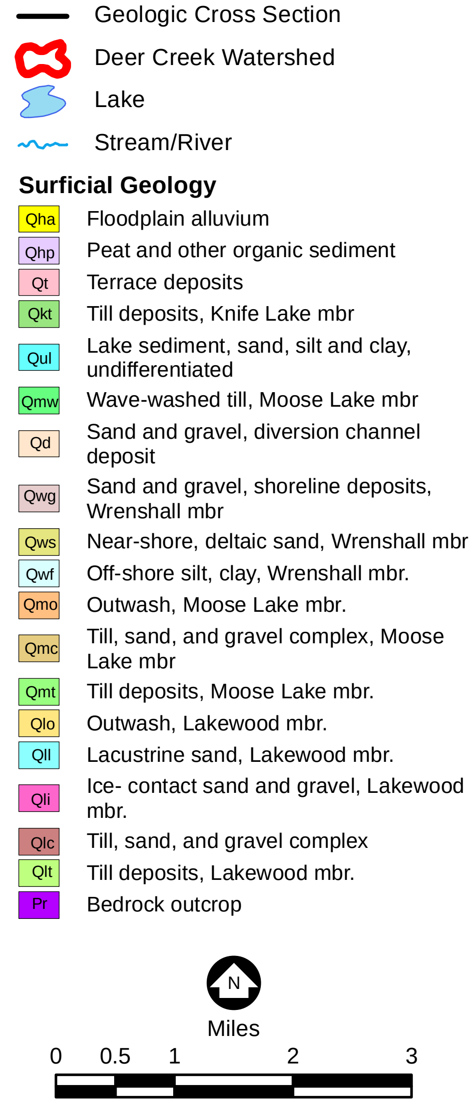
Watermark Numerical Computing 2005. PEST: Model-Independent Parameter Estimation, User Manual: 5th Edition.

Watermark Numerical Computing 2011. Addendum to the PEST Manual.

Appendix A Figures



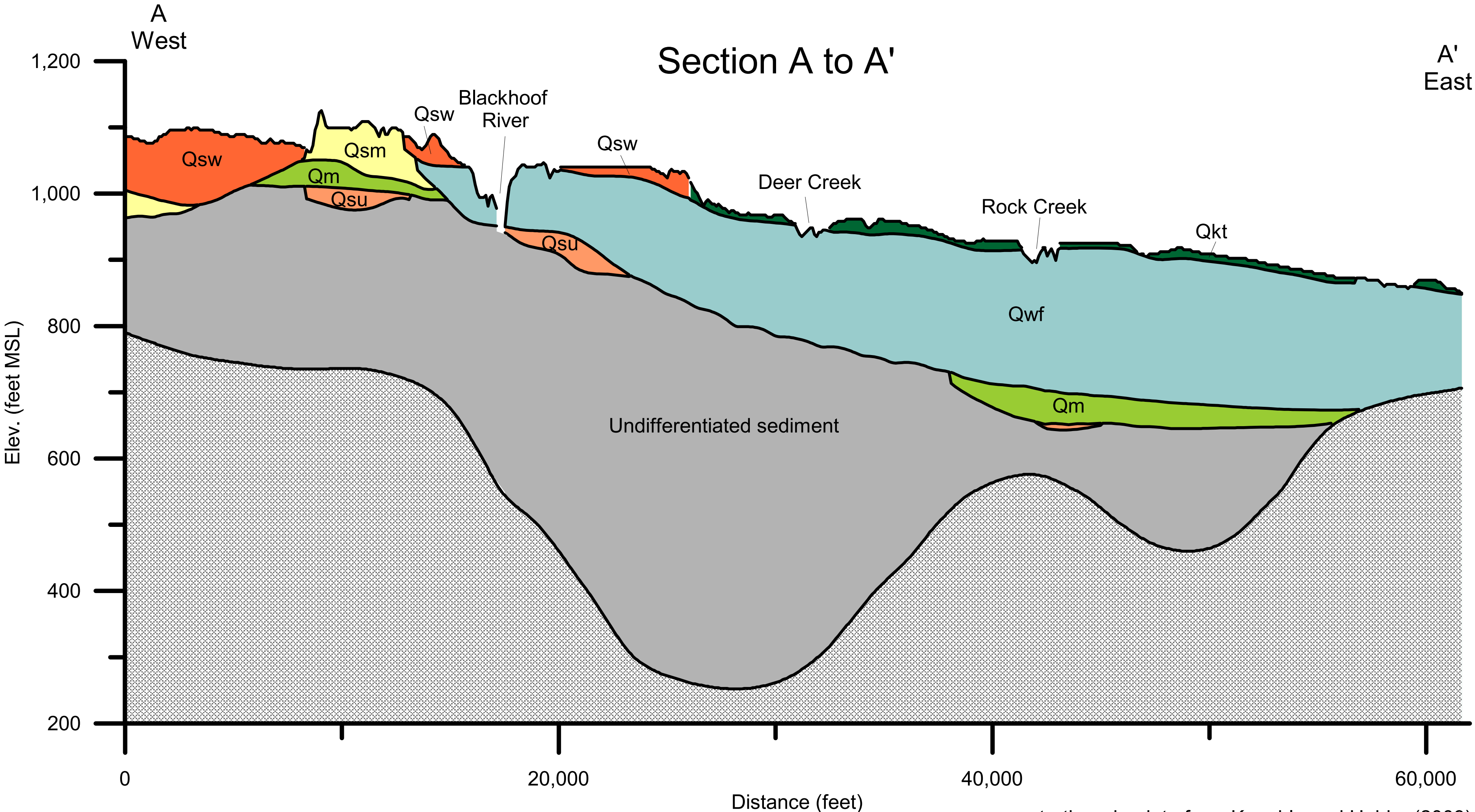
surficial geology from Knaeble and Hobbs (2009)



BARR

Figure A-1

SURFICIAL GEOLOGY
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota



stratigraphy data from Knaeble and Hobbs (2009)

Qkt, till deposits, Barnum Fm., Knife River mbr.

Qsw, shoreline, near-shore, and deltaic sand and gravel, Barnum Fm., Wrenshall mbr. (combined surficial map units Qwg and Qws)

Qwf, off-shore silt and clay lake deposits, Barnum Fm., Wrenshall mbr.

Qsm, outwash sand and gravel, Barnum Fm., Moose Lake mbr. (combined surficial map units Qmo and sand and gravel portions of Qmc)

Qm, till deposits, Barnum Fm., Mosse Lake mbr. (combined surficial map units Qmt, Qmw, and till portion of Qmc)

Qsl, outwash sand and gravel, Barnum Fm., Lakewood mbr. (combined surficial unit Qat and sand and gravel portions of Qlc)

Ql, till deposits, Barnum Fm., Lakewood mbr. (combined surfical units Qlt and till portions of Qlc)

Qsc, outwash sand and gravel, Cromwell Fm. (combined surficial units Qco and sand and gravel portions of Qcc)

Qc, till deposits, Cromwell Fm. (combined surficial units Qct and till portions of unit Qcc)

Qsu, undifferentiated outwash

Undifferentiated Pleistocene sediment

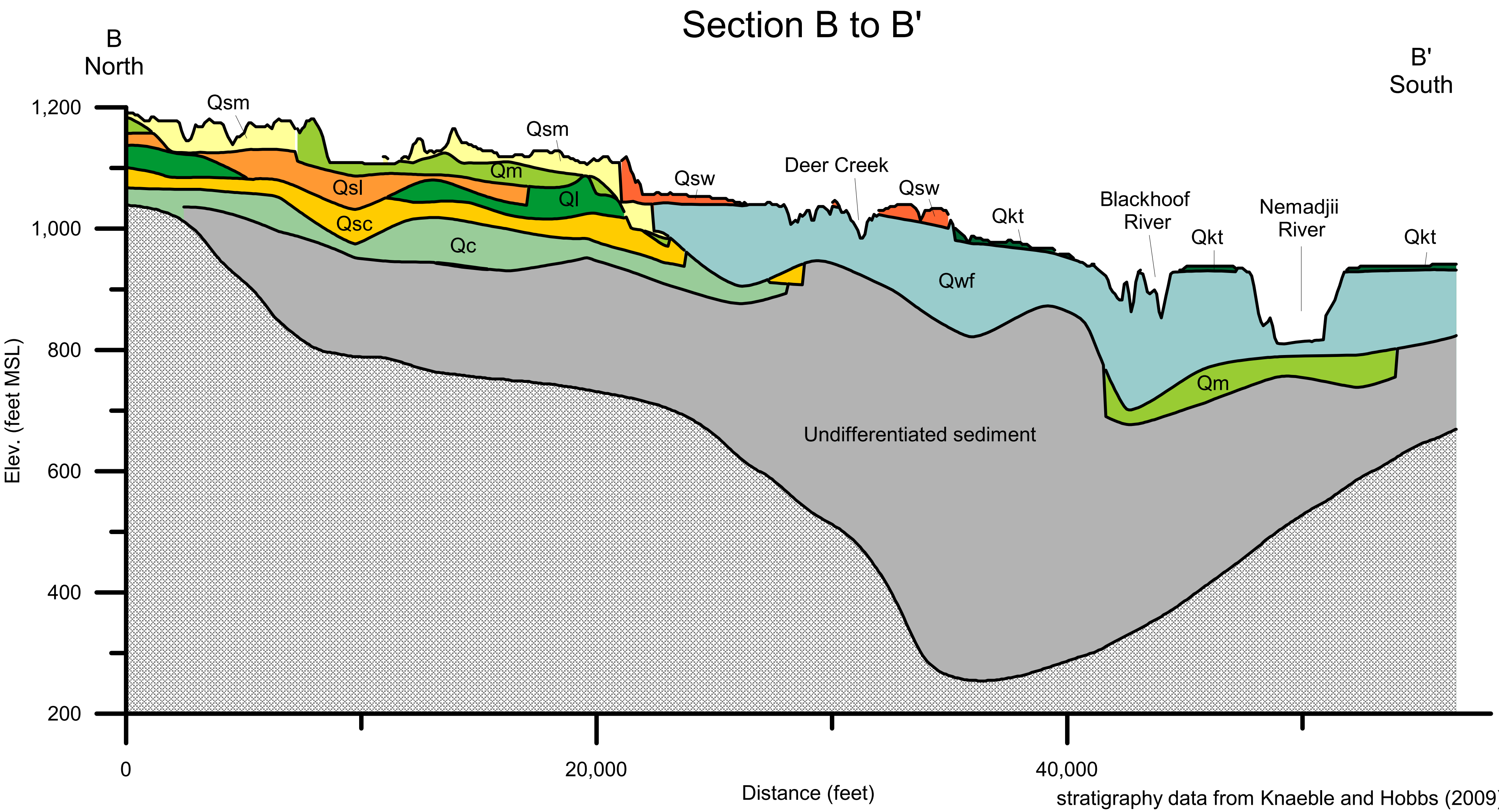
Undifferentiated Bedrock

BARR

Figure A-2

GEOLOGIC CROSS SECTION A to A'
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota

\Mpls\23 MN\09\23091014 Deer Crk Watershed TMDL\WorkFiles\Groundwater_Model\Model_Report\Section_A.grf



stratigraphy data from Knaeble and Hobbs (2009)

Qkt, till deposits, Barnum Fm., Knife River mbr.

Qsw, shoreline, near-shore, and deltaic sand and gravel, Barnum Fm., Wrenshall mbr. (combined surficial map units Qwg and Qws)

Qwf, off-shore silt and clay lake deposits, Barnum Fm., Wrenshall mbr.

Qsm, outwash sand and gravel, Barnum Fm., Moose Lake mbr. (combined surficial map units Qmo and sand and gravel portions of Qmc)

Qm, till deposits, Barnum Fm., Mosse Lake mbr. (combined surficial map units Qmt, Qmw, and till portion of Qmc)

Qsl, outwash sand and gravel, Barnum Fm., Lakewood mbr. (combined surficial unit Qat and sand and gravel portions of Qlc)

Ql, till deposits, Barnum Fm., Lakewood mbr. (combined surfical units Qlt and till portions of Qlc)

Qsc, outwash sand and gravel, Cromwell Fm. (combined surficial units Qco and sand and gravel portions of Qcc)

Qc, till deposits, Cromwell Fm. (combined surficial units Qct and till portions of unit Qcc)

Qsu, undifferentiated outwash

Undifferentiated Pleistocene sediment

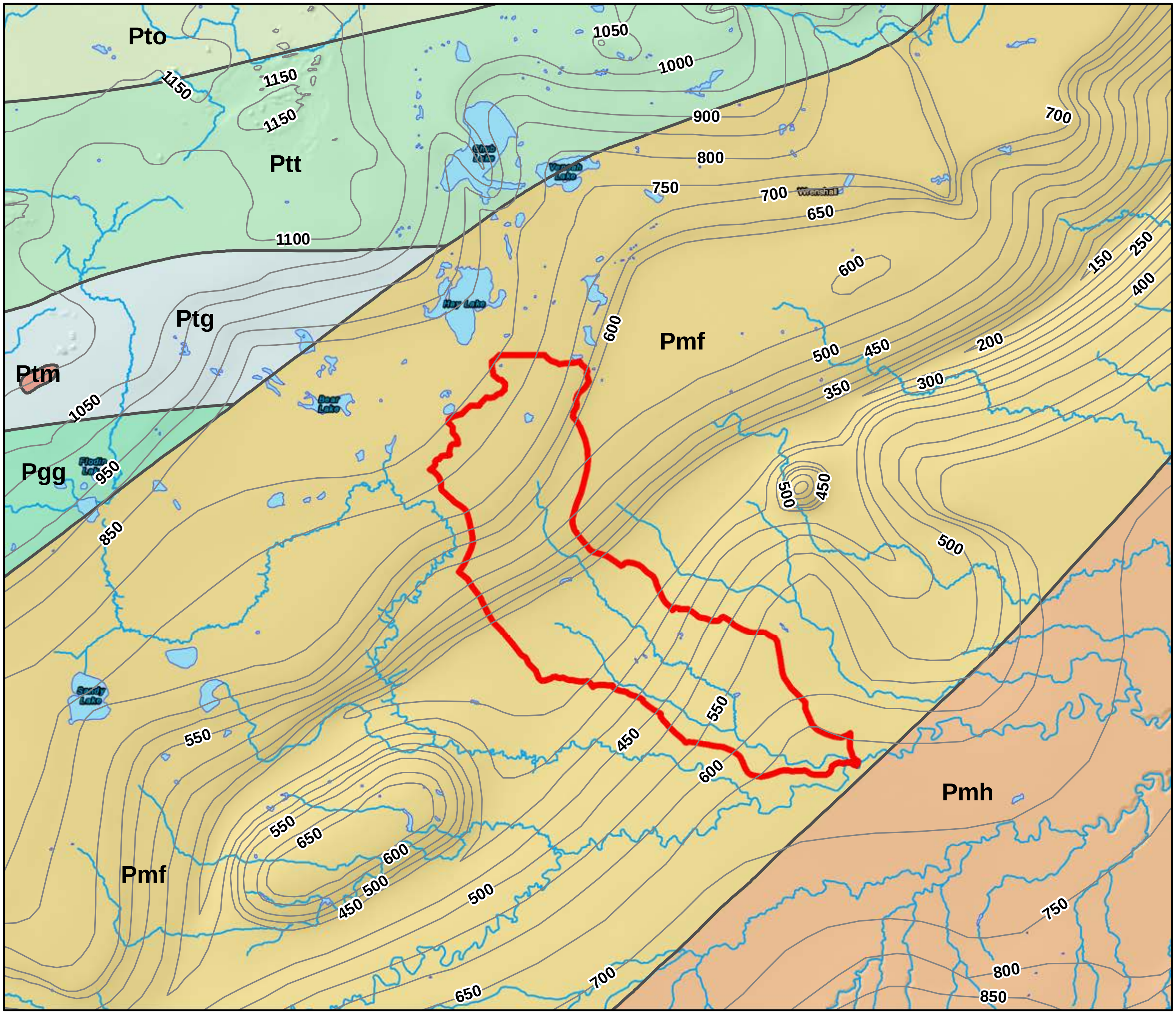
Undifferentiated Bedrock

BARR

Figure A-3

GEOLOGIC CROSS SECTION B to B'
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota

