Minnesota River
Turbidity Total Maximum Daily Load

Draft Report

Minnesota Pollution Control Agency

wq-iw7-32b

February 2012

Project Team

MPCA Staff
Pat Baskfield
Eileen Campbell
Edwin Dumalag
Robert Finley
Lee Ganske
Larry Gunderson
Marco Graziani
Bruce Henningsgaard
Bill Kell
Anna Kerr
Hafiz Munir
Forrest Peterson
Chuck Regan
Nels Rasmussen
Norman Senjem
Mike Trojan

Contractor
Dr. Jonathan Butcher, Tetra Tech

Minnesota River Turbidity TMDL Stakeholder Advisory Committee
Doug Albin - Minnesota Corn Growers Association
Ryan Barney - Minnesota Department of Transportation
Adam Birr - Minnesota Department Of Agriculture
Scott Bohling - Minnesota State University Mankato
Kent Bosch - Chippewa River Watershed-Farmer
Steve Commerford - Minnesota Soybean Growers Association
David Craigmile - Lac qui Parle/Yellow Bank CWP
Dean Dambroten - Hawk Creek Watershed Project
Mark Dittrich - Department of Agriculture
Chris Domeier - Department of Natural Resources
Bill Douglass - Bolton & Menk
Matt Drewitz - Board of Water and Soil Resources
Jamie Duininck - Prinsco
Loren Engelby - Kandiyohi County
Les Everett - University of Minnesota
Shannon Fisher - Minnesota River Basin Data Center
Cory Netland - Hawk Creek Watershed Project
Warren Formo - Minnesota Agriculture Water Resources Coalition
Mary Fralish - City of Mankato
Jeremy Geske - Minnesota Farm Bureau Federation

Doug Goodrich - Redwood/Cottonwood Rivers Control Area
Marion Haayer - City of North Mankato
Desiree Hohenstein - Brown County Water Planner
Ed Hohenstein - Brown-Nicollet-Cottonwood Water Quality Board
Carrie Jennings - Minnesota Geological Survey
Paul Jurek - Minnesota Department of Transportation
Amy Kamm - City of St. Peter
Stephanie Klamm - Hawk Creek Watershed Project
Jim Klang - Kieser and Associates
Steve Koehler - City of New Ulm
Todd Kolander - Department of Natural Resources
Randy Kramer - Hawk Creek Watershed Farmer
Scott Matteson - Minnesota River Basin Data Center
Linda Meschke - Rural Advantage
Patrick Moore - Clean Up the River Environment
Pete Moulton - City of St. Peter
Cory Netland - Hawk Creek Watershed Project
Jeff Nielsen - Board of Water and Soil Resources
Mike Nienaber - Natural Resources Conservation Service
Bob Patton - Department of Agriculture
Greg Roiger - Brown SWCD Supervisor
Diane Sander - Crow River Watershed
Wesley Saunders-Pearce - Minnesota Department of Transportation
Craig Schrader - University of Minnesota Extension Service
Steve Sodeman - Minnesota Corn Growers Association
Scott Sparlin - Coalition for a Clean Minnesota River
Ralph Stadick - National Farmers Union
Michele Stindtman - Faribault Soil and Water Conservation District
Jeff Strock - University of Minnesota
Karen Swenson - Brown-Nicollet-Cottonwood Water Quality Board
Nick Tiedeken - Minnesota Department of Transportation
Henry VanOffelen - Minnesota Center for Environmental Advocacy
Dave Ward - Minnesota Corn Growers Association
Shane Waterman - City of Marshall
Marla Watje - Waseca County Soil and Water Conservation District
Tom Watson - Prairie Waters Convention and Visitors and Bureau
Paul Wymar - Chippewa River Watershed Project

Glossary of Acronyms

Acronym	Full Name
AUID	Assessment Unit Identification Number
BOD	Biochemical Oxygen Demand
BMP	Best Management Practice
BWSR	Board of Water and Soil Resources
CWP	Clean Water Partnership
CRP	Conservation Reserve Program
CREP	Conservation Reserve Enhancement Program
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
HSPF	Hydrologic Simulation Program Fortran
JD	Judicial Ditch
LiDAR	Light Detection and Ranging
LA	Load Allocation
LDC	Load Duration Curve
MOS	Margin of Safety
MCES	Metropolitan Council Environmental Services
mg/L	milligrams per liter
MPCA	Minnesota Pollution Control Agency
MSU	Minnesota State University
MVTL	Minnesota Valley Testing Lab
MS4	Municipal Separate Storm Sewer System
NASS	National Agricultural Statistics Service
NED	National Elevation Dataset
NLCD	National Land Cover Data
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NTU	Nephelometric Turbidity Units
NGP	Northern Glaciated Plains
PCB	Polychlorinated biphenyls
RC	Reserve Capacity
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	Waste Load Allocation
WWTP	Wastewater Treatment Plant
WCBP	Western Corn Belt Plains
WREP	Wetland Reserve Enhancement Program

Contents

Executive Summary 1
1. Introduction 3
2. Background Information 4
   a. *General Discussion of Minnesota River Water Quality* *6*
   b. *Turbidity Sources* *7*
3. Applicable Water Quality Standards 15
   a. *Description of Turbidity and Development of TSS Surrogates* *16*
4. Methodology for Waste Load Allocations, Load Allocations and the Margin of Safety 20
   a. *Wastewater and Water Treatment Facilities and Industrial Dischargers* *20*
   b. *Regulated Stormwater* *21*
   c. *Margin of Safety* *22*
   d. *Load Allocations* *23*
5. TMDL Allocations for Individual Impaired Reaches 25
6. Model Description and Results 162
   a. *Preliminary Scenarios* *167*
   b. *Target Scenario (Scenario 5)* *173*
   c. *Total Sediment Loads by Major Watershed* *176*
   d. *Sediment and Phosphorus Load Export from the Minnesota River at Jordan* *176*
7. Future Growth – New and Expanding Discharges 180
8. Critical Conditions and Seasonal Variation 181
9. Reasonable Assurance 182
10. Monitoring Plan to Track TMDL Effectiveness 185
11. Implementation Strategy 188
12. Public Participation 195
13. Submittal Letter 196
14. Administrative Record 196
15. References 197
Appendix A Municipal and industrial dischargers associated with waste load allocations
Appendix B Development of total suspended solids (TSS) surrogates for turbidity in the Minnesota River Basin

List of Figures

FIGURE 2.1 MINNESOTA RIVER TURBIDITY TMDL REACHES 5
FIGURE 5.1 YELLOW MEDICINE RIVER FLOW DURATION CURVE. 27
FIGURE 5.2 YELLOW MEDICINE RIVER LOAD DURATION CURVE. 27
FIGURE 5.3 2006 LAND COVER MAP FOR THE YELLOW MEDICINE RIVER WATERSHED CONTRIBUTING TO SPRING CR TO MINNESOTA R. IMPAIRED REACH. 32
FIGURE 5.4 2006 LAND USE STATISTICS FOR THE YELLOW MEDICINE RIVER WATERSHED CONTRIBUTING TO SPRING CR TO MINNESOTA R. IMPAIRED REACH. 33
FIGURE 5.5 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE YELLOW MEDICINE RIVER WATERSHED CONTRIBUTING TO SPRING CR TO MINNESOTA R. IMPAIRED REACH. 34
FIGURE 5.6 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE YELLOW MEDICINE RIVER WATERSHED CONTRIBUTING TO SPRING CR TO MINNESOTA R. IMPAIRED REACH. 35
FIGURE 5.7 YELLOW MEDICINE RIVER LOAD DURATION CURVE. 36
FIGURE 5.8 2006 LAND COVER MAP FOR THE CHIPPEWA RIVER; WATSON SAG DIVERSION TO MINNESOTA R. 40
FIGURE 5.9 2006 LAND USE STATISTICS FOR THE CHIPPEWA RIVER; WATSON SAG DIVERSION TO MINNESOTA R. 41
FIGURE 5.10 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE CHIPPEWA RIVER; WATSON SAG DIVERSION TO MINNESOTA R. 42
FIGURE 5.11 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE CHIPPEWA RIVER; WATSON SAG DIVERSION TO MINNESOTA R. 43
FIGURE 5.12 CHIPPEWA RIVER LOAD DURATION CURVE. 44
FIGURE 5.13: 2006 LAND COVER MAP FOR HAWK CREEK; SPRING CR TO MINNESOTA R. 48
FIGURE 5.14: 2006 LAND USE STATISTICS FOR HAWK CREEK; SPRING CR TO MINNESOTA R. 49
FIGURE 5.15: CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE HAWK CREEK; SPRING CR TO MINNESOTA R. 50
FIGURE 5.16: CONSERVATION LAND LOCATIONS AND STATISTICS FOR HAWK CREEK; SPRING CR TO MINNESOTA R. 51
FIGURE 5.17: 2006 LAND COVER MAP FOR THE REDWOOD RIVER; RAMSEY CR TO MINNESOTA R. 55
FIGURE 5.18: 2006 LAND USE STATISTICS FOR THE REDWOOD RIVER; RAMSEY CR TO MINNESOTA R. 56
FIGURE 5.19: CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE REDWOOD RIVER; RAMSEY CR TO MINNESOTA R. 57
FIGURE 5.20: CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE REDWOOD RIVER; RAMSEY CR TO MINNESOTA R. 58
FIGURE 5.21: REDWOOD RIVER LOAD DURATION CURVE. 59
FIGURE 5.22: 2006 LAND COVER MAP FOR THE COTTONWOOD RIVER; JD #30 TO MINNESOTA R. 63
FIGURE 5.23: 2006 LAND COVER STATISTICS FOR THE COTTONWOOD RIVER; JD #30 TO MINNESOTA R. 64
FIGURE 5.24: CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE COTTONWOOD RIVER; JD #30 TO MINNESOTA R. 65
FIGURE 5.25: CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE COTTONWOOD RIVER; JD #30 TO MINNESOTA R. 66
FIGURE 5.26: COTTONWOOD RIVER LOAD DURATION CURVE. 67
FIGURE 5.27: 2006 LAND COVER MAP FOR THE BLUE EARTH RIVER; LESUEUR R TO MINNESOTA R. 71
FIGURE 5.28: 2006 LAND USE STATISTICS FOR THE BLUE EARTH RIVER; LESUEUR R TO MINNESOTA R. 72
FIGURE 5.29: CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE BLUE EARTH RIVER; LESUEUR R TO MINNESOTA R. 73
FIGURE 5.30: CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE BLUE EARTH RIVER; LESUEUR R TO MINNESOTA R. 74
FIGURE 5.31: BLUE EARTH RIVER OUTLET LOAD DURATION CURVE. 75
FIGURE 5.32 2006 LAND COVER MAP FOR THE BLUE EARTH RIVER: RAPIDAN DAM TO LESUEUR R. 78
FIGURE 5.33 2006 LAND USE STATISTICS FOR THE BLUE EARTH RIVER: RAPIDAN DAM TO LESUEUR R. 79
FIGURE 5.34: CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE BLUE EARTH RIVER: RAPIDAN DAM TO LESUEUR R. 80
FIGURE 5.35 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE BLUE EARTH RIVER: RAPIDAN DAM TO LESUEUR R. 81
FIGURE 5.36 BLUE EARTH RIVER-RAPIDAN LOAD DURATION CURVE. 82
FIGURE 5.37 2006 LAND COVER MAP FOR THE WATONWAN RIVER: PERCH CREEK TO BLUE EARTH RIVER. 85
FIGURE 5.38 2006 LAND USE STATISTICS FOR THE WATONWAN RIVER: PERCH CREEK TO BLUE EARTH RIVER 86
FIGURE 5.39 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE WATONWAN RIVER: PERCH CREEK TO BLUE EARTH RIVER. 87
FIGURE 5.40 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE WATONWAN RIVER: PERCH CREEK TO BLUE EARTH RIVER. 88
FIGURE 5.41 WATONWAN RIVER LOAD DURATION CURVE. 89
FIGURE 5.42 2006 LAND COVER MAP FOR THE LESUEUR RIVER; MAPLE RIVER TO BLUE EARTH RIVER. 93
FIGURE 5.43 2006 LAND USE STATISTICS FOR THE LESUEUR RIVER; MAPLE RIVER TO BLUE EARTH RIVER. 94
FIGURE 5.44 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE LESUEUR RIVER; MAPLE RIVER TO BLUE EARTH RIVER. 95
FIGURE 5.45 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE LESUEUR RIVER; MAPLE RIVER TO BLUE EARTH RIVER. 96
FIGURE 5.46 LESUEUR RIVER LOAD DURATION CURVE. 97

FIGURE 5.47 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; CHIPPEWA RIVER TO STONEY RUN CREEK. 101
FIGURE 5.48 2006 LAND USE STATISTICS FOR THE MINNESOTA RIVER; CHIPPEWA RIVER TO STONEY RUN CREEK. 102
FIGURE 5.49 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; CHIPPEWA RIVER TO STONEY RUN CREEK. 103
FIGURE 5.50 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; CHIPPEWA RIVER TO STONEY RUN CREEK. 104
FIGURE 5.51 MINNESOTA RIVER AT MONTEVIDEO LOAD DURATION CURVE. 105
FIGURE 5.52 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; MINNESOTA FALLS DAM TO HAZEL CREEK. 108
FIGURE 5.53 2006 LAND USE STATISTICS FOR THE MINNESOTA RIVER; MINNESOTA FALLS DAM TO HAZEL CREEK. 109
FIGURE 5.54 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; MINNESOTA FALLS DAM TO HAZEL CREEK.110
FIGURE 5.55 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; MINNESOTA FALLS DAM TO HAZEL CREEK. 111
FIGURE 5.56 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; TIMMS CREEK TO REDWOOD RIVER. 115
FIGURE 5.57 2006 LAND USE STATISTICS FOR THE MINNESOTA RIVER; TIMMS CREEK TO REDWOOD RIVER. 116
FIGURE 5.58 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; TIMMS CREEK TO REDWOOD RIVER. 117
FIGURE 5.59 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; TIMMS CREEK TO REDWOOD RIVER. 118
FIGURE 5.60 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; SHANASKA CREEK TO ROGERS CREEK. 122
FIGURE 5.61 2006 LAND USE STATISTICS FOR THE MINNESOTA RIVER; SHANASKA CREEK TO ROGERS CREEK. 123
FIGURE 5.62 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; SHANASKA CREEK TO ROGERS CREEK. 124
FIGURE 5.63 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; SHANASKA CREEK TO ROGERS CREEK. ...125
FIGURE 5.64 MINNESOTA RIVER; SHANASKA CREEK TO ROGERS CREEK LOAD DURATION CURVE. 126
FIGURE 5.65 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; BLUE EARTH R TO SHANASKA CR. 129
FIGURE 5.66 2006 LAND USE STATISTICS FOR THE MINNESOTA RIVER; BLUE EARTH R TO SHANASKA CR. 130
FIGURE 5.67 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; BLUE EARTH R TO SHANASKA CR. 131
FIGURE 5.68 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; BLUE EARTH RIVER TO SHANASKA CREEK 132
FIGURE 5.69 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; SWAN LAKE TO MINNEOPA CREEK. 136
FIGURE 5.70 2006 LAND COVER STATISTICS FOR THE MINNESOTA RIVER; SWAN LAKE TO MINNEOPA CREEK. 137
FIGURE 5.71 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; SWAN LAKE TO MINNEOPA CREEK. 138
FIGURE 5.72 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; SWAN LAKE TO MINNEOPA CREEK. 139
FIGURE 5.73 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; COTTONWOOD R TO LITTLE COTTONWOOD R. 143
FIGURE 5.74 2006 LAND USE STATISTICS FOR THE MINNESOTA RIVER; COTTONWOOD R TO LITTLE COTTONWOOD R. 144
FIGURE 5.75 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; COTTONWOOD R TO LITTLE COTTONWOOD R. 145
FIGURE 5.76 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; COTTONWOOD RIVER TO LITTLE COTTONWOOD RIVER. 146
FIGURE 5.77 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; BEAVER CR TO BIRCH COULEE. 150
FIGURE 5.78 2006 LAND USE STATISTICS FOR THE MINNESOTA RIVER; BEAVER CR TO BIRCH COULEE. 151
FIGURE 5.79 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; BEAVER CR TO BIRCH COULEE. 152
FIGURE 5.80 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; BEAVER CR TO BIRCH COULEE. 153
FIGURE 5.81 2006 LAND COVER MAP FOR THE MINNESOTA RIVER; RUSH RIVER TO HIGH ISLAND CREEK. 157
FIGURE 5.82 2006 LAND USE STATISTICS FOR THE MINNESOTA RIVER; RUSH RIVER TO HIGH ISLAND CREEK. 158
FIGURE 5.83 CROPLAND ON STEEPLY SLOPED LAND ANALYSIS FOR THE MINNESOTA RIVER; RUSH RIVER TO HIGH ISLAND CREEK. 159
FIGURE 5.84 CONSERVATION LAND LOCATIONS AND STATISTICS FOR THE MINNESOTA RIVER; RUSH RIVER TO HIGH ISLAND CREEK. 160
FIGURE 5.85 MINNESOTA RIVER AT JORDAN LOAD DURATION CURVE. 161
FIGURE 6.1 MINNESOTA RIVER MODEL SUBWATERSHEDS AND SEGMENTS. 162
FIGURE 6.2 MEAN DAILY FLOW: MODEL VS. USGS 05325000 MINNESOTA RIVER AT MANKATO, MN 164
FIGURE 6.3 SIMULATED SCATTER PLOT OF SIMULATED VS. OBSERVED TSS LOADS, WATONWAN RIVER. 165
FIGURE 6.4 SEASONAL FLOW-WEIGHTED AVERAGE TSS, MINNESOTA RIVER AT ST. PETER 169
FIGURE 6.5 SEASONAL FLOW-WEIGHTED AVERAGE TSS, LESUEUR RIVER AT RAPIDAN. 170
FIGURE 6.6 SEASONAL FLOW-WEIGHTED AVERAGE TSS, REDWOOD RIVER AT REDWOOD FALLS 170
FIGURE 6.7 YELLOW MEDICINE RIVER AT GRANITE FALLS, SCENARIO 4 SIMULATED TSS 171
FIGURE 6.8 LESUEUR RIVER AT RAPIDAN, SCENARIO 4 SIMULATED TSS 172
FIGURE 6.9 MODELED LAND USE FOR EXISTING CONDITIONS AND SCENARIO 4 FOR THE YELLOW MEDICINE RIVER. 172

Figure 6.10 Modeled land use for existing conditions and Scenario 4 for the LeSueur River. 172
Figure 6.11 Scenario 5 Results for Blue Earth River at Rapidan....175
Figure 6.12 Seasonal Flow-Weighted Average TSS for Scenario 5, Blue Earth River at Mankato 175
Figure 6.13 Total Sediment Load by Major Watershed, Existing Baseline Conditions 177
Figure 6.14 Total Sediment Load by Major Watershed, Scenario 5 177
Figure 6.15 Comparison of Total Suspended Solids Load Results for All Scenarios 178
Figure 6.16 Comparison of Total Phosphorus Load Results for All Scenarios 178
Figure 6.17 Total Phosphorus Load by Major Watershed, Existing Baseline Conditions....179
Figure 6.18 Total Phosphorus Load by Major Watershed, Scenario 5 Conditions 179
Figure 11.1 TSS levels from Minnesota River watersheds....191
Figure 11.2 Phased approach for implementation activities. 193

List of Tables

Table 2.1 Minnesota River Turbidity TMDL Reaches....4
Table 3.1 Site data summary....17
Table 3.2 Turbidity surrogates in mg/L equivalent to 25 NTU (Tetra Tech, 2009) 18
Table 4.1 Regulated MS4 communities. 22
Table 5.1 Drainage area by watershed and adjustments to flow data. 26
Table 5.2 Yellow Medicine River TSS Loading Capacities and Allocations....36
Table 5.3 Chippewa River TSS Loading Capacities and Allocations....44
Table 5.4 Hawk Creek TSS Loading Capacities and Allocations....52
Table 5.5 Redwood River TSS Loading Capacities and Allocations. 59
Table 5.6 Cottonwood River TSS Loading Capacities and Allocations....67
Table 5.7 Blue Earth River Outlet TSS Loading Capacities and Allocations. 75
Table 5.8 Blue Earth River-Rapidan TSS Loading Capacities and Allocations. 82
Table 5.9 Watonwan River TSS Loading Capacities and Allocations. 89
Table 5.10 LeSueur River TSS Loading Capacities and Allocations....97
Table 5.11 Minnesota River at Montevideo TSS Loading Capacities and Allocations....105
Table 5.12 Minnesota River; Minnesota Falls to Hazel Creek TSS Loading Capacities and Allocations. 112
Table 5.13 Minnesota River, Timms Creek to Redwood River TSS Loading Capacities and Allocations. 119
Table 5.14 Minnesota River; Shanaska Creek to Rogers Creek TSS Loading Capacities and Allocations. 126
Table 5.15 Minnesota River; Blue Earth River to Shanaska Creek TSS Loading Capacities and Allocations. 133
Table 5.16 Minnesota River; Swan Lake to Minneopa Creek TSS Loading Capacities and Allocations....140
Table 5.17 Minnesota River; Cottonwood River to Little Cottonwood River TSS Loading Capacities and Allocations. 147
Table 5.18 Minnesota River; Beaver Cr to Birch Coulee TSS Loading Capacities and Allocations. 154
Table 5.19 Minnesota River; Rush River to High Island Creek TSS Loading Capacities and Allocations. 161
Table 6.1 Alternative land use and management options in model scenarios 3, 4 and 5....166
Table 11.1 Ten-year schedule for monitoring, planning and implementation activities by major watershed. 192

TMDL Summary Table

Required Elements	Summary	TMDL Page #
Location	The eighteen turbidity impairments are located on the mainstem of the Minnesota River and the lower reaches of the Chippewa, Redwood, Cottonwood, Blue Earth, Yellow Medicine, Watonwan, LeSueur Rivers and Hawk Creek.	4
303(d) Listing Information	Describe the waterbody as it is identified on the State/Tribe's 303(d) list: • Eighteen reaches as listed in Table 2.1 • Impaired Beneficial Use(s) - Aquatic life • Impairment/TMDL Pollutant(s) of Concern: Turbidity • Priority ranking of the waterbody (i.e. schedule): Scheduled for completion in 2010 • Original listing year: 2002-2008	4
Applicable Water Quality Standards/ Numeric Targets	The turbidity water quality standard for Classes 2Bd and 2B waters is 25 NTU (According to Minn. R. Ch. 7050.0222). Turbidity surrogates of TSS were developed using simple linear regression. Six different surrogates were used.	15-19
Loading Capacity (expressed as daily load)	The loading capacities for the 18 reaches are provided in Section 5.	25-161
Waste Load Allocation	Waste Load Allocations, by reach, are provided in Section 5.	25-161
Load Allocation	Load allocations are provided in Section 5.	25-161
Margin of Safety	An explicit 10 percent margin of safety was applied to the turbidity surrogates.	22
Seasonal Variation	Turbidity levels are at their highest following significant storm events, especially when crop canopy is limited in spring and early summer months. Seasonal variation is captured in the duration curve methodology.	181
Reasonable Assurance	Changes in the landscape and hydrology will need to occur if turbidity and sediment levels are going to decrease. An implementation plan will be developed following the approval of this report. Additionally, Minnesota voters have approved an amendment to increase the state sales tax to fund water quality improvements, which will help to fund many improvement initiatives.	182

Required Elements	Summary	TMDL Page #
Monitoring	A detailed monitoring plan has not been developed as a part of this TMDL. Monitoring at watershed outlets is already in place and intensive watershed monitoring will occur on a ten-year schedule. More work is needed on estimating the amount of sediment coming from near channel and upland sources.	185
Implementation	The implementation strategy includes practices to reduce sediment at its source as well as those targeting interception and treatment (water storage, fixing ravines, and near channel sources). Additional research and targeting are needed to help target much of this work.	188
Public Participation	• Public Comment period (dates) • Comments received • Summary of other key elements of public participation process • Document participation by regulated entities in TMDL development, particularly regulated cities and industries with stormwater and wastewater requirements	195

Executive Summary

The Clean Water Act, Section 303(d), requires that every two years, States publish a list of streams and lakes that do not meet water quality standards. Waters placed on the list are considered "impaired", leading to the requirement of a Total Maximum Daily Load (TMDL). TMDL studies determine the maximum amount of a pollutant a stream can receive, while maintaining water quality standards. A TMDL is divided into a waste load allocation (point sources), a load allocation (non-point sources and natural background) and a margin of safety.

The Minnesota River flows 335 miles southeast from the Minnesota-South Dakota Border to Mankato and then northeast to its confluence with the Mississippi River near St. Paul. The state's namesake river is a major tributary of the Mississippi River and its watershed encompasses about 20 percent of the state.

Data collected by local, state and federal agencies indicate that the Minnesota River and its tributaries have elevated sediment and nutrient concentrations and high bacteria counts. Sediment can be a cause of turbidity which reduces water clarity and subsequently negatively impacts aquatic life. Turbidity is an optical property of water that causes light to be scattered or reflected rather than transmitted through a water sample or water column. Suspended sediment is the dominant cause of elevated turbidity levels on the Minnesota River under most flow conditions. Nutrients can simulate the growth of living organisms, such as algae. This increase in organic matter concentration may contribute to elevated turbidity levels, especially during low flow periods. This project covers eighteen reaches, including nine on the mainstem of the Minnesota River from Lac qui Parle Lake to the city of Jordan, and the lower reaches of the Chippewa, Redwood, Cottonwood, Blue Earth, Yellow Medicine, Watonwan, LeSueur Rivers and Hawk Creek. The targets set to meet the turbidity standard are based on total suspended solids and range from 50 mg/L in the western part of the basin to 100 mg/L in the eastern part. The turbidity problem generally does not occur during low flow conditions.

Research has helped to better identify sediment sources. Sediment sources vary from uplands to near-channel sources such as ravines, bluffs and streambanks, as well as impervious areas. As the name implies, the near-channel sources are located near the stream channel and downstream of the uplands. Impervious areas allow little to no infiltration and transport materials in the water. Parking lots, roads and driveways are examples of impervious surfaces.

A stakeholder committee has helped to shape this study. One of their main tasks was to suggest alternative practices to reduce sediment. A water quality model was used to predict the changes in water quality by simulating the suggested changes in land use. A variety of practices were tested in the model to determine the combination of alternatives that would meet the water quality standard. Five sets of alternatives, or model scenarios, with differing combinations of practices were used to evaluate the changes to water quality. Scenario 4 substantially reduced sediment loading, but the results did not meet water quality standards. The results of scenario 5 were the closest to meeting water quality standards. According to the model, the effective practices included crop residue, protection of open tile intakes, perennial vegetation, reducing sediment from ravines, stormwater source reduction, in-line ditch treatment, water storage and increasing channel stability. The practices are intended to represent broad categories of options (e.g. source reduction, hydrologic storage, interception, etc.) and not a precise narrow list of the only things that will work.

Turbidity is a significant water quality problem throughout the Minnesota River basin. This TMDL report describes the problem and turbidity sources, sets forth the load reductions to meet water quality standards, and outlines the actions needed. Addressing turbidity in the Minnesota River will require a balanced approach that considers the economy, society and the environment. This TMDL study takes one step in the direction of achieving the optimal balance. An implementation strategy will be drafted following the approval of this TMDL report.

1. Introduction

Section 303(d) of the Clean Water Act provides authority for completing Total Maximum Daily Loads (TMDLs) to achieve state water quality standards or designated uses. A TMDL is a calculation of the maximum amount of pollutant that a water body can receive and still meet water quality standards or designated uses. It is the sum of the loads of a single pollutant from all contributing point and nonpoint sources. The TMDLs are approved by the U.S. Environmental Protection Agency (EPA) based on the following elements:

1. Designed to implement applicable water quality criteria
2. Include load and waste load allocations
3. Consider the impacts of background pollutant contributions
4. Consider critical environmental conditions
5. Consider seasonal environmental variations
6. Include a margin of safety
7. Provide opportunity for public participation
8. Have reasonable assurance that the TMDL can be met

In general, the TMDL is developed according to the following relationship:

$$TMDL = \sum WLA + \sum LA + MOS + RC$$

Where:

WLA = waste load allocation; the portion of the TMDL allocated to existing or future point sources of the relevant pollutant.

LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources of the relevant pollutant. The load allocation may also encompass natural background contributions.

MOS = margin of safety, or an accounting for uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity.

RC = reserve capacity, an allocation for future growth.

This TMDL report applies to eighteen reaches that are impaired for turbidity within the Minnesota River basin. The impairments in this report are currently on the 2008 303(d) list of impaired waters. The TMDL Report is divided into sections. Section 2 provides background information. Section 3 includes the water quality standards, Section 4 the allocation methodology and Section 5 provides the allocations by reach. Model results appear in Section 6. Reserve capacity, seasonal variation, reasonable assurance, the monitoring plan, the implementation strategy and public participation can be found in Sections 7-15.

2. Background Information

The Minnesota River begins near the Minnesota-South Dakota border, flows for 335 miles through some of the richest agricultural land in Minnesota, and joins the Mississippi River near the city of St. Paul. The river drains a 16,770 square mile basin, including all or parts of 37 counties. Thirteen major watersheds range in size from 703 square miles (Redwood River Watershed) to 2,085 square miles (Chippewa River Watershed).

A large portion of the Minnesota River basin is included in this project. The project area begins near Lac qui Parle Lake, ends near the city of Jordan, and involves 18 reaches on the mainstem and tributaries. It includes the Chippewa, Redwood, Cottonwood, Blue Earth, Yellow Medicine, Watonwan, LeSueur Rivers and Hawk Creek (Table 2.1 and Figure 2.1).

Table 2.1 Minnesota River Turbidity TMDL Reaches

Stream Name	Description	Year Listed	MPCA Assessment Unit ID
Minnesota River	Chippewa R to Stony Run Cr	2002	07020004-501
Yellow Medicine River	Spring Cr to Minnesota R	2002	07020004-502
Minnesota River	Timms Cr to Redwood R	2004	07020004-509
Minnesota River	Minnesota Falls Dam to Hazel Cr	2008	07020004-515
Hawk Creek	Spring Cr to Minnesota R	2004	07020004-587
Chippewa River	Watson Sag to Minnesota R	2002	07020005-501
Redwood River	Ramsey Cr to Minnesota R	2004	07020006-501
Minnesota River	Shanaska Cr to Rogers Cr	2002	07020007-501
Minnesota River	Blue Earth R to Shanaska Cr	2002	07020007-502
Minnesota River	Cottonwood R to Little Cottonwood R	2002	07020007-503
Minnesota River	Swan Lk outlet to Minneopa Cr	2002	07020007-505
Minnesota River	Beaver Cr to Birch Coulee	2002	07020007-514
Cottonwood River	JD 30 to Minnesota R	2002	07020008-501
Blue Earth River	LeSueur R to Minnesota R	2002	07020009-501
Blue Earth River	Rapidan Dam to LeSueur R	2004	07020009-509
Watonwan River	Perch Cr to Blue Earth R	2002	07020010-501
LeSueur River	Maple R to Blue Earth R	2002	07020011-501
Minnesota River	Rush R to High Island Cr	2002	07020012-503

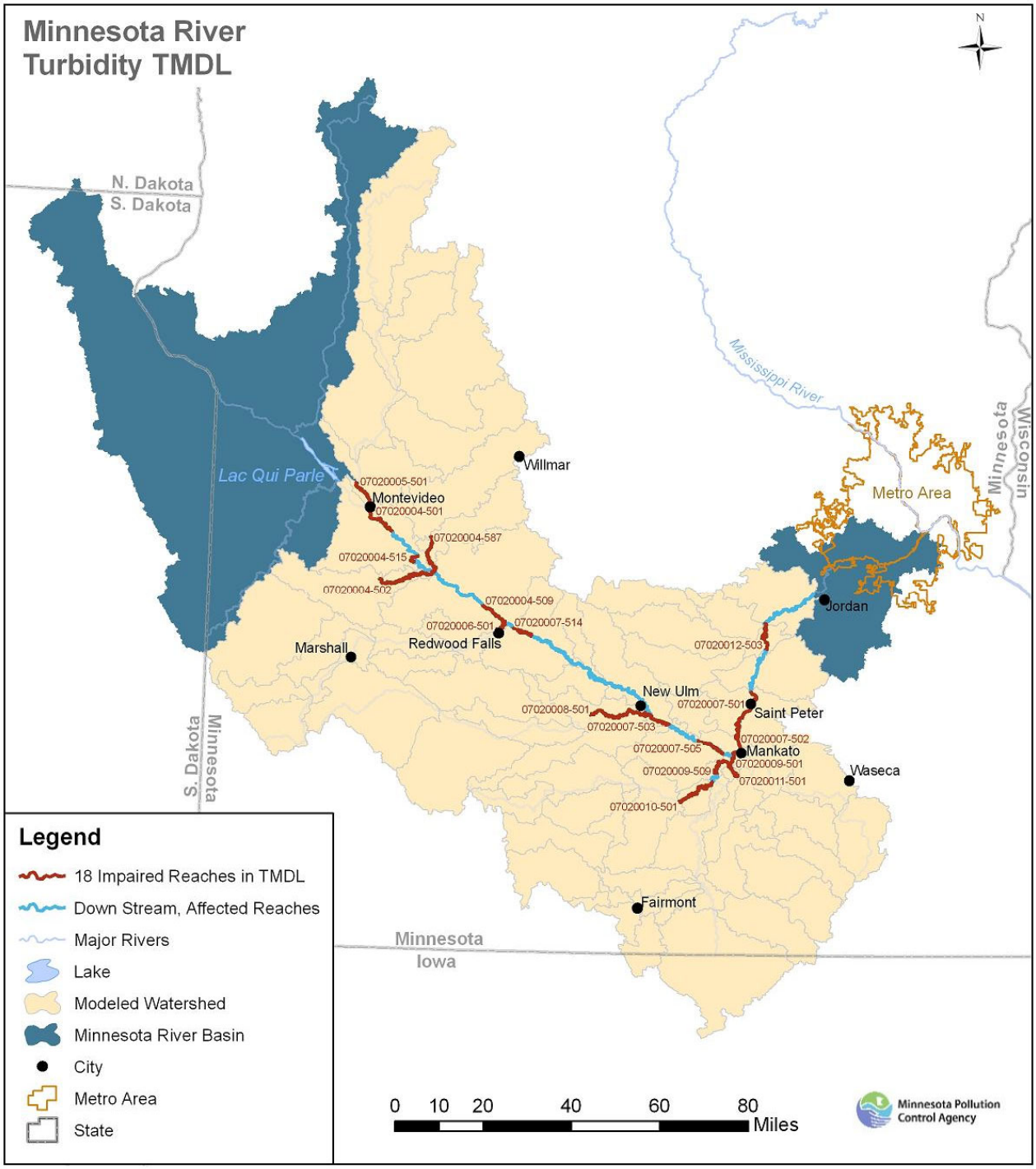


Figure 2.1 Minnesota River Turbidity TMDL Reaches

Land use in the 7.6 million acre area is dominated by agriculture with less land in urban, wetlands and forest. Conservation tillage is used in the Minnesota River basin. The practices include mulch till, no till, or chisel plowing. The land in conservation tillage (statewide) shifted from 20.2 percent of soybean acres (previous year's crop was likely corn) in 1989 to

56.6 percent in 2007, and corn acres (previous year's crop was likely soybeans) peaked in 1993 at 27.2 percent (Minnesota State University, Mankato, 2009). The land in conservation tillage is measured by the tillage transect survey, which estimates the amount of crop residue on the surface of a field. Acres are designated in conservation tillage if there is 30 percent or greater crop residue present at planting.

Six percent of the land receives manure. Perennial vegetation, including enrolled in the Conservation Reserve Program (CRP) (280,077 acres), Conservation Reserve Enhancement Program (CREP) (112,850 acres), and pasture make up approximately six percent of the land use in the Minnesota River basin. Urban and developed land, including cities, small towns, roads and rural residences, encompasses just over six percent. Approximately 346,700 people live in the area, mostly located in the eastern portion of the watershed. Since 1990, the population has increased by approximately 1.9 percent. These figures may be slightly different from those in other reports because the project area does not include the upper Minnesota River or the metro area below the city of Jordan.

Nine of the reaches in this TMDL project are at the mouths of the major watersheds and nine are on the mainstem of the Minnesota River. In the Watonwan River, for example, 115 of 302 samples were above the turbidity surrogate from 1996 to 2006. In the Redwood, 79 of 189 samples were over the target. Most violations of the turbidity standard occur during high flow conditions.

The Minnesota River Turbidity TMDL is consistent with other TMDL projects in the Minnesota River basin. The modeled area for this TMDL was the same as that of the Lower Minnesota River Dissolved Oxygen TMDL. Model scenarios were developed using the framework established in the dissolved oxygen TMDL. Upstream impairments are covered in separate TMDLs, which are coordinated with this project. These include turbidity TMDLs in the Greater Blue Earth, Redwood and Cottonwood River watersheds, among others. The TMDLs will be consistent with each other. Representatives from these projects were a part of the Minnesota River Turbidity TMDL stakeholder advisory committee. The allocations will provide targets that can be used in other TMDL studies.

Lake Pepin is located downstream of the Minnesota River's confluence with the Mississippi River. Scientists project that, at current deposition rates, the lake will be filled in about 340 years. Without the increase in sedimentation rate, the lake could persist another 4,000 years (Engstrom, 2009). Reductions in TSS from the Minnesota River will slow the rate of sediment accumulation in Lake Pepin. Allocations for downstream TMDL projects will also affect the Minnesota River, and may require further reductions in TSS. The South Metro Mississippi River TMDL for TSS and the Lake Pepin TMDL for phosphorus are two examples of downstream projects underway.

a. General Discussion of Minnesota River Water Quality

In addition to sediment and turbidity, nutrients, oxygen demanding materials and bacteria have been identified as problems in the Minnesota River. There are a few sites in the basin where ample data have been collected to conduct a statistical trends analysis. Results from on-going work by the Water Resources Center at Minnesota State

University-Mankato (Minnesota State University, Mankato, 2009) indicate that the Minnesota River at the city of St. Peter is showing statistically significant decreases in TSS and total phosphorus, for the period 1998-2008. Over a longer time period (1967-2007), the Minnesota River at the city of Mankato showed a statistically significant decrease in suspended sediment concentrations. Previous trend analysis by the University of Minnesota (Johnson, Gupta, Vecchia, & Zvomuya, 2009) and the MPCA also showed decreasing TSS and total phosphorus concentrations.

b. Turbidity Sources

The purpose of this section is to describe the potential sources of turbidity for the eighteen reaches in the Minnesota River basin addressed by this project. An understanding of the sources and processes that cause elevated turbidity levels is necessary for the development of an effective implementation plan to reduce these impairments. The objectives of this section are to: briefly define turbidity, describe the relationship between turbidity and TSS as used in this project, and to provide a brief overview of the region's geologic history and its effects on the current topographic relief of the basin. A list of the geologic and anthropogenic sources of turbidity and the processes by which those sources cause elevated turbidity in the impaired rivers is also discussed.

Turbidity is an optical property associated with the water column or a water sample. Unlike many water quality parameters that are measurements of the mass of a constituent in a fixed volume of water (i.e. concentration); turbidity is a measure of the solution's ability to scatter and absorb light. Both dissolved and suspended materials contribute to a water sample's turbidity. Due to differences in optical properties, the degree of light scattering and absorption caused by different water-born constituents is variable. For instance, a given suspended concentration of clay (kaolinite) typically causes more light scattering then a water sample with the same suspended concentration of fine sand (quartz). Thus, a sample's turbidity value is not only a function of the concentration (mass per unit water volume) of the suspended constituents, but also of the optical properties of those constituents.

Turbidity can be caused by various constituents including dissolved organic compounds (stains), suspended organic materials (algae and other organisms, plant and soil matter) and suspended inorganic matter (clay, silt, sand and other clastic materials). In the Minnesota River and its tributaries, suspended inorganic particles are the primary contributors of turbidity, especially during medium and high flows when turbidity levels are often elevated. Although targeting inorganic sources, the practices to address TSS will deal with both. For example, additional perennial vegetation will increase the uptake of nutrients, retaining soil on the land will hold both soil and attached phosphorus in place, and increased water storage will decreased the amount of nutrients available.

The development of a TMDL requires that the pollutant be quantified in terms of a mass load. Watershed models, including the application of the HSPF model used in this allocation study, do not simulate turbidity explicitly. For these reasons, the MPCA has developed a set of mathematical relationships to equate a concentration of total

suspended solids (TSS) to its corresponding turbidity value. These turbidity surrogate values are used in establishing targets.

The components of TSS can be derived from various source types and locations within a basin. Some of the sources are external to the channel and derived from the contributing watershed area. These components are, at times, transported to the channel through a variety of mechanisms. Other sources are internal and originate within the river channel. Most point and nonpoint sources are considered to be external since they exist outside of the channel and yet contribute TSS to the waterbody. Internal sources are components (and associated processes) that occur within the channel. Internal sources would include streambanks, streambeds, and possibly floodplains and bluffs, all of which are potential sediment sources to a river. Algal growth and decay could be considered an internal process even though the phosphorus that drives its production is usually from external sources such as upland areas or wastewater treatment plants. At this basinwide level, approximately ten to forty percent of the sediment is from upland sources and sixty to ninety percent from near channel sources (Wilcock, et al., 2009). These estimates differ by major watershed and by location within each major watershed.

The inorganic components of TSS in the current drainage system are geologically derived. The glacial geologic history of the Minnesota River basin has been a topic of many investigations (Matsch, 1972) (Upham, Report of exploration of the glacial Lake Agassiz in Manitoba: Geological Survey of Canada Annual Report, 1890). Approximately 12,000 years ago, the Minnesota River basin was covered by a thick ice layer known as the Des Moines Lobe of the Wisconsin ice sheet. The Des Moines Lobe transported large amounts of poorly sorted sediment from the north and west to the current day Minnesota River basin. Much of the basin was mantled by a thick flat-lying layer of unconsolidated material known as Des Moines Lobe Till. The Des Moines Lobe Till is composed of approximately equal amounts of clay, silt and sand; and is the uppermost and exposed surficial layer throughout most of the basin today.

Subsequently, the Des Moines Lobe till plain was incised. Glacial Lake Agassiz occupied a large area northwest of the current day Minnesota River basin. Approximately 11,500 years ago, the Glacial River Warren drained Lake Agassiz by breaching the lake's southern boundary. The River Warren carved a very large valley which is now partially occupied by the Minnesota River. The steep bluffs found at the margins of the Minnesota River valley and the escarpments adjacent to the outlets of the tributaries are remnants of the River Warren incision. This incision divides the tributary watersheds into an upper more flat-lying zone where sediment is primarily derived from field and stream erosion, and a lower, steeply incised zone, which receives additional sediment from bluffs and ravines. In addition to the flat-lying uplands and the steeply-incised valley margins, the watershed of the mainstem Minnesota River also contains the lower flat-lying area which was once occupied by the River Warren. This relict channel contains terraces formed at various stages as the flows of the River Warren waned. Many low lying areas bounded by the terraces are now occupied by the floodplains of the Minnesota River. The geologic history of the basin gives rise to a topography that has a profound impact on the presence and location of erosion features, many of which will be discussed in the sections below.

More recently, several studies have examined the relative contributions of near channel (such as streambanks, bluffs and ravines) and upland sources of sediment loading to the Minnesota River and its tributaries. Research suggests that near channel sources are more significant than previously thought. Thoma et al. estimated that up to 56 percent of the sediment in the Blue Earth River was from bank erosion (Thoma, Gupta, Bauer, & Kirchoff, 2005). Sekely et al. estimated 31 to 44 percent of the sediment from streambank slumping at the mouth of the Blue Earth River (Sekely, Mulla, & Bauer, 2002). Via sediment fingerprinting, Engstrom and Schottler estimated ten to forty percent of the sediment from upland sources and sixty to ninety percent from near channel sources (Schottler & Daniel R. Engstrom, 2010). A sediment budget developed for the LeSueur River took a next step in partitioning sources by using geochemical fingerprinting, geomorphic change detection techniques and a sediment mass balance (Belmont, et al., 2011). According to the sediment budget, bluffs contributed approximately 56 percent of the sediment, ravines 9 percent, uplands 27 percent, and floodplains and stream channels 8 percent. This was for the period from 2000 to 2010 and can vary from year to year (Gran et al, 2011). The St. Croix Watershed Research Station, the University of Minnesota and the National Center for Earth-surface Dynamics and others continue to research sediment sources.

Definitions

The areas adjacent to the Minnesota River and its tributaries are largely made up of bluffs, streambanks and floodplains. At times these terms are used interchangeably.

Streambanks are ridges of material which generally occur parallel to the river channel. They are typically composed of material which was deposited by the water in the river channel. Streambanks are dynamic and their size, shape and composition, often change between seasons and, in some cases, between storm events.

Floodplains are generally flat lying areas which occur on the side of a streambank opposite the river. They are also composed of material which was deposited by river water, however the material is only reworked during flood events when the river level rises above the height of the streambank and water covers the floodplain.

Bluffs are steep exposures of material not deposited by the present day river. Bluffs may be located immediately adjacent to the river, or can be set back from the channel at the margins of a mile-wide valley. Bluffs commonly occur adjacent to the tributary channels near the confluences of the tributaries with the mainstem. Bluffs carved by the River Warren are usually, but not always, set back from the current day Minnesota River.

Near Channel Sources of sediment are those that are close in proximity to the stream channel. This would include bluffs, banks, ravines and the stream channel itself. However, uplands would not be a near channel source of sediment since they are distant from the channel and the topography is often flatter.

Processes
This section will describe the processes by which these features supply sediment to the river channels. Streambanks and floodplains will be discussed together since they typically occur in the same setting. Bluffs may be adjacent to the river, in lieu of a streambank. Since tall bluffs extend to heights above the highest flood stage, there are no floodplains behind the bluffs.

Streambanks and Floodplains
As previously mentioned, streambanks and floodplains are, for the most part, composed of material that was "reworked" or deposited by the water conveyed in the river. Under most flow conditions, the water in the channel is in direct contact with the sediment at the face of the streambed (bottom of channel), and, to varying degrees, the streambanks (sides of channel). Floodplain material is only reworked when high flows cause the river level to rise above the streambanks and the floodplains themselves become inundated.

When sediment from the streambed, streambanks and floodplains is in direct contact with water, there is a potential for sediment entrainment or erosion and subsequent transportation. This type of erosion is generally called hydraulic or fluvial, since it is caused by water moving within a river channel. The movement of water along the fluid/sediment interface generates a shear stress. This shear stress is largely a function of the water velocity at that interface, which is in turn, largely dependent on the volume of water moving through the river reach as well as the longitudinal slope of the reach. At very low shear stresses, even very small particles, like clays, will settle out and be deposited. As the water velocity and the associated shear stresses increase, the river will be able to keep more material in suspension and thus material entering a river reach will stay entrained and not be deposited. At high flows, shear stresses will be great enough not only to keep suspended sediment entrained, but to also lift or erode additional sediment particles off the surface of the beds, banks, or floodplains. This particle entrainment will increase the amount of TSS in the water column and therefore, increase turbidity.

Since it is possible for sediment to be both deposited on and eroded from streambeds, banks and floodplains, these features are both sinks and sources of sediment. It is natural for rivers to meander, a process that couples erosion on the outer bend (cutbank) with near-simultaneous sediment deposition on the inner bend (point bar). Therefore, since rivers are dynamic systems, it is important to consider the integrated net effect of streambeds, banks and floodplains in an overall watershed sediment budget, since on a local scale they are both sites of visually observable deposition and erosion. River systems where the channels are actively widening or downcutting are net sources of sediment to the channel. The beds, banks and floodplains of these downcutting and widening river systems have the potential to be significant net sources of sediment and turbidity. In the basin, the downcutting process is evident at most of the major tributary outlets through observations of longitudinal profiles. Erosion generated by these downcutting processes can contribute sediment, and therefore turbidity, to the river.

Bluffs

Bluffs are steeply sloping exposures of material which were not deposited by water in the river channel. In the Minnesota River basin, most bluffs are made up of sub-horizontal layers of glacially deposited sediment, with the Des Moines Lobe Till often occurring at or near the top of the profile. Older tills, or other types of glacial deposits are found beneath the Des Moines Lobe, and in some cases the bluff may contain layers of older consolidated bedrock near the base.

Bluff erosion may be hydraulically driven if the bluff bounds the river channel. Specifically, if the bluff exists on the outer bend of a meander, the shear stresses produced in the river channel will erode the submerged portion of the bluff. In this manner, the toe of the bluff is removed or undercut and the upper portion of the bluff lacks foundational support. This hydraulically-driven undercutting process is eventually followed by a gravity-driven process known as slumping. In most instances, a detached block of the bluff remains mostly undeformed and slumps downward around a rotational axis. Although slumping is for the most part, a gravity-driven process, other factors such as the weight of additional burden near the edge of the bluff, freeze-thaw cycles, and changes in pore pressures due to groundwater seepage can accelerate collapse.

It is possible for slumping to occur without the antecedent undercutting, however the combination of the two processes are particularly relevant to turbidity production. Bluff faces not next to a river cannot be undercut by channel shear stresses. The faces of these bluffs can fail due to slumping, or a slower deformational process called creeping. However, when bluffs not adjacent to the river fail, the falling material does not land in the river channel. This material can contribute to turbidity at a later time, but it must be carried to the channel, most likely by overland runoff.

When a block of bluff material falls into the river, it is typically not an immediate source of turbidity. Generally the bluff material is not greatly deformed and remains as one or a few discrete masses. Shear stresses and chemical dissolution in the river will eventually break the blocks into smaller pieces and separate the individual sediment particles. The length of this process depends on the cohesiveness of the block material. Bedrock is often lithified or cemented and therefore very resistant to erosion. Additionally, much of the glacial material in the bluffs is very well consolidated due to the prehistoric overburden of massive ice sheets. Therefore, the collapse of bounding bluffs can be a significant source of (consolidated) sediment to the drainage system, although the impact on turbidity levels is likely metered over time as the consolidated masses break down.

Ravines

Ravines are v-notched erosional features typically occurring at the boundary of flat lying uplands and steep-sloping surfaces, such as bluffs or other steep valley walls. The terms “ravine” and “gully” are often used interchangeably, although many refer to a gully as a smaller linear depression which can be filled by common tillage equipment. Ravines are usually referred to as larger, more permanent features with a depth of 0.5 to 30 meters (Poesen, 2003).

Ravines can be eroded by water moving through their channel, similar to streambanks (hydraulically driven); as well as by rotational failure of their sides, similar to bluffs (gravitationally driven). However, ravine erosion is primarily driven by overland runoff which moves through rills and then is ultimately concentrated into one ephemeral channel, cutting downward into the steep face. Ravines are unique because they funnel water and sediment from larger upland areas over the edge of a steep surface. This funneling allows the ravines to incise vertically and elongate longitudinally.

Many actively eroding ravines in the Minnesota River basin have sub-surface tile drain outlets near the head of the incision. In addition to water from overland flow, these outlets convey infiltrated water to the head of the ravine. Since the rate of ravine erosion is a function of the amount of water entering the top of a ravine, the routing of sub-surface drainage to the heads of ravines increases the associated sediment erosion.

Like bluffs, ravines can be found next to a river, or set back from the channel. Ravines set back some distance from a river may deposit sediment on a more gently sloping unchannelized area. Ravines adjacent to a receiving stream reach are more severe and more immediate contributors of sediment to the river and their contributions to turbidity closely coincide with storm events.

The distribution of bluffs and ravines are controlled by the migration of knickpoints. Knickpoints define abrupt breaks in slope. They divide lower-lying downstream areas near the Minnesota River from higher upstream areas. The knickpoints formed in response to extensive downcutting by the Glacial River Warren 11,000 years ago, which lowered the base level of the Minnesota River. Rivers like the LeSueur are presently downcutting in an attempt to achieve a new longitudinal gradient in equilibrium with this new lower base level. Limited information is known about the effects of ravines and knickpoints.

Uplands

Generally, uplands are the broad flat-lying areas that comprise most of the watershed. Unlike floodplains, most uplands are not inundated with standing water during flood conditions, and they are not always located in close proximity to a waterbody. Uplands are divided into pervious and impervious areas. The majority of the impervious areas are found in urban areas. The pervious areas are subdivided in terms of land use. The dominant land use in the Minnesota River basin is row croplands or fields, but other land uses such as other types of agriculture, forests, wetlands, native grasses and urban land uses are also found.

Land areas can supply sediment to receiving waters through rill and sheet erosion processes or gully scour. The erosion of sediment associated with rill and sheet processes has two parts. First, sediment particles must become detached from the soil matrix and made available for transport. Second, the particle is carried away from the surface by overland flow. Gully scour involves the removal of undetached sediment from the soil matrix by overland flow.

Land use has a profound impact on the degree to which erosive processes can effect a particular surface. For example, land which has well-developed vegetative cover will intercept drops of rainfall, whereas rainfall on bare land can detach sediment particles from the soil matrix. Well-developed vegetative cover can impede the movement of water on the land surface, while runoff on bare land can move freely across the surface and allow rills or gullies to form. Water moving in the rills and gullies can transport sediment off the land. Additionally, open tile intakes can transport sediment to a stream through drainage tile.

Ditches/Channelization

Ditches and/or straightened portions of the stream are not turbidity sources per se, but are important factors to consider when evaluating excess stream turbidity. Such watercourses are shorter than the natural channel and, thus, are 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 of the stream is confined to the channel. Straightened channels also exhibit a continuous tendency to revert to a meandering condition. The net result is increased potential for bank erosion.

Stormwater Runoff from Urban Areas

Stormwater runoff comes from cities, towns, roads, homesteads, etc. Runoff can contribute to excess turbidity directly via sediment and phosphorus delivery and indirectly via increased runoff of water leading to increased bank and bed erosion. Impervious surfaces (roads, parking lots, roofs, etc.) can be problematic because most of the water runs off, leaving little opportunity for storage.

In 1987, the federal Clean Water Act was amended to include provisions for a program to address stormwater runoff. There are currently ten regulated MS4 communities in the portion of the Minnesota River basin covered by this project. Overall, however, there is relatively limited growth and development in these communities given the size of the watershed.

Erosion from construction sites can be source of sediment. The MPCA issues 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
- Less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources

Although stormwater runoff at construction sites with inadequate runoff controls can be significant on a per acre basis, MPCA records show that the number of projects per year in this predominantly rural watershed is relatively small. Therefore, this source appears to be a minor turbidity source.

Industrial discharge permit holders in the watershed do not appear to represent a TSS loading concern in this watershed. For the purpose of the TMDL, industrial discharges are lumped with construction stormwater to calculate a waste load allocation.

Urban and developed land, including cities, small towns and roads encompasses approximately six percent of the area. This figure may differ somewhat with other land use statistics because the project area does not include the entire Minnesota River basin.

Wastewater

Wastewater and water treatment facilities discharge total suspended solids. Relative to turbidity and TSS, most National Pollutant Discharge Elimination System (NPDES) wastewater permits contain calendar month average effluent limits of either 30 mg/L or 45 mg/L TSS, which are below the turbidity surrogates, which range from 50 to 100 mg/L TSS. Waste load allocations for industrial waste streams are not subject to TSS effluent limits and are based on maximum permitted flow and the lowest downstream TSS surrogate for the 25 NTU water quality standard.

3. Applicable Water Quality Standards

A discussion of water classes in Minnesota and the standards for those classes is provided below in order to define the regulatory context and environmental endpoint of the TMDL.

All waters of Minnesota are assigned 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

One reach, Minnesota River, Chippewa R to Stony Run Cr (07020004-501) is classified as 1C, 2Bd, 3C, 4A, 4B, 5 and 6. The other 17 reaches are 2B, 3C, 4A, 4B, 5 and 6 waters.

Minnesota assesses Class 2 waters for aquatic life beneficial use. According to Minn. R. Ch. 7050.0222, the turbidity water quality standard for Classes 2Bd and 2B waters is 25 nephelometric turbidity units (NTUs). Impairment assessment procedures for turbidity are provided in The Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment (MPCA, 2007). Essentially, listings occur when greater than ten percent of data points collected within the previous ten-year period exceed the 25 NTU standard.

A description of Class 2Bd and 2B waters:

2Bd – Support healthy communities of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water.

2B – Support healthy communities of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface water is not protected as a source of drinking water.

As part of Minnesota's 2008-2011 triennial review of water quality standards, the MPCA is considering a modification to the turbidity standard, which has been in place since 1967 (State of Minnesota, 2009). A revised standard may be based on total suspended solids and assigned by region. If new TSS targets vary from those provided in this TMDL report, it could change the amount of reduction needed to meet the goals.

a. Description of Turbidity and Development of TSS Surrogates

Turbidity samples in this study were measured in Nephelometric Turbidity Units (NTUs). Table 3.1 shows the three laboratories which tested the samples, the sampling organization, the number of observations, and years of data used in the analysis. The data used in this analysis include turbidity and TSS from several sites in the basin. Major tributary sampling stations were at or near the watershed outlets unless otherwise noted. Data collected by the Metropolitan Council Environmental Services after 2006 were not included in this report due to a different turbidity meter.

Surrogate development

Turbidity is a qualitative measure associated with water clarity, but not concentration or mass (MPCA, 2007). A commonly used surrogate is total suspended solids (TSS), which allows the calculation of loads based on concentration. TSS measures sediment and organic materials in a sample. Simple linear regression was used to establish the relationship, by station, between paired turbidity and TSS concentrations. R^2 values ranged from 0.63 to 0.87. Data from major watershed monitoring stations were grouped into categories in cases where there were no statistically significant differences between surrogates (Table 3.2) (Campbell, 2009). See Appendix B for more details.

Table 3.1 Site data summary.

Site (Impaired Reach AUID)	Years of Data used in Analysis	Number of Observations	Organization(s) that Collected Sample	Lab
Chippewa River (07020005-501)	2001-2007	84	Chippewa River Watershed Project	Era*
Hawk Creek (07020004-587)	2004-2007	75	Hawk Creek Watershed Project	Era*
Redwood River (07020006-501)	2003-2007	47	Redwood Cottonwood Rivers Control Area	MVTL**
Cottonwood River (07020008-501)	2003-2007	48	Redwood Cottonwood Rivers Control Area	MVTL**
Watonwan River (07020010-501)	2000-2007	227	Maple River Watershed Project, MPCA, Watonwan County Environmental Services	MVTL**
Blue Earth River (07020009-509)	2000-2005	86	Metropolitan Council Environmental Services, MSU-Mankato Water Resources Center	MCES***
LeSueur River (07020011-501)	2000-2005	54	Metropolitan Council Environmental Services, MSU-Mankato Water Resources Center	MCES***
Minnesota River at Judson (07020007-505)	2000-2005	112	Metropolitan Council Environmental Services, MSU-Mankato Water Resources Center	MCES***
Minnesota River at St. Peter (07020007-501)	2000-2005	97	Metropolitan Council Environmental Services, MSU-Mankato Water Resources Center	MCES***
Minnesota River at Jordan (n/a)	2000-2005	140	Metropolitan Council Environmental Services	MCES***

* Era Laboratories, Inc.
** Minnesota Valley Testing Lab
***Metropolitan Council Environmental Services Lab

Table 3.2 Turbidity surrogates in mg/L equivalent to 25 NTU (Tetra Tech, 2009) .

Stream Name	Description	MPCA Assessment Unit ID	Drainage Area (mi^2)	Turbidity Surrogate (mg/L TSS)
Minnesota River	Rush R to High Island Cr	07020012-503	15,994	100 mg/L
Minnesota River	Shanaska Cr to Rogers Cr	07020007-501	15,105	100 mg/L
Minnesota River	Blue Earth R to Shanaska Cr	07020007-502	15,023	100 mg/L
Minnesota River	Swan Lk outlet to Minneopa Cr	07020007-505	11,337	100 mg/L
Minnesota River	Cottonwood R to Little Cottonwood R	07020007-503	10,876	85 mg/L
Minnesota River	Beaver Cr to Birch Coulee	07020007-514	9,026	85 mg/L
Minnesota River	Timms Cr to Redwood R	07020004-509	8,200	75 mg/L
Minnesota River	Minnesota Falls Dam to Hazel Cr	07020004-515	6,439	75 mg/L
Minnesota River	Chippewa R to Stony Run Cr	07020004-501	6,221	75 mg/L
Blue Earth River	LeSueur R to Minnesota R	07020009-501	3,540	90 mg/L
Blue Earth River	Rapidan Dam to LeSueur R	07020009-509	2,427	90 mg/L
LeSueur River	Maple R to Blue Earth R	07020011-501	1,112	90 mg/L
Watonwan River	Perch Cr to Blue Earth R	07020010-501	877	90 mg/L
Cottonwood River	JD 30 to Minnesota R	07020008-501	1,313	70 mg/L
Redwood River	Ramsey Cr to Minnesota R	07020006-501	705	70 mg/L

Stream Name	Description	MPCA Assessment Unit ID	Drainage Area (mi^2)	Turbidity Surrogate (mg/L TSS)
Yellow Medicine River	Spring Cr to Minnesota R	07020004-502	674	50 mg/L
Hawk Creek	Spring Cr to Minnesota R	07020004-587	506	50 mg/L
Chippewa River	Watson Sag to Minnesota R	07020005-501	2,083	50 mg/L

4. Methodology for Waste Load Allocations, Load Allocations and the Margin of Safety

The TMDLs developed for stream reaches in this report consist of three main components: 1) Waste Load Allocation (WLA), 2) Load Allocation (LA) and 3) a Margin of Safety (MOS). The WLA includes wastewater and water treatment facilities with permitted TSS limits; and stormwater, which includes both regulated MS4 communities and industrial and construction sites. The LA includes nonpoint sources described in the previous section. The MOS is the amount of the allocation that accounts for uncertainty in the science and uncertainty the allocation will meet the water quality standard. Section 5 contains the total maximum daily loads (including specifics for WLA, LA and MOS) for each of the eighteen reaches.

a. Wastewater and Water Treatment Facilities and Industrial Dischargers

Municipal and Industrial Wastewater permits with TSS Effluent Limits: Most NPDES permits for wastewater treatment facilities (municipal and industrial) and other industrial wastewater dischargers in the Minnesota River basin contain calendar month average TSS effluent limits of 30 or 45 mg/L, which are below the lowest surrogate of 50 mg/L used in computing TMDLs for the eighteen impaired reaches and therefore help to attain and maintain the turbidity water quality standard. Three industrial permits include Federal categorical technology based effluent TSS limits that are less than 30 mg/L and one industrial permit contains a water quality based effluent TSS limit that exceeds 45 mg/L. Wastewater WLAs were calculated based on permitted discharge design flow rates and TSS concentration limits or, if applicable, their permitted daily loading rates.

Industrial Wastewater Permits Without TSS Effluent Limits: Noncontact cooling water and reverse osmosis reject water permits do not contain effluent TSS permit limits. In the development of effluent limitation guidelines for certain waste streams, such as cooling water and reject water from reverse osmosis systems, the EPA has determined that TSS effluent limits are not required because TSS is not present at treatable levels. For other industrial sectors discharging cooling water and reverse osmosis reject water, and for which the EPA has not developed technology based effluent limitations, MPCA permit writers have used best professional judgment to determine that TSS effluent limits are not required because these wastewaters do not contain TSS at treatable levels. Waste load allocations for permits that do not contain TSS effluent limits were calculated based on the maximum permitted flow and the most restrictive downstream TSS surrogate concentration for the 25 NTU water quality standard.

Electric Services Sector Permits: NPDES permits for electric power generation facilities often include very large design flow values. Large volumes withdrawn from surface waters are used to cool condensers and are discharged without the addition of pollutants that contribute to increasing TSS concentrations. Influent and effluent TSS loads are expected to be equivalent to each other. Waste load allocations are not assigned to these large volume cooling waters from surface water sources. Waste load

allocations for electric power generation facility permits are based on maximum permitted flows and applicable effluent TSS concentrations for waste streams other than condenser cooling waters withdrawn from surface water sources. Waste load allocations for low volume waste streams, such as water treatment processes for which TSS effluent limits do not apply, were calculated based on the maximum permitted flows for those waste streams and the most restrictive downstream TSS surrogate concentration for the 25 NTU water quality standard.

Permitted wastewater treatment facilities and their waste load allocations are listed in Appendix A.

b. Regulated Stormwater

Stormwater regulated under a NPDES permit must be included in the WLA. This includes discharges associated with regulated Municipal Separate Storm Sewer Systems (MS4s), industrial stormwater activities and construction stormwater activities.

Model scenarios 3, 4 and 5 assumed one inch of infiltration in urban areas with no other best management practices (BMPs). The corresponding export of sediment from urban areas was 50 lbs/acre/year during mid-flow conditions. The WLA for mid-flow conditions loads was calculated by multiplying the export coefficient by the regulated MS4 area. The area represents the total developed area within regulated MS4 boundaries. The National Land Cover Data (NLCD) from 2001 were used to estimate the areas. The NLCD contain nine broad land use classifications. One of the classifications is developed land, which includes the following subdivisions:

- developed, low intensity
- developed, medium intensity
- developed, high intensity
- developed, open space

The developed areas within the regulated MS4 boundaries were considered to be urbanized areas and assumed to be covered under the MS4 NPDES permit. Table 4.1 includes the regulated MS4 communities, permit numbers and major watersheds. The WLAs were calculated for mid-flow conditions and increased or decreased in proportion to flow for the other flow zones.

Most of the MS4s in the study area do not have comprehensive land use plans so it is difficult to project future growth. Comparison of impervious cover data shows an increase of approximately five percent for the period 1990-2000. To account for this in the WLA, the developed area in the NLCD was increased by five percent to allow for future growth. If regulated MS4 communities expand beyond this five percent, or expand into areas currently included in the load allocation, mass from the load allocation will be moved to the waste load allocation proportional to the amount of land affected.

The WLA for regulated stormwater includes discharges from future urban areas that are expected to become regulated MS4 communities. These include LeHillier and Benning, Blue Earth and Nicollet Counties, MnDOT and Minnesota State University-Mankato. Reserve capacity is not provided separately. The allocation for these potential future permittees was calculated following the method used for the existing regulated MS4 communities. The allocation set aside for future regulated MS4 permittees applies to seven reaches. All are near or downstream of Mankato since this is where the growth is projected.

Table 4.1 Regulated MS4 communities.

MS4ID	Name	Major Watershed
MS400239	Fairmont City MS4	Blue Earth
MS400226	Mankato City MS4	Majority in Minnesota River-Mankato*. Small areas in Blue Earth and LeSueur
MS400241	Marshall City MS4	Redwood
MS400261	Montevideo City MS4	Chippewa and Hawk Creek
MS400228	New Ulm City MS4	Cottonwood and Minnesota River-Mankato
MS400229	North Mankato City MS4	Minnesota River-Mankato
MS400236	Redwood Falls City MS4	Redwood and Minnesota River-Mankato
MS400245	St Peter City MS4	Minnesota River-Mankato
MS400258	Waseca City MS4	LeSueur and Cannon
MS400272	Willmar City MS4	Hawk Creek and South Fork Crow

*Minnesota River-Mankato commonly known as Middle Minnesota River Watershed.

Regulated MS4 permittees will be deemed to be achieving their waste load allocations if they are in compliance with their NPDES permit. The year 2000 baseline year from which reductions must be made. Implicitly, the model represents the levels of treatment that were in place in 2000. BMPs implemented since then will receive credit toward meeting the required load reductions.

c. Margin of Safety

The purpose of the MOS is to account for uncertainty that the allocations will result in attainment of water quality standards. For this TMDL an explicit ten percent MOS was applied. This is expected to provide an adequate accounting of uncertainty, especially given that the wastewater treatment facilities in the watershed have demonstrated consistently being well below their permitted TSS discharge limit. Many of the wastewater treatment facilities in the watershed are also pond systems, which only discharge during spring and fall windows (i.e., before June 15 and after September 15). The very low flow regime is most likely to occur during these periods. However, the WLAs were developed assuming constant discharges, and therefore overestimates the TSS discharged from the facilities.

Additionally, abundant TSS and flow data are available. At least 12 years of TSS concentration data and nearly 30 years of flows provide adequate information with

which to inform the TMDL. This long term flow and water quality data record provides some additional certainty with the targets.

d. Load Allocations

This section of the TMDL report deals with nonpoint sources. A description of sediment sources is available in Section 2. Once the WLA and MOS were determined for each reach and flow zone, the remaining loading capacity was considered LA. The LA includes nonpoint pollution sources that are not subject to permit requirements, as well as natural background sources of sediment from upland areas and near channel sources.

There have been concerns about not specifying natural background sources of sediment in the report. Natural background sources are not separately calculated because the research is not sufficient to define or allocate the sources. The EPA does not require this in a TMDL Report.

The implementation process will define, in more detail, how these different sources will be addressed to achieve the LA.

Under Minnesota's Clean Water Legacy Act, natural background is defined as:

"Natural background" means characteristics of the water body resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the physical, chemical, or biological conditions in a water body, but does not include measurable and distinguishable pollution that is attributable to human activity or influence. (Minn. Stat. 114D.15, 2006)

Additionally, Minn. R. ch. 7050, Waters of the State defines natural causes as:

"Natural causes" means the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a water body in the absence of measurable impacts from human activity or influence. (Minn. R. 7050.0150, Subp. 4N)

Natural background and natural sources are important considerations. A 2007 document discussed phosphorus in lakes. Similar concepts can be applied to rivers. Loading from natural sources is the loading the rivers receive or would receive with essentially no influence from human activity. Natural background levels of sediment should be considered during implementation as better information becomes available. Sources of anthropogenic sediment, and therefore turbidity, are runoff from urban landscapes, agricultural land, construction sites and other altered landscapes. These point and nonpoint sources are generally controlled through the application of BMPs as required by permit or through the application of voluntary BMPs (MPCA, 2007).

One of the main issues in the presentation of the load allocation in turbidity TMDLs is the separation of natural background from anthropogenic nonpoint sources. Over

time, to the extent that natural background can be more clearly defined through emerging research, the ability to set goals will improve. Multiple lines of evidence indicate that most of the sediment in Lake Pepin comes from the Minnesota River basin (Wilcock, et al., 2009). Research on sediment cores from the lake indicates that sediment accumulation rates have increased almost an order of magnitude from pre-European settlement (c.1830) to 1996 (Engstrom, 2009). This is at the Lake Pepin scale and results for individual major watersheds in the Minnesota River basin may vary.

5. TMDL Allocations for Individual Impaired Reaches

This section provides the allocations for the impaired reaches as well as information on land use, conservation lands, and steeply sloped land and load duration curves. Load duration curves were developed for many of the watersheds included in this project. Not all sites were gaged by the USGS, and therefore did not have flow data. In these cases, flows were adjusted by applying drainage area ratio factors. Most adjustments to the flow and load duration curve values were for the Minnesota River mainstem reaches that fall between the long-term USGS stations at Montevideo and Mankato. Table 5.1 shows the drainage area of each watershed and the how the flows and associated loads were estimated.

The total daily loading capacity determination used for this report is based on the Duration Curve method, which has been widely used for TMDLs. The load duration curve approach relies on having a flow record that reasonably represents the range of conditions that would be expected. This is typically accomplished by using a long-term flow record. For this project, a 30-year flow record (from 1977 to 2006) was used. The source for most of the data was the USGS. A flow duration curve and load duration curve from the Yellow Medicine River provide an example (Figures 5.1 and 5.2).

Loading capacities for TSS are related directly to flow volume. As flows increase, the loading capacity of the stream will also increase. Thus, it is necessary to determine loading capacities across the range of flow. To illustrate portions of the flow record it is useful to divide up the record into “flow zones.” For this approach, daily flow values for each site are sorted by flow volume, from highest to lowest and a percentile scale was created (where a flow at the Xth percentile means X percent of all measured flows equal or exceed that flow). Five flow zones are illustrated in this approach: “very high” (0-10th percentile), “high” (10th- 40th percentile), “mid” (40th-60th percentile), “low” (60th-90th percentile) and “very low” (90th-100th percentile). The flows at the mid-points of each of these zones (i.e., 5th, 25th, 50th, 75th and 95th percentiles) can then be multiplied by the water quality standard concentration and a conversion factor to yield the allowable loading capacity or TMDL at those points.

A TSS equivalent or surrogate to the turbidity standard is calculated via linear regression. For example, a surrogate for the Yellow Medicine River is 50 mg/L TSS. The “mid-range” (50th percentile) flow is 44 cubic feet/sec, the loading capacity for TSS is:

44 cubic feet/sec x 50 mg/L TSS x 28.31 L/cubic ft x 86,400 s/day ÷ 907,184,740 mg/ton
= 5.93 tons TSS/day (Figure 5.2).

Table 5.1 Drainage area by watershed and adjustments to flow data.

Stream Name	Description	MPCA Assessment Unit ID	Drainage Area (sq. miles)	Source of Flow Data
Minnesota River	Rush R to High Island Cr	07020012-503	15994	Estimated from USGS gage at Jordan using watershed area ratio factor of 0.987
Minnesota River	Shanaska Cr to Rogers Cr	07020007-501	15105	Estimated from USGS gage at Mankato using watershed area ratio factor of 1.01
Minnesota River	Blue Earth R to Shanaska Cr	07020007-502	15023	USGS gage at Mankato
Minnesota River	Swan Lk outlet to Minneopa Cr	07020007-505	11337	Estimated from USGS gage at Montevideo using watershed area ratio factor of 1.83
Minnesota River	Cottonwood R to Little Cottonwood R	07020007-503	10876	Estimated from USGS gage at Montevideo using watershed area ratio factor of 1.76
Minnesota River	Beaver Cr to Birch Coulee	07020007-514	9026	Estimated from USGS gage at Montevideo using watershed area ratio factor of 1.46
Minnesota River	Timms Cr to Redwood R	07020004-509	8200	Estimated from USGS gage at Montevideo using watershed area ratio factor of 1.32
Minnesota River	Minnesota Falls Dam to Hazel Cr	07020004-515	6439	Estimated from USGS gage at Montevideo using watershed area ratio factor of 1.04
Minnesota River	Chippewa R to Stony Run Cr	07020004-501	6221	USGS gage at Montevideo
Blue Earth River	Le Sueur R to Minnesota R	07020009-501	3540	Estimated from combined flow at USGS gages at Rapidan and on LeSueur
Blue Earth River	Rapidan Dam to Le Sueur R	07020009-509	2427	USGS gage at Rapidan
Le Sueur River	Maple R to Blue Earth R	07020011-501	1112	USGS gage at mouth of LeSueur
Watonwan River	Perch Cr to Blue Earth R	07020010-501	877	USGS gage at mouth of Watonwan
Cottonwood River	JD 30 to Minnesota R	07020008-501	1313	USGS gage at mouth of Cottonwood
Redwood River	Ramsey Cr to Minnesota R	07020006-501	705	Adjusted to account for USGS gage location upstream of Ramsey Creek; watershed area ratio factor of 1.121
Yellow Medicine River	Spring Cr to Minnesota R	07020004-502	674	USGS gage at mouth of Yellow Medicine
Hawk Creek	Spring Cr to Minnesota R	07020004-587	506	Estimated from USGS gage on Yellow Medicine River using watershed area ratio factor of 0.762
Chippewa River	Watson Sag to Minnesota R	07020005-501	2083	Value provided by Tetra Tech.; corrected from USGS gage upstream of Watson Sag diversion; impaired reach is below diversion

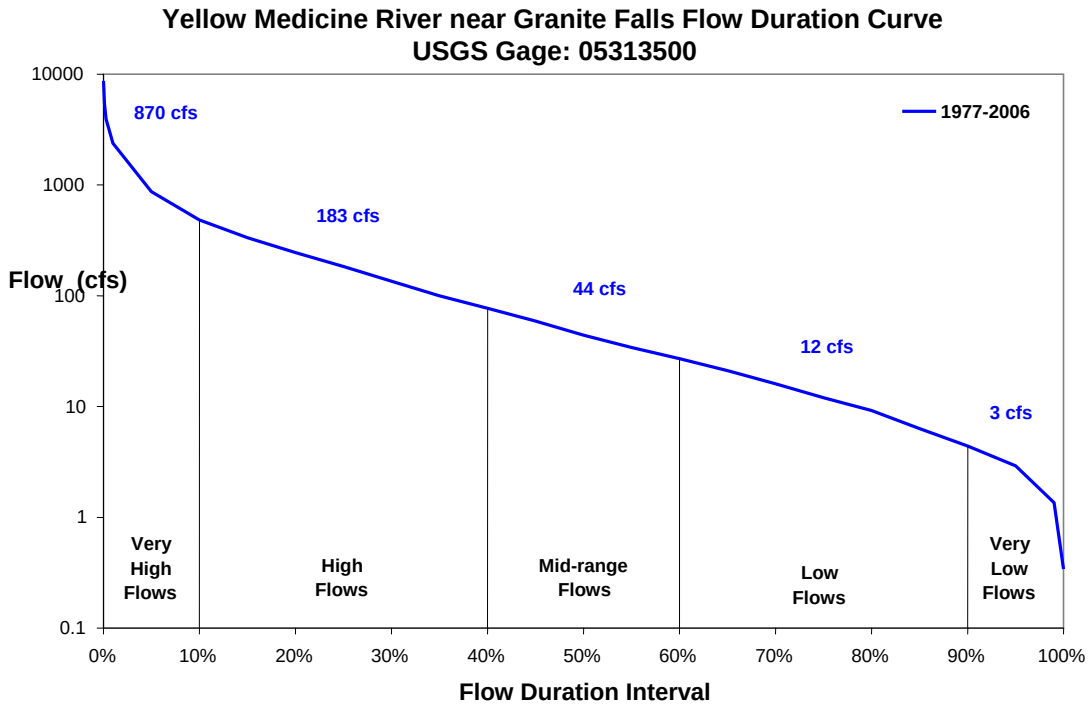


Figure 5.1 Yellow Medicine River Flow Duration Curve.