P:\Mpls\23 MN\09\23091014 Deer Crk Watershed TMDL\WorkFiles\Groundwater_Model\Model_Report\Section_B.grf



Bedrock Elevation Contour (ft, MSL)
Deer Creek Watershed
Lake
Stream/River

Bedrock geology

Keweenawon Supergroup

- Pmh Hinckley Sandstone
- Pmf Fond du Lac Formation

Thomson Formation

- Pto Slate and metagraywacke
- Ptt Variably graphitic slate and metagraywacke
- Ptg Graphitic slate and metagraywacke
- Ptm Graphitic pyritic slate and metagraywacke

Little Falls Formation

- Pgg Phyllitic schist and metagraywacke

N

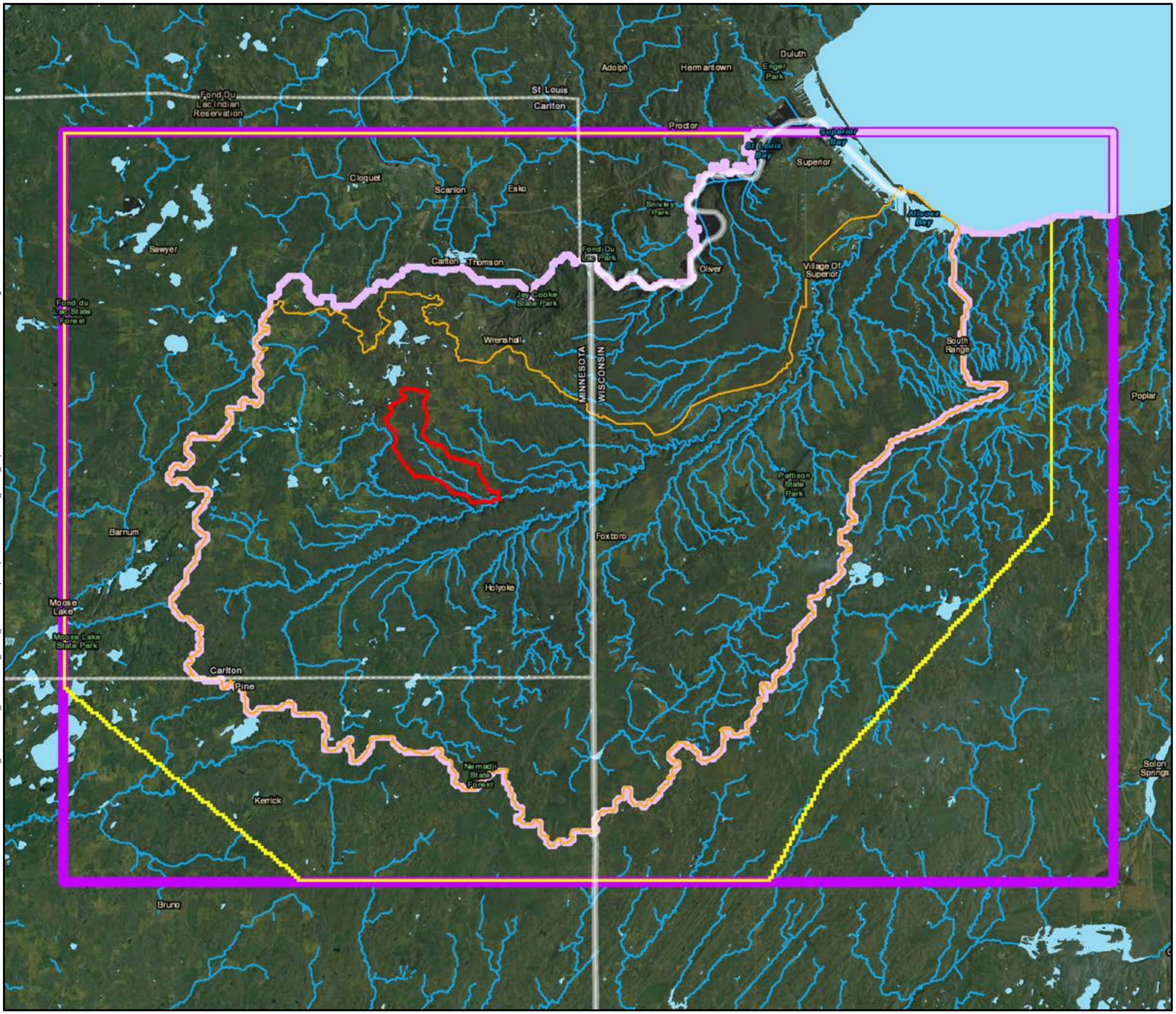
Miles

0 0.5 1 2 3

BARR

Figure A-4

BEDROCK GEOLOGY
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota



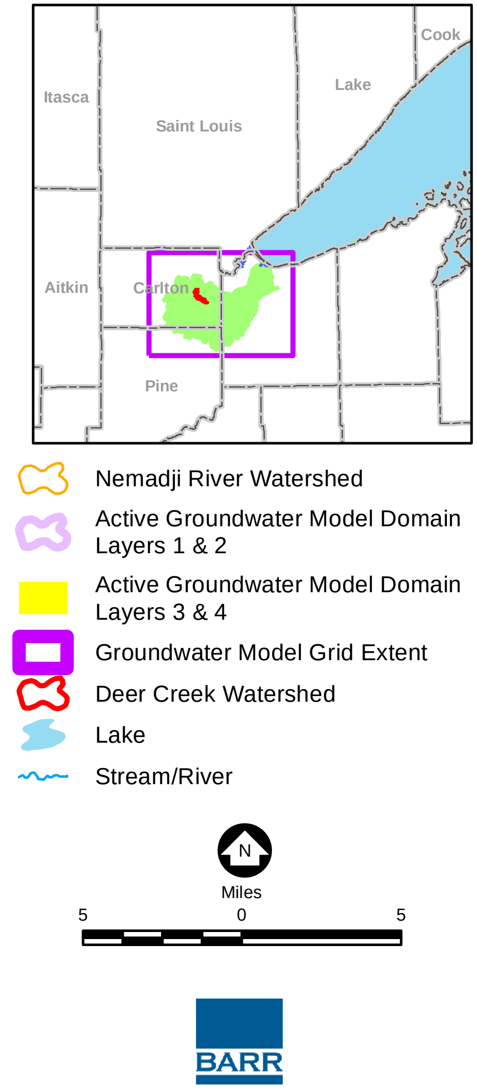
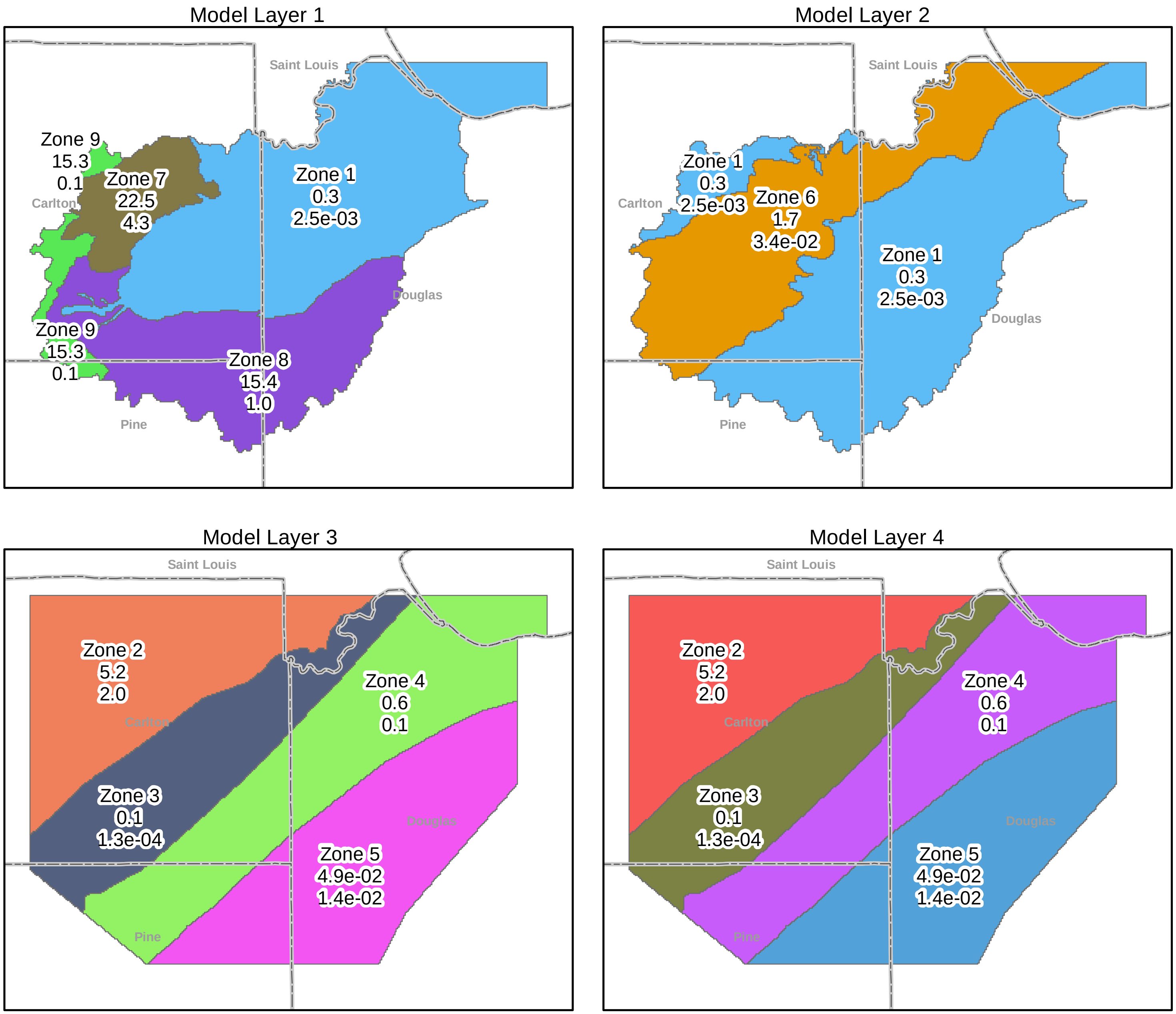


Figure A-5

GROUNDWATER MODEL DOMAIN
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota



Zone #
Horizontal Hydraulic Conductivity (m/d)
Vertical Hydraulic Conductivity (m/d)

N

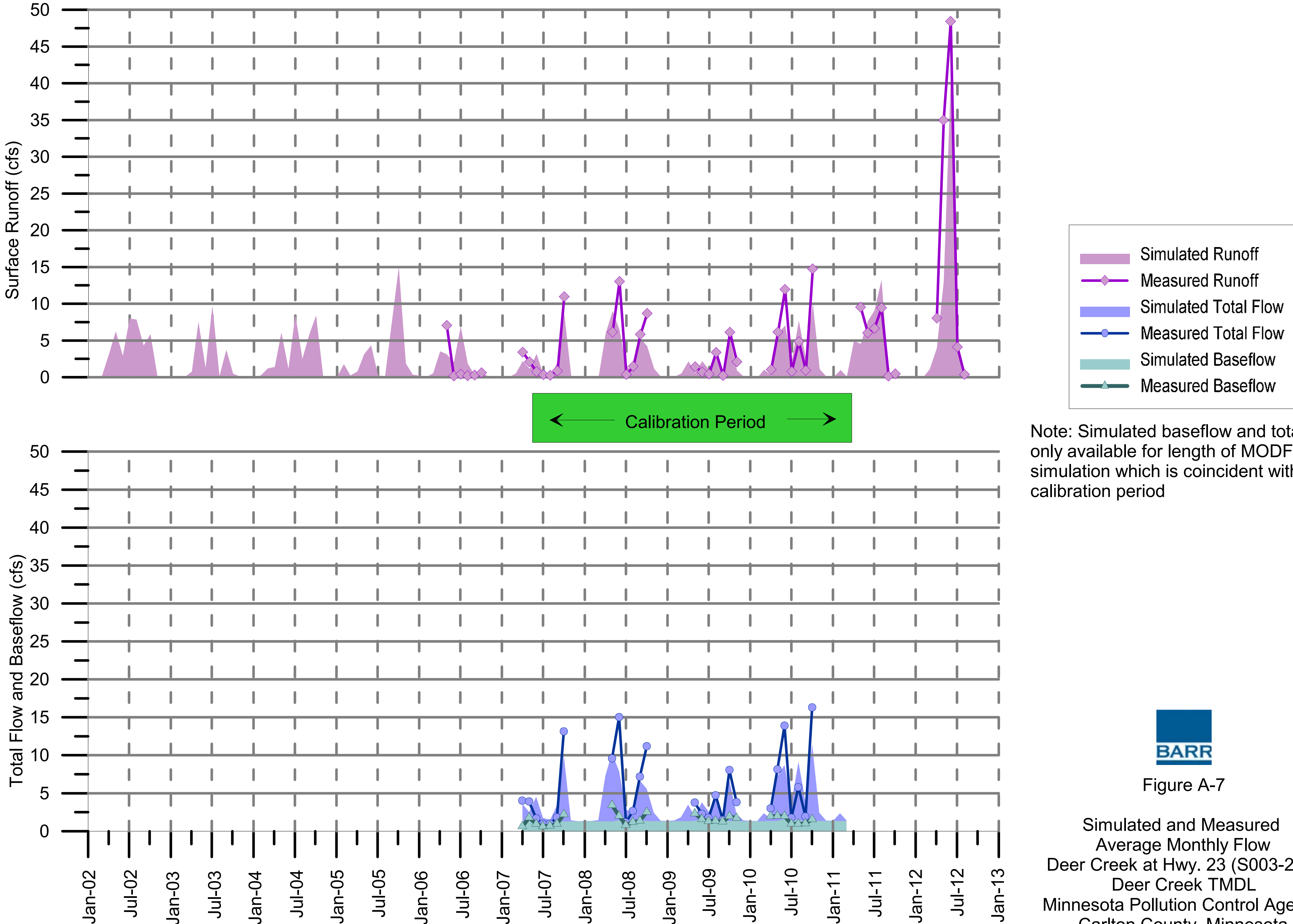
Miles

5 0 5 10 15 20

BARR

Figure A-6

HYDRAULIC CONDUCTIVITY ZONES
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota



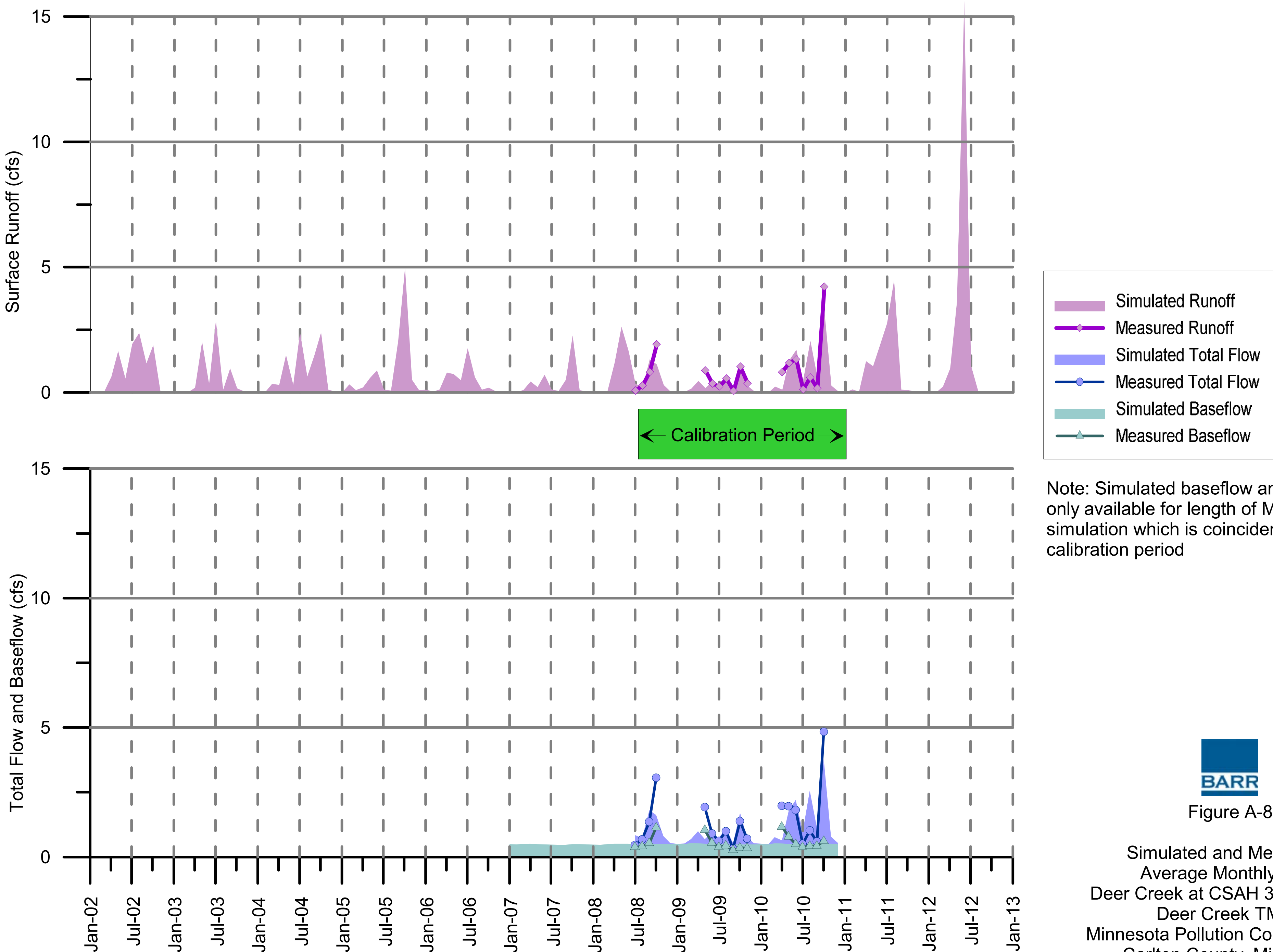
Note: Simulated baseflow and total flow only available for length of MODFLOW simulation which is coincident with the calibration period

BARR

Figure A-7

Simulated and Measured
Average Monthly Flow
Deer Creek at Hwy. 23 (S003-250)
Deer Creek TMDL
Minnesota Pollution Control Agency
Carlton County, Minnesota

P:\Mpls\23 MN\09\23091014 Deer Crk Watershed TMDL\WorkFiles\Groundwater_Model\Model_Report\Measured_vs_Simulated_Flows_Site2.grf



Note: Simulated baseflow and total flow only available for length of MODFLOW simulation which is coincident with the calibration period

BARR

Figure A-8

Simulated and Measured
Average Monthly Flow
Deer Creek at CSAH 3 (S004-929)
Deer Creek TMDL
Minnesota Pollution Control Agency
Carlton County, Minnesota

P:\Mpls\23 MN\09\23091014 Deer Crk Watershed TMDL\WorkFiles\Groundwater_Model\Model_Report\Measured_vs_Simulated_Flows_Site3.grf

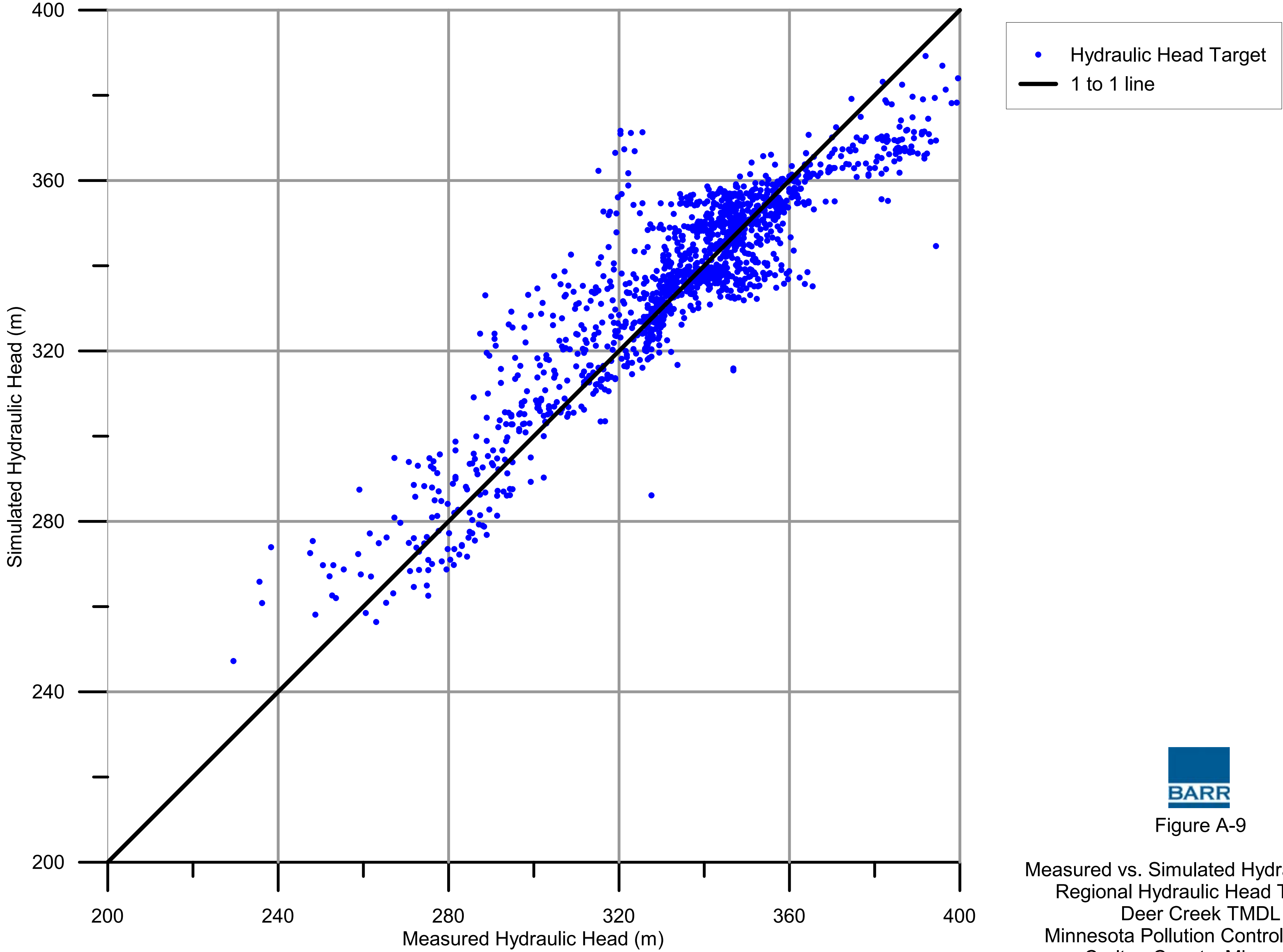
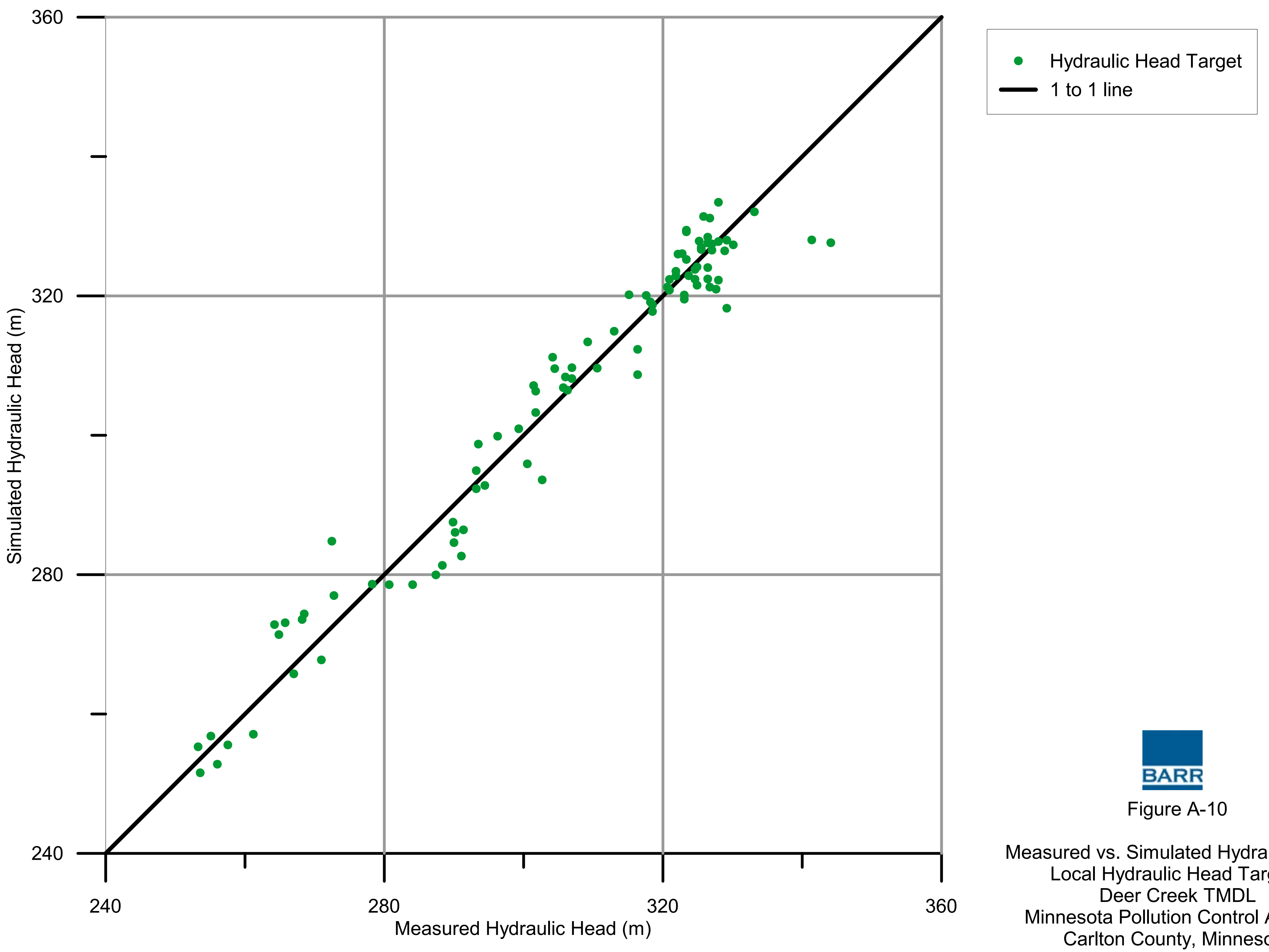


Figure A-9

Measured vs. Simulated Hydraulic Head
Regional Hydraulic Head Targets
Deer Creek TMDL
Minnesota Pollution Control Agency
Carlton County, Minnesota

P:\Mpls\23 MN\09\23091014 Deer Crk Watershed TMDL\WorkFiles\Groundwater_Model\Model_Report\Regional_Head_Measured_vs_Simulated.grf