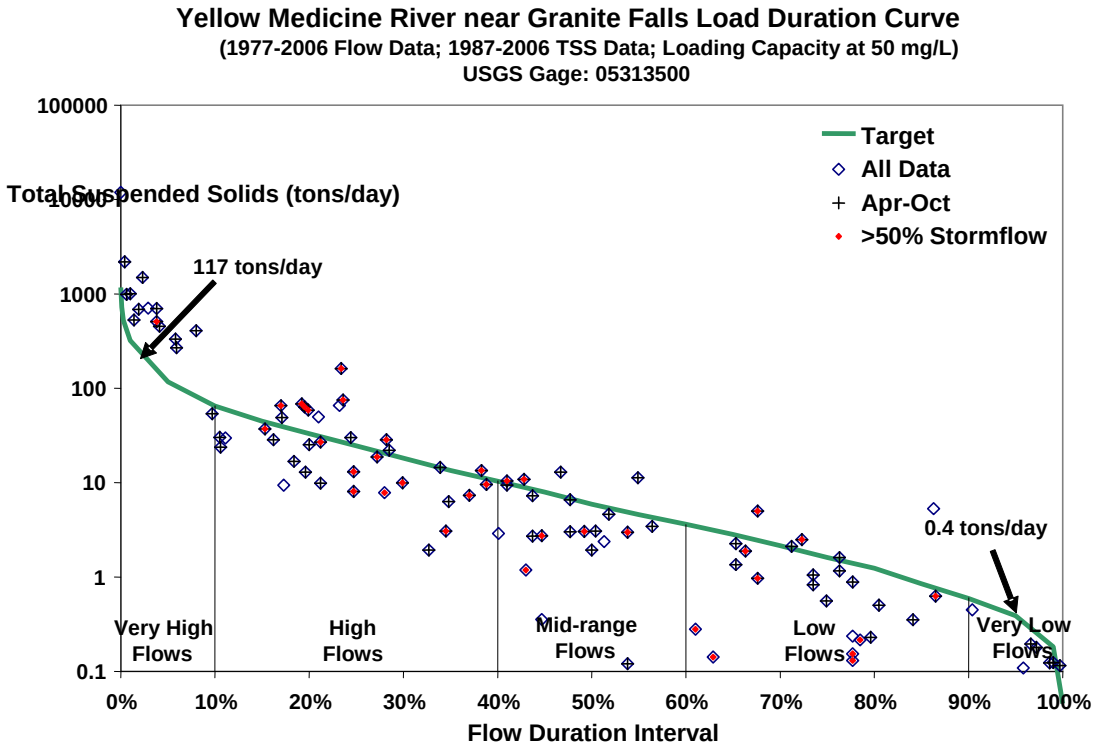


Figure 5.2 Yellow Medicine River Load Duration Curve.

The total daily loading capacities were calculated for the five highest flow zones for each of the listed reaches in this project. The TMDLs were then divided into a Margin of Safety (MOS), Waste Load Allocations (WLAs) and a Load Allocations (LAs). For this TMDL an explicit ten percent MOS was used.

Although the watersheds in this project are nested, each is treated as a single entity. Allocations are based on the needs for each watershed. The Lower Minnesota River from Rush River to High Island Creek is the reach farthest downstream on the Minnesota River and includes all the watersheds. The allocations are not double counted.

The WLAs for the communities subject to MS4 NPDES requirements for mid-flow conditions were calculated by multiplying the model coefficient of 50 lbs/acre/year by the built up area in acres by five percent to allow for growth. The WLA for construction and industrial stormwater was calculated in a similar fashion, with the exception of allowing for five percent growth. Calculations for the other flow zones were increased or decreased proportionally based on flow. Again, the allocations were provided categorically by watershed.

The LA was calculated by subtracting the WLA and the MOS from the total loading capacity.

Load duration curve figures in the report display the allowable load across the range of flows in the timeframe selected. The loads (points) represented by grab samples were calculated and plotted. Data points are plotted with the following designations: 1) Open diamonds represent data from November through March; 2) Diamonds with crosses symbolize data collected from April through October, showing the samples collected in the spring and summer, post snow melt in the spring and prior to freezing in the fall. 3) Red diamonds indicate over 50 percent stormflow was present, signifying high flow conditions. The samples representing greater than 50 percent storm flow were calculated using the methodology described in “HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis”, US Geological Survey, Water-Resources Investigations Report 96-4040. Categorizing the samples has been useful in showing that the highest concentrations tend to occur during the high flow conditions (i.e. more red points) and that winter TSS concentrations are lower (i.e. most open points are below the targets).

Maps and graphs showing land use, slope and conservation acres are included for each watershed. Lands with high slopes, whether they are located in upland or near channel areas, can be high contributors of sediment. The conservation lands maps show locations of conservation acres, which can be useful in targeting. These characteristics are important because they directly or indirectly drive water quality. The cropland information is from the 2006 USDA-NASS cropland dataset and the slope information is from the National Elevation Dataset 30 meter Digital Elevation Model. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use, and consequently these estimates, will change from year to year.

The maps with land in Iowa show the Iowa portion of the watershed labeled as “No Data”. For land use and slope, data were available but not used, since this is a small portion of the watershed and would have had a minimal impact on the land use and slope estimates.

5.1 Yellow Medicine River; Spring Cr to Minnesota R

Reach AUID:
07020004-502

Stream Status:
Impaired Stream Reach (mercury, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

Impaired Segment Length:
26.83 miles

Contributing Watershed Size:
431,707.72 acres
674.54 square miles

Total Stream Miles:
1,270.29 miles

Elevation*:
Maximum = 1972 ft above sea level
Minimum = 869 ft above sea level
Total relief = 1103 ft

Slope*:
Maximum Slope: 47.8 percent
Minimum Slope: 0 percent
Average Slope: 1.98 percent

Cities:
Arco, Cottonwood, Hanley Falls, Hazel Run, Ivanhoe, Minneota, Porter, St. Leo, Taunton

Counties:
Lincoln, Lyon, Yellow Medicine

*derived from the NED 30m DEM

The main branch of the Yellow Medicine River originates at Lake Shaokatan in western Lincoln County, and flows to the northeast. Each of the maps of the Yellow Medicine watershed depict the pronounced landscape differences between the Coteau des Prairies morainal plateau in the upper portion of the watershed, and the lowland plains of the lower portion. These geomorphic features have a strong influence on land use (Figures 5.3 and 5.4), soil erosion potential (Figure 5.5) and the distribution of conservation easements (Figure 5.6). The percentage of land in a corn/soybean rotation (68 percent) is somewhat lower than other parts of the Minnesota River basin; and the percentage of land under conservation easements (8.3 percent) is somewhat higher. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

Figure 5.7 is the load duration curve depicting daily total suspended solids (TSS) loads consistent with achievement of the 25 NTU water quality standard. In the case of the Yellow Medicine River, the TSS surrogate value for 25 NTUs was determined to be 50 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less. The diamond-shaped symbols on the chart represent calculated TSS loads based on water quality samples. These symbols are further qualified to show if the samples were collected during the April-October time period, and if they represent conditions where more than 50 percent of the water in the river is estimated to be made up of storm flow runoff. There does not appear to be a clear pattern explaining the conditions under which TSS loads exceeding the TMDL occur. Exceedances are observed during all but very low flows, at times beyond April through October, and under both storm flow and non-storm flow conditions.

Table 5.2 summarizes the total loading capacity, the waste load allocations and load allocations for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves.

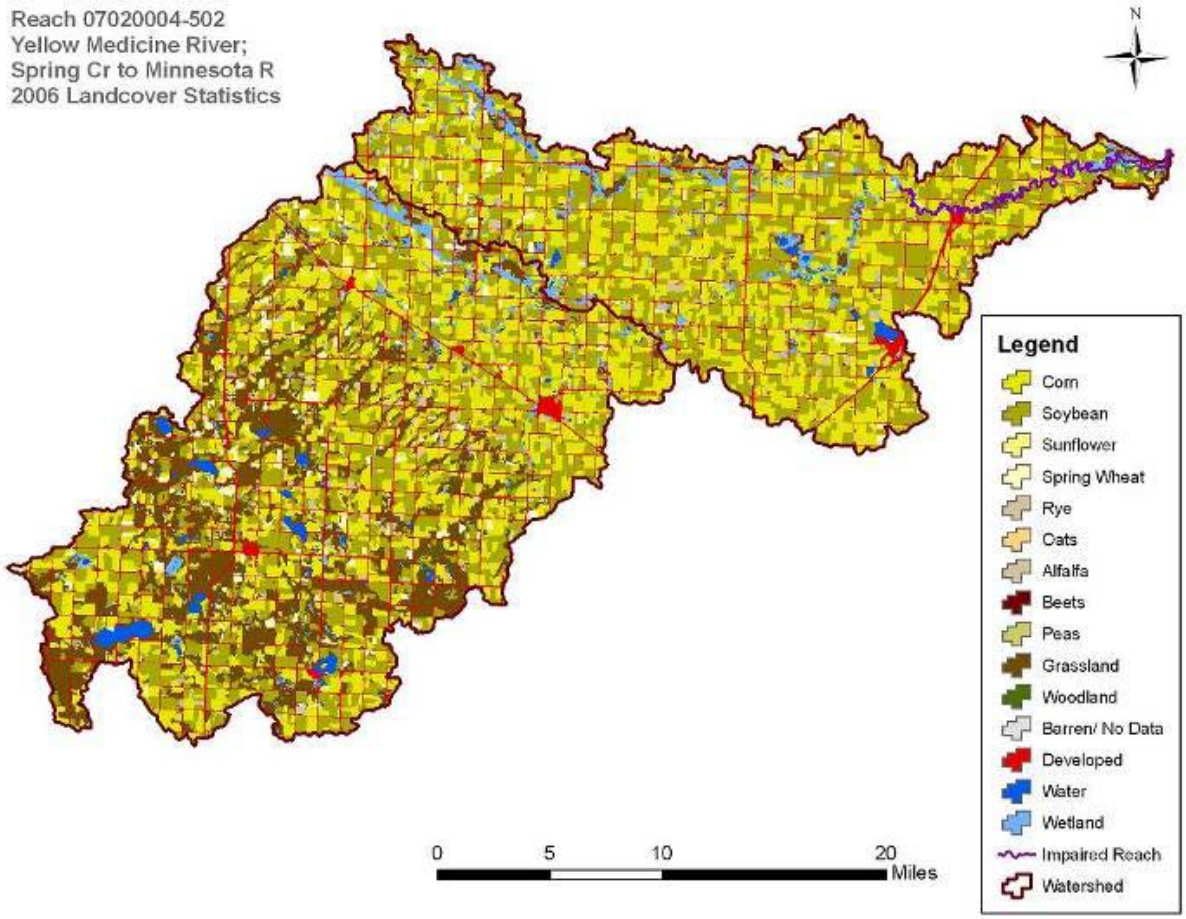


Figure 5.3 2006 Land Cover Map for the Yellow Medicine River Watershed contributing to Spring Cr to Minnesota R. impaired reach.

LANDUSE	ACRES	PERCENT
No Data	113.91	0.03%
Corn	148,471.51	34.39%
Soybean	143,099.74	33.15%
Sunflower	477.35	0.11%
Spring Wheat	11,574.26	2.68%
Oats	32.55	0.01%
Alfalfa	7,231.59	1.68%
Beets	206.90	0.05%
Grassland	61,075.61	14.15%
Woodland	2,850.17	0.66%
Barren	13.95	0.00%
Developed	34,057.90	7.89%
Water	4,931.61	1.14%
Wetland	17,574.49	4.07%
Total	431,711.55	100.00%

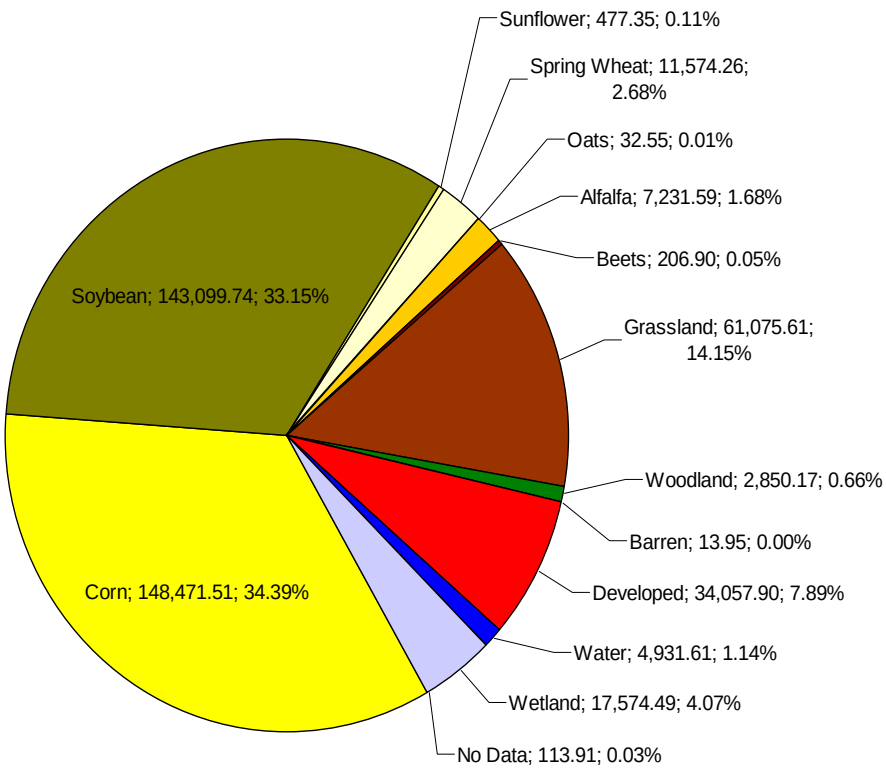
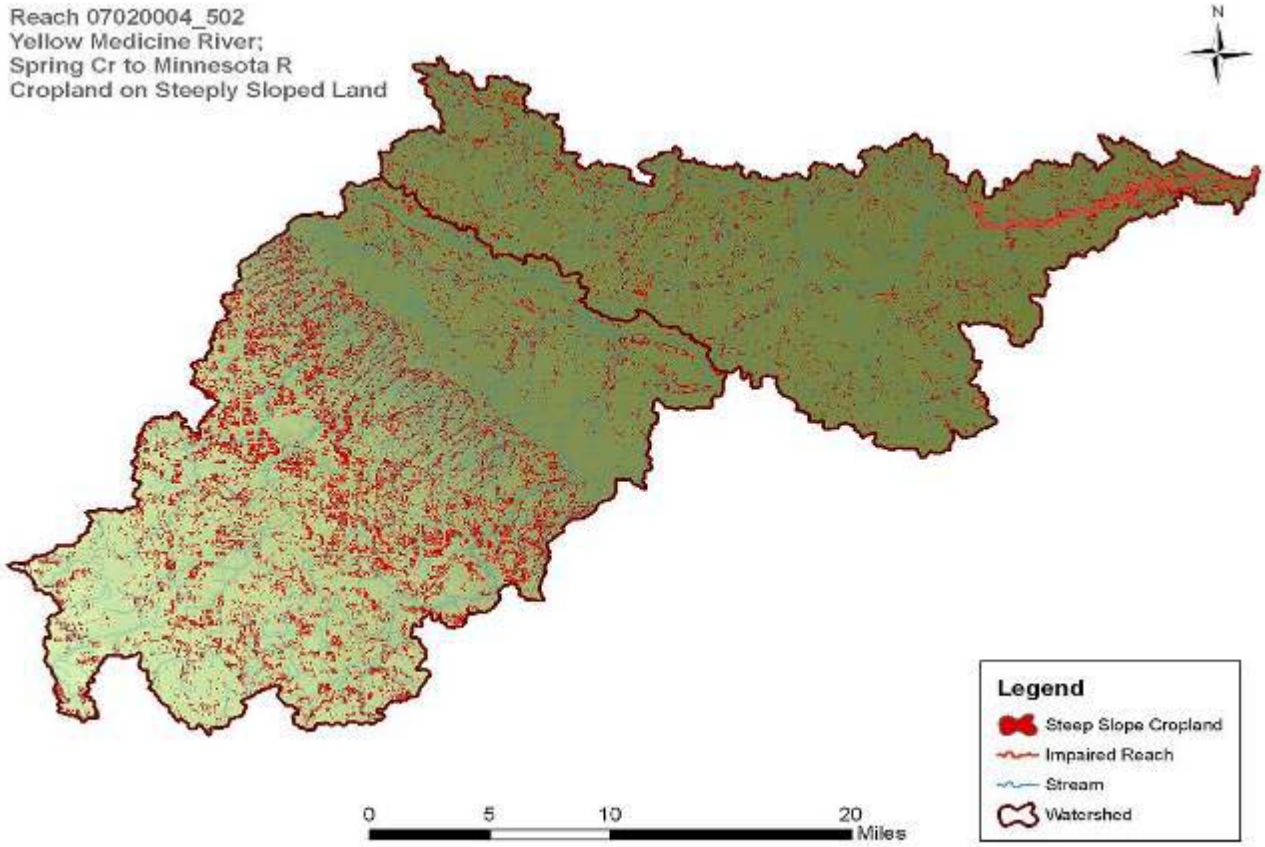
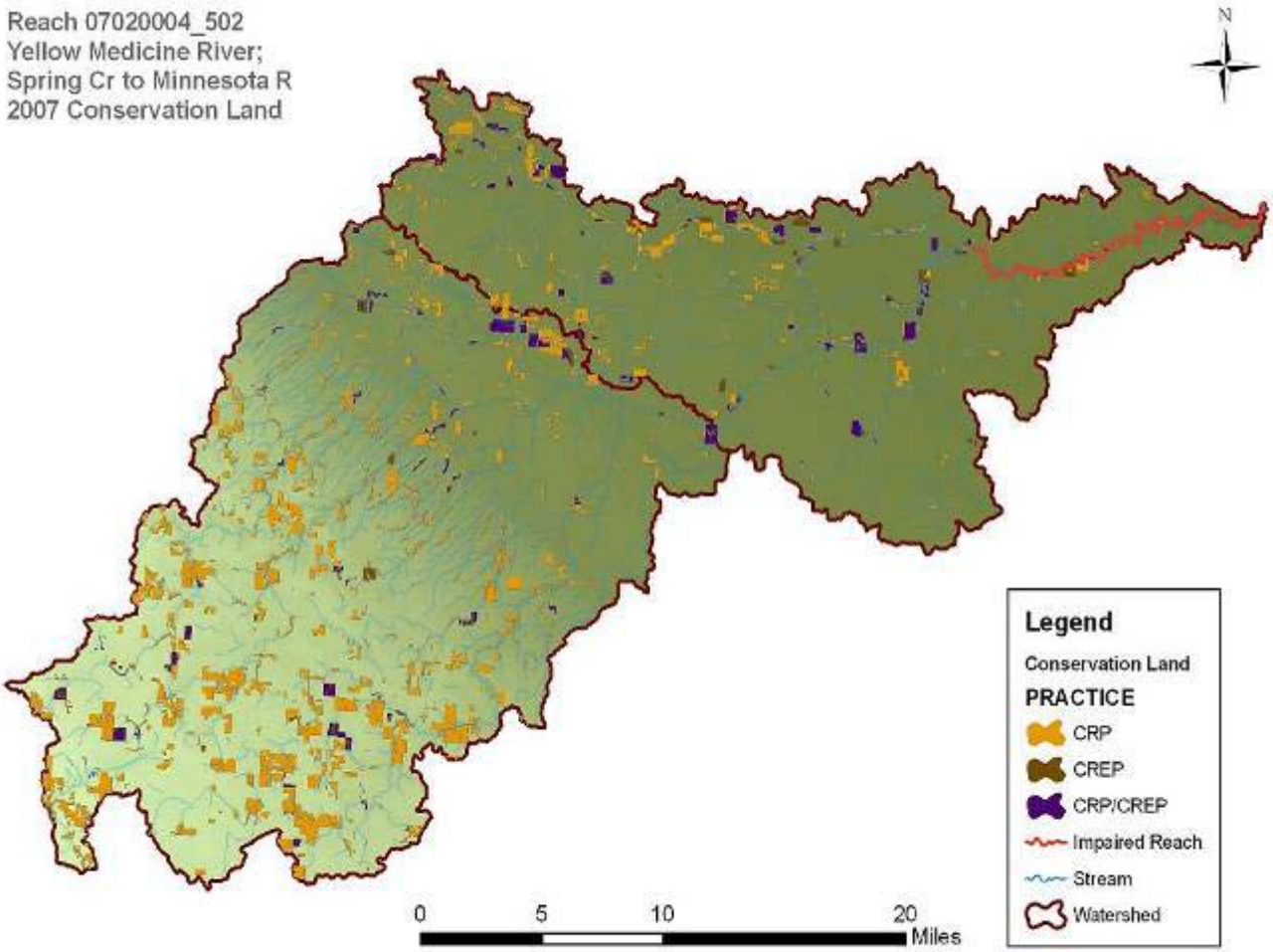


Figure 5.4 2006 Land Use Statistics for the Yellow Medicine River Watershed contributing to Spring Cr to Minnesota R. impaired reach.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
431,707.72	311,093.89	50,370.04	11.67%	16.19%

Figure 5.5 Cropland on Steeply Sloped Land Analysis for the Yellow Medicine River Watershed contributing to Spring Cr to Minnesota R. impaired reach.



PROGRAM	ACRES	PERCENT
CRP	33,881.45	7.85%
CREP	6,350.18	1.47%
CRP,CREP	35,880.79	8.31%

Figure 5.6 Conservation Land Locations and Statistics for the Yellow Medicine River Watershed contributing to Spring Cr to Minnesota R. impaired reach.

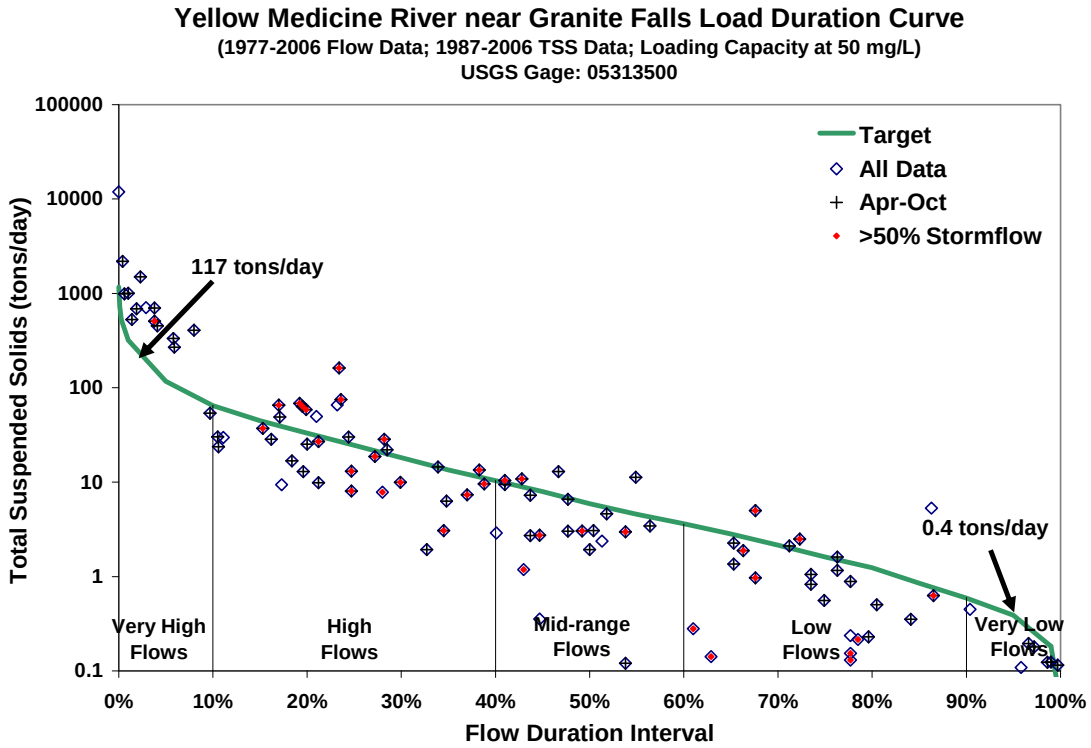


Figure 5.7 Yellow Medicine River Load Duration Curve.

Table 5.2 Yellow Medicine River TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	117	25	6	2	0.4
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	0.93	0.93	0.93	0.93	*
Communities Subject to MS4 NPDES Requirements	0.00**	0.00**	0.00**	0.00**	*
Construction and Industrial Stormwater	0.02	0.01	0.01	0.01	*
Load Allocation	104.35	21.56	4.46	0.86	*
Margin of Safety	11.70	2.50	0.60	0.20	*

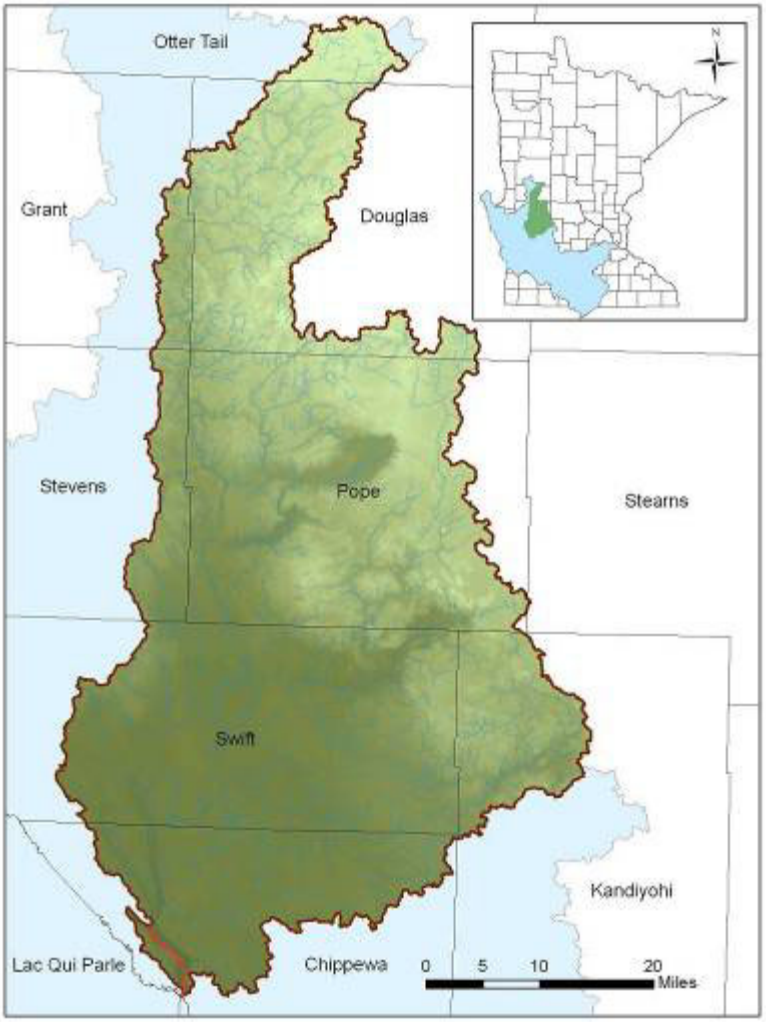
* The total daily loading capacity in the very low flow zone is very small due to the occurrence of very low flows in the long-term flow records. Consequently, for some of the impaired reaches, the permitted wastewater treatment facility design flows exceed the stream flow in the very low

flow zone. Since it is a component of stream flow, actual treatment facility flow can never exceed stream flow, but in some cases the calculated MOS would take up all of the remaining allocation capacity in the very low flow zone. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

Allocation = (flow contribution from a given source) x (*X* mg/L TSS), where *X* equals 45 for the municipal stabilization ponds, 30 for other wastewater treatment facilities and 50 mg/L for other sources.

**No regulated MS4 communities currently exist in this watershed so the waste load allocation is 0.00. If Montevideo, the nearest regulated MS4 community, expands into this watershed, the load allocation will be moved to the waste load allocation proportional to the amount of land affected.

5.2 Chippewa River; Watson Sag Diversion to Minnesota R



Reach AUID:
07020005-501

Stream Status:
Impaired Stream Reach (mercury, bacteria, turbidity, aquatic consumption, aquatic life, and aquatic recreation). This report only addresses the turbidity impairment.

Impaired Segment Length:
12.67 miles

Contributing Watershed Size:
1,333,540.92 acres
2,083.66 square miles

Total Stream Miles:
2,465.59 miles

Elevation*:
Maximum = 1710 ft above sea level
Minimum = 918 ft above sea level
Total relief = 792 ft

Slope*:
Maximum Slope: 45.4 percent
Minimum Slope: 0 percent
Average Slope: 2.17 percent

Cities:
Benson, Brandon, Clontarf, Cyrus, Danvers, De Graff, Evansville, Farwell, Forada, Glenwood, Hancock, Hoffman, Holloway, Kensington, Kerkhoven, Long Beach, Lowry, Millerville, Montevideo, Murdock, Sedan, Starbuck, Sunburg, Urbank, Villard, Watson.

Counties:
Chippewa, Douglas, Grant, Kandiyohi, Otter Tail, Pope, Stearns, Stevens, Swift

*derived from the NED 30m DEM

One of the largest major watersheds in the Minnesota River basin, the 2,085 square-mile Chippewa River Watershed, begins in the headwater lakes of Central Minnesota and outlets to the Minnesota River at the city of Montevideo. The watershed is divided by ecoregion types, with the eastern portion lying within the North Central Hardwood Forests Ecoregion and the western portion falling in the Northern Glaciated Plains Ecoregion. The Chippewa River is split near Watson, Minnesota, forming the Watson Sag, which is upstream of the impaired reach. Much of the high flows and sediment loads are diverted into Lac qui Parle Lake.

The land use diversity in this area is higher (Figures 5.8 and 5.9) than in the eastern portion of the Minnesota River basin. Agriculture is still the dominant category at approximately 61 percent, but higher percentages are seen in grasslands (13.4 percent), water (6 percent) and wetlands (6.6 percent). Developed land use is estimated to be 8 percent for the entire watershed.

Figure 5.10 shows the slopes found in the Chippewa River Watershed, with more steeply sloped land in the east and flatter land in the west. The eastern portion of the watershed is classified as moderate-to-high in water erosion potential, due to soil types and slopes, while the western half is generally classified as moderate. The geomorphology of the area includes a mixture of moraines, till, lacustrine and outwash plains. These variations play a role in erosion potential.

Conservation practices occur at higher percentages within the watershed. Figure 5.11 shows the combination of CRP and other programs that have been utilized on 8 percent of the watershed. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

The load duration curve depicts daily total suspended solids (TSS) loads consistent with achievement of the 25 NTU water quality standard (Figure 5.12). The flow values for the duration curve were provided by Tetra Tech, since the impaired reach is located below the Watson Sag diversion and the USGS gage is upstream of it. In the case of the Chippewa River, the TSS surrogate value for 25 NTUs was determined to be 50 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less. The diamond-shaped symbols on the chart represent calculated TSS loads based on water quality samples. These symbols are further qualified to show if the samples were collected during the April-October time period, and if they represent conditions where more than 50 percent of the water in the river is estimated to be made up of storm flow runoff. There does not appear to be a clear pattern explaining the conditions under which TSS loads exceeding the TMDL occur. Exceedances are observed during all but very low flows, at times beyond April through October, and under both storm flow and non-storm flow conditions.

Table 5.3 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves.

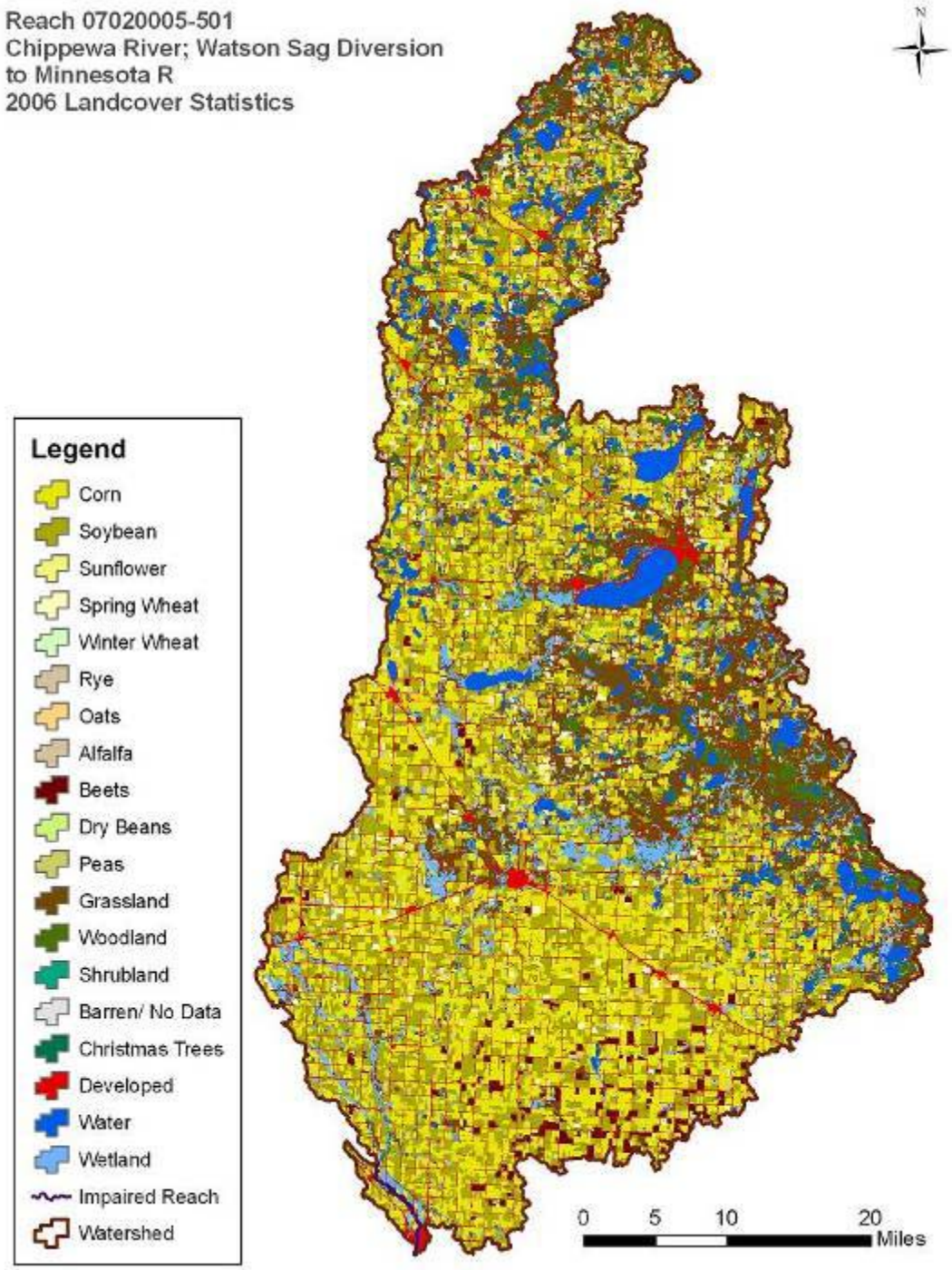


Figure 5.8 2006 Land Cover Map for the Chippewa River; Watson Sag Diversion to Minnesota R.

LANDUSE	ACRES	PERCENT
Corn	388,666.86	29.14%
Soybean	329,948.57	24.74%
Sunflower	90.67	0.01%
Spring Wheat	34,856.84	2.61%
Winter Wheat	423.11	0.03%
Rye	34.87	0.00%
Oats	89.12	0.01%
Alfalfa	29,598.99	2.22%
Beets	22,111.67	1.66%
Dry Beans	1,154.64	0.09%
Peas	233.25	0.02%
Grassland	178,594.34	13.39%
Woodland	73,073.76	5.48%
Shrubland	49.60	0.00%
Barren	68.97	0.01%
Christmas Tree	154.98	0.01%
Developed	106,348.20	7.97%
Water	79,659.83	5.97%
Wetland	88,407.95	6.63%
Total	1,333,566.21	100.00%

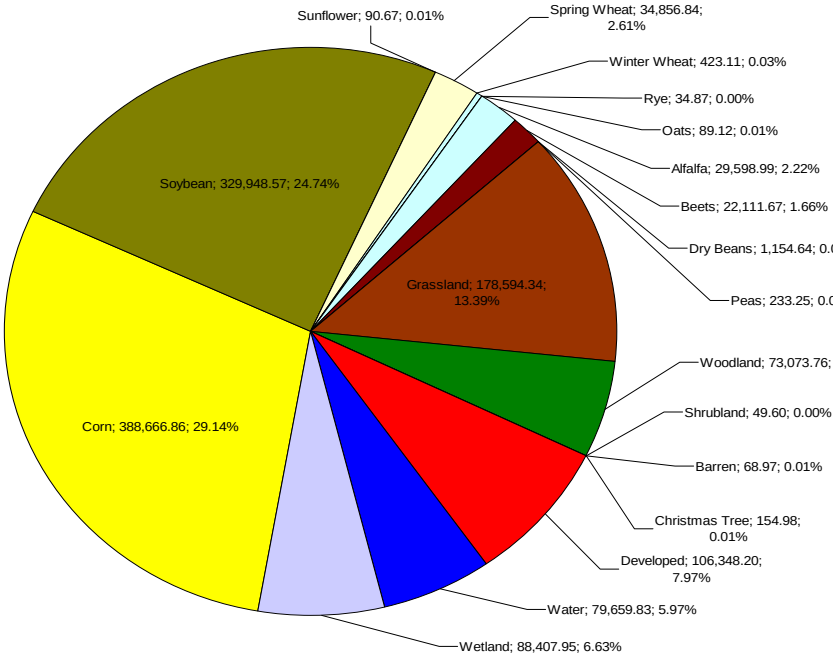
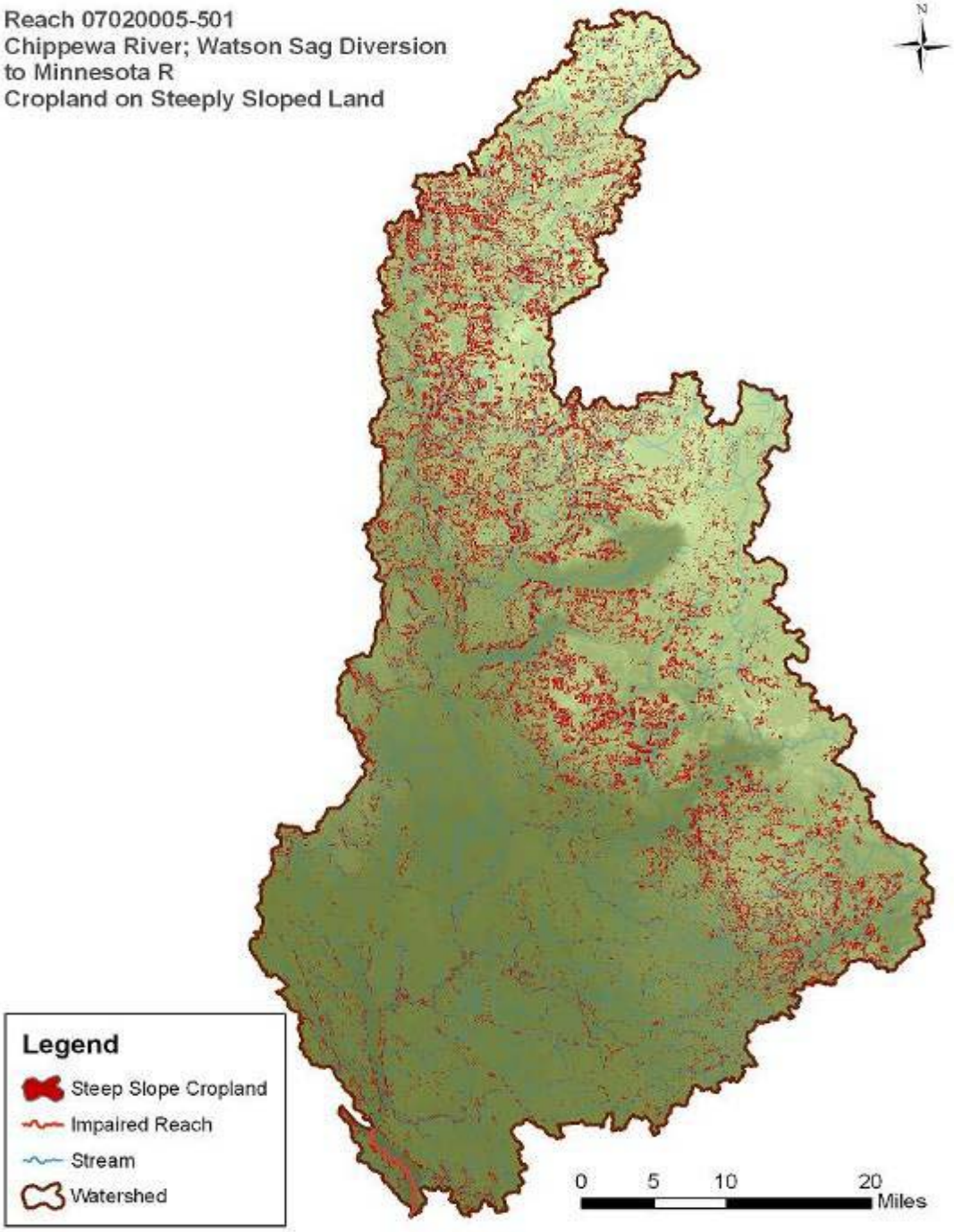
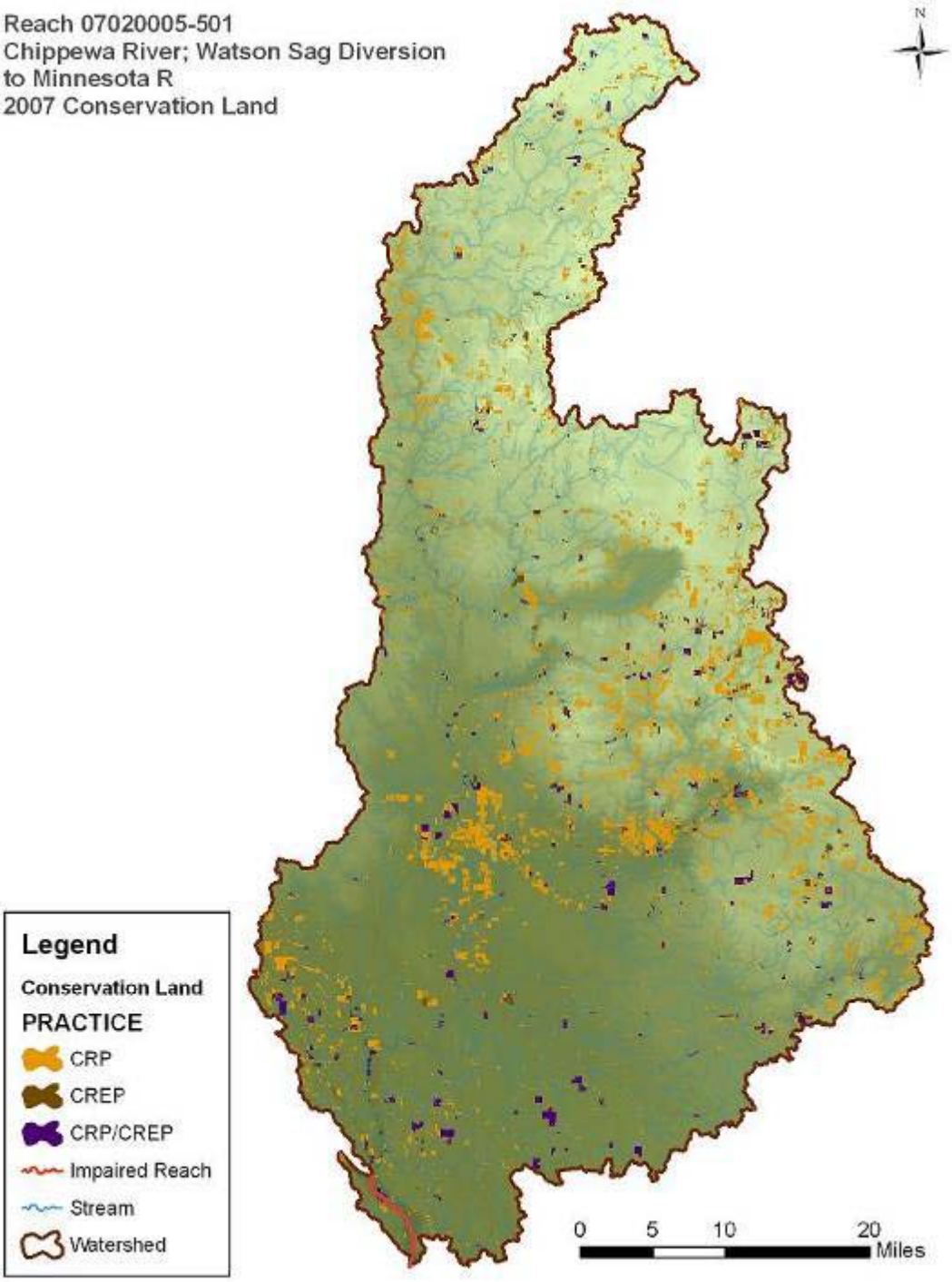


Figure 5.9 2006 Land Use Statistics for the Chippewa River; Watson Sag Diversion to Minnesota R.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
1,333,540.92	807,208.58	147,842.27	11.09%	18.32%

Figure 5.10 Cropland on Steeply Sloped Land Analysis for the Chippewa River; Watson Sag Diversion to Minnesota R.



PROGRAM	ACRES	PERCENT
CRP	100,168.40	7.51%
CREP	20,930.90	1.57%
CRP,CREP	108,096.34	8.11%

Figure 5.11 Conservation Land Locations and Statistics for the Chippewa River; Watson Sag Diversion to Minnesota R.

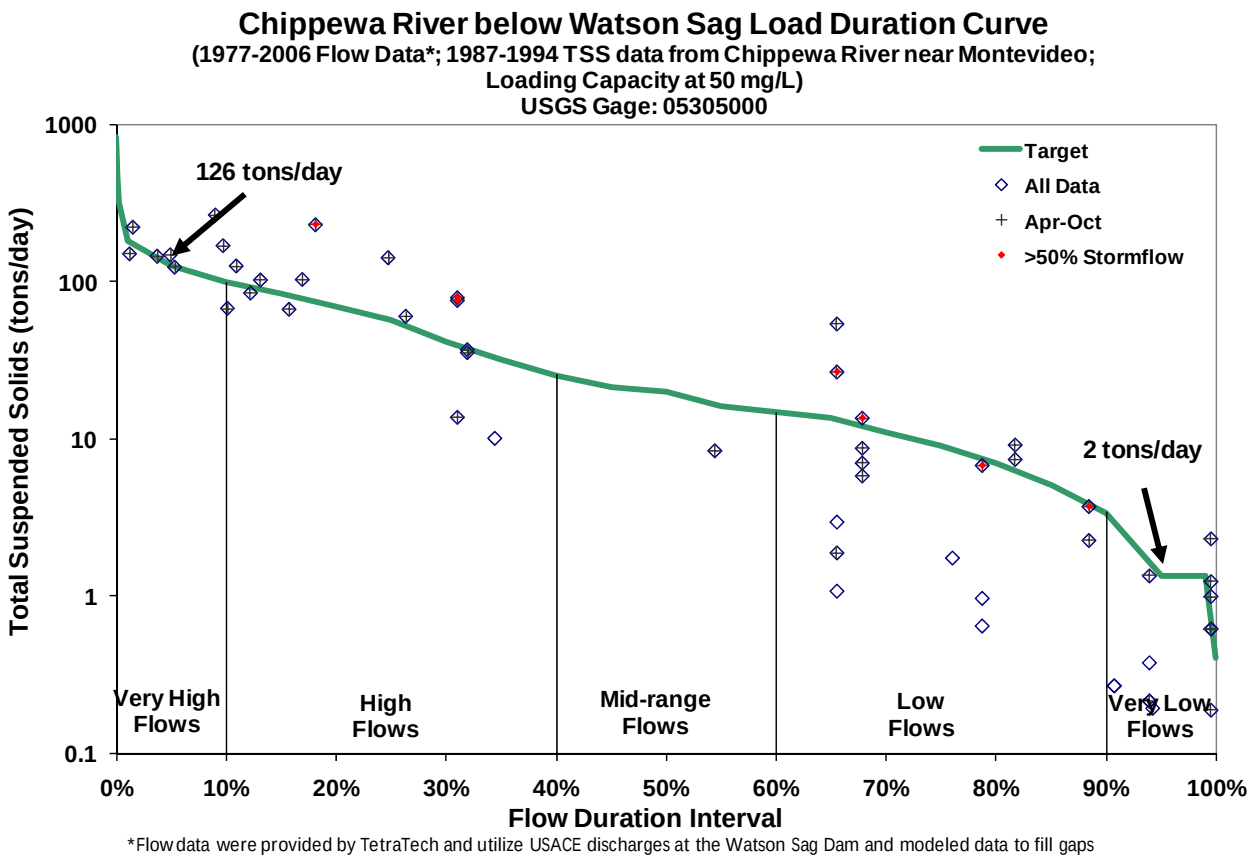


Figure 5.12 Chippewa River Load Duration Curve.

Table 5.3 Chippewa River TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	126	57	20	9	1
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	1.75	1.75	1.75	1.75	*
Communities Subject to MS4 NPDES Requirements	0.38	0.17	0.06	0.03	*
Construction and Industrial Stormwater	0.11	0.05	0.02	0.01	*
Load Allocation	111.15	49.32	16.17	6.31	*
Margin of Safety	12.60	5.70	2.00	0.90	*

* The total daily loading capacity in the very low flow zone is very small due to the occurrence of very low flows in the long-term flow records. Consequently, for some of the impaired reaches, the permitted wastewater treatment facility design flows exceed the stream flow in the very low flow zone. Since it is a component of stream flow, actual treatment facility flow can never exceed stream flow, but in some cases the calculated MOS would take up all of the remaining allocation capacity in the very low flow zone. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

Allocation = (flow contribution from a given source) x (*X* mg/L TSS), where *X* equals 45 for the municipal stabilization ponds, 30 for other wastewater treatment facilities and 50 mg/L for other sources.

5.3 Hawk Creek; Spring Cr to Minnesota R

Reach AUID:
07020004-587

Stream Status:
Impaired Stream Reach (mercury, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

Impaired Segment Length:
15.09 miles

Contributing Watershed Size:
323,947.74 acres
506.17 square miles

Total Stream Miles:
694.78 miles

Elevation*:
Maximum = 1290 ft above sea level
Minimum = 869 ft above sea level
Total relief = 421 ft

Slope*:
Maximum Slope: 84.4 percent
Minimum Slope: 0 percent
Average Slope: 1.3 percent

Cities:
Blomkest, Clara City, Maynard, Pennock, Prinsburg, Raymond, Willmar

Counties:
Chippewa, Kandiyohi, Renville

*derived from the NED 30m DEM

Hawk Creek originates in a glacial moraine complex that covers only the very upper portion of the watershed. This area includes several lakes and the city of Willmar. The geomorphology of the remainder of the watershed is glacial till plain. Hawk Creek's main tributary is Chetomba Creek, which drains more than a third of the watershed. It joins Hawk Creek at the city of Maynard. Over eight percent of the land in the watershed is used for sugar beet production; and combined with corn and soybeans, over 75 percent of the land in the watershed is cultivated. Grassland, woodland, wetlands and conservation easement lands are concentrated mainly in the more rolling upper portion of the watershed, and the very lower portions of the watershed where Hawk Creek drops to meet the Minnesota River (Figures 5.13 and 5.14). Figures 5.15 and 5.16 show the steeply sloped cropland and land in conservation programs. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

Hawk Creek does not have a long term flow gaging station and therefore, the load duration curve for the Yellow Medicine River (Figure 5.7) was used to develop the daily total suspended solids (TSS) loads consistent with achievement of the 25 NTU water quality standard. To determine the loading capacity, the MPCA estimated the flows in this reach by using a watershed area ratio of 0.762. While the geomorphology of the headwater areas of the two watersheds are clearly different, the majority of both watersheds share similar landscape characteristics. The TSS surrogate value for 25 NTUs was determined to be 50 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less.

Table 5.4 summarizes the total loading capacity, the WLA, and LA for the watershed. The methods for calculating the allocations appear in Section 5. The five flow zones correspond to those in the load duration curves.

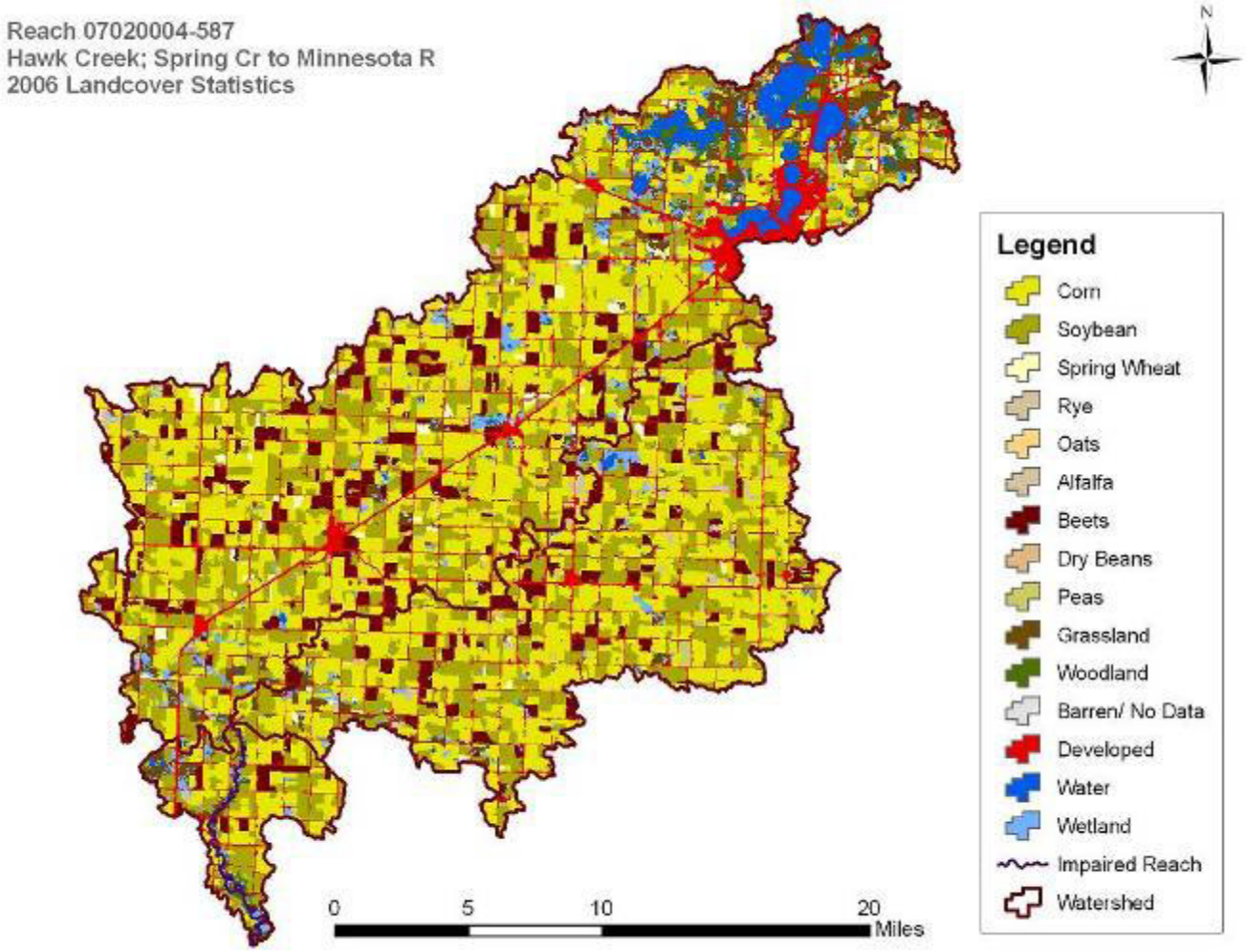


Figure 5.13: 2006 Land Cover Map for Hawk Creek; Spring Cr to Minnesota R.

LANDUSE	ACRES	PERCENT
Corn	133,827.00	41.31%
Soybean	83,748.33	25.85%
Spring Wheat	4,196.99	1.30%
Oats	13.17	0.00%
Alfalfa	3,270.18	1.01%
Beets	27,216.87	8.40%
Dry Beans	958.58	0.30%
Peas	666.43	0.21%
Grassland	13,218.65	4.08%
Woodland	5,322.18	1.64%
Barren/No Data	176.68	0.05%
Developed	31,051.19	9.58%
Water	8,440.47	2.61%
Wetland	11,851.68	3.66%
Total	323,958.41	100.00%

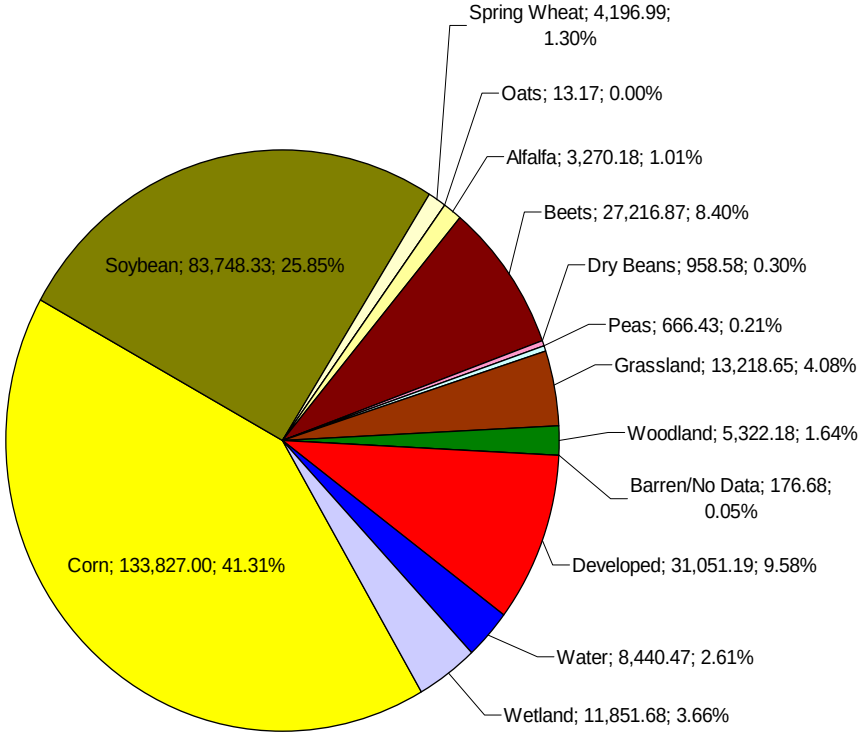
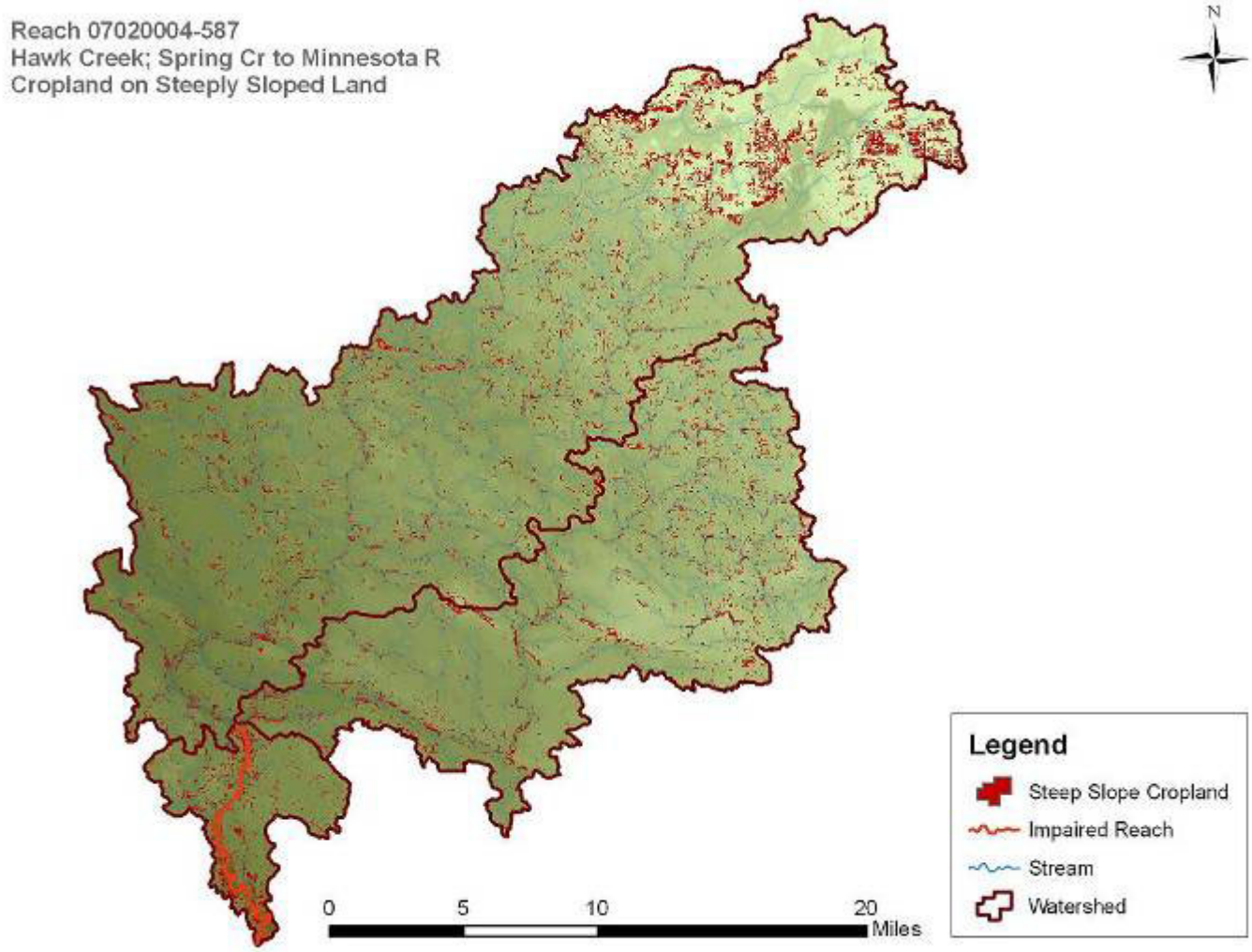
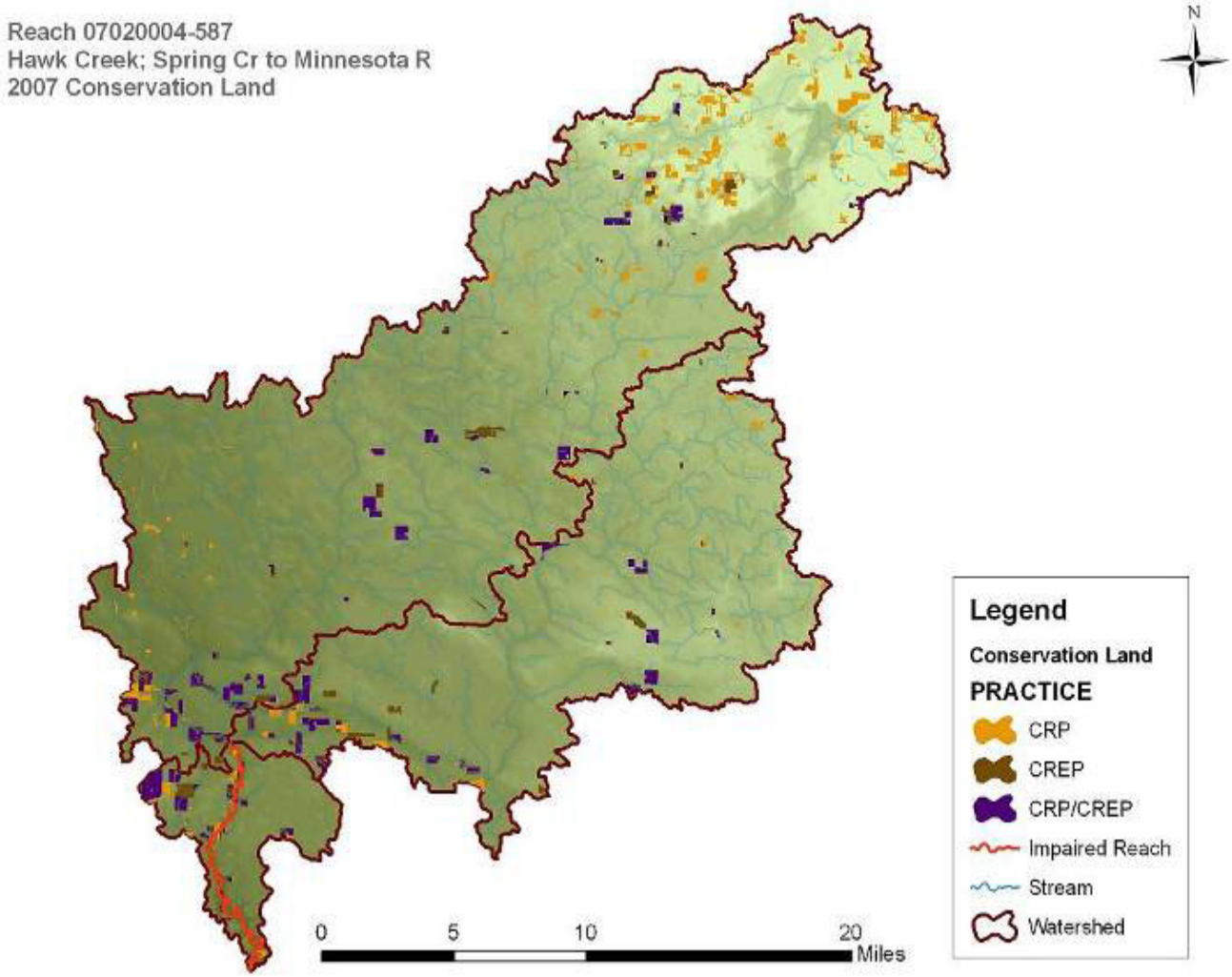


Figure 5.14: 2006 Land Use Statistics for Hawk Creek; Spring Cr to Minnesota R.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
323,947.74	253,897.55	18,759.35	5.79%	7.39%

Figure 5.15: Cropland on Steeply Sloped Land Analysis for the Hawk Creek; Spring Cr to Minnesota R.



PROGRAM	ACRES	PERCENT
CRP	13,321.88	4.11%
CREP	7,921.83	2.45%
CRP,CREP	15,750.79	4.86%

Figure 5.16: Conservation Land Locations and Statistics for Hawk Creek; Spring Cr to Minnesota R.

Table 5.4 Hawk Creek TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	89	19	5	1	0.3
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	0.38	0.38	0.38	0.38	*
Communities Subject to MS4 NPDES Requirements	4.00	0.85	0.22	0.04	*
Construction and Industrial Stormwater	0.08	0.02	0.01	0.01	*
Load Allocation	75.64	15.85	3.89	0.47	*
Margin of Safety	8.90	1.90	0.50	0.10	*

* The total daily loading capacity in the very low flow zone is very small due to the occurrence of very low flows in the long-term flow records. Consequently, for some of the impaired reaches, the permitted wastewater treatment facility design flows exceed the stream flow in the very low flow zone. Since it is a component of stream flow, actual treatment facility flow can never exceed stream flow, but in some cases the calculated MOS would take up all of the remaining allocation capacity in the very low flow zone. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

Allocation = (flow contribution from a given source) x (*X* mg/L TSS), where *X* equals 45 for the municipal stabilization ponds, 30 for other wastewater treatment facilities and 50 mg/L for other sources.

5.4 Redwood River; Ramsey Cr to Minnesota R

Reach AUID:
07020006-501

Stream Status:
Impaired Stream Reach (Hg, FC, T, aquatic consumption, aquatic life, and aquatic recreation). This report only addresses the turbidity impairment.

Impaired Segment Length:
4.05 miles

Contributing Watershed Size:
451,257.49 acres
705.09 square miles

Total Stream Miles:
962.02 miles

Elevation*:
Maximum = 1992 ft above sea level
Minimum = 826 ft above sea level
Total relief = 1166 ft

Slope*:
Maximum Slope: 56.6 percent
Minimum Slope: 0 percent
Average Slope: 1.84 percent

Cities:
Echo, Florence, Ghent, Lake Benton, Lucan, Lynd, Marshall, Milroy, North Redwood, Redwood Falls, Russell, Ruthton, Seaforth, Tyler, Vesta

Counties:
Lincoln, Lyon, Murray, Pipestone, Redwood, Yellow Medicine

*derived from the NED 30m DEM

The 705 square-mile watershed of the Redwood River extends to the western border of Minnesota in Lincoln County. The Redwood flows northeast and then east to its confluence with the Minnesota River near Redwood Falls. The upper third of the watershed is situated on the Coteau des Prairies morainal plateau; the remainder of the watershed drains the Blue Earth Till Plain. Major tributaries of the Redwood River include Coon Creek, which originates from Lake Benton; Three Mile Creek, which joins the Redwood below Marshall; and Ramsey Creek, which enters the Minnesota River after a substantial waterfall in the city of Redwood Falls. The landscape differences between the Coteau des Prairies and the Blue Earth Till Plain have a strong influence on land use (Figures 5.17 and 5.18), where steeply-sloped land occurs (Figure 5.19) and the distribution of conservation easements (Figure 5.20). The percentage of land under cultivation for crop production (73 percent) is average for the basin; while the percentage of land in perennial grass appears somewhat higher than average. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

Figure 5.21 is the load duration curve depicting daily total suspended solids (TSS) loads consistent with achievement of the 25 NTU water quality standard. In the case of the Redwood River, the TSS surrogate value for 25 NTUs was determined to be 70 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less. The diamond-shaped symbols on the chart represent calculated TSS loads based on water quality samples. These symbols are further qualified to show if the samples were collected during the April-October time period, and if they represent conditions where more than 50 percent of the water in the river is estimated to be made up of storm flow runoff. Exceedances are observed under all but very low flows, and appear to be more likely to occur under storm flow runoff conditions, and during the months of April-October.

Table 5.5 summarizes the total loading capacity, the WLA, and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. The duration curve was developed based on the flows from the closest USGS flow gage, which is upstream of Ramsey Creek. To determine the loading capacity in the table, the MPCA estimated the flows in this reach by using a watershed area ratio of 1.121.

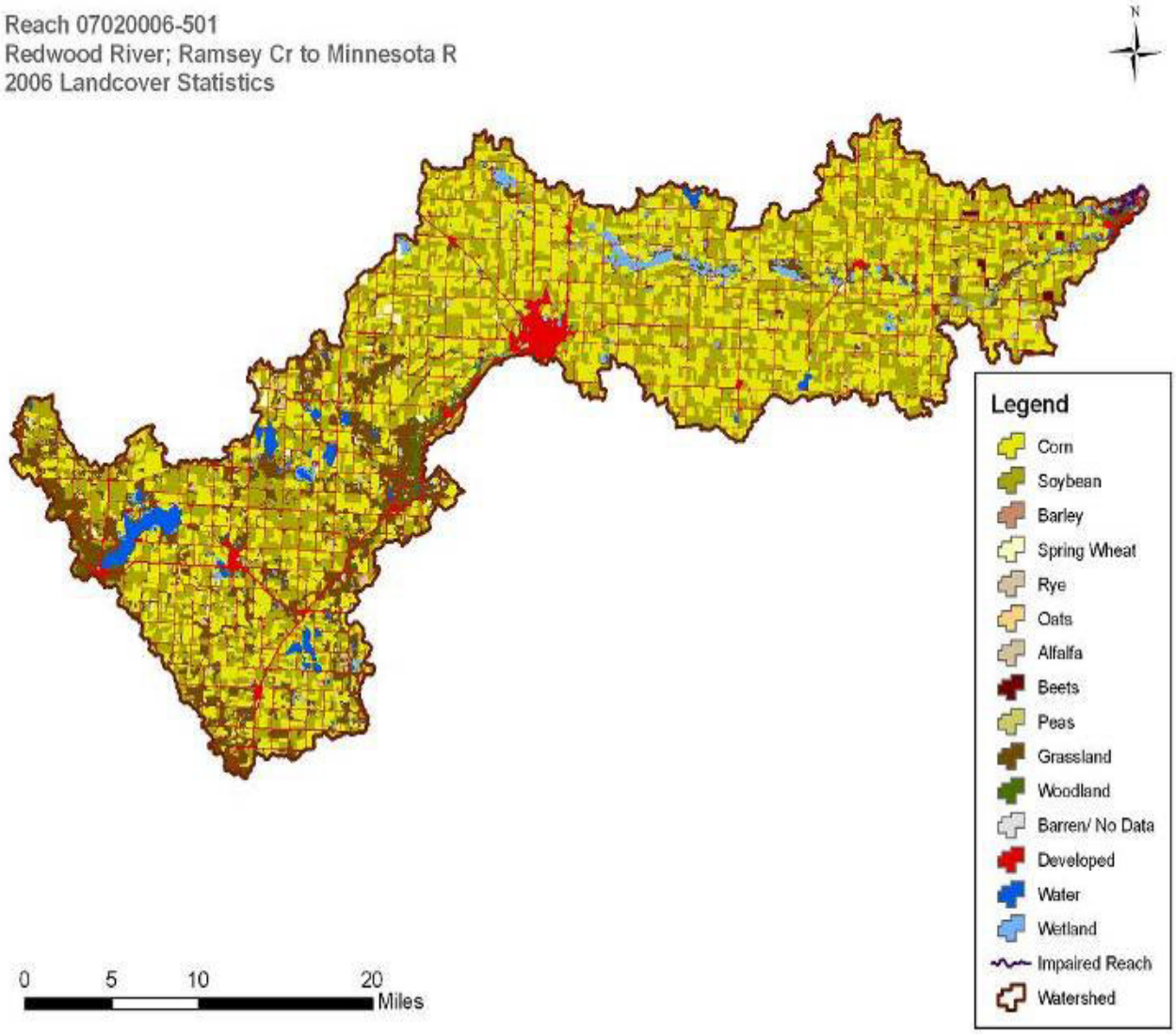


Figure 5.17: 2006 Land Cover Map for the Redwood River; Ramsey Cr to Minnesota R.

LANDUSE	ACRES	PERCENT
Corn	172,759.17	38.28%
Soybean	157,046.04	34.80%
Barley	222.40	0.05%
Spring Wheat	3,275.60	0.73%
Oats	14.72	0.00%
Alfalfa	4,666.59	1.03%
Beets	1,237.55	0.27%
Peas	37.20	0.01%
Grassland	49,864.79	11.05%
Woodland	3,921.11	0.87%
Barren	74.39	0.02%
Developed	39,491.66	8.75%
Water	7,650.05	1.70%
Wetland	11,017.87	2.44%
Total	451,279.15	100.00%

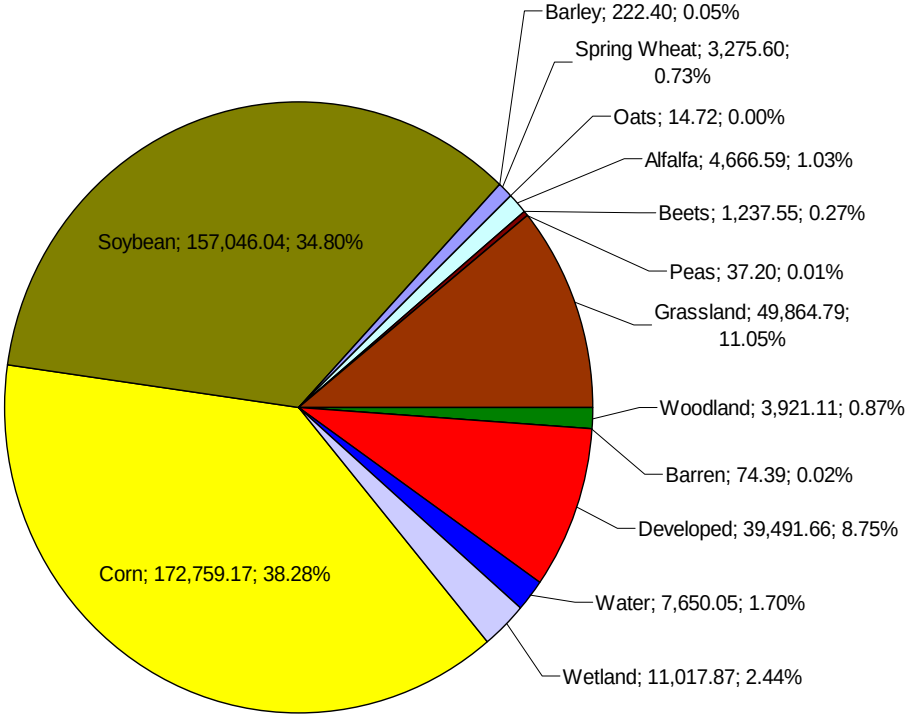
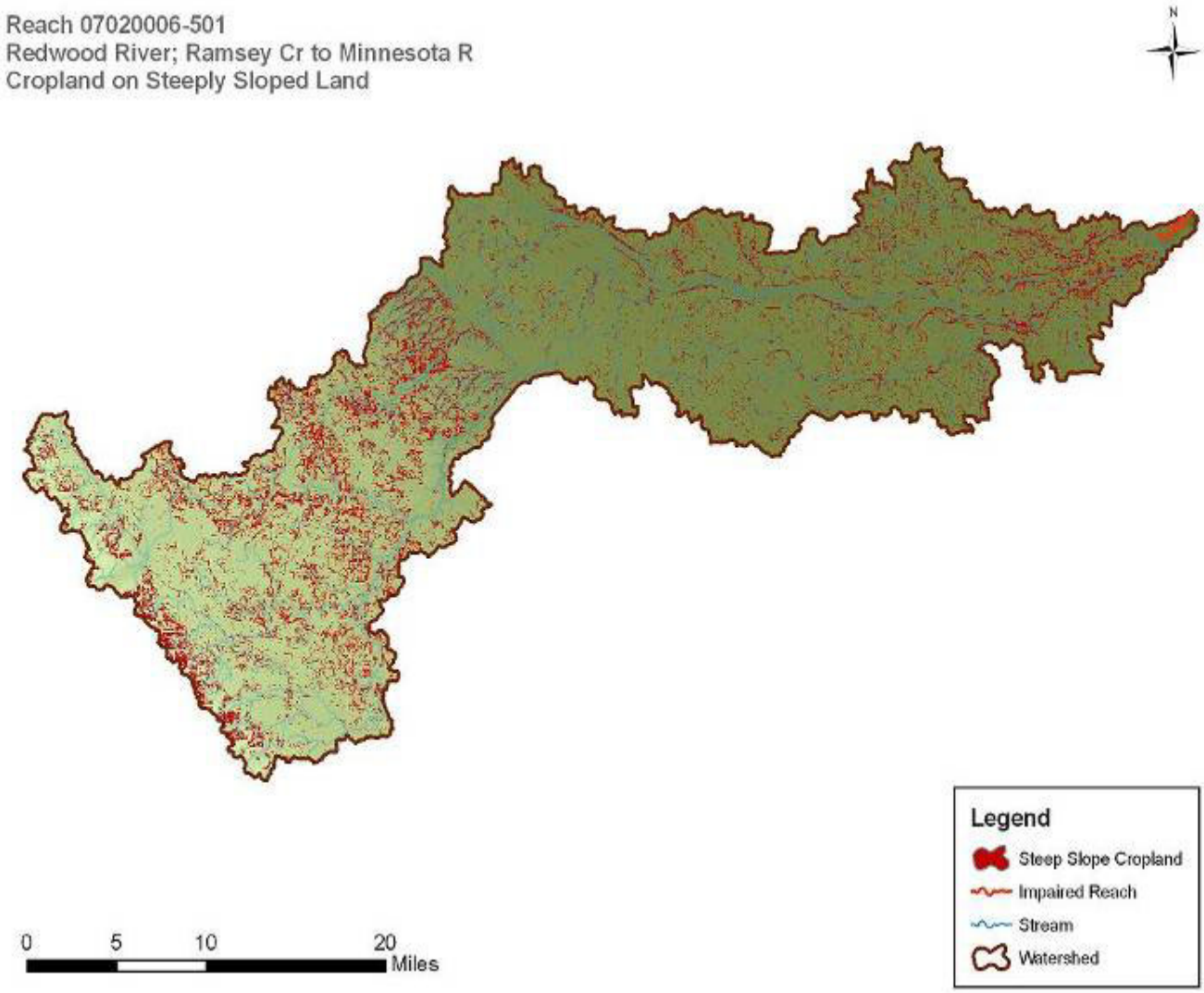
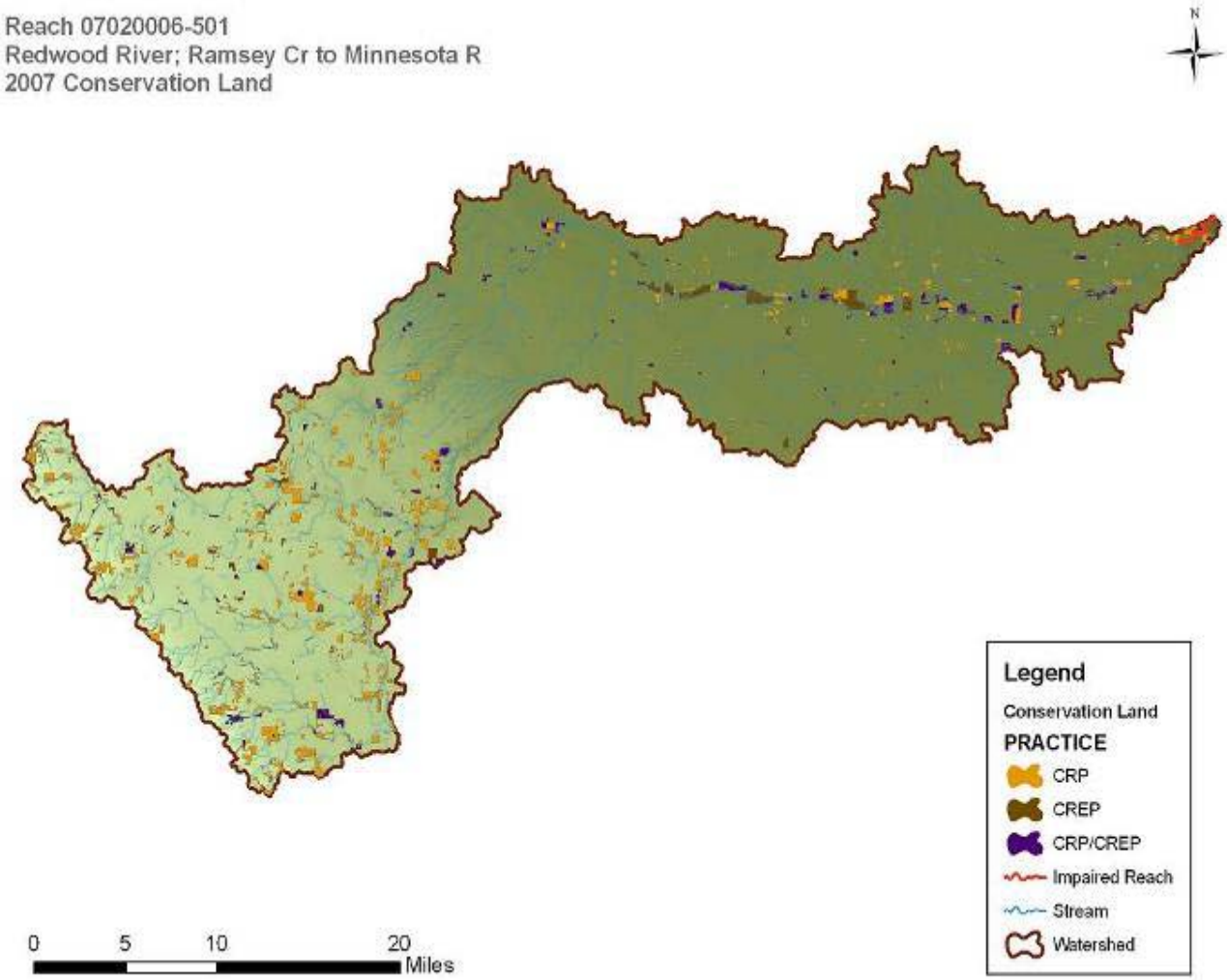


Figure 5.18: 2006 Land Use Statistics for the Redwood River; Ramsey Cr to Minnesota R.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
451,257.49	339,259.27	52,022.18	11.53%	15.33%

Figure 5.19: Cropland on Steeply Sloped Land Analysis for the Redwood River; Ramsey Cr to Minnesota R.



PROGRAM	ACRES	PERCENT
CRP	22,351.88	4.95%
CREP	7,336.15	1.63%
CRP,CREP	25,858.91	5.73%

Figure 5.20: Conservation Land Locations and Statistics for the Redwood River; Ramsey Cr to Minnesota R.

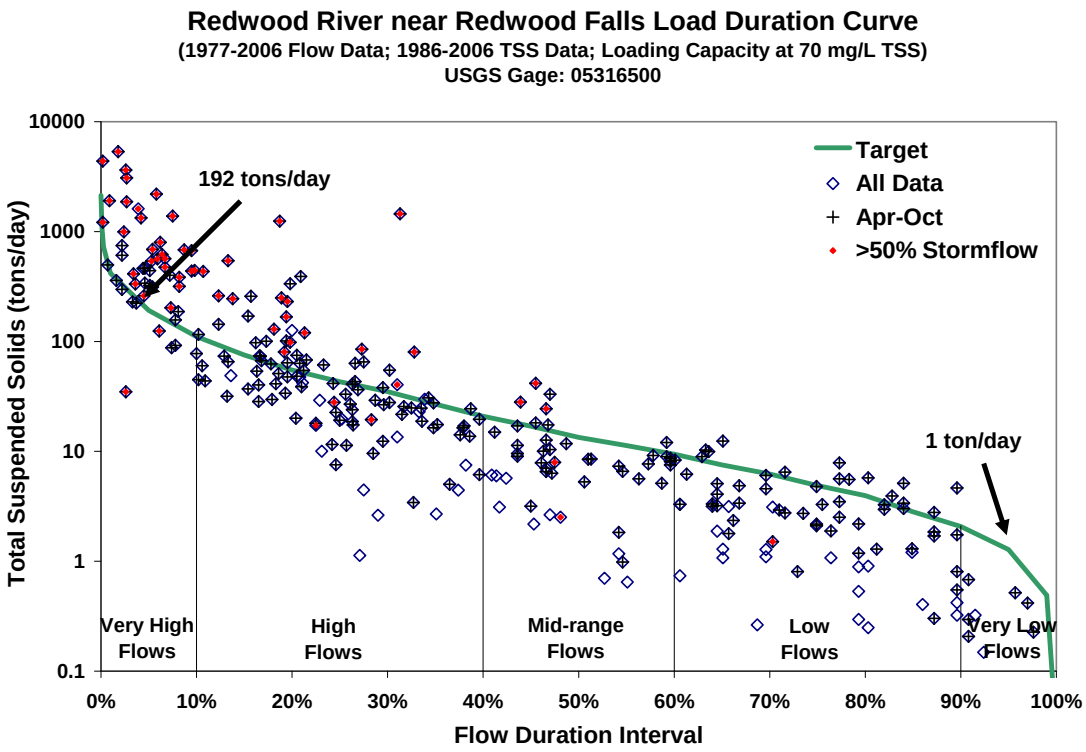


Figure 5.21: Redwood River Load Duration Curve.

Table 5.5 Redwood River TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	215	48	15	5	1
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	1.49	1.49	1.49	1.49	*
Communities Subject to MS4 NPDES Requirements	4.28	0.96	0.30	0.10	*
Construction and Industrial Stormwater	0.26	0.06	0.02	0.01	*
Load Allocation	187.47	40.70	11.70	2.91	*
Margin of Safety	21.50	4.80	1.50	0.50	*

* The total daily loading capacity in the very low flow zone is very small due to the occurrence of very low flows in the long-term flow records. Consequently, for some of the impaired reaches, the permitted wastewater treatment facility design flows exceed the stream flow in the very low flow zone. Since it is a component of stream flow, actual treatment facility flow can never exceed stream flow, but in some cases the calculated MOS would take up all of the remaining allocation capacity in the very low flow zone. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

Allocation = (flow contribution from a given source) x (*X* mg/L TSS), where *X* equals 45 for the municipal stabilization ponds, 30 for other wastewater treatment facilities and 70 mg/L for other sources.

5.5 Cottonwood River; JD #30 to Minnesota R

Reach AUID:
07020008-501

Stream Status:
Impaired Stream Reach (mercury, bacteria, turbidity, aquatic consumption, aquatic life, and aquatic recreation. This report only addresses the turbidity impairment.

Impaired Segment Length:
23.74 miles

Contributing Watershed Size:
840,189.49 acres
1312.79 square miles

Total Stream Miles:
1981.12 miles

Elevation*:
Maximum = 1700 ft above sea level
Minimum = 787 ft above sea level
Total relief = 913 ft

Slope*:
Maximum Slope: 74.3 percent
Minimum Slope: 0 percent
Average Slope: 1.74 percent

Cities:
Balaton, Clements, Cobden, Dovray, Evan, Garvin, Jeffers, Lamberton, Lucan, Marshall, New Ulm, Revere, Sanborn, Sleepy Eye, Springfield, Storden, Tracy, Wabasso, Walnut Grove, Wanda, Westbrook

Counties:
Brown, Cottonwood, Lyon, Murray, Redwood

*derived from the NED 30m DEM

The Cottonwood River Watershed, like those of the Yellow Medicine and Redwood rivers to the west, has its headwaters on the Coteau des Prairies, a morainal plateau. The Cottonwood, however, is a substantially larger watershed (1,284 square miles) with proportionally less of its land area on the Coteau, and more in the Blue Earth Till Plain. These landscape differences, both within the Cottonwood watershed and with neighboring watersheds, have an influence on land use conditions. The percentage of land under cultivation for corn and soybean production (82 percent) is higher than average for the Minnesota River basin. The percentage of land in perennial grasses, (Figures 5.22 and 5.23), steeply-sloped cropland (Figure 5.24) and land devoted to conservation easements (Figure 5.25) is somewhat lower than average. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

Figure 5.26 is the load duration curve depicting daily TSS loads consistent with achievement of the 25 NTU water quality standard. In the case of the Cottonwood River, the TSS surrogate value for 25 NTUs was determined to be 70 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less. The diamond-shaped symbols on the chart represent calculated TSS loads based on water quality samples. These symbols are further qualified to show if the samples were collected during the April-October time period, and if they represent conditions where more than 50 percent of the water in the river is estimated to be made up of storm flow runoff. Exceedances are observed under all but low flows, and appear to be more likely to occur under storm flow runoff conditions, and during the months of April-October.

Table 5.6 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves.

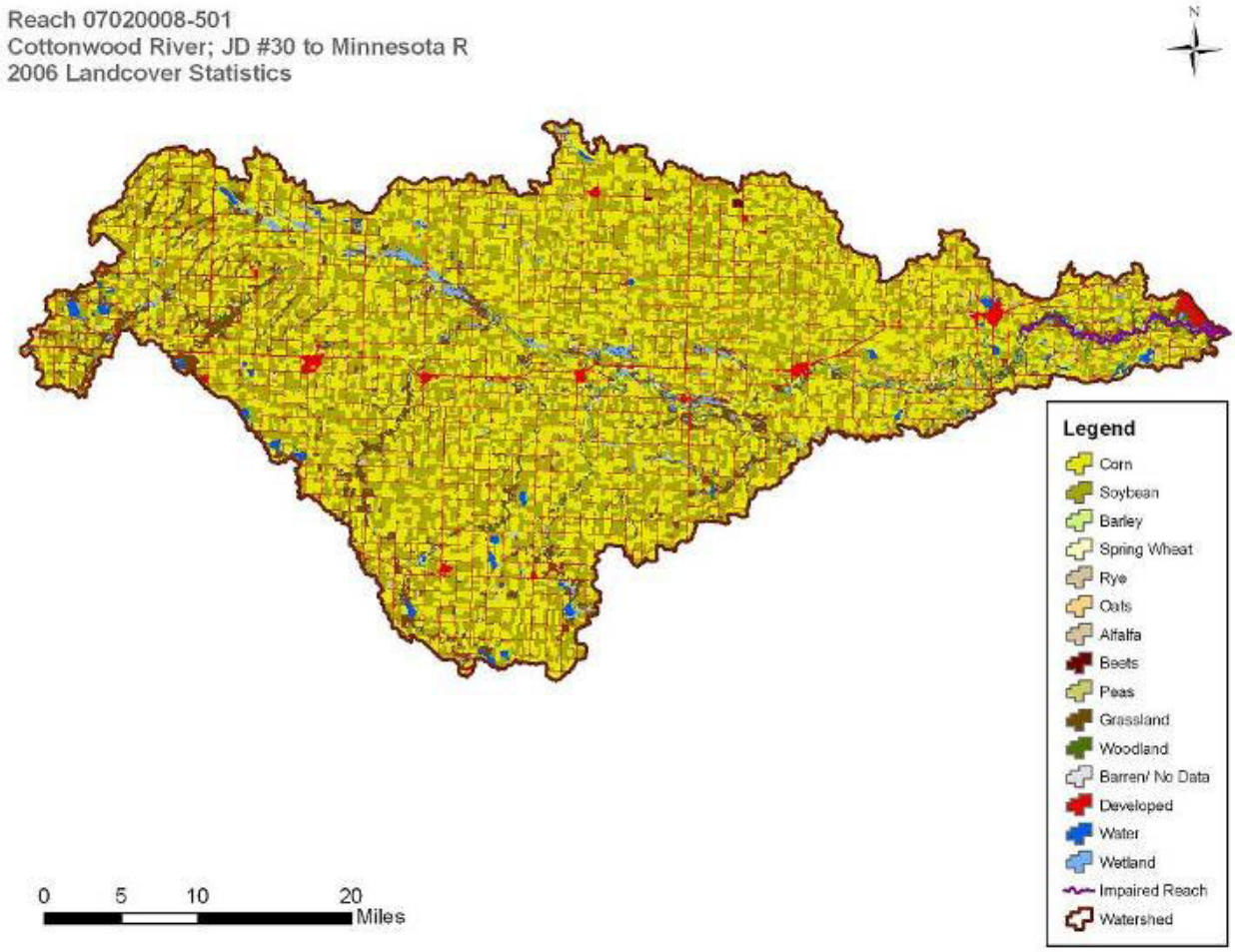


Figure 5.22: 2006 Land Cover Map for the Cottonwood River; JD #30 to Minnesota R.

LANDCOVER	ACRES	PERCENT
Corn	362,510.86	43.15%
Soybean	327,029.43	38.92%
Barley	48.82	0.01%
Spring Wheat	1,239.10	0.15%
Oats	56.57	0.01%
Alfalfa	5,378.75	0.64%
Beets	570.34	0.07%
Peas	270.45	0.03%
Grassland	43,009.82	5.12%
Woodland	11,040.34	1.31%
Barren	8.52	0.00%
Developed	63,144.66	7.52%
Water	6,779.81	0.81%
Wetland	19,101.09	2.27%
Total	840,188.56	100.00%

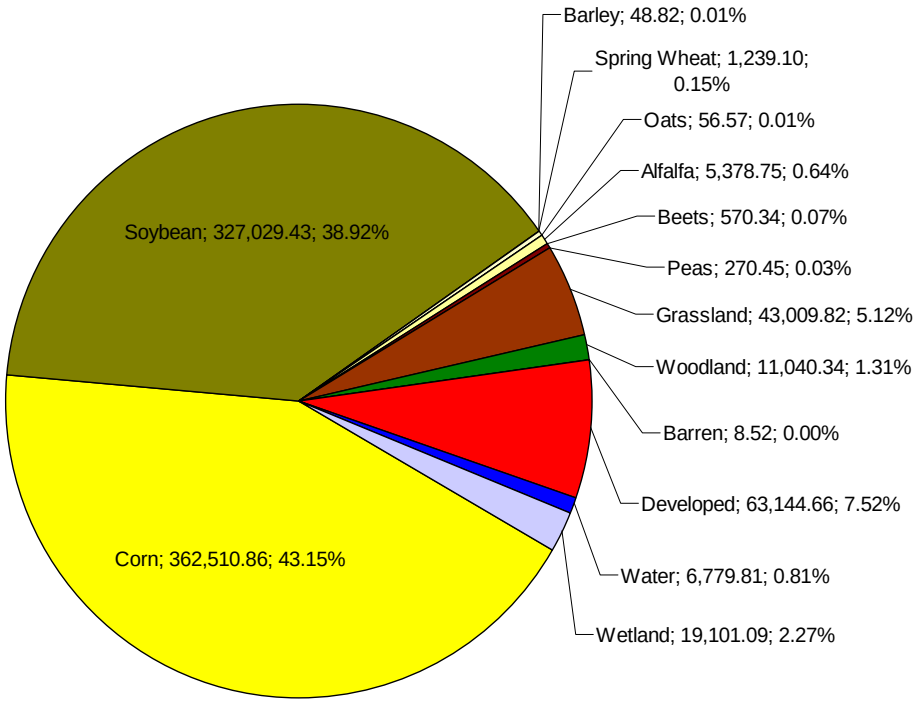
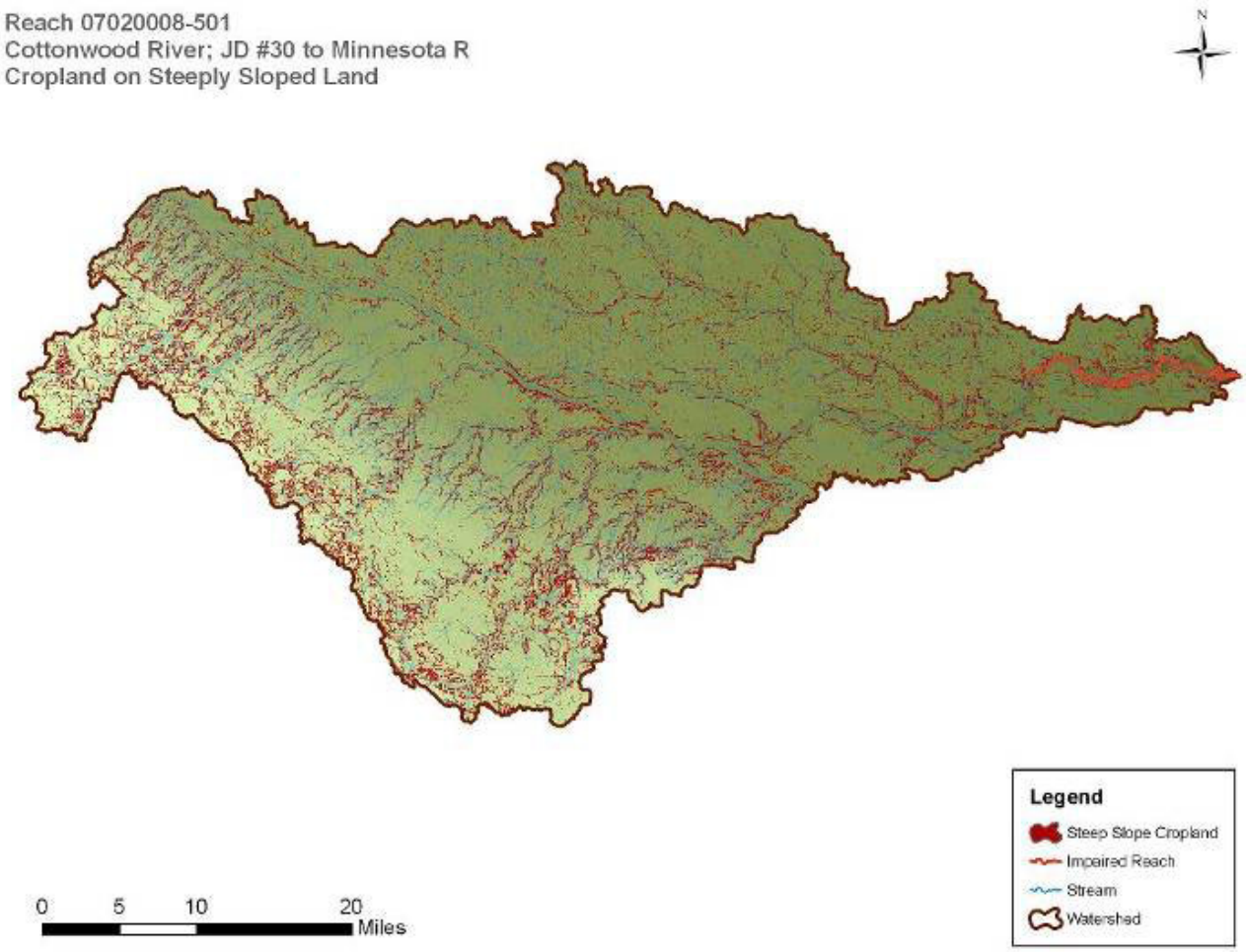
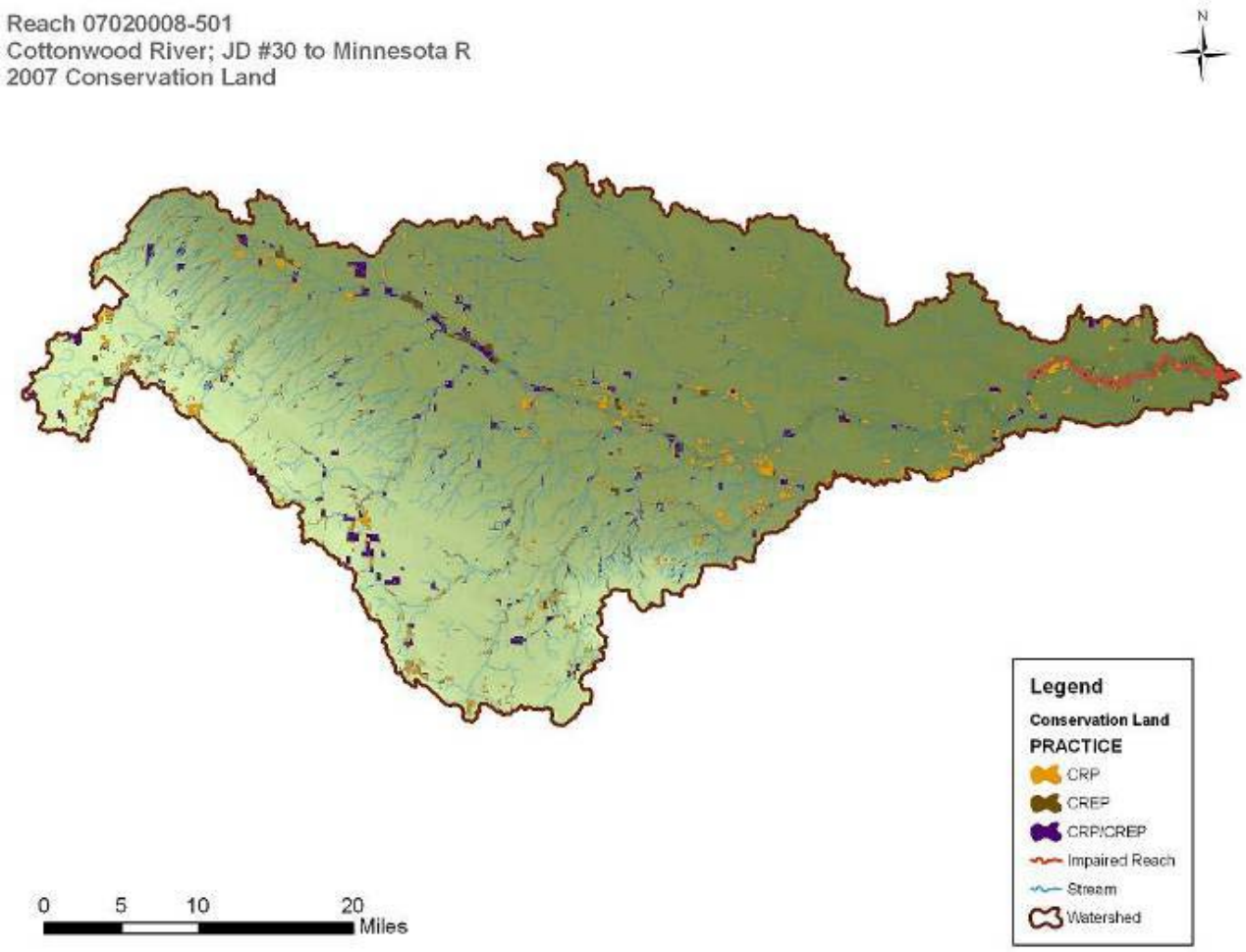


Figure 5.23: 2006 Land Cover Statistics for the Cottonwood River; JD #30 to Minnesota R.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
840,189.49	697,104.32	93,442.63	11.12%	13.40%

Figure 5.24: Cropland on Steeply Sloped Land Analysis for the Cottonwood River; JD #30 to Minnesota R.



PROGRAM	ACRES	PERCENT
CRP	31,810.27	3.79%
CREP	14,625.85	1.74%
CRP,CREP	36,401.78	4.33%

Figure 5.25: Conservation Land Locations and Statistics for the Cottonwood River; JD #30 to Minnesota R.

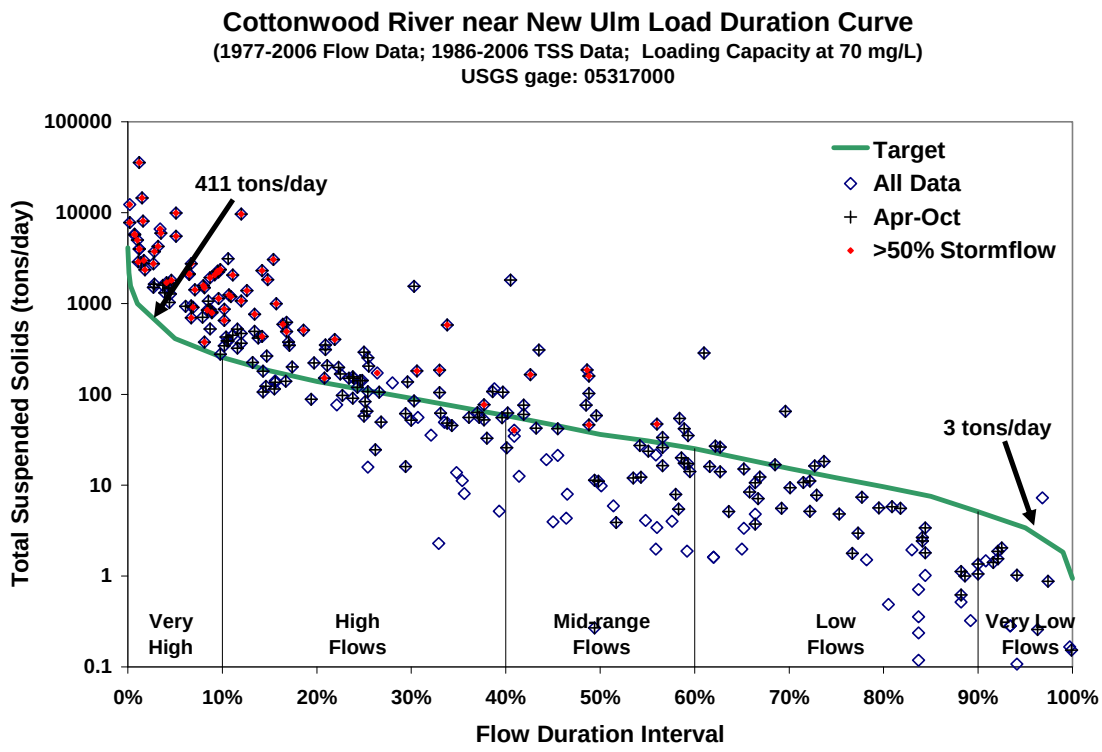


Figure 5.26: Cottonwood River Load Duration Curve.

Table 5.6 Cottonwood River TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	410	112	36	12	3
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	3.71	3.71	3.71	3.71	*
Communities Subject to MS4 NPDES Requirements	1.14	0.31	0.10	0.03	*
Construction and Industrial Stormwater	0.06	0.02	0.01	0.01	*
Load Allocation	364.09	96.76	28.58	7.05	*
Margin of Safety	41.00	11.20	3.60	1.20	*

* The total daily loading capacity in the very low flow zone is very small due to the occurrence of very low flows in the long-term flow records. Consequently, for some of the impaired reaches, the permitted wastewater treatment facility design flows exceed the stream flow in the very low flow zone. Since it is a component of stream flow, actual treatment facility flow can never exceed stream flow, but in some cases the calculated MOS would take up all of the remaining allocation capacity in the very low flow zone. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

Allocation = (flow contribution from a given source) x (*X* mg/L TSS), where *X* equals 45 for the municipal stabilization ponds, 30 for other wastewater treatment facilities and 70 mg/L for other sources.

5.6 Blue Earth River; LeSueur R to Minnesota R

Reach AUID:
07020009-501

Stream Status:
Impaired Stream Reach (mercury, bacteria, turbidity, aquatic consumption, aquatic life, and aquatic recreation). This report only addresses the turbidity impairment.

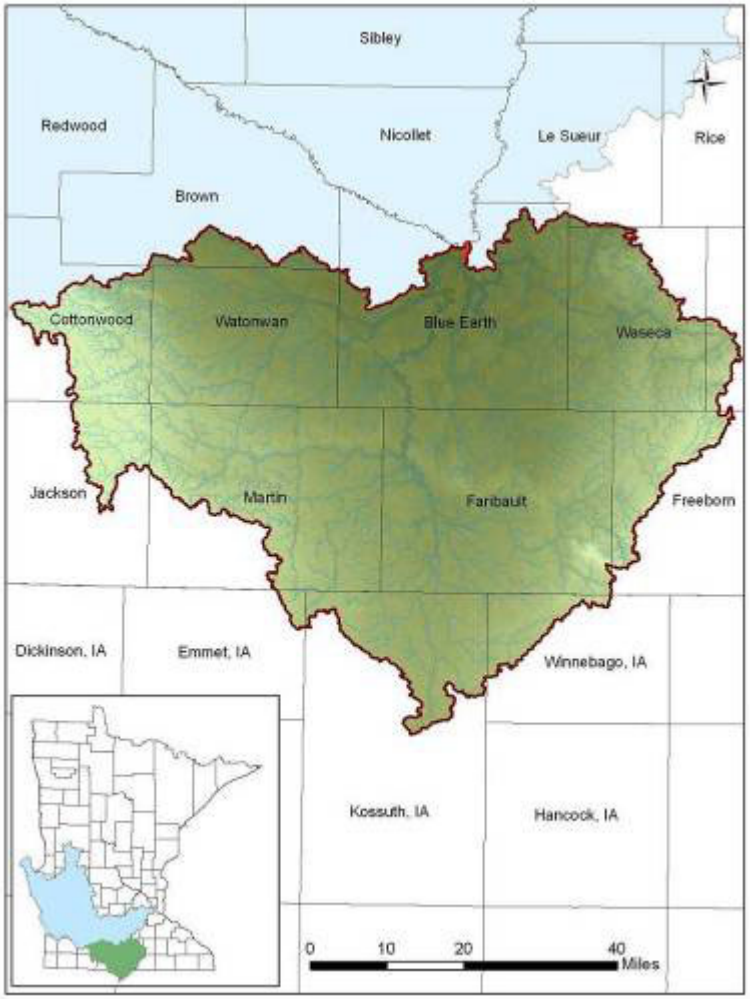
Impaired Segment Length:
3.2 miles

Contributing Watershed Size:
2,265,491.96 acres
(2,048,668.75 MN)
3,539.83 square miles
(3,201.04 MN)

Total Stream Miles:
4,159.16 miles
(3,670.61 MN)

Elevation*:
Maximum = 1569 ft above sea level
Minimum = 754 ft
Above sea level
Total relief = 815 ft

Slope*:
Maximum Slope: 84.4 percent
Minimum Slope: 0 percent
Average Slope: 1.58 percent



Cities:
Alden, Amboy, Bingham Lake, Blue Earth, Bricelyn, Butterfield, Darfur, Delavan, Eagle Lake, Easton, Elmore, Elysian, Fairmont, Freeborn, Frost, Good Thunder, Granada, Hartland, Jackson, Janesville, Kiester, La Salle, Lewisville, Madelia, Madison Lake, Mankato, Mapleton, Minnesota Lake, Mountain Lake, New Richland, Northrop, Odin, Ormsby, Pemberton, Sherburn, Skyline, St. Clair, St. James, Trimont, Truman, Vernon Center, Waldorf, Walters, Waseca, Welcome, Wells, Winnebago, Buffalo Center, Lakota, Ledyard, Rake.

Counties:
Blue Earth, Brown, Cottonwood, Faribault, Freeborn, Jackson, LeSueur, Martin, Steele, Waseca, Watonwan, Emmet (Iowa), Kossuth (Iowa); Winnebago (Iowa)

*derived from the NED 30m DEM

The Greater Blue Earth River Basin includes the main stem of the Blue Earth River and two tributaries, the Watonwan River entering from the southwest, and the LeSueur River from the southeast. The Blue Earth River contributes 46 percent of the flow to the Minnesota River at Mankato, with a total drainage area of 3,135 square miles within Minnesota.

Each tributary watershed is nearly as large as the Blue Earth itself, making the system composed of three major stream systems, each coming together with their own physical and geomorphological characteristics combining to outlet to the Minnesota River. Figures 5.27 and 5.28 show land cover and land use, respectively. Nearly 85 percent of the land use within the watershed is in agriculture with approximately 7.5 percent of the remaining land dedicated to developed areas including many small towns and cities. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

Overall geomorphology of the watershed can be described as nearly level to gently rolling. Surface relief from the three watersheds converges toward the central portion of the Blue Earth River channel. The watershed is extensively drained through both public and private drainage systems. This drainage has contributed to the loss of an estimated 80 percent of the natural wetlands existing prior to settlement.

The major streams have channels that have been eroded from the headwaters to the outlets. The impaired watershed contains approximately 237,780 acres of cropland with slopes of three percent or greater (Figure 5.29). This constitutes approximately 13.8 percent of the total cropland and 10.5 percent of the total watershed area. Figure 5.30 shows lands enrolled in conservation and set aside programs within the watershed. Estimated total land enrolled in programs is 49,827 acres or 2.20 percent.

Figure 5.31 is the load duration curve depicting daily TSS loads consistent with achievement of the 25 NTU water quality standard. The TSS surrogate value for 25 NTUs was determined to be 90 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. The diamond-shaped symbols on the chart represent calculated TSS loads based on water quality samples. These symbols are further qualified to show if the samples were collected during the April-October time period, and if they represent conditions where more than 50 percent of the water in the river is estimated to be made up of storm flow runoff. Taken together, TSS loads exceeding the TMDL are most likely to occur from April through October, during flows that are mid-range or higher, and under conditions of storm flow runoff.

Table 5.7 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves.

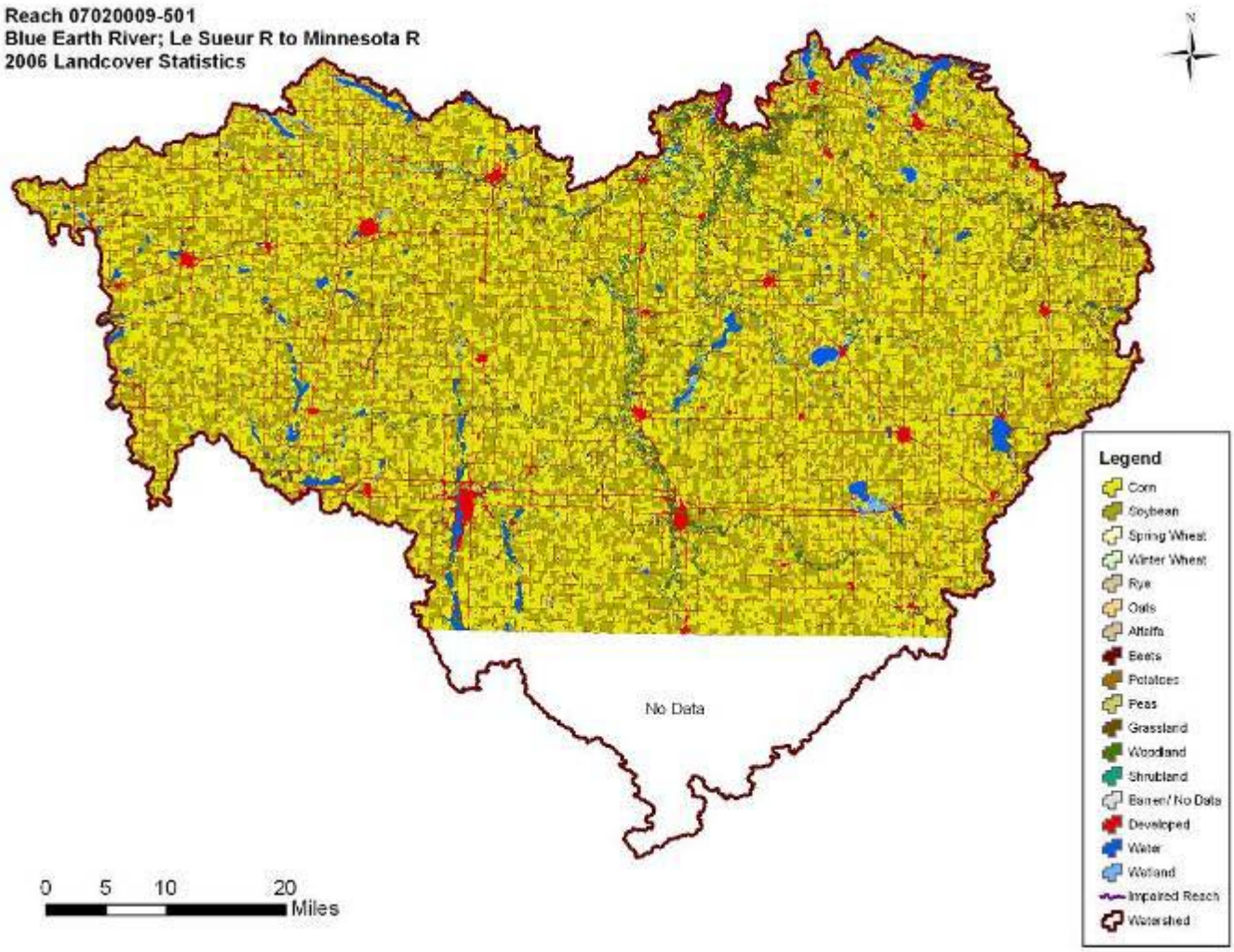


Figure 5.27: 2006 Land Cover Map for the Blue Earth River; LeSueur R to Minnesota R.

LANDCOVER	ACRES	PERCENT
Corn	934,781.23	45.63%
Soybean	783,218.02	38.23%
Spring Wheat	672.63	0.03%
Winter Wheat	22.47	0.00%
Rye	72.84	0.00%
Oats	184.43	0.01%
Alfalfa	5,562.39	0.27%
Beets	304.54	0.01%
Potatoes	18.60	0.00%
Peas	3,607.26	0.18%
Grassland	41,056.94	2.00%
Woodland	57,978.92	2.83%
Shrubland	6.20	0.00%
Baren	264.25	0.01%
Developed	152,958.85	7.47%
Water	35,805.29	1.75%
Wetland	32,153.86	1.57%
Total	2,048,668.75	100.00%

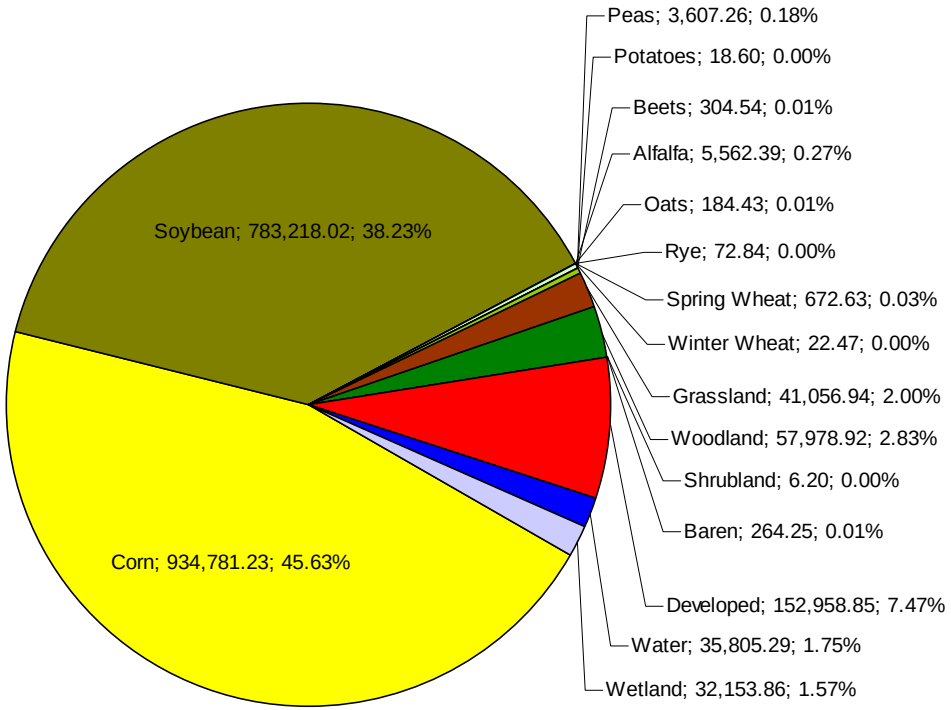
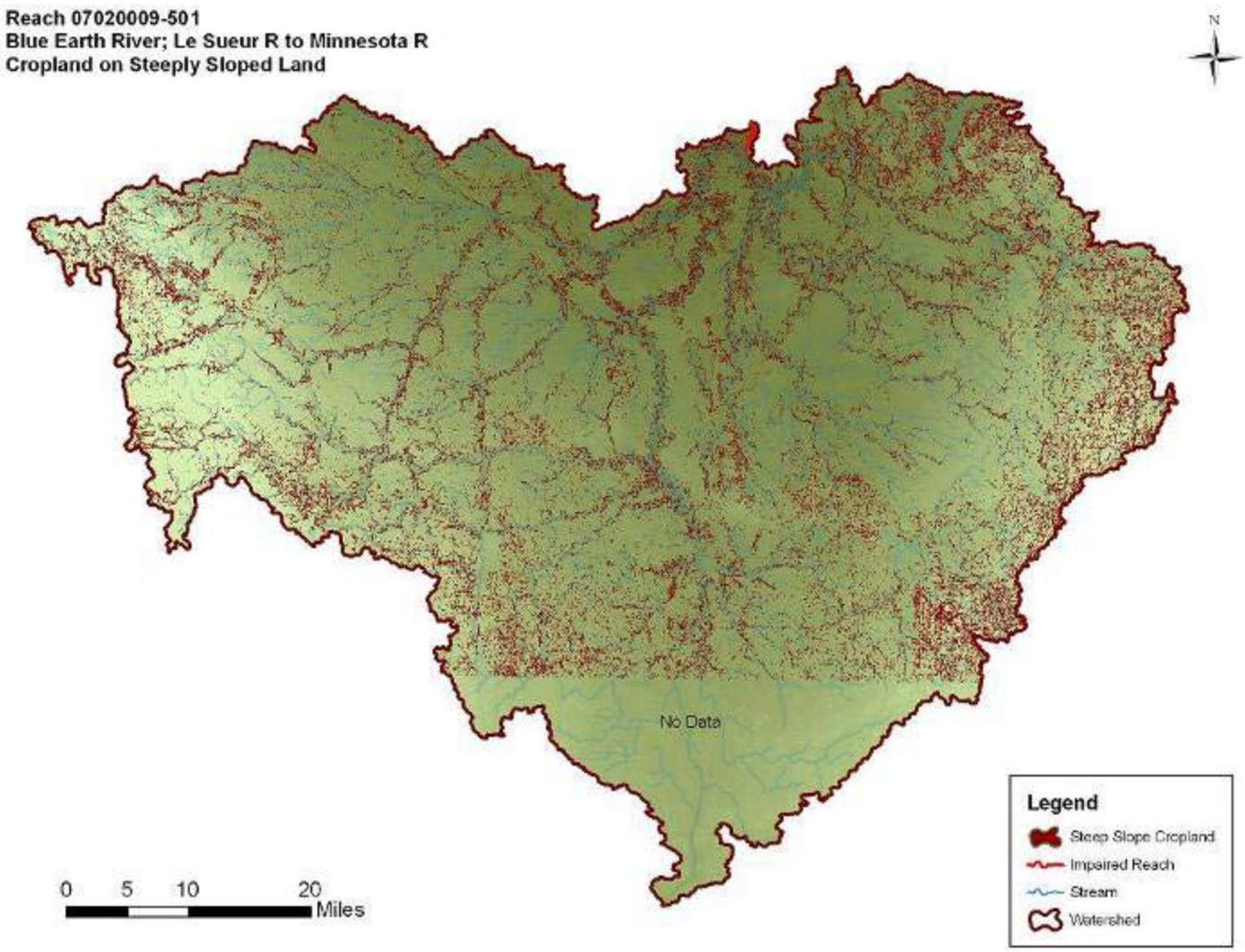
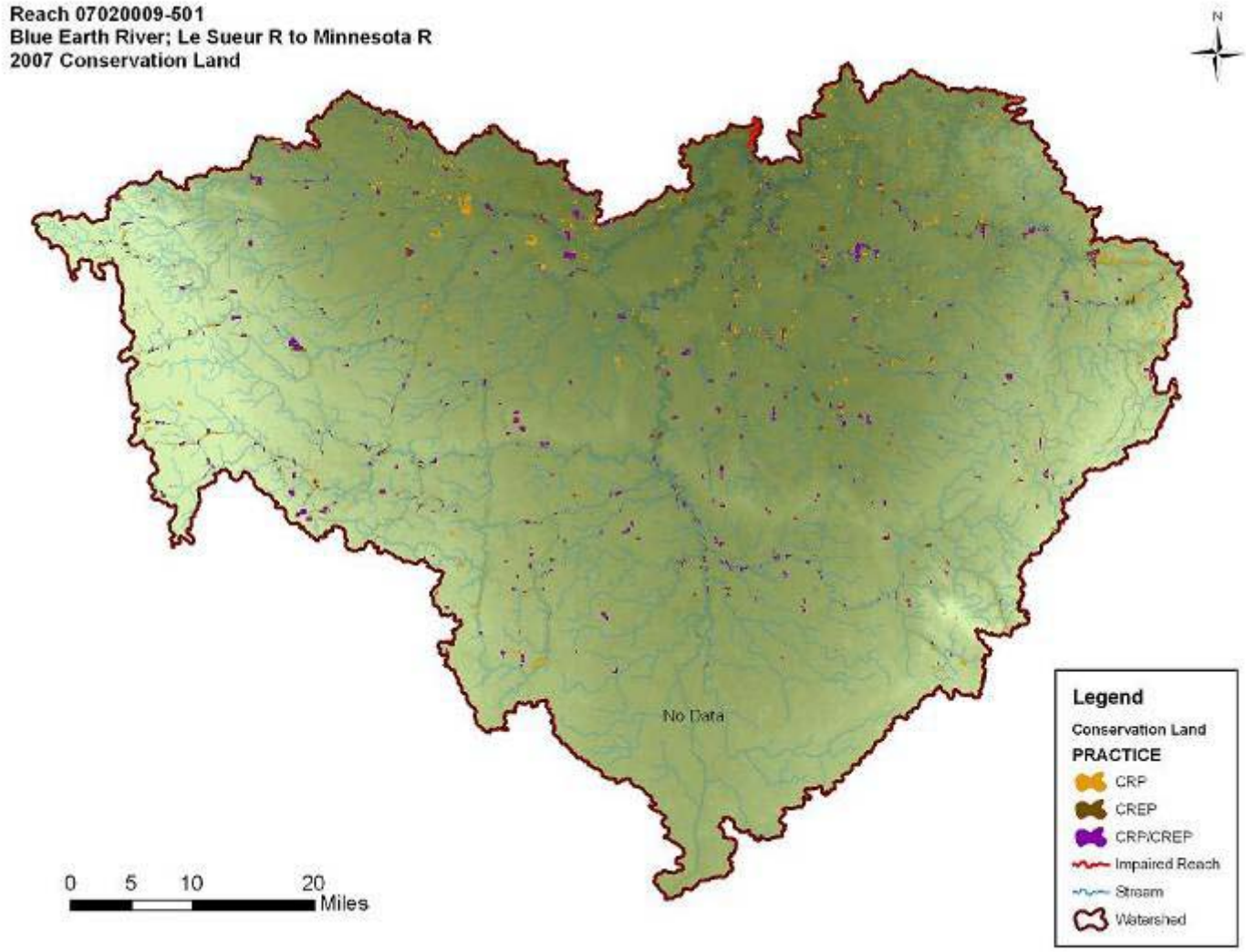


Figure 5.28: 2006 Land Use Statistics for the Blue Earth River; LeSueur R to Minnesota R.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
2,265,491.96	1,728,444.43	237,780.31	10.50%	13.76%

Figure 5.29: Cropland on Steeply Sloped Land Analysis for the Blue Earth River; LeSueur R to Minnesota R.



PROGRAM	ACRES	PERCENT
CRP	42,144.93	1.86%
CREP	23,914.20	1.06%
CRP,CREP	49,826.65	2.20%

Figure 5.30: Conservation Land Locations and Statistics for the Blue Earth River; LeSueur R to Minnesota R.

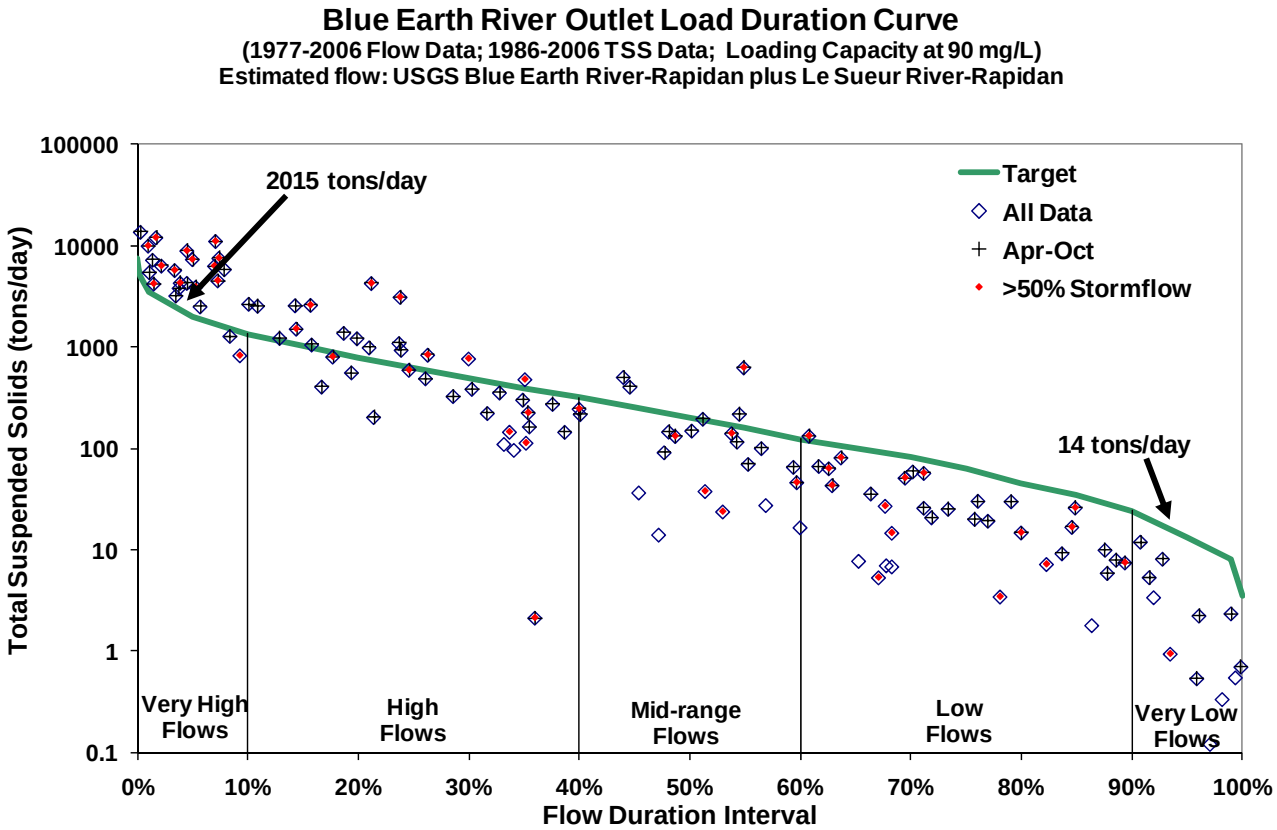


Figure 5.31: Blue Earth River Outlet Load Duration Curve.

Table 5.7 Blue Earth River Outlet TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	2015	620	203	63	13
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	10.24	10.24	10.24	10.24	10.24
Communities Subject to MS4 NPDES Requirements	5.03	1.55	0.51	0.16	0.03
Construction and Industrial Stormwater	0.36	0.11	0.04	0.01	0.01
Load Allocation	1797.87	546.10	171.92	46.29	1.42
Margin of Safety	201.50	62.00	20.30	6.30	1.30

5.7 Blue Earth River: Rapidan Dam to LeSueur R

Reach AUID:
07020009-509

Stream Status:
Impaired Stream Reach (mercury, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

Impaired Segment Length:
8.78 miles

Contributing Watershed Size:
1,553,653.55 acres
(1,336,836.58 MN)
2,427.58 square miles
(2,088.8 MN)

Total Stream Miles:
2,893.73 miles
(2,411.31 MN)

Elevation*:
Maximum = 1569 ft above sea level
Minimum = 754 ft above sea level
Total relief = 815 ft

Slope*:
Maximum Slope: 74 percent
Minimum Slope: 0 percent
Average Slope: 1.5 percent

Cities:
Alden, Amboy, Bingham Lake, Blue Earth, Bricelyn, Butterfield, Darfur, Elmore, Fairmont, Frost, Good Thunder, Granada, Jackson, Kiester, La Salle, Lewisville, Madelia, Mankato, Mountain Lake, Northrop, Odin, Ormsby, Sherburn, Skyline, St. James, Trimont, Truman, Vernon Center, Walters, Welcome, Wells, Winnebago, Buffalo Center, Lakota, Ledyard, Rake.

Counties:
Blue Earth, Brown, Cottonwood, Faribault, Freeborn, Jackson, Martin, Watonwan, Emmet (Iowa), Kossuth (Iowa), Winnebago (Iowa)

*derived from the NED 30m DEM

This reach covers the Watonwan River Watershed and includes the Blue Earth River Watershed upstream of the LeSueur River outlet. The Blue Earth River Watershed has a total area of approximately 1,550 square miles or 992,034 acres. Of this, 775,590 acres are in Minnesota and 216,444 are in Iowa. Land use data from Iowa were not utilized in the analysis of this project.

The Blue Earth River's valleys and ravines cut into a landscape that is predominantly rolling prairie and glacial moraine. The Blue Earth flows north and northeast, and is joined by the Watonwan River above the Rapidan dam. The prevailing land use in the watershed is agriculture (Figures 5.32 and 5.33), which includes cropland and feedlot operations. Approximately 85 percent of the area is in agricultural production with corn and soybeans as the main crops. Developed land again makes up approximately eight percent of the land use in the watershed. Approximately 86 percent of wetlands have been lost to artificial drainage designed to facilitate the movement of water out of the watershed.

Figure 5.34 shows areas in the watershed associated with steep slopes on cropland. Areas prone to erosion include steep slopes and vertical stream banks. Thirteen percent of the cropland is considered steeply sloping, with slopes of three percent or greater within the watershed. Increased tillage and erosion control practices could benefit these areas in reducing the amount of soil entering waterways.

Conservation practices (Figure 5.35) in the watershed total approximately two percent of the land area. Total acres enrolled in various programs total 29,147. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

The Load Duration Curve, included in Figure 5.36, depicts the daily TSS loads to achieve the 25 NTU standard. For this reach, the 25 NTU standard was determined to be 90 mg/L. The load varies based on flow conditions in the five flow zones listed. Samples collected that exceed the standard tend to occur in the high to very high flow regime with a majority of the samples associated with storm runoff.

Table 5.8 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves.

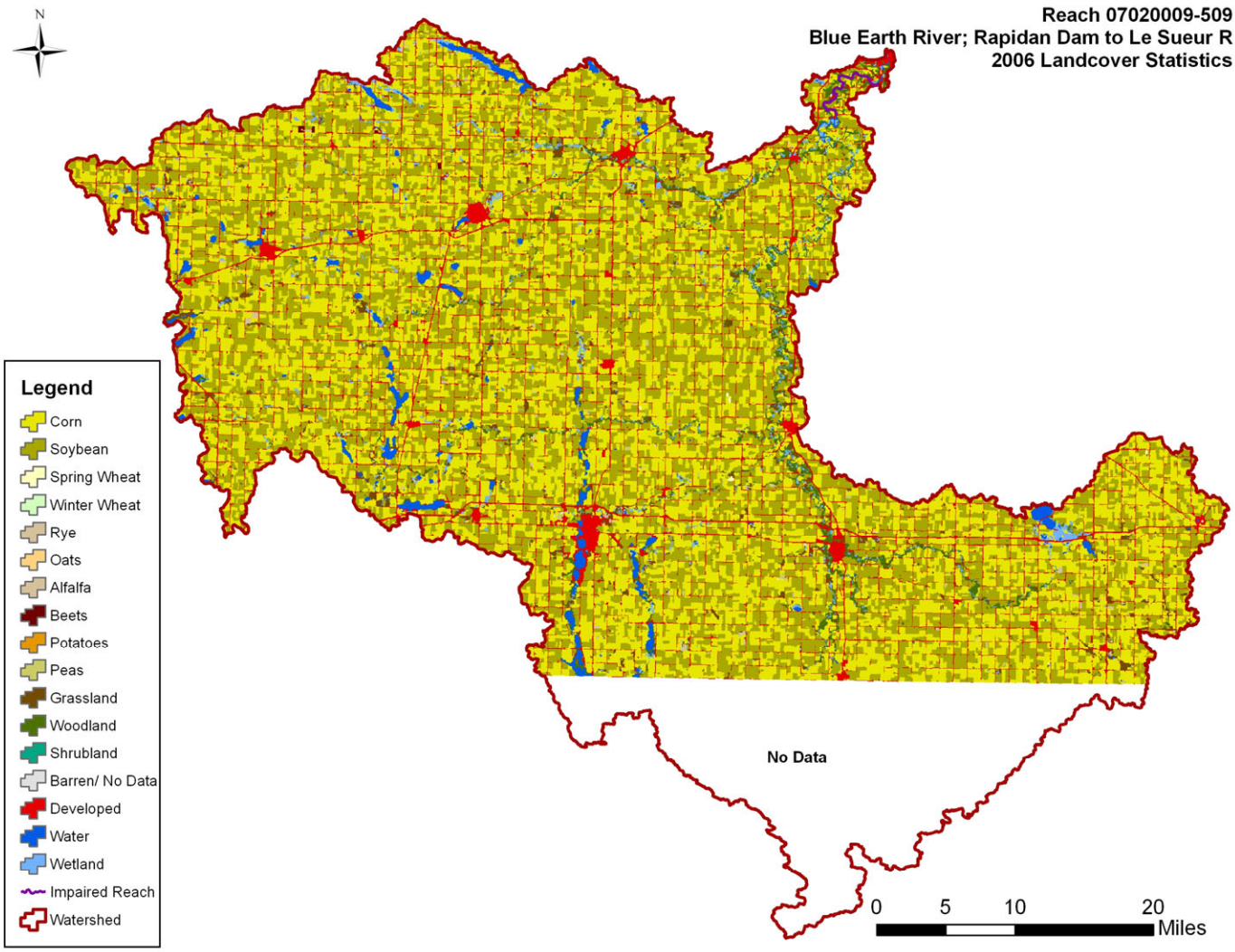


Figure 5.32 2006 Land Cover Map for the Blue Earth River: Rapidan Dam to LeSueur R.

LANDCOVER	ACRES	PERCENT
Corn	617,272.25	46.17%
Soybean	520,052.80	38.90%
Spring Wheat	410.71	0.03%
Winter Wheat	22.47	0.00%
Rye	47.27	0.00%
Oats	39.52	0.00%
Alfalfa	3,098.91	0.23%
Beets	304.54	0.02%
Potatoes	18.60	0.00%
Peas	1,681.58	0.13%
Grassland	22,608.36	1.69%
Woodland	29,759.35	2.23%
Shrubland	6.20	0.00%
Barren	123.99	0.01%
Developed	102,134.01	7.64%
Water	20,554.82	1.54%
Wetland	18,701.20	1.40%
Total	1,336,836.58	100.00%

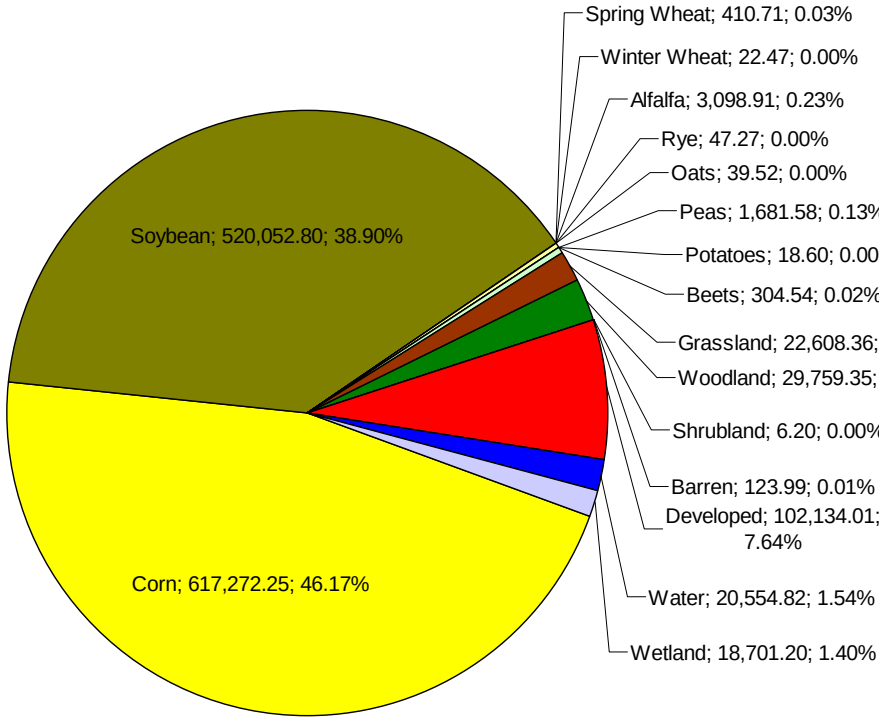
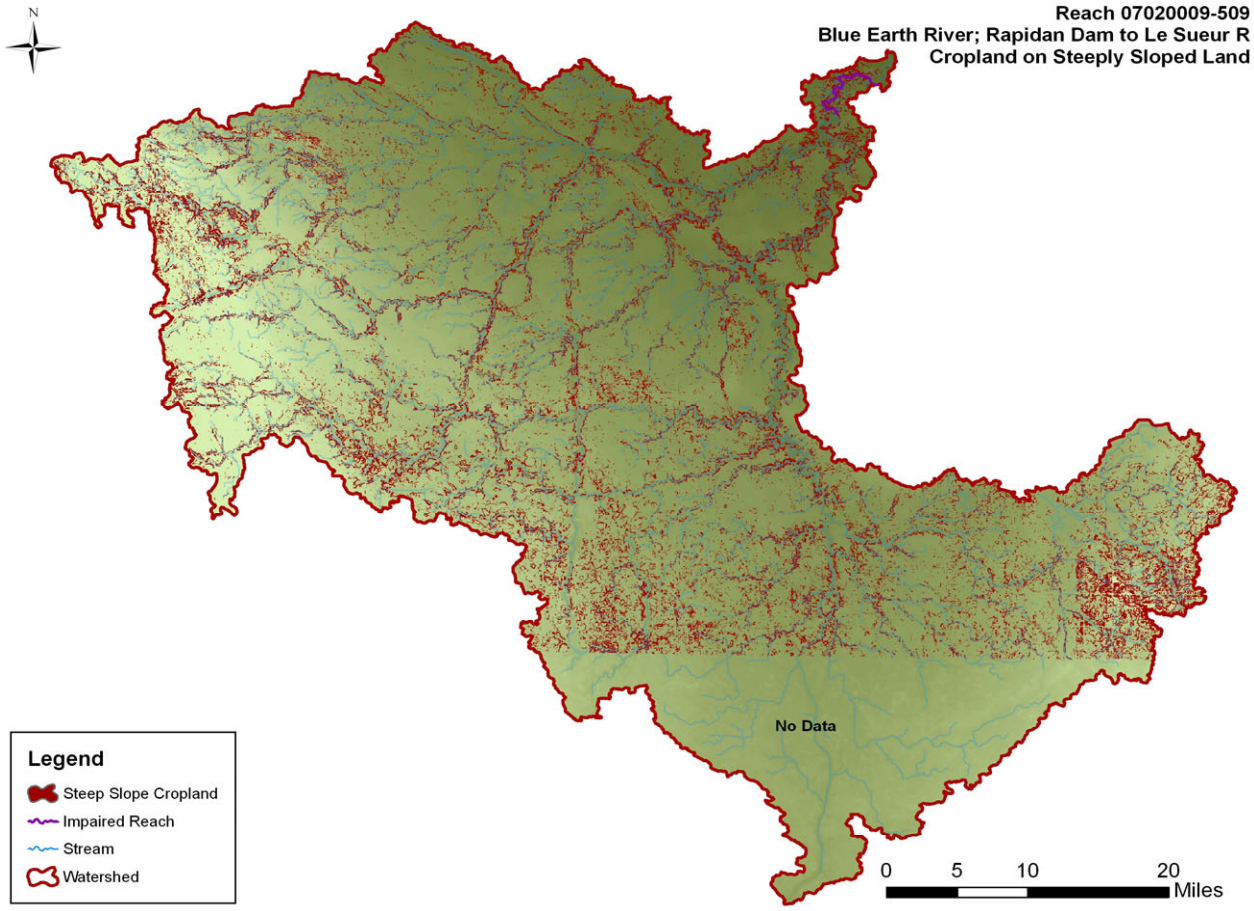
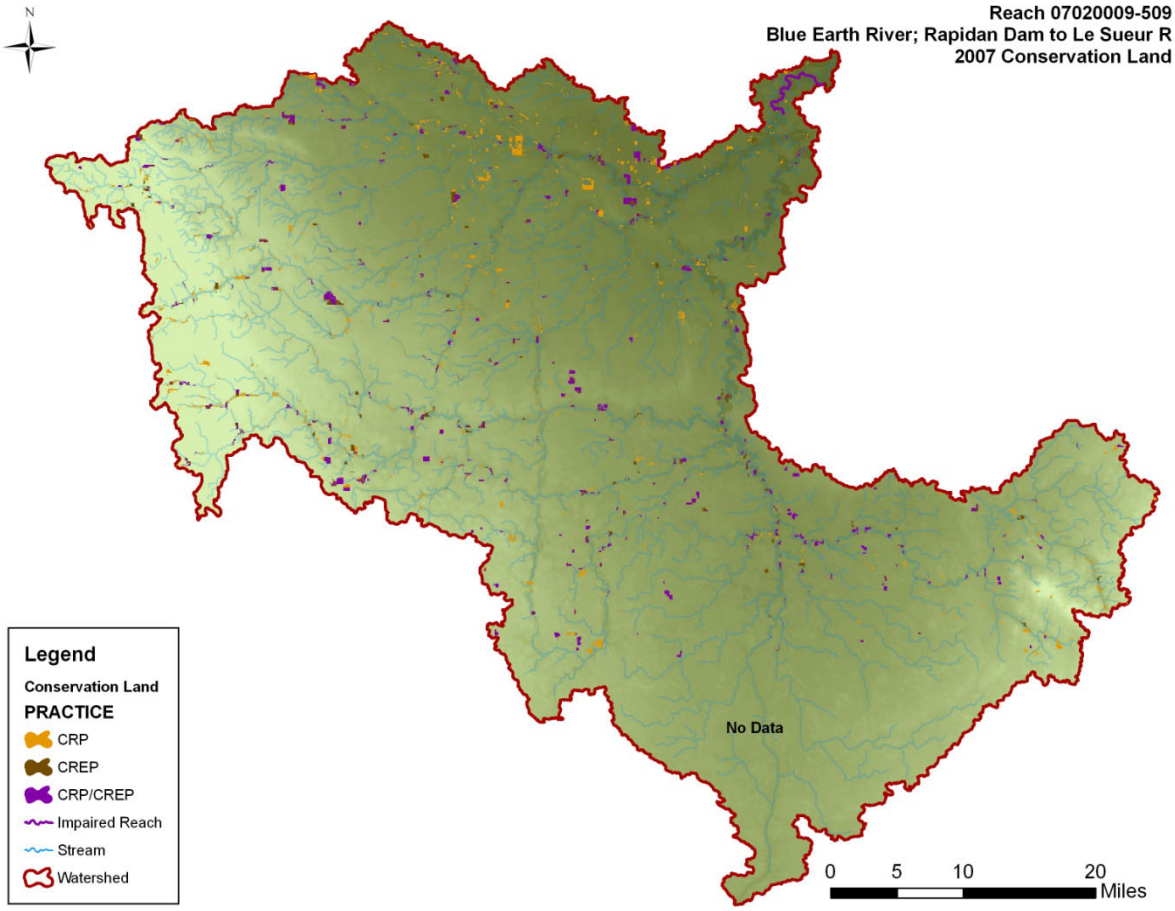


Figure 5.33 2006 Land Use Statistics for the Blue Earth River: Rapidan Dam to LeSueur R.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
1,336,836.58	1,142,948.66	149,198.15	11.16%	13.05%

Figure 5.34: Cropland on Steeply Sloped Land Analysis for the Blue Earth River: Rapidan Dam to LeSueur R.



PROGRAM	ACRES	PERCENT
CRP	24,281.55	1.82%
CREP	15,288.45	1.14%
CRP,CREP	29,146.52	2.18%

Figure 5.35 Conservation Land Locations and Statistics for the Blue Earth River: Rapidan Dam to LeSueur R.

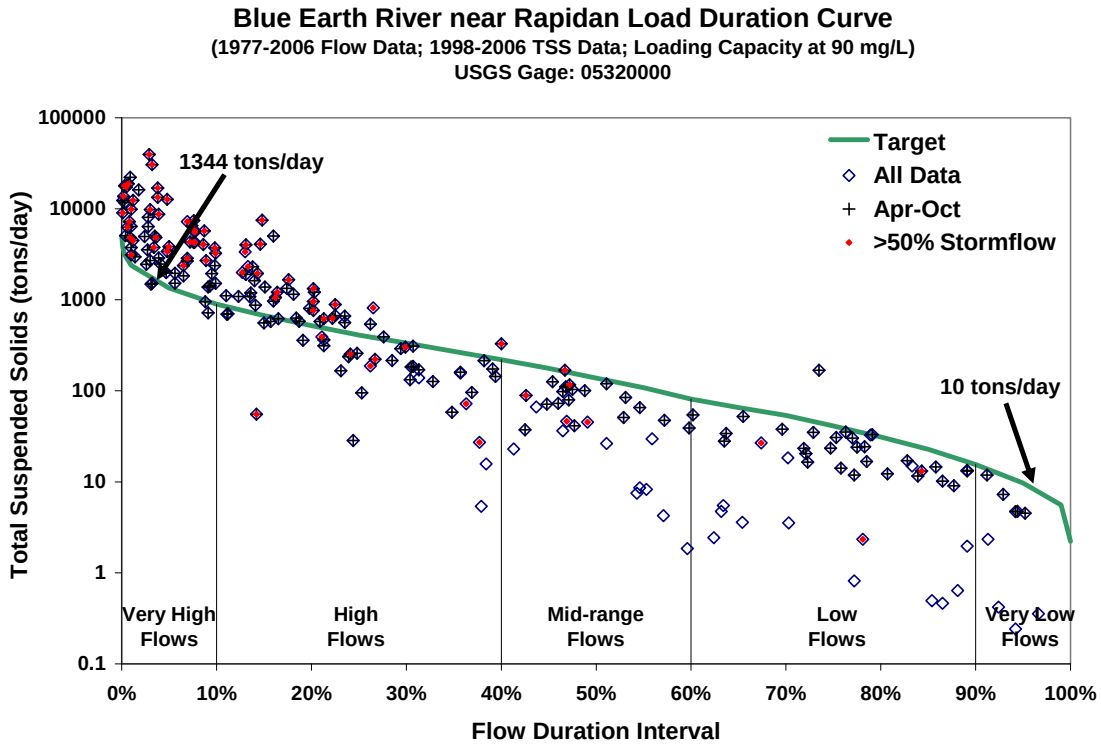


Figure 5.36 Blue Earth River-Rapidan Load Duration Curve.

Table 5.8 Blue Earth River-Rapidan TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	1344	409	138	41	10
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	4.84	4.84	4.84	4.84	4.84
Communities Subject to MS4 NPDES Requirements	3.36	1.02	0.34	0.10	0.02
Construction and Industrial Stormwater	0.16	0.05	0.02	0.01	0.01
Load Allocation	1201.24	362.19	119.00	31.95	4.12
Margin of Safety	134.40	40.90	13.80	4.10	1.00

5.8 Watonwan River: Perch Creek to Blue Earth River

Reach AUID:
07020010-501

Stream Status:
Impaired Stream Reach (mercury, bacteria, turbidity, aquatic consumption, aquatic life, and aquatic recreation). This report only addresses the turbidity impairment.

Impaired Segment Length:
17.52 miles

Contributing Watershed Size:
561,619.79 acres
877.53 square miles

Total Stream Miles:
1,150.96 miles

Elevation*:
Maximum = 1568 ft above sea level
Minimum = 869 ft above sea level
Total relief = 699 ft

Slope*:
Maximum Slope: 51.9 percent
Minimum Slope: 0 percent
Average Slope: 1.3 percent

Cities:
Bingham Lake, Butterfield, Darfur, La Salle, Lewisville, Madelia, Mountain Lake, Odin, Ormsby, St. James, Truman, Vernon Center.

Counties:
Blue Earth, Brown, Cottonwood, Jackson, Martin, Watonwan

*derived from the NED 30m DEM

The contributing area for this reach is the Watonwan River watershed to its outlet at the Blue Earth River. The watershed area is in a region of gently rolling ground moraine with a total area of approximately 878 square miles or 561,607 acres. The main stem of the Watonwan flows west to east towards its confluence with the Blue Earth River. The watershed represents approximately five percent of the Minnesota River basin's total area. Deep ravines cut into the lower reaches and larger tributaries to the Watonwan River. The drainage network is defined by perennial and intermittent streams, lakes and wetlands and has been significantly altered through public and private drainage.

Figures 5.37 and 5.38 represent land cover and land use. Approximately 87 percent of the watershed is farmed with corn and soybeans as the main cropping system. Developed land is the second largest land use at approximately eight percent. Steeply-sloped land, defined as land with a three percent or greater slope (Figure 5.39), constitutes eight percent of the total land surface and nine percent of the cropped land within the watershed. Conservation practices comprise 15,055 acres within the watershed. These practices represent approximately three percent of the land and are related mainly to CRP and CREP (Figure 5.40). The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

The Load Duration Curve (Figure 5.41) shows most of the exceedances to the target goal occur at the high to very high flow levels. The TSS surrogate value for 25 NTUs was determined to be 90 mg/L. Loading varies based on flow conditions that have been divided into five zones based on historical records of flows. The chart represents water quality samples taken over the flow regime and their relationships to the 90 mg/L goal. Samples are marked to show if the samples were collected during the April-October time period, and if they represent conditions where more than 50 percent of the water in the river is estimated to be made up of storm flow runoff.

Table 5.9 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves.

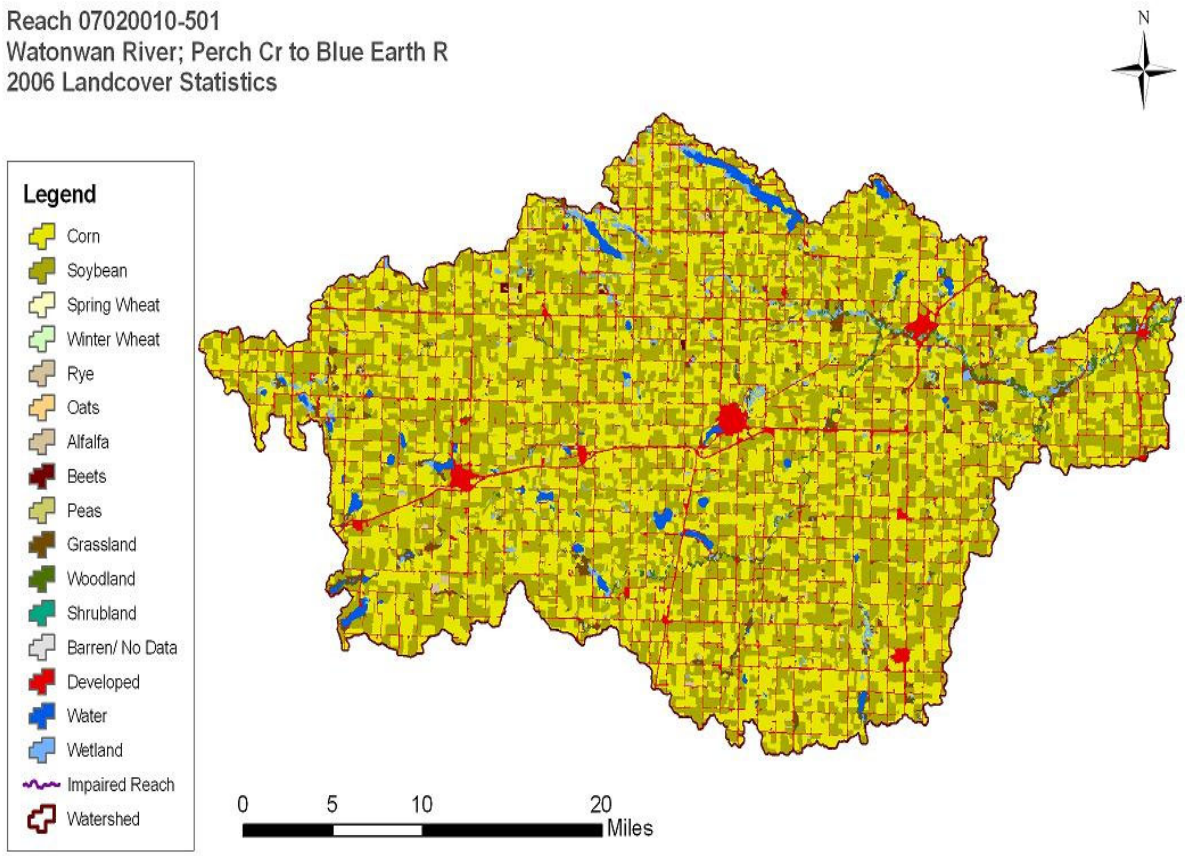


Figure 5.37 2006 Land Cover Map for the Watonwan River: Perch Creek to Blue Earth River.