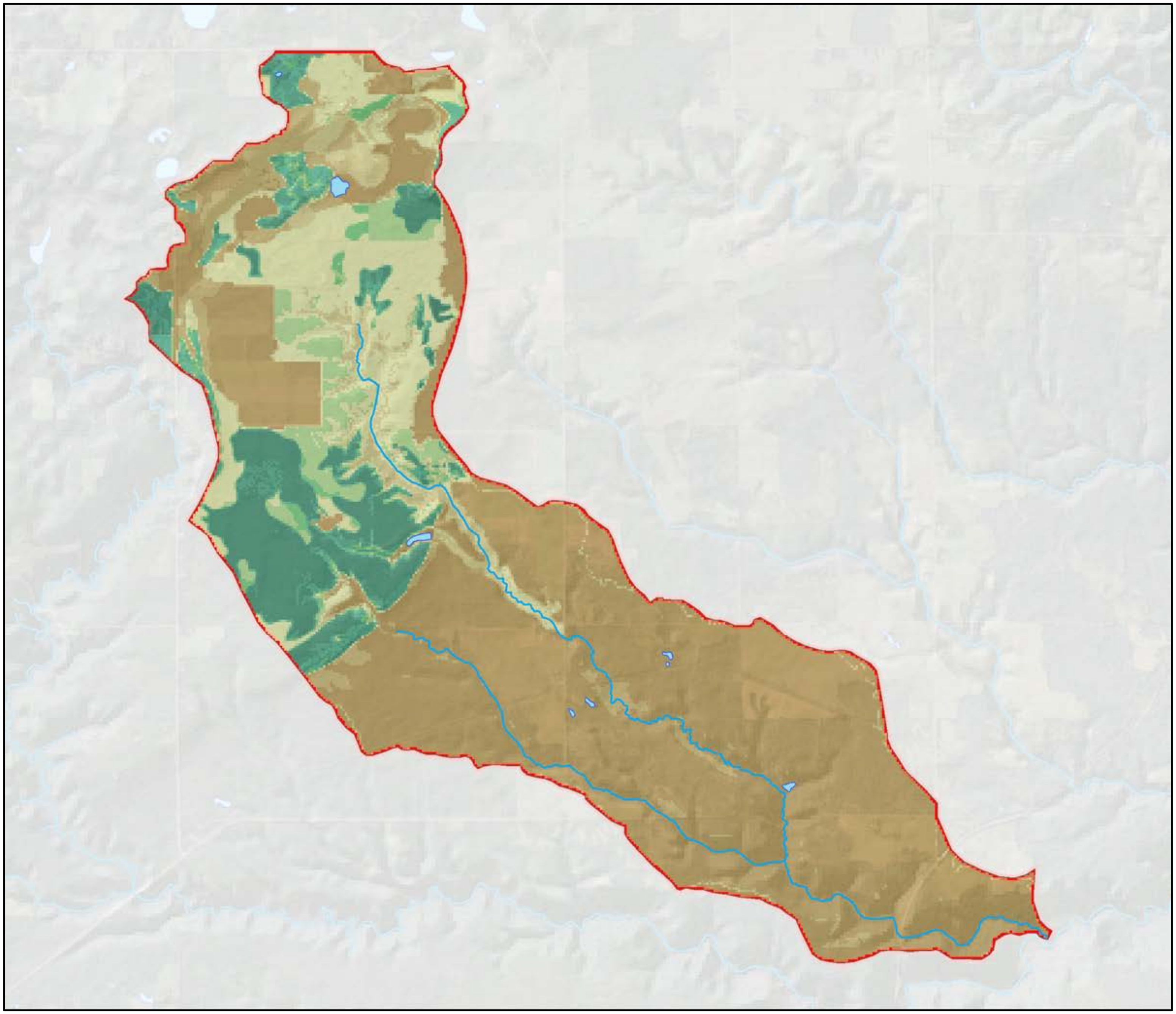


BARR

Figure A-10

Measured vs. Simulated Hydraulic Head
Local Hydraulic Head Targets
Deer Creek TMDL
Minnesota Pollution Control Agency
Carlton County, Minnesota

P:\Mpls\23 MN\09\23091014 Deer Crk Watershed TMDL\WorkFiles\Groundwater_Model\Model_Report\Local_Head_Measured_vs_Simulated.grf



Lake

Stream/River

Avg. Groundwater Recharge (in/yr)

- >9.0
- 8.1 - 9.0
- 7.1 - 8.0
- 6.1 - 7.0
- 5.1 - 6.0
- 4.1 - 5.0
- 3.1 - 4.0
- 2.1 - 3.0
- 1.1 - 2.0
- <1

Deer Creek Watershed

N

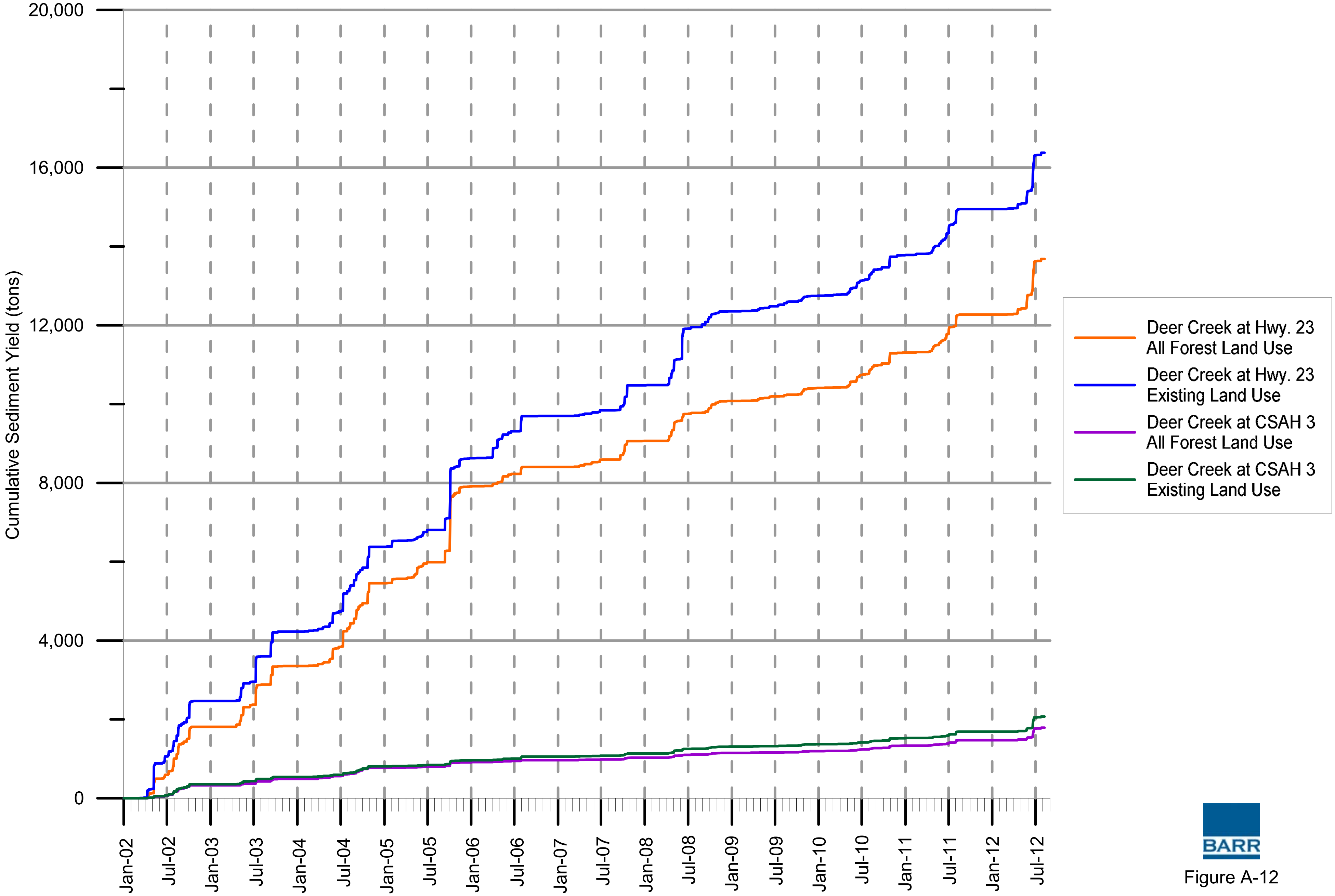
Miles

0 0.25 0.5 1

BARR

Figure A-11

GROUNDWATER RECHARGE
Deer Creek TMDL Implementation Plan
Minnesota Pollution Control Agency
Carlton County, Minnesota



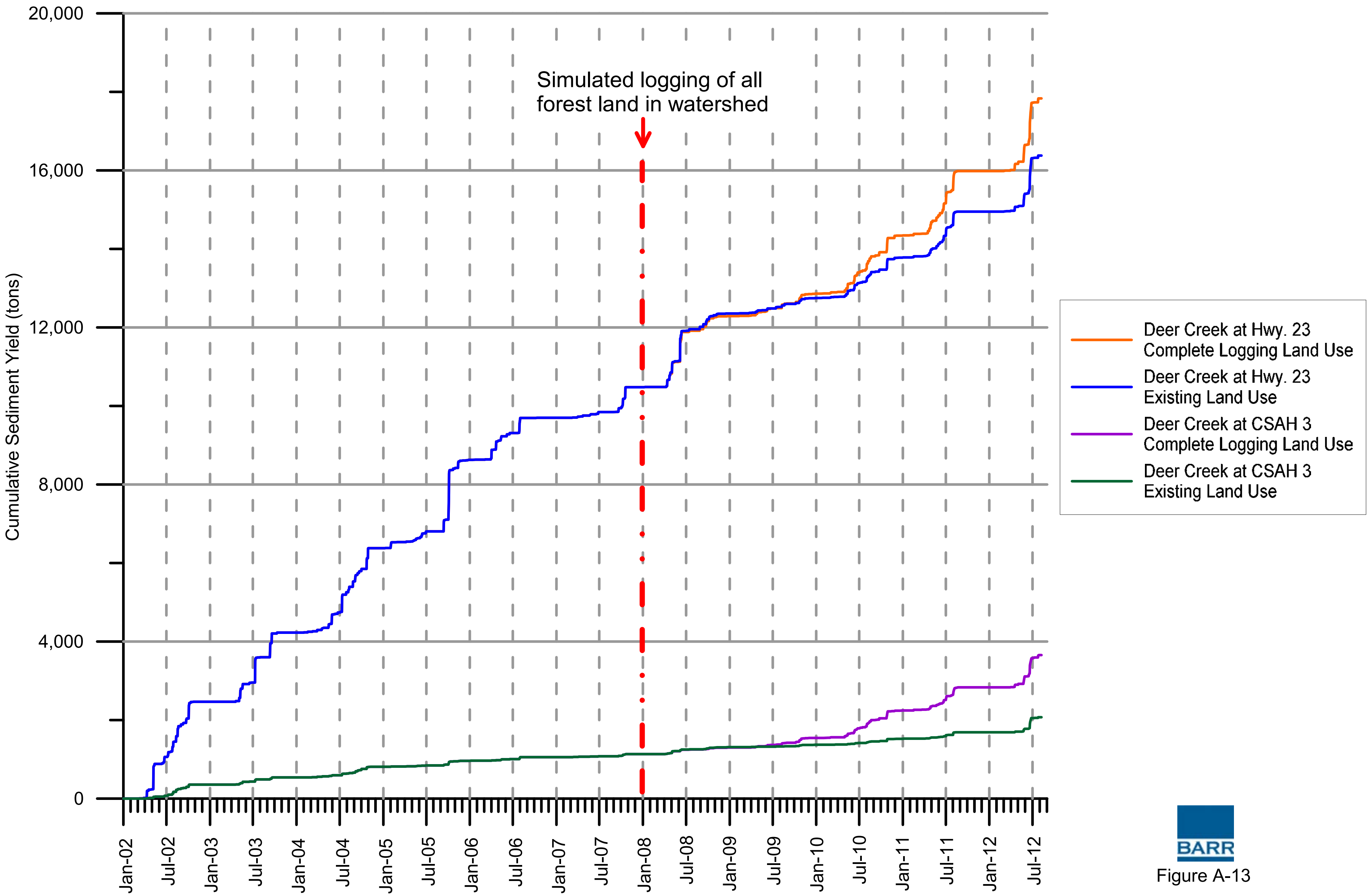
Note: Cumulative sediment yields for Deer Creek at Hwy. 23 do not include yield from sediment volcanoes.

BARR

Figure A-12

Cumulative Sediment Yields
All Forest vs. Existing Land Use
Deer Creek TMDL
Minnesota Pollution Control Agency
Carlton County, Minnesota

\Mpls\23 MN\09\23091014 Deer Crk Watershed TMDL\WorkFiles\Groundwater_Model\Model_Report\Compare_All_Forest_Sed_Yield.grf



Note: Cumulative sediment yields for Deer Creek at Hwy. 23 do not include yield from sediment volcanoes.

\Mpls\23 MN\09\23091014 Deer Crk Watershed TMDL\WorkFiles\Groundwater_Model\Model_Report\Compare_Complete_Logging_Sed_Yield.grf

BARR

Figure A-13

Cumulative Sediment Yields
Complete Logging vs. Existing Land Use
Deer Creek TMDL
Minnesota Pollution Control Agency
Carlton County, Minnesota

Appendix B

Carlton County Zoning Ordinance Information

Subd. H. Shoreland Management Overlay District

1. Statutory Authorization. This shoreland management overlay district is adopted pursuant to the authorization and policies contained in Minnesota Statutes, Chapter 105, Minnesota Regulations, Parts 6120.2500 - 6120.3900, and the planning and zoning enabling legislation in Minnesota Statutes, Chapter 394.
2. Establishment of Shoreland Management Overlay District. The shoreland areas identified in this Subdivision are intended to include provisions that are in addition to or overlay one or more underlying districts established in Section 4 of this Article, and over those districts shown on the official Zoning Map of Thomson Township.
3. Purpose. The uncontrolled use of shorelands of Carlton County, Minnesota affects the public health, safety and general welfare not only by contributing to pollution of public waters, but also by impairing the local tax base. Therefore, it is in the best interests of the public health, safety and welfare to provide for the wise subdivision, use and development of shorelands of public waters. The Legislature of Minnesota has delegated responsibility to local governments of the state to regulate the subdivision, use and development of the shorelands of public waters and thus preserve and enhance the quality of surface waters, conserve the economic and natural environmental values of shorelands, and provide for the wise use of waters and related land resources. This responsibility is hereby recognized by Carlton County.
4. Shoreland Permit Required. A permit is required for the construction of buildings or building additions (including related items such as decks and signs), the installation and/or alteration of individual sewage treatment systems, and grading and filling activities within the shoreland overlay district. An application for a permit shall be made to the Zoning Administrator on forms provided by the County. The application shall include sufficient information as determined by the Zoning Administrator to adequately analyze suitability of the site in question for the intended use and that all sewage produced as a result of and in relation to said intended use shall be treated in compliance with this Ordinance.
5. Notifications to the Department of Natural Resources (DNR).
   A. Copies of all notices of any public hearings to consider variances, ordinance amendments, or conditional uses under the shoreland management overlay district shall be sent to the commissioner or the commissioner's designated representative and be postmarked at least ten days before the hearings. Notices of hearings to consider proposed subdivisions/plats must include copies of the subdivision/plat.

   B. A copy of approved amendments and subdivisions/plats and final decisions granting variances or conditional uses under the shoreland management overlay district shall be sent to the commissioner or the commissioner's designated representative and postmarked within ten days of final action.
6. Shoreland Classification System. Water bodies in Carlton County have been classified into lake and river classifications in accordance with the criteria found in Minnesota Regulations, Part 6120.330, and the Public Waters Inventory Map for Carlton County, Minnesota. The three categories of lakes are natural environment, recreational development, and general development. The three categories of rivers present in the County are remote and forested rivers, and tributary streams.
   A. The shoreland areas for the water bodies listed in this subpart shall be as defined in Article 2, Rules and Definitions, of this Ordinance and as may be shown on the Shoreland Management Overlay Map attached to the Official Zoning Map of Carlton County and the Official Zoning Map of Thomson Township.

   B. The shoreland management overlay district shall apply to the shoreland areas of the following lakes classified as natural environment, recreational development, or general development by the DNR.