LANDUSE	ACRES	PERCENT
Corn	257,617.96	45.87%
Soybeans	227,125.49	40.44%
Spring Wheat	27.90	0.00%
Winter Wheat	22.47	0.00%
Alfalfa	1,567.67	0.28%
Beets	304.55	0.05%
Peas	216.20	0.04%
Grassland	9,108.45	1.62%
Woodland	5,748.38	1.02%
Shrubland	6.20	0.00%
Barren/No Data	12.40	0.00%
Developed	43,074.13	7.67%
Water	8,045.26	1.43%
Wetland	8,729.52	1.55%
Total	561,606.58	100.00%

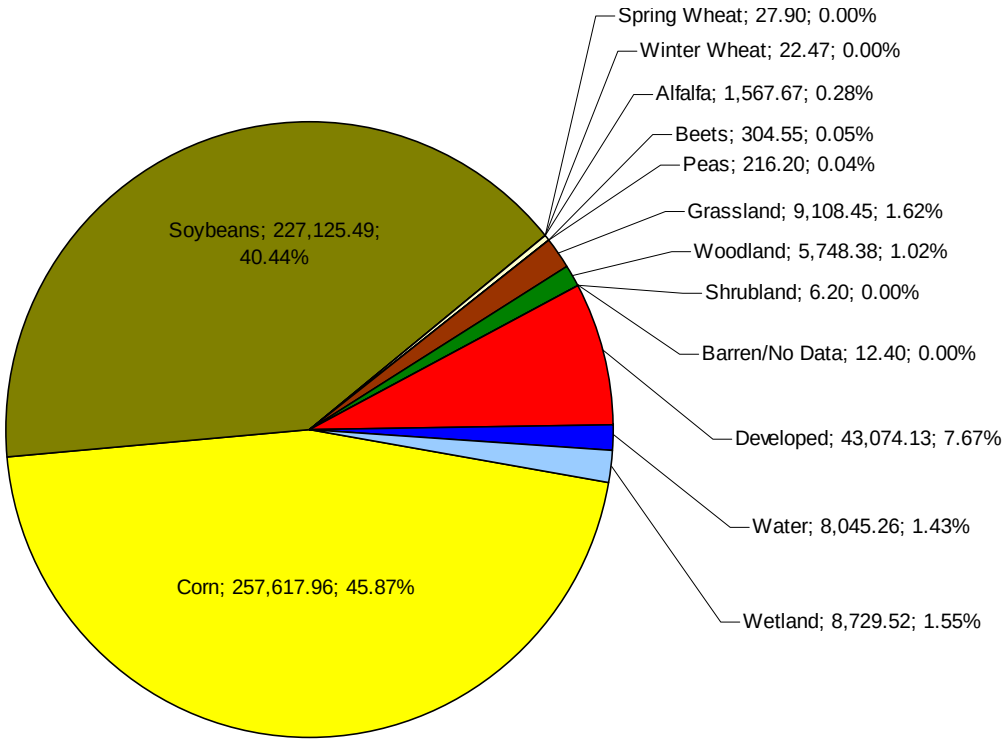
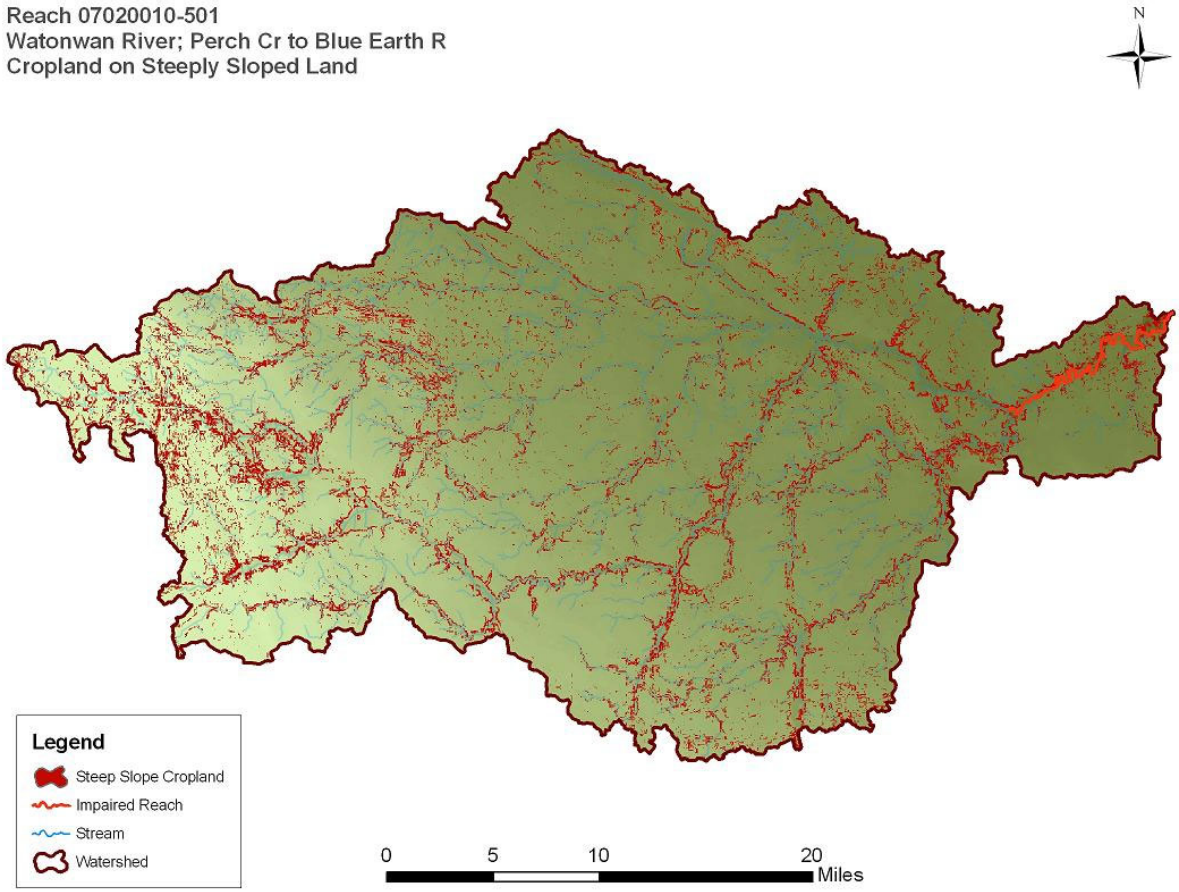
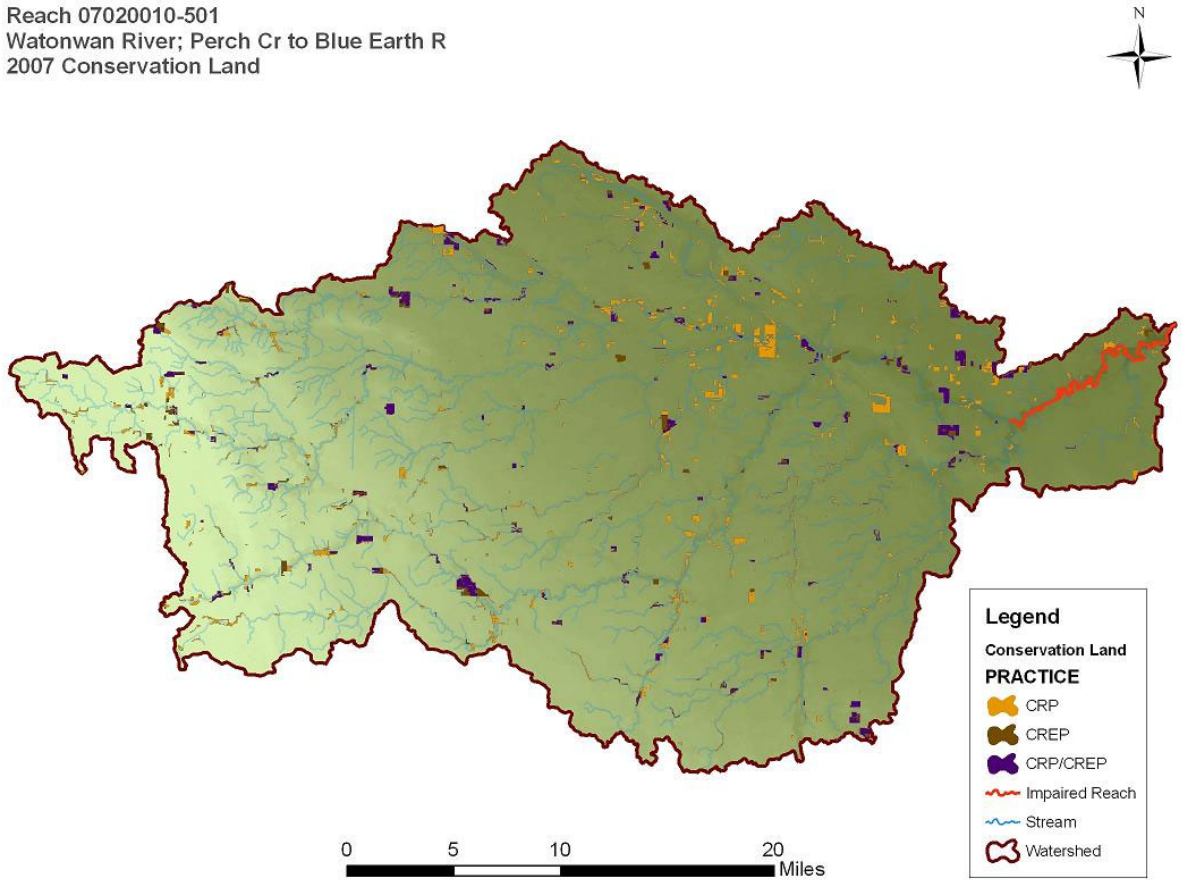


Figure 5.38 2006 Land Use Statistics for the Watonwan River: Perch Creek to Blue Earth River



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
561,606.58	486,882.24	44,861.88	7.99%	9.21%

Figure 5.39 Cropland on Steeply Sloped Land Analysis for the Watonwan River: Perch Creek to Blue Earth River.



PROGRAM	ACRES	PERCENT
CRP	12,652.78	2.25%
CREP	7,184.20	1.28%
CRP,CREP	15,055.18	2.68%

Figure 5.40 Conservation Land Locations and Statistics for the Watonwan River: Perch Creek to Blue Earth River.

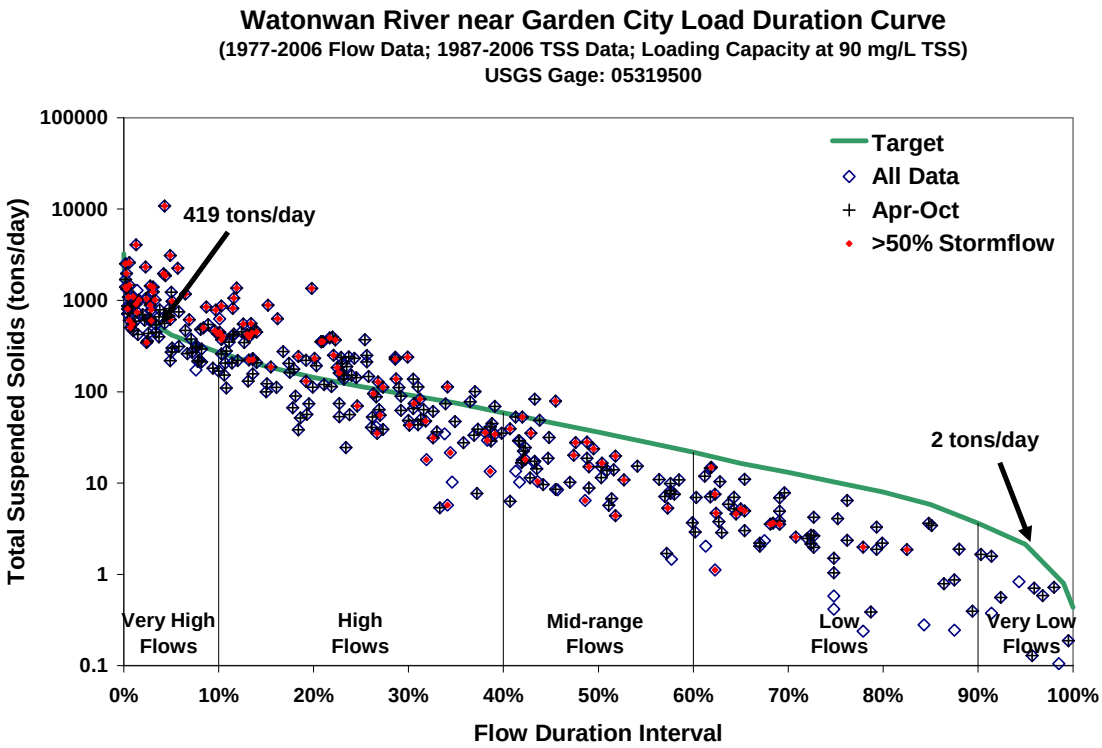


Figure 5.41 Watonwan River Load Duration Curve.

Table 5.9 Watonwan River TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	419	114	36	10	2
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	2.13	2.13	2.13	2.13	*
Communities Subject to MS4 NPDES Requirements	0.00**	0.00**	0.00**	0.00**	*
Construction and Industrial Stormwater	0.06	0.02	0.01	0.01	*
Load Allocation	374.91	100.45	30.27	6.86	*
Margin of Safety	41.90	11.40	3.60	1.00	*

* The total daily loading capacity in the very low flow zone is very small due to the occurrence of very low flows in the long-term flow records. Consequently, for some of the impaired reaches, the permitted wastewater treatment facility design flows exceed the stream flow in the very low flow zone. Since it is a component of stream flow, actual treatment facility flow can never exceed stream flow, but in some cases the calculated MOS would take up all of the remaining allocation capacity in the very low flow zone. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

Allocation = (flow contribution from a given source) x (*X* mg/L TSS), where *X* equals 45 for the municipal stabilization ponds, 30 for other wastewater treatment facilities and 90 mg/L for other sources.

**No regulated MS4 communities currently exist in this watershed so the waste load allocation is 0.00. If a regulated MS4 allocation is needed in the future, the load allocation will be moved to the waste load allocation proportional to the amount of land affected.

5.9 LeSueur River; Maple River to Blue Earth River

Reach AUID:
07020011-501

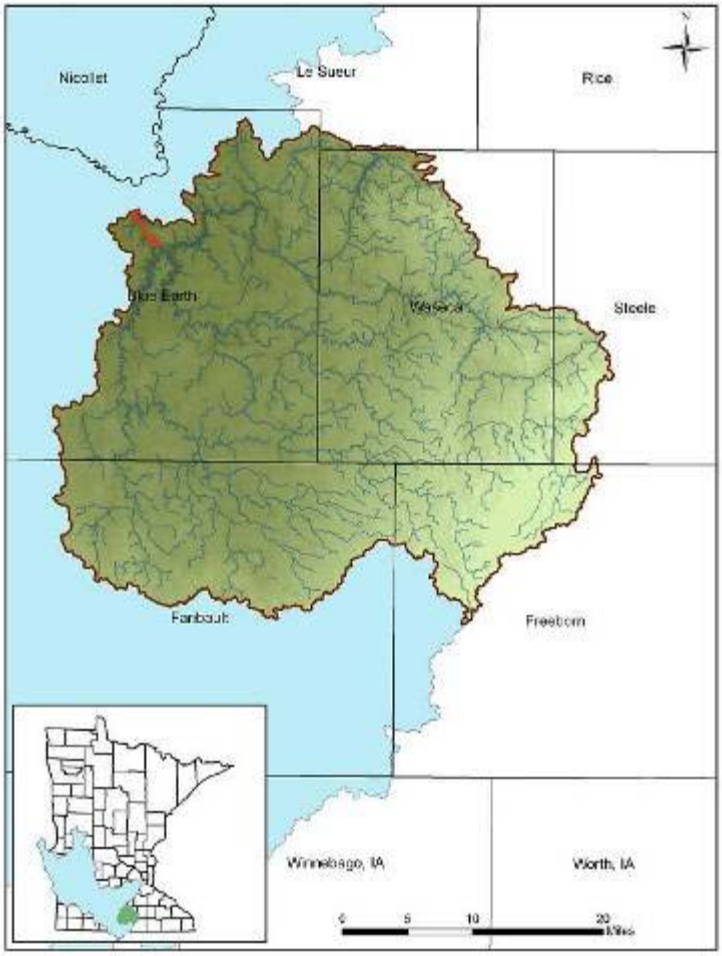
Stream Status:
Impaired Stream Reach (mercury, PCB, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

Impaired Segment Length:
5.92 miles

Contributing Watershed Size:
711,838.4 acres
1,112.2 square miles

Total Stream Miles:
1,321.3 miles

Elevation*:
Maximum = 1368 ft above sea level
Minimum = 764 ft above sea level
Total relief = 604 ft



Slope*:
Maximum Slope: 84.4 percent
Minimum Slope: 0 percent
Average Slope: 1.7 percent

Cities:
Amboy, Delavan, Eagle Lake, Easton, Elysian, Freeborn, Good Thunder, Hartland, Janesville, Madison Lake, Mankato, Mapleton, Minnesota Lake, New Richland, Pemberton, St. Clair, Waldorf, Waseca, Wells, Winnebago.

Counties: Blue Earth, Faribault, Freeborn, LeSueur, Steele, Waseca

*derived from the NED 30m DEM

The LeSueur River watershed is among the most heavily cultivated in the Minnesota River basin with 82 percent of the land in a corn/soybean rotation. Developed land makes up over seven percent of the watershed, second only to agricultural land use (Figures 5.42 and 5.43). Major tributaries of the LeSueur include the Cobb and Maple Rivers. Figure 5.44 depicts the location of steeply-sloped cropland within the watershed. Steeply-sloped land, whether under development or used as agricultural cropland, may be a significant source of sediment depending on how it is managed. This figure also depicts the natural geomorphic variation within the watershed. The western three-quarters is largely flat glacial lake plain with incising river channels. The eastern quarter is a much more rolling glacial moraine topography. The deeply-incised river channel and associated ravines in the lower portion of the watershed are considered a major factor in sediment loading.

Figure 5.45 shows enrollment in the Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP). These programs compensate land owners for taking environmentally sensitive land out of crop production for periods of time ranging from 10 years to perpetuity. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

Figure 5.46 is the load duration curve depicting daily TSS loads consistent with achievement of the 25 NTU water quality standard. In the case of the LeSueur River, the TSS surrogate value for 25 NTUs was determined to be 90 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less. The diamond-shaped symbols on the chart represent calculated TSS loads based on water quality samples. These symbols are further qualified to show if the samples were collected during the April-October time period, and if they represent conditions where more than 50 percent of the water in the river is estimated to be made up of storm flow runoff. Taken together, TSS loads exceeding the TMDL are most likely to occur from April through October, during flows that are mid-range or higher, and under conditions of storm flow runoff.

Table 5.10 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves.

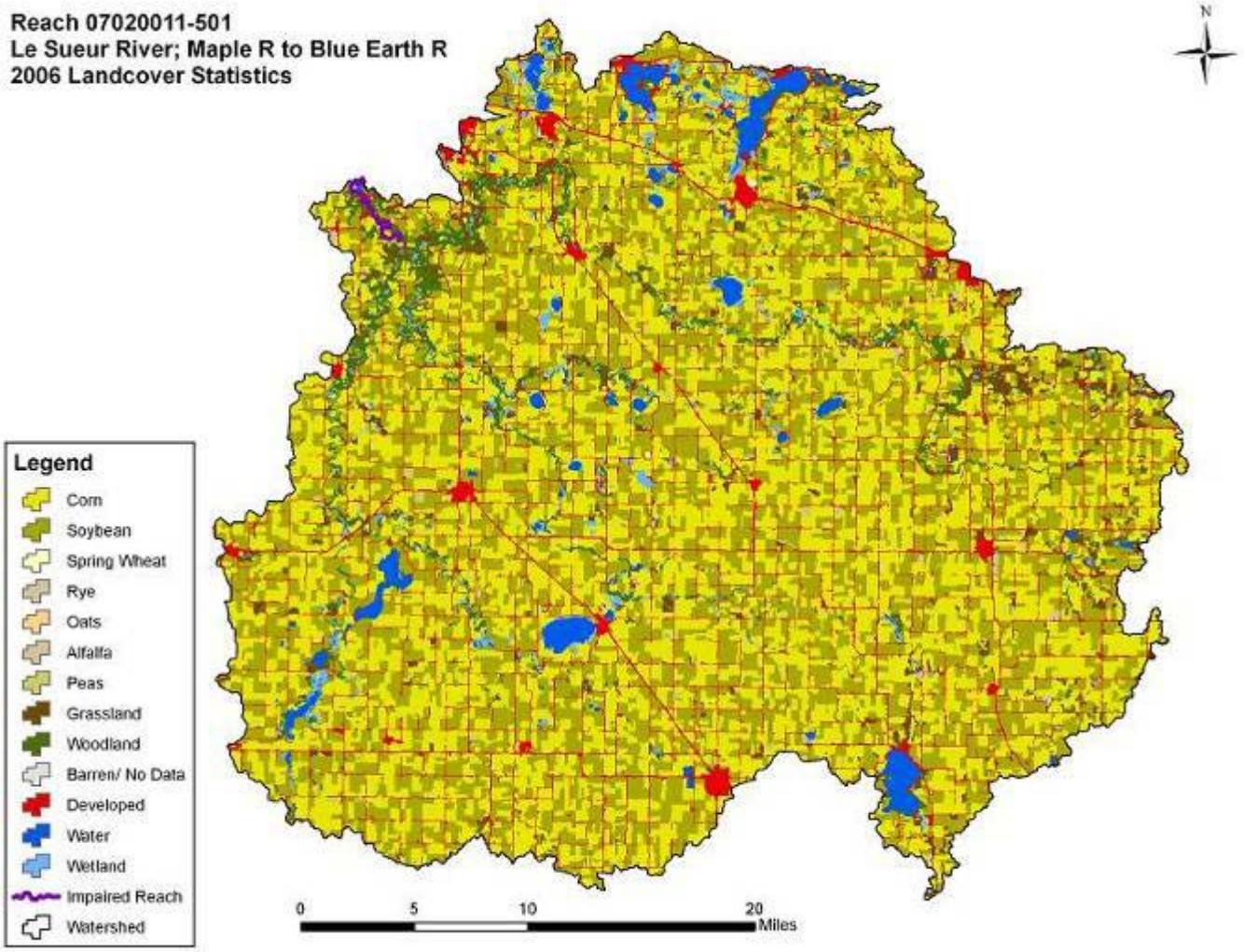


Figure 5.42 2006 Land Cover Map for the LeSueur River; Maple River to Blue Earth River.

LANDUSE	ACRES	PERCENT
Corn	317,404.37	44.59%
Soybean	263,129.58	36.97%
Sping Wheat	259.60	0.04%
Rye	25.57	0.00%
Oats	144.14	0.02%
Alfalfa	2,464.25	0.35%
Peas	1,924.13	0.27%
Grassland	18,412.16	2.59%
Woodland	28,218.80	3.96%
Barren/No Data	140.26	0.02%
Developed	50,970.53	7.16%
Water	15,252.80	2.14%
Wetland	13,474.35	1.89%
Total	711,820.54	100.00%

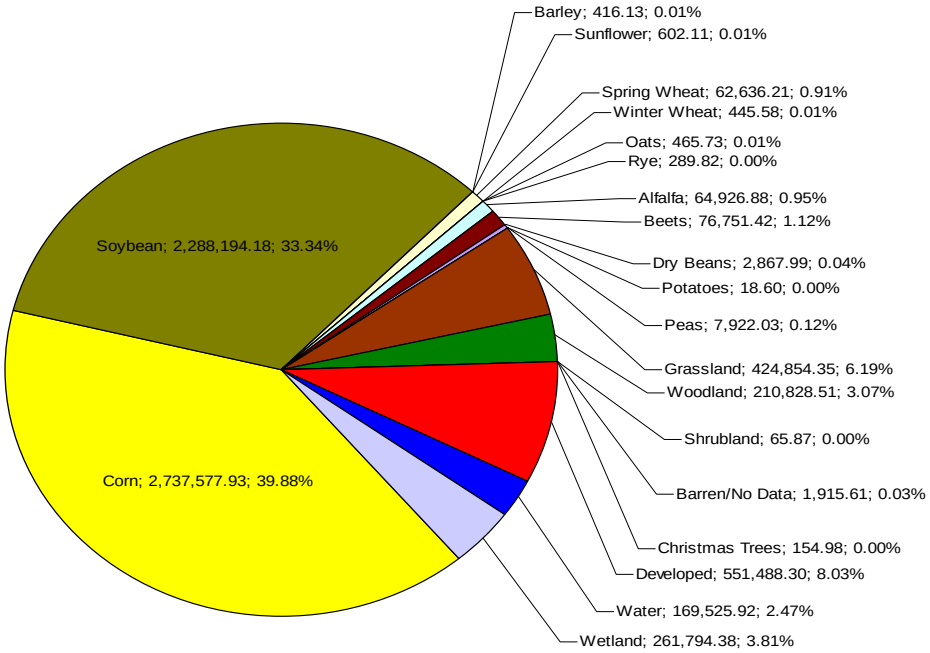
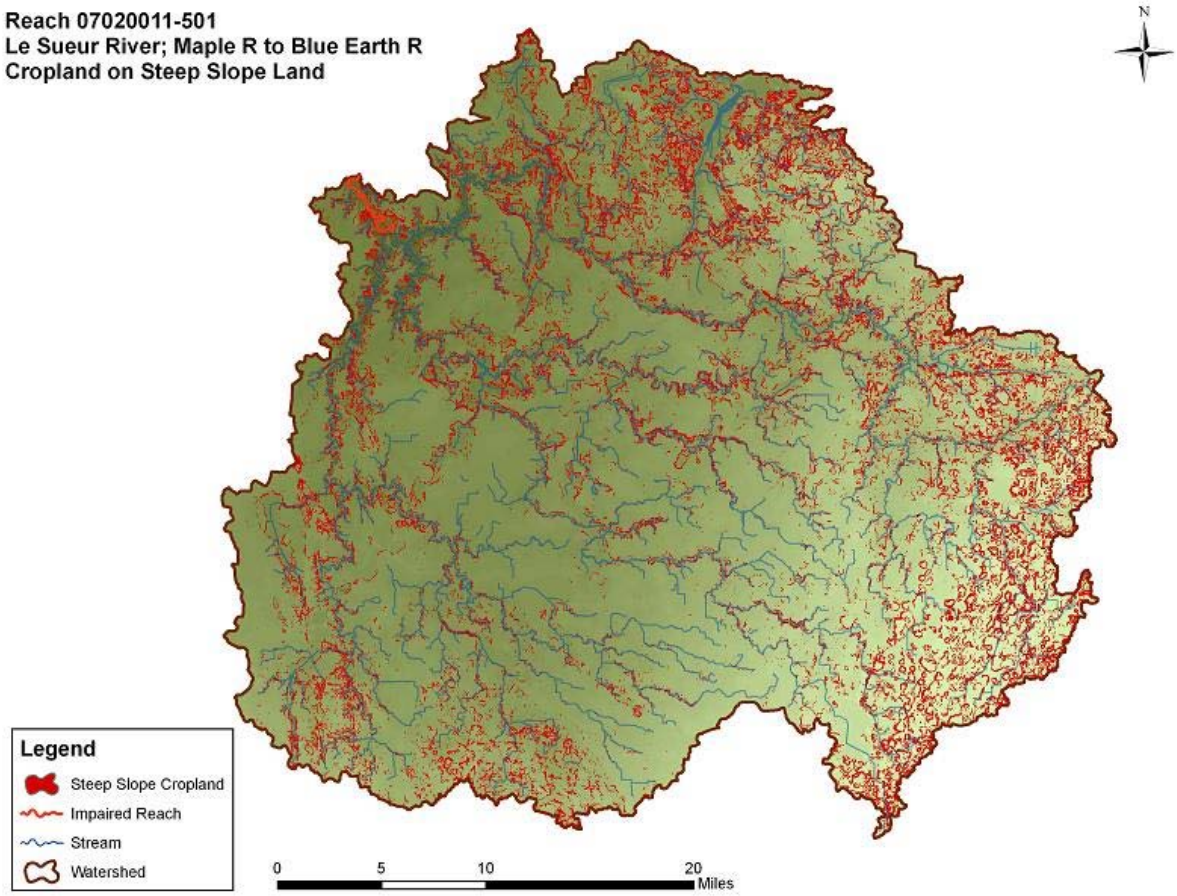
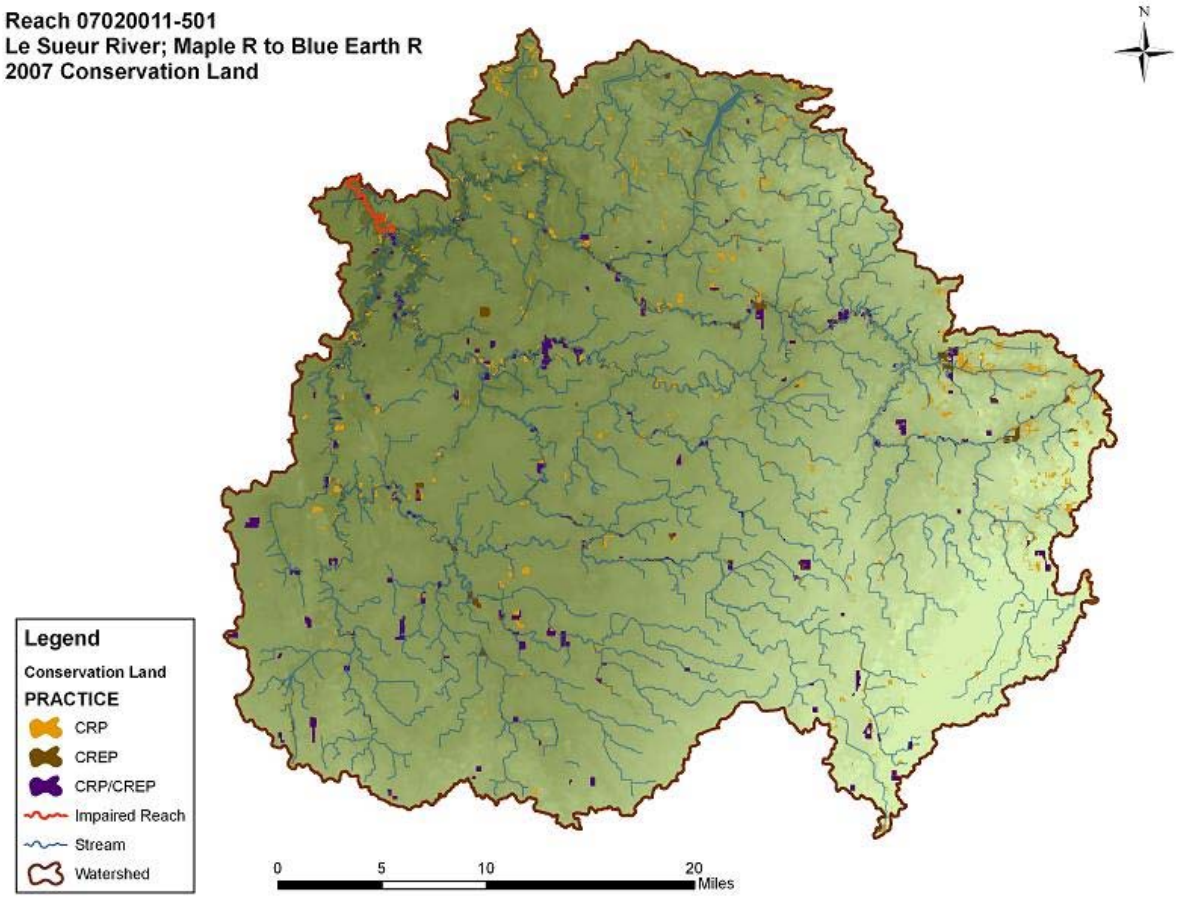


Figure 5.43 2006 Land Use Statistics for the LeSueur River; Maple River to Blue Earth River.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
711,820.54	585,351.64	88,226.47	12.39%	15.07%

Figure 5.44 Cropland on Steeply Sloped Land Analysis for the LeSueur River; Maple River to Blue Earth River.



PROGRAM	ACRES	PERCENT
CRP	18,121.50	2.55%
CREP	8,625.70	1.21%
CRP,CREP	20,680.10	2.91%

Figure 5.45 Conservation Land Locations and Statistics for the LeSueur River; Maple River to Blue Earth River.

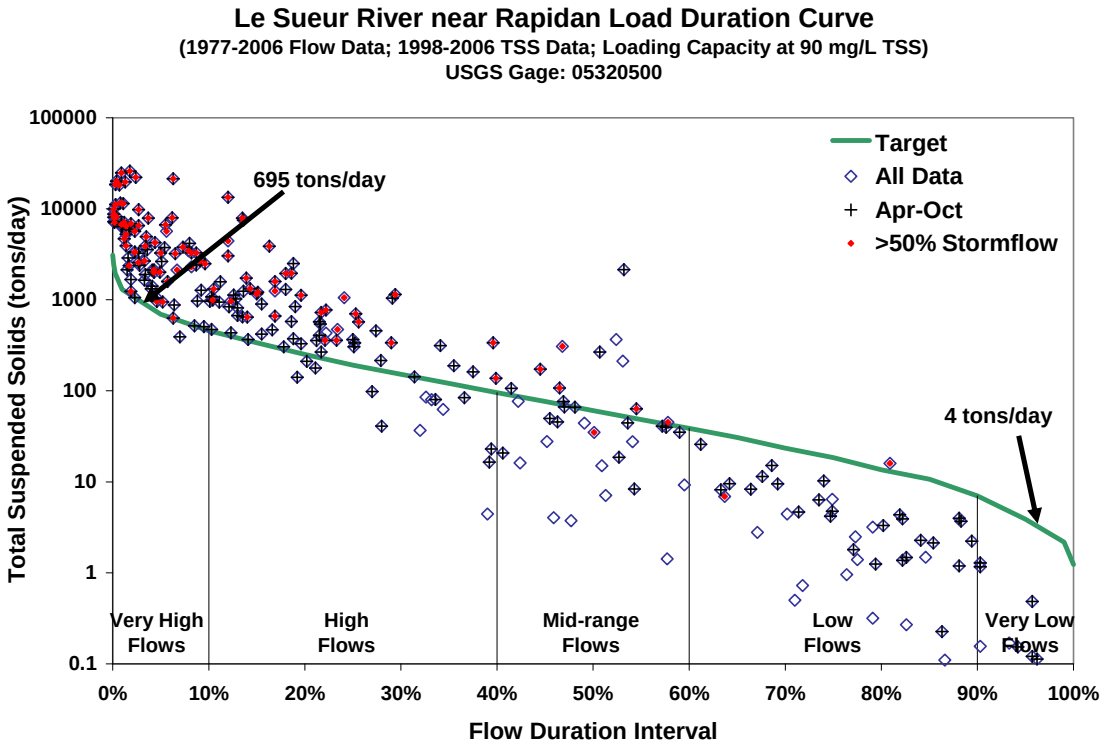


Figure 5.46 LeSueur River Load Duration Curve.

Table 5.10 LeSueur River TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	695	192	61	18	4
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	5.40	5.40	5.40	5.40	*
Communities Subject to MS4 NPDES Requirements	1.84	0.51	0.16	0.05	*
Construction and Industrial Stormwater	0.28	0.08	0.02	0.01	*
Load Allocation	617.98	166.82	49.31	10.75	*
Margin of Safety	69.50	19.20	6.10	1.80	*

* The total daily loading capacity in the very low flow zone is very small due to the occurrence of very low flows in the long-term flow records. Consequently, for some of the impaired reaches, the permitted wastewater treatment facility design flows exceed the stream flow in the very low flow zone. Since it is a component of stream flow, actual treatment facility flow can never exceed stream flow, but in some cases the calculated MOS would take up all of the remaining allocation capacity in the very low flow zone. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

Allocation = (flow contribution from a given source) x (*X* mg/L TSS), where *X* equals 45 for the municipal stabilization ponds, 30 for other wastewater treatment facilities and 90 mg/L for other sources.

5.10 Minnesota River; Chippewa River to Stoney Run Creek

Reach AUID:
07020004-501

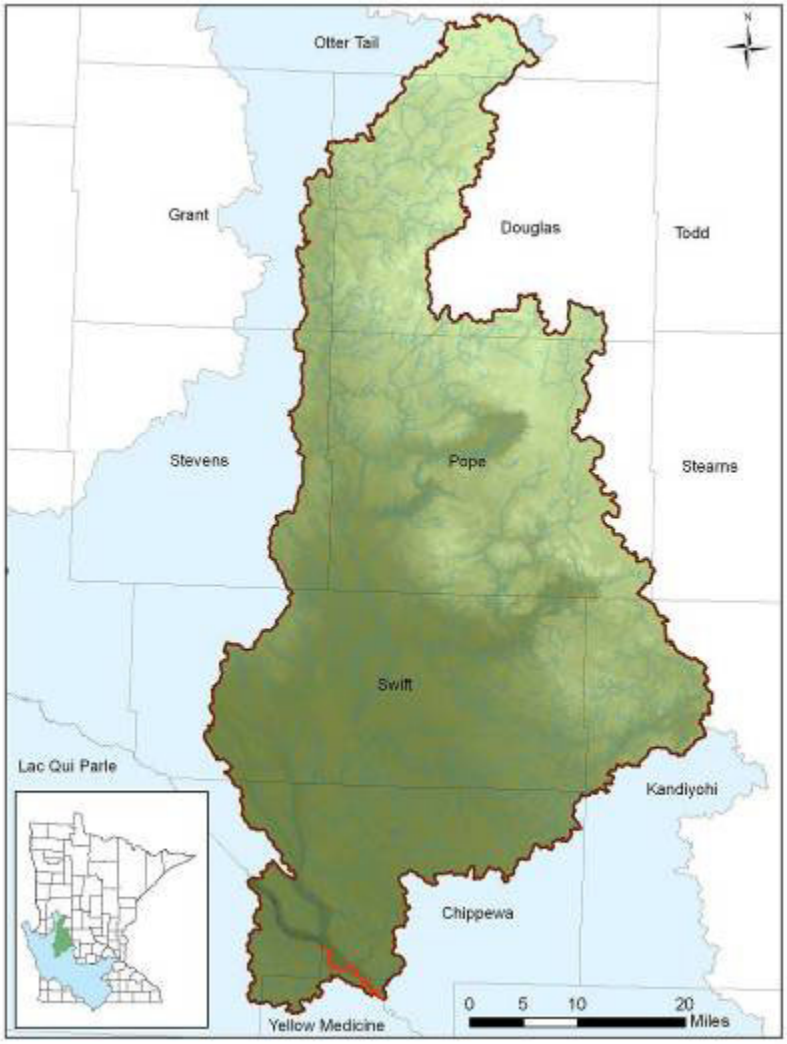
Stream Status:
Impaired Stream Reach (mercury, bacteria, turbidity, aquatic consumption, aquatic life, and aquatic recreation). This report only addresses the turbidity impairment.

Impaired Segment Length:
11.43 miles

Contributing Watershed Size:
3,954,729.78 acres
6,179.29 sq. miles

Total Stream Miles:
2,639.76 miles

Elevation*:
Maximum = 1710 ft above sea level
Minimum = 905 ft above sea level
Total relief = 805 ft



Slope*:
Maximum Slope: 45.4 percent
Minimum Slope: 0 percent
Average Slope: 2.1 percent

Counties: Chippewa, Douglas, Grant, Kandiyohi, Lac Qui Parle, Otter Tail, Pope, Stearns, Stevens, Swift, Yellow Medicine

*derived from the NED 30m DEM

The contributing area for this reach of the Minnesota River from the Chippewa River to Stoney Run Creek includes the Chippewa, Lac Qui Parle/Yellow Bank, Pomme de Terre and Upper Minnesota Watersheds. The upstream boundary of the watershed model is Lac Qui Parle outlet. As such, the maps that follow include the area downstream of Lac Qui Parle.

Figures 5.47 and 5.48 depict land cover and land use statistics for this watershed. As shown in the figures, corn and soybean production make up the majority of land use, followed by grassland and developed lands.

Figure 5.49 illustrates cropland with respect to landscape slope. The impaired watershed contains approximately 153,722 acres of cropland on slope of three percent or greater. This constitutes approximately 18 percent of the total cropland and 11 percent of the total watershed area.

Lands enrolled in conservation set-aside programs in the watershed are represented by Figure 5.50. The total area enrolled in these conservation programs is 112,010 acres, accounting for eight percent of the watershed area. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

Figure 5.51 is the load duration curve depicting daily TSS loads consistent with achievement of the 25 NTU water quality standard. For this reach of the Minnesota River, the TSS surrogate value for 25 NTUs was determined to be 75 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less.

Table 5.11 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves.

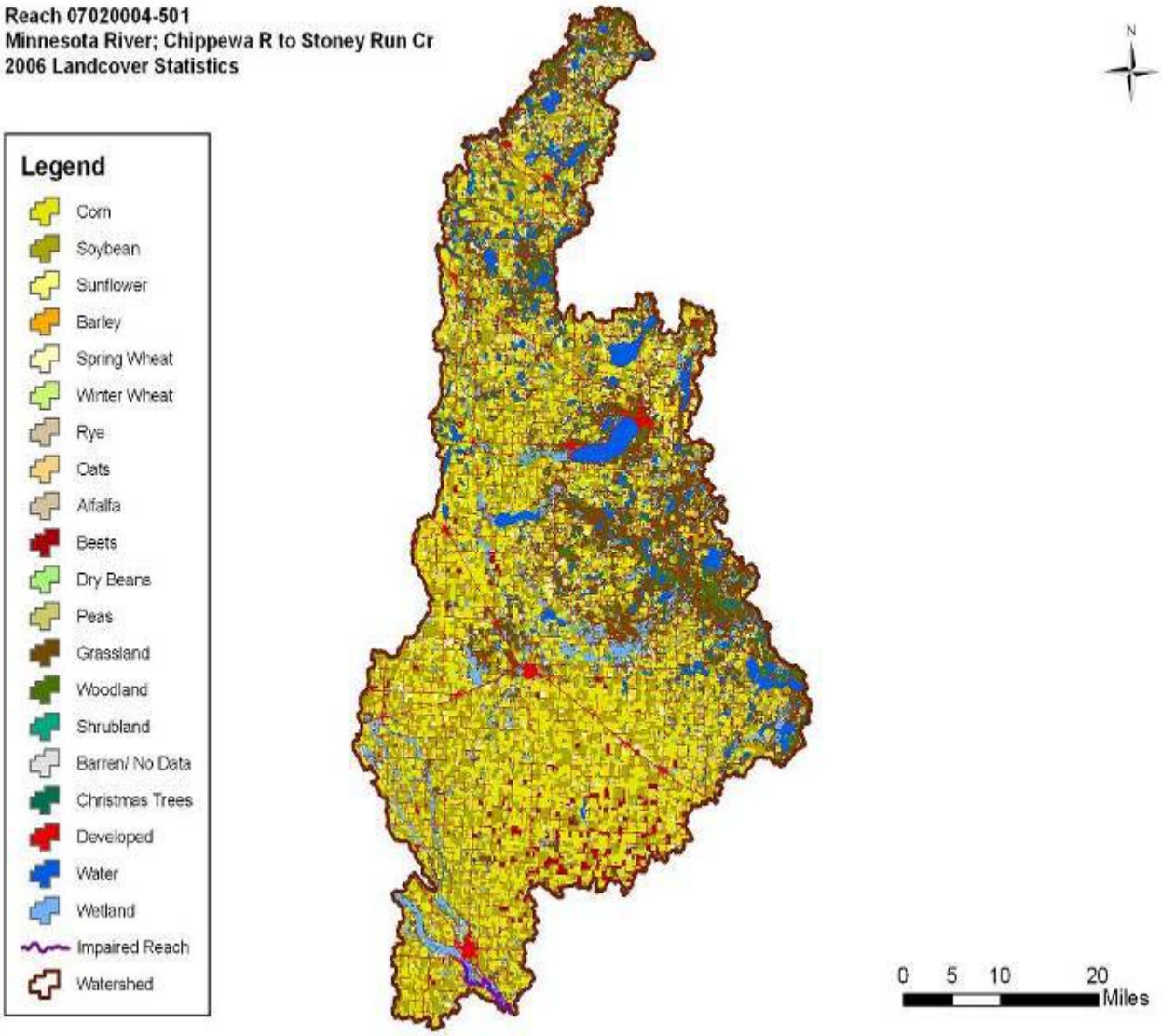


Figure 5.47 2006 Land Cover Map for the Minnesota River; Chippewa River to Stoney Run Creek.

LANDUSE	ACRES	PERCENT
Corn	408,109.05	29.26%
Soybean	350,445.52	25.13%
Sunflower	90.67	0.01%
Spring Wheat	35,482.93	2.54%
Winter Wheat	423.11	0.03%
Rye	34.87	0.00%
Oats	86.79	0.01%
Alfalfa	30,209.58	2.17%
Beets	22,490.57	1.61%
Dry Beans	1,240.65	0.09%
Peas	227.83	0.02%
Grassland	181,376.80	13.00%
Woodland	74,229.05	5.32%
Shrubland	49.60	0.00%
Barren	68.19	0.00%
Christmas Trees	154.98	0.01%
Developed	112,231.25	8.05%
Water	80,321.49	5.76%
Wetland	97,515.47	6.99%
Total	1,394,788.39	100.00%

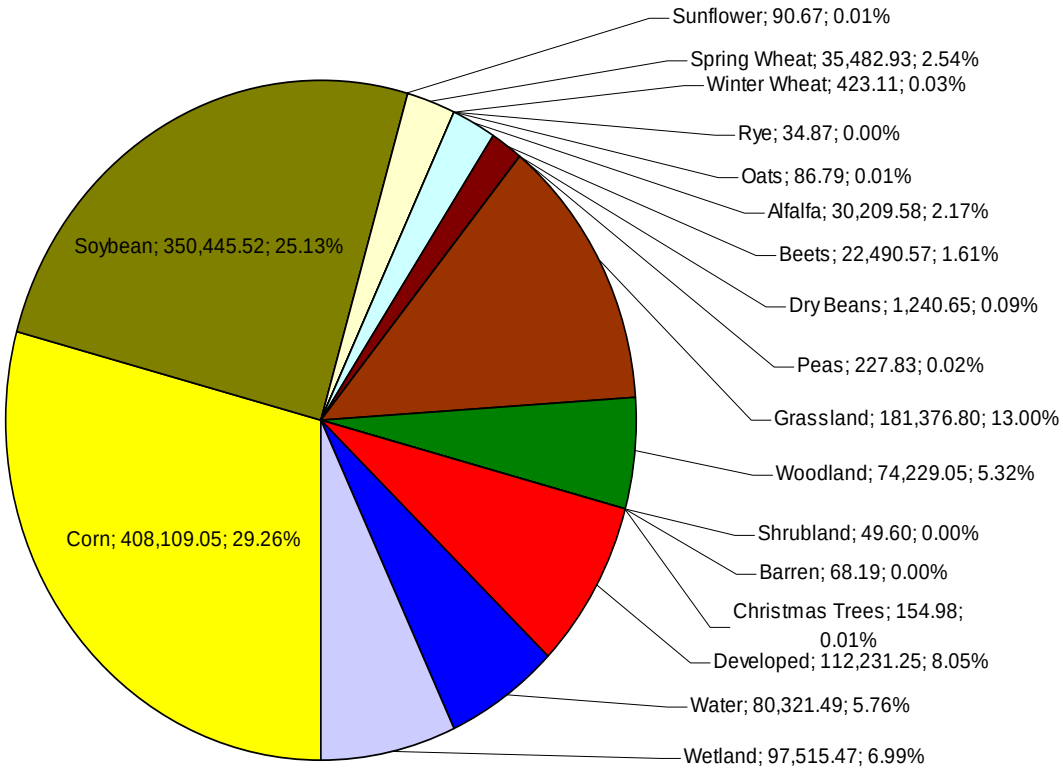
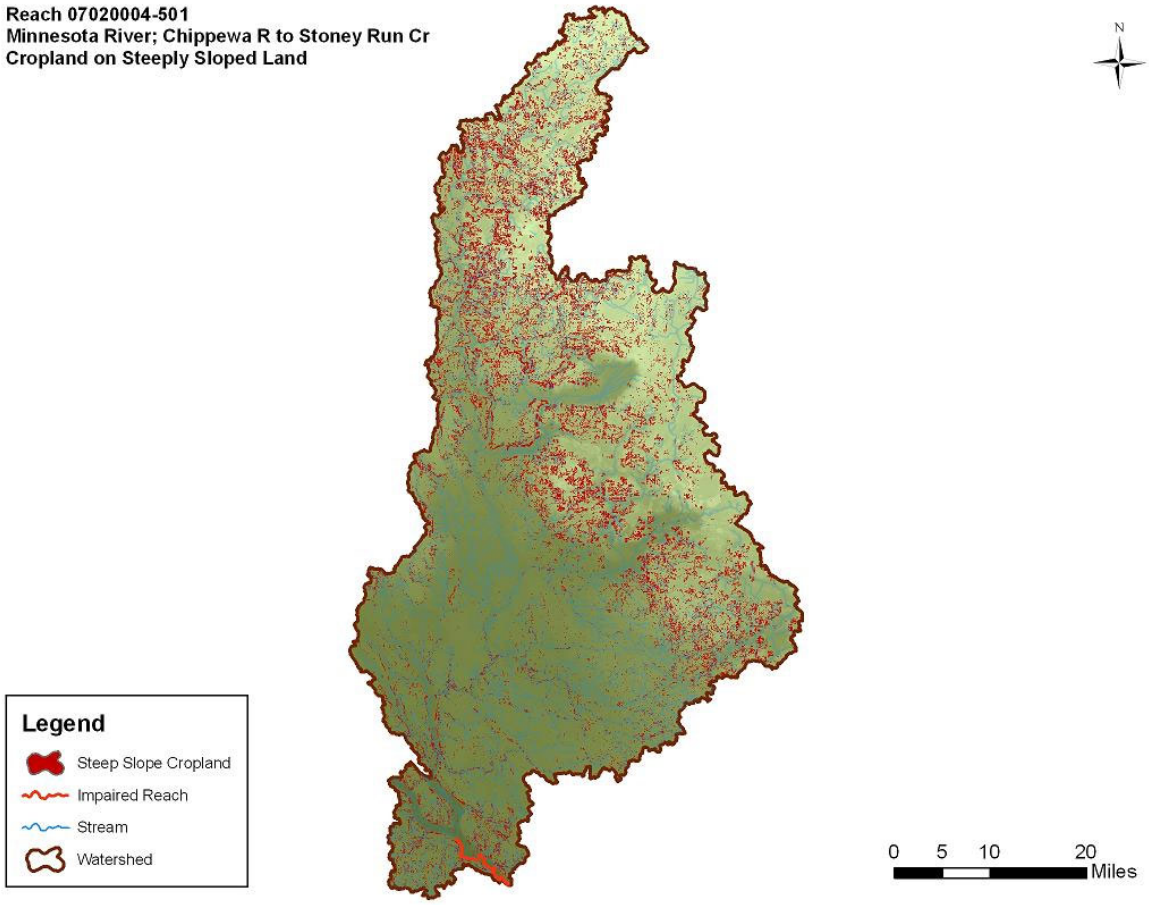
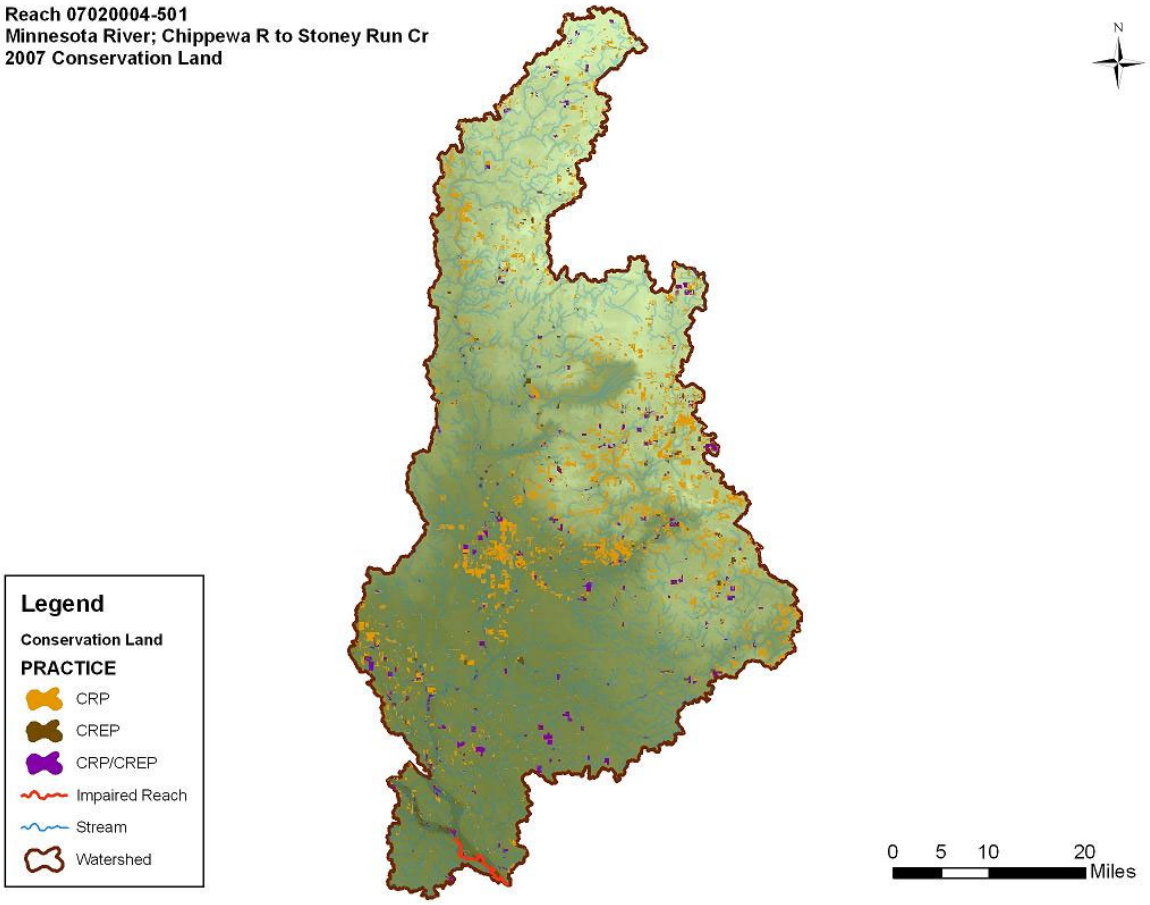


Figure 5.48 2006 Land Use Statistics for the Minnesota River; Chippewa River to Stoney Run Creek.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
1,394,746.06	848,841.55	153,722.17	11.02%	18.11%

Figure 5.49 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Chippewa River to Stoney Run Creek.



PROGRAM	ACRES	PERCENT
CRP	102,440.57	7.34%
CREP	23,346.63	1.67%
CRP,CREP	112,010.91	8.03%

Figure 5.50 Conservation Land Locations and Statistics for the Minnesota River; Chippewa River to Stoney Run Creek.

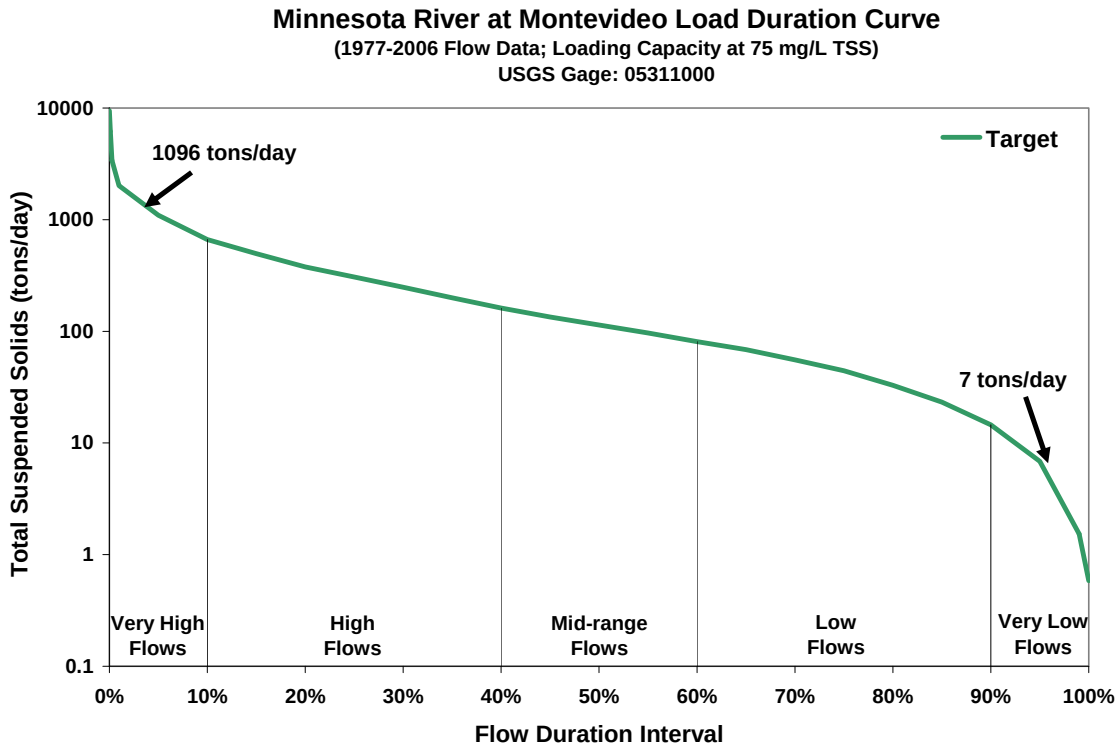


Figure 5.51 Minnesota River at Montevideo Load Duration Curve.

Table 5.11 Minnesota River at Montevideo TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	1096	307	114	44	7
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	1.75	1.75	1.75	1.75	1.75
Communities Subject to MS4 NPDES Requirements	1.19	0.33	0.12	0.05	0.01
Construction and Industrial Stormwater	0.17	0.05	0.02	0.01	0.01
Load Allocation	983.29	274.17	100.71	37.79	4.53
Margin of Safety	109.60	30.70	11.40	4.40	0.70

5.11 Minnesota River; Minnesota Falls Dam to Hazel Creek

Reach AUID:
07020004-515

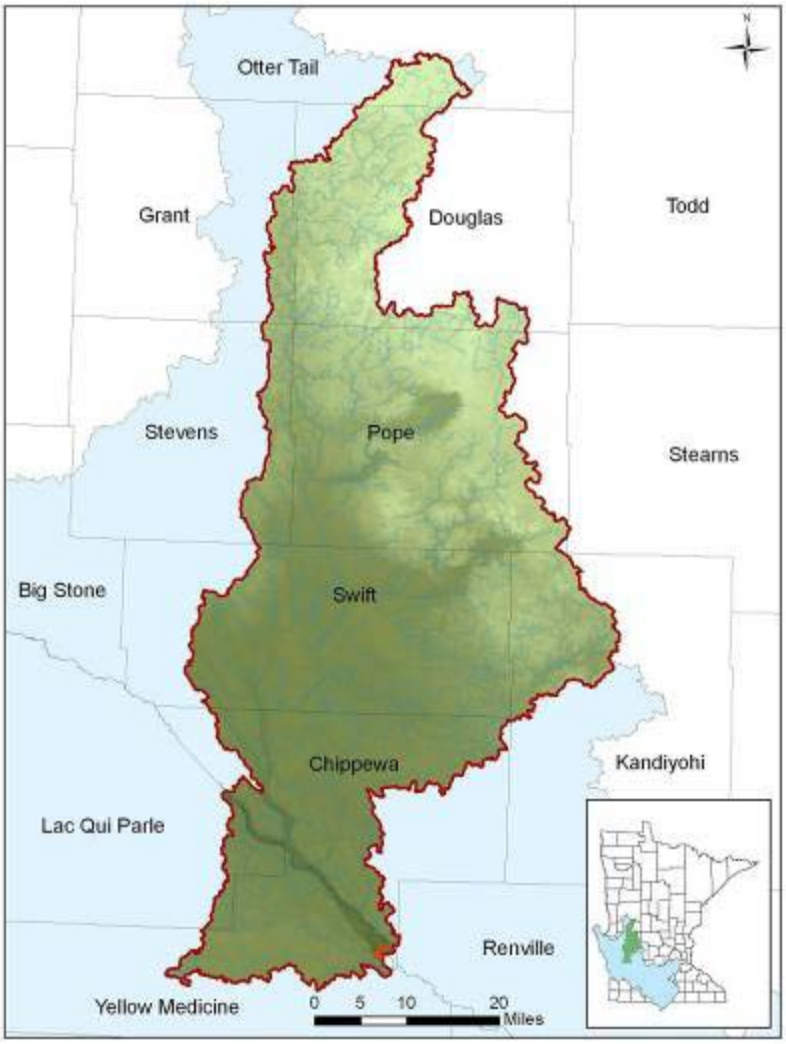
Stream Status:
Impaired Stream Reach (mercury, PCB, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

Impaired Segment Length:
4.12 miles

Contributing Watershed Size:
4,094,063.62 acres
6,397.97 sq. miles

Total Stream Miles:
2,903.92 miles

Elevation*:
Maximum = 1713 ft above sea level
Minimum = 866 ft above sea level
Total relief = 847 ft



Slope*:
Maximum Slope: 61.4 percent
Minimum Slope: 0 percent
Average Slope: 2.1 percent

Counties: Chippewa, Douglas, Grant, Kandiyohi, Lac Qui Parle, Otter Tail, Pope, Renville, Stearns, Stevens, Swift, Yellow Medicine

*derived from the NED 30m DEM

The watershed for the segment of the Minnesota River from the Minnesota Falls Dam to Hazel Creek includes the entire Chippewa Watershed, and several minor watersheds that contribute directly to the Minnesota River. The segment picks up an additional 314 square miles of minor watershed for a total of 2,398 square miles of watershed area.

Figures 5.52 and 5.53 show land use within the watershed. Even with the addition of the direct contributions from the minor watersheds, the percentages of land use change very little. This helps to confirm the assumption that land use within these areas is similar to the surrounding major watersheds. The major land use in the watershed is agriculture at approximately 63 percent. Grasslands are the next greatest category at 12 percent with developed areas following at eight percent. The area shows a slightly higher percentage in the Water (5.3 percent), Wetland (6.95 percent) and Woodland (4.96 percent) categories than the downstream watershed of the Minnesota River.

Figure 5.54 shows steeply-sloped agricultural land with the watershed. A higher percentage (17.29 percent) of the watershed contains cropland with greater than three percent slope. These steeper slopes have the potential to contribute sediment to the system if not protected from erosion.

Approximately 4 percent of the watershed has been enrolled in some type of conservation program (Figure 5.55) for a total of 116,288 total acres enrolled. CREP acres enrolled are permanent easement acres at a total of 25,382 acres. The CRP acreage can fluctuate depending on the number of acres enrolled in the program. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

For this reach of the Minnesota River, the TSS surrogate value for 25 NTUs was determined to be 75 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less.

Table 5.12 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. There is a slight difference between the loads presented on the load duration curve and the loading capacity in the table due to differences in flows. The duration curve was developed based on the flows from the closest USGS flow gage, which is near the city of Montevideo (Figure 5.51). To determine the loading capacity in the table, the MPCA estimated the flows in this reach by using a watershed area ratio of 1.04.

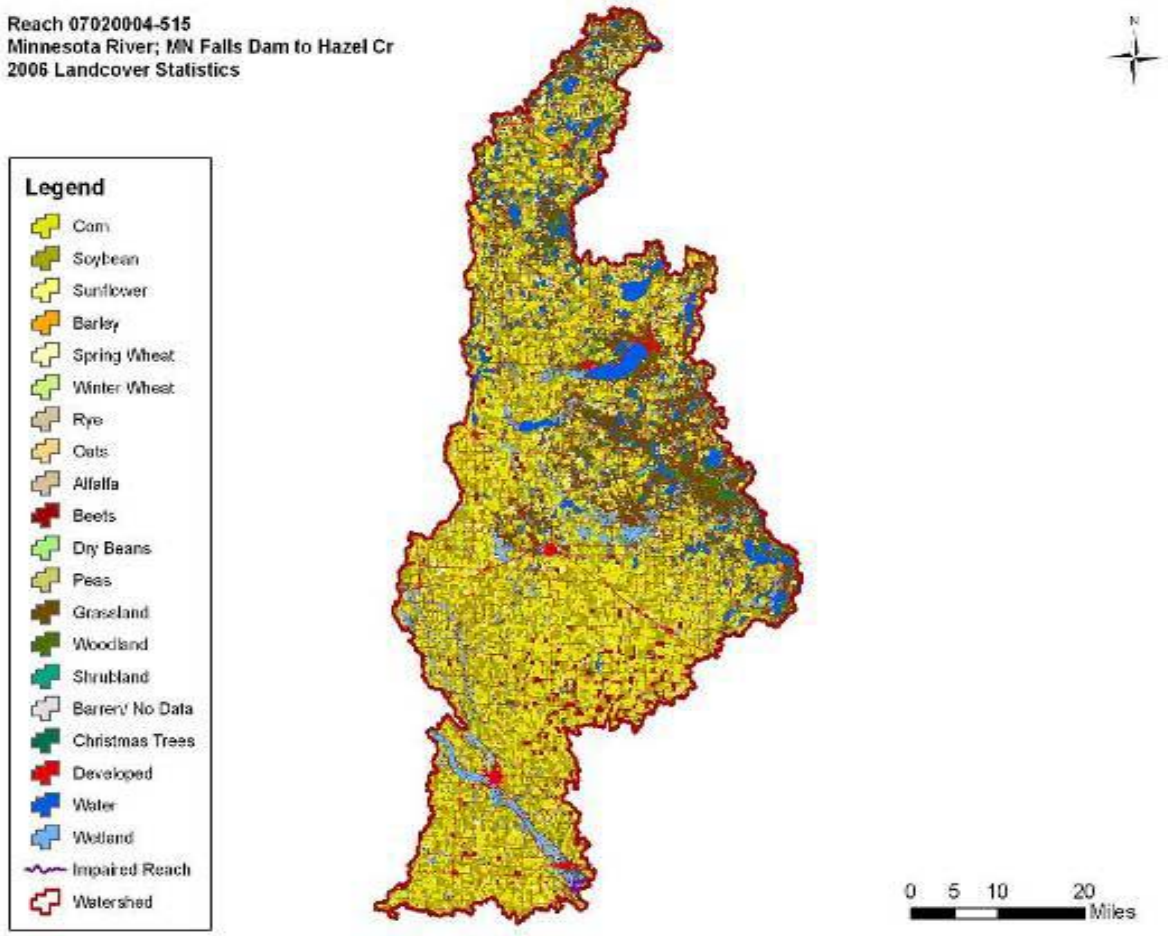


Figure 5.52 2006 Land Cover Map for the Minnesota River; Minnesota Falls Dam to Hazel Creek.

LANDUSE	ACRES	PERCENT
Corn	463,615.97	30.21%
Soybean	401,256.41	26.15%
Sunflower	90.67	0.01%
Spring Wheat	37,643.41	2.45%
Winter Wheat	423.11	0.03%
Rye	34.87	0.00%
Oats	89.89	0.01%
Alfalfa	31,043.39	2.02%
Beets	25,570.12	1.67%
Dry Beans	1,236.00	0.08%
Peas	231.70	0.02%
Grassland	184,504.39	12.02%
Woodland	76,079.56	4.96%
Shrubland	48.82	0.00%
Barren/No Data	120.89	0.01%
Christmas Trees	154.98	0.01%
Developed	124,633.88	8.12%
Water	81,325.01	5.30%
Wetland	106,622.36	6.95%
Total	1,534,725.44	100.00%

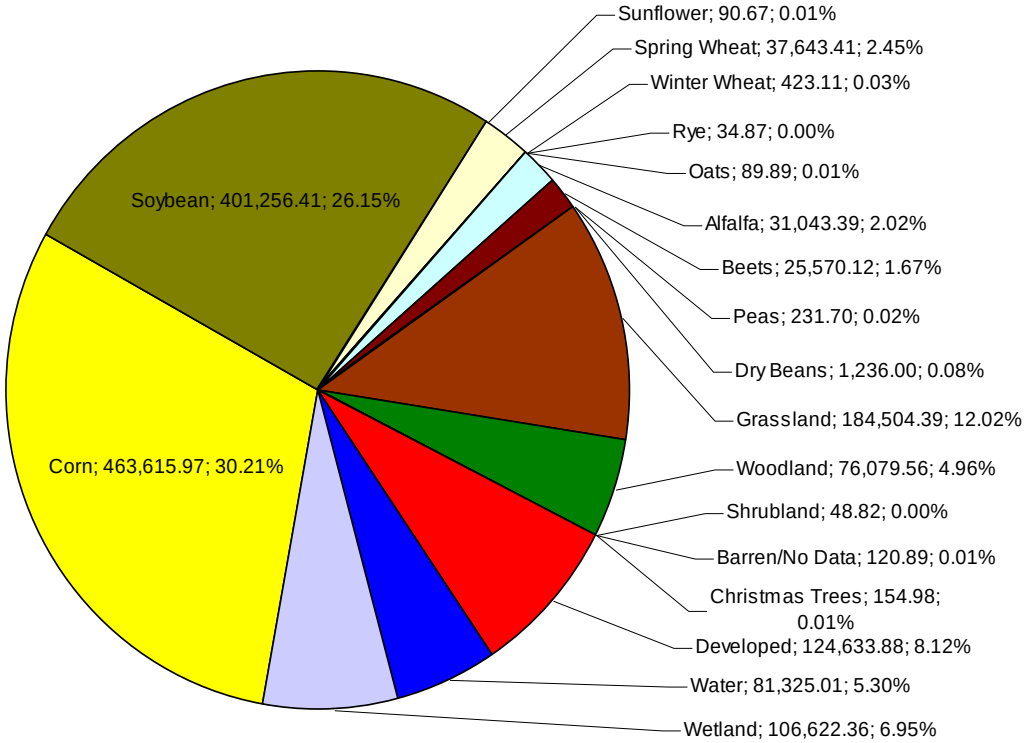
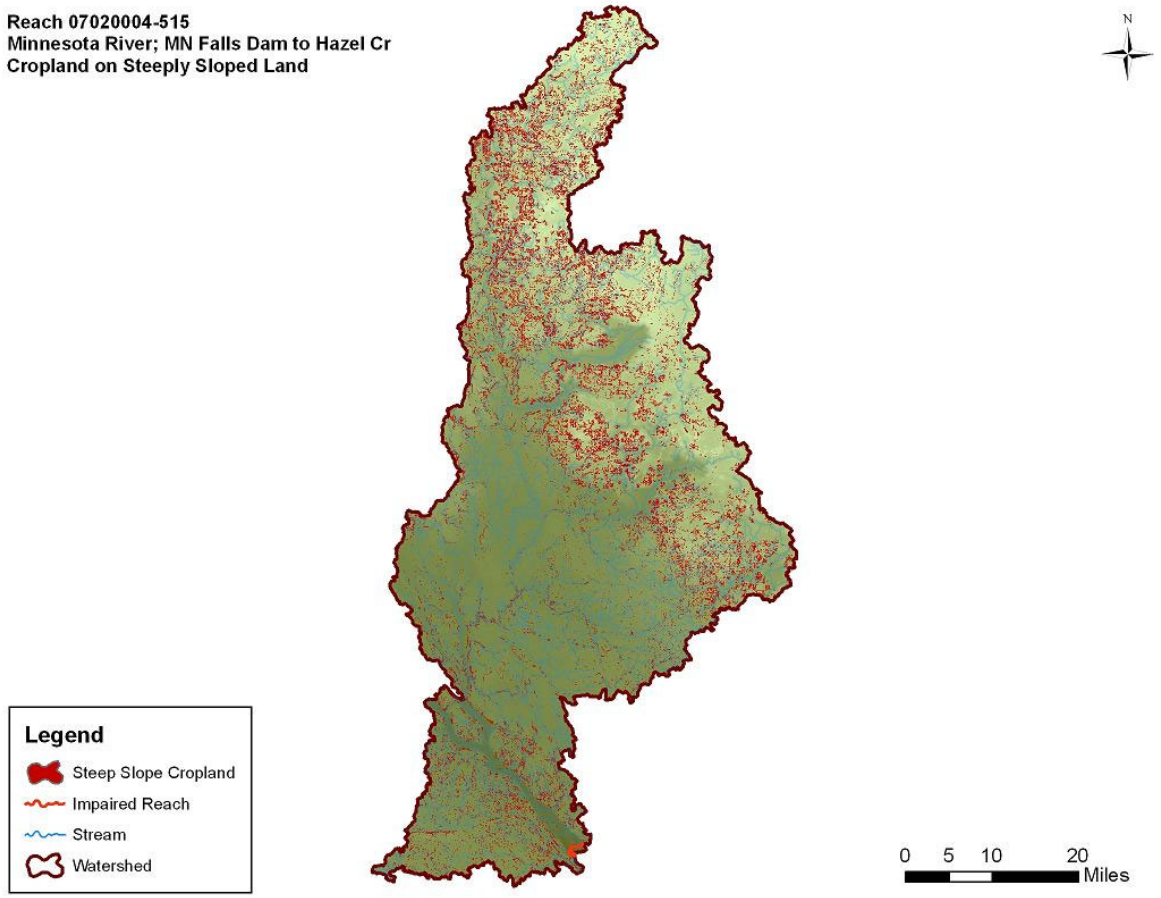
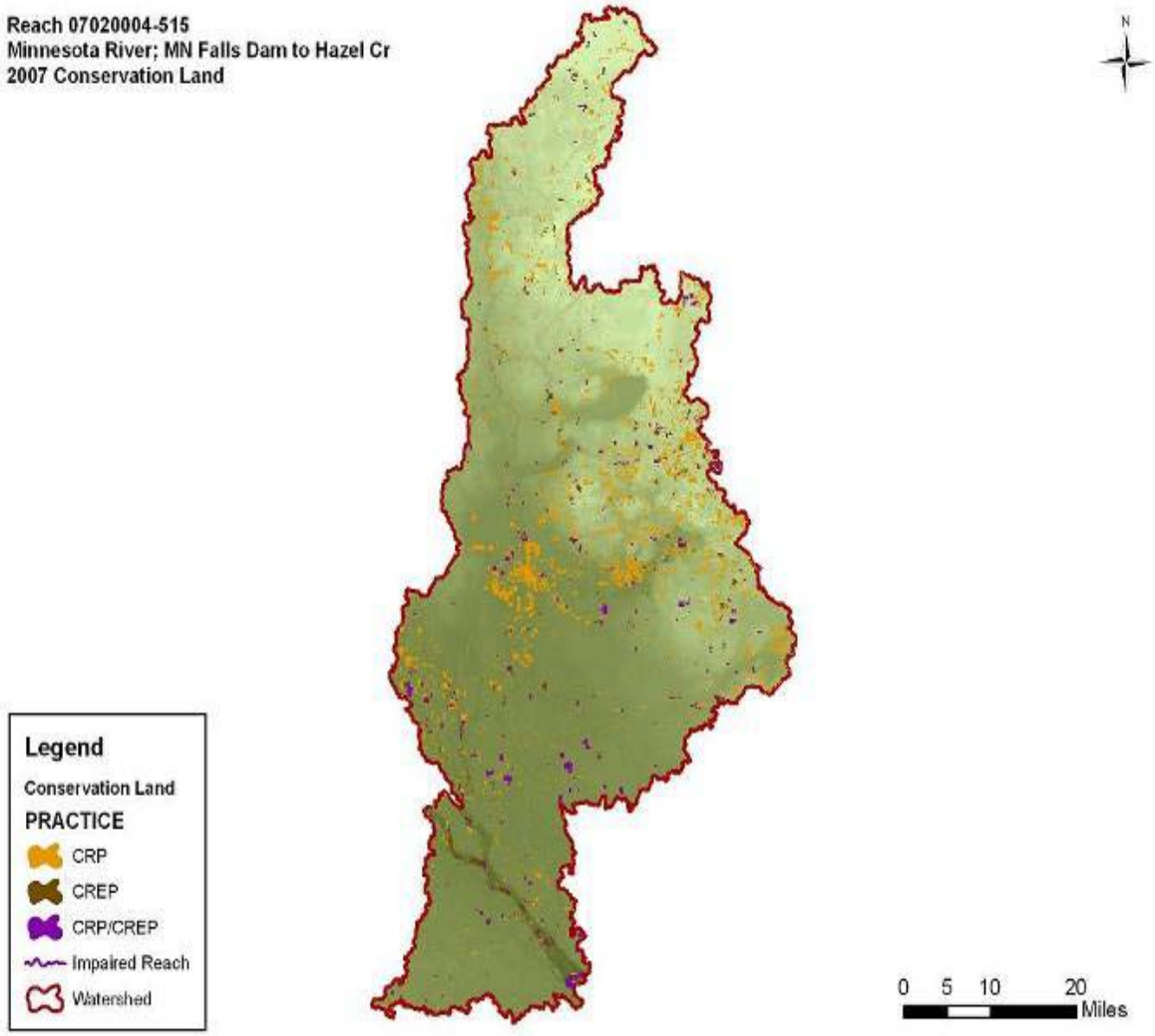


Figure 5.53 2006 Land Use Statistics for the Minnesota River; Minnesota Falls Dam to Hazel Creek.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
1,534,725.44	961,235.54	166,199.95	10.83%	17.29%

Figure 5.54 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Minnesota Falls Dam to Hazel Creek.