      1.) Natural Environment Lakes

Name	Public Waters Inventory I.D. #	Name	Public Waters Inventory I.D. #
Forbay Lake	9-2	Perch Lake	9-36

Soper Lake	9-4	Rice Portage Lake	9-37
Bear Lake	9-5	Eddy Lake	9-39
Blackhoof Lake	9-6	Kohring Lake	9-42
Spring Lake	9-7	Echo Lake	9-44
Venoah Lake	9-9	Spring Lake	9-47
Hay Lake	9-10	Corona Lake	9-48
Flodin Lake	9-14	Kettle Lake	9-49
Ellstrom Lake	9-15	Jaskari Lake	9-50
Sand Lake	9-16	Dead Fish Lake	9-51
Hizer Lake	9-18	Miller Lake	9-53
Munson Lake	9-19	Merwin Lake	9-58
Crystal Lake	9-20	Cross Lake	9-62
Benfield Lake	9-21	Woodbury Lake	9-63
Lake Twenty-Nine	9-22	Long Lake	9-66
Wild Rice Lake	9-23	Mattila Lake	9-70
Unnamed	9-28	Walli Lake	9-71
Hardwood Lake	9-30	Unnamed	9-73
Cedar Lake	9-31	Kettle Lake	9-74
Sophie Lake	9-33	Heikkila Lake	69-846

2.) Recreational Development Lakes

Name	Public Waters Inventory I.D. #	Name	Public Waters Inventory I.D. #
Graham Lake	9-3	Hanging Horn Lake	9-38
Chub Lake	9-8	Moose Lake	9-43
Lac La Belle Lake	9-11	Coffee Lake	9-45
Torch Light Lake	9-25	Bang Lake	9-46
Bob Lake	9-26	Eagle Lake	9-57
Park Lake	9-29	Tamarack Lake	9-67
Big Lake	9-32	Cole Lake	9-68
Bear Lake	9-34	Net Lake	58-38
Little Hanging Horn Lake	9-35	Sand Lake	58-81

3.) General Development Lakes

Name	Public Waters Inventory I.D. #	Name	Public Waters Inventory I.D. #
Thomson Reservoir	9-1	Island Lake	9-60
Moosehead Lake	9-41		

C. The shoreland management overlay district shall apply to the shoreland areas of the following rivers classified as either remote rivers, forested rivers, and tributary streams by the DNR or as either a St. Louis River remote area or a St. Louis River recreational area as defined by the St. Louis River Management Plan.

1.) Remote Rivers

Name	Public Waters Inventory I.D. #	Legal Description From	To
North Fork Nemadji	9-219	East section line, Sec 32, T46N, R17W	Border of Carlton Co. and State of WI in Sec 19, T47N, R15W
South Fork Nemadji	9-254	Confluence with Net River, Sec 34, T47N, R16W	Border of Carlton Co. and State of WI
Net	9-260	West Section Line, Sec 21, T46N, R16W	Confluence with S. Fork Nemadji River in Sec 34, T47N, R16W

2). Forested Rivers

Name	Public Waters Inventory I.D. #	Legal Description From	To
Kettle	9-166	State Hwy 210 Bridge, N Section Line, Sec 6, T48N, R19W	NE 1/4, Sec 7, T48N, R19W
		(Public ditch that has altered the natural watercourse)	
		SW1/4, Sec 36, T48N, R20W	Border of Carlton and Pine Counties in Sec 32/33, T46N, R20W
Moose	9-182	Outlet of Moosehead Lake in Sec 29, T46N, R19W	Border of Carlton and Pine Counties in Sec 36, T46N, R20W
Moose Horn	9-183	W Section Line, Sec 15, T48N, R18W	Inlet of Moosehead Lake in Sec 21, T46N, R19W.
Blackhoof Creek (BC)	9-234	E Section Line, Sec 30, T48N, R17W	Confluence with Nemadji River in Sec 29, T47N, R16W
Net	9-260	Border of Pine and Carlton Counties	E Section Line, Sec 20, T46N, R16W

3.) Tributary Streams

Name	Public Waters Inventory I.D. #	Legal Description From Sec-Twp-Rg	To Sec-Twp-Rg
Hasty Brook (HB)	9-158	18-49-19	4-49-20
Unnamed to HB	9-159	24-49-20	14-49-20
Unnamed to HB	9-160	5-49-20	5-49-20

Tamarack River (TR)	9-161	32-49-20	31-49-21
Unnamed to TR	9-162	8-48-20	9-48-20
Unnamed to TR	9-163	33-49-20	32-49-20
Unnamed to TR	9-164	32-49-20	32-49-20
Little Tamarack River	9-165	15-49-21	7-49-21
Unnamed to KR (Kettle River)	9-167	19-48-19	18-48-19
Heikkila Creek	9-168	29-48-20	9-47-20
Unnamed to KR	9-169	8-47-20	16-47-20
West Branch Kettle River (WBKR)	9-170	18-48-21	20-47-20
Unnamed Tributary	9-171	17-48-21	17-48-21
Unnamed to WBKR	9-172	4-47-21	4-47-21
Dead Moose River	9-173	19-47-21	5-46-20
Silver Creek (SC)	9-174	32-47-21	16-46-20
Unnamed to SC	9-175	3-46-21	3-46-21
Unnamed to SC	9-176	18-46-20	17-46-20
Gillespie Brook (GB)	9-177	26-47-20	28-46-20
Unnamed to GB	9-178	13-47-20	30-47-19
Split Rock River (SRR)	9-179	31-46-21	32-46-20
Unnamed to SRR	9-180	30-46-21	30-46-21
Unnamed to SRR	9-181	36-46-21	25-46-21
Moose Horn River (MHR)	9-183	3-48-18	15-48-18
Unnamed to MHR	9-184	27-48-18	35-48-18
Park Lake Creek	9-185	29-48-18	8-47-18
King Creek (KC)	9-186	1-47-19	19-47-18
Unnamed to KC	9-187	1-47-19	1-47-19
West Branch Moose Horn River (WBMHR)	9-188	3-47-19	36-47-19
Unnamed to WBMHR	9-189	20-47-19	29-47-19
Unnamed to MHR	9-190	16-46-19	21-46-19
Portage River	9-191	5-46-18	21-46-19
Unnamed tributary	9-192	36-49-19	2-48-19
Simian Creek	9-194	10-49-18	1-49-18
Crystal Creek	9-198	17-49-16	31-49-16
Crystal Creek	9-199	1-48-17	6-48-16
Midway River (MR)	9-200	1-49-16	5-48-16
Elm Creek	9-201	2-49-16	1-49-16
Unnamed to MR	9-202	2-49-16	12-49-16
Unnamed to Unnamed	9-203	12-49-16	12-49-16
Unnamed to MR	9-204	12-49-16	12-49-16
Hay Creek	9-205	4-49-16	15-49-16
Unnamed to MR	9-206	29-49-16	33-49-16
Otter Creek (OC)	9-207	26-49-18	8-48-16
Unnamed to OC	9-209	4-48-17	10-48-17
Little Otter Creek (LOC)	9-210	11-48-18	10-48-17
Unnamed to LOC	9-211	5-48-17	7-48-17
Silver Creek (SiC)	9-212	17-48-16	15-48-16
Unnamed to SiC	9-213	29-48-16	16-48-16
Gill Creek	9-214	2-48-16	2-48-16
Little River	9-215	2-48-16	1-48-16
Mission Creek	9-216	26-49-16	36-49-16

Red River (RR)	9-217	26-48-16	30-48-15
Unnamed to RR	9-218	24-48-16	19-48-15
North Fork Nemadji River (NFNR)	9-219	33-46-17	33-46-17
Unnamed to NFNR	9-220	31-46-17	31-46-17
Unnamed to Unnamed	9-221	36-46-18	31-46-17
Unnamed to NFNR	9-222	26-46-18	25-46-18
Unnamed to NFNR	9-223	19-46-17	19-46-17
Nemadji Creek (NC)	9-224	22-46-18	9-46-17
Unnamed to NC	9-225	16-46-18	15-46-18
Unnamed to NC	9-226	16-46-18	15-46-18
Hunter’s Creek (HC)	9-227	35-47-18	13-46-18
Unnamed to HC	9-228	34-47-18	35-47-18
Unnamed to HC	9-229	34-47-18	2-46-18
Unnamed to NC	9-230	7-46-17	7-46-17
Skunk Creek (SkC)	9-231	28-47-17	36-47-17
Unnamed to SkC	9-232	30-47-17	35-47-17
Unnamed to Unnamed	9-233	6-46-17	34-47-17
Unnamed to BC	9-235	30-48-17	30-48-17
Unnamed to BC	9-236	14-47-18	12-47-18
Unnamed to BC	9-237	20-47-17	27-47-17
Deer Creek (DC)	9-238	11-47-17	28-47-16
Unnamed to DC	9-239	19-47-16	20-47-16
Unnamed to DC	9-240	24-47-17	29-47-16
Rock Creek (RC)	9-241	12-47-17	24-47-16
Unnamed to RC	9-242	17-47-16	17-47-16
Unnamed to Unnamed	9-243	17-47-16	17-47-16
Mud Creek (MC)	9-244	6-47-16	18-47-15
Unnamed to MC	9-245	9-47-16	16-47-16
Unnamed to Unnamed	9-246	16-47-16	16-47-16
Unnamed to MC	9-247	10-47-16	14-47-16
Unnamed to MC	9-248	10-47-16	13-47-16
Unnamed to MC	9-249	13-47-16	13-47-16
Clear Creek (CC)	9-250	33-48-16	7-47-15
Unnamed to CC	9-251	27-48-16	3-47-16
Unnamed to CC	9-252	2-47-16	2-47-16
Unnamed to CC	9-253	1-47-16	1-47-16
South Fork Nemadji River (SFNR)	9-254	12-46-17	34-47-16
Clear Creek	9-255	29-46-17	12-46-17
Anderson Creek	9-256	26-46-17	12-46-17
Silver Creek	9-257	25-46-17	14-46-17
Stony Brook	9-258	21-46-17	11-46-17
Unnamed to SFNR	9-259	7-46-16	6-46-16
Net River (NR)	9-260	36-46-17	36-46-17
Unnamed to NR	9-261	33-46-16	32-46-16
Unnamed to NR	9-262	9-46-16	9-46-16
Unnamed to NR	9-263	4-46-16	4-46-16
Little Net River (LNR)	9-264	34-46-16	3-46-16
Unnamed to LNR	9-265	26-46-16	26-46-16
Unnamed to LNR	9-266	27-46-16	27-46-16

Unnamed to NR	9-267	11-46-16	34-47-16
Section 36 Creek (SeC)	9-268	13-46-16	36-47-16
Unnamed to SeC	9-269	11-46-16	1-46-16
Unnamed to SeC	9-270	13-46-16	36-47-16
Unnamed to SeC	9-271	1-46-16	36-47-16
State Line Creek	9-272	31-46-15	30-47-15

4) St. Louis River

Designation	Public Waters Inventory I.D. #	Legal Description Sec-Twp-Rg
Remote	9-1193	South of I-35 in the S1/2 of Sec 30 and Sec 31, T49N, R16W
Recreational	9-1193	North of I-35 in Sec 18, Sec 19, and the N1/2 of Sec 30, T49N, R16W
Recreational	9-1193	N1/2 of T 48N, R. 16-15W

D. Land Use District Descriptions.

1.) The land use districts as delineated on the Carlton County Official Zoning Map are consistent with the goals and policies of the Carlton County Community-Based Comprehensive Plan, adopted April 2001 by the Carlton County Board, as well as being consistent with the St. Louis River Management Plan, adopted February 28, 1994, by the Carlton County Board, the Carlton County Water Plan 2002 Update, and the following provisions as established by Minnesota Rules 61120.3100:

a.) the management of areas unsuitable for development due to wet soils, steep slopes, flooding, inadequate drainage, severe erosion potential, presence of significant historic sites, or any other feature likely to be harmful to the health, safety, or welfare of the residents of the community;

b.) the reservation of areas suitable for residential development from encroachment by commercial and industrial uses;

c.) the centralization of service facilities for residential areas and enhancement of economic growth for those areas suitable for limited commercial development;

d.) the management of areas for commercial or industrial uses which, by their nature, require location in shoreland areas;

e.) the protection of valuable agricultural lands from conversion to other uses; and

f.) the preservation and enhancement of the quality of water-based recreational use of public waters including provisions for public accesses.

2.) The land uses allowable for the shoreland management overlay district shall follow the permitted and conditional uses of the underlying zoning as established in Section 5 of this Article and as delineated on the official Carlton County Zoning Map.

7. Dimensional Requirements for Lots within Lake Shoreland Areas.

A. Lot area requirements. Only land above the Ordinary High Water Level (OHWL) of public waters can be used to meet the lot area requirements within the shoreland overlay district. In addition, the following standards shall apply:

1.) Riparian lots: The minimum lot size shall be as follows or the area necessary to meet the requirements of Carlton County Ordinance No. 25: Individual Sewage Treatment Systems Ordinance, as amended from time to time. In case of a conflict, the stricter standard shall apply. Lots served with public sewer shall meet the minimum lot sizes identified below.

Lot with residential structure type:	Minimum Riparian Lot Area by Lake Type: Natural Environment Non-Sewered	Natural Environment Sewered	Recreational Development Non-Sewered	Recreational Development Sewered	General Development Non-Sewered	General Development Sewered
Single family	80,000 sq. ft.	40.000 sq. ft.	40,000 sq. ft.	20.000 sq. ft.	20,000 sq. ft.	15.000 sq. ft.
Duplex	120,000 sq. ft.	70.000 sq. ft.	80,000 sq. ft.	40.000 sq. ft.	40,000 sq. ft.	35.000 sq. ft.
Triplex	160,000 sq. ft.	100.000 sq. ft.	120,000 sq. ft.	60.000 sq. ft.	60,000 sq. ft.	50.000 sq. ft.
Quad	200,000 sq. ft.	130.000 sq. ft.	160,000 sq. ft.	80.000 sq. ft.	80,000 sq. ft.	65.000 sq. ft.

2.) Non-riparian lots. The minimum lot size shall be the same as the primary zoning district or the area necessary to meet the requirements of *Carlton County Ordinance No. 25: Individual Sewage Treatment Systems Ordinance*, as amended from time to time. In case of a conflict, the stricter standard shall apply. Lots served with public sewer shall meet the standards established for riparian lots in Subsection 7.A.1.), above.

B. Lot width requirements. Lot width requirements shall be the same as the primary zoning district except for riparian lots which are illustrated below.

Lot with residential structure type:	Minimum Riparian Lot Width by Lake Type: Natural Environment Non-Sewered	Natural Environment Sewered	Recreational Development Non-Sewered	Recreational Development Sewered	General Development Non-Sewered	General Development Sewered
Single family	200’	125’	150’	75	100	75’
Duplex	300’	225’	225’	135’	180’	135’
Triplex	400’	325’	300’	195’	260’	195’
Quad	500’	425’	375’	255’	340’	255’

C. Other dimensional requirements (lot depth, lot coverage, building height, and yard area setbacks) of the primary zoning district shall apply to all lots unless modified by the standards of this Subdivision. In case of a conflict, the stricter standard shall apply.

D. In addition to the standards in A. and B. above, the following minimum standards shall be met:

1.) General development lakes:

Structure setback from OHWL	75’
Sewered structure setback from OHWL	50’
Structure setback from top of bluff	30’
Elevation of lowest floor above OHWL[1]	3’
ISTS setback from OHWL	100’
Structure setback from unplatted cemetery	50’
Front yard (street) and side yard setbacks	Underlying District

[1]Or highest known water level whichever is higher.

2.) Recreational development lakes:

Structure setback from OHWL	100’

Sewered structure setback from OHWL	75’
Structure setback from top of bluff	30’
Elevation of lowest floor above OHWL[1]	3’
ISTS setback from OHWL	100’
Structure setback from unplatted cemetery	50’
Front yard (street) and side yard setbacks	Underlying District

[1]Or highest known water level whichever is higher.

3.) Natural environment lakes:

Structure setback from OHWL	150’
Structure setback from top of bluff	30’
Elevation of lowest floor above OHWL[1]	3’
ISTS setback from OHWL	150’
Structure setback from unplatted cemetery	50’
Front yard (street) and side yard setbacks	Underlying District

[1]Or highest known water level whichever is higher.

8. Dimensional Requirements for Lots within Riverine Shoreland Areas.

A. The dimensional requirements (minimum lot size, lot width, lot depth, lot coverage, building height, and yard area setbacks) of the primary zoning district shall apply to all riparian and non-riparian lots within shoreland areas except for lots within the St. Louis River area designations unless:

1.) modified by the standards of this Subdivision, or

2.) the area necessary to meet the requirements of Carlton County Ordinance No. 25: Individual Sewage Treatment Systems Ordinance, as amended from time to time.

3.) Lots are served with public sewer and meet the standards in Subsection 7.A.1.), above.

In case of a conflict, the stricter standard shall apply.

B. Only land above the OHWL of public waters can be used to meet the lot area requirements within the shoreland overlay district.

C. In addition to the minimum standards of the primary zoning district, the following minimum standards shall be met:

1.) Tributary streams:

Structure setback from OHWL	100’
Sewered structure setback from OHWL	50’
Structure setback from top of bluff	30’
Elevation of lowest floor above OHWL[1]	3’
ISTS setback from OHWL	100’
Structure setback from unplatted cemetery	50’
Front yard (street) and side yard setbacks	Underlying District

[1]Or highest known water level whichever is higher.

2.) Forested rivers:

Structure setback from OHWL	150’
Structure setback from top of bluff	30’

Elevation of lowest floor above OHWL[1]	3’
ISTS setback from OHWL	100’
Structure setback from unplatted cemetery	50’
Front yard (street) and side yard setbacks	Underlying District

1Or highest known water level whichever is higher.

3.) Remote rivers:

Structure setback from OHW	200’
Structure setback from top of bluff	30’
Elevation of lowest floor above OHWL[1]	3’
ISTS setback from OHWL	150’
Structure setback from unplatted cemetery	50’
Front yard (street) and side yard setbacks	Underlying District

[1]Or highest known water level whichever is higher.

4.) Floor area separation: The lowest floor area of a structure shall be placed a minimum of 3’ above the flood of record, if data is available. If data is not available, the lowest floor shall be placed at least 3’ above the OHWL or the flood protection elevation established by a technical evaluation conducted on flood stages and flood flows. Under all three approaches, technical evaluations must be done by a qualified engineer or hydrologist consistent with Minnesota Rules Parts 6120.5000 to 6120.6200 governing the management of floodplain areas. If more than one approach is used, the highest flood protection elevation must be used for the placement of structures and other facilities.

D. Red clay areas within shorelands. The red clay areas of the St. Louis and Nemadji River basins have been identified as having significant potential for erosion. Such erosion would severely impact the streams of these areas. The definitions for red clay area bluff and red clay area bluff impact zone shall apply within the entire basins of the St. Louis and Nemadji Rivers and shall apply to the state shoreland portions of the St. Louis and Nemadji River basins areas unless the application of the state shoreland, bluff, and bluff impact zone definitions results in more restrictive building setbacks or other standards.

E. St. Louis River area designations. The following requirements shall be met for lots within the St. Louis River area designations, except for lot width which shall be the same as the primary zoning district:

1.) Standards	Remote area	Recreational area
Lot size	17 acres	4.5 acres
Lot width/frontage	600’	300’
Structure setback from OHWL	200’	150’
Shore impact zone	150’	75’
ISTS setback	150’	150’

2.) Bluff impact zone requirements. The bluff impact zone shall be the same as the red clay area bluff impact zone:

a.) The principal structure setback from the top of the bluff shall be 30 feet.

b.) No water-oriented accessory structures are permitted in the bluff impact zone.

3.) Floor area separation. Shall be the same as required for the river and stream classifications in C.4.), above.

9. Design Criteria for Certain Structures and/or Uses.

A. Residential subdivisions shall be consistent with unit densities allowed in shoreland areas. Only land above the OHWL of public waters can be used to meet lot area standards, and lot width standards must be met at both the OHWL and at the building line.

B. Subdivisions of duplexes, triplexes, and quads on natural environment lakes shall also meet the following standards:

1.) Each building must be set back at least 200' from the OHWL.

2.) The buildings must have common sewage treatment and water systems in one location and serve all dwelling units in the buildings.

3.) Watercraft docking facilities for each lot must be centralized in one location and serve all dwelling units in the building.

4.) No more than 25% of a lake's shoreline can be in duplex, triplex, or quad developments.

C. Guest cottages on certain lots. One guest cottage may be allowed on lots meeting or exceeding the duplex lot area and width dimensions presented in Subsection 7 of this Subdivision, provided the following standards are met:

1.) For lots exceeding the minimum lot dimensions of duplex lots, the guest cottage must be located within the smallest duplex-sized lot that could be created, including the principal dwelling unit.

2.) A guest cottage must not cover more than 700 sq. ft. of land surface and must not exceed 15' in height.

3.) A guest cottage must be located or designed to reduce its visibility as viewed from public waters and adjacent shorelands by vegetation, topography, increased setbacks or color, assuming summer, leaf-on conditions.

D. Controlled access lots to public waters or as recreation areas for use by owners of non-riparian lots within subdivisions. Controlled access lots are permissible and must meet or exceed the following standards:

1.) They must meet the width and size requirements for residential lots, and be suitable for the intended uses of controlled access lots.

2.) If docking, mooring, or over-water storage of more than six watercraft is to be allowed at a controlled access lot, then the width of the lot (keeping the same lot depth) must be increased by a percentage of the requirements for riparian residential lots for each watercraft beyond six, consistent with the following table:

Controlled access lot frontage requirements

Ratio of lake size to shore length (acres/mile)	Required increase in frontage per stored watercraft more than six
Less than 100	25%
100 – 200	20%
201 – 300	15%
301 – 400	10%
Greater than 400	5%

3.) They must be jointly owned by all purchasers of lots in the subdivision or by all purchasers of non-riparian lots in the subdivision who are provided riparian access rights on the access lot.

4.) Covenants or other equally effective legal instruments must be developed that specify which lot owners have authority to use the access lot and what activities are allowed. The activities may include watercraft launching, loading, storage, beaching, mooring, or docking. The covenants or legal instruments must also include other outdoor recreational activities that do not significantly conflict with general public use of the public water or the enjoyment of normal property rights by adjacent property owners. Examples of the non-significant conflict activities include swimming, sunbathing, and picnicking.

The covenants must limit the total number of vehicles allowed to be parked and the total number of watercraft allowed to be continuously moored, docked, or stored over water, and must require centralization of all common facilities and activities in the most suitable locations on the lot to minimize topographic and vegetation alterations. They must also require all parking areas, storage buildings, and other facilities to be screened by vegetation or topography as much as practical from view from the public water, assuming summer, leaf-on conditions.

E. Accessory structures. All accessory structures and facilities must meet or exceed the structural setback requirements of the primary zoning district except as modified below:

1.) Water-oriented accessory structures.

a.) The structure may have the lowest floor placed lower than required if constructed of flood-resistant materials to the OHWL and electrical and mechanical equipment is placed above the OHWL. If long-duration flooding is anticipated, the structure shall be built to withstand ice action and wind-driven waves and debris.

b.) On general development and recreational development lakes, water-oriented accessory structures used solely for watercraft storage and storage of related boating and water-oriented sporting equipment may occupy an area up to 400 sq. ft. provided the maximum width of the structure is 20' as measured parallel to the shoreline.

c.) The structure or facility must not be designed or used for human habitation and must not contain water supply or sewage treatment facilities.

2.) Water-oriented accessory structures not meeting the structure setback from the OHWL. Each residential lot may have one water-oriented accessory structure or facility located closer to the OHWL of public waters than the required structure setback if all of the following standards are met:

a.) The structure or facility must not exceed 10' in height, exclusive of safety rails, and cannot occupy more than 160 sq. ft. in area.

b.) The structure setback from the OHWL shall be a minimum of 10', except in the St. Louis River area designations, where the minimum setback shall be 30' from the OHWL.

c.) The structure or facility must be treated to reduce its visibility as viewed from public waters and adjacent shorelands by vegetation, topography, increased setbacks or color, assuming summer, leaf-on conditions.

d.) The height of the structure shall not be constructed 3' above the main floor level of any principal structure on the lot or adjoining lots within 200' of the proposed building site.

3.) Stairways, lifts and landings: Stairways and lifts are the preferred alternative to major topographic alterations for achieving access up and down bluffs and steep slopes to shore areas. Stairways and lifts must meet the following design requirements:

a.) Stairways and lifts must not exceed 4' in width on residential lots, or 8' in width on commercial, public open space recreational, or planned unit development properties.

b.) Landings for stairways and lifts on residential lots must not exceed 32 sq. ft. in area. Landings for stairways and lifts on commercial, public open space recreational, or planned unit development properties must not exceed 80 sq. ft. in area.

c.) Canopies or roofs shall not be allowed on stairways, lifts, or landings.

d.) Stairways, lifts, and landings may be either constructed above the ground on posts or pilings, or placed into the ground, provided they are designed and built in a manner that ensures control of soil erosion.

e.) Stairways, lifts, and landings must be located in the most visually inconspicuous portions of the lots, as viewed from the surface of the public water assuming summer, leaf-on conditions, whenever practical.

f.) Handicapped accessibility: Facilities such as ramps, lifts, or mobility paths for physically handicapped persons are also allowed for achieving access to shore areas, provided that the dimensional and performance standards of this Subsection are complied with in addition to the requirements of Minnesota Rules Chapter 1341.

F. Special provisions for commercial, industrial, public/semipublic, agricultural, forestry and extractive uses and mining of metallic minerals and peat.

1.) Commercial, industrial, public, and semipublic uses standards.

a.) Surface water-oriented uses with similar needs to have access to and use of public waters may be located on parcels or lots with frontage on public waters. Those uses with water-oriented needs must meet the following standards:

i.) In addition to meeting impervious coverage limits, setbacks, and other standards in this Ordinance, the uses must be designed to incorporate topographic and vegetative screening of parking areas and structures.

ii.) Uses that require short-term watercraft mooring for patrons must centralize these facilities and design them to avoid obstructions of navigation and to be the minimum size necessary to meet the need.

iii.) Uses that depend on patrons arriving by watercraft may use signs and lighting to convey needed information to the public, subject to the following general standards:

iiia.) No advertising signs or supporting facilities for signs may be placed in or upon public waters. Signs conveying information or safety messages may be placed in or on public waters by a public authority or under a permit issued by the County sheriff.

iiib.) Signs may be placed, when necessary, within the shore impact zone if they are designed and sized to be the minimum necessary to convey needed information. They must only convey the location and name of the establishment and the general types of goods or services available. The signs must not contain other detailed information such as product brands and prices, must not be located higher than ten feet above the ground, and must not exceed 32 sq. ft. in size. If illuminated by artificial lights, the lights must be shielded or directed to prevent illumination out across public waters.

iiic.) Other outside lighting may be located within the shore impact zone or over public waters if it is used primarily to illuminate potential safety hazards and is shielded or otherwise directed to prevent direct illumination out across public waters. This does not preclude use of navigational lights.

b.) Uses without water-oriented needs must be located on lots or parcels without public waters frontage, or, if located on lots or parcels with public waters frontage, must either be set back double the normal OHWL setback or be substantially screened from view from the water by vegetation or topography, assuming summer, leaf-on conditions.

2.) Agricultural use standards.

a.) General cultivation farming, grazing, nurseries, horticulture, truck farming, sod farming, and wild crop harvesting are permitted uses if steep slopes and shore and bluff impact zones are maintained in permanent vegetation or operated under an approved conservation plan consistent with the field office technical guides of the Soil and Water Conservation District as provided by a qualified individual or agency. The shore impact zone for parcels with permitted agricultural land uses is equal to a line parallel to and 50’ from the ordinary high water level.

b.) Animal feedlots as defined by the Minnesota Pollution Control Agency (MPCA) must meet the feedlot standards of the Minnesota Rules 7020, as amended from time to time, pertaining to feedlots.

3.) Forest management standards. The harvesting of timber and associated reforestation must be conducted consistent with the provisions of the Minnesota Voluntary Site-Level Forest Management Guidelines and the provisions of Water Quality in Forest

Management "Best Management Practices in Minnesota."

4.) Extractive use standards.

a.) An extractive use site development and restoration plan must be developed, approved, and followed over the course of operation of the site. The plan must address dust, noise, possible pollutant discharges, hours and duration of operation, and anticipated vegetation and topographic alterations. It must also identify actions to be taken during operation to mitigate adverse environmental impacts, particularly erosion, and must clearly explain how the site will be rehabilitated after extractive activities end.

b.) Processing machinery must be located consistent with setback standards for structures from OHWL's of public waters and from bluffs.

5.) Mining of metallic minerals and peat standards. Mining of metallic minerals and peat, as defined in Minnesota Statutes, Sections 93.44 to 93.51, shall be a permitted use provided the provisions of Minnesota Statutes, Sections 93.44 to 93.51, are satisfied.

G. Significant historic sites. No structure may be placed on a significant historic site in a manner that affects the values of the site unless adequate information about the site has been removed and documented in a public repository.

H. Public and private roads and parking areas.

a.) Must be designed to take advantage of natural vegetation and topography to achieve maximum screening from view from public waters. Documentation must be provided by a qualified individual that all roads and parking areas are designed and constructed to minimize and control erosion to public waters consistent with the field office technical guides to the Soil and Water Conservation District or other applicable technical materials.

b.) Roads, driveways, and parking areas must meet structure setbacks and must not be placed within bluff and shore impact zones, when other reasonable and feasible placement alternatives exist. If no alternatives exist, they may be placed within these areas, and must be designed to minimize adverse impacts.

c.) Public and private watercraft access-related parking areas must be located outside the shore impact zone. Vegetative screening and erosion control conditions of this subpart must be met. The grading and filling provisions of Subsection 10 of this Subdivision must be met.

d.) All parking lots of over 50 spaces shall have a plan prepared to control runoff using Soil and Water Conservation District guidelines.

e.) Roads, driveways, and parking areas shall have an area available for snow storage that will not result in rapid runoff into surface waters. Snow storage shall be outside the principal structure setback area.