PROGRAM	ACRES	PERCENT
CRP	106,040.82	3.98%
CREP	25,382.11	0.95%
CRP,CREP	116,288.31	4.37%

Figure 5.55 Conservation Land Locations and Statistics for the Minnesota River; Minnesota Falls Dam to Hazel Creek.

Table 5.12 Minnesota River; Minnesota Falls to Hazel Creek TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	1141	320	119	46	7
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	2.55	2.55	2.55	2.55	2.55
Communities Subject to MS4 NPDES Requirements	1.19	0.33	0.12	0.05	0.01
Construction and Industrial Stormwater	0.19	0.05	0.02	0.01	0.01
Load Allocation	1022.97	285.06	104.40	38.79	3.73
Margin of Safety	114.10	32.00	11.90	4.60	0.70

5.12 Minnesota River; Timms Creek to Redwood River

Reach AUID:
07020004-509

Stream Status:
Impaired Stream Reach (mercury, PCB, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

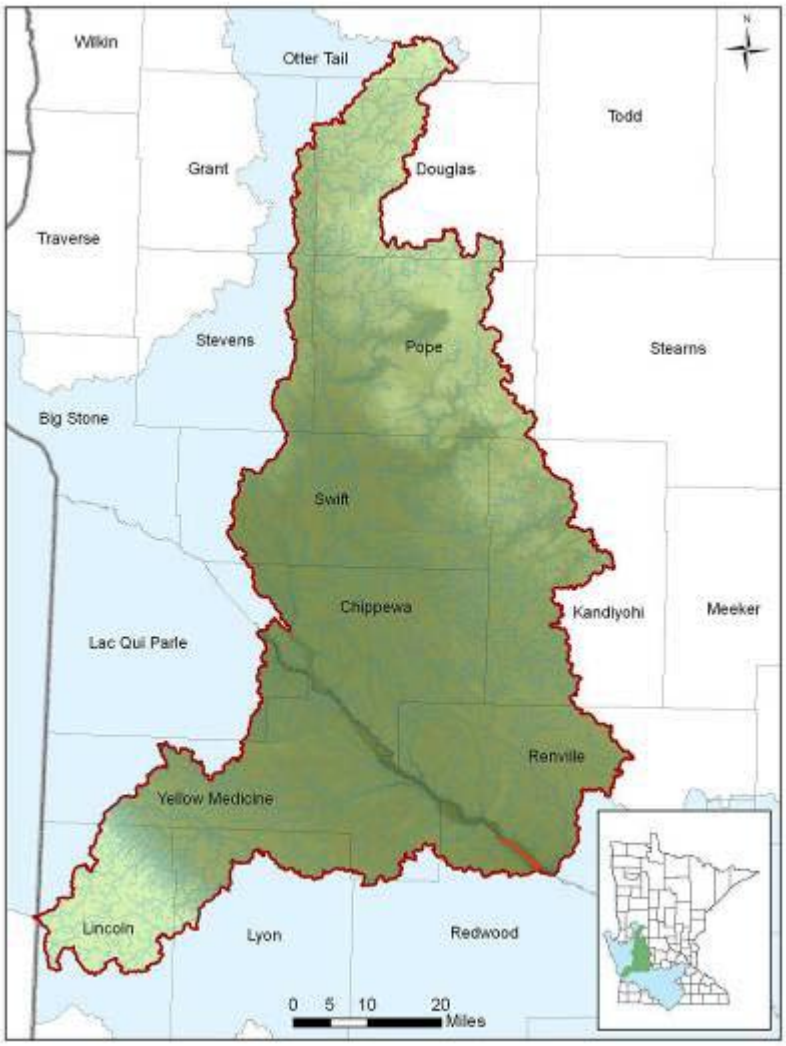
Impaired Segment Length:
9.32 miles

Contributing Watershed Size:
5,221,214.31 acres
8,158.18 sq. miles

Total Stream Miles:
5,489.94 miles

Elevation*:
Maximum = 1972 ft above sea level
Minimum = 816 ft above sea level
Total relief = 1156 ft

Slope*:
Maximum Slope: 61.5 percent
Minimum Slope: 0 percent
Average Slope: 1.9 percent



Counties: Chippewa, Douglas, Grant, Kandiyohi, Lac Qui Parle, Lincoln, Lyon, Otter Tail, Pope, Redwood, Renville, Stearns, Stevens, Swift, Yellow Medicine

*derived from the NED 30m DEM

This reach includes the Chippewa, Yellow Medicine and Hawk Creek watersheds previously described in the report, along with several smaller watersheds connected to the main stem of the Minnesota River. The land use is similar within these minor watershed areas with direct connection to the Minnesota River.

The impaired reach's watershed encompasses 4,158 square miles, and has connections with three ecoregion systems including the Northern Glaciated Plains in the Yellow Medicine and Chippewa River watersheds, the Northern Central Hardwood Forests in the eastern Chippewa and the Western Corn Belt Plains in parts of the Hawk Creek Watershed. This variety of geologic features is due in part to the draining of Glacial Lake Agassiz by the Glacial River Warren and its associated valley. This reach includes the only sets of rapids and waterfalls on the Minnesota River.

Figures 5.56 and 5.57 show the primary land use as agriculture, with corn and soybeans the main crops. Agricultural practices account for approximately 69 percent of land use, with grassland the next highest percentage at approximately 10 percent. Developed land in the watershed is slightly more the eight percent of the land.

Figure 5.58 shows steeply-sloped cropland within the watershed. Described as land with a slope greater than three percent, approximately 14 percent of agricultural land meets the slope criteria. In areas such as the Yellow Medicine River Watershed, where a majority of land (72 percent) is classified as having high water erosion potential, these areas could be targeted for sediment reduction.

Conservation practices including CREP and CRP have been somewhat well received within the watersheds with 6.84 percent of the land in some type of program. Figure 5.59 shows the percentage and location of practices within the watershed. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

For this reach of the Minnesota River, the TSS surrogate value for 25 NTUs was determined to be 75 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less.

Table 5.13 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. There is a slight difference between the loads presented on the load duration curve and the loading capacity in the table due to differences in flows. The duration curve was developed based on the flows from the closest USGS flow gage, which is near the city of Montevideo (Figure 5.51). To determine the loading capacity in the table, the MPCA estimated the flows in this reach by using a watershed area ratio of 1.32.

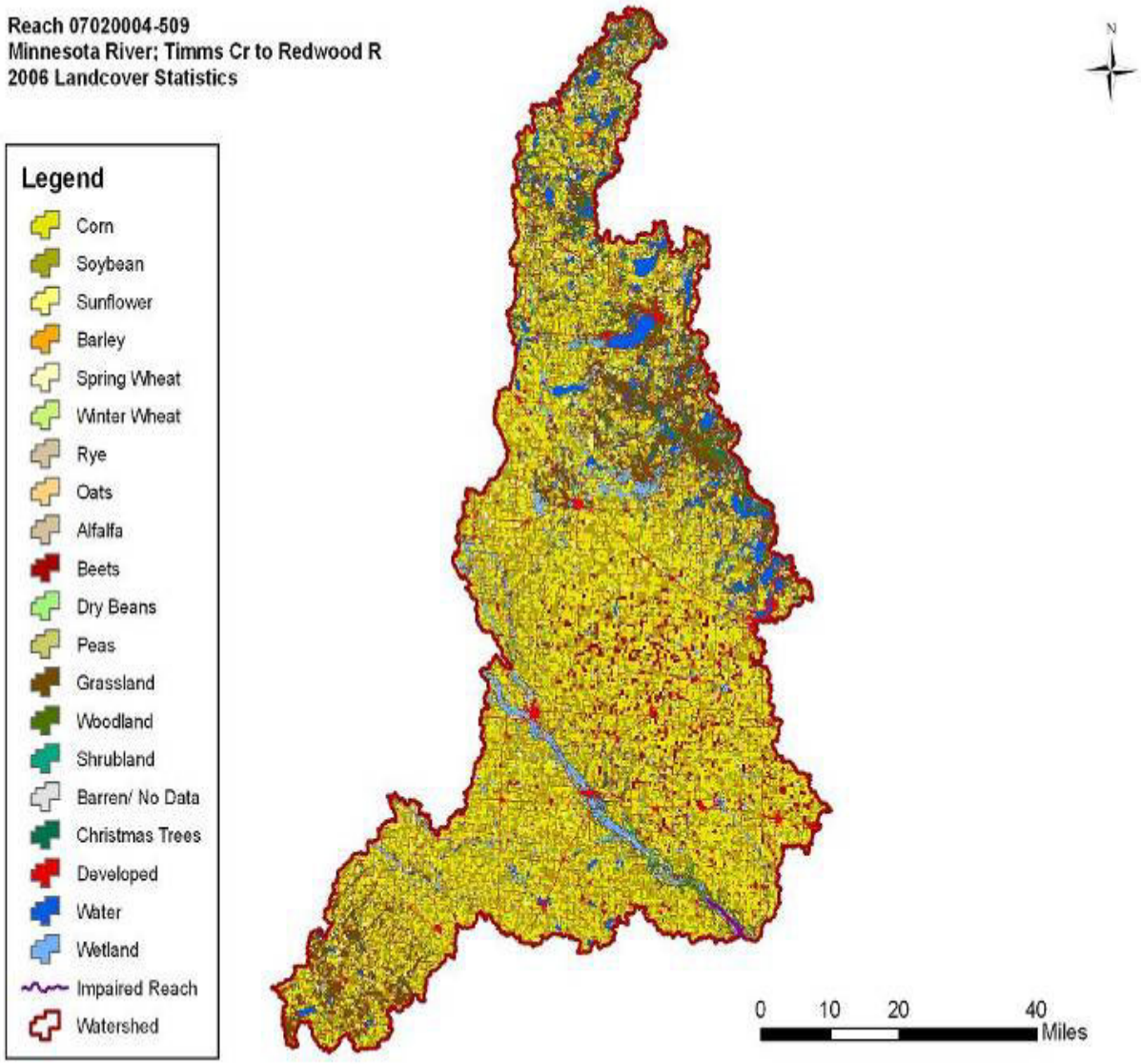


Figure 5.56 2006 Land Cover Map for the Minnesota River; Timms Creek to Redwood River.

LANDUSE	ACRES	PERCENT
Corn	901,726.14	33.88%
Soybean	743,801.59	27.95%
Sunflower	600.56	0.02%
Barley	72.84	0.00%
Spring Wheat	56,430.63	2.12%
Winter Wheat	423.11	0.02%
Rye	34.87	0.00%
Oats	153.43	0.01%
Alfalfa	43,926.48	1.65%
Beets	69,512.87	2.61%
Dry Beans	2,647.91	0.10%
Peas	2,668.83	0.10%
Grassland	268,224.69	10.08%
Woodland	96,815.71	3.64%
Shrubland	48.82	0.00%
Barren/No Data	584.29	0.02%
Christmas Trees	154.98	0.01%
Developed	218,543.64	8.21%
Water	99,266.79	3.73%
Wetland	155,639.30	5.85%
Total	2,661,277.51	100.00%

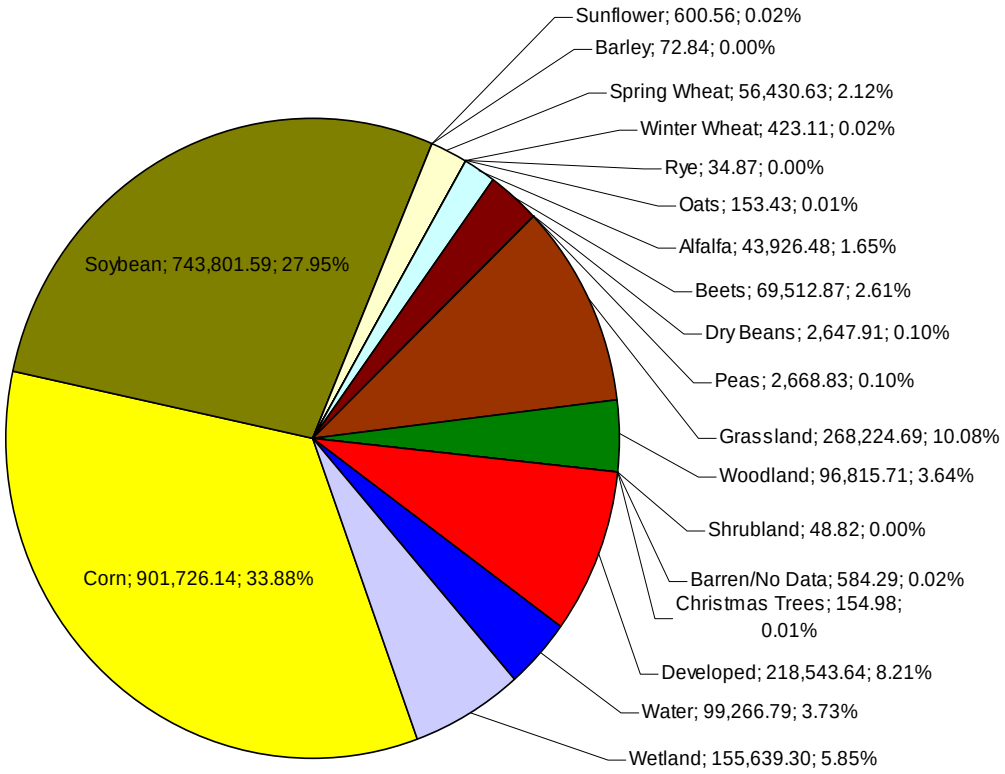
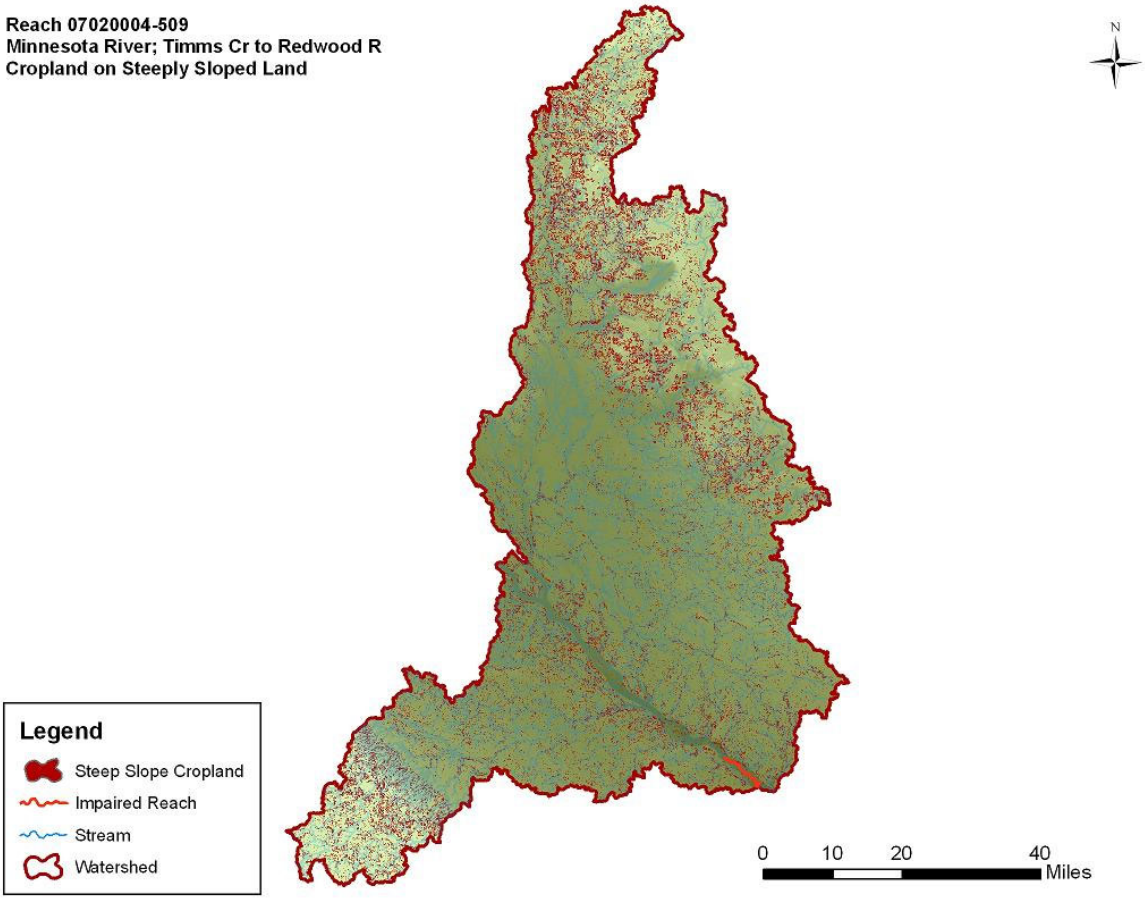
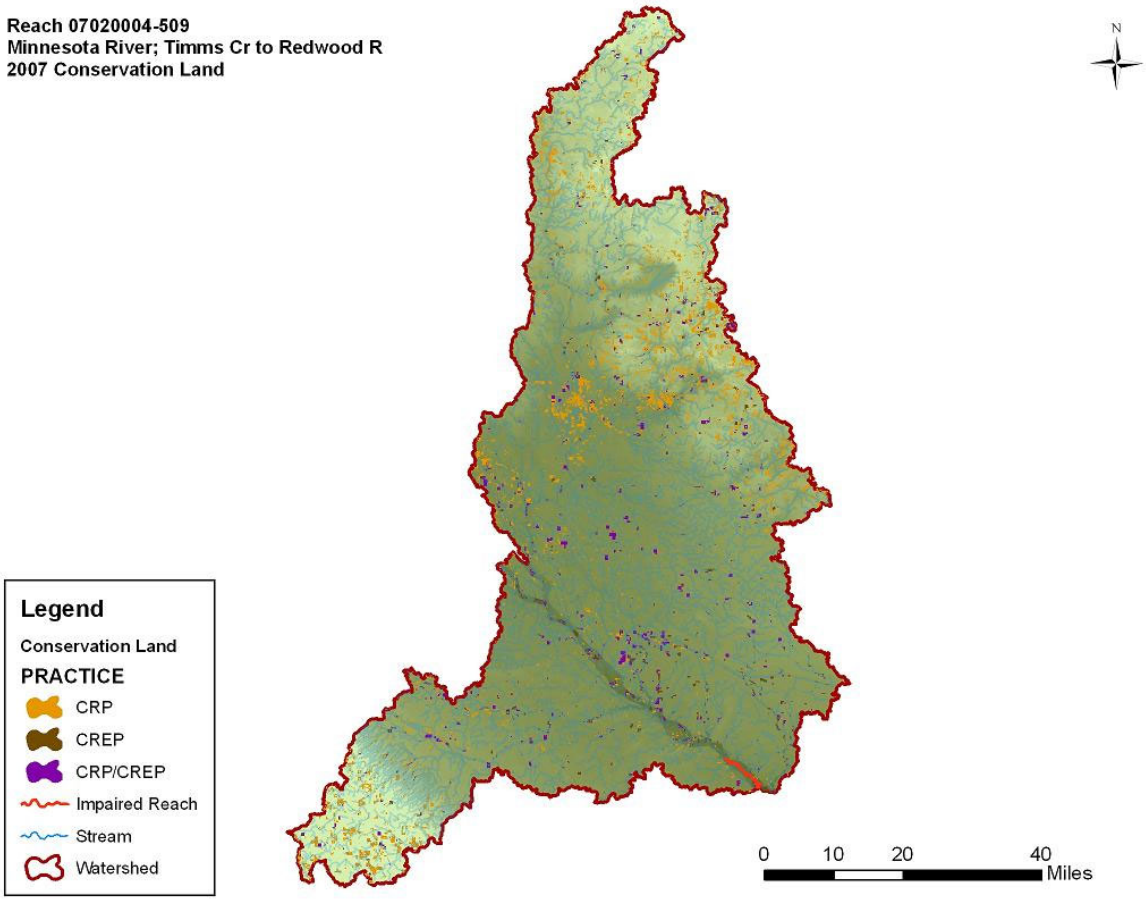


Figure 5.57 2006 Land Use Statistics for the Minnesota River; Timms Creek to Redwood River.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
2,661,236.95	1,821,999.27	262,084.98	9.85%	14.38%

Figure 5.58 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Timms Creek to Redwood River.



PROGRAM	ACRES	PERCENT
CRP	162,360.83	6.10%
CREP	49,275.26	1.85%
CRP,CREP	182,022.23	6.84%

Figure 5.59 Conservation Land Locations and Statistics for the Minnesota River; Timms Creek to Redwood River.

Table 5.13 Minnesota River, Timms Creek to Redwood River TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	1454	407	152	59	9
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	5.57	5.57	5.57	5.57	5.57
Communities Subject to MS4 NPDES Requirements	3.34	0.93	0.35	0.14	0.02
Construction and Industrial Stormwater	0.23	0.07	0.02	0.01	0.01
Load Allocation	1299.46	359.73	130.86	47.38	2.50
Margin of Safety	145.40	40.70	15.20	5.90	0.90

5.13 Minnesota River; Shanaska Creek to Rogers Creek

Reach AUID:
07020007-501

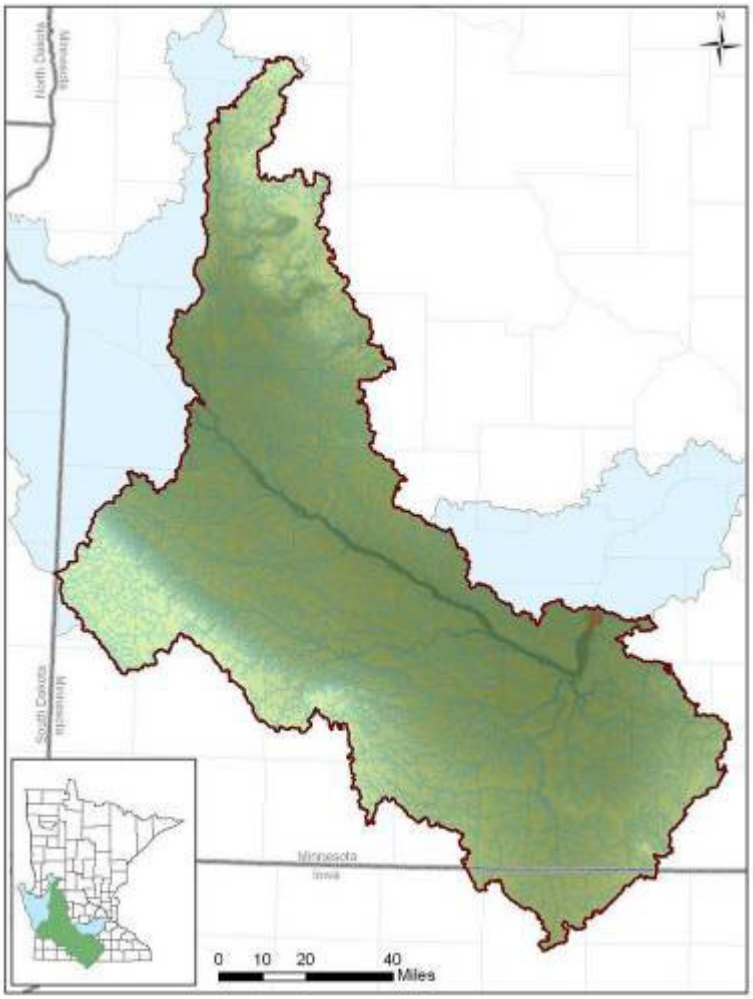
Stream Status:
Impaired Stream Reach (bacteria, mercury, PCB, turbidity, aquatic consumption, aquatic life, and aquatic recreation). This report only addresses the turbidity impairment.

Impaired Segment Length:
6.39 miles

Contributing Watershed Size:
9,640,543.83 acres
(9,423,706.3 acres MN)
15,063.41 sq. miles
(14,724.6 sq. miles MN)

Total Stream Miles:
14,257.5 miles
(13,768.91 miles MN)

Elevation*:
Maximum = 1992 ft above sea level
Minimum = 734 ft above sea level
Total relief = 1258 ft



Slope*:
Maximum Slope: 84.4 percent
Minimum Slope: 0 percent
Average Slope: 1.8 percent

Counties: Blue Earth, Brown, Chippewa, Cottonwood, Douglas, Faribault, Freeborn, Grant, Jackson, Kandiyohi, Lac Qui Parle, LeSueur, Lincoln, Lyon, Martin, Murray, Nicollet, Otter Tail, Pipestone, Pope, Redwood, Renville, Sibley, Stearns, Steele, Stevens, Swift, Waseca, Watonwan, Yellow Medicine, Emmet (Iowa), Kossuth (Iowa), Winnebago (Iowa)

*derived from the NED 30m DEM

Major watersheds included in this impaired reach are the Chippewa, Yellow Medicine, Hawk Creek, Redwood, Cottonwood, Middle Minnesota, Watonwan, Blue Earth and LeSueur. This particular reach adds an additional 82 square miles of minor watersheds, as compared to the previous impaired reach.

The watershed is dominated by agricultural use (Figures 5.60 and 5.61), with 76 percent of the land in some form of agricultural production. Corn and soybeans make up the major share of production at 73 percent of the land use. Developed land remains at about eight percent throughout the watershed.

In this large share of the Minnesota River basin, the steeply-sloped land analysis shows that 13.42 percent of the land is greater than three percent slope (Figure 5.62).

Conservation programs in the watershed are shown in Figure 5.63. Within the larger basin, the amount of lands enrolled in conservation programs is approximately 320,095 acres or 4.66 percent of the total land area. A major portion of these lands are enrolled in the CRP program which fluctuates with landowner participation due to economic and incentives options. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

The Load Duration Curve depicts the daily TSS loads to achieve the 25 NTU standard (Figure 5.64). For this reach, the 25 NTU standard was determined to be 100 mg/L. The load varies based on flow conditions in the five flow zones listed. Samples collected that exceed the standard tend to occur in the high to very high flow regime with a majority of the samples associated with storm runoff.

Table 5.14 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. There is a slight difference between the loads presented on the load duration curve and the loading capacity in the table due to differences in flows. The duration curve was developed based on the flows from the closest USGS flow gage, which is near the city of Mankato. To determine the loading capacity in the table, the MPCA estimated the flows in this reach by using a watershed area ratio of 1.01.

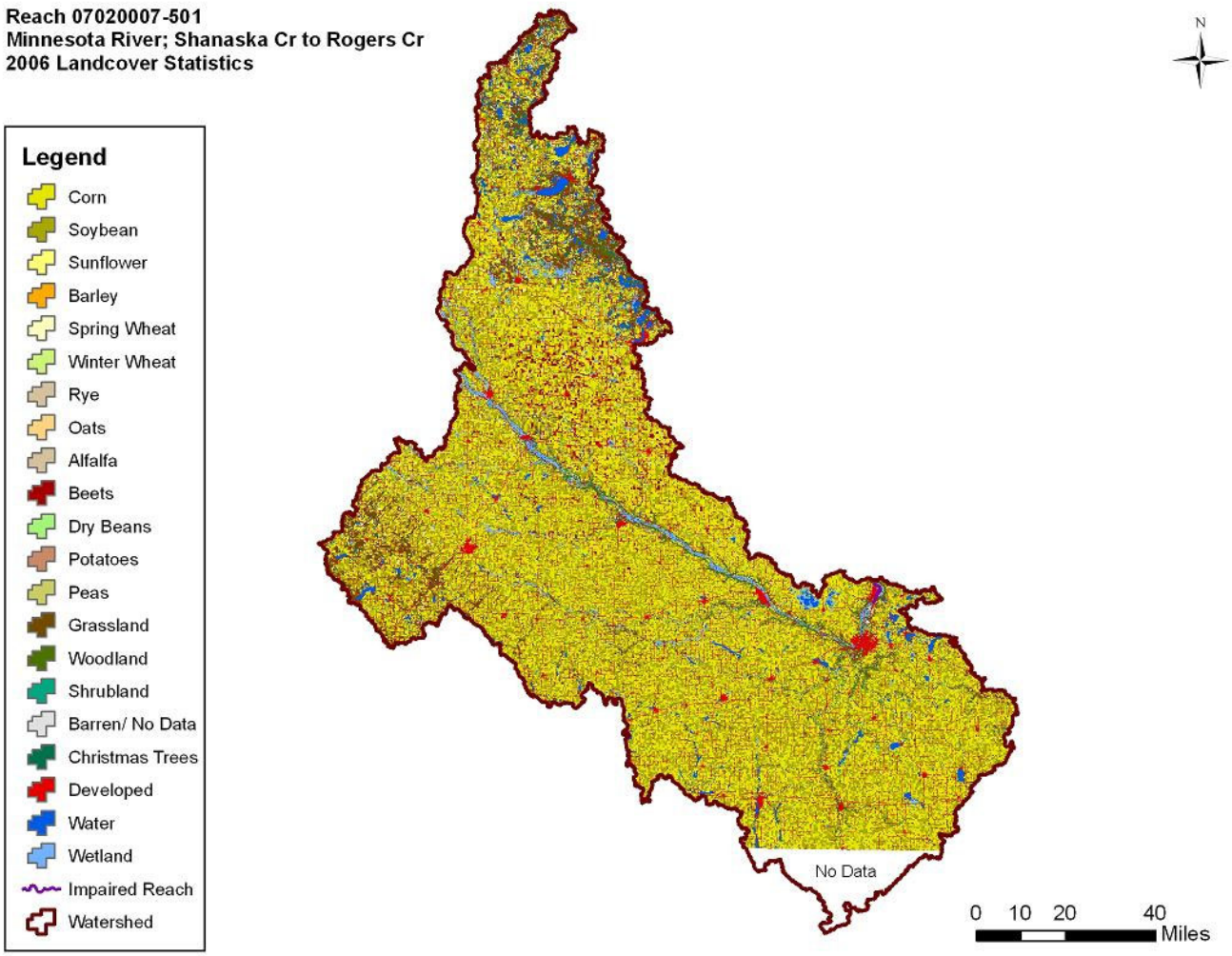


Figure 5.60 2006 Land Cover Map for the Minnesota River; Shanaska Creek to Rogers Creek.

LANDUSE	ACRES	PERCENT
Corn	2,737,577.93	39.88%
Soybean	2,288,194.18	33.34%
Sunflower	602.11	0.01%
Barley	416.13	0.01%
Spring Wheat	62,636.21	0.91%
Winter Wheat	445.58	0.01%
Rye	289.82	0.00%
Oats	465.73	0.01%
Alfalfa	64,926.88	0.95%
Beets	76,751.42	1.12%
Dry Beans	2,867.99	0.04%
Potatoes	18.60	0.00%
Peas	7,922.03	0.12%
Grassland	424,854.35	6.19%
Woodland	210,828.51	3.07%
Shrubland	65.87	0.00%
Barren/No Data	1,915.61	0.03%
Christmas Trees	154.98	0.00%
Developed	551,488.30	8.03%
Water	169,525.92	2.47%
Wetland	261,794.38	3.81%
Total	6,863,742.53	100.00%

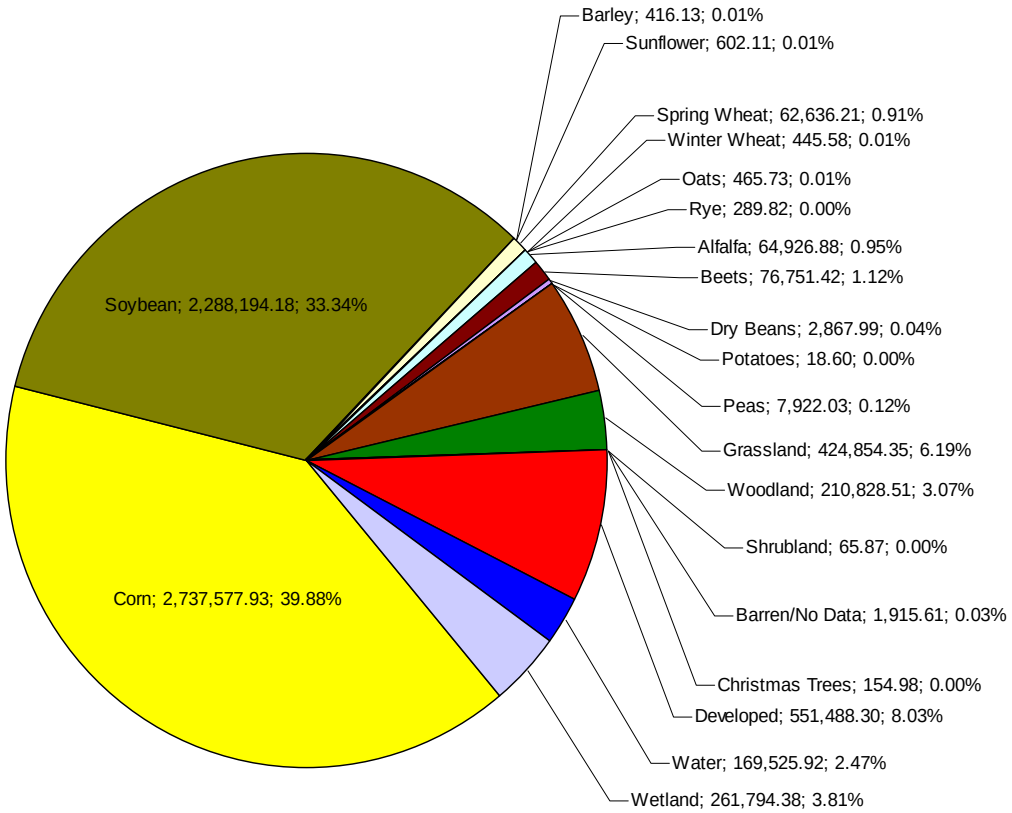
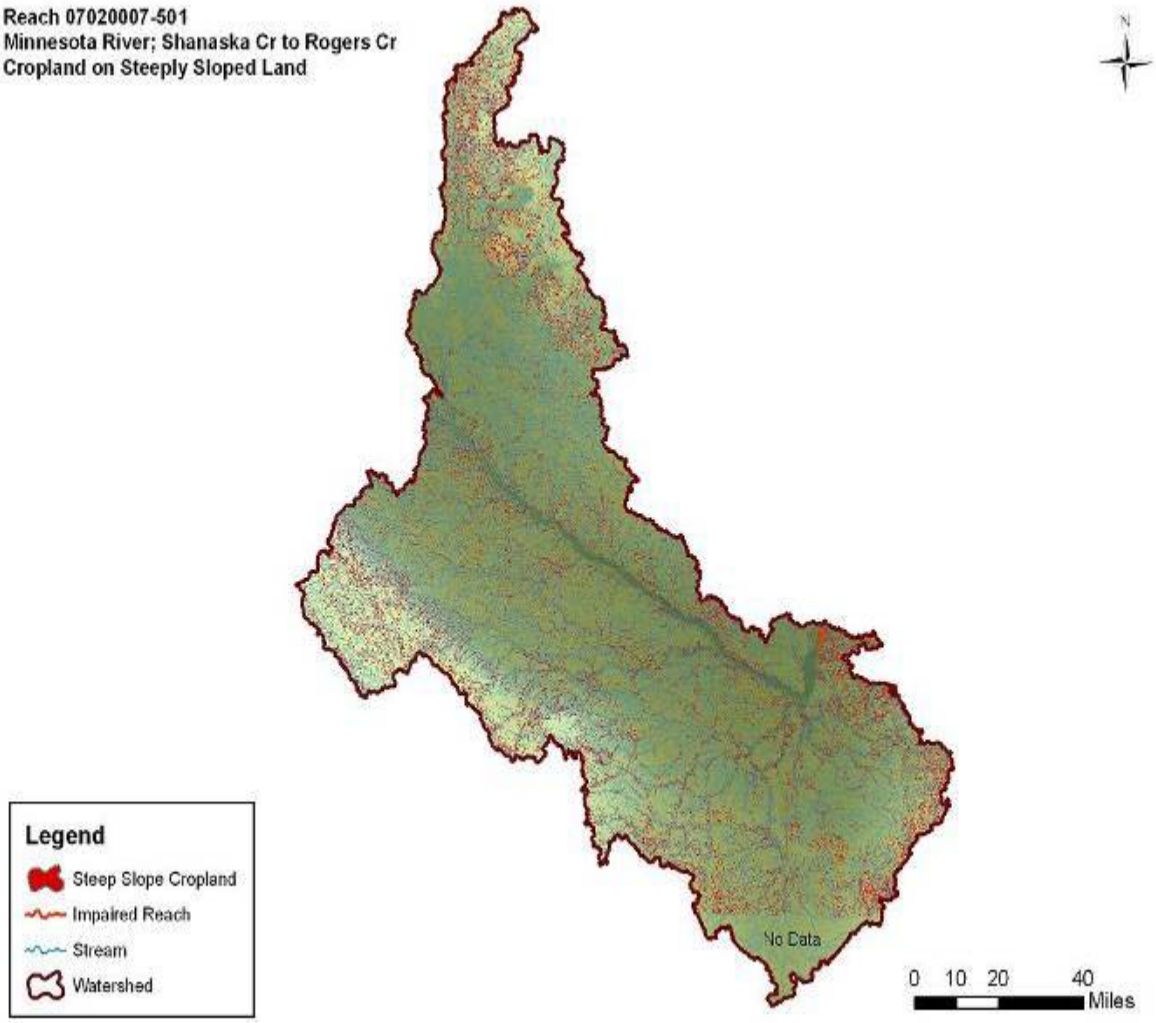
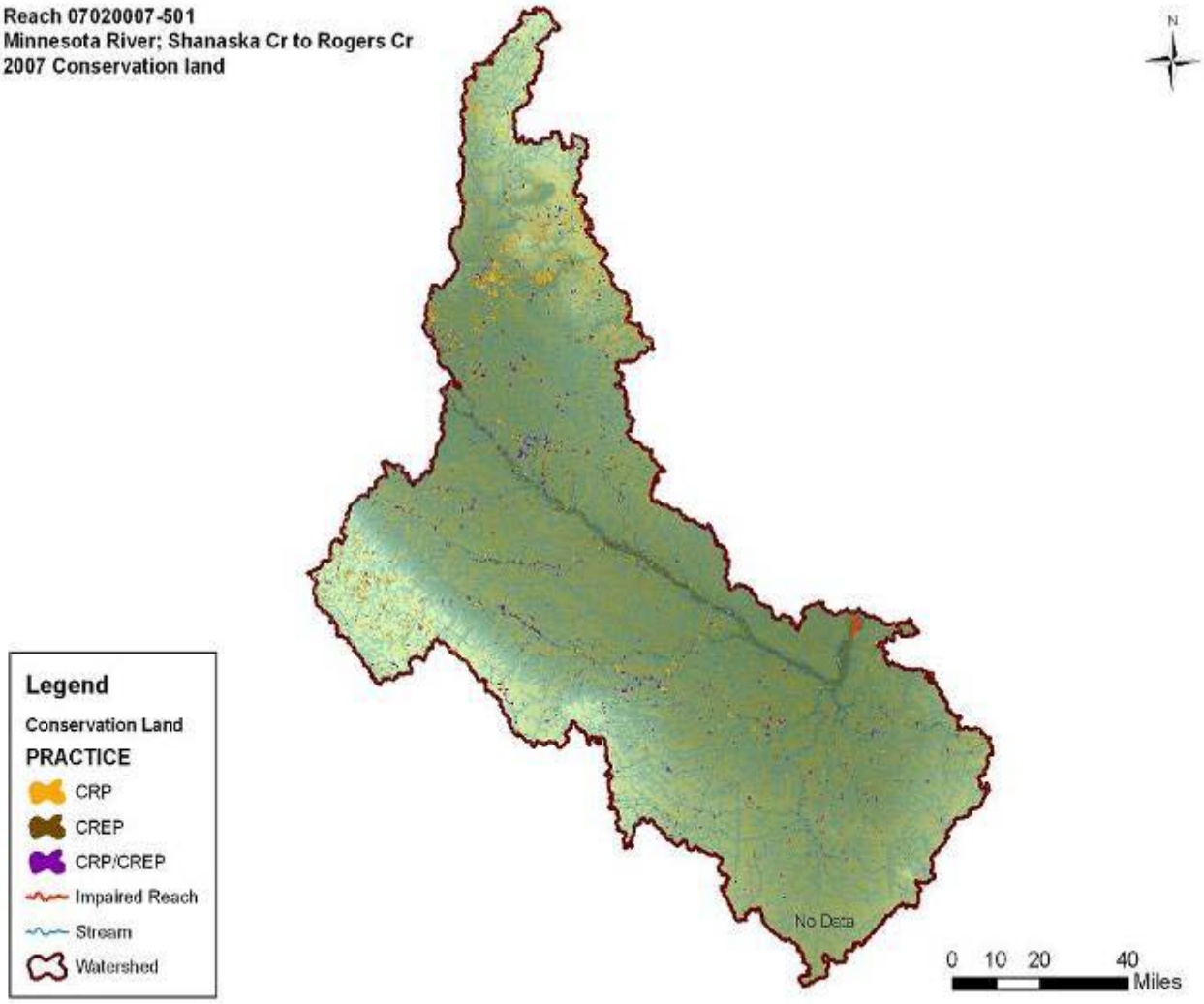


Figure 5.61 2006 Land Use Statistics for the Minnesota River; Shanaska Creek to Rogers Creek.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
6,863,742.53	5,243,114.62	703,703.22	10.25%	13.42%

Figure 5.62 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Shanaska Creek to Rogers Creek.



PROGRAM	ACRES	PERCENT
CRP	278,881.81	4.06%
CREP	107,853.40	1.57%
CRP,CREP	320,095.87	4.66%

Figure 5.63 Conservation Land Locations and Statistics for the Minnesota River; Shanaska Creek to Rogers Creek.

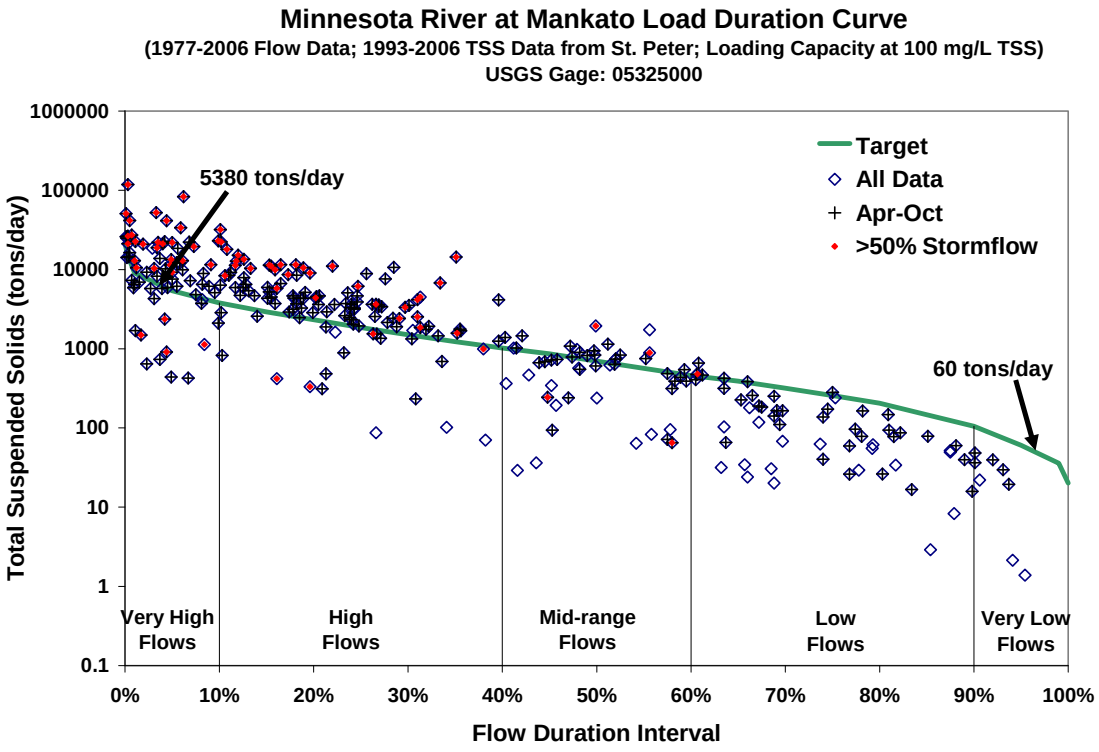
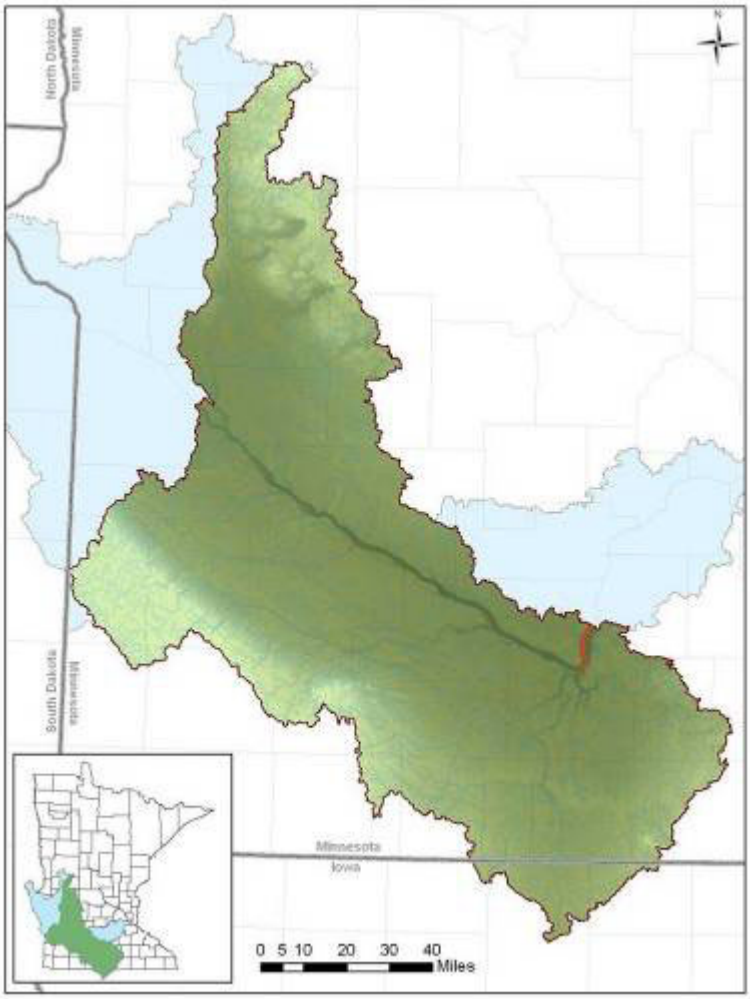


Figure 5.64 Minnesota River; Shanaska Creek to Rogers Creek Load Duration Curve.

Table 5.14 Minnesota River; Shanaska Creek to Rogers Creek TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	5454	1860	709	260	61
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	32.95	32.95	32.95	32.95	32.95
Communities Subject to MS4 NPDES Requirements	19.38	6.61	2.52	0.92	0.22
Construction and Industrial Stormwater	0.73	0.25	0.10	0.03	0.01
Load Allocation	4855.54	1634.19	602.53	200.09	21.72
Margin of Safety	545.40	186.00	70.90	26.00	6.10

5.14 Minnesota River; Blue Earth R to Shanaska Cr



Reach AUID:
07020007-502

Stream Status:
Impaired Stream Reach (bacteria, mercury, PCB, turbidity, aquatic consumption, aquatic life, and aquatic recreation). This report only addresses the turbidity impairment.

Impaired Segment Length:
16.84 miles

Contributing Watershed Size:
9,587,948.84 acres
(9,371,130.51 MN)
14,981.23 square miles
(14,642.45 MN)

Total Stream Miles:
14,147.25 miles
(13,658.67 MN)

Elevation*:
Maximum = 1992 ft above sea level
Minimum = 741 ft above sea level
Total relief = 1251 ft

Slope*:
Maximum Slope: 84.4 percent; Minimum Slope: 0 percent; Average Slope: 1.81 percent

Counties:
Blue Earth, Brown, Chippewa, Cottonwood, Douglas, Faribault, Freeborn, Grant, Jackson, Kandiyohi, Lac Qui Parle, LeSueur, Lincoln, Lyon, Martin, Murray, Nicollet, Otter Tail, Pipestone, Pope, Redwood, Renville, Sibley, Stearns, MN, Steele, Stevens, Swift, Waseca, Watonwan, Yellow Medicine, Emmet (Iowa), Kossuth (Iowa), Winnebago (Iowa).

*derived from the NED 30m DEM

Major watersheds included in this impaired reach are the Chippewa, Yellow Medicine, Hawk Creek, Redwood, Cottonwood, Middle Minnesota, Watonwan, Blue Earth and LeSueur. Of particular note is the addition of the Middle Minnesota Watershed where the drainage relies less on a main tributary than on a number of relatively small streams and springs draining to numerous ravines and valleys.

The watershed is dominated by agricultural use (Figures 5.65 and 5.66) with 76 percent of the land in some form of agricultural production. Corn and soybeans comprise the major crops at 73 percent of the land use. Developed land remains at about eight percent throughout the watershed.

Steeply-sloped land analysis shows that 14.47 percent of the land is in the greater than three percent slope category (Figure 5.67). The Glacial River Warren's impact is reflected in the these lower reaches where tributary streams generally have a low gradient until they reach the steep walls of the Minnesota River Valley, where they can drop upwards of 200 feet within a short distance. This fact, along with land use concerns, can create sediment control problems.

Conservation programs are shown in Figure 5.68. Within the larger basin, the amount of lands enrolled in conservation programs is approximately 318,343 acres or 4.67 percent of the total land area. A major portion of these lands are enrolled in the CRP program which fluctuates with landowner participation. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

For this reach of the Minnesota River, the TSS surrogate value for 25 NTUs was determined to be 100 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less.

Table 5.15 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. The duration curve from the previous section (Figure 5.64) was used to develop the loading capacity and allocations.

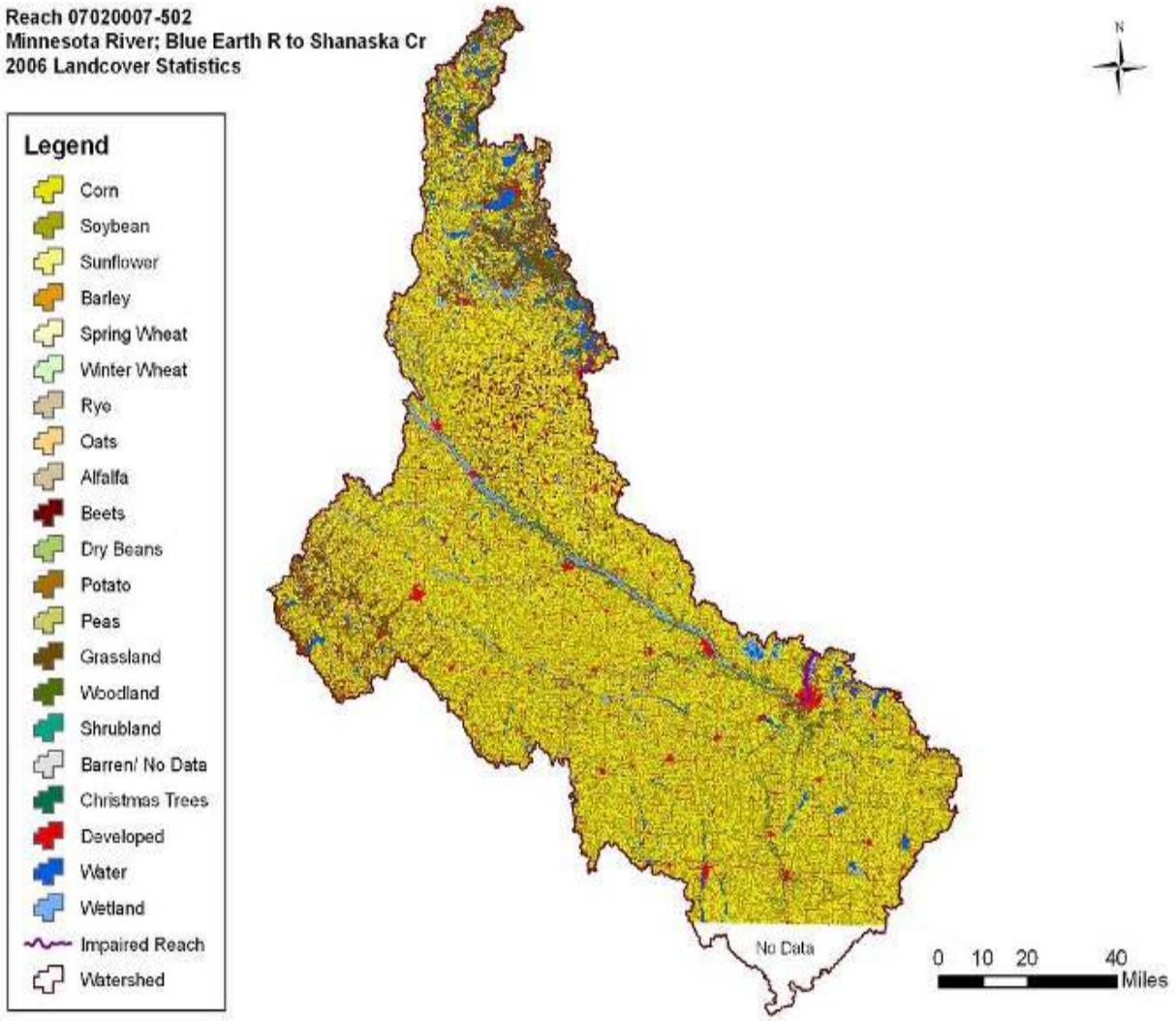


Figure 5.65 2006 Land Cover Map for the Minnesota River; Blue Earth R to Shanaska Cr.

LANDUSE	ACRES	PERCENT
Corn	2,716,416.34	39.88%
Soybean	2,274,299.05	33.39%
Sunflower	602.11	0.01%
Barley	416.13	0.01%
Spring Wheat	62,545.54	0.92%
Winter Wheat	445.58	0.01%
Rye	191.41	0.00%
Oats	465.73	0.01%
Alfalfa	64,625.43	0.95%
Beets	76,751.42	1.13%
Dry Beans	2,867.99	0.04%
Potato	18.60	0.00%
Peas	7,855.39	0.12%
Grassland	423,233.21	6.21%
Woodland	205,922.47	3.02%
Shrubland	65.87	0.00%
Barren	1,867.56	0.03%
Christmas Trees	154.98	0.00%
Developed	545,528.37	8.01%
Water	168,105.48	2.47%
Wetland	258,790.01	3.80%
Total	6,811,168.69	100.00%

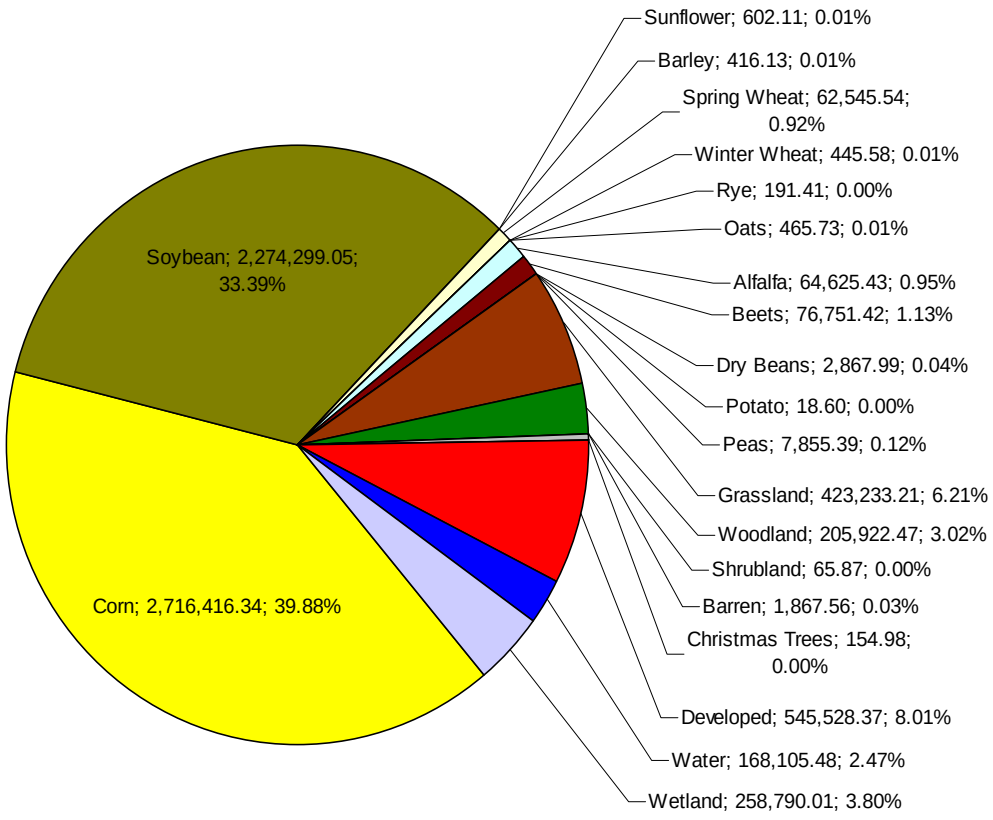
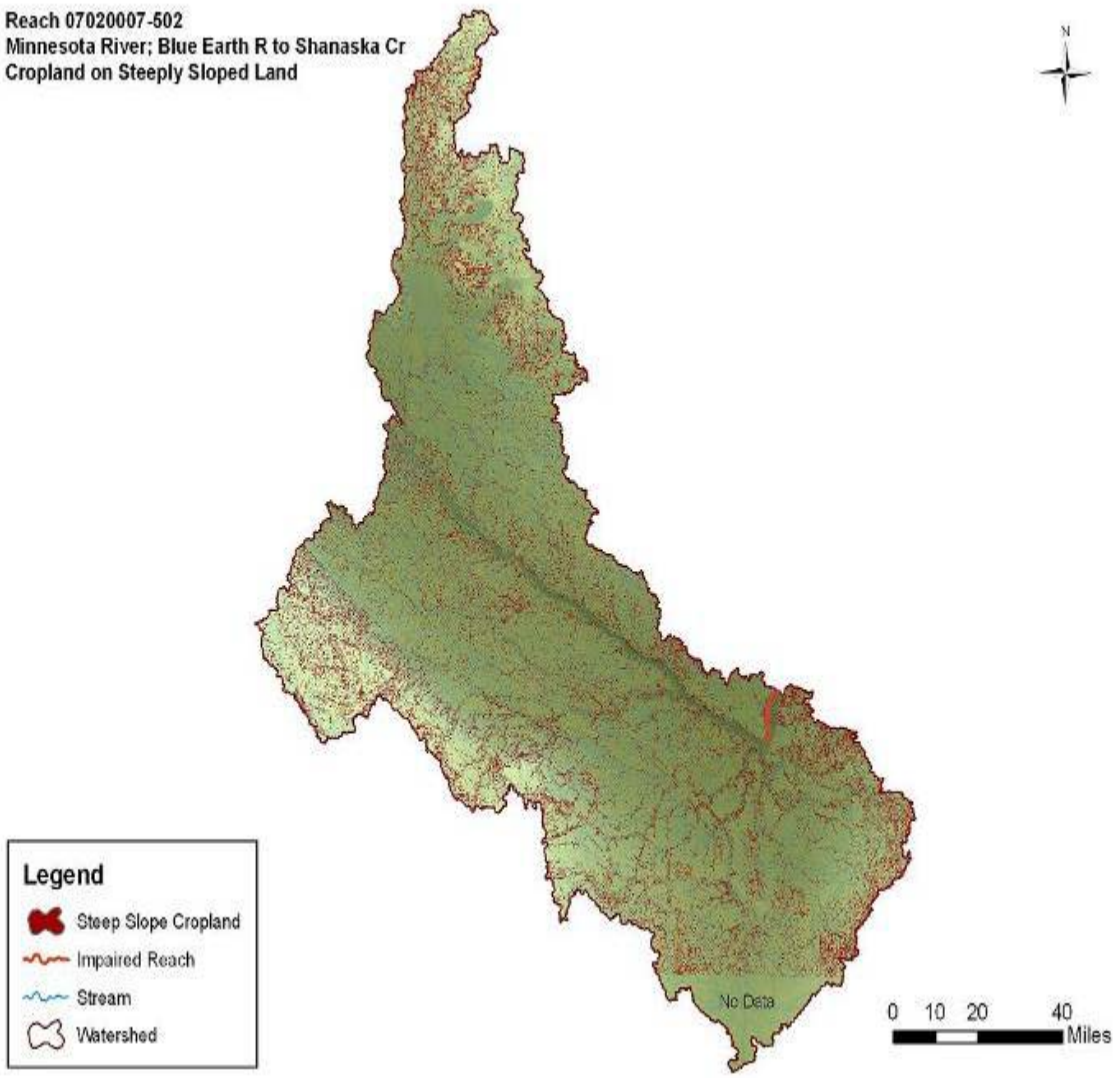
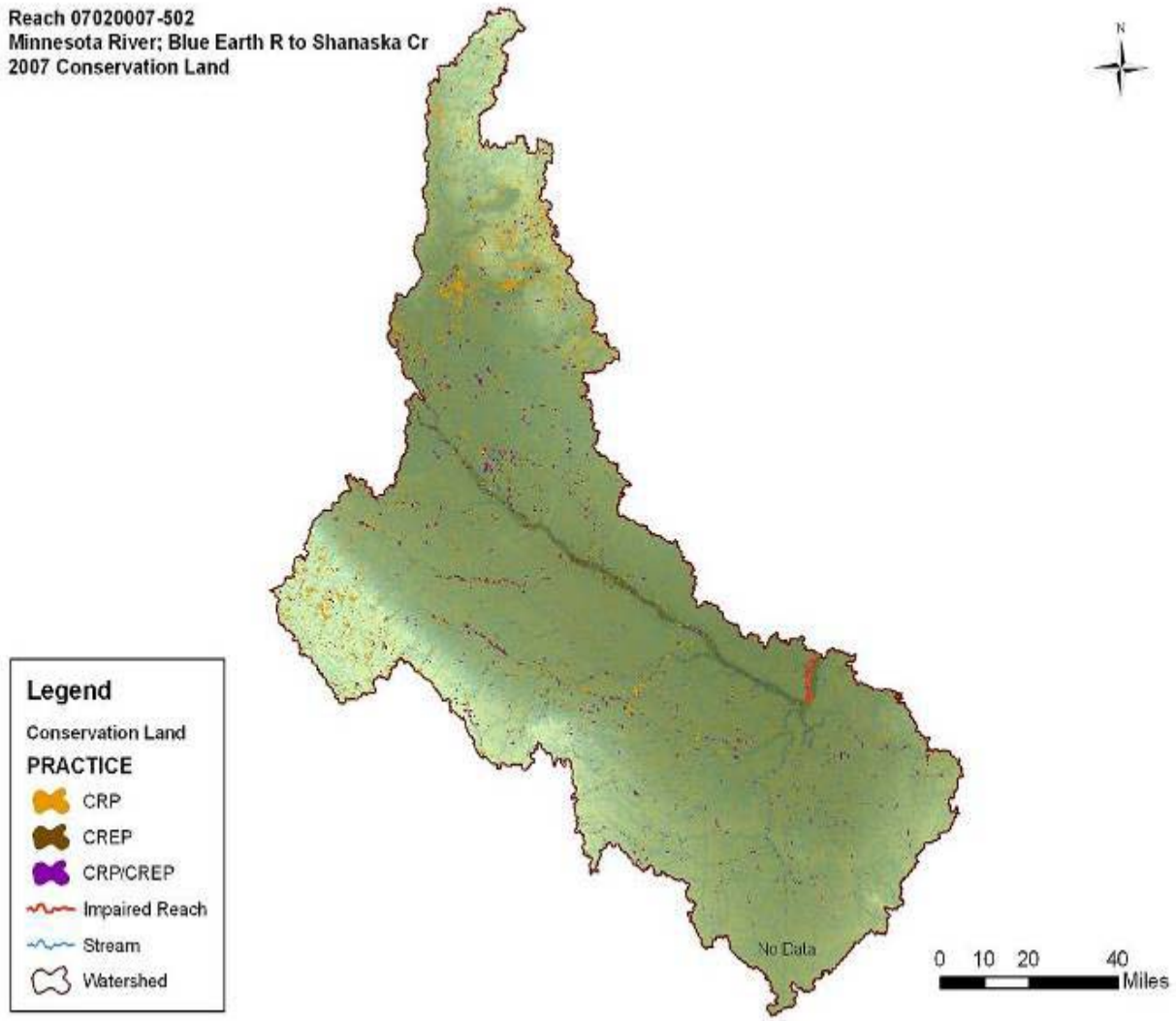


Figure 5.66 2006 Land Use Statistics for the Minnesota River; Blue Earth R to Shanaska Cr.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
6,811,168.69	5,207,500.00	753,569.49	11.06%	14.47%

Figure 5.67 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Blue Earth R to Shanaska Cr.



PROGRAM	ACRES	PERCENT
CRP	277,523.90	4.07%
CREP	107,374.61	1.58%
CRP,CREP	318,342.96	4.67%

Figure 5.68 Conservation Land Locations and Statistics for the Minnesota River; Blue Earth River to Shanaska Creek

Table 5.15 Minnesota River; Blue Earth River to Shanaska Creek TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	5380	1835	699	256	60
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	28.49	28.49	28.49	28.49	28.49
Communities Subject to MS4 NPDES Requirements	18.31	6.25	2.38	0.87	0.20
Construction and Industrial Stormwater	0.72	0.25	0.09	0.03	0.01
Load Allocation	4794.48	1616.51	598.13	201.00	25.29
Margin of Safety	538.00	183.50	69.90	25.60	6.00

5.15 Minnesota River; Swan Lake to Minneopa Cr.

Reach AUID:
07020007-505

Stream Status:
Impaired Stream Reach (mercury, PCB, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

Impaired Segment Length:
8.44 miles

Contributing Watershed Size:
7,229,007.88 acres
11,295.37 square miles

Total Stream Miles:
9,808.3 miles

Elevation*:
Maximum = 1992 ft above sea level
Minimum = 754 ft above sea level
Total relief = 1238 ft

Slope*:
Maximum Slope: 84.4 percent
Minimum Slope: 0 percent
Average Slope: 1.9 percent

Counties:
Blue Earth, Brown, Chippewa, Cottonwood, Douglas, Grant, Kandiyohi, Lac Qui Parle, Lincoln, Lyon, Murray, Nicollet, Otter Tail, Pipestone, Pope, Redwood, Renville, Sibley, Stearns, Stevens, Swift, Watonwan, Yellow Medicine

*derived from the NED 30m DEM

The Swan Lake to Minneopa Creek reach includes the addition of the full Middle Minnesota watershed along with the Chippewa, Yellow Medicine, Hawk Creek, Redwood and Cottonwood Watersheds. The southern portion of the Middle Minnesota includes the Little Cottonwood tributary to the Minnesota River. Several small direct tributaries to the Minnesota River are also added in this reach.

Land use statistics (Figures 5.69 and 5.70) show the watershed to be primarily agricultural with 37 percent of the total acres in corn production and 31 percent in soybeans. The total land area in some sort of agricultural production is 73 percent. Water and Wetlands are limited at 2.72 percent and 4.73 percent of the total land area. Loss of wetlands within the prairie areas of the watershed is estimated at 90 percent or more. A Natural Resources Conservation Service (NRCS) survey indicated that, prior to settlement, potentially 40-60 percent of the watershed in the Minnesota River basin was covered with wetlands.

Steeply-sloped land analysis for this reach (Figure 5.71) shows that 13.57 percent of the cropland in the watershed exceeds three percent slope.

Figure 5.72 shows conservation project estimates for the watershed. Total acreage that is permanently set aside in the CREP program is 82,806 acres, or approximately 1.77 percent of the watershed. The CRP related programs add an additional 232,686 acres of conservation practices to obtain a total land area of 5.69 percent in some type of program. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

For this reach of the Minnesota River, the TSS surrogate value for 25 NTUs was determined to be 100 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less.

Table 5.16 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. There is a slight difference between the loads presented on the load duration curve and the loading capacity in the table due to differences in flows. The duration curve was developed based on the flows from the closest USGS flow gage, which is near the city of Montevideo (Figure 5.51). To determine the loading capacity in the table, the MPCA estimated the flows in this reach by using a watershed area ratio of 1.83.

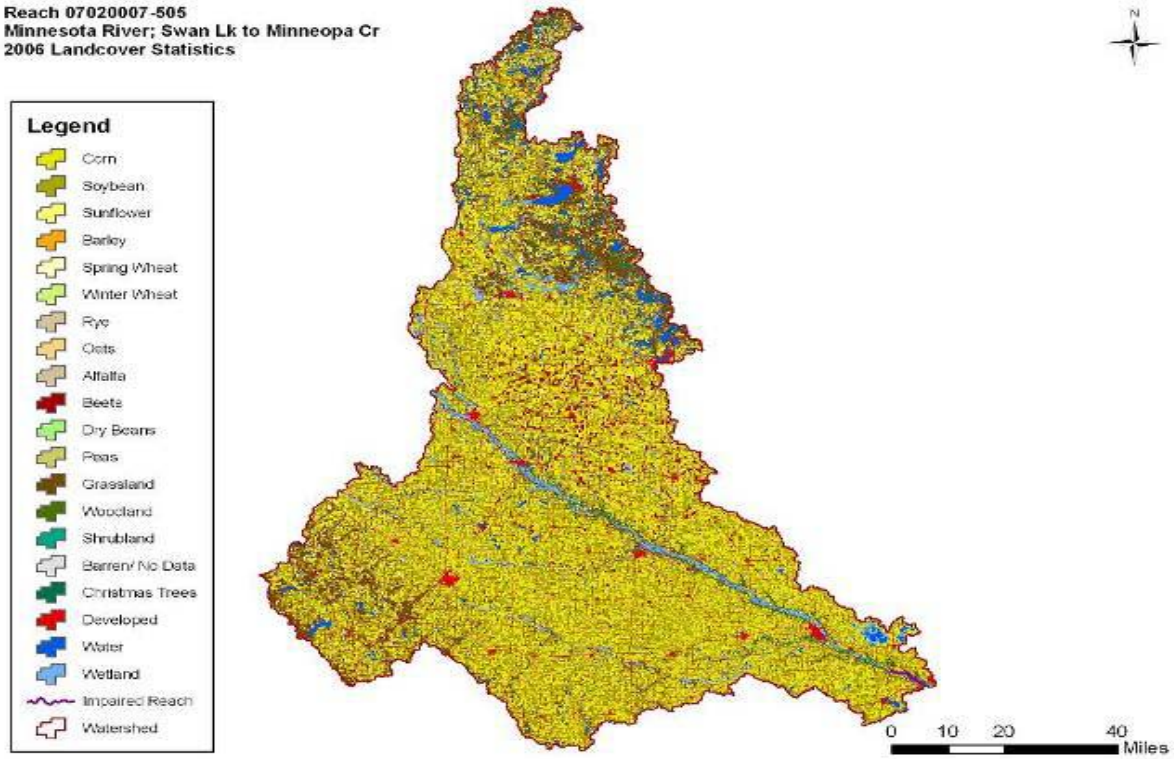


Figure 5.69 2006 Land Cover Map for the Minnesota River; Swan Lake to Minneopa Creek.

LANDUSE	ACRES	PERCENT
Corn	1,750,318.17	37.49%
Soybean	1,470,709.87	31.50%
Sunflower	602.11	0.01%
Barley	416.13	0.01%
Spring Wheat	61,836.49	1.32%
Winter Wheat	423.11	0.01%
Rye	34.87	0.00%
Oats	281.30	0.01%
Alfalfa	58,590.34	1.25%
Beets	76,446.88	1.64%
Dry Beans	2,867.99	0.06%
Peas	4,218.68	0.09%
Grassland	377,624.37	8.09%
Woodland	139,788.27	2.99%
Shrubland	59.67	0.00%
Barren/No Data	926.81	0.02%
Christmas Trees	154.98	0.00%
Developed	375,866.07	8.05%
Water	127,216.70	2.72%
Wetland	220,680.87	4.73%
Total	4,669,063.67	100.00%

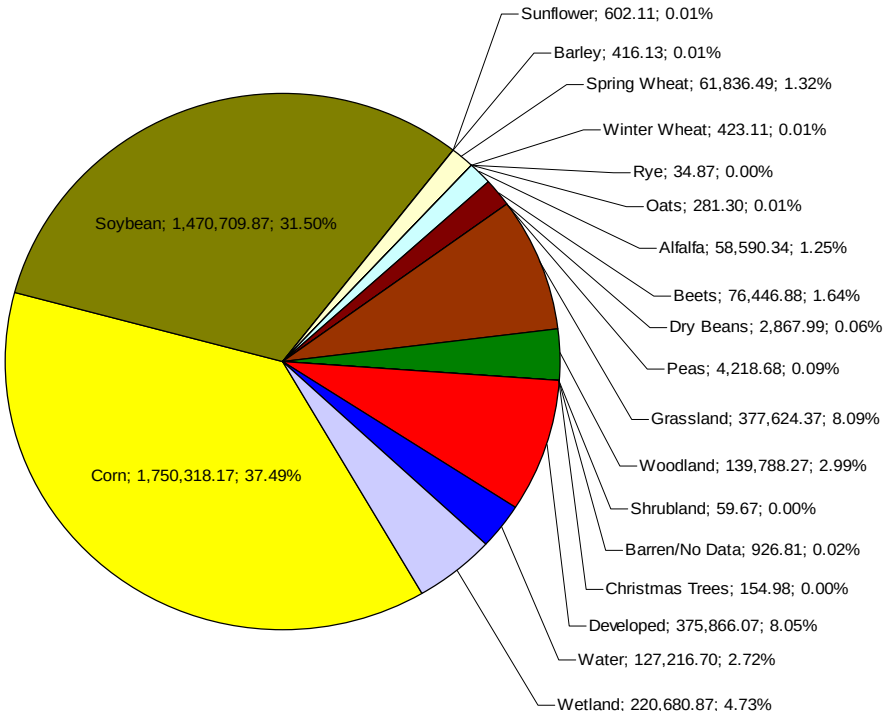
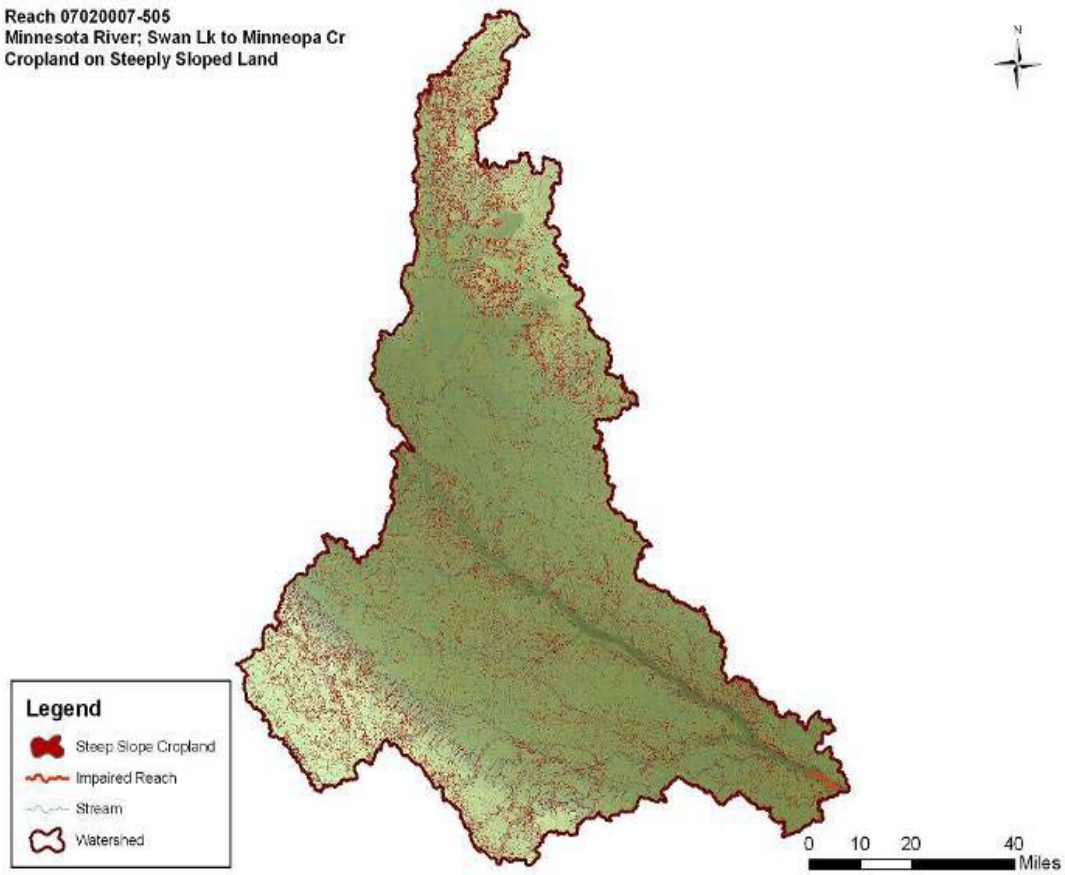
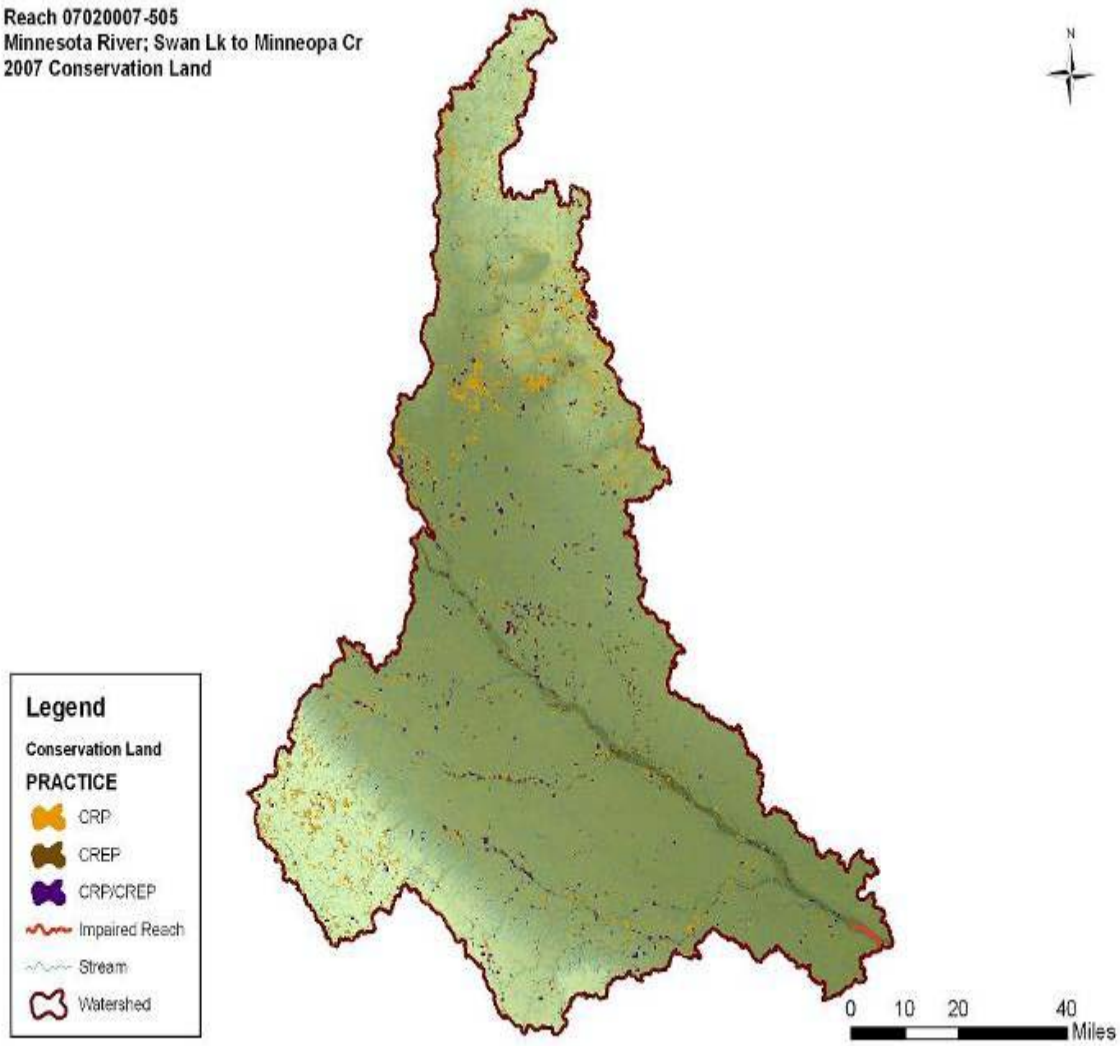


Figure 5.70 2006 Land Cover Statistics for the Minnesota River; Swan Lake to Minneopa Creek.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
4,669,063.69	3,426,745.93	464,863.59	9.96%	13.57%

Figure 5.71 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Swan Lake to Minneopa Creek.