10. Shoreland Alterations. Alterations of vegetation and topography shall be regulated to prevent erosion into public waters, to fix nutrients, to preserve shoreland aesthetics, to preserve historic values, to prevent bank slumping, and to protect fish and wildlife habitat. The preservation of existing native vegetation and soils shall be a management priority within shoreland impact zones. Re-vegetation with native species and replacement or re-grading of disturbed areas with native soils shall also be a priority when removal and alterations occur.

A. Vegetation alterations and removal.

1.) Vegetative alteration necessary for authorized construction of structures, sewage treatment systems, stairways and landings, pathways, roads and parking areas regulated by this Subdivision are exempt from the vegetation alteration standards of this Subsection.

2.) Vegetation removal is regulated within the shore, bluff, and red clay bluff impact zones.

a.) In the shore impact zone, an area no wider than 33% of the lot width, or 40 feet, whichever is less, and no deeper than 25 feet from the OHWL, may be cleared for lake usage purposes. This area must include the water-oriented accessory structures and facilities and other clearings for water access. All cleared areas must be stabilized with native vegetative ground cover (except exposed bedrock areas) to prevent erosion and sedimentation.

b.) In the bluff and red clay bluff impact zones, one-quarter (¼) of the trees greater than 5 inches in diameter at breast height (DBH, 4½ feet above ground) and one-third (1/3) of the trees or shrubs less than 5 inches DBH may be removed. The area cleared may not exceed 15% of the lot width, or 25 feet, whichever is less, and must include facilities and clearings for lake access. All cleared areas must be stabilized with native vegetative ground cover (except exposed bedrock areas) to prevent erosion and sedimentation. On properties where the shore area clearance in Subsection a.), above, has occurred, the number of trees and shrubs removed from the shore area shall count toward the allowable tree/shrub removal in this Subsection.

c.) In the shore impact zone , one-quarter (¼) of the trees greater than 5 inches in diameter at breast height (DBH, 4½ feet above ground) and one-third (1/3) of the trees or shrubs less than 5 inches DBH may be removed. The area cleared may not exceed 25% of the lot width, or 40 feet, whichever is less, and must include facilities and clearing for lake access. All cleared areas must be stabilized with permanent vegetative ground cover (except exposed bedrock areas) to prevent erosion and sedimentation. On properties where the shore area clearance in Subsection a.), above, has occurred, the number of trees and shrubs removed from the shore area shall count toward the allowable tree/shrub removal in this Subsection.

d.) Between the shore impact zone and the building setback line, 50 % of the trees greater than 5 inches in diameter at breast height (DBH, 4½ feet above ground) and 100 % of the trees or shrubs less than 5 inches DBH may be removed.

3.) Removal in excess of the limitations in Subsection 2.), above, is allowed under the following conditions:

a.) The vegetation is replaced native species or with trees, shrubs and plants that have similar or more beneficial ecological, erosion preventative, and screening values than previously presented. A re-vegetation plan demonstrating adherence to this provision shall be submitted for review and approval to the County Zoning Administrator.

b.) Vegetation removal is allowed within the A-1 and A-2 primary zoning districts outside of the shore, bluff, or red clay bluff impact zone for on-going timber production and management of forest crops where the long-term intention is not to convert the area to residential, commercial or recreational uses.

4.) All vegetative alterations are subject to the following conditions:

a.) The screening of structures, vehicles, or other facilities as viewed from the water, assuming summer, leaf-on conditions, is not substantially reduced;

b.) All cutting is done by hand or human means and shall not be done by heavy equipment except for vegetation removal conducted under 3.) b.) above.

c.) Erosion and stormwater control methods are implemented according to guidelines of the Soil and Water Conservation District.

B. Topographic alterations/grading and filling. Permits shall be required for grading and filling activities within 300’ of any lake, river or stream. However, no separate grading and filling permit shall be required for grading, filling, and excavations necessary for the construction of structures, sewage treatment systems, and driveways under other permits provided that these structures, sewage treatment systems, and driveways are constructed in a manner that complies with the requirements below.

1.) A permit for grading and filling activities shall be obtained from the Zoning Administrator for the following grading and filling activities:

a.) the movement of between 5 and 10 cubic yards of material per site within a bluff or red clay bluff zone and steep slopes provided that the standards listed in Subsection 3.) of this subpart are followed.

b.) the movement of 10 to 50 cubic yards of material per site within the shore impact zone but outside a bluff or red clay bluff zone and steep slopes provided that the standards listed in Subsection 3.) of this subpart are followed; and

c.) the movement of more than 50 cubic yards of material per site outside of the shore and bluff impact zones, provided that plans are submitted in accordance with Subsection 2.) c.) and the standards listed in Subsection 3.) of this subpart are followed.

2.) A conditional use permit shall be required from the County Board for grading and filling activities that involve:

a.) The movement of 10 or more cubic yards of material per site within a bluff or red clay bluff zone and steep slopes; and

b.) The movement of more than 50 cubic yards of material per site within the shore and bluff impact zones.

c.) Plans for a.) and b.) above shall be submitted that have been prepared by a engineer, soil scientist, landscape designer, or other qualified professional that include the following information:

i.) existing and final topography utilizing 2’ contours,

ii.) a site restoration plan showing trees to be removed and replaced, and final ground cover,

iii.) a drainage and erosion control plan showing the type and location of erosion control measures to be used,

iv.) a development plan showing how the re-contoured lot may be developed in a manner consistent with this Ordinance, and

v.) the plan shall be reviewed by the Soil and Water Conservation District before commencement of grading/filling activity.

d.) For excavations in public waters where the intended purpose is connection to a public water, such as boat slips, canals, channels, lagoons and harbors, a permit for excavation may be granted after the commissioner has approved the proposed connection to public waters.

3.) The following permit standards shall be complied with by the applicant:

a.) The applicant shall prepare and submit a plan for review showing existing and proposed contours, erosion control plan, and final ground cover. If required, the plan shall be reviewed by the Soil and Water Conservation District.

b.) Alterations must be designed and conducted in a manner that ensures only the smallest area of soil is exposed for the shortest time possible.

c.) Mulches or similar materials must be used for temporary bare soil coverage and permanent vegetation established within a reasonable period of time.

d.) Methods to minimize soil erosion and trap sediments before they reach any surface water feature must be used. Methods to trap sediments must be in place before soil disturbance begins.

e.) Fill or excavated material shall not be placed upon/within bluffs, bluff impact zones, or steep slopes.

f.) Any alterations below the ordinary high water level of public waters must be authorized by the Commissioner.

g.) Alterations to topography must be accessory to a permitted use or conditional use and not adversely affect adjacent or nearby properties.

h.) Placement of natural rock riprap, including associated grading of the shoreline and placement of a filter blanket, is permitted if the steepness of the finished slope does not exceed 3’ horizontal to 1’ vertical, the landward extent of the riprap is within 10’ of the ordinary high water level, and the height of the riprap above the ordinary high water level does not exceed 3’.

C. After-the-fact alterations, noncompliance/violation of shoreland alteration standards. Any after-the-fact alterations, noncompliance or violations to the vegetative removal or topographic alteration provisions of this Section shall adhere to in the following:

1.) In the case of after-the-fact (as defined in Article 2, Section 2 of this Ordinance) alterations, a permit and plans shall be submitted to the Zoning Administrator in accordance with the requirements and procedures of this Section. The alteration shall comply with all standards of this Ordinance.

2.) Any noncompliance or violation of this Section shall require the submittal of a restoration plan to the County that mitigates the extent of violation or noncompliance to the pre-noncompliance or pre-violation condition of the property. The plan shall be approved by the Zoning Administrator and complied with within one year of plan submittal. The alteration shall comply with all standards of this Ordinance.

11. Stormwater Management. The following general and specific standards shall apply:

A. General standards:

1.) When possible, existing natural drainageways, wetlands, and vegetated soil surfaces must be used to convey, store, filter, and retain stormwater runoff before discharge to public waters.

2.) Development must be planned and conducted in a manner that will minimize the extent of disturbed areas, runoff velocities, erosion potential, and reduce and delay runoff volumes. Disturbed areas must be stabilized and protected as soon as possible and facilities or methods used to retain sediment on the site.

3.) When development density, topography features, and soil and vegetation conditions are not sufficient to adequately handle stormwater runoff using natural features and vegetation, various types of constructed facilities such as diversions, settling basins, skimming devices, dikes, waterways, and ponds may be used. Preference must be given to designs using surface drainage, vegetation, and infiltration rather than buried pipes and man-made materials and facilities.

B. Specific standards.

1.) Impervious surface coverage of lots shall not exceed 25% of the lot area.

2.) When constructed facilities are used for stormwater management, documentation must be provided by a qualified individual that they are designed and installed consistent with the recommendations of the Soil and Water Conservation District.

3.) Newly constructed stormwater outfalls to public waters must provide for filtering or settling of suspended solids and skimming of surface debris before discharge.

12. Water Supply and Sewage Treatment.

A. Water supply. Any public or private supply of water for domestic purposes must meet or exceed standards for water quality of the Minnesota Department of Health and the MPCA.

B. Sewage treatment. Any premises used for human occupancy must be provided with an adequate method of sewage treatment, as follows:

1.) Publicly owned sewer systems must be used where available;

2.) Individual sewage treatment systems as regulated by Carlton County Ordinance No. 25: Individual Sewage Treatment Systems Ordinance. All provisions of Carlton County Ordinance No. 25 shall be complied with including any standard that may require lot areas, widths and any other dimensional requirement that exceeds the minimum standards of this Ordinance; or

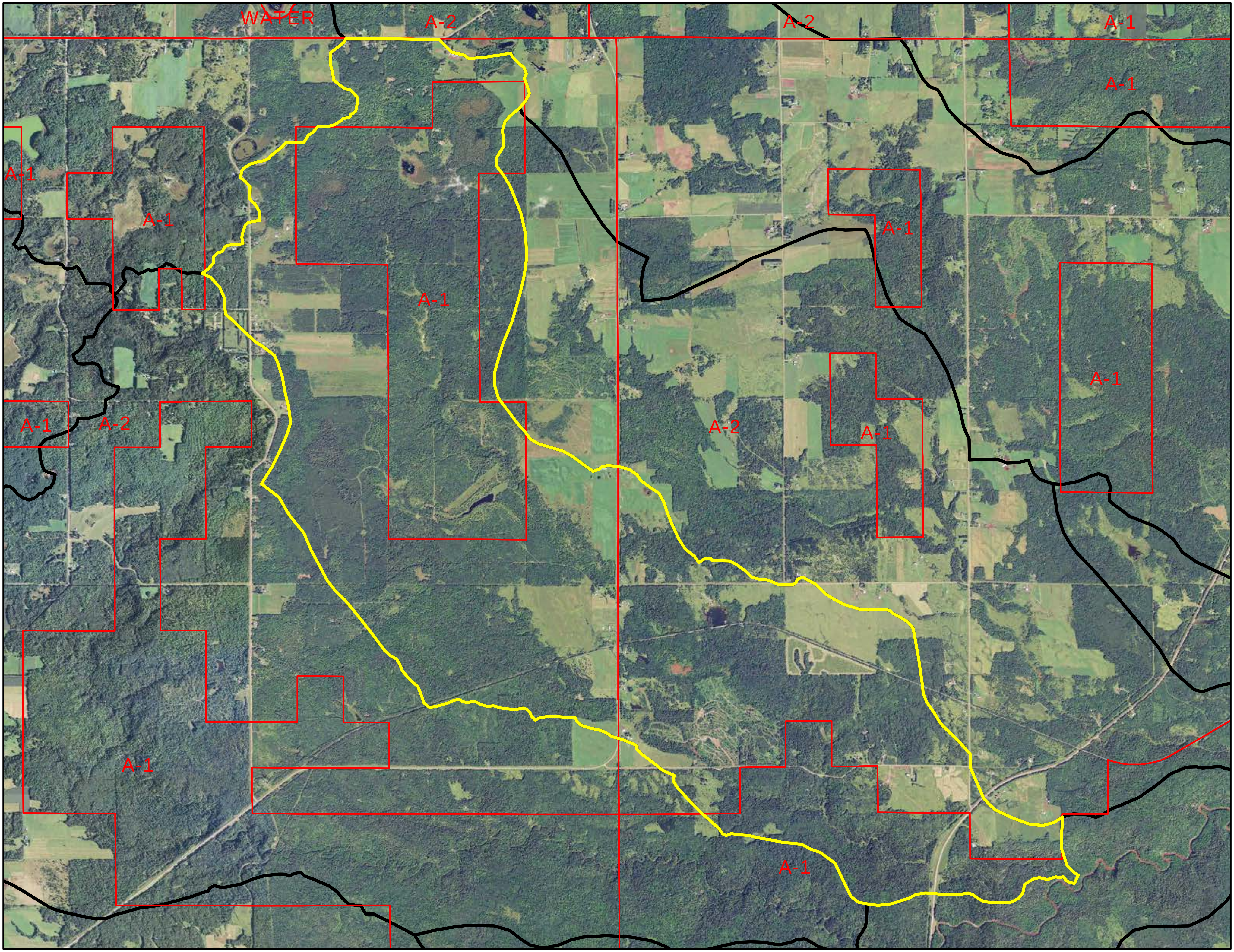
3.) Individual sewage treatment systems shall meet the setback requirements from the OHWL in accordance with the setbacks contained in this Subdivision.

13. Nonconformities. (Refer to Article 3, Section 8.)

14. Variance Applications in the Shoreland District. (Refer to Article 3, Section 6.)

15. Conditional Uses. (Refer to Article 3, Section 5.)

16. Planned Unit Developments. (Refer to Article 5, Section 20.)


WATER
A-2
A-2
A-1
A-1
A-1
A-1
A-1
A-1
A-1
A-1
A-2
A-2
A-1
A-1
A-1
A-1

FACT SHEET
SHORELAND VEGETATION ALTERATIONS
CARLTON COUNTY ZONING ORDINANCE #27

WHY IS IT REGULATED? Alterations of vegetation and topography are regulated within shoreland to prevent erosion into public waters, reduce excess nutrients like phosphorous and nitrogen from washing into the lake, preserve shoreland aesthetics and historic values, prevent bank slumping, and to protect fish and wildlife habitat. The preservation of existing native vegetation and soils are a priority in shoreland. A list of vegetation native to Carlton County can be obtained at the Planning and Zoning Office.