PROGRAM	ACRES	PERCENT
CRP	232,685.96	4.98%
CREP	82,806.11	1.77%
CRP,CREP	265,813.29	5.69%

Figure 5.72 Conservation Land Locations and Statistics for the Minnesota River; Swan Lake to Minneopa Creek.

Table 5.16 Minnesota River; Swan Lake to Minneopa Creek TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	2680	750	279	109	17
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	13.00	13.00	13.00	13.00	13.00
Communities Subject to MS4 NPDES Requirements	10.58	2.96	1.10	0.43	0.07
Construction and Industrial Stormwater	0.52	0.14	0.05	0.02	0.01
Load Allocation	2387.90	658.89	236.94	84.65	2.22
Margin of Safety	268.00	75.00	27.90	10.90	1.70

5.16 Minnesota River; Cottonwood R to Little Cottonwood R

Reach AUID:
07020007-503

Stream Status:
Impaired Stream Reach (mercury, PCB, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

Impaired Segment Length:
7.4 miles

Contributing Watershed Size:
6,934,058.66 acres
10,834.51 square miles

Total Stream Miles:
9,198.09 miles

Elevation*:
Maximum = 1992 ft above sea level
Minimum = 774 ft above sea level
Total relief = 1218 ft

Slope*:
Maximum Slope: 74.3 percent
Minimum Slope: 0 percent
Average Slope: 1.9 percent

Counties:
Blue Earth, Brown, Chippewa, Cottonwood, Douglas, Grant, Kandiyohi, Lac Qui Parle, Lincoln, Lyon, Murray, Nicollet, Otter Tail, Pipestone, Pope, Redwood, Renville, Sibley, Stearns, Stevens, Swift, Yellow Medicine

*derived from the NED 30m DEM

This reach includes the Chippewa, Yellow Medicine, Hawk Creek, Redwood, Cottonwood and northern portion of the Middle Minnesota watersheds. The portions of the Middle Minnesota watershed have no major tributaries, but have many small tributaries with connections to ravines and bluffs that directly outlet to the Minnesota River.

Land cover and land use statistics (Figures 5.73 and 5.74) for the watershed show the major land use to be agriculture with 73 percent of the land in some form of production. Corn makes up 37 percent of the land area, while soybeans remain close behind at 31 percent. Developed land, which includes several cities and towns, makes up approximately eight percent of the land use within the watershed.

The steeply-sloped land analysis (Figure 5.75) shows that 15 percent of the cropland exceeds 3 percent or greater slope or 11 percent of the total land area. A total of 480,908 acres of cropland fall into the steep category. These acres should be analyzed to ensure protection from erosion.

Conservation land practices account for 255,673 acres within the watershed. The major portion of these lands are enrolled in the CRP program at 223,637 acres. Land in the permanently-retired CREP program totals 78,108 acres (Figure 5.76). The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

For this reach of the Minnesota River, the TSS surrogate value for 25 NTUs was determined to be 85 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less.

Table 5.17 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. There is a slight difference between the loads presented on the load duration curve and the loading capacity in the table due to differences in flows. The duration curve was developed based on the flows from the closest USGS flow gage, which is near the city of Montevideo (Figure 5.51). To determine the loading capacity in the table, the MPCA estimated the flows in this reach by using a watershed area ratio of 1.76.

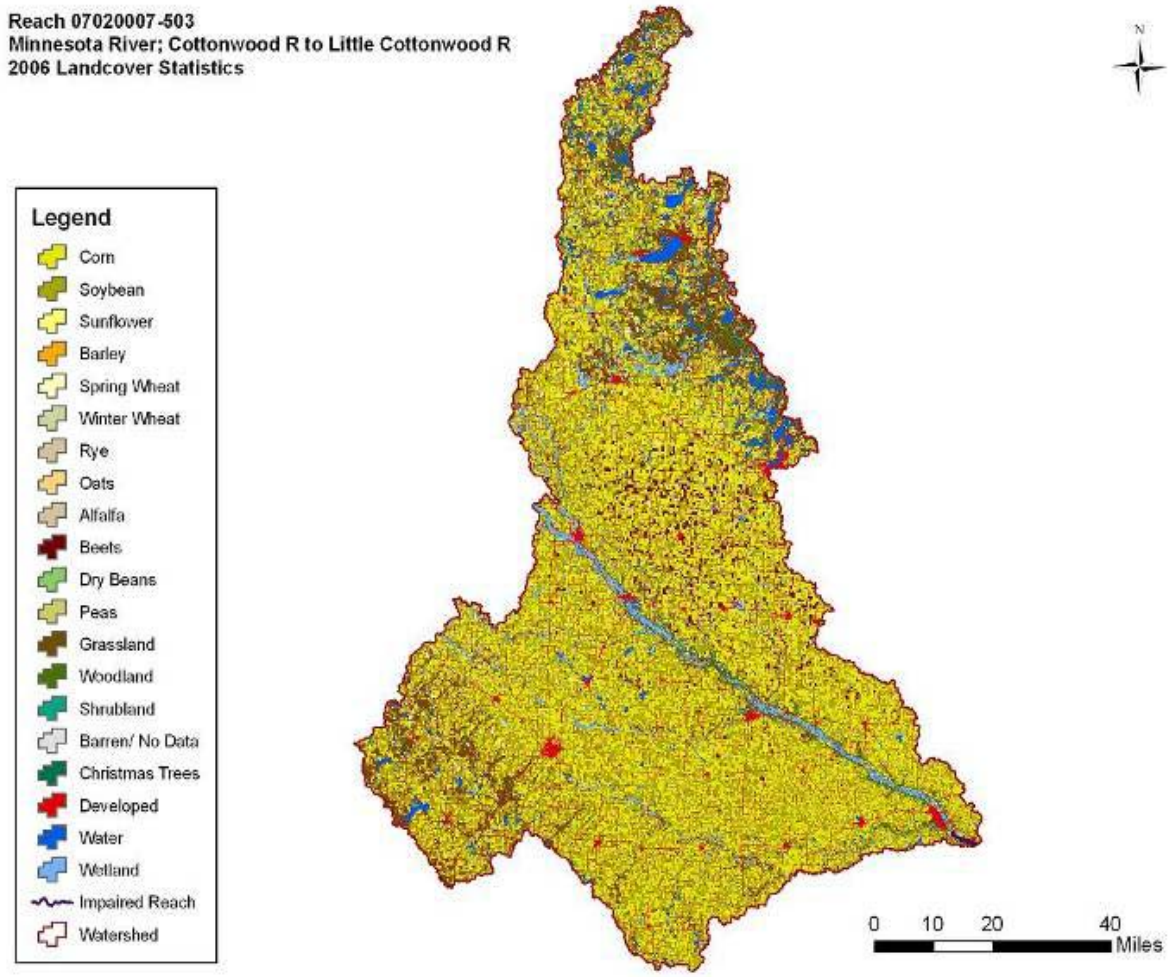


Figure 5.73 2006 Land Cover Map for the Minnesota River; Cottonwood R to Little Cottonwood R.

LANDUSE	ACRES	PERCENT
Corn	1,624,159.24	37.13%
Soybean	1,371,137.75	31.35%
Sunflower	602.11	0.01%
Barley	416.13	0.01%
Spring Wheat	61,402.53	1.40%
Winter Wheat	423.11	0.01%
Rye	34.87	0.00%
Oats	246.43	0.01%
Alfalfa	57,022.67	1.30%
Beets	76,277.17	1.74%
Dry Beans	2,867.99	0.07%
Peas	3,716.53	0.08%
Grassland	369,343.55	8.44%
Woodland	129,415.93	2.96%
Shrubland	55.79	0.00%
Barren	781.90	0.02%
Christmas Trees	154.98	0.00%
Developed	353,525.83	8.08%
Water	117,496.07	2.69%
Wetland	204,953.82	4.69%
Total	4,374,034.41	100.00%

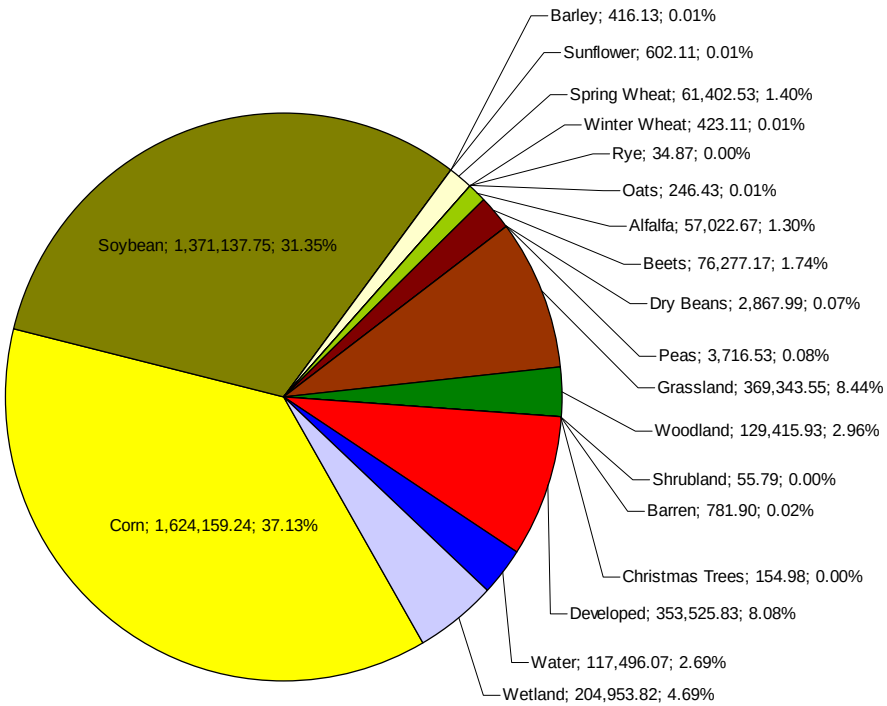
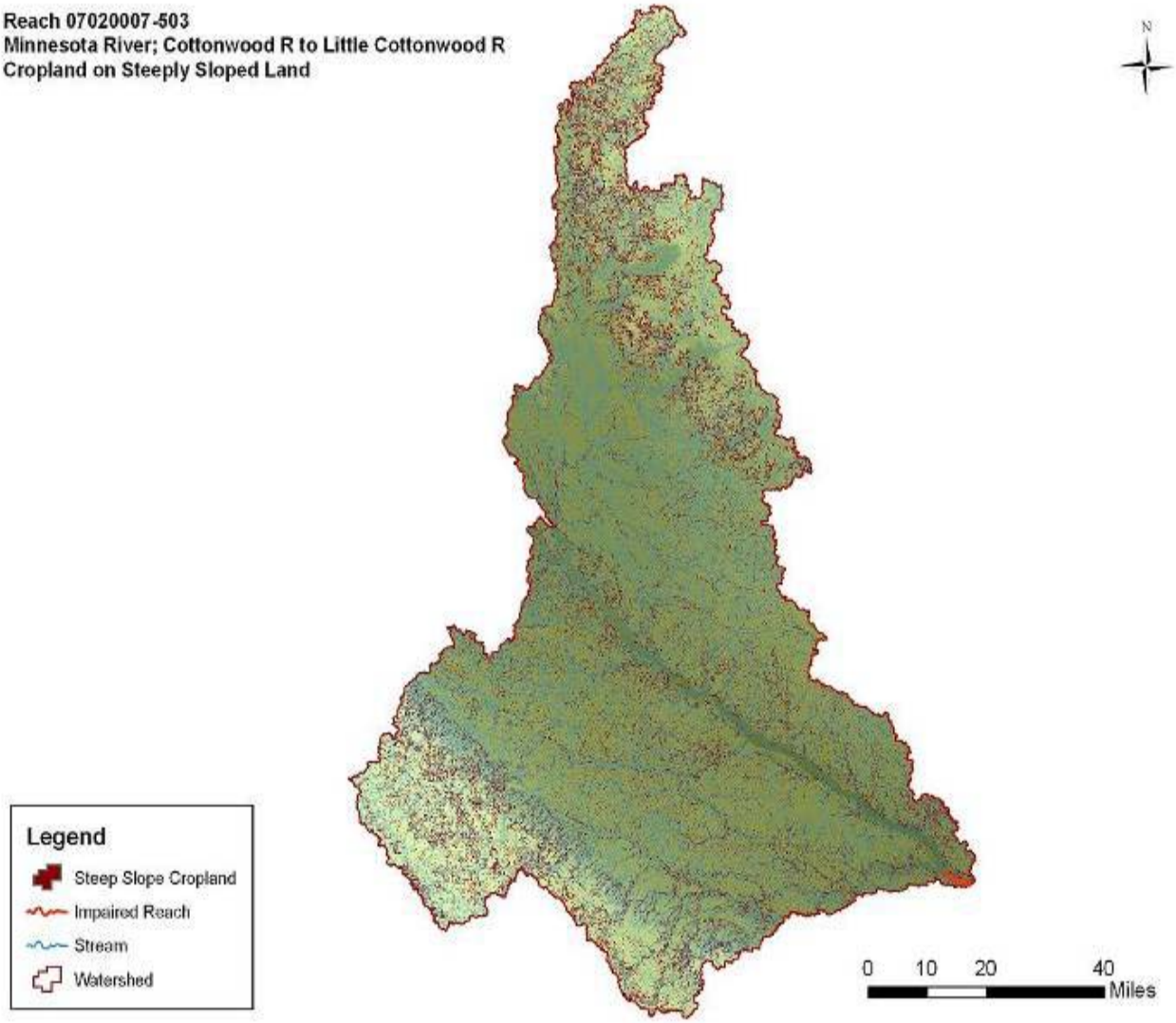
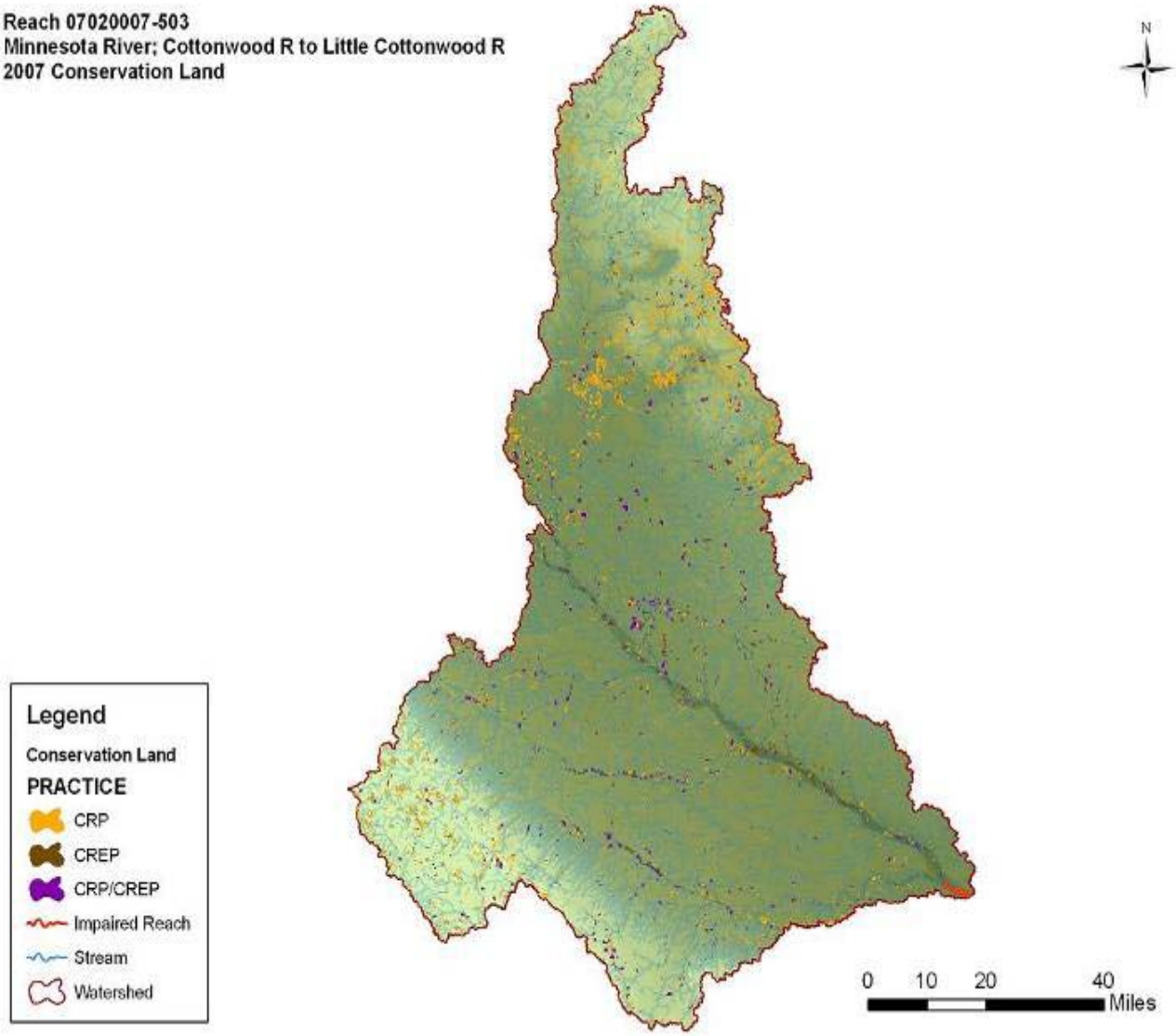


Figure 5.74 2006 Land Use Statistics for the Minnesota River; Cottonwood R to Little Cottonwood R.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
4,374,034.41	3,198,306.53	480,908.36	10.99%	15.04%

Figure 5.75 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Cottonwood R to Little Cottonwood R.



PROGRAM	ACRES	PERCENT
CRP	223,637.28	5.11%
CREP	78,107.83	1.79%
CRP,CREP	255,673.06	5.85%

Figure 5.76 Conservation Land Locations and Statistics for the Minnesota River; Cottonwood River to Little Cottonwood River.

Table 5.17 Minnesota River; Cottonwood River to Little Cottonwood River TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	2185	612	228	89	14
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	12.18	12.18	12.18	12.18	12.18
Communities Subject to MS4 NPDES Requirements	9.23	2.58	0.96	0.38	0.06
Construction and Industrial Stormwater	0.37	0.10	0.04	0.02	0.01
Load Allocation	1944.72	535.93	192.01	67.52	0.35
Margin of Safety	218.50	61.20	22.80	8.90	1.40

5.17 Minnesota River; Beaver Cr to Birch Coulee

Reach AUID:
07020007-514

Stream Status:
Impaired Stream Reach (mercury, PCB, turbidity, aquatic consumption and aquatic life). This report only addresses the turbidity impairment.

Impaired Segment Length:
9.23 miles

Contributing Watershed Size:
5,749,749.8 acres
8,984.02 square miles

Total Stream Miles:
6,547.36 miles

Elevation*:
Maximum = 1992 ft above sea level
Minimum = 816 ft above sea level
Total relief = 1,176 ft

Slope*:
Maximum Slope: 60.7 percent
Minimum Slope: 0 percent
Average Slope: 1.9 percent

Counties:
Chippewa, Douglas, Grant, Kandiyohi, Lac Qui Parle, Lincoln, Lyon, Murray, Otter Tail, Pipestone, Pope, Redwood, Renville, Stearns, Stevens, Swift, Yellow Medicine

*derived from the NED 30m DEM

This reach includes the Chippewa, Yellow Medicine, Hawk Creek and Redwood Watersheds within the Minnesota River basin. The addition of the Redwood watershed adds another 703 square miles of land area situated between the Yellow Medicine and Cottonwood watersheds. The headwaters of the Redwood watershed begin in the Coteau des Prairies, or "Highland of the Prairies," an important drainage divide named by French explorers. This divide drains to the southwest to the Big Sioux River and to the northeast to the Des Moines and Minnesota River.

Figures 5.77 and 5.78 show the land cover map and land use statistics for the watershed. Approximately 70 percent of the watershed is in agricultural production with corn and soybeans as the main crops. Developed land, including cities and towns, account for 8.3 percent of the total land use. Figure 5.79 shows approximately 14.36 percent or 319,368 acres of cropland, or 10 percent of the total land area exceeds three percent slope.

Conservation practices in the watershed total 209,892 acres or 6.58 percent of the total land area. Approximately 185,689 of those acres are in a CRP related program while 58,185 acres are in the permanent set aside CREP program (Figure 5.80). The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

For this reach of the Minnesota River, the TSS surrogate value for 25 NTUs was determined to be 85 mg/L. The allowable loading varies based on flow conditions that have been divided into five flow zones. Based on a 30-year historical record, flows in the very high zone, for example, occur 10 percent of the time or less.

Table 5.18 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. There is a slight difference between the loads presented on the load duration curve and the loading capacity in the table due to differences in flows. The duration curve was developed based on the flows from the closest USGS flow gage, which is near the city of Montevideo (Figure 5.51). To determine the loading capacity in the table, the MPCA estimated the flows in this reach by using a watershed area ratio of 1.46.

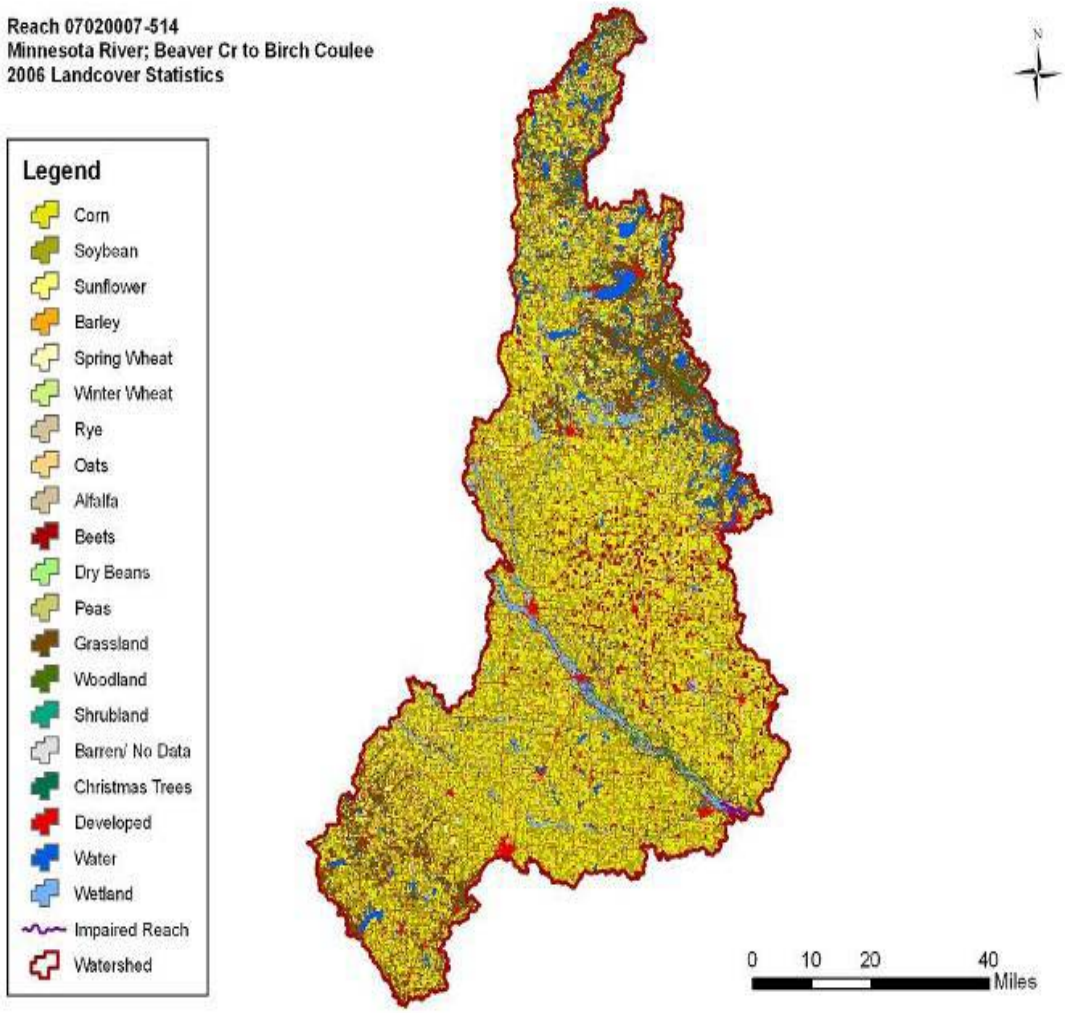


Figure 5.77 2006 Land Cover Map for the Minnesota River; Beaver Cr to Birch Coulee.

Landuse	ACRES	PERCENT
Corn	1,106,920.96	34.70%
Soybean	928,061.88	29.10%
Sunflower	599.79	0.02%
Barley	367.31	0.01%
Spring Wheat	59,803.87	1.87%
Winter Wheat	423.11	0.01%
Rye	34.87	0.00%
Oats	167.38	0.01%
Alfalfa	48,739.52	1.53%
Beets	72,928.73	2.29%
Dry Beans	2,787.40	0.09%
Peas	3,009.02	0.09%
Grassland	319,871.72	10.03%
Woodland	103,596.29	3.25%
Shrubland	49.60	0.00%
Barren/No Data	546.32	0.02%
Christmas Trees	154.98	0.00%
Developed	264,447.72	8.29%
Water	107,275.62	3.36%
Wetland	169,895.55	5.33%
Total	3,189,681.65	100.00%

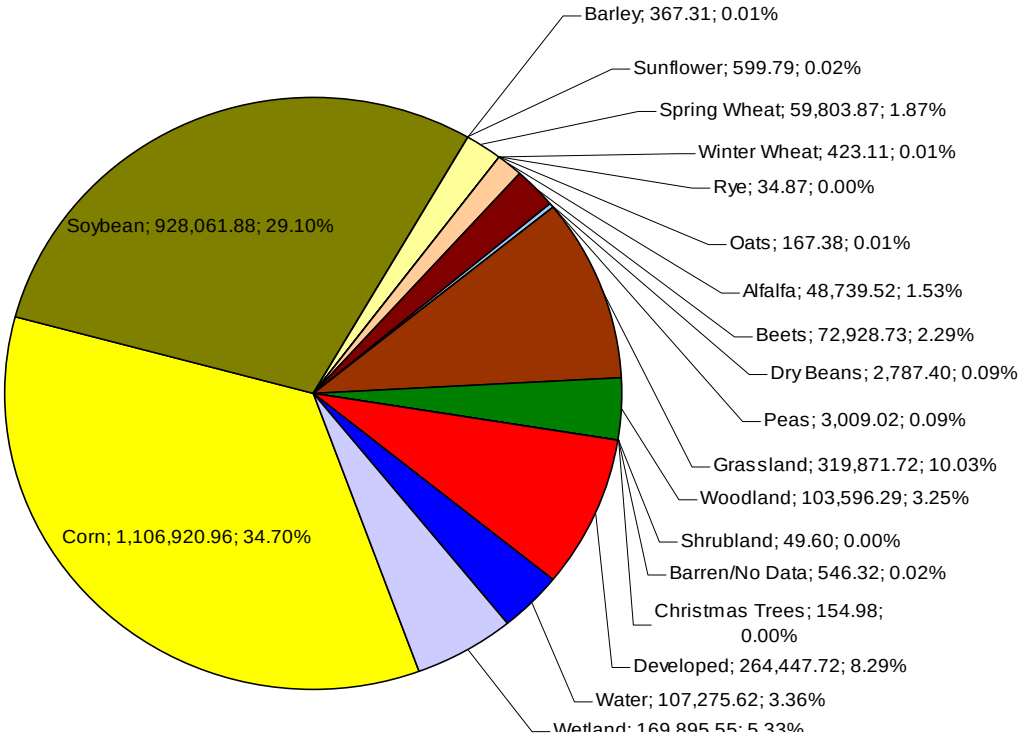
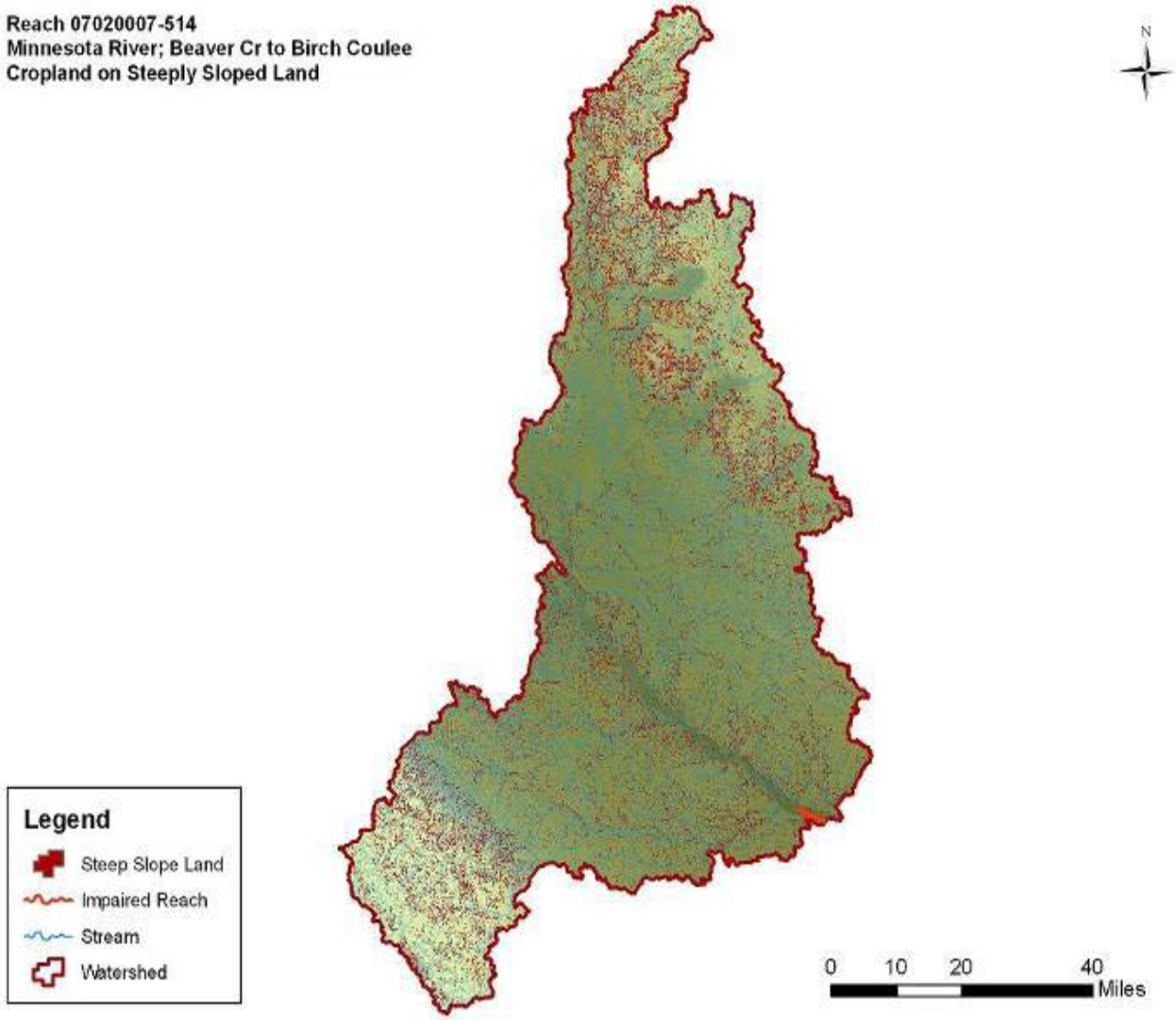


Figure 5.78 2006 Land Use Statistics for the Minnesota River; Beaver Cr to Birch Coulee.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
3,189,681.65	2,223,843.85	319,368.02	10.01%	14.36%

Figure 5.79 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Beaver Cr to Birch Coulee.

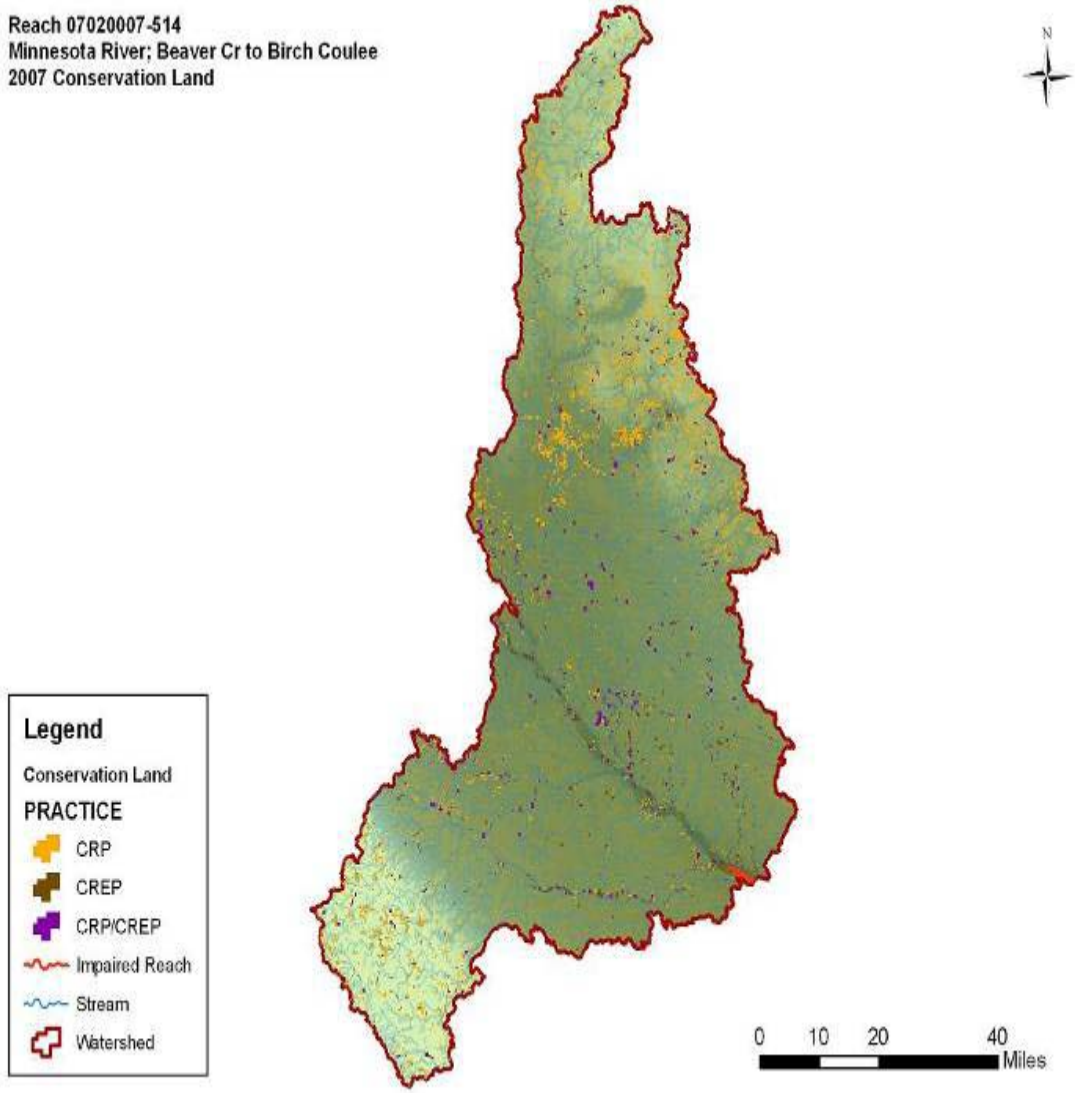


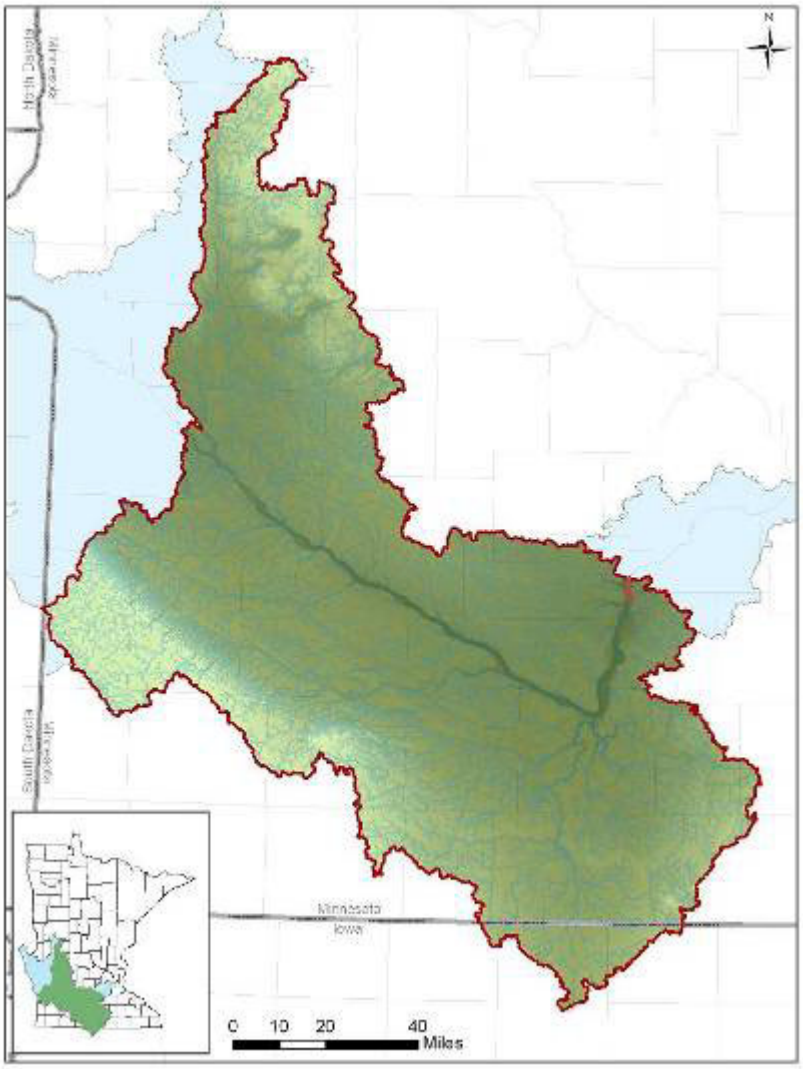
Figure 5.80 Conservation Land Locations and Statistics for the Minnesota River; Beaver Cr to Birch Coulee.

PROGRAM	ACRES	PERCENT
CRP	185,689.29	5.82%
CREP	58,185.32	1.82%
CRP,CREP	209,892.31	6.58%

Table 5.18 Minnesota River; Beaver Cr to Birch Coulee TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	1813	508	189	73	11
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	7.12	7.12	7.12	7.12	7.12
Communities Subject to MS4 NPDES Requirements	6.89	1.93	0.72	0.28	0.04
Construction and Industrial Stormwater	0.35	0.10	0.04	0.01	0.01
Load Allocation	1617.33	448.05	162.22	58.28	2.72
Margin of Safety	181.30	50.80	18.90	7.30	1.10

5.18 Minnesota River; Rush River to High Island Creek



Reach AUID:
07020012-503

Stream Status:
Impaired Stream Reach (bacteria, mercury, PCB, turbidity, aquatic consumption, aquatic life, and aquatic recreation). This report only addresses the turbidity impairment.

Impaired Segment Length:
9.63 miles

Contributing Watershed Size:
10,209,181.56 acres
(9,992,248.03 acres MN)
15,951.91 sq. miles
(15,612.95 sq. miles MN)

Total Stream Miles:
15,528.87 miles
(15,040.29 miles MN)

Elevation*:
Maximum = 1992 ft above sea level
Minimum = 698 ft above sea level
Total relief = 1294 ft

Slope*:
Maximum Slope: 84.4 percent; Minimum Slope: 0 percent; Average Slope: 1.8 percent

Counties:
Blue Earth, Brown, Chippewa, Cottonwood, Douglas, Faribault, Freeborn, Grant, Jackson, Kandiyohi, Lac Qui Parle, LeSueur, Lincoln, Lyon, McLeod, MN, Martin, Murray, Nicollet, Otter Tail, Pipestone, Pope, Redwood, Renville, Scott, Sibley, Stearns, Steele, Stevens, Swift, Waseca, Watonwan, Yellow Medicine, Emmet (Iowa), Kossuth (Iowa), Winnebago (Iowa)

*derived from the NED 30m DEM

Watersheds included in this lowest reach include Chippewa, Yellow Medicine, Hawk Creek, Redwood, Cottonwood, Middle Minnesota, Watonwan, Blue Earth, LeSueur, the Rush and High Island portions of the Lower Minnesota watershed. This reach gives a broad image of the remnants of the last ice age throughout the basin. The landscape, its soils and water bodies, have been shaped by the actions of glaciers thousands of years ago. Today, the Minnesota River follows the oversized channel of the Glacial River Warren. Tributaries to this oversized channel are continuously trying to cut down to reach an equilibrium with the main channel. Land use plays a role in this activity. Soil lost through land activities, ravine action and bank erosion add to the turbidity problems within the watershed.

Land use within the watershed is dominated by agriculture. Approximately 77 percent of the watershed is in some form of crop production with nearly 74 percent in corn and soybeans (Figures 5.81 and 5.82). The soil surface can be vulnerable to erosion at times when the crop canopy is not fully developed. Drainage has been utilized to increase tillable acres and provide for earlier spring planting by drawing down the water table sooner. This drainage network is currently being studied to better understand the connections to flows and their impact on the watershed and erosion. Developed areas account for eight percent of the watershed, and their impacts are felt in the form of impervious surfaces that won't allow for infiltration of water through the soil column. Other potential concerns include chemical contamination from the watershed and soil loss through construction sites.

Steeply-sloped land is a concern due to the potential for lost soil to enter the system. Figure 5.83 shows steeply-sloped areas within the basin. 13.31 percent of the watershed acres are in agricultural production and meet the three percent or greater slope requirements. These areas can potentially provide a means for increased surface erosion, and should be managed to reduce their input of sediment to the system.

Conservation Practices related to CRP and CREP are seen on 4.49 percent of the land area (Figure 5.84). Permanently retired land accounts for 1.52 percent of the acreage. As studies continue and begin to narrow down areas that are more susceptible to and contribute more sediment to the system, emphasis should be put on providing the incentives to permanently retiring these areas. The figures showing land use and conservation acres are from 2006 and 2007, respectively. Land use changes from year to year.

Figure 5.85 shows the load duration curve for the reach based on the 30-year flow data at the USGS site on the Minnesota River at the city of Jordan. A surrogate value of 100 mg/L of TSS has been calculated to meet the 25 NTU standard for this reach. Allowable loading varies based on flow conditions set at the five flow zones. As seen in this reach, most exceedances of the standard are seen in the Mid to Very High flow zones.

Table 5.19 summarizes the total loading capacity, the WLA and LA for the watershed. The methods for calculating the allocations appear in Section 4. The five flow zones correspond to those in the load duration curves. There is a slight difference between the loads presented on the load duration curve and the loading capacity in the table due to differences in flows. The duration curve was developed based on the flows from the closest USGS flow gage, which is near the city of Jordan. To determine the loading capacity in the table, the MPCA estimated the flows in this reach by using a watershed area ratio of 0.987.

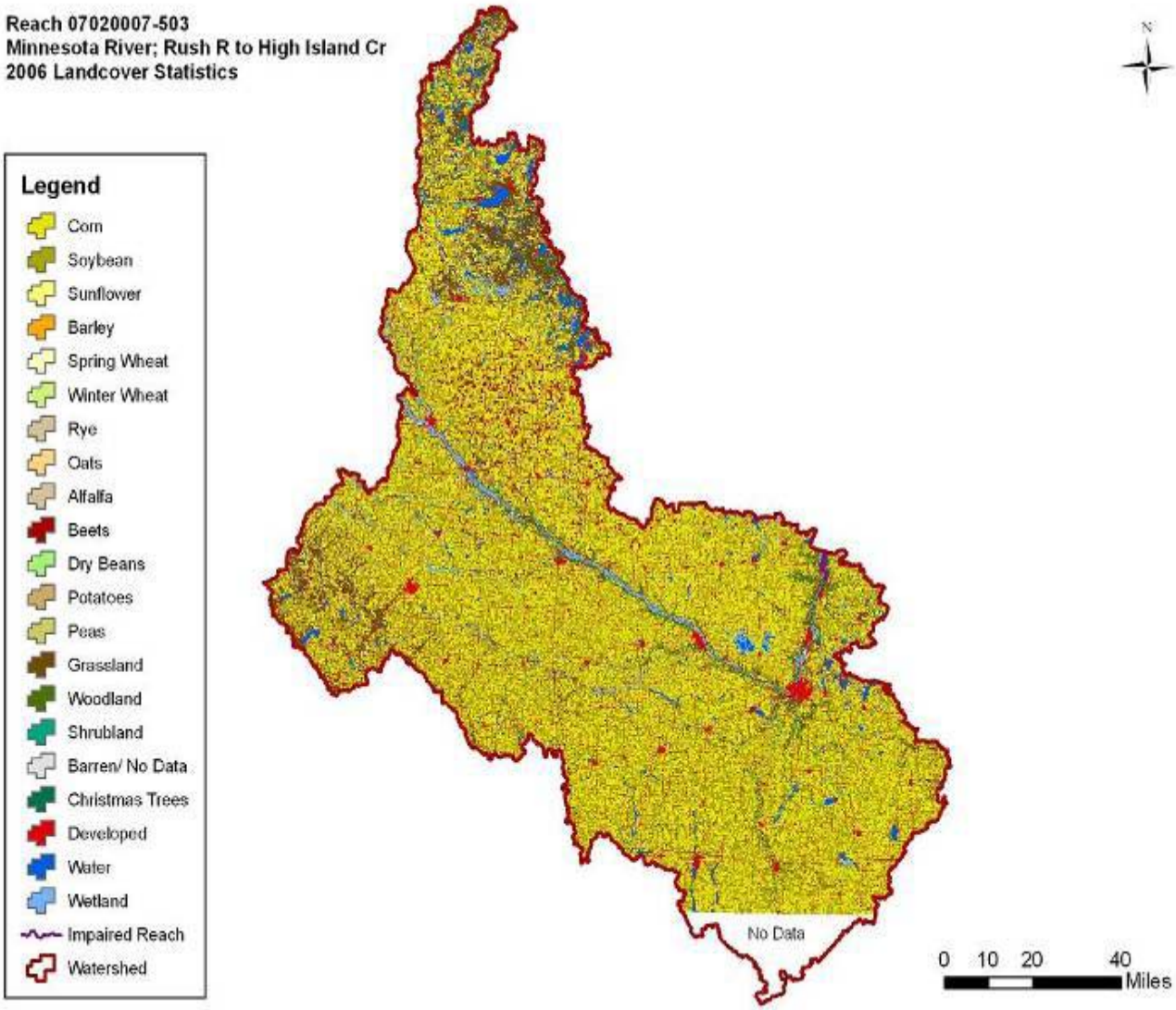


Figure 5.81 2006 Land Cover Map for the Minnesota River; Rush River to High Island Creek.

LANDUSE	ACRES	PERCENT
Corn	2,995,487.62	40.30%
Soybean	2,473,721.47	33.28%
Sunflower	615.29	0.01%
Barley	416.13	0.01%
Spring Wheat	64,296.09	0.87%
Winter Wheat	456.43	0.01%
Rye	289.82	0.00%
Oats	541.67	0.01%
Alfalfa	68,583.74	0.92%
Beets	80,109.94	1.08%
Dry Beans	2,967.95	0.04%
Potatoes	18.60	0.00%
Peas	11,723.80	0.16%
Grassland	435,487.83	5.86%
Woodland	247,452.89	3.33%
Shrubland	151.11	0.00%
Barren/No Data	2,178.31	0.03%
Christmas Trees	154.98	0.00%
Developed	593,214.78	7.98%
Water	177,672.68	2.39%
Wetland	276,846.48	3.72%
Total	7,432,387.62	100.00%

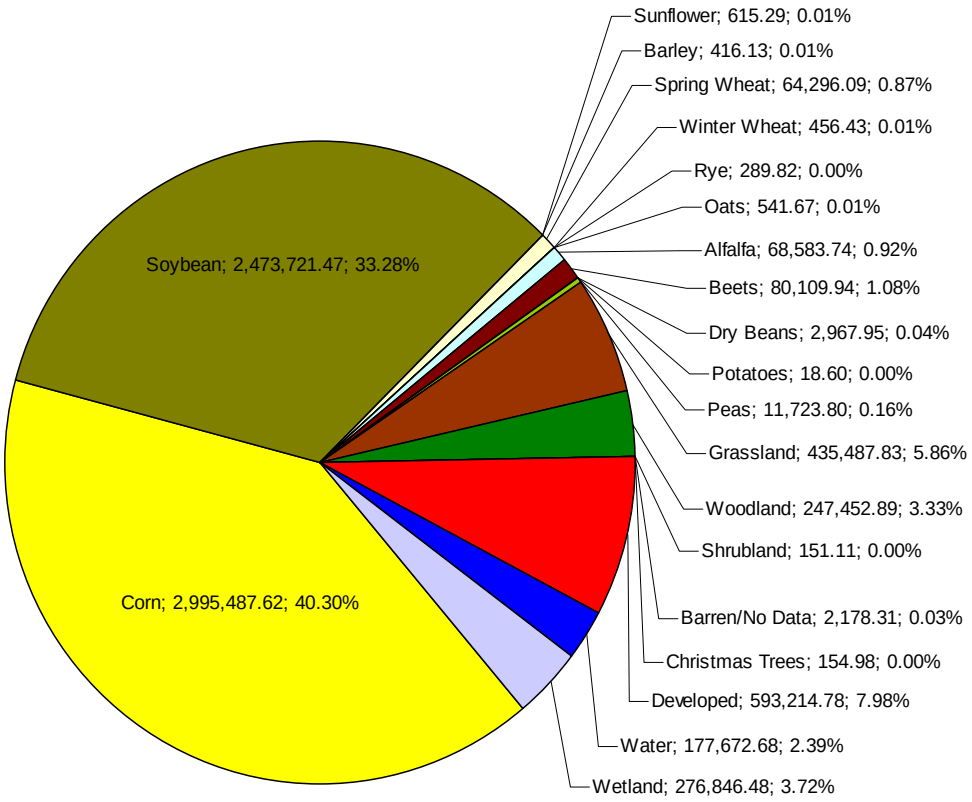
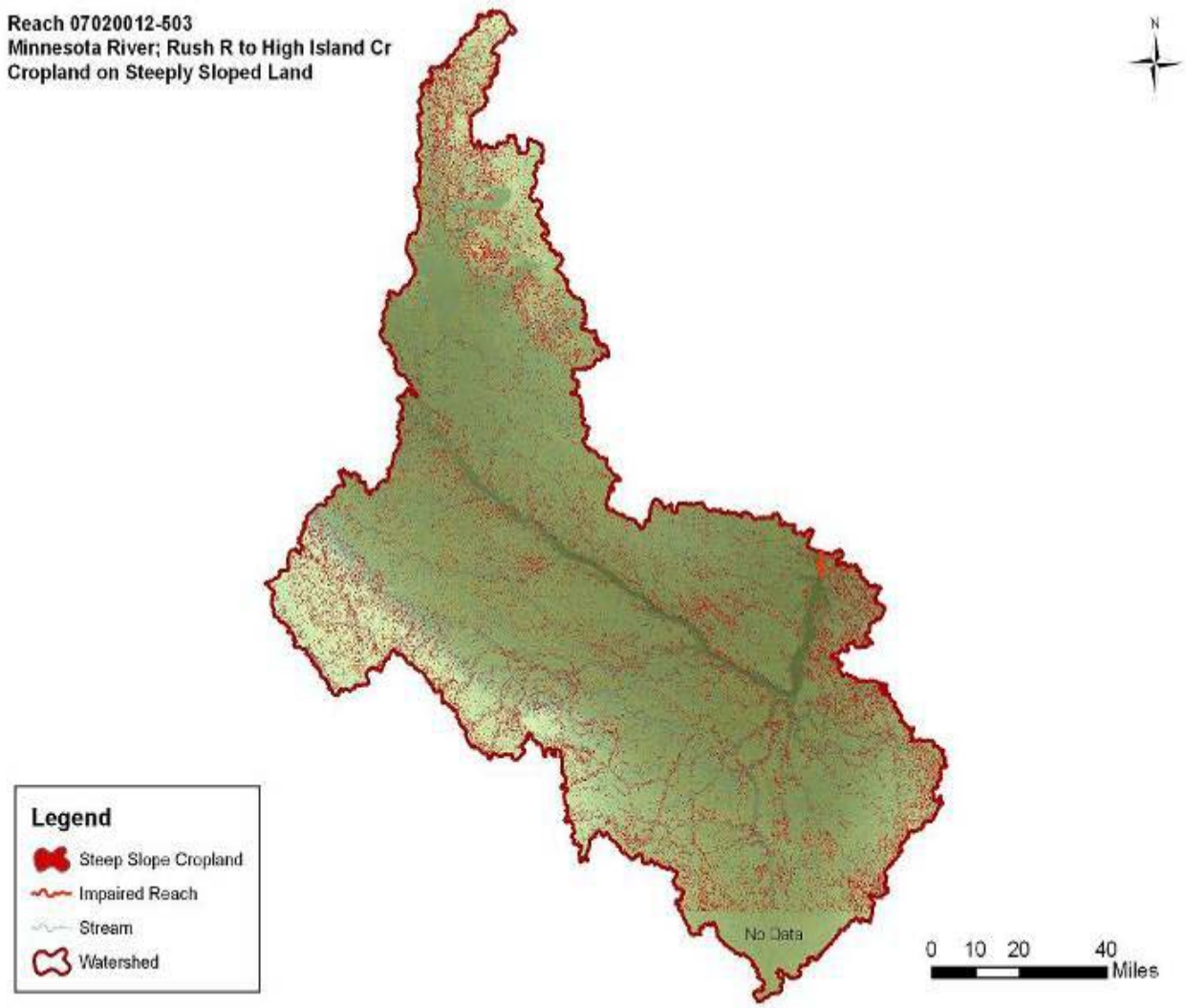
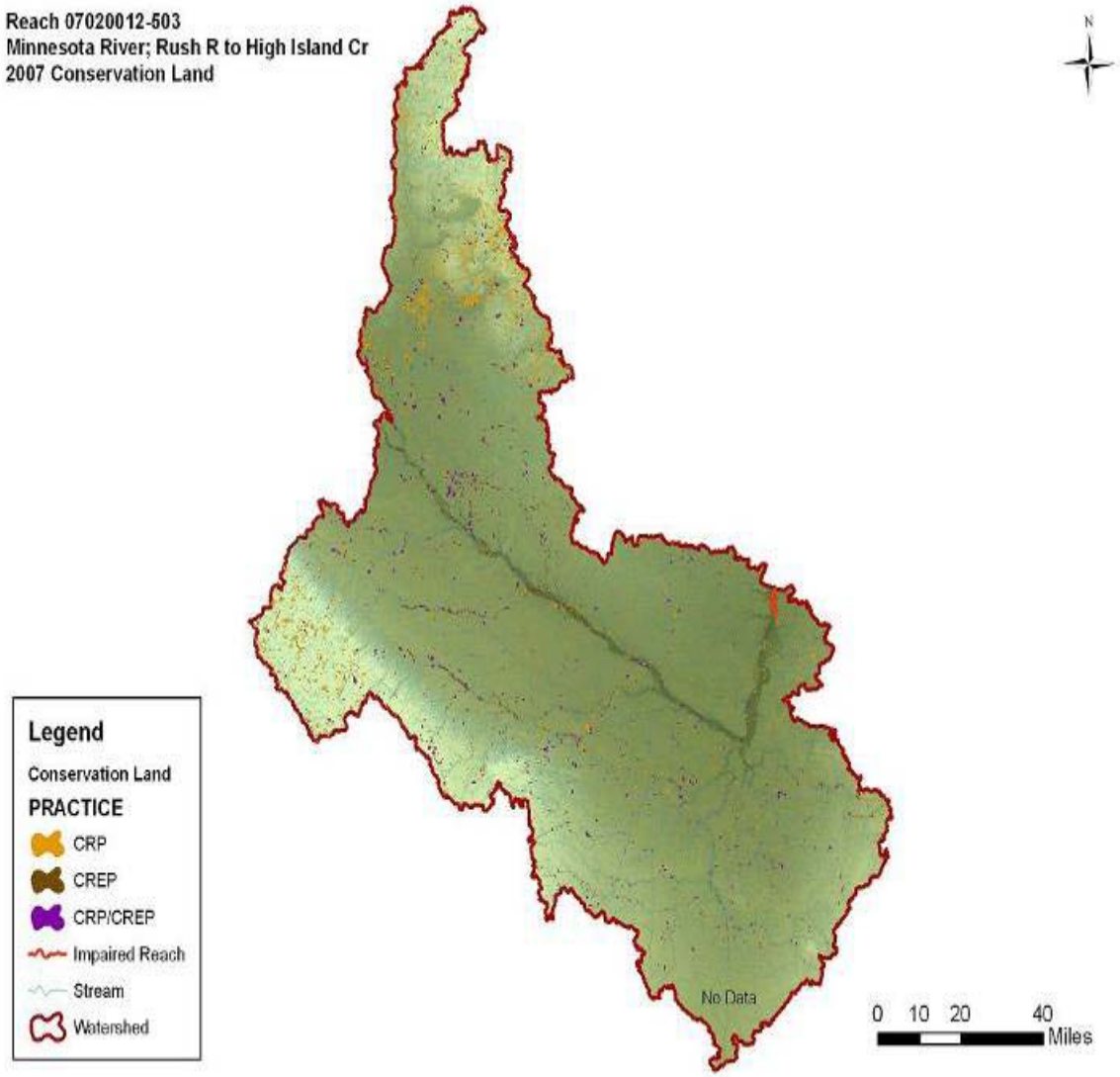


Figure 5.82 2006 Land Use Statistics for the Minnesota River; Rush River to High Island Creek.



TOTAL ACRES	CROPLAND ACRES	STEEP SLOPE CROPLAND	PERCENT: TOTAL	PERCENT: CROPLAND
7,432,387.62	5,699,228.56	758,574.71	10.21%	13.31%

Figure 5.83 Cropland on Steeply Sloped Land Analysis for the Minnesota River; Rush River to High Island Creek.



PROGRAM	ACRES	PERCENT
CRP	289,577.73	3.90%
CREP	112,887.72	1.52%
CRP,CREP	333,868.28	4.49%

Figure 5.84 Conservation Land Locations and Statistics for the Minnesota River; Rush River to High Island Creek.

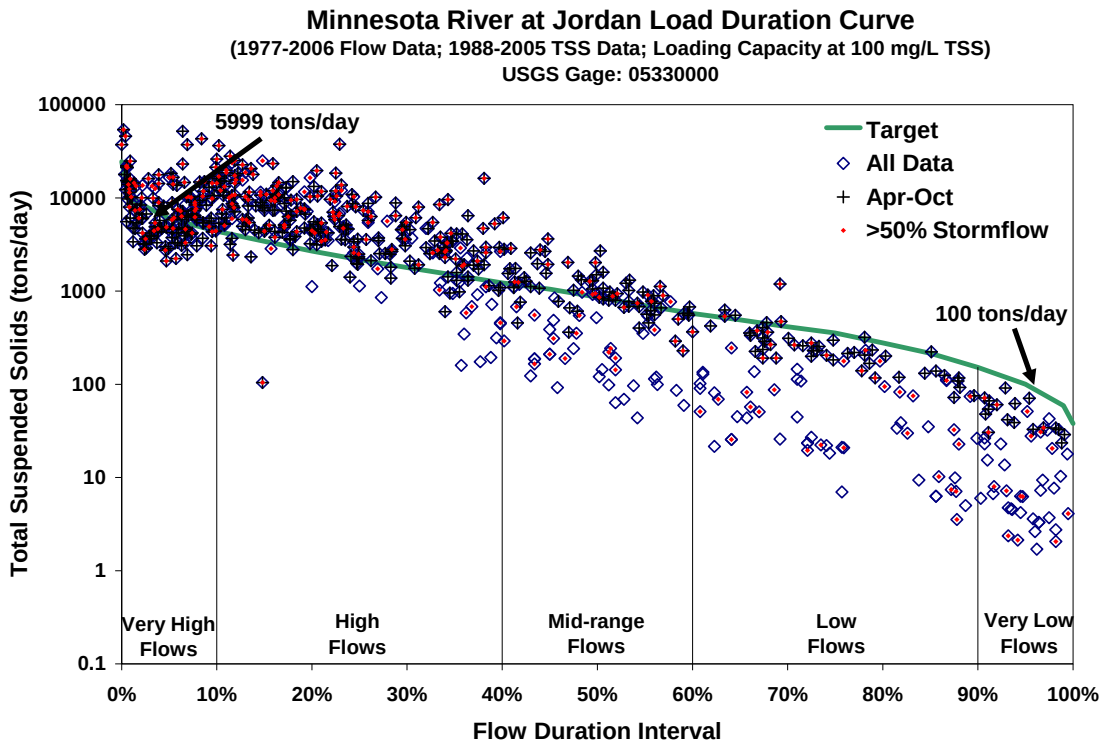


Figure 5.85 Minnesota River at Jordan Load Duration Curve.

Table 5.19 Minnesota River; Rush River to High Island Creek TSS Loading Capacities and Allocations.

	Flow Zone				
	Very High	High	Mid	Low	Very Low
Total Daily Loading Capacity	5922	2142	850	351	99
	Tons/day				
Waste Load Allocation					
Permitted Wastewater Treatment Facilities	35.40	35.40	35.40	35.40	35.40
Communities Subject to MS4 NPDES Requirements	17.55	6.35	2.52	1.04	0.29
Construction and Industrial Stormwater	0.73	0.27	0.11	0.04	0.01
Load Allocation	5276.12	1885.79	726.98	279.42	53.40
Margin of Safety	592.20	214.20	85.00	35.10	9.90

6. Model Description and Results

The MPCA contracted with Tetra Tech to develop a water quality simulation model using the Hydrologic Simulation Program – FORTRAN (HSPF). The HSPF model is a comprehensive modeling package developed by the EPA for simulating water quantity and quality for a wide range of pollutants from complex watersheds. The model has been used nationally for completing watershed TMDLs. The Minnesota River basin HSPF Model addresses eight major subwatersheds plus the Middle Minnesota River mainstem and Lower Minnesota River mainstem. The upstream boundary for the HSPF model is Lac qui Parle Lake near the city of Montevideo and the lower boundary is a United States Geological Survey (USGS) flow monitoring station at the city of Jordan, Minnesota. See Figure 6.1 for Minnesota River model subwatersheds and HSPF model segments as applied to the Minnesota River. Much of the text in this section was taken from the Model Calibration Report developed by Tetra Tech (Tetra Tech, 2008). Additional detail is available in the report.

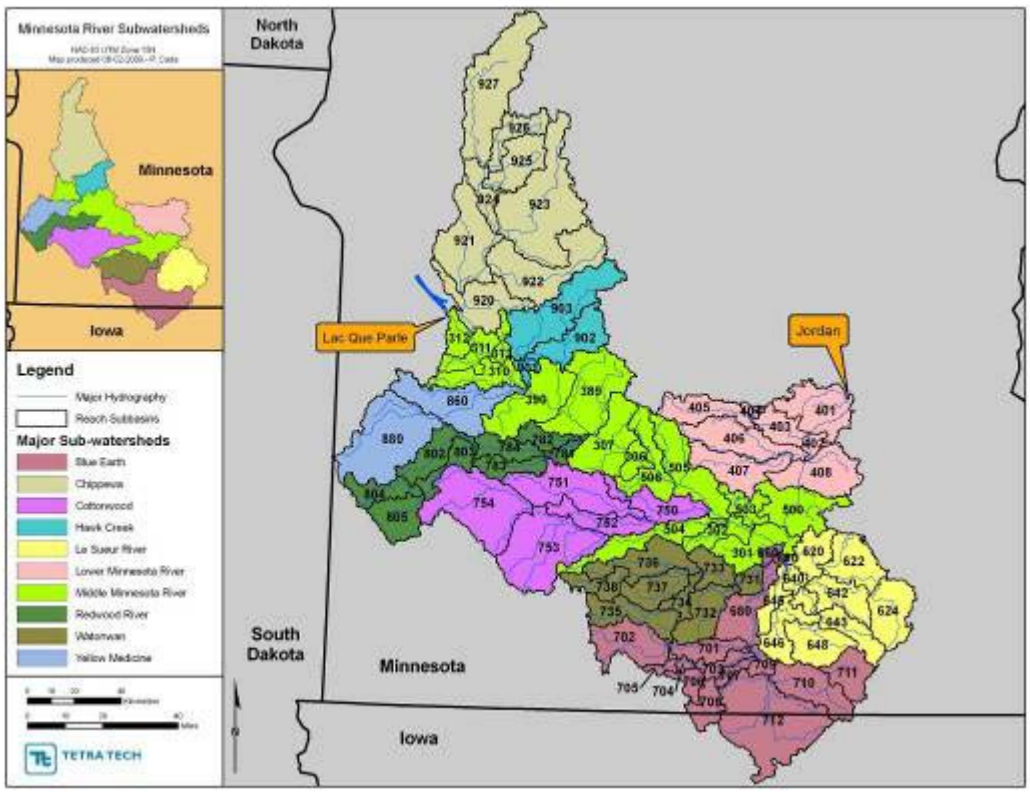


Figure 6.1 Minnesota River model subwatersheds and segments.

In HSPF, land processes for pervious and impervious areas are simulated. Hydrology is modeled as a water balance in multiple surface and soil layer storage compartments. Interception, infiltration, evapotranspiration, interflow, groundwater loss and overland flow processes are considered and are generally represented by empirical equations. Sediment production is based on detachment and/or scour from a soil matrix and transport by overland flow in pervious areas, whereas solids buildup and washoff is simulated for impervious areas. It includes agricultural components for land-based nutrient and pesticide processes and a

special actions block for simulating management activities. The HSPF model also simulates the in-stream fate and transport of a wide variety of pollutants, such as nutrients, sediments, tracers, dissolved oxygen (DO)/biochemical oxygen demand (BOD), temperature, bacteria and other constituents.

Development of HSPF models for the Minnesota River basin has occurred over many years. In 2000, the MPCA contracted with Tetra Tech to review early progress on the model and complete the development of the model for the entire Minnesota River basin between Lac qui Parle Lake and the city of Jordan. In 2002, Tetra Tech completed the development and calibration of comprehensive HSPF watershed and receiving-water models. The focus of the 2002 modeling effort was to support a DO/BOD TMDL for the Lower Minnesota River, which required accurate simulation of nutrient loading and algal response, in addition to DO and BOD.

The early version of the Minnesota River basin model was developed and calibrated using land use data from 1989-90 and meteorological time series for 1986 to 1992. The previous model simulated flow, sediment, nutrients, algae, dissolved oxygen, oxygen demand and bacteria, but was calibrated only through 1992. In addition, the focus of the previous application was on dissolved oxygen and nutrients, rather than sediment.

Although a detailed simulation model already existed for sediment in the previous modeling system, it had some limitations for sediment simulation to support TMDL allocations for turbidity. In 2007, the MPCA again contracted with Tetra Tech to further enhance the sediment simulation modules from the earlier version of the model and reflect current land use and management practices. The intent was for the updated model to support the development of the turbidity TMDL.

This began with updating the model simulation period and underlying data coverages from 1993 through 2006 to provide a significantly longer period for model testing. In addition, a number of specific enhancements were made to the model to better refine the suspended sediment calibration. One of the most significant changes included the use of existing flood models to improve estimates of channel shear stress and better characterization of river corridor sources. A variety of lines of evidence, including radioisotope analyses, were used to ensure that the model provided an accurate attribution of pollutant loads to different source classes. These sources included surface washoff, development of ravines, channel erosion and deposition processes and point source loads.

The model was further improved by incorporating the information from smaller-scale modeling efforts and more recent monitoring and calibrated modeling efforts at the local-scale. The additions have resulted in the creation of an improved model to meet the MPCA's needs for completing turbidity TMDLs. The revised model was recalibrated for flow, sediment, total phosphorus and total nitrogen. In addition, the model continues to predict a full suite of other components, including BOD/DO, algae and fecal coliform bacteria, based on the parameters established for the previous version of the model. The general objective for model calibration was to create a reliable, predictive tool that can be used to evaluate such responses.

As described in the Model Calibration Report (Tetra Tech, 2008), model calibration and validation was conducted in accordance with a Quality Assurance Project Plan and the model achieved the majority of the statistical targets for quality of model fit specified therein. Thus, the model provides a high quality representation of the generation, fate, and transport of flows, sediment, and pollutant loads in the watershed appropriate to analysis of TMDL scenarios. The model also provides an excellent visual fit to measured flows and sediment loads (Figures 6.2 and 6.3). Figure 6.2 is an example of matched flow records for the Minnesota River at the city of Mankato.

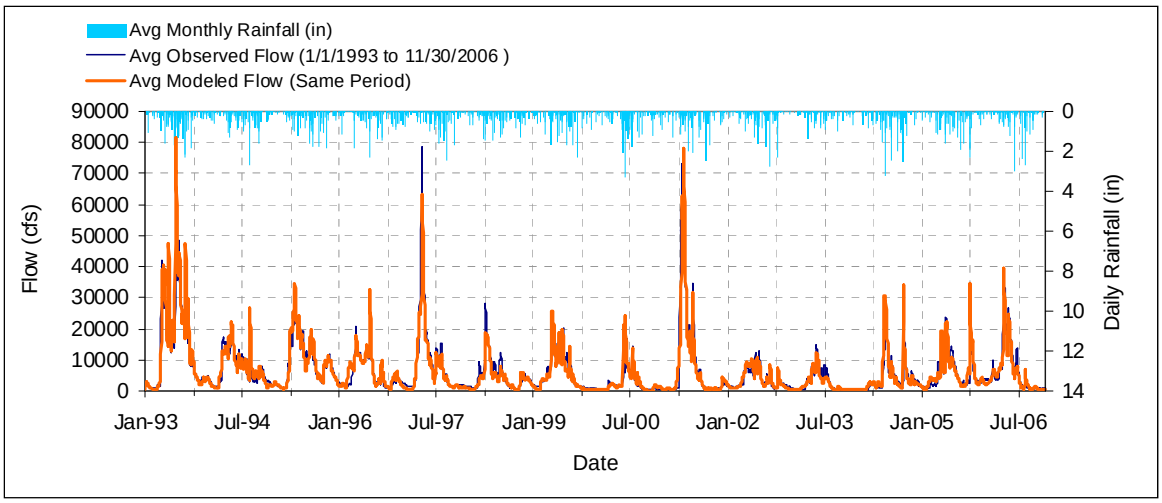


Figure 6.2 Mean Daily Flow: Model vs. USGS 05325000 Minnesota River at Mankato, MN

Figure 6.3 is an example of a scatter plot of simulated load versus same day load estimated from point-in-time sampling for the Watonwan River, which shows reasonable agreement between observed and simulated loads (observed loads are not directly measured but are inferred from concentration monitoring).

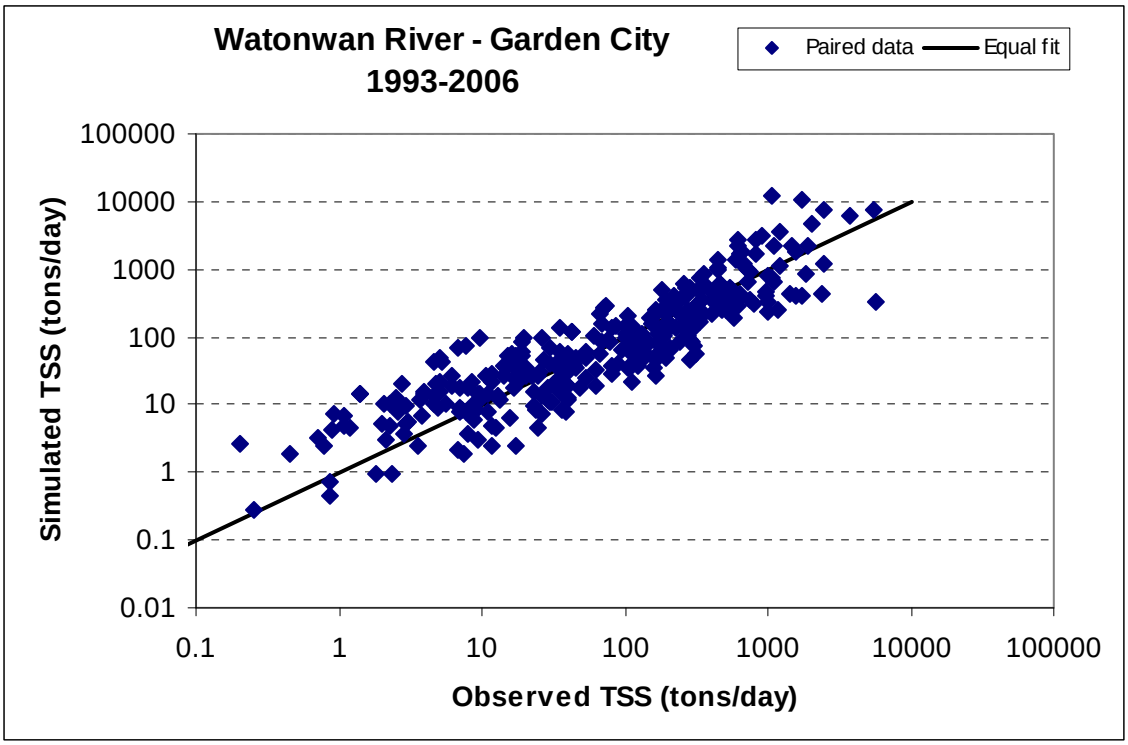


Figure 6.3 Simulated scatter plot of simulated vs. observed TSS loads, Watonwan River.

Following calibration and validation, the model performance was considered acceptable and used to test implementation alternatives. The developed model was peer-reviewed by a science advisory panel consisting of researchers from the University of Minnesota, Metropolitan Council Environmental Services, Minnesota Department of Agriculture and the Natural Resources Conservation Service, among others.

One of the steps in the Minnesota River Turbidity TMDL Study was to simulate potential land use and land management alternatives using the HSPF model. This offers a chance to test options before attempting to implement them and will aid in identifying effective practices. The modeling results, however, will not make the decisions about what will be done – people will. Model results will be used as a guide in predicting the most effective practices that must be balanced with economics, ease of use, and other factors.

A stakeholder committee designed scenarios 1-4; and scenario 5 was developed to achieve the TMDL targets. The first four scenarios, developed primarily to test various management alternatives proposed by stakeholders, are grouped as preliminary scenarios in this report. The resulting information was then used to construct a scenario that would achieve the TMDL targets (Scenario 5). Table 6.1 summarizes scenarios 3, 4 and 5. Additional details of the components included in all scenarios are summarized in the Minnesota River Basin Turbidity TMDL Scenario Report (Tetra Tech, 2009).

Table 6.1 Alternative land use and management options in model scenarios 3, 4 and 5.

Scenario 3 **Advancing Change**	**Scenario 4** **Accelerating Change**	**Scenario 5** **Paradigm Change**
Perennial vegetation Increase perennial vegetation to 20% of the watershed. Target **steepest sloping land**.	**Perennial vegetation** Same plus increase Chippewa to 30%. Target **areas near knickpoints**, particularly in Blue Earth and LeSueur.	**Perennial vegetation** Same
Cropping system Row cropland with slopes >3 percent: **Crop residue on 75 percent of acres**. Crop residue defined as 30 percent or greater as a rotation average.	**Cropping System** Row cropland with slopes >3 percent: **Crop residue increased to 37.5 percent or greater.**	**Cropping System** In most model subwatersheds that had less than 75 percent of cropland acres in conservation increased to a minimum of 75 percent conservation tillage.
These lands have **cover crops** to increase the spring cover.	Same	Same
Cropland with slopes less than 3 percent: **50 percent of surface tile intakes protected** (e.g. buffers, risers, rock inlets, etc.).	Surface tile inlets eliminated.	Same
Cropland with slopes greater than 12 percent: **No-till, strip till, and other reduced tillage methods or perennial crops.**	Same	Same
Nutrient management: Follow U of M fertilizer recommendations.	Same	Same
Manure management plans adjusted to nitrogen; full implementation of plans with setbacks from sensitive areas.	Same	Same
30% reduction in sediment from ravines due to use of drop structures.	Blue Earth and LeSueur River watersheds changed to 40% reduction.	Same
Upland Drainage Management	**Upland Drainage Management** Controlled drainage on cropland with < 1% slope (5/15-9/15). Two-stage ditch design. Store 1” runoff for at least 24 hours.	**Upland Drainage Management** Same

Scenario 3 Advancing Change	Scenario 4 Accelerating Change	Scenario 5 Paradigm Change
Bank and Bluff Erosion	**Bank and Bluff Erosion** Increase bank stabilization	**Bank and Bluff Erosion** Same
MS4 Urban Stormwater Infiltrate the first inch of runoff from both impervious and pervious urban surfaces.	**MS4 Urban Stormwater** Infiltrate the first inch of runoff from both impervious and pervious urban surfaces.	**Urban Stormwater** Same for MS4s + An additional reduction in sediment load from developed land *outside* of MS4 boundaries was imposed: An 85 percent reduction is applied to load from impervious surfaces and 50 – 85 percent reductions applied to loads from pervious surfaces. These are applied as direct reductions in sediment load because it is assumed that this improvement will be achieved by a variety of dispersed management practices, including source reduction, rather than explicitly through retention of runoff. As a result, this reduction in load is represented without a change in hydrology.
		Model adjustments Changes in critical sheer stress, sediment from bluffs, erodibility factors, etc. adjusted in model.

a. Preliminary Scenarios

This section summarizes the development of four preliminary scenarios. The stakeholder committee designed the first three scenarios, increasing the changes in land use with each iteration. The stakeholder committee helped to design Scenario 4, which added a hydrology component by simulating the storage of water. Scenario 5 modified some of the model infrastructure and focused on the near channel sources of sediment.

Scenario 1: Scenario 1 was designed to represent "continuous change." It generally represents a continuation of current trends in land use and management practices, and is expected to achieve a small but steady course of incremental improvements. The focus was on two areas: 1) current trends in crop production and management and 2) permitting requirements for Municipal Separate Storm Sewer Systems (MS4s).

The results showed that the net changes from baseline conditions were minimal, with increases and reductions in approximate balance. The flow-weighted mean TSS concentration followed the same trend.

Scenario 2: Scenario 2 was designed to represent "innovative change" and entails pursuing breakthrough ideas, such as modification of land use and cropping systems, to accelerate progress. Options in this category were considered challenging.

The results showed consistent, but small decreases in flow-weighted mean TSS concentrations. Most spring and summer TSS concentrations remained above the values needed to achieve TSS targets.

Scenario 3: Scenario 3 represents "advancing change" - a higher level of effort that is intended to represent a transformation of current thinking. Management options are focused at the structural level and are perceived to be difficult, but potentially feasible, involving use of the best alternatives. Although these aggressive actions may appear onerous and difficult, they do not appear to be sufficient to fully achieve water quality standards.

This scenario yielded further incremental reductions in TSS concentrations, but the resulting concentrations are still in excess of targets during spring and summer periods. Concentrations remain high in large part because loading from bank, bluff, and channel processes was not addressed. In addition, only a small amount of reduction was simulated for loading from ravines, another important component of the total sediment load.

Scenario 4 The results of Scenario 3 demonstrated that additional management measures would be needed to meet targets. After a presentation of the Scenario 3 results, participants at the Minnesota River Turbidity TMDL Stakeholder Committee meeting of July 24, 2008, developed a list of additional ideas for the next model scenario. Four important areas for additional focus included 1) an effort to reduce sediment loading from ravines and gullies, 2) water storage and upland drainage management, 3) land use changes including conversion of agriculture to perennial crops and 4) reductions in bank and bluff erosion. Together these ideas formed the framework for Scenario 4 – "accelerating change."

Scenario 4 includes a variety of practices (including crop changes, reduction in ravine loads, retention of the first inch of runoff near the source, and other practices) that drastically reduce the sediment loading rate from agricultural lands. Reductions were imposed on urban or developed lands, but only for those lying within MS4 boundaries. The various components of Scenario 4, taken together, resulted in significant

changes in the distribution of land uses in the Minnesota River watershed. These changes are summarized graphically in the Scenario Report.

Results of each scenario were summarized in tables and graphs. These results demonstrated that Scenarios 1 through 3 provide only modest reductions in flow-weighted mean TSS concentrations relative to existing baseline conditions. Scenario 4 showed reductions in TSS loads and concentrations. Figures 6.4 through 6.6 show sample plots of seasonal flow-weighted mean TSS concentrations of the Minnesota mainstem near the city of St. Peter and the LeSueur and Redwood Rivers. Scenario 4 appears as the lowest line, indicating the additional reduction in TSS achieved by simulating the supplementary practices.

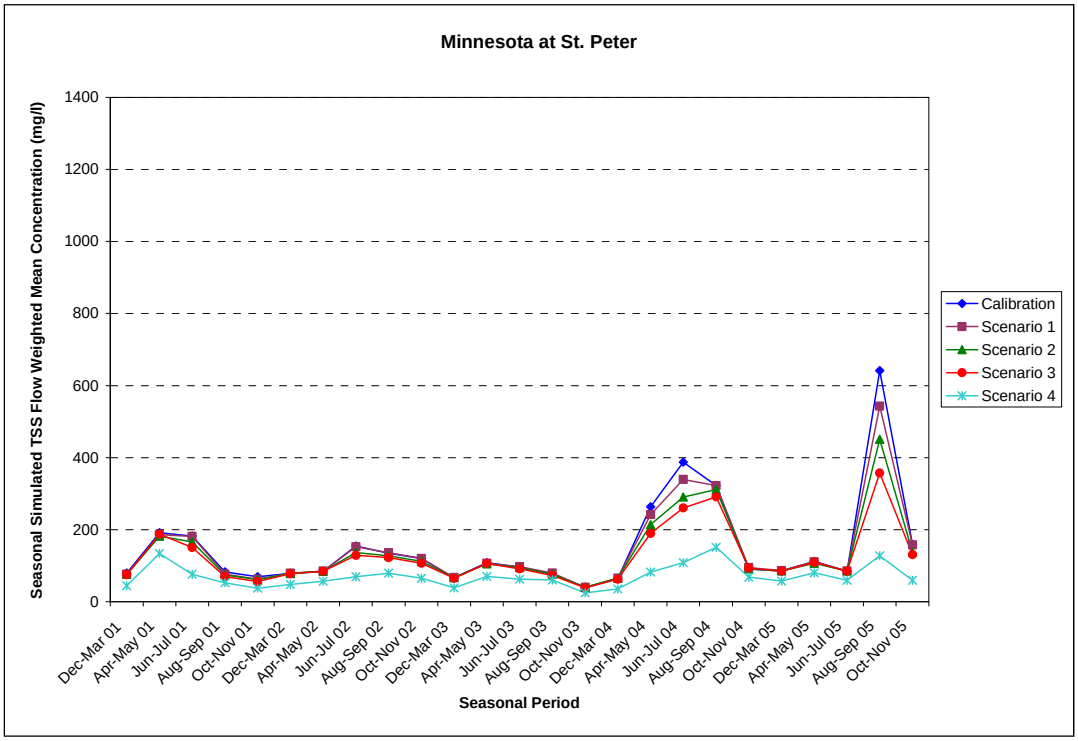


Figure 6.4 Seasonal Flow-Weighted Average TSS, Minnesota River at St. Peter

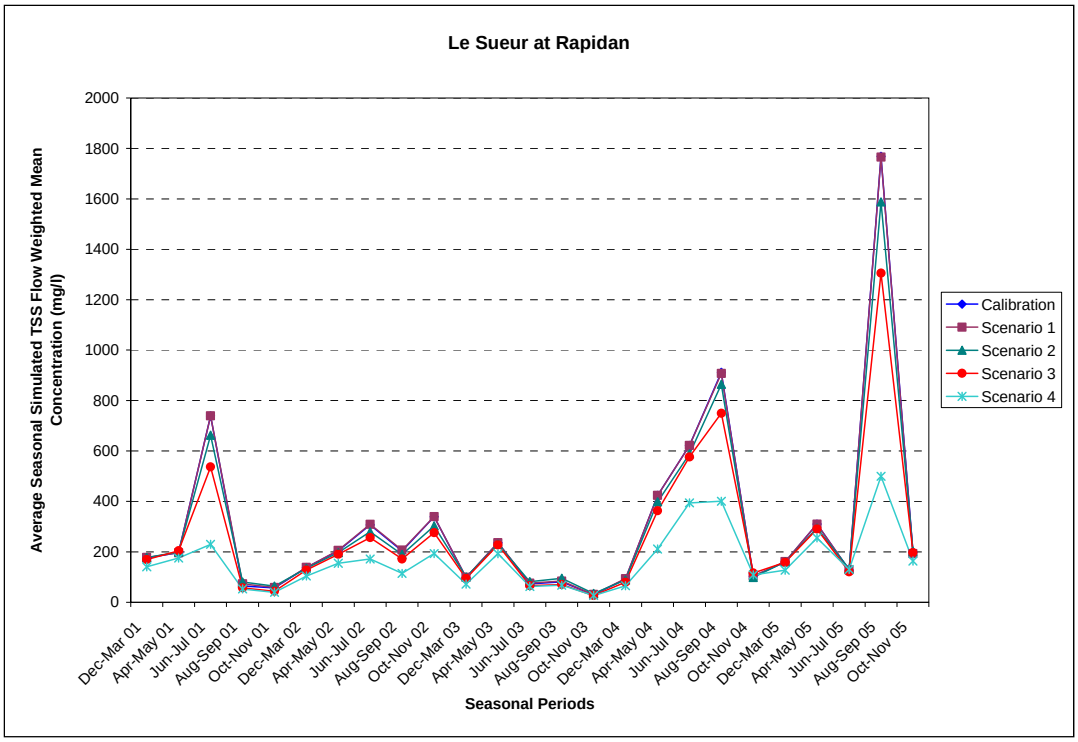


Figure 6.5 Seasonal Flow-Weighted Average TSS, LeSueur River at Rapidan.

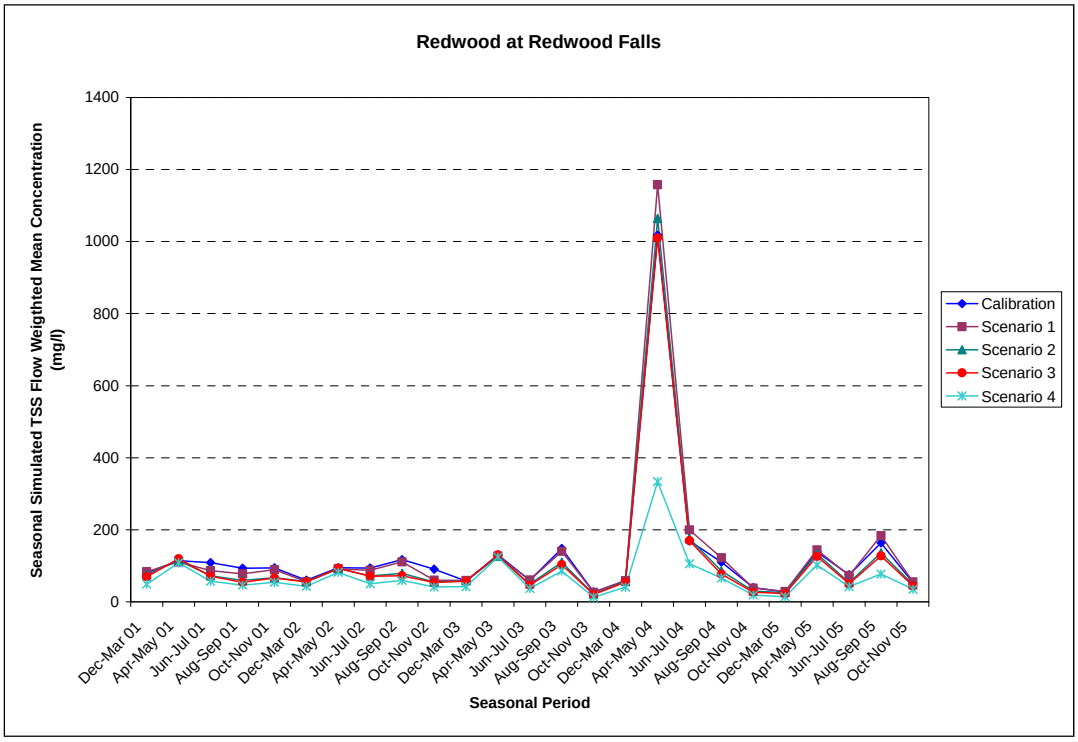


Figure 6.6 Seasonal Flow-Weighted Average TSS, Redwood River at Redwood Falls

While Scenario 4 achieves load reductions, the objective is to meet the water quality standard for turbidity. The MPCA has developed TSS targets that are consistent with meeting the turbidity criteria, ranging from 50 mg/L in the upper watershed to 100 mg/L in the lower mainstem Minnesota River. The performance of Scenario 4 relative to these TSS objectives for the Yellow Medicine and LeSueur Rivers are summarized in Figures 6.7 and 6.8. The remaining reaches can be found in the Scenario Report. The change in the distribution of land use is shown in Figures 6.9 and 6.10. Land in conventional tillage decreases while land in pasture/CRP and cropland with manure application increases. See pages 15 through 18 of the Minnesota River Turbidity TMDL Scenario Report for the distribution of existing land use and Scenario 4 land use in all watersheds.
Even with simulated changes in land use in Scenario 4, the surrogate targets are frequently exceeded. It thus appeared that the reductions of Scenario 4 were not sufficient to achieve water quality standards. The results for the other reaches in this project were similar to these two examples. Overall, Scenario 4 provided a 47.2 percent reduction in delivered sediment loads at the mouth of the LeSueur River, despite much larger reductions in loads from agricultural lands.

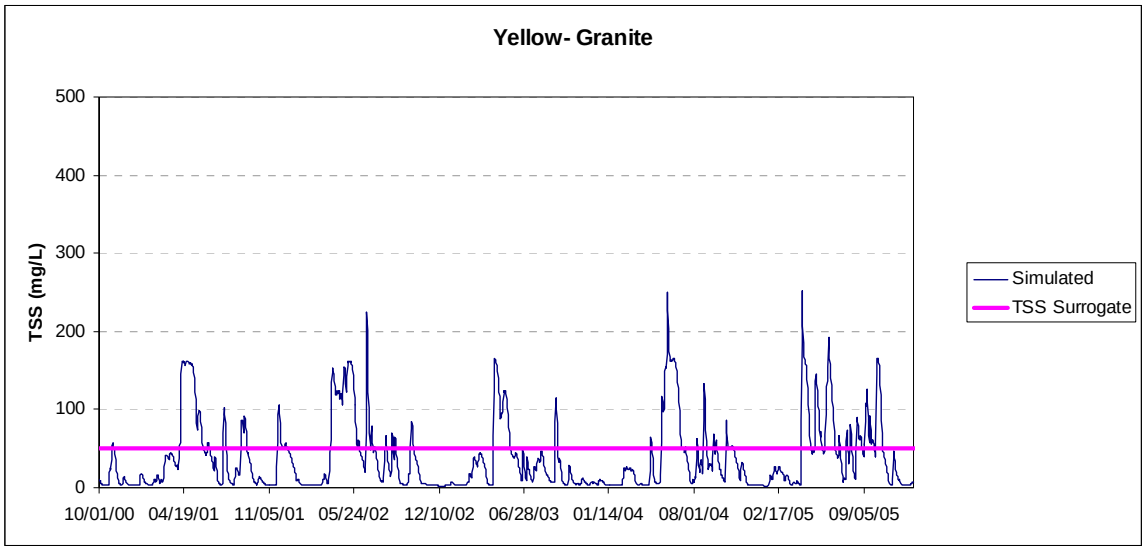


Figure 6.7 Yellow Medicine River at Granite Falls, Scenario 4 Simulated TSS

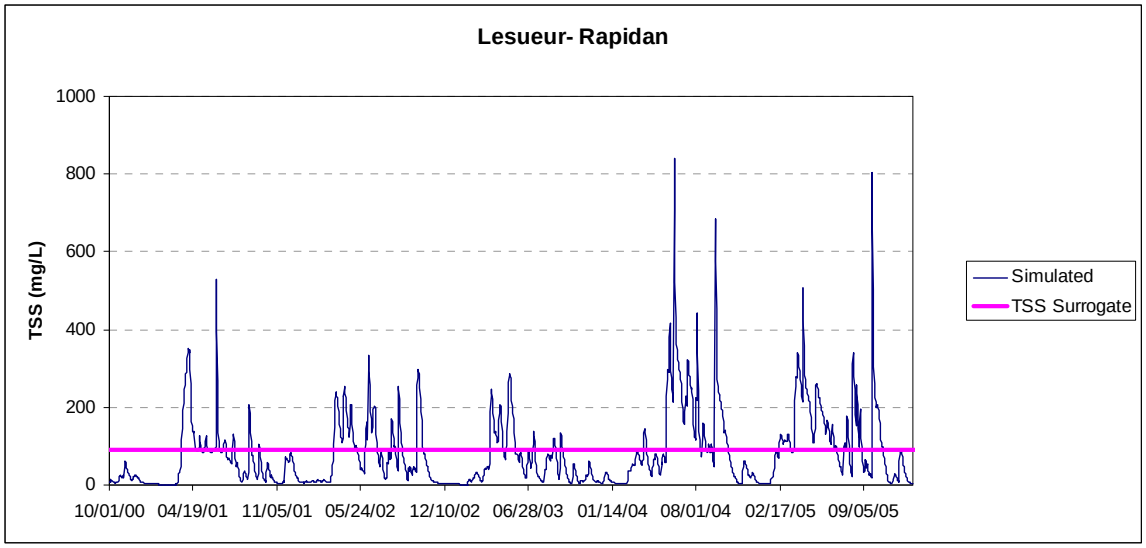


Figure 6.8 LeSueur River at Rapidan, Scenario 4 Simulated TSS

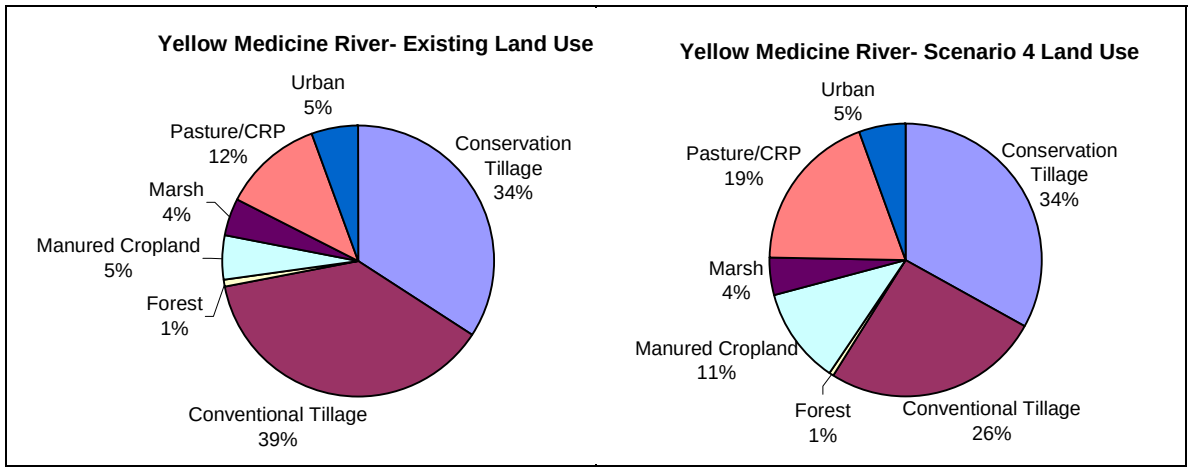


Figure 6.9 Modeled land use for existing conditions and Scenario 4 for the Yellow Medicine River.

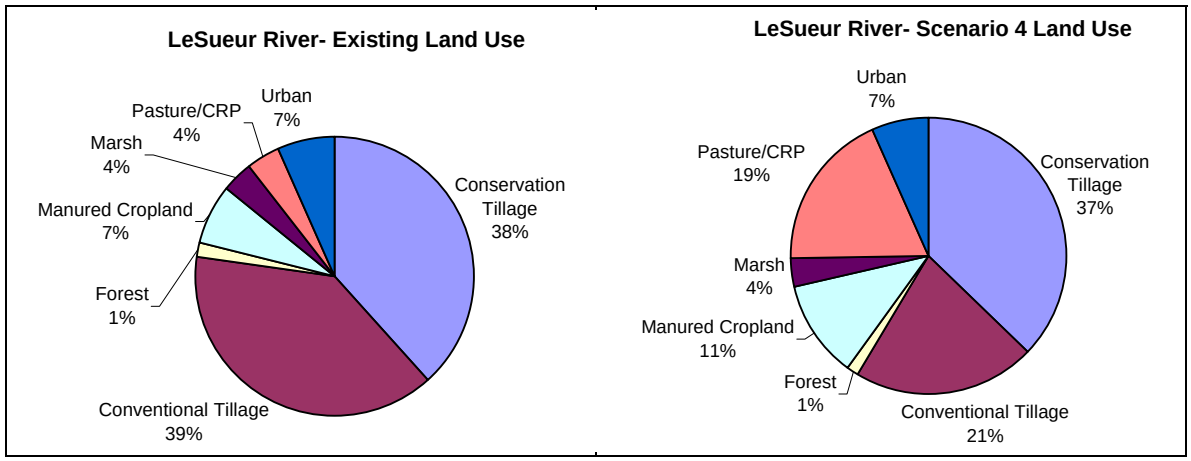


Figure 6.10 Modeled land use for existing conditions and Scenario 4 for the LeSueur River.

b. Target Scenario (Scenario 5)

Scenario 4 did not achieve the needed load reduction targets. For the most part, load reductions were from upland and ravine loads and not streambeds, banks, or bluffs. Scenario 5 represents "paradigm change" – simulating the level of change of both the landscape and the stream network that were needed to achieve the turbidity surrogate concentrations.

The TSS loading targets were set by the MPCA using a load-duration curve approach. The turbidity surrogates were used to develop the load duration curves. This approach focuses on flows up to the 95th percentile (i.e. the mid-point of the high flow zone on the load duration curves). In addition, a 10 percent explicit margin of safety will be built in, so the objective will be set at 90 percent of the TSS surrogate value. For example, in the LeSueur River near the city of Rapidan, the scenario should achieve a daily average suspended sediment concentration of 81 mg/L (90 percent of the 90 mg/L target) on days when the flow is less than or equal to the 95th percentile flow of 2,870 cubic feet per second. The attainment of the target is assessed, as previously, over the period from December 2000 to November 2005 (crop years 2001-2005).

The TMDL target scenario (Scenario 5) was developed iteratively. First, a set of baseline measures was applied to all watersheds. Then, additional measures were applied on an individual watershed basis, as needed, to achieve targets.

Analysis of the results of Scenario 4 demonstrated that large reductions were achieved in loads from upland sources and ravine loading. Most of the remaining load is derived from channel and bank/bluff erosion, particularly in the bluff reaches. A reduction in these sources is needed to achieve standards. However, it was also determined that some excursions appeared to be caused by runoff from developed ("urban") land outside of MS4 boundaries, for which no enhanced management has been proposed in earlier scenarios. A detailed description of baseline components of Scenario 5 is provided in the Minnesota River basin Turbidity TMDL Scenario Report (Tetra Tech, 2009). Given below is a brief summary of the Scenario 5 components.

- All upland management practices simulated in Scenario 4 were used in Scenario 5;
- An additional reduction in sediment load from developed land *outside* of MS4 boundaries was imposed;
- The rates of sediment supply from the bluffs were reduced by 25 percent; and
- Other adjustments.

The baseline components of Scenario 5 reduced rates of excursion of the TSS surrogate objectives to around 5 – 10 percent, but did not fully achieve the targets. Therefore, additional management measures were applied on a watershed by watershed basis to meet the targets. In many cases, these additional measures were needed to address a few isolated excursions of the objectives. These additional measures included:

- The transport capacity for sheet and rill erosion from the pasture/grass/CRP land use was reduced in all basins. Such a reduction appears reasonable, as there is a

shift from grazed pasture to CRP within this land class. Intact grass lands with good cover should provide low erosion rates, but significant erosion can occur in areas that are overgrazed, from tracks and paths and in areas where cattle have access to streams. A 50 percent reduction in transport capacity was required for the Chippewa, Hawk Creek, Yellow Medicine and Watonwan watersheds; an 80 percent reduction was required in the Cottonwood, Redwood, Blue Earth, LeSueur, Middle Minnesota and Lower Minnesota watersheds;

- Sediment load derived from the pervious portion of developed lands outside of MS4 boundaries was further reduced in several watersheds, with a 75 percent reduction in the Cottonwood, Blue Earth and Middle Minnesota watersheds and an 85 percent reduction in the LeSueur watershed;
- In the Hawk Creek, Yellow Medicine, Redwood, Cottonwood, Blue Earth, LeSueur and Middle Minnesota watersheds, model subwatersheds that had less than 75 percent of cropland in conservation tillage under Scenario 4 were increased to a minimum of 75 percent conservation tillage;
- Erosion from ravines prevented attainment in the Blue Earth watershed and was further reduced to about half of the Scenario 4 rates;
- Additional reductions to bluff-area transport capacity beyond those specified in the baseline were applied in the Blue Earth and Redwood watersheds.

The final configuration of Scenario 5 represents an extremely effective suite of management measures. Different combinations of management measures that achieve similar levels of reduction might also achieve targets, but it is clear that any successful strategy would need to address both channel and upland loads, and include measures that reduce loading during both large events (where upland loading is dominated by runoff from cropland) and smaller events (where significant contributions come from impervious surfaces associated with developed land).

Results of Scenario 5 for the tributary watersheds and the Minnesota River mainstem were summarized in appropriate graphs and tables and are provided in the *Minnesota River Basin Turbidity TMDL Scenario Report* (Tetra Tech, 2009). A sample of TSS results for Scenario 5 for the Blue Earth River at Rapidan is shown graphically in Figure 6.11. In the figure, the TSS concentrations associated with flows above the 95th percentile are marked in magenta. Results show that there are no remaining excursions of the surrogate objectives, and only a few excursions when the 10 percent Margin of Safety is applied.

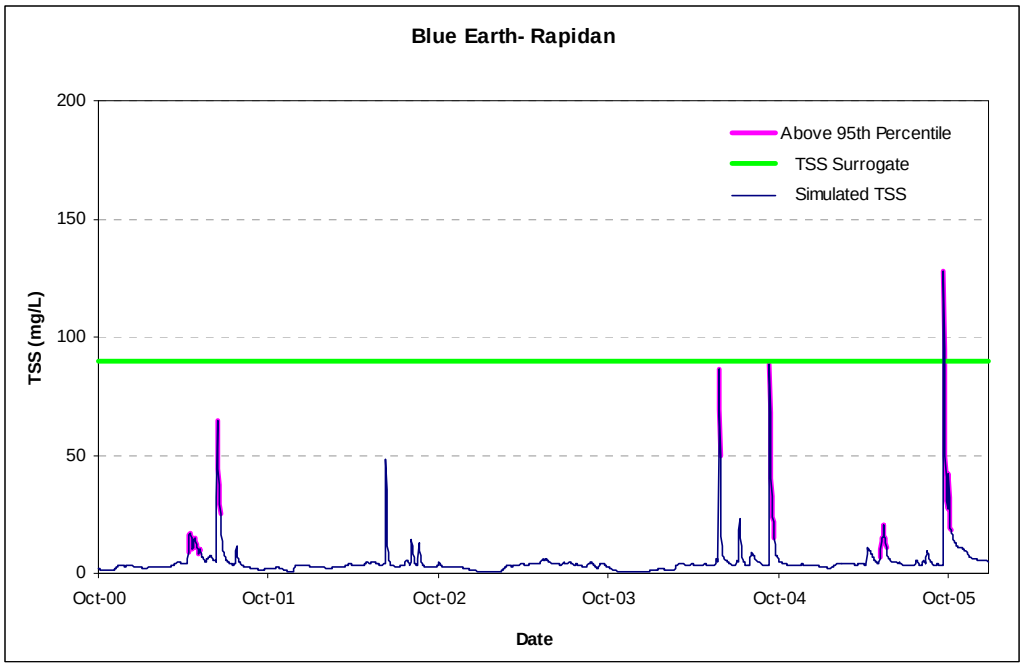


Figure 6.11 Scenario 5 Results for Blue Earth River at Rapidan

The reductions in instream loads needed to meet the TSS surrogates resulted in a corresponding reduction in flow-weighted mean concentrations. Results for the Blue Earth River at Mankato are compared to existing conditions and to Scenario 4 in Figure 6.12.

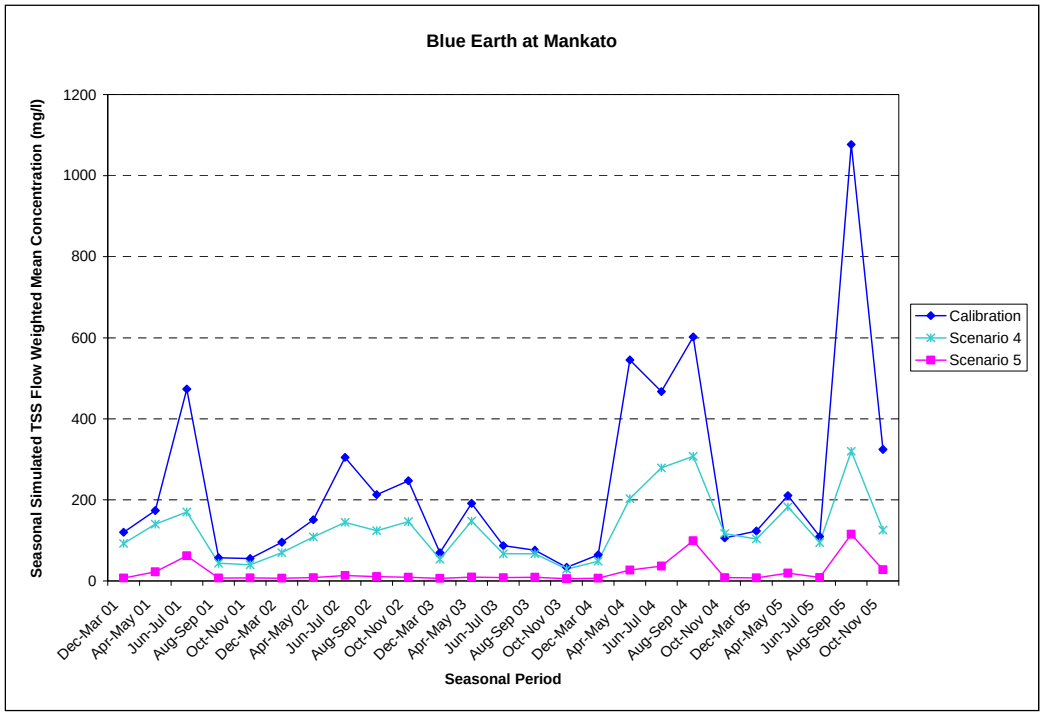


Figure 6.12 Seasonal Flow-Weighted Average TSS for Scenario 5, Blue Earth River at Mankato

The results from the HSPF model scenarios were instructional and provided the following information:

1. To meet the turbidity standard a high level of reduction and associated land use change is needed;
2. Simulating water storage in the landscape made a large difference in reducing turbidity;
3. Key practices in the model included:
   a. Perennial vegetation;
   b. Redistribution of the perennial vegetation to the lower parts of each watershed;
   c. Controlled drainage on land with less than 1 percent slope;
   d. Temporary storage of runoff. In rural areas half of the first two inches was stored for 24 hours and in urban areas the first inch was infiltrated; and
   e. Reducing ravine erosion

The HSPF model also provides: 1) Sediment loads by major watershed under current and future conditions; and 2) Sediment and phosphorus loads exported from the Minnesota River at the city of Jordan. Results for the Minnesota River at the city of Jordan are important for downstream projects. The lower Minnesota River is impaired for dissolved oxygen during low flow conditions. Phosphorus from upstream is part of the cause of that impairment. Additionally, turbidity impairs the lower Minnesota River and a Lake Pepin TMDL targets nutrients and turbidity. Model results at the city of Jordan are informative for those downstream projects by estimating the future loads and the management practices needed to attain them.

c. Total Sediment Loads by Major Watershed

Figures 6.13 and 6.14 summarize the total sediment load by major watershed for existing and Scenario 5 conditions, respectively. In these figures “mainstem” includes the Minnesota River channel itself and smaller tributaries, such as the Little Cottonwood River and High Island Creek. Note that the scale differs between the figures to make the graphics in the second figure legible. Mainstem sediment loads do not appear in the bars representing 2004 and 2005. During these years the mainstem stored sediment.

d. Sediment and Phosphorus Load Export from the Minnesota River at Jordan

The TMDL target scenario results in a large reduction in the total sediment export at Jordan. The average annual load (over water years 2001-2006) is reduced to 86,375 tons/yr, or only 10 percent of the baseline load for existing conditions. A comparison of TSS load results for all scenarios is given in Figure 6.15.

As should be expected, the reduction in sediment loading also causes a large reduction in phosphorus export. The average phosphorus export at Jordan is 463 tons/yr, or about half of the baseline export of 908 tons/yr. Phosphorus can cause algal blooms, and therefore turbidity. Phosphorus contributes to low dissolved oxygen levels during low flow conditions in the lower Minnesota River (MPCA, 2004) and also contributes to the nutrient impairment in Lake Pepin. A comparison of total phosphorus load results for all scenarios is given in Figure 6.16. The net phosphorus loading delivered to the mainstem

by major watershed under existing and Scenario 5 conditions is summarized in Figures 6.17 and 6.18.

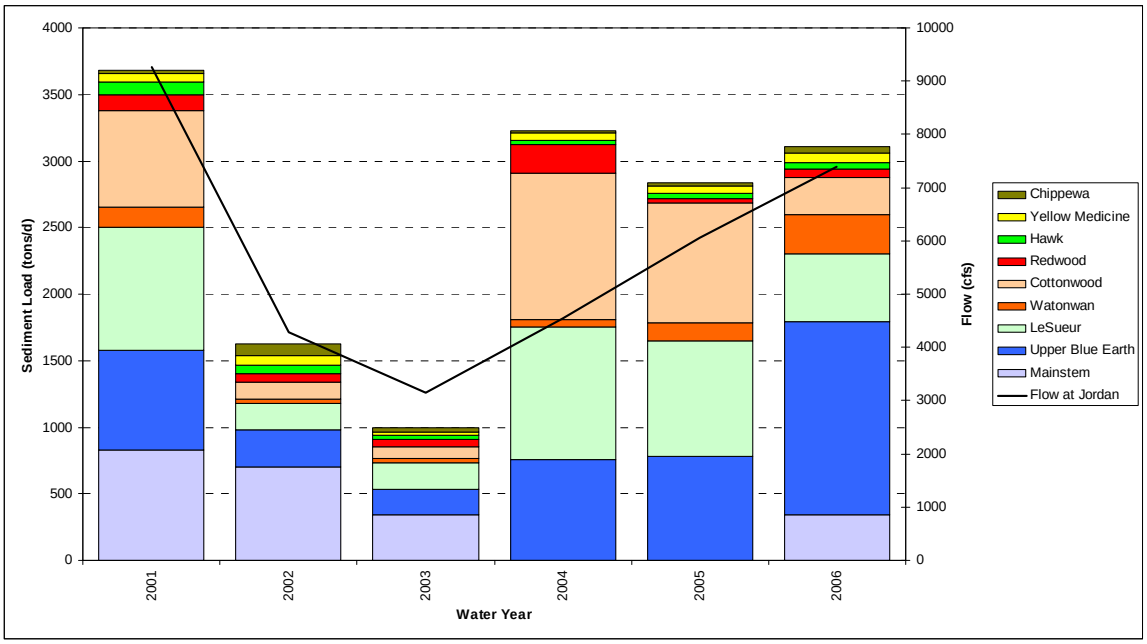


Figure 6.13 Total Sediment Load by Major Watershed, Existing Baseline Conditions

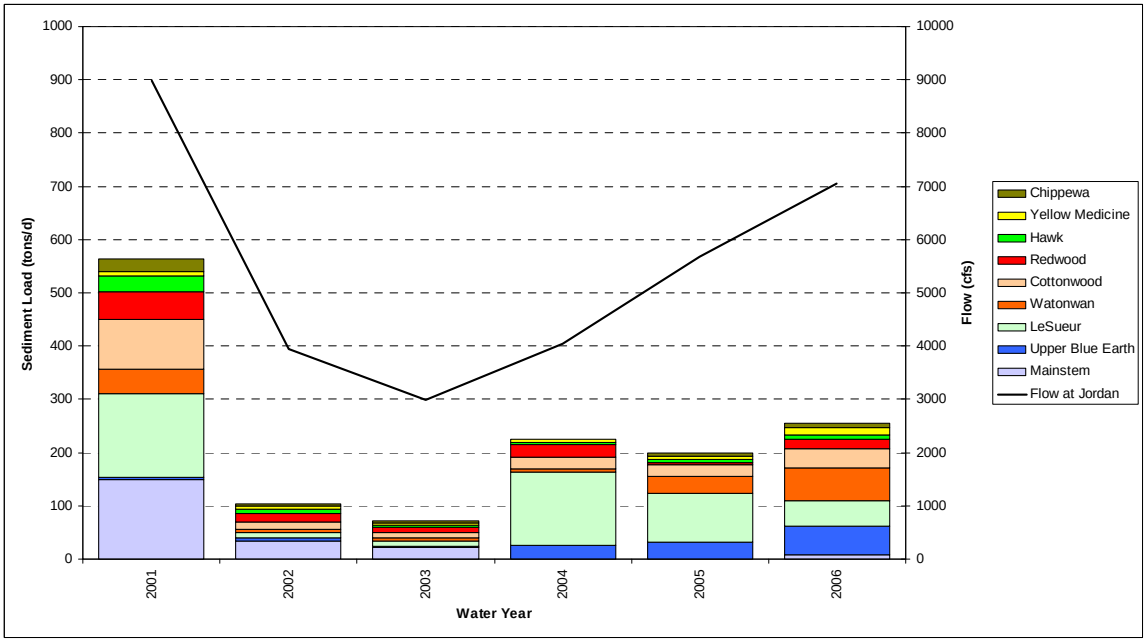


Figure 6.14 Total Sediment Load by Major Watershed, Scenario 5

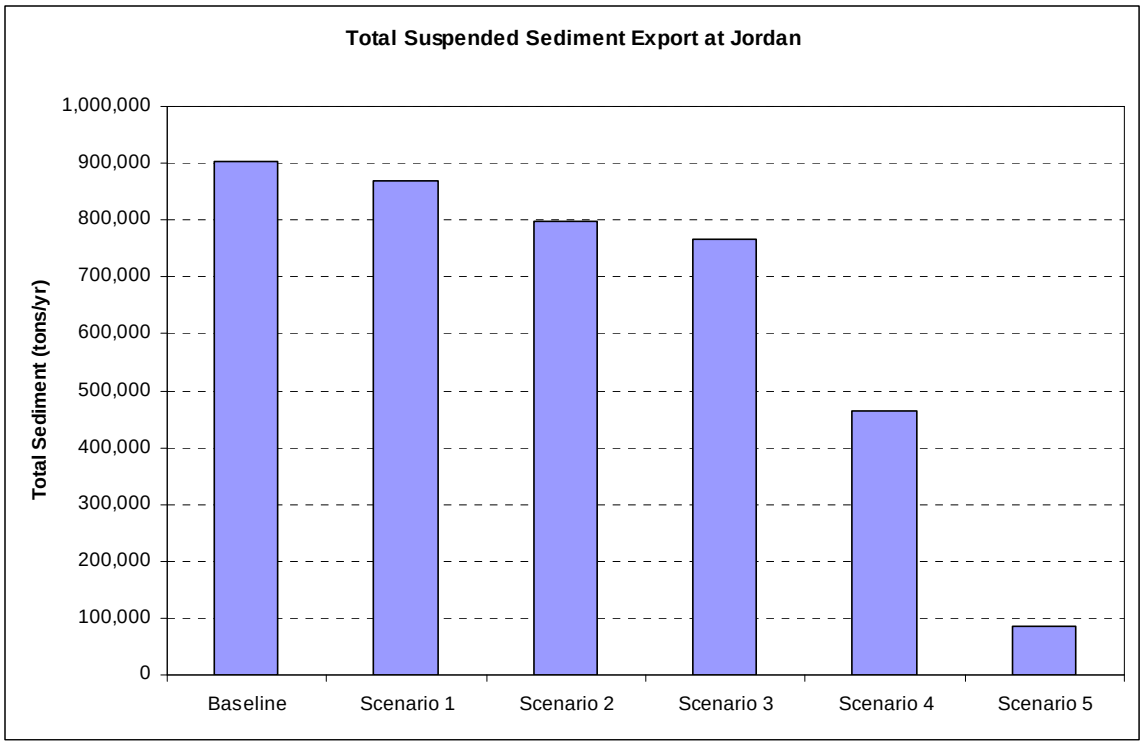


Figure 6.15 Comparison of Total Suspended Solids Load Results for All Scenarios

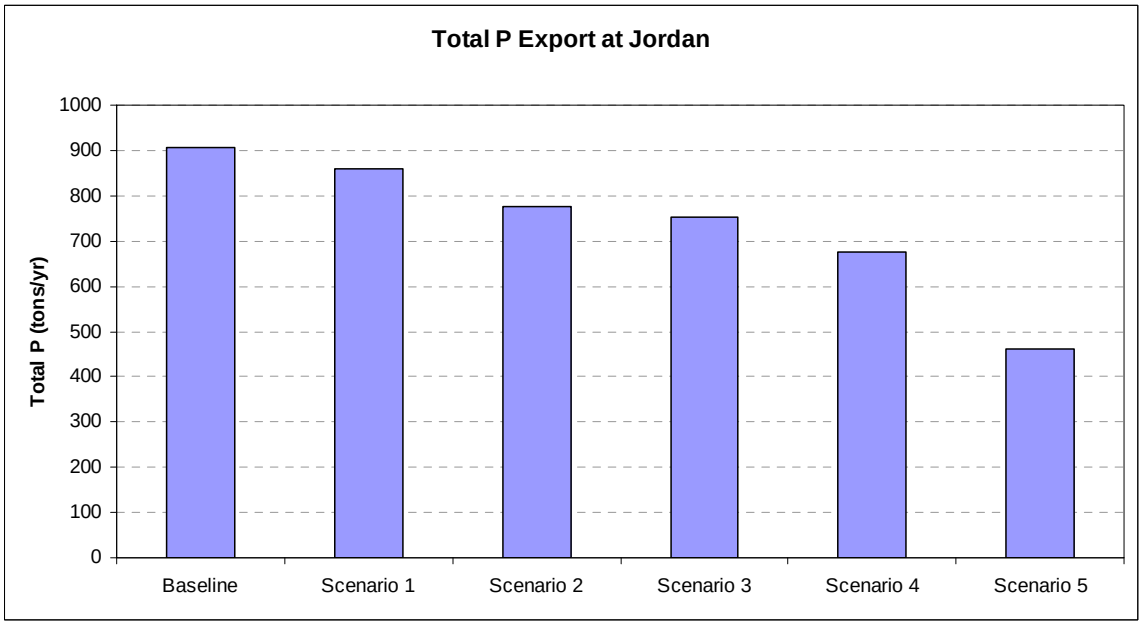


Figure 6.16 Comparison of Total Phosphorus Load Results for All Scenarios

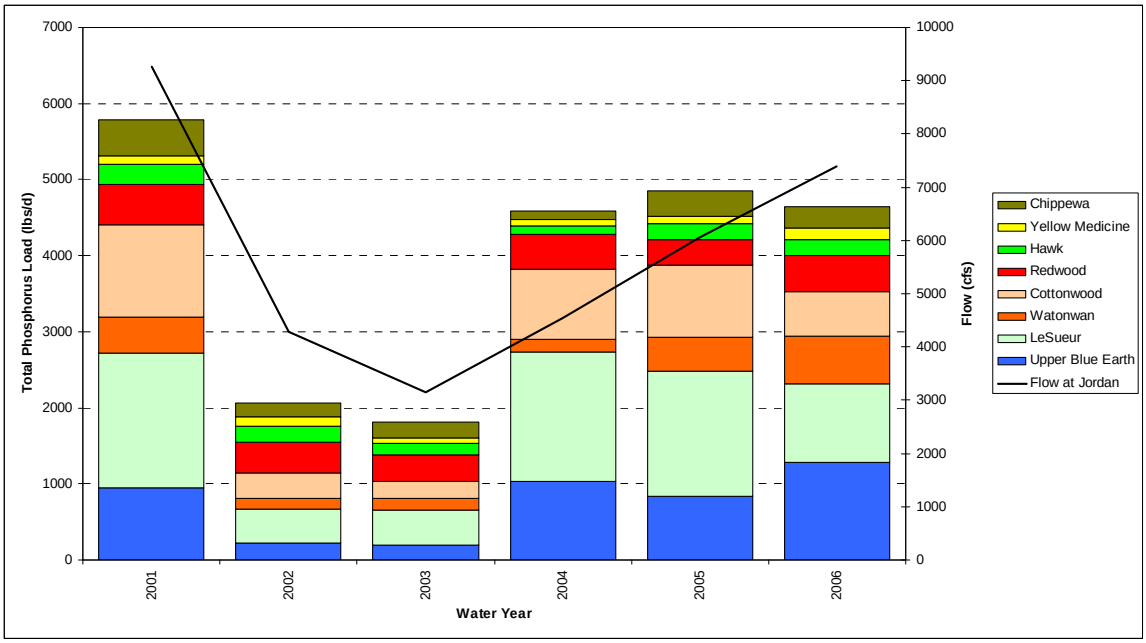


Figure 6.17 Total Phosphorus Load by Major Watershed, Existing Baseline Conditions

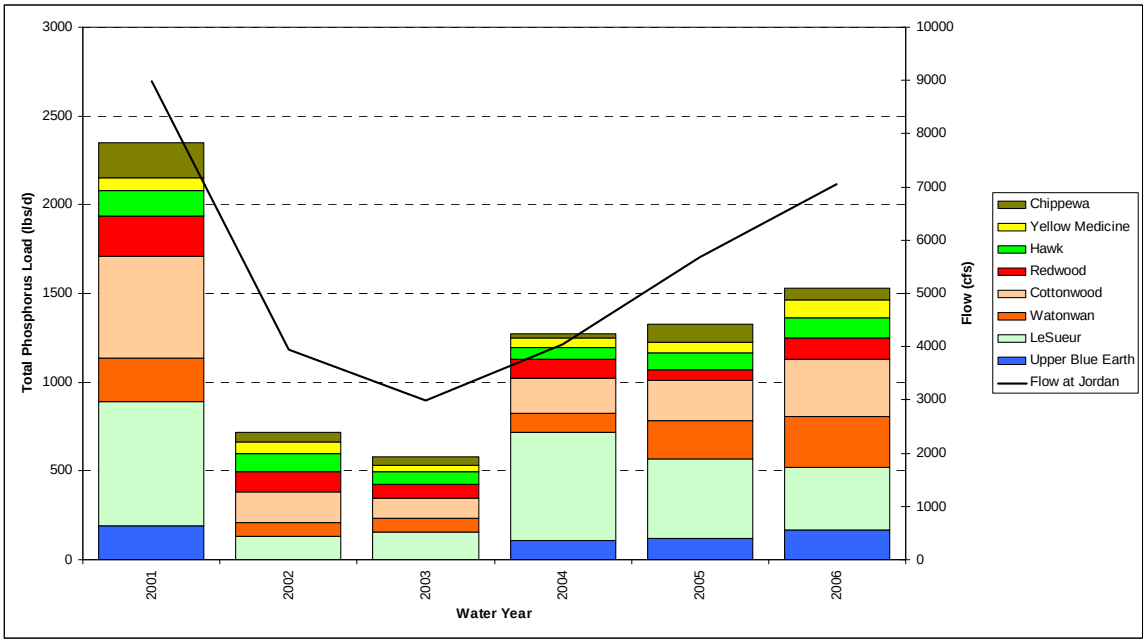


Figure 6.18 Total Phosphorus Load by Major Watershed, Scenario 5 Conditions

7. Future Growth – New and Expanding Discharges

The MPCA used the Load Duration Curve (LDC) method to determine the loads required to attain water quality standards. The LDC method uses river flows to determine the allowable loads of TSS. A comparison between the in-stream TSS targets and technology-driven TSS effluent limits contained in MPCA NPDES permits shows that the effluent limits are below the in-stream targets. Thus, as demonstrated by Tetratech (Cleland, 2011), discharges from these facilities provide assimilative capacity beyond that which is required to offset their respective TSS loads. Although facilities are discharging below the in-stream targets, they are still discharging the pollutant of concern (TSS), and therefore individual waste load allocations are required (waste load allocations are listed in Appendix A; derivation methodology is described in section 4).

The NPDES waste load allocations in this TMDL are based upon current discharges. For a new or expanding (non-stormwater) NPDES-permitted facility in the watershed, permit limits will maintain discharge effluent at a concentration below the respective in-stream TSS concentration target. A new or expanding facility will increase both load and flow. This effect will be most pronounced in lower flows, when conventional point sources have the greatest impact. The increased flow will effectively increase the overall assimilative capacity of the river, as the flow increase will be larger proportionally than the load increase.

The analysis by Tetratech (Cleland, 2011) summarized above demonstrates that current discharges can be expanded and new NPDES discharges can be added while maintaining water quality standards, provided the permitted NPDES effluent concentrations remain below the in-stream targets. Given this circumstance, a streamlined process for updating TMDL waste load allocations to incorporate new or expanding discharges will be employed. This process will apply to the non-stormwater facilities identified in Appendix A of the TMDL (in the case of expansion) and any new wastewater or cooling water discharge in the portion of the Minnesota River basin to which this TMDL applies:

1. A new or expanding discharger will file with the MPCA permit program a permit modification request or an application for a permit reissuance. The permit application information will include documentation of the current and proposed future flow volumes and TSS loads.

2. The MPCA permit program will notify the MPCA TMDL program upon receipt of the request/application, and provide the appropriate information, including the proposed discharge volumes and the TSS loads.

3. TMDL Program staff will provide the permit writer with information on the TMDL waste load allocation to be published with the permit's public notice.

4. The supporting documentation (fact sheet, statement of basis, effluent limits summary sheet) for the proposed permit will include information about the TSS discharge requirements, noting that for TSS, the effluent limit is below the in-stream TSS target and the increased discharge will maintain the turbidity water quality standard. The public will have the opportunity to provide comments on the new proposed permit, including the TSS

discharge and its relationship to the TMDL.

5. The MPCA TMDL program will notify the EPA TMDL program of the proposed action at the start of the public comment period. The MPCA permit program will provide the permit language with attached fact sheet (or other appropriate supporting documentation) and new TSS information to the MPCA TMDL program and the US EPA TMDL program.

6. EPA will transmit any comments to the MPCA Permits and TMDL programs during the public comment period, typically via e-mail. MPCA will consider any comments provided by EPA and by the public on the proposed permit action and waste load allocation and respond accordingly; conferring with EPA if necessary.

7. If, following the review of comments, MPCA determines that the new or expanded TSS discharge, with a concentration below the in-stream target, is consistent with applicable water quality standards and the above analysis, MPCA will issue the permit with these conditions and send a copy of the final TSS information to the USEPA TMDL program. MPCA's final permit action, which has been through a public notice period, will constitute an update of the WLA only.

8. EPA will document the update to the WLA in the administrative record for the TMDL. Through this process EPA will maintain an up-to-date record of the applicable waste load allocation for permitted facilities in the watershed.

8. Critical Conditions and Seasonal Variation

Turbidity levels are at their highest following significant storm events, especially when crop canopy is absent in spring and early summer months. Turbidity levels can also vary annually. Seasonal variation is captured in the duration curve methodology used in this TMDL. Few violations of the standard occur during extremely low flow conditions.

9. Reasonable Assurance

A TMDL needs to provide reasonable assurance that water quality targets will be achieved through a specified combination of point and nonpoint source reductions reflected in the load allocations and waste load allocations. "When a TMDL is developed for waters impaired by both point and nonpoint sources and the WLA is based on an assumption that nonpoint source load reductions will occur. The TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for EPA to determine that the TMDL, including the load and WLA, has been established at a level necessary to implement water quality standards" (EPA, 1992).

Required point source controls will not be effective in improving water quality in the Minnesota River basin unless accompanied by reductions in nonpoint sources. These steps are intended to link programs to environmental outcomes:

- Revise tributary strategies to identify controls needed to meet TMDL allocations;
- Evaluate existing programmatic, funding and technical capacity to fully implement tributary strategies;
- Identify gaps in current programs and local capacity needed to make progress;
- Commit to systematically fill gaps and build program capacity:
- Demonstrate increased implementation and/or pollutant reductions:
- Commit to track/monitor/assess progress at set times – adaptive management; and
- Accept contingency requirements if milestones are not met.

  (USEPA, 2009)

The MPCA will use the following for reasonable assurance:

- Develop basin-level strategies for the Minnesota River to meet TMDL allocations according to a phased schedule of implementation. This strategy will include how specific activities will be implemented at the appropriate scale – broad basin-wide initiatives and more specific actions for major watersheds. Subsequent watershed projects will provide additional information and targeting as impairments are approached on a watershed basis;
- Further targeting and prioritization schemes can be created at the watershed level. Consider how to best distribute programs for water storage and perennial vegetation. In the past this has been done through CREP, CRP, WREP, and EQIP, among others;
- Evaluate existing programmatic, funding and technical capacity to fully implement basin and watershed strategies;
- Identify gaps in current programs, funding and local capacity to achieve the needed controls;
- Commit to systematically fill gaps and build program capacity. Demonstrate increased implementation and/or pollutant reductions;
- Commit to track/monitor/assess, adjust strategies and report progress at set regular times. Use the State of the Minnesota River Report, Minnesota River Progress Report and Trends analysis as well as data from eLink, watershed projects and other sources; and

- Consider other options if milestones are not met after a previously agreed upon time or after specific actions have been taken.

Options if sediment reductions are not made:

- Change access to funding by local units of government;
- Setting specific priorities or requirements for RFPs;
- Review of statewide nonpoint source control programs and policies by state agencies, and their implementation by local agencies;
- Requirements or inducements to implement existing nonpoint source authorities, including protected shoreland buffers (Minn Stat. 103F.201);
- Prohibition against excessive soil loss (Minn Stat. 103F.415). Prohibition of nuisance nonpoint source pollution (Minn. R. 7050.0210, subp. 2);
- Encourage drainage ditch buffers – some counties have elected to redetermine benefits through Minn. Stat. 103E.021. Drainage ditch buffers need to be installed upon a redetermination of benefits. Five counties in the Minnesota River basin have ordered a redetermination of benefits on all systems. These include Martin, Sibley, Freeborn, Steel and Faribault. Fourteen other counties are using this process on selected drainage systems; and
- Non-regulated MS4s can be designated for permit coverage if it is demonstrated that the MS4 is determined to be a significant contributor of pollutants (Minn. R. 7090.1010, subp. 2, B).

Within this framework of implementation, reasonable assurance will be provided with regard to nonpoint sources through commitments of funding, watershed planning and use of existing regulatory authorities. The Clean Water Legacy Act (2006) provided the MPCA authority and direction for carrying out section 303(d) of the Clean Water Act, in addition to one-time funding to initiate a comprehensive 10-year process of assessment and TMDL development in Minnesota. In November 2008, Minnesotans voted in support of the Clean Water, Land and Legacy Amendment to the state constitution. Through this historic vote, approximately $5.5 billion will be dedicated to the protection of water and land over the next 25 years. One third of the annual proceeds from sales tax revenue, an estimated $80 to $90 million, will be devoted to a Clean Water Fund to protect, enhance and restore water quality of lakes, rivers, streams and groundwater. The Amendment specifies that this funding must supplement and not replace traditional funding. Approximately two-thirds of the annual proceeds will be earmarked for water quality protection and restoration. The Minnesota River represents approximately 20 percent of the land area in Minnesota, so approximately 20 percent of the funding, should be spent here.

In addition, efforts will be made to make more effective use of existing land-use authorities, such as the Clean Water Legacy Act (Minn Stat. ch. 114D.20, subd 3), which calls for state agencies to "…use existing regulatory authorities to achieve restoration for point and nonpoint sources of pollution where applicable, and promote the development and use of effective nonregulatory measures to address pollution sources for which regulations are not applicable." The MPCA will seek to pursue the following policies with state and local agencies:

- Comply with 50 foot buffer required for the shore impact zone of streams classed as protected waters (Minn Stat. 103F.201) for agricultural land uses;
- Comply with requirements to buffer highly erodible land within the 300-foot shoreland district, as described in the state shoreland rule;
- Comply with the requirement for a 16.5-foot buffer on agricultural drainage ditches as defined in Minn. Stat. 103E.021;
- Review the use of excessive soil loss ordinances by counties (described in MN Stat. 103F.415) and the potential benefits of applying soil loss ordinances specifying a maximum rate of "T" (the tolerable rate of soil erosion which the NRCS defines as the rate at which soil can replenish itself) to areas contributing high amounts of sediment; and
- Review the MPCA's authorities on the prohibition of nuisance nonpoint source pollution (Minn. R. 7050.0210, subp.2.).

10. Monitoring Plan to Track TMDL Effectiveness

This monitoring plan provides an overview of what is expected to occur in multiple watersheds. Aquatic life will be the ultimate measure of the effectiveness of this project. Improving aquatic life depends on many factors and will likely not be detected over the next five to ten years. Consequently, a monitoring plan is needed to track shorter term changes in water quality and land management.

Several types of monitoring will be important to measuring success. Some are already underway and will be continued while others are not yet developed. The five basic types of monitoring listed below are based on the EPA's Protocol for Developing Sediment TMDLs.

Baseline monitoring – baseline or conditioning monitoring is completed to identify the environmental condition of a water body to see if it meets established standards or reference conditions. The MPCA has a strategy to assess the condition of Minnesota's waters via a 10-year cycle relying on a combination of MPCA monitoring; monitoring by other local, state and federal agencies; citizen monitoring; and remote sensing. An outcome of this monitoring is the identification of waters that are impaired (i.e., do not meet standards and need restoration) and waters in need of further protection to prevent impairment. Over time condition monitoring can also identify trends in water quality. This helps determine whether water quality conditions are improving or declining, and identifies how management actions are improving the State's waters overall.

Another type of baseline monitoring involves land management practices. The number of acres in conservation practices is tracked by watershed. BWSR and the USDA are two of the agencies that keep this information. Section 5 of the TMDL includes the acres enrolled in the Conservation Reserve Program and Conservation Reserve Enhancement Program by watershed.

Implementation monitoring –upland implementation practices will be tracked using existing systems. Examples include eLink and the transect tillage survey. Practices not captured by these systems will also be tracked. This could include stream channel practices, for example.

Implementation activities and research projects will be coordinated with the Minnesota Department of Agriculture, the Board of Soil and Water Resources, the University of Minnesota, the National Center for Earth-surface Dynamics, agricultural organizations and others.

Effectiveness monitoring – this type of monitoring determines whether or not a practice or combination of practices are effective in improving water quality. Since near channel sources of sediment are significant, it will be important to work in those locations. This includes keeping many of the intermediate monitoring stations, which are located upstream of the knickpoints of the tributaries. Another advantage to keeping the upstream gages is that they primarily document what is happening in the fields because there are so few ravines and bluffs. A portion of the sediment passing the upper gages comes from upland sources. This monitoring also allows the estimation of the amount of sediment from the near channel

sources near to the mouths of the streams. Data from the gages, in combination with fingerprinting and/or some physical measurements of bank erosion will adequately constrain this and can help to determine the effectiveness of the near channel BMPs.

Trend monitoring – research to investigate trends allows the statistical determination of whether or not water quality conditions are improving. Minnesota State University-Mankato conducted a statistical trend analysis in the Minnesota River basin using the Seasonal Kendall and QWTREND tests. Trend analyses were performed on three mainstem, eight major tributary, and nine minor tributary sites. For the long-term stations, the period of record went back to about 1970. For many of the major watersheds, the data went back to the late 1990s. Data through 2008 were used so that at least ten years of data were available. Additional sites may be added in the future as additional data become available. Flow trends are also important since flow is a stressor when it comes to sediment sources. A minimum of ten years of data are needed for these statistical packages.

Additionally, the State of the Minnesota River Report provides water quality data at the mainstem, major, and minor watershed scales. This type of information will be provided periodically.

Leading indicators are needed to help to determine environmental improvement. These indicators would act as a sign showing that the water quality is improving or declining. Some of these measurements could be flow, runoff ratios, increases in the width-to-depth ratio of channels, or higher sand fractions in bank and floodplain deposits (Belmont, 2010).

Validation monitoring – this type of monitoring is used to validate the source analysis and linkage methods. Stakeholders remain uncertain about sediment sources at this watershed scale. Research done this far has helped to better define the upland vs. near-channel sources, but more work remains to be done. This research needs to move along with implementation to provide more certainty and as a method of prioritization of sources (e.g. banks, bluffs, ravines, and uplands). For example, additional information is needed about knickpoints. (Knickpoints define abrupt breaks in slope, dividing lower-lying downstream areas near the Minnesota River from higher upstream areas.) Monitoring above and below these features can help to constrain sediment loading and identify sediment sources. Additionally, monitoring the features directly using ground-based LiDAR, fingerprinting, and/or field surveys provides additional benefits. Load monitoring at the watershed outlets alone is insufficient to identify and ultimately target the appropriate areas for sediment reducing BMPs. Hence there is a need to keep many of the intermediate monitoring stations in place.

A group of scientists compiled a synthesis of sediment research in the Minnesota River basin in 2009 (Wilcock, et al., 2009). Much of the work depends on monitoring. The research they identified as important included:

- Continued monitoring of TSS loads from principal tributaries to the Minnesota River as well as multiple mainstem stations in order to track the response of river water quality to changes in land use, climate, and management actions.

- Continued gauging upstream and downstream of incised portions of key watersheds in order to identify the magnitude of bluff and ravine contribution and to test methods for estimating the contribution from different sources within a watershed. These gauges provide a high return in improved understanding of the magnitude, location, and mechanism of sediment supply in the Minnesota River basin.
- Complete sediment budget for the LeSueur watershed, combining all sources in a model that accounts for the routing and storage of sediment along the rivers, using a mass balance to constrain estimates and define uncertainty. This has been completed and is available on the MPCA's web site. A next step is to upscale this to the Greater Blue Earth River Basin.
- Complete an inventory of ravines and bluffs for the incised portion of the Minnesota River basin. Conduct research to measure sediment loads from these features.
- Use a mass balance to reconcile erosion estimates from different methods, including extrapolation of local erosion rates, different various fingerprinting methods, physical measurements of erosion (terrestrial LiDAR, field surveys, etc.), and gauging records.
- Develop a basis for extrapolating sediment budgets from one watershed to another in order better characterize sediment sources throughout the Minnesota River basin.
- Develop a sediment budget for the Minnesota River mainstem in order to identify the magnitude of sediment storage and the factors that control changes in sediment storage. Evaluate possible management actions along the mainstem that may alter the proportion of TSS stored in the river floodplain.
- Conduct research to identify the relative roles of changing climatic patterns versus changing land use and land management patterns on sediment delivery from fields, banks, bluffs, and ravines.
- Explore the role of tile and ditch drainage as well as changes in cropping systems in changing stream hydrology and the erosive potential of Minnesota River tributaries.

11. Implementation Strategy

The Clean Water Legacy Act requires an implementation plan to be developed for TMDLs, following approval by U.S. EPA. The plan is a document detailing restoration activities needed to meet the approved TMDL's pollutant load allocations for point and nonpoint sources. A TMDL of the magnitude of the Minnesota River poses challenges and developing an actionable implementation plan is almost impossible. Therefore, detailed implementation planning for the Minnesota River will occur at the individual major watershed level.

The starting point for this high level plan will be an outline of general strategies and actions for achieving TMDL targets. The MPCA will incorporate input from the stakeholder advisory committee process into this plan. The MPCA will also incorporate ideas and testimony from citizens, interest groups, agencies and others, through the formal public comment process and through various informal meetings and interactions. The MPCA will share this draft plan with the range of stakeholders and interest groups throughout the basin to gather their input before adopting a final set of strategies.

In addition, this plan will address requirements in both the South Metro Mississippi and Minnesota River given that the Minnesota River is the predominant contributor of sediment to the Mississippi. A central purpose of this document is to focus the most significant strategies on attaining water quality standards in the Mississippi and Minnesota rivers, based on the findings of the two respective TMDL studies.

Another purpose for this high-level plan will be to guide state policy and coordinate actions among the major watershed implementation plans in the basin.

The intent of this high-level plan is to direct activities to achieve the load allocations and waste load allocations set forth in the Minnesota River Turbidity TMDL. The plan will specify TSS load-reduction targets, strategies and broad activities at the Mississippi River and Minnesota River Basin scales. At the major watershed scale, implementation plans will describe the process and schedule for the targets, strategies and activities to reduce TSS loads. Thus, the implementation plans at the major watershed scale will add details not contained in the high-level plan.

The TMDL implementation plan will be structured around the following four principles:

1. Stakeholder involvement and scientific review.
2. The MPCA's watershed approach of studying major watersheds on a 10-year cycle.
3. Linkage to water resource management plans at the federal, state and local levels.
4. The adaptive management process of plan, implement, monitor, evaluate, adapt the plan, etc.

Overall Reduction Strategies and Research

At this basinwide level, approximately ten to forty percent of the sediment is from upland sources and sixty to ninety percent from near channel sources (Wilcock, et al., 2009;

Schottler & Daniel R. Engstrom, 2010). These estimates differ by watershed. While implementation activities will need to address both of these major sources, it is likely that people in different watersheds within the basin will put more focus on one or the other. And some sources may be harder to reduce than others. Different combinations of management measures than presented in the modeling may also achieve targets, but it is clear that any successful strategy would need to address both near channel and upland sources, and include measures that reduce loading during both large events (where upland loading is dominated by runoff from cropland) and smaller events (where significant contributions come from impervious surfaces associated with developed land).

Point and Nonpoint Source Activities

Wastewater treatment facilities will follow requirements in the NPDES regulatory program. Activities include establishment of effluent limits, compliance tracking and enforcement, including required corrective action, if needed.

Regulated MS4 communities – The permitted communities have a choice of monitoring stormwater discharges, modeling practices for their communities, or adopting performance measures. If performance measures are selected, a list of practices and a compliance schedule will be developed that will appear in the implementation plan.

Industrial and Construction stormwater activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit. Similarly, industrial stormwater activities are considered in compliance with provisions of the TMDL if they obtain an Industrial Stormwater General Permit or General Sand and Gravel general permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit, or meet local industrial stormwater requirements if they are more restrictive than requirements of the permit.

Nonpoint sources – Regarding nonpoint source practice implementation, a more detailed implementation strategy addressing those sources will be developed following approval of this TMDL study. A balance of practices that keep the soil in place, temporarily store water, and address near channel sources will be selected.

Prioritization mechanisms

The highest flow-weighted-mean-concentrations tend to correspond to where the near channel sources are the highest and downstream of knickpoints. Watersheds on the east side of the Minnesota River basin are the highest contributors (Figure 11.1). A prioritization mechanism will take these high contributing areas into account. A challenge will be to determine the approach for these sources of sediment. One method could be direct, where implementation measures hold the soil in place at a bluff or ravine, preventing soil from reaching the water. An indirect approach would target upstream areas to reduce flow. In this case costs could be spread out over a larger area.

Research needs

Scenarios 4 and 5 in the Minnesota River model showed that changing land use and management at a significant scale would result in decreases in TSS levels. This is largely due to water storage. The practices are well understood for uplands, wastewater and stormwater. Implementation practices for near channel sources (ravines, stream banks, bluffs, floodplains and ravines) are not as well developed, nor is a mechanism available for prioritization. Further research will need to establish relationships between sediment sources and stressors, such as flow, for example. Research also needs to consider:

a. How to reduce turbidity during higher flow conditions where current practices tend to be less effective;
b. Using latest research on terrain analysis and LiDAR to enhance the understanding of the system;
c. How to more precisely identify sources where possible;
d. Prioritization and targeting of sources so that the fixes will have the greatest impact with the least cost;
e. Understanding the causes/stressors leading to the high sediment/turbidity levels;
f. Development of practices in areas where there are few alternatives for reducing turbidity (such as bluffs or during higher flow periods). Focus on practices to reduce flow peaks and volumes (ag stormwater ponds, side inlet controls, culvert sizing, etc.);
g. Developing targets and strategies for storing a certain quantity of water; and
h. Providing information for people to implement practices to reduce sediment.

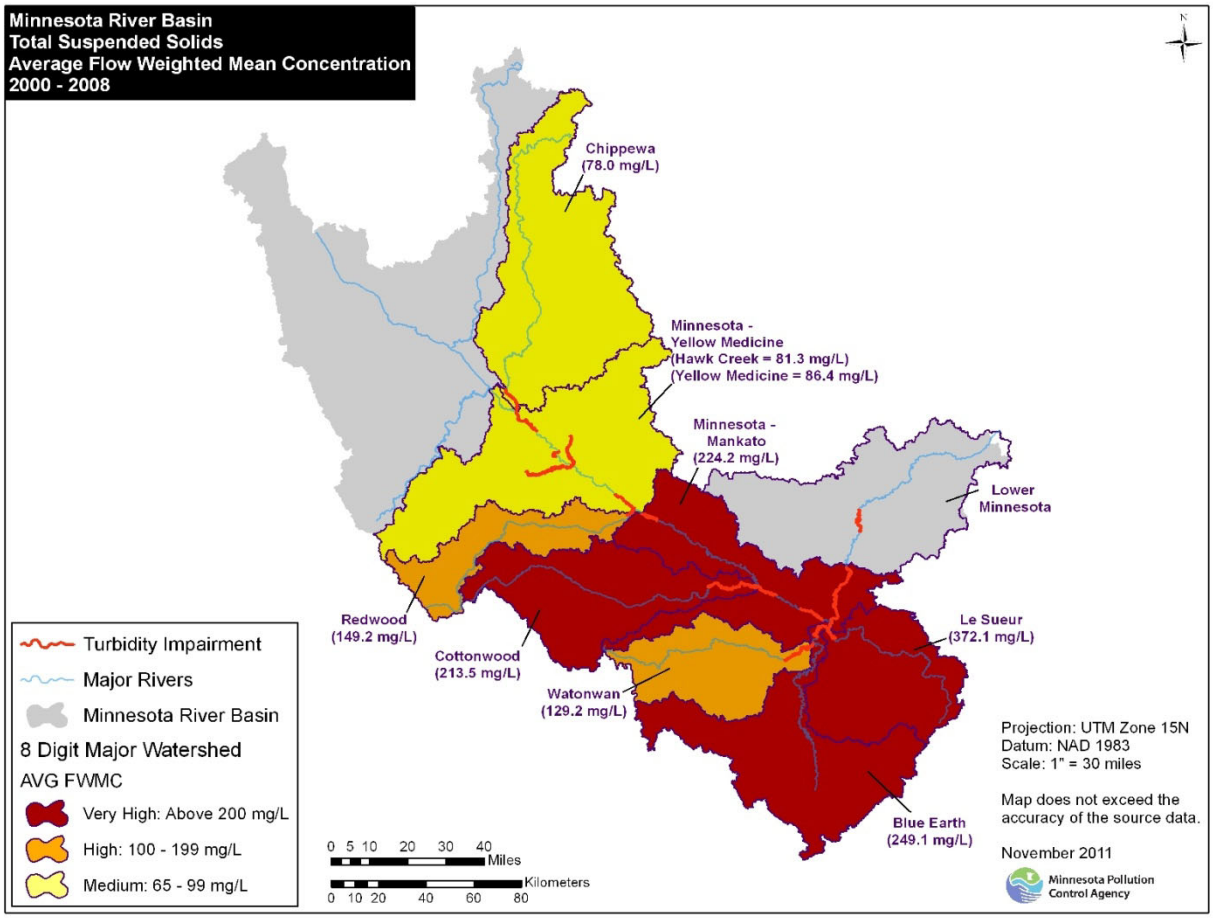


Figure 11.1TSS levels from Minnesota River watersheds.

Major Watershed Scale

Nine of the impairments in this project occur near the mouths of the major watersheds. Implementation planning will occur in conjunction with the watershed approach, which is a ten-year rotation for addressing waters at the major watershed level. It focuses on the watershed's condition as the starting point for water quality assessment, planning, implementation, and measurement of results. This approach may be modified to meet local conditions, based on factors such as watershed size, landscape diversity and geographic complexity. The steps include 1) Monitoring and gathering information, 2) Assessing the data, 3) Establishing implementation strategies and 4) Implementing activities to protect and restore waters. Involving local residents and people with a stake in how to address the needs is a priority. Local partners in the watersheds will draft implementation plans to reduce sediment and meet other local water needs. An advantage of this method is that the planning will occur at the local level and efforts will be targeted in each watershed.

Implementation planning will occur via the ten-year planning cycle (Table 11.1) in conjunction with other TMDLs. At the major watershed level, the following practices will be considered:

BMP Strategy - the types of alternative practices include:

a. Perennial vegetation to keep soil in place in increase infiltration;
b. Crop residue or cover crops to keep soil in place;
c. Elimination or protection of surface tile inlets to decrease the amount of sediment transported directly to surface water;
d. Decreasing ravine erosion;
e. In-line ditch design;
f. Water storage (surface or subsurface storage of one inch of runoff for 24 hours); and
g. Focusing on areas downstream of knickpoints where near channel source contributions are high.

Table 11.1 Ten-year schedule for monitoring, planning and implementation activities by major watershed.

Watershed	Monitoring	Planning	Implementation
LeSueur	2009	2012	2012-2017
Chippewa	2009	2012	2013-2018
Hawk Creek	2010	2013	2014-2019
Yellow Medicine	2010	2013	2014-2019
Watonwan	2013	2016	2017-2022
Middle Minnesota	2013	2016	2017-2022
Lower Minnesota	2014	2017	2018-2023
Redwood/Cottonwood	2016	2019	2020-2025
Blue Earth	2017	2020	2021-2025

A Phased Approach

The sediment reduction needs in the TMDL represent aggressive goals. Implementation will be conducted using an adaptive management approach. Changes in water quality standards, technology, research and weather may alter the course of action detailed here. Continued monitoring and adjustments responding to monitoring results are the most appropriate strategy for attaining the water quality targets established in this TMDL.

A first phase could target practices near mid-range flow and high flow levels. Subsequent phases may target increasingly higher flow events, with the time between now and then used for research and prioritization.

Implementation activities will occur over a 30-year period. Three types of activities are needed: 1) Groundwork including research and developing more specific strategies prior to implementation based on planning and logistical work, prioritization and the identification of funding mechanisms; 2) Implementation activities based on the groundwork already described; and 3) Continued implementation in cases where practices are not adopted (Figure 11.2). Adjustments to this timeline will occur as organizations undertake various facets of the research and implementation agendas. Additionally, local watershed projects may elect to prioritize the list differently given local needs. This timeline is not intended to delay work. Rather the approach is to allow time for research, demonstrations, and the development of targeting mechanisms prior to focused implementation activities.

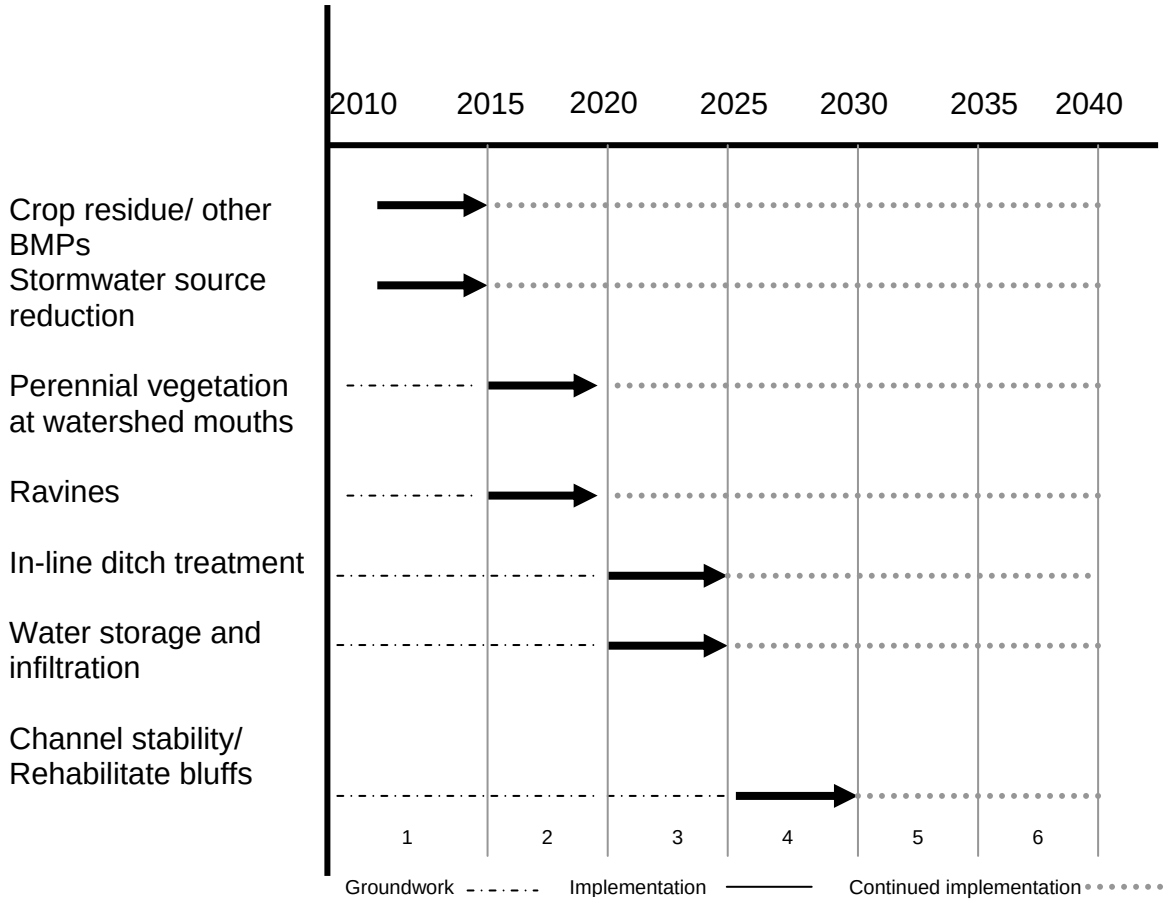


Figure 11.2 Phased approach for implementation activities.

Since a phased approach is used, pollutant trading is an option in offsetting sediment loads between sources. It can provide a cost-effective alternative to reducing sediment based on scale and technology factors. Credits must be purchased from upstream sellers to ensure that water quality is improved by trading. A pollutant trading program does not exist for stormwater and would need to be developed.