Did you know:

- ☞ That when there is precipitation, water will evaporate, run off the land, or soak (infiltration) into the ground. The amount of vegetative cover on the ground will significantly impact the amount of runoff and infiltration.
- ☞ Natural Shoreline: 40% evaporation, 50% infiltration and 10% runoff. Disturbed/Mowed Shoreline: 55% runoff, 30% evaporation and 15% infiltration.
- ☞ Runoff can erode shorelines and carry nutrients, like phosphorus, to the lake. A lawn up to the water's edge can cause 7 times the amount of phosphorus and 18 times the amount of sediment to enter the water compared to natural shorelines.
- ☞ Phosphorus is the key nutrient needed for aquatic plant and algae growth. When excessive phosphorus reaches the lake, it fuels the overgrowth of aquatic plants and algae. Excessive plant and algae growth decreases water clarity, interferes with recreational use of the lake, and diminishes oxygen for fish.

DEFINITIONS:

ORDINARY HIGH WATER LEVEL (OHWL): The boundary of public waters and wetlands is the elevation delineating the highest water level which has been maintained for a sufficient period of time to leave evidence upon the landscape. This point is commonly where the natural vegetation changes from predominantly aquatic to predominately terrestrial. For rivers and streams, the OHWL is the elevation at the top of the bank of the channel.

SHORE IMPACT ZONE: The shore impact zone is the land located between the ordinary high water level (OHWL) of a public water and a line parallel to it at a setback of 50% of the structure setback.

LAKE ACCESS AREA: The lake access area is an area no wider than 33% of the lot width, or 40 feet, whichever is less, and no deeper than 25 feet from the OWHL.

VIEWING CORRIDOR (Red Clay or Bluff Zone): The viewing corridor in a red clay or bluff zone is an area than may not exceed 15% of the lot width, or 25 feet, whichever is less.

VIEWING CORRIDOR (outside Red Clay or Bluff Zone): The viewing corridor outside a red clay or bluff zone is an area than may not exceed 25% of the lot width, or 40 feet, whichever is less.

CARLTON COUNTY ZONING ORDINANCE #27 - Article 4, Section 5, Subd. H 10A:

This section of the ordinance regulates the alteration and removal of vegetation effective March 1, 2005. If your lawn along the shore was created before this date, but you wish to revegetate to these standards, call the Planning and Zoning Office for guidance and possible grant opportunities.

All vegetation alterations are subject to the following conditions:

- ☞ The screening of structures, vehicles, or other facilities as viewed from the water, assuming summer, leaf-on conditions, is not substantially reduced;
- ☞ All cutting is done by hand or human means and shall not be done by heavy equipment;
- ☞ Erosion and stormwater control methods are implemented according to guidelines of the Soil and Water Conservation District.
- ☞ Removal in excess of the limitations is allowed when vegetation is replaced with native species that have more ecological benefit, prevent erosion, or add more screening values. A revegetation plan must be approved by the County Zoning Administrator prior to work.
- ☞ After-the-fact alterations will require submittal of, and adherence to, an approved restoration plan that mitigates the extent of the violation.

The following summarizes restrictions on shoreland alterations and vegetation removal:

SHORE IMPACT ZONE: The shore impact zone is the land located between the ordinary high water level (OHWL) of a public water and a line parallel to it at a setback of 50% of the structure setback.

AREA A - LAKE ACCESS AREA: The lake access area is an area no wider than 33% of the lot width, or 40 feet, whichever is less, and no deeper than 25 feet from the OWHL. This area may be cleared to access the lake. This area must include water-oriented accessory structures (such as a boathouse). Docks, lifts and landings are located within this area, at the water's edge. All cleared areas must be stabilized with native vegetative ground cover (except exposed bedrock areas).

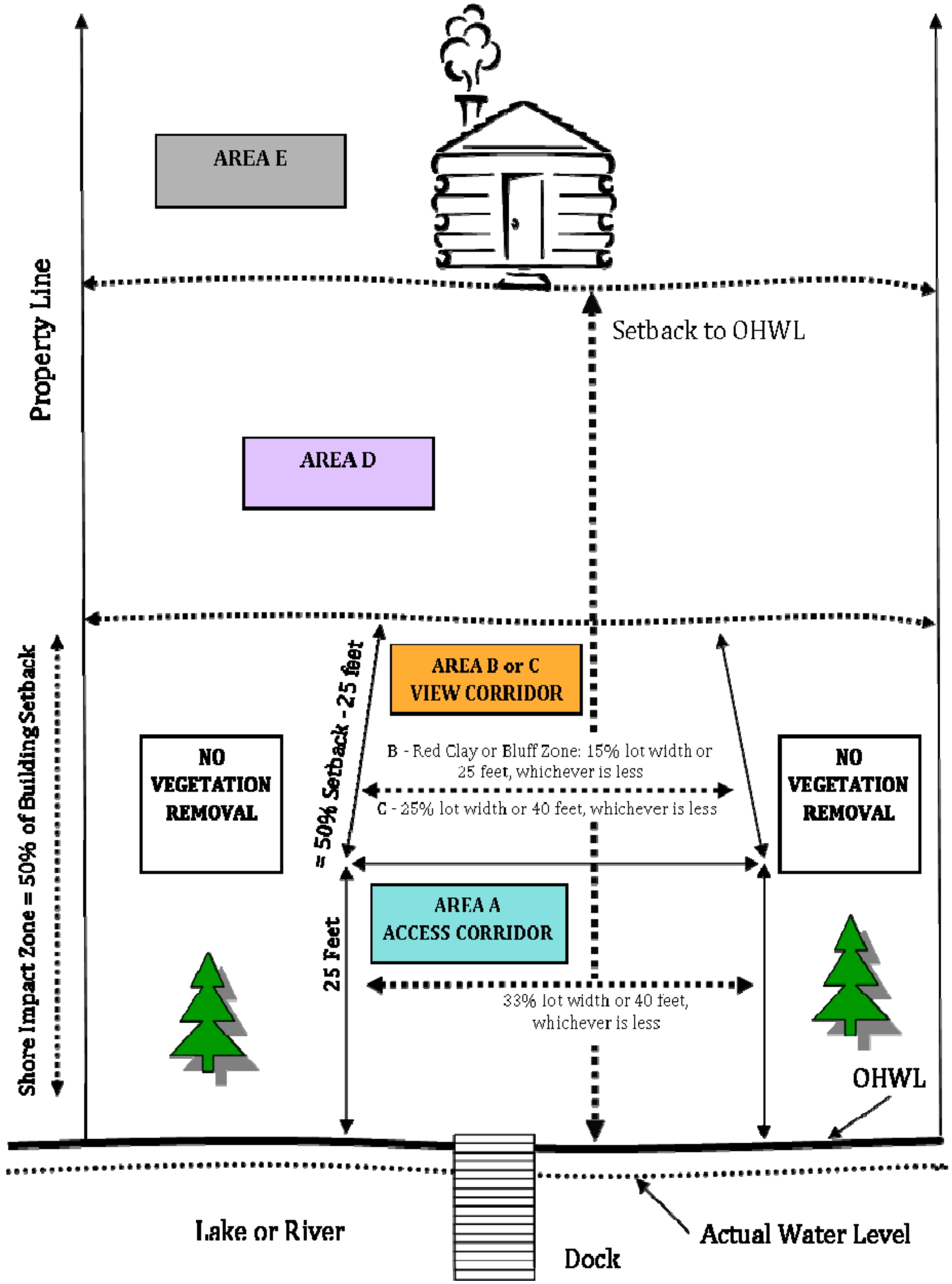
AREA B - VIEWING CORRIDOR (Red Clay or Bluff Zone): The viewing corridor in a red clay or bluff zone is an area that may not exceed 15% of the lot width, or 25 feet, whichever is less. The area must include facilities (such as stairways and landings) and clearings for lake access. Within this corridor, 1/4 of the trees greater than 5 inches in diameter at breast height (DBH) and 1/3 of the trees and shrubs less than 5 inches in DBH may be removed. All cleared areas must be stabilized with native vegetative ground cover (except exposed bedrock areas). On properties where the lake access area has been cleared, the number of trees and shrubs removed from the lake access area shall count toward the allowable tree/shrub removal in the viewing corridor.

OR

AREA C - VIEWING CORRIDOR (outside Red Clay or Bluff Zone): The viewing corridor outside a red clay or bluff zone is an area that may not exceed 25% of the lot width, or 40 feet, whichever is less. The area must include facilities (such as stairways and landings) and clearings for lake access. Within this corridor, 1/4 of the trees greater than 5 inches in diameter at breast height (DBH) and 1/3 of the trees and shrubs less than 5 inches in DBH may be removed. All cleared areas must be stabilized with native vegetative ground cover (except exposed bedrock areas). On properties where the lake access area has been cleared, the number of trees and shrubs removed from the lake access area shall count toward the allowable tree/shrub removal in the viewing corridor.

AREA D: Between the shore impact zone and the building setback line, 50% of the trees greater than 5 inches in DBH and 100% of the trees or shrubs less than 5 inches in DBH may be removed.

AREA E: No restriction on vegetation removal.



FACT SHEET
GRADING AND FILLING
CARLTON COUNTY ZONING ORDINANCE #27

WHY IS IT REGULATED? Alterations of vegetation and topography are regulated within shoreland to prevent erosion into public waters, reduce excess nutrients like phosphorous and nitrogen from washing into the lake, preserve shoreland aesthetics and historic values, prevent bank slumping, and to protect fish and wildlife habitat. The preservation of existing native vegetation and soils are a priority in shoreland. A list of vegetation native to Carlton County can be obtained at the Planning and Zoning Office.

DEFINITIONS:

ORDINARY HIGH WATER LEVEL (OHWL): The boundary of public waters and wetlands is the elevation delineating the highest water level which has been maintained for a sufficient period of time to leave evidence upon the landscape. This point is commonly where the natural vegetation changes from predominantly aquatic to predominately terrestrial. For rivers and streams, the OHWL is the elevation at the top of the bank of the channel.

SHORE IMPACT ZONE: The shore impact zone is the land located between the ordinary high water level (OHWL) of a public water and a line parallel to it at a setback of 50% of the structure setback.

GRADING AND FILLING: Soil materials that are removed from an area of land such as an excavation (grading) and soil materials that are added to an area of land (filling). The soil graded plus the soil filled equals the total disturbance.

CARLTON COUNTY ZONING ORDINANCE #27 - Article 4, Section 5, Subd. H 10B:

This section of the ordinance regulates topographic alterations such as grading and filling. Permits shall be required for grading and filling activities within 300 feet of any lake, river or stream. However, no separate grading and filling permit shall be required for grading, filling and excavations necessary for the construction of structures, sewage treatment systems, and driveways that are constructed in a manner that complies with the requirements below.

GRADING AND FILLING PERMIT

A permit for grading and filling activities shall be obtained from the Zoning Administrator for the following grading and filling activities:

- ☞ The movement (total disturbance) of between 5 and 10 cubic yards of material per site within a bluff, red clay bluff zone or steep slope.
- ☞ The movement (total disturbance) of between 10 to 50 cubic yards of material per site within the shore impact zone, but outside a bluff, red clay bluff zone or steep slope.
- ☞ The movement (total disturbance) of more than 50 cubic yards of material per site outside of the shore impact zone and bluff impact zone.

CONDITIONAL USE PERMIT

A conditional use permit shall be required from the County Board for grading and filling activities that involve the following:

- ☞ The movement (total disturbance) of 10 or more cubic yards of material per site within a bluff, red clay bluff zone or steep slope.
- ☞ The movement (total disturbance) of more than 50 cubic yards of material per site within the shore and bluff impact zones.
- ☞ Plans for a grading and filling conditional use permit shall be prepared and submitted by an engineer, soil scientist, landscape designer, or other qualified professional and include the following information:
    - existing and final topography utilizing 2 foot contours;
    - a site restoration plan showing trees to be removed and replaced, and final ground cover;
    - a drainage and erosion control plan showing the type and location of erosion control measures to be used;
    - a development plan showing how the re-contoured lot may be developed in a manner consistent with Ordinance #27; and
    - the plan shall be reviewed by the Soil and Water Conservation District before commencement of grading and filling activity.

PERMIT STANDARDS

All grading and filling permits shall comply with the following standards:

- ☞ The applicant shall prepare and submit a plan for review showing existing and proposed contours, erosion control plan, and final ground cover. If required, the plan shall be reviewed by the Soil and Water Conservation District.
- ☞ Alterations must be designed and conducted in a manner that ensures only the smallest area of soil is exposed for the shortest time possible.
- ☞ Mulches or similar materials must be used for temporary bare soil coverage and permanent vegetation established within a reasonable period of time.
- ☞ Methods to minimize soil erosion and trap sediments before they reach any surface water feature must be used. Methods to trap sediments must be in place before soil disturbances begin.
- ☞ Fill or excavated material shall not be placed upon/within bluffs, bluff impact zones, or steep slopes.
- ☞ Any alterations below the OHWL of public waters must be authorized by the Department of Natural Resources.
- ☞ Alterations to topography must be accessory to a permitted use or conditional use and not adversely affect adjacent or nearby properties.
- ☞ After-the-fact alterations will require submittal of and adherence to an approved restoration plan that mitigates the extent of the violation.

TIPS TO CONSIDER:

- ☞ Verify with the Carlton County Planning and Zoning Office that you are not disturbing a wetland. Grading and filling in a wetland requires a separate permit process.

- ☞ Plan to preserve existing vegetation as much as possible. Vegetation will naturally curb erosion, improve the appearance and value of your property, and reduce the cost of landscaping later. **As a reminder, removal of any vegetation within the building setback of lakes, rivers and streams is regulated under Carlton County Ordinance #27.** Please call Carlton County Planning and Zoning before removing any vegetation.

- ☞ Discuss clearing limits with your contractor in advance. Field mark these limits with ribbons or flagging. Flag particular trees and shrubs that you want protected. Remember to keep heavy machinery away from trees to avoid compacting their roots, otherwise they will die a few years later.

- ☞ Discuss with your contractor exactly which erosion control measures will be used, who is responsible for the purchase of the erosion control supplies (silt fencing, seed, mulch, etc.), and who is responsible for implementation. Timely stabilization with the appropriate materials will save you time and money and help minimize the impact of your activity on surface waters.

- ☞ Plan earth moving activities early enough in the year so that you can revegetate the site by September 15th. Plan to mulch disturbed areas over the winter if construction is delayed past September 15th. This will protect bare soil from spring runoff.

- ☞ Before doing anything else, install a filter barrier on the downslope side of the construction area. This barrier should include a silt fence and embedded hay bales. Trench silt fencing in about 6 inches. Trench and stake hay bales (4 inch trench, 2 stakes per bale).

- ☞ When earth moving, separate topsoil so it can be spread back on top of the site. You'll have greater success in establishing a new lawn or buffer strip area, and you won't have the added expense of buying topsoil. Ring the downslope edge of topsoil stockpiles with silt fencing and/or embedded hay bales.

- ☞ Install an erosion control blanket and anchor properly so the soil and seed won't wash away. Always follow the manufacturers instructions for installation of erosion control blankets. This is not a place to cut corners as loss of soil, seed and mulch will cost you more in the end.

- ☞ The best time to seed in Minnesota is late summer (mid-August to mid-September) due to favorable conditions for germination and growth. Seeding can be done in the spring from mid-May to mid-June; however, weeds and high summer temperatures often reduce the chance of success.