Economic Analysis

The Clean Water Legacy Act requires that a TMDL include an overall approximation of implementation costs. Estimating costs at this scale is challenging and does not allow for precise targeting or local priorities. It is simply an attempt to provide a sense of the magnitude of costs to attain water quality standards. Costs for nonpoint sources are likely to be in the hundreds of millions of dollars. To offer some perspective, an example is provided using a practice that would call for the largest change in land use. One component of the model scenarios was to increase perennial vegetation (pasture, CRP, perennial crops, and forest on cropland) to 20 percent of each watershed. This could amount to about 1.5 million acres and range in cost from $2,000 to $4,500 per acre, depending on local land prices. Approximately two to eight percent of the land in each watershed is enrolled in conservation

programs. If five percent of the cropland is already in perennial vegetation, the remaining fifteen percent would amount to an additional 1.1 million acres.

Cost estimates for point sources of urban stormwater were based on a study by Weiss et al. (2007) and use the same assumptions applied to the South Metro Mississippi River TSS TMDL. Applying these cost estimates to the required TSS reduction load for regulated MS4s results in an aggregate cost estimate of $175,000,000 for the MS4s affected by this TMDL. This value could vary significantly depending on specific BMPs selected and with different site conditions. It is likely that many permittees have achieved some reductions and this number therefore includes money that has already been expended on stormwater management.

Possible Changes to the Water Quality Standard

The estimate of land use change needed to meet water quality goals is based on Minnesota's current water quality standard for turbidity. Changes to the standard will soon be proposed. If promulgated, the new proposed standards would likely change the reduction targets and the associated land use change to meet the targets. Whether or not such changes occur, a significant reduction in sediment is needed in the Minnesota River basin. A thirty-year implementation timeline anticipates the need to adjust implementation strategies and measures in response to ongoing changes in the ultimate goals, better research and how the rivers respond.

12. Public Participation

Recognizing the scale of this TMDL project, and attempting to link it long-term with other studies completed and anticipated, citizen engagement was approached systemically. In the period from June 2005 through June 2010, the MPCA augmented traditional approaches with several innovative steps designed to foster communication and commitment.

Early in the process, a stakeholder advisory committee was formed, comprised of representatives from major interest sectors, principally agriculture, cities, watersheds, local government and state agencies, but also including environmental organizations such as Coalition for a Clean Minnesota River. The advisory committee met once a quarter, on average, with additional smaller gatherings by sector as needed.

The main meetings, attended by approximately 40 people each, and lasting about four hours, were designed with at least three purposes in mind:

1. To keep stakeholders informed about progress on the TMDL.
2. To present timely technical information in lay language, and to seek feedback.
3. To facilitate dialogue in order to build shared understanding of the TMDL process and the choices facing the community.

Presenters and panelists included MPCA staff and managers, hydrologic modeling experts, watershed professionals, researchers and stakeholders.

Owing to the gaps in knowledge about sediment sources, the MPCA contracted with four major research groups. The principal investigators plus an associate from each were formed into a Sediment Research Colloquium, which worked to integrate and summarize in lay language what is known with certainty at this point. In this way, it was believed, allocation decisions and implementation strategies could be streamlined and better understood. A summary report of the colloquium's findings was published in August, 2009, and made widely available to stakeholders [http://www.pca.state.mn.us/index.php/view-document.html?gid=8099]. The report augmented the numerous fact sheets, slide presentations, and occasional progress reports designed to keep everyone in the loop. Prior to formation of this colloquium, another much larger technical advisory panel had been established at the University of Minnesota – again to ensure that the knowledge and assumptions in the study would be sound.

In addition to these actions directly associated with the turbidity TMDL, encompassing 18 reaches in the Minnesota River basin, the MPCA took several steps to build capability and capacity among stakeholders. With most of the watershed being farmed, much of it in row crop agriculture, the challenge is to bring about change without regulation.

- In January, 2007, the agency organized a "Minnesota River Summit", attended by 200 stakeholders who had played leadership roles for water quality improvement over several decades. With its emphasis on identifying how progress could be accelerated, perhaps the most commonly-held goal among the group, the two-day meeting surfaced two general conclusions:

- Communication throughout the watershed, from Western Minnesota to the Twin Cities, needs strengthening. With many groups addressing multiple agendas, the need for raising the profile of water quality work was underscored.
- Owing to the size of the watershed, the complexity of both pollutants and societal issues, the group felt the need for a way to see the problem whole: How do these TMDL studies and others fit together, and with that, what are the high-leverage points for exponential change?

- In June, 2007, a second summit was held, like the first one also at New Ulm, Minnesota, attended by about 50 selected stakeholders. The focus here was on discussing strategies for moving forward.

Whether any of these steps can be effective depends on continuous conversations by MPCA with individuals, groups and communities throughout the watershed. Led by the basin coordinator and regional manager, numerous staff members visit meetings of organizations such as the Minnesota River Board, the Minnesota Watershed Alliance and smaller watershed improvement organizations, along with the spectrum of activities sponsored by environment interest organizations such as picnics, canoe outings, annual meetings and the like.

Smaller scale turbidity TMDL projects are underway in many other Minnesota River watersheds. The impairments are located upstream from the eighteen covered in this project. Coordination and communication at the various scales will be necessary for implementation activities.

These activities, taken together, are intended to anticipate the MPCA's developing strategy of completing TMDL studies by major watersheds in the future. For this approach, communication and a holistic understanding – shared widely throughout the community – are deemed to be critical.

Public notice in the Minnesota State Register provided for a xx-day comment period that occurred between [include public notice dates].

13. Submittal Letter

14. Administrative Record

To be added

15. References

Belmont, P. (2010). Personal Communication.

Belmont, P., Gran, K. B., Schottler, S. P., Wilcock, P. R., Day, S. S., Jennings, C., et al. (2011). Large Shift in Source of Fine Sediment in the Upper Mississippi River. *Environmental Science and Technology* , 8804-8810.

Bicknkell, B. J. (2001). *Hydrological Simulation Program - FORTRAN, HSPF Verision 12, User's Manual.* Athens, GA.: National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.

Campbell, E. &. (2009). *Development of Total Suspended Solids (TSS) Surrogates for Turbidity in the Minnesota River Basin.* St. Paul, MN: Minnesota Pollution Control Agency.

Cleland, B.R. March 2011. Zumbro River Watershed TMDL: WLA Linkage Analysis. Prepared for the US EPA.

Engstrom, D. J. (2009). *Historical changes in sediment and phosphorus loading to the upper Mississippi River: mass balance reconstructions from the sediments of Lake Pepin.* Journal of Paleolimnology.

Gran, K., Belmont, P., Day, S., Jennings, C., Lauer, J.W., Viparelli, E., Wilcock, P., & Parker, G. (2011) An Integrated Sediment Budget for the LeSueur River Basin.

Johnson, H. O., Gupta, S. C., Vecchia, A. V., & Zvomuya, F. (2009). Assessment of Water Quality Trends in the Minnesota River using Non-Parametric and Parametric Methods. *J Environ. Qual , 38*, 1018-1030.

Matsch, C. (1972). *Quaternary geology of southwestern Minnesota, in Sims, P.K., and Morey, G. B., eds., Geology of Minnesota: A Centennial Volume.* St. Paul: Minnesota Geological Survey.

Minn. R. 7050.0150, Subp. 4N. (n.d.). Determination of Water Quality, Biological and Physical Conditions and Compliance with Standards.

Minn. R. 7090.1010, subp. 2, B. (n.d.). MS4 Permit Requirement Designation Criteria.

Minn. Stat. 114D.15. (2006). Clean Water Legacy Act TMDLs.

Minnesota State University, Mankato. (2009, November). *Minnesota River Basin Statistical Trend Analysis.* Retrieved 2009, from http://mrbdc.mnsu.edu/sites/mrbdc.mnsu.edu/files/public/reports/statistical_trends/pdfs/statistical_trends.pdf

MPCA. (2004). *Lower Minnesota River Dissolved Oxygen Total Maximum Daily Load Report.* St. Paul.

MPCA. (2007, July). Statement of Need and Reasonableness In the Matter of Proposed Revisions of Minnesota Rules Chapter 7050. *2* .

MPCA. (2007). *The Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment.* St. Paul, MN: Minnesota Pollution Control Agency.

MPCA. (2007). *Turbidity TMDL Protocols and Submittal Requirements.* St. Paul, MN: Minnesota Pollution Control Agency.

Poesen, J. N. (2003). Gully Erosion and Environmental Change: Importance and Research Needs. *Catena* , 91-123.

Schottler, S. P., & Daniel R. Engstrom, D. B. (2010). *Fingerprinting Sources of Sediment in Large Agricultural River Systems.* St. Croix Watershed Research Station: Science Museum of Minnesota.

Sekely, A., Mulla, D., & Bauer, D. (2002). Streambank Slumping and its Contribution to the Phosphorus and Suspended Sediment Loads of the Blue Earth River, Minnesota. *Journal of Soil and Water Conservation , 57* (5), 243-250.

State of Minnesota. (2009, March 2). Request for Comments for Planned Amendments to Rules Governing Water. *State Register* . St. Paul, MN, USA.

Tetra Tech. (2008). *Minnesota River Basin Turbidity TMDL and Lake Pepin Excessive Nutrient TMDL Model Calibration and Validation Report.* Research Triangle Park, NC: Tetra Tech.

Tetra Tech. (2009). *Minnesota River Basin Turbidity TMDL Scenario Report.* Research Triangle Park, NC: Tetra Tech.

Thoma, D., Gupta, S., Bauer, M., & Kirchoff, C. (2005). Airborne Laser Scanning for Riverbank Erosion Assessment. *Remote Sensing of Environment , 95*, 493-501.

Upham, W. (1890). *Report of exploration of the glacial Lake Agassiz in Manitoba: Geological Survey of Canada Annual Report.* Geological Survey of Canada.

Upham, W. (1895). The Glacial Lake Agassiz. USGS.

Weiss, Peter T., John S. Gulliver, and Andrew J. Erickson. 2007. Cost and Pollutant Removal of Stormwater Treatment Practices. Journal of Water Resources Planning and Management. pp 218-229.

Wilcock, P., Baskfield, P., Belmont, P., Birr, A., Cooper, P., Engstrom, D., et al. (2009). *Indentifying Sediment Sources in the Minnesota River Basin.*

Appendix A

Municipal and industrial dischargers associated with waste load allocations.
Highlighted columns indicate primary watershed.

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Benson WWTP	MN0020036	26037	X	X	X			X		X		X	X					X	X	X	88.68
Clontarf WWTP	MNG580108	26005	X	X	X			X		X		X	X					X	X	X	36.00
Danvers WWTP	MNG580119	26037	X	X	X			X		X		X	X					X	X	X	32.10
Evansville WWTP	MN0023329	26130	X	X	X			X		X		X	X					X	X	X	127.50
Farwell Kensington Sanitary Dist WWTP	MNG580220	26001	X	X	X			X		X		X	X					X	X	X	97.00
Hancock WWTP	MN0023582	26006	X	X	X			X		X		X	X					X	X	X	233.30
Hoffman WWTP	MNG580134	26127	X	X	X			X		X		X	X					X	X	X	420.20
Kerkhoven WWTP	MNG550010	26050	X	X	X			X		X		X	X					X	X	X	17.00
Lowry WWTP	MN0024007	26009	X	X	X			X		X		X	X					X	X	X	71.80
Millerville WWTP	MN0054305	26117	X	X	X			X		X		X	X					X	X	X	43.20

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Montevideo WWTP	MN0020133	26079	X	X	X			X		X		X	X					X	X	X	280.00
Murdock WWTP	MNG580086	26092	X	X	X			X		X		X	X					X	X	X	54.00
Starbuck WWTP	MN0021415	26010	X	X	X			X		X		X	X					X	X	X	39.70
Sunburg WWTP	MNG580125	26046	X	X	X			X		X		X	X					X	X	X	20.08
Urbank WWTP	MN0068446	26063	X	X	X			X		X		X	X					X	X	X	13.60
Watson WWTP	MN0022144	26079	X	X	X			X		X		X	X					X	X	X	4.00
Chippewa Valley Ethanol Co	MN0062898	26037	X	X	X			X		X		X	X					X	X	X	12.26
Clarkfield WWTP	MNG580093	25089			X			X		X		X	X					X	X	X	498.80
Granite Falls Energy LLC	MN0066800	25061			X			X		X		X	X					X	X	X	14.99
Granite Falls WWTP	MN0021211	25061			X			X		X		X	X					X	X	X	91.00
Xcel - Minnesota Valley Plant	MN0000906	25061			X			X		X		X	X					X	X	X	118.00

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Cottonwood WWTP	MNG580010	25154				X		X		X		X	X					X	X	X	315.10
Hanley Falls WWTP	MNG580122	25075				X		X		X		X	X					X	X	X	41.60
Ivanhoe WWTP	MNG580103	25132				X		X		X		X	X					X	X	X	94.30
Minneota WWTP	MNG580033	25151				X		X		X		X	X					X	X	X	304.80
Porter WWTP	MNG580128	25113				X		X		X		X	X					X	X	X	27.70
St Leo WWTP	MN0024775	25094				X		X		X		X	X					X	X	X	24.00
Taunton WWTP	MNG580090	25134				X		X		X		X	X					X	X	X	33.30
Blomkest Svea Sewer Board WWTP	MN0069388	25021					X	X		X		X	X					X	X	X	77.00
Clara City WWTP	MN0023035	25025					X	X		X		X	X					X	X	X	45.40
Maynard WWTP	MN0056588	25025					X	X		X		X	X					X	X	X	17.40
Pennock WWTP	MNG580104	25005					X	X		X		X	X					X	X	X	111.00

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Prinsburg WWTP	MN0063932	25018					X	X		X		X	X					X	X	X	6.18
Prinsco Inc	MN0069876	25018					X	X		X		X	X					X	X	X	5.70
Raymond WWTP	MNG580197	25009					X	X		X		X	X					X	X	X	80.40
Belview WWTP	MNG580003	25080						X		X		X	X					X	X	X	147.70
Bird Island WWTP	MN0022829	25048						X		X		X	X					X	X	X	193.00
Danube WWTP	MNG580057	25047						X		X		X	X					X	X	X	110.00
Delhi WWTP	MN0067008	25160						X		X		X	X					X	X	X	1.63
Echo WWTP	MNG580059	25079						X		X		X	X					X	X	X	110.80
Morton WWTP	MNG550018	25053						X		X		X	X					X	X	X	22.50
Olivia WWTP	MN0020907	25048						X		X		X	X					X	X	X	62.00
Redwood Falls WWTP	MN0020401	25060						X		X		X	X					X	X	X	225.00
Renville WWTP	MN0020737	25045						X		X		X	X					X	X	X	96.90
Sacred Heart WWTP	MN0024708	25039						X		X		X	X					X	X	X	26.87

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Southern Minnesota Beet Sugar - Renvil	MN0040665	25043						X		X		X	X					X	X	X	500.00
Wood Lake WWTP	MNG580107	25081						X		X		X	X					X	X	X	61.00
ADM Corn Processing - Marshall	MN0057037	27042							X	X		X	X					X	X	X	299.77
Ghent WWTP	MNG580121	27049							X	X		X	X					X	X	X	44.00
Lynd WWTP	MNG580030	27043							X	X		X	X					X	X	X	58.20
Marshall WWTP	MN0022179	27042							X	X		X	X					X	X	X	510.00
Milroy WWTP	MNG580124	27027							X	X		X	X					X	X	X	42.00
Russell WWTP	MNG580062	27043							X	X		X	X					X	X	X	99.80
Ruthton WWTP	MNG580105	27016							X	X		X	X					X	X	X	64.30
Tyler WWTP	MNG580116	27010							X	X		X	X					X	X	X	185.70
Vesta WWTP	MNG580043	27032							X	X		X	X					X	X	X	44.10
Franklin WWTP	MNG550004	28013								X		X	X					X	X	X	19.60

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Northern Con-Agg LLP - Redwood Falls	MN0059331	28099								X		X	X					X	X	X	40.88
Acme-Ochs Plant	MN0061646	29020									X	X	X					X	X	X	84.31
August Schell Brewing Co	MN0022284	29001									X	X	X					X	X	X	3.97
Balaton WWTP	MN0020559	29095									X	X	X					X	X	X	139.00
Clements WWTP	MNG580094	29027									X	X	X					X	X	X	27.71
Del Monte Corp - Plant 114	MN0001171	29007									X	X	X					X	X	X	131.00
Garvin WWTP	MNG580101	29036									X	X	X					X	X	X	28.80
Lamberton WWTP	MNG580100	29063									X	X	X					X	X	X	222.00
Lucan WWTP	MNG580112	29033									X	X	X					X	X	X	38.80
New Ulm WWTP	MN0030066	29001									X	X	X					X	X	X	768.00

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Revere WWTP	MNG580114	29053									X	X	X					X	X	X	25.50
Sanborn WWTP	MNG580115	29015									X	X	X					X	X	X	58.20
Sleepy Eye WWTP	MNG580041	29010									X	X	X					X	X	X	1,097.90
Springfield WWTP	MN0024953	29020									X	X	X					X	X	X	88.60
Storden WWTP	MNG580106	29080									X	X	X					X	X	X	44.90
Tracy WWTP	MN0021725	29041									X	X	X					X	X	X	194.00
Wabasso WWTP	MNG550026	29029									X	X	X					X	X	X	12.80
Walnut Grove WWTP	MN0021776	29047									X	X	X					X	X	X	23.00
Wanda WWTP	MNG580126	29057									X	X	X					X	X	X	30.50
Westbrook WWTP	MNG580127	29073									X	X	X					X	X	X	346.38
Courtland WTP	MNG640025	28058										X	X					X	X	X	0.23
Evan WWTP	MN580202	28094										X	X					X	X	X	24.70
Fairfax WWTP	MNG580060	28021										X	X					X	X	X	717.70

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Firmenich Inc	MNG255006	28073										X	X					X	X	X	55.59
Morgan WWTP	MN0020443	28103										X	X					X	X	X	40.70
New Ulm Quartzite Quarries Inc	MN0061638	28073										X	X					X	X	X	340.65
Northern Con-Agg LLP - Frohrip Kaolin	MN0062154	28094										X	X					X	X	X	45.20
St George District Sewer System	MN0064785	28077										X	X					X	X	X	0.74
Comfrey WWTP	MN0021687	28090											X					X	X	X	8.50
Hanska WWTP	MNG580207	28082											X					X	X	X	63.80
Jeffers WWTP	MNG580111	28080											X					X	X	X	58.20
Lake Crystal WWTP	MN0055981	28048											X					X	X	X	67.00
Nicollet WWTP	MNG580037	28067											X					X	X	X	435.60

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
POET Biorefining - Lake Crystal	MN0067172	28047											X					X	X	X	14.72
Searles WWTP	MNG580080	28057											X					X	X	X	65.50
Wis-Pak of Mankato Inc	MN0063029	28043											X					X	X	X	29.52
Butterfield WWTP	MN0022977	31020												X	X		X	X	X	X	471.00
Delft Sanitary District WWTP	MN0066541	31057												X	X		X	X	X	X	0.65
La Salle WWTP	MN0067458	31040												X	X		X	X	X	X	1.70
Lewisville WTP	MN0043958	31011												X	X		X	X	X	X	1.93
Lewisville WWTP	MN0065722	31025												X	X		X	X	X	X	79.00
Madelia WWTP	MN0024040	31027												X	X		X	X	X	X	149.00
Milk Specialties Company (MSC)	MN0066036	31047												X	X		X	X	X	X	8.18

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Mountain Lake WTP	MN0002763	31058												X	X		X	X	X	X	5.67
Mountain Lake WWTP	MNG580035	31034												X	X		X	X	X	X	701.00
Neuhof Hutterian Brethren	MNG580113	31047												X	X		X	X	X	X	19.70
Odin-Ormsby WWTP	MN0069442	31061												X	X		X	X	X	X	51.00
POET Biorefining - Ethanol 2000 LLP	MN0063118	31059												X	X		X	X	X	X	16.35
Saint James WWTP	MN0024759	31020												X	X		X	X	X	X	336.00
Truman WTP	MNG640129	31001												X	X		X	X	X	X	1.70
Truman WWTP	MN0021652	31001												X	X		X	X	X	X	88.00
Amboy WWTP	MN0022624	32056														X	X	X	X	X	32.50
Delavan WWTP	MNG580109	32055														X	X	X	X	X	69.30
Freeborn WWTP	MNG580018	32039														X	X	X	X	X	41.60

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Good Thunder WWTP	MNG580206	32062														X	X	X	X	X	120.70
Guardian Energy	MN0068331	32019														X	X	X	X	X	116.96
Hartland WWTP	MNG580102	32027														X	X	X	X	X	67.40
Janesville WWTP	MNG580025	32019														X	X	X	X	X	582.70
Mapleton WWTP	MN0021172	32065														X	X	X	X	X	610.00
New Richland WWTP	MNG550019	32025														X	X	X	X	X	68.00
Pemberton WWTP	MNG580075	32067														X	X	X	X	X	111.00
St Clair WWTP	MN0024716	32079														X	X	X	X	X	24.00
Waldorf WWTP	MN0021849	32029														X	X	X	X	X	11.00
Waseca WWTP	MN0020796	32005														X	X	X	X	X	397.00

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Wells-Easton-Minnesota Lake WWTP	MN0025224	32083														X	X	X	X	X	2,646.00
Alden WWTP	MNG580118	30004													X		X	X	X	X	419.00
Blue Earth WWTP	MN0020532	30021													X		X	X	X	X	111.00
Bricelyn WWTP	MNG580129	30050													X		X	X	X	X	79.40
Buffalo Lake Energy LLC	MN0068063	30067													X		X	X	X	X	57.80
Darling International Inc - Blue Earth	MN0002313	30043													X		X	X	X	X	79.80
Elmore WTP	MN0043010	30041													X		X	X	X	X	0.61
Elmore WWTP	MN0021920	30041													X		X	X	X	X	424.00
Fairmont Foods of Minnesota Inc	MN0001996	30057													X		X	X	X	X	7.37
Fairmont WTP	MN0045527	30067													X		X	X	X	X	0.34

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Fairmont WWTP	MN0030112	30057													X		X	X	X	X	443.00
Frost WWTP	MNG580120	30044													X		X	X	X	X	66.90
Granada WWTP	MNG580023	30028													X		X	X	X	X	61.60
Great River Energy Lakefield	MN0067709	30081													X		X	X	X	X	1.02
Interstate Power - Fox Lake Station	MN0000957	30077													X		X	X	X	X	129.45
Kiester WWTP	MNG580097	30010													X		X	X	X	X	84.60
Northrop WWTP	MN0024384	30055													X		X	X	X	X	78.30
Seneca Foods Corp - Blue Earth 2	MN0001287	30046													X		X	X	X	X	42.24
Trimont WWTP	MN0022071	30075													X		X	X	X	X	21.00
Vernon Center WWTP	MNG550024	30089													X		X	X	X	X	10.00
Walters WWTP	MN0068756	30007													X		X	X	X	X	24.90

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Welcome WWTP	MN0021296	30073													X		X	X	X	X	29.50
Winnebago WWTP	MN0025267	30025													X		X	X	X	X	290.00
ADM - Mankato	MN0061514	28042																X	X	X	45.42
CHS Oilseed Processing - Mankato	MN0001228	28041																X	X	X	1,471.00
Hard Rock Quarries Inc	MN0067237	28034																X	X	X	18.17
Hiniker Co	MN0064408	28032																X	X	X	0.58
Knollwood Mobile Home Park WWTP	MN0030651	28041																X	X	X	2.00
Mankato WWTP	MN0030171	28042																X	X	X	1,277.00
Midwest Electric Products Inc	MN0004111	28034																X	X	X	6.66

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Unimin Minnesota Corp - Kasota Quarry	MN0053082	28060																X	X	X	1,892.50
Xcel - Wilmarth Generating Plant	MN0000914	28042																X	X	X	49.20
Cleveland WWTP	MNG580009	28037																	X	X	183.10
St Peter WWTP	MN0022535	28038																	X	X	454.00
Unimin Corp - Ottawa Plant	MN0001716	28038																	X	X	3,406.50
Altona Hutterian Brethren WWTP	MN0067610	33096																		X	20.00
Arlington WWTP	MN0020834	33090																		X	91.00

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Dairy Farmers of America - Winthrop	MN0003671	33060																		X	390.69
Gaylord WWTP	MNG580204	33062																		X	749.10
Gibbon WWTP	MNG580020	33047																		X	169.30
Heartland Corn Products	MN0062561	33060																		X	8.40
Lafayette WWTP	MN0023876	33064																		X	10.80
Le Center WWTP	MN0023931	33040																		X	93.60
Le Sueur Cheese Co	MN0060216	33044																		X	24.92
MG Waldbaum Co - Gaylord	MN0060798	33062																		X	45.40
MRVPUC WWTP	MN0068195	33044																		X	209.00
Seneca Foods Corp - Arlington	MN0000264	33090																		X	22.70

NAME	Preferred ID	MN DNR MINOR	07020005-501	07020004-501	07020004-515	07020004-502	07020004-587	07020004-509	07020006-501	07020007-514	07020008-501	07020007-503	07020007-505	07020010-501	07020009-509	07020011-501	07020009-501	07020007-502	07020007-501	07020012-503	LOAD kg/day
Starland Hutterian Brethren Inc	MN0067334	33049																		X	27.00
Winco Inc	MNG255043	33041																		X	1.36
Winthrop WWTP	MN0051098	33060																		X	356.00

Appendix B

Development of total suspended solids (TSS) surrogates for turbidity in the Minnesota River Basin.
October 28, 2008. (E. Campbell., L. Ganske, G Johnson)

I. Background

The Minnesota River Total Maximum Daily Load (TMDL) project addresses turbidity impairments in the Minnesota River Basin. The project area begins near Lac Qui Parle in western Minnesota and ends at the city of Jordan near the Twin Cities metropolitan area. It includes 18 reaches on the mainstem and lower tributaries, including the Chippewa, Redwood, Cottonwood, Blue Earth, Hawk Creek, Yellow Medicine, Watonwan, and Le Sueur Rivers (MPCA, 2005). A map of the project area is shown in Figure B-1.

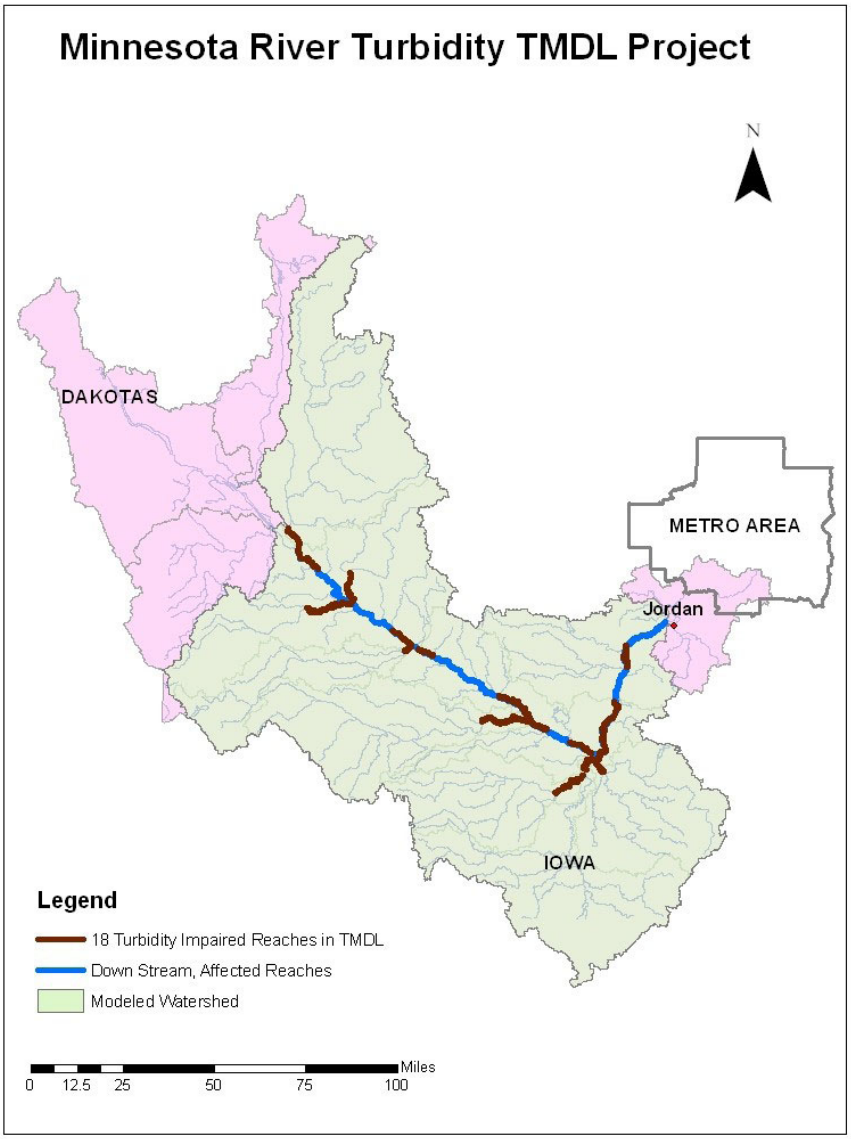


Figure B-1 Minnesota River Turbidity TMDL project area (MPCA, 2005).

Turbidity is a measurement of the clarity of water, determined by how much light is absorbed and scattered in a water sample (MPCA, 2005). Suspended organic matter, inorganic sediment and dissolved organic matter all can affect turbidity. It is not a direct measure of pollutant mass. However, because light scatter and absorption is strongly affected by particles suspended in the water, there is a strong relationship between turbidity and the commonly used mass-based water quality parameter total suspended solids (TSS). For this reason, and because mass loads are needed for TMDL calculations and allocations, TSS is commonly used as a surrogate for turbidity.

Correlation analysis was conducted on a large data set of paired TSS and turbidity values from samples taken in the Minnesota, Lower Mississippi, Cedar, Des Moines and Missouri River basins indicate that it is possible to use TSS values to predict turbidity. This analysis showed a strong relationship between turbidity and TSS measurements (MPCA, 2001).

MPCA staff completed analysis of TSS surrogates for turbidity using data from 1996-2005 within the Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) ecoregions (Christopherson, 2008). A natural log transformation of the data was performed. TSS was plotted as the independent variable and turbidity as the dependent variable. This resulted in a TSS surrogate of 60 mg/L for the turbidity standard of 25 NTU being used in the assessment process for the impaired waters {303(d)} list. The plots were also used to demonstrate when turbidity exceedances are correctly identified by TSS, when a false positive occurs, when a false negative occurs, and when acceptable turbidity is correctly identified by TSS. Current MPCA assessment guidance applies the surrogate to impaired waters listing decisions (MPCA, 2007).

In addition to deriving TSS surrogates from TSS-turbidity regression, TSS benchmarks have been previously established using ecoregion percentile values. The TSS values selected as the thresholds were 58 and 66 mg/L in the WCBP and NGP ecoregions, respectively. These are the 75th percentile values in the distribution of TSS values measured at minimally impacted sites (not influenced by point sources) in the two ecoregions (MPCA, 2006). The 58 and 66 mg/L surrogates have been used as TSS benchmark goals by several watershed groups in the Minnesota River Basin. One noted use of this application is in the State of the Minnesota River report.

This paper describes the methods and results of TSS-turbidity regression analysis performed on watershed specific data sets to determine watershed or river specific surrogate values. These results were then compared across watersheds to determine regional specific surrogate TSS values and to simplify the number of TSS surrogates used in the Minnesota River Turbidity TMDL.

II. Data Utilized and Analysis Techniques

The data used in this analysis include turbidity and TSS from several sites across the basin. The years of data, number of observations, sampling organization and labs used in sample analysis are summarized in Table B-1 for each site. For major tributaries, all sites are at or near the outlet unless otherwise noted. 2007 MCES data were not used because of a change in meter type.

Table B-1: Site information, years of data, and number of observations used in the regressions.

Site	Years of Data used in Analysis	Number of Observations	Organization(s) that Collected Sample	Lab
Chippewa River	2001-2007	84	Chippewa River Watershed Project	Era – Duluth*
Hawk Creek	2004-2007	75	Hawk Creek Watershed Project	Era – Duluth
Redwood River	2003-2007	47	RCRCA	MVTL – New Ulm**
Cottonwood River	2003-2007	48	RCRCA	MVTL – New Ulm
Watonwan River	2000-2007	227	MPCA, Watonwan County Environmental Services, Maple River Watershed Project	MVTL – New Ulm
Blue Earth River (Mile 12.0)	2000-2005	86	MCES, MSU-WRC	MCES***
Le Sueur River	2000-2005	54	MCES, MSU-WRC	MCES
Minnesota River at Judson	2000-2005	112	MCES, MSU-WRC	MCES
Minnesota River at St. Peter	2000-2005	97	MCES, MSU-WRC	MCES
Minnesota River at Jordan	2000-2005	140	MCES	MCES

*Era Laboratories, Inc.
**Minnesota Valley Testing Lab
***Metropolitan Council Environmental Services Lab

There are a number of factors that need consideration in the work to establish a TSS surrogate for the turbidity water quality standard. These include the effect of suspended particle size and concentration on turbidity meter response, parametric data analysis assumptions, and differences between turbidity meters.

In order to minimize bias to the TSS-turbidity regressions from values at the extreme ends of the sample range, data sets used in the analysis were limited to sample pairs less than 40 NTU for turbidity and greater than 10 mg/L for TSS following the MPCA

Turbidity TMDL Protocol (MPCA, 2007). TSS was plotted as the independent variable and turbidity was plotted as the dependent variable.

To use linear regression in this work, a data transformation was needed to meet the assumption of the data being normally distributed for the appropriate use of the parametric statistical method. A natural log transformation of the data were found to provide a reasonably normal distribution of the data. Using the natural log transformation as opposed to a transformation of another sort (e.g. log10) was chosen because much of the related regression work within the MPCA has been performed using a natural log transformation.

Meter differences between labs are another component of the analysis that had to be addressed. ERA uses a Hach 2100AN turbidimeter with the ratio mode "Off", which reports in NTUs. Until 2006, both MVTL and MCES used a Hach 2100A turbidimeter, which reports in NTUs. Beginning in March 2006, MCES began using a Hach 2100N with the ratio mode “On” (Campbell, personal communication with D. Fuchs, 2008), which reports turbidity as NTRUs. Because of this, MCES results from 2006 and 2007 were not used in this analysis, so that NTRU to NTU conversions did not have to be made. In 2006, MVTL switched from a Hach 2100A to a HF Scientific Micro100, which also reports in NTUs (Johnson, personal communication with J. Smith, 2007). Since the meter change did not result in a unit change, no MVTL data were omitted from the analysis.

The Hach 2100A uses a single white light source and a single light detector. The Hach 2100AN and Hach 2100N use a single white light source and multiple light detectors (Johnson, 2007; MPCA 2007; Hach 2008). The Hach 2100AN and Hach 2100N meters reports turbidity as NTU when the ratio mode is “Off” and NTRU when the ratio mode is “On”. The HF Scientific Micro100 operates in a similar fashion as the Hach 2100A. The USGS has investigated the differences between meters and has compiled a list of meters and their reporting units at http://water.usgs.gov/owq/turbidity_codes.xls (USGS, 2007).

Along with regressions for each of the sites individually, grouped regressions were also performed. The groups are: Chippewa and Hawk; Redwood and Cottonwood; Watonwan, Blue Earth and Le Sueur; and the three Minnesota River sites. These groups were chosen based on similar geology and land use within the watersheds and also on results from past MPCA data analysis that show similar differences between the data sets. The groups were then confirmed with statistical analysis.

A few data points obviously skewed the regressions and were removed as outliers. A statistical computation was not performed, but the points that were removed are documented in Table B-2 below and if needed in the future, a statistical test can be performed.

Table B-2: Outliers removed from analysis

Site	Sample pairs removed as outliers Date (TSS mg/L, Turbidity NTU)
Chippewa River	none
Hawk River	none
Redwood River	none
Cottonwood River	none
Watonwan River	none
Blue Earth River	5/12/00 (339, 26)
Le Sueur River	Pairs with <10 NTU (due to scatter); 5/23/04 (648, 39)
MN River at Judson	9/23/03 (45, 2.4)
MN River at St. Peter	10/20/04 (397, 24); 12/14/04 (313, 18)
MN River at Jordan	6/8/04 (943, 40)

III. Results

A. Individual Regressions

TSS-Turbidity regression plots for each site are shown in Figures B-2 – B-11.

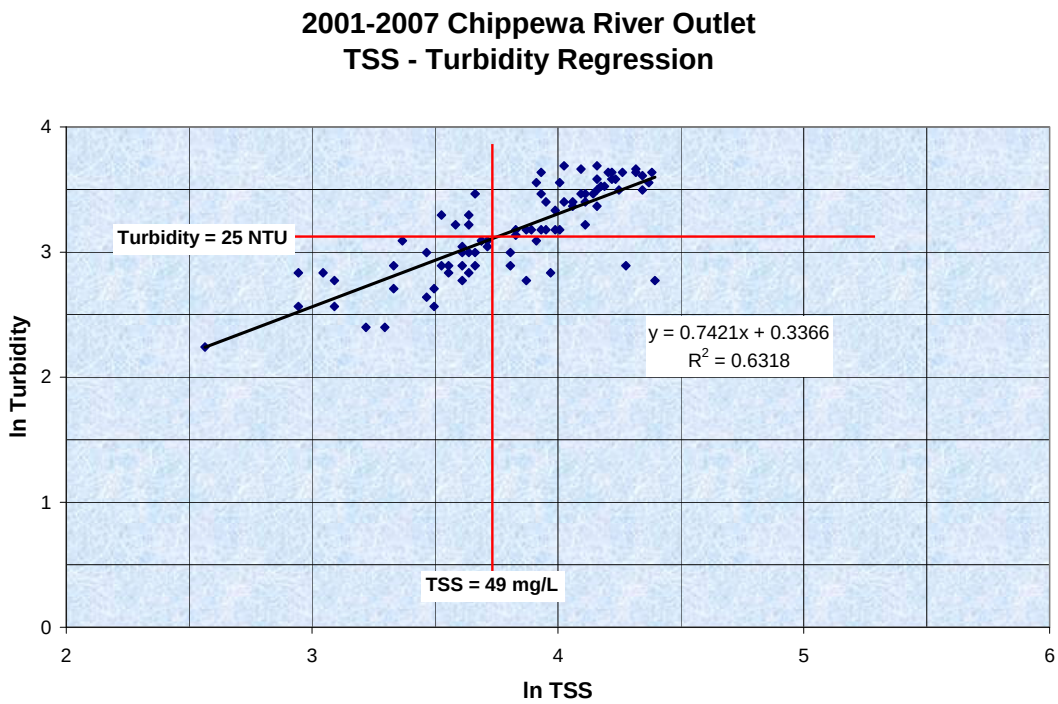


Figure B-2 Chippewa River TSS-Turbidity Regression.

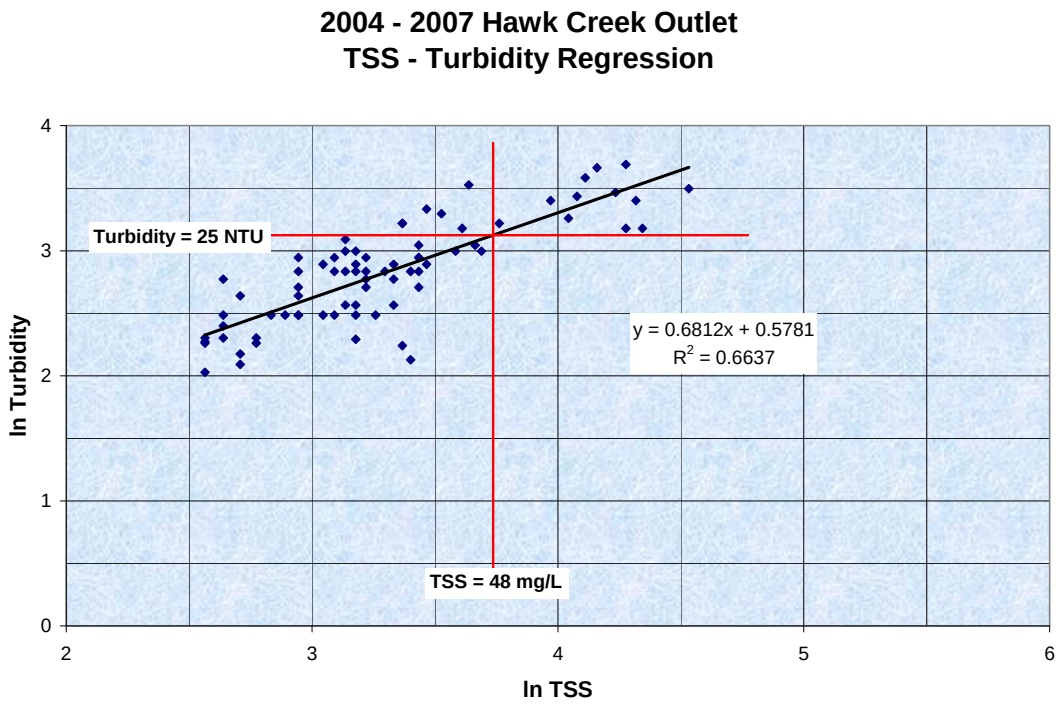
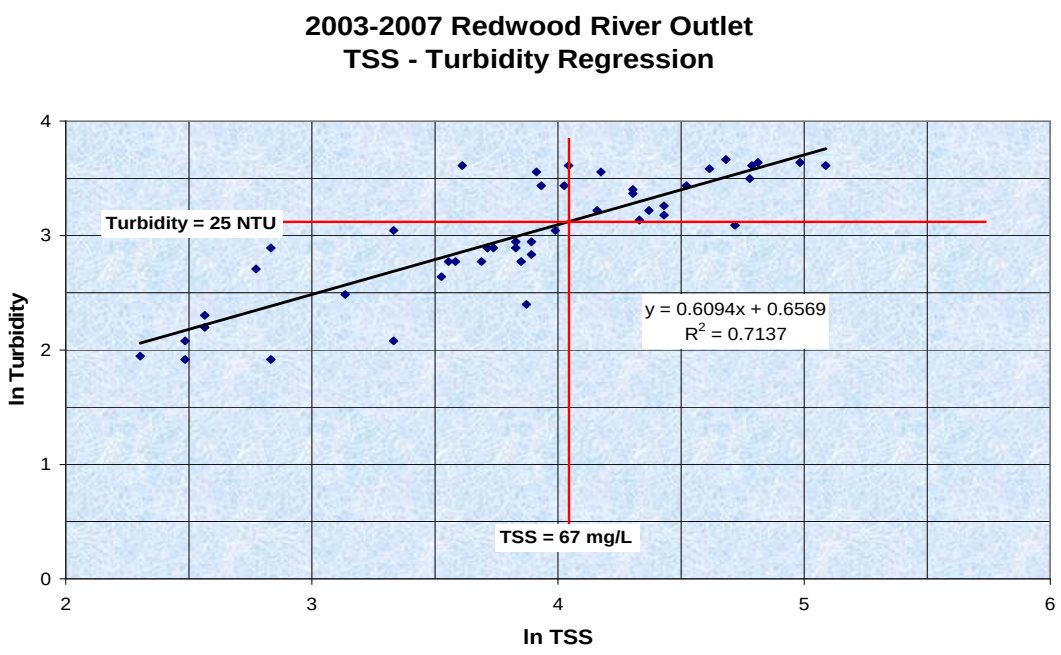


Figure B-3 Hawk Creek TSS-Turbidity Regression.

Figure



B-4 Redwood River TSS-Turbidity Regression

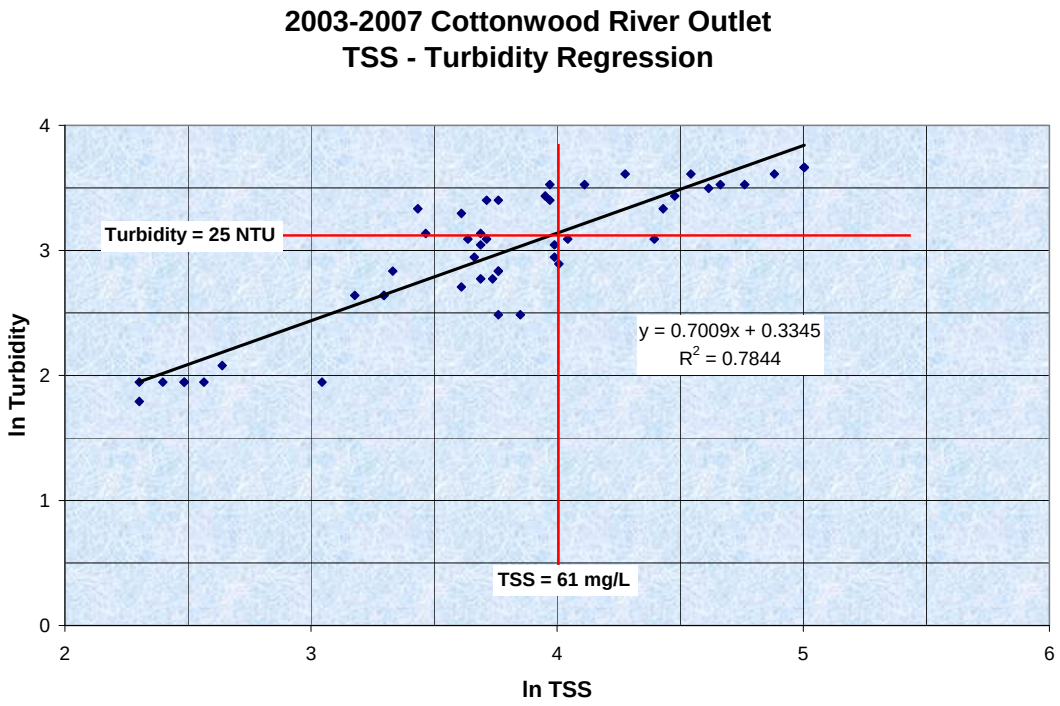


Figure B-5: Cottonwood River TSS-Turbidity Regression

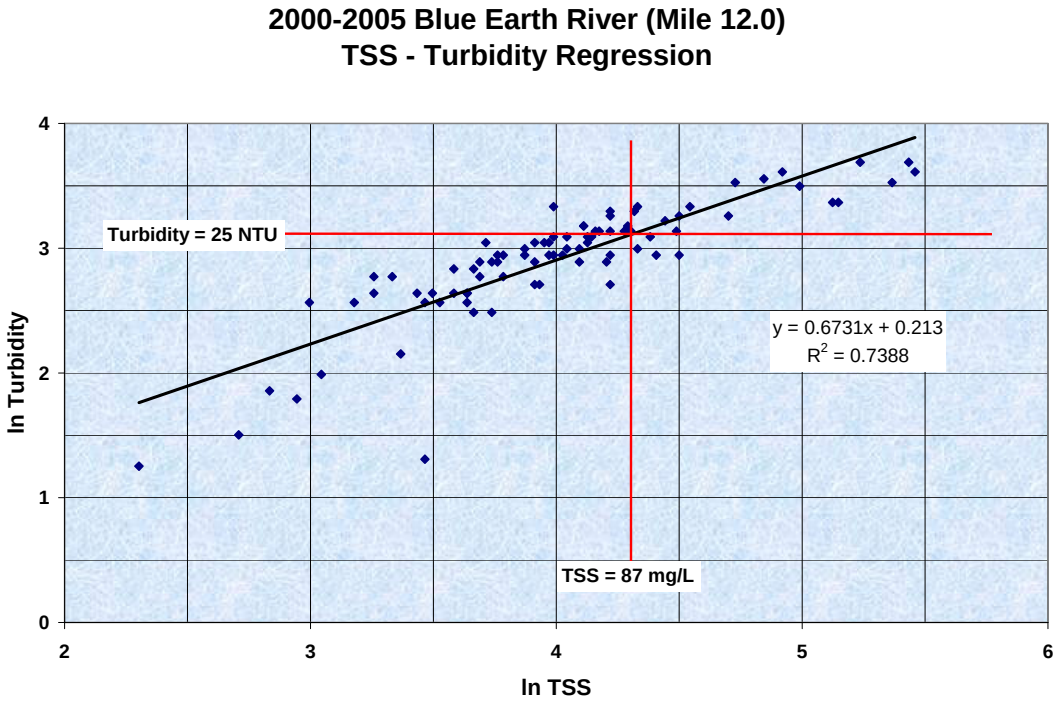


Figure B-6: Blue Earth River TSS-Turbidity Regression

2000 - 2007 Watonwan River Outlet
TSS - Turbidity Regression

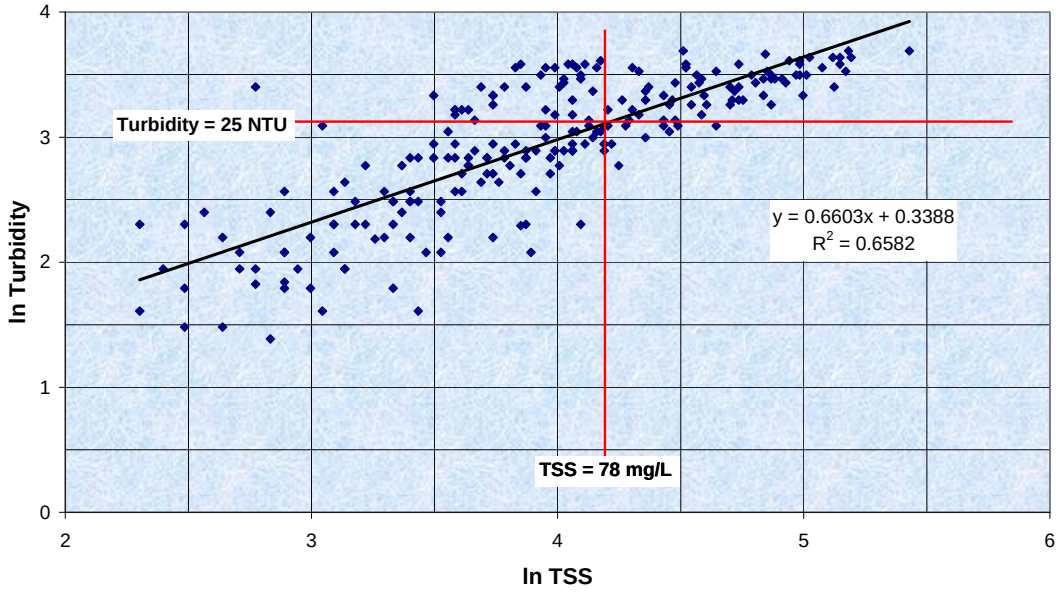


Figure B-7: Watonwan River TSS-Turbidity Regression

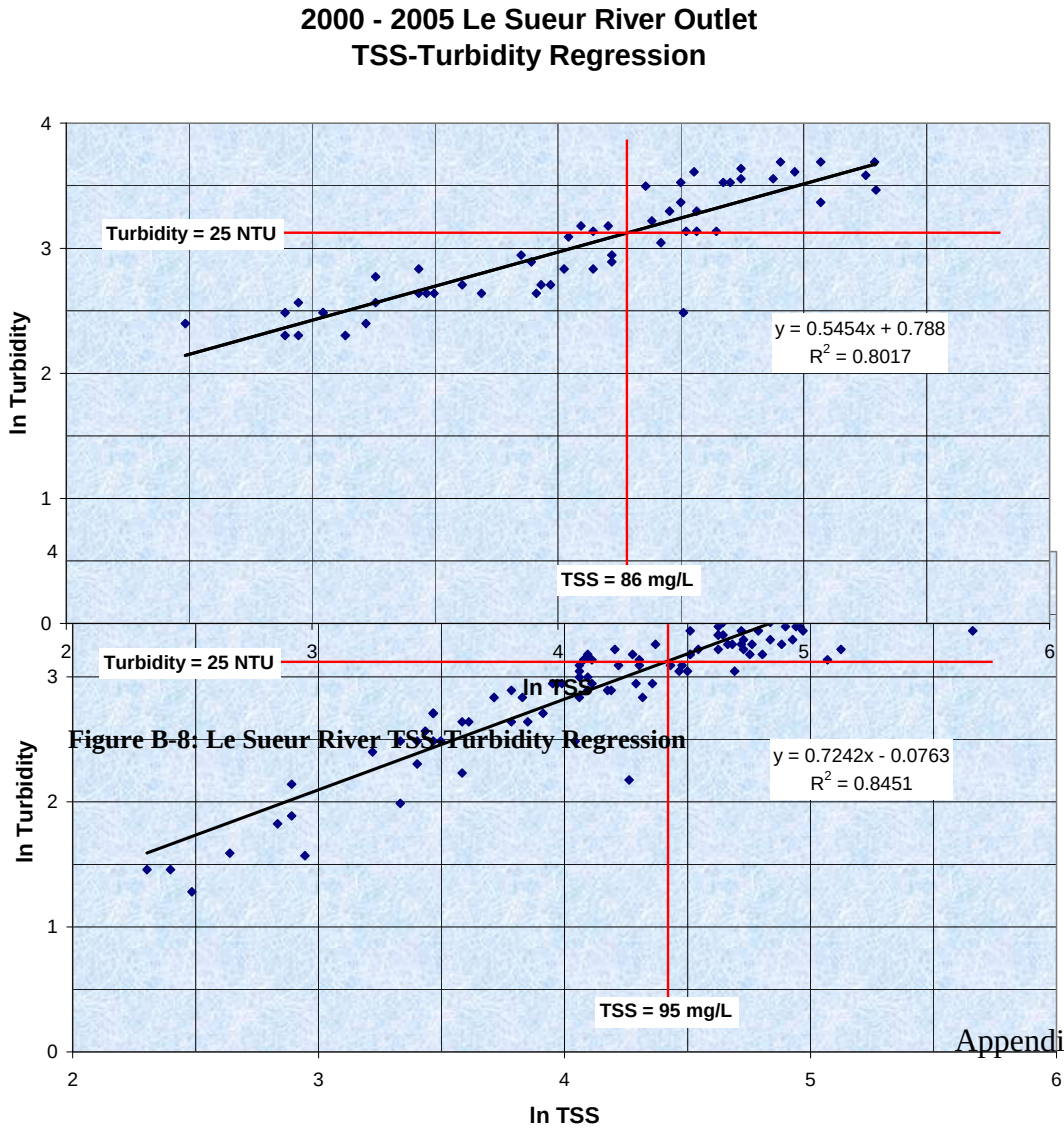


Figure B-8: Le Sueur River TSS-Turbidity Regression

Figure B-9: Minnesota River at Judson TSS-Turbidity Regression

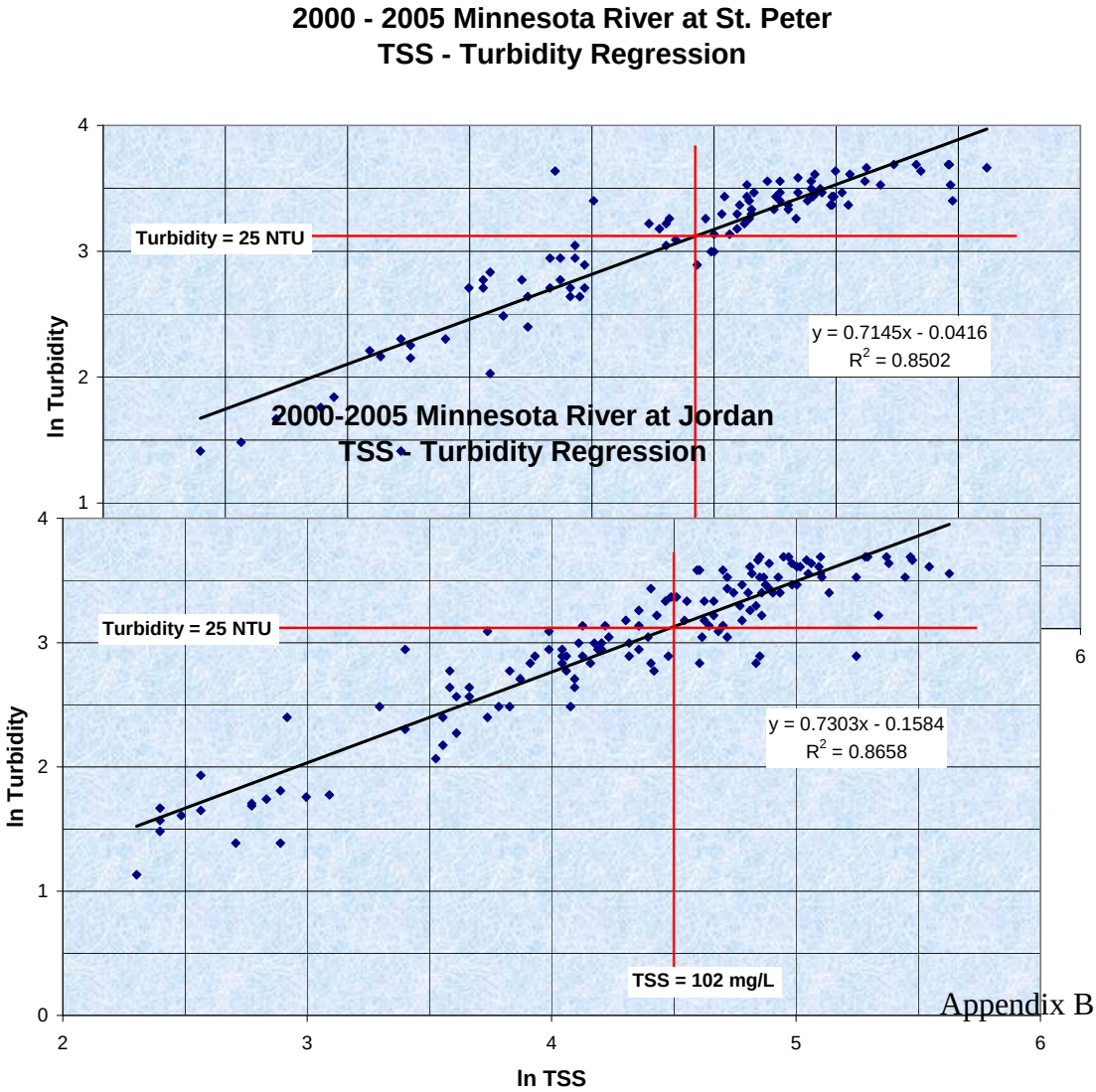


Figure B-11: Minnesota River at Jordan TSS-Turbidity Regression

The TSS surrogate value was computed by using the regression equation to solve for TSS when turbidity equals 25 NTU. The initial TSS surrogate values for each site and the corresponding r-squared value from the regression analysis are summarized in Table B-3 below. Values are rounded to the nearest whole number.

Table B-3: Initial TSS surrogate values summary table by site

Site	TSS (mg/L) surrogate value of 25 NTU	R^2
Chippewa River	49	0.63
Hawk River	48	0.66
Redwood River	67	0.71
Cottonwood River	61	0.78
Watonwan River	78	0.66
Blue Earth River	87	0.74
Le Sueur River	86	0.80
MN River at Judson	95	0.85
MN River at St. Peter	96	0.85
MN River at Jordan	102	0.87

These surrogate values were developed based on data from monitoring sites at or near the mouth of these watersheds. Given variation in the relationship between turbidity and TSS due to suspended solids composition, dissolved organics and other factors, there may be different TSS-turbidity relationships at other locations within the watersheds. The TSS surrogates listed above are specific to the monitoring sites and location on the rivers. They may be considered for application in other parts of the watershed; however, the appropriateness of their use should be evaluated on a case by case basis.

B. Grouped Regressions

In an effort to simplify the number of TSS surrogates used in the Minnesota River Turbidity TMDL, the data from individual sites were combined into groups to evaluate TSS-turbidity relationships in areas with similar geology and land use. Several group possibilities were considered and were analyzed statistically to determine if the data could be combined. The results are discussed below in Section IV. The combined data sets are:

- Chippewa and Hawk
- Redwood and Cottonwood
- Watonwan, Blue Earth, and Le Sueur
- Minnesota River at Judson, St. Peter and Jordan

TSS-Turbidity regression plots for each combination of sites are shown in Figures B-12 – B-15.

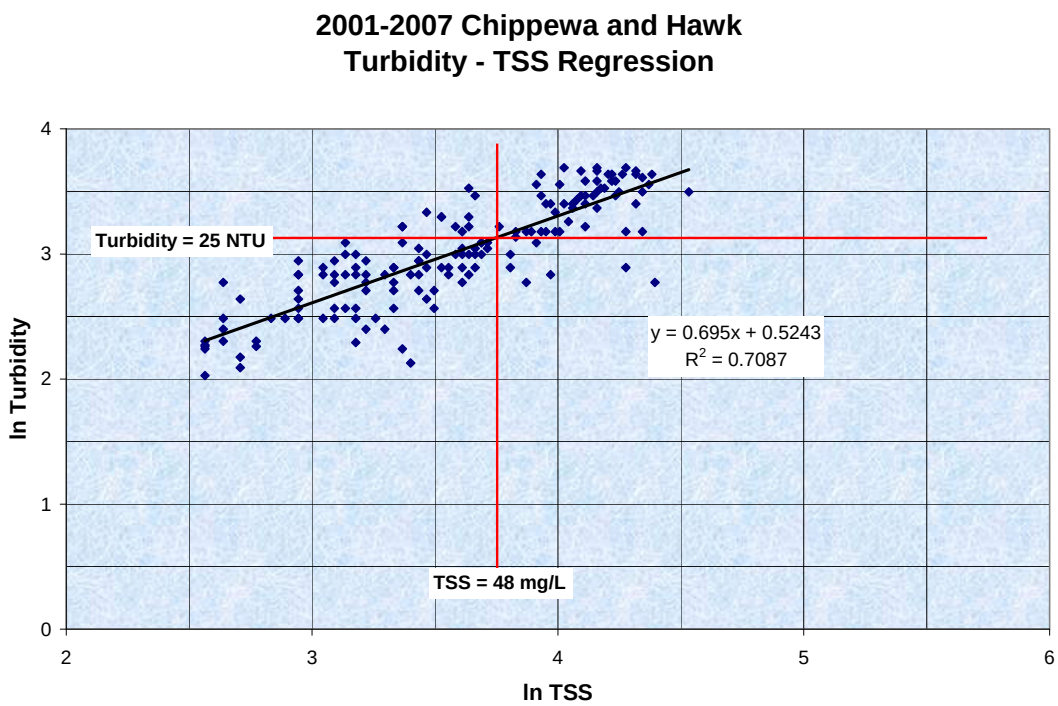


Figure B-12: Chippewa River and Hawk Creek Combined TSS-Turbidity Regression.

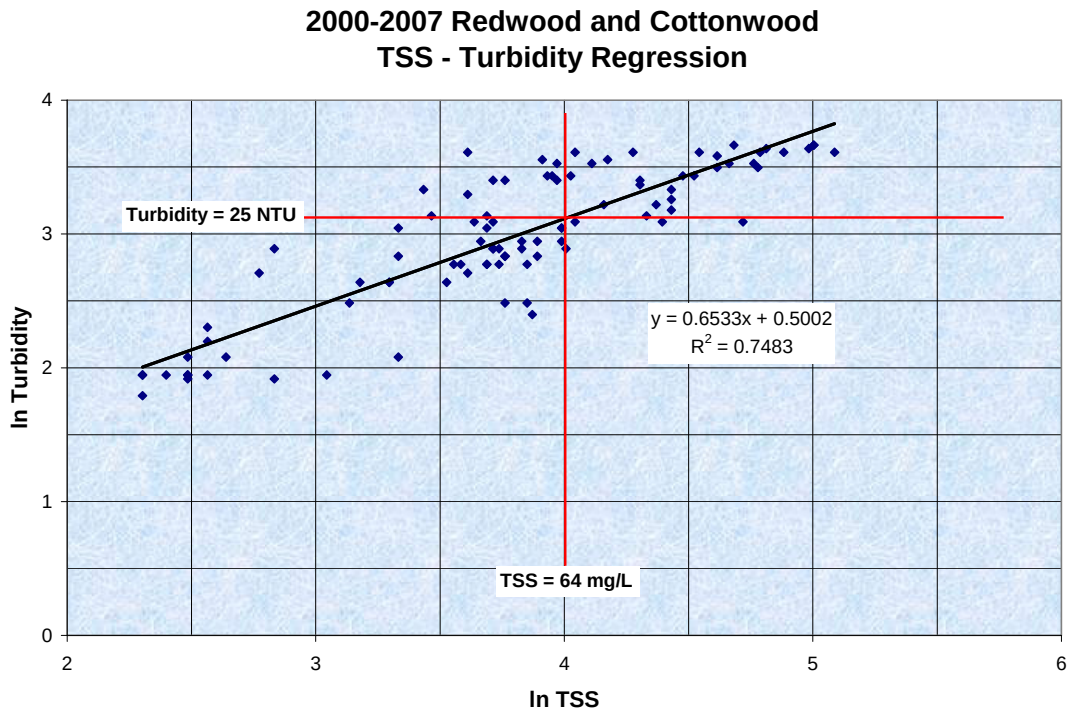


Figure B-13: Redwood and Cottonwood Rivers Combined TSS-Turbidity Regression

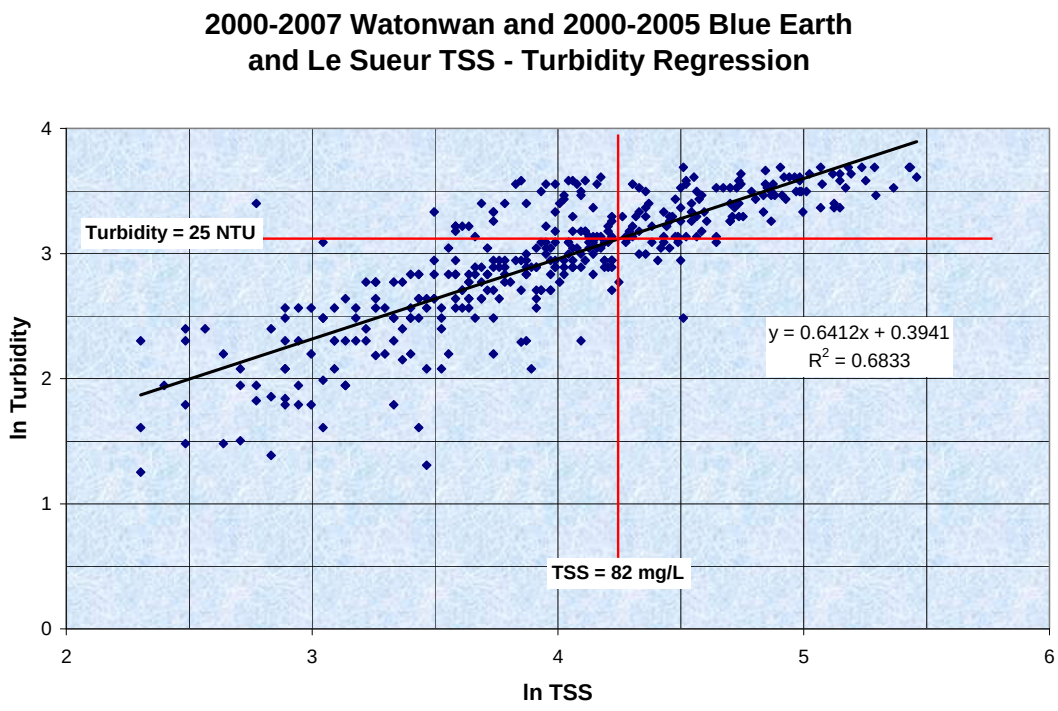


Figure B-14: Watonwan, Blue Earth and Le Sueur Rivers Combined TSS-Turbidity Regression

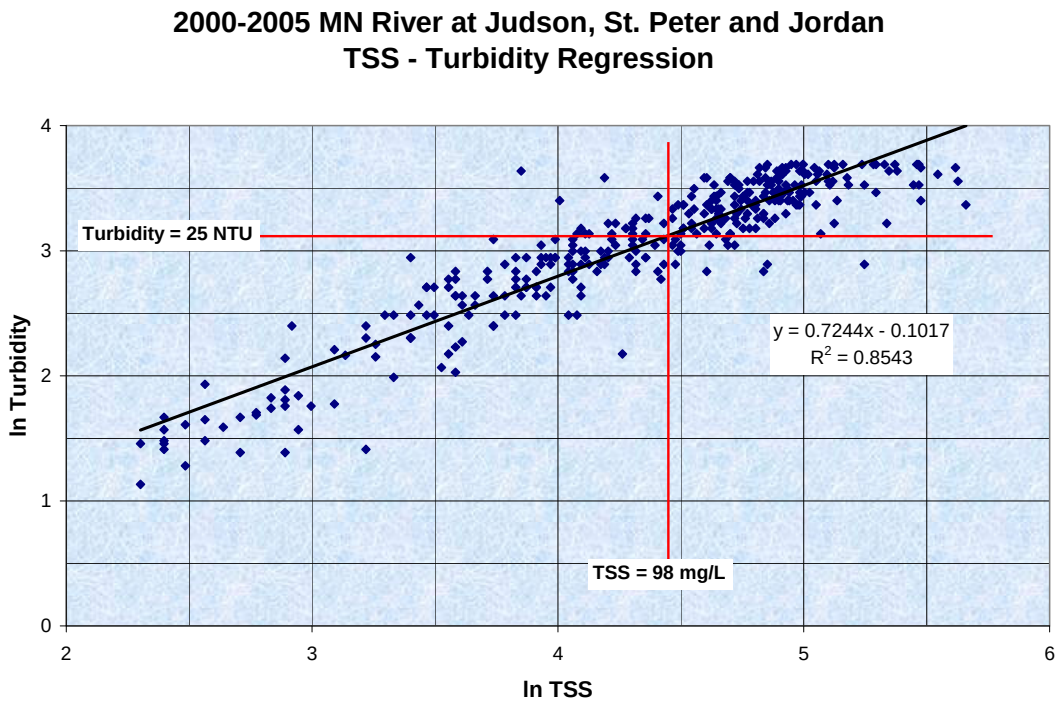


Figure B-15: Minnesota River at Judson, St. Peter and Jordan Combined TSS-Turbidity Regression

The TSS surrogate values of 25 NTU for each group of sites and the corresponding r-squared value from the regression analysis are summarized in Table B-4 below.

Table B-4: TSS surrogate values summary table by groups of sites

Sites	TSS (mg/L) surrogate value of 25 NTU	R^2
Chippewa and Hawk	48	0.71
Redwood and Cottonwood	64	0.75
Watonwan, Blue Earth and Le Sueur	82	0.68
Minnesota River at Judson, St. Peter and Jordan	98	0.85

C. Bias Correction

Retransforming log-transformed regression estimates to provide "raw" data value estimates results in a retransformation bias given that the logarithmic transformation is nonlinear. The estimates are biased on the low side. A bias correction method known as Duan's smearing estimator is calculated by summing the anti-logs of the individual residuals and dividing the sum by the number of residuals **(**Johnson, personal communication, 2008). This bias correction method was applied to the dataset, resulting in a correction of approximately 1-7 mg/L depending on the site or group. The results of this correction to TSS surrogate values that have not been rounded to the nearest whole number are shown in Table B-5.

Table B-5: TSS Surrogate Estimates for 25 NTU WQ Standard (with and without bias adjustment)

Site(s)	TSS Surrogate without Bias Correction	Duan's Smearing Estimator	TSS Surrogate adjusted for Bias	Difference
Chippewa River	48.6	1.022	50.1	1.5
Hawk Creek	48.3	1.027	50.2	1.9
Redwood River	67.0	1.040	71.4	4.5
Cottonwood River	61.3	1.034	64.3	3.0
Watonwan River	78.4	1.055	85.0	6.6
Blue Earth River	87.0	1.026	90.3	3.3
Le Sueur River	86.2	1.018	89.0	2.8
MN River at Judson	94.6	1.021	97.4	2.8
MN River at St. Peter	95.9	1.025	99.2	3.3
MN River at Jordan	102.0	1.024	105.4	3.4
Chippewa and Hawk	48.3	1.025	50.0	1.7
Redwood and Cottonwood	64.2	1.037	67.8	3.7
Watonwan, Blue Earth and Le Sueur	81.9	1.042	87.4	5.5
Minnesota River at Judson, St. Peter and Jordan	97.9	1.023	101.1	3.2

IV. Statistical Analysis of Watershed Grouping

In order to determine whether or not sites could be grouped together, two statistical analyses were performed.

A. Test for Coincidental Regressions

The first test for verifying grouping was a test for coincidental regressions (Zar, 1996). This test determines whether the slope and elevation of the regression lines of each data set are statistically different from each other. The results of the test are shown in Table B-6 below.

Table B-6: Results from the test for coincidental regressions

Sites	Regression Lines Statistically Different?	Test Results
Chippewa and Hawk	No	$F = 0.04$ $F_{crit\ (1,\ 159)} \approx 3.91$ $F_{crit} > F$ H_0 accepted $P > 0.05$ [$P = 0.84$]
Redwood and Cottonwood	No	$F = 0.11$ $F_{crit\ (1,\ 95)} \approx 3.96$ $F_{crit} > F$ H_0 accepted $P > 0.05$ [$P = 0.74$]
Watonwan, Blue Earth and Le Sueur	No	$F = 0.43$ $F_{crit\ (2,\ 367)} \approx 3.02$ $F_{crit} > F$ H_0 accepted $P > 0.05$ [$P = 0.65$]
Redwood, Cottonwood, Watonwan, Blue Earth and Le Sueur	Yes	$F = 2.54$ $F_{crit\ (4,\ 462)} \approx 2.40$ $Fcrit < F$ H_0 rejected $P < 0.05$ [$P = 0.04$]
Minnesota River at Judson, St. Peter and Jordan	No	$F = 0.28$ $F_{crit\ (2,\ 349)} \approx 3.02$ $F_{crit} > F$ H_0 accepted $P > 0.05$ [$P = 0.76$]
All Tributaries	Yes	$F = 13.63$ $F_{crit\ (6,\ 621)} = 2.10$ $F_{crit} < F$ H_0 rejected $P < 0.05$ [$P = 0.00$]
All Sites	Yes	$F = 22.58$ $F_{crit\ (9,\ 970)} = 1.88$ $F_{crit} < F$ H_0 rejected $P < 0.05$ [$P = 0.00$]

B. Confidence Intervals

Using SYSTAT, 95 percent confidence intervals were computed. Results are shown in Table B-7 and in Figures B-16 and B-17.

Table B-7: 95% confidence intervals of the TSS surrogate value (mg/L) with bias correction by site or group

Site	Lower Confidence Level	TSS surrogate value (mg/L) with Bias Correction	Upper Confidence Level
Chippewa River	48	51	54
Hawk Creek	45	50	57
Redwood River	63	72	83
Cottonwood River	57	64	72
Watonwan River	80	85	92
Blue Earth River	82	90	99
Le Sueur River	80	89	99
MN River at Judson	92	98	104
MN River at St. Peter	93	99	105
MN River at Jordan	99	105	111
Chippewa and Hawk	48	50	53
Redwood and Cottonwood	62	68	75
Watonwan, Blue Earth and Le Sueur	83	88	95
Minnesota River at Judson, St. Peter and Jordan	98	101	104

Also presented in Figure B-16 are possible rounded surrogate values for the grouped data: 50 mg/L for Chippewa and Hawk; 70 mg/L for Redwood and Cottonwood; 90 mg/L for Watonwan, Blue Earth and Le Sueur and 100 mg/L for the Minnesota River at Judson, St. Peter and Jordan. These rounded values were a result of discussions about the data and results of the statistical analyses within the MPCA Minnesota River Turbidity TMDL Technical Team.

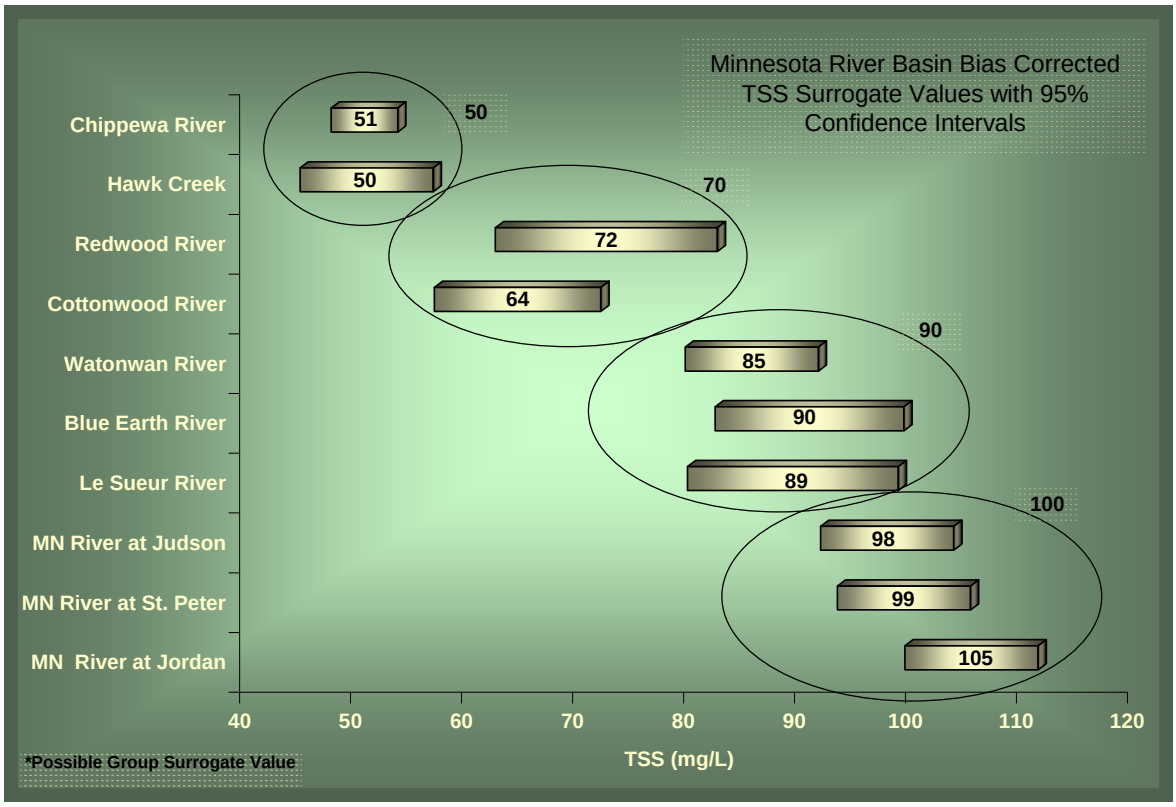


Figure B-16: Minnesota River Basin bias corrected TSS surrogate values with 95% confidence intervals and possible rounded group surrogate values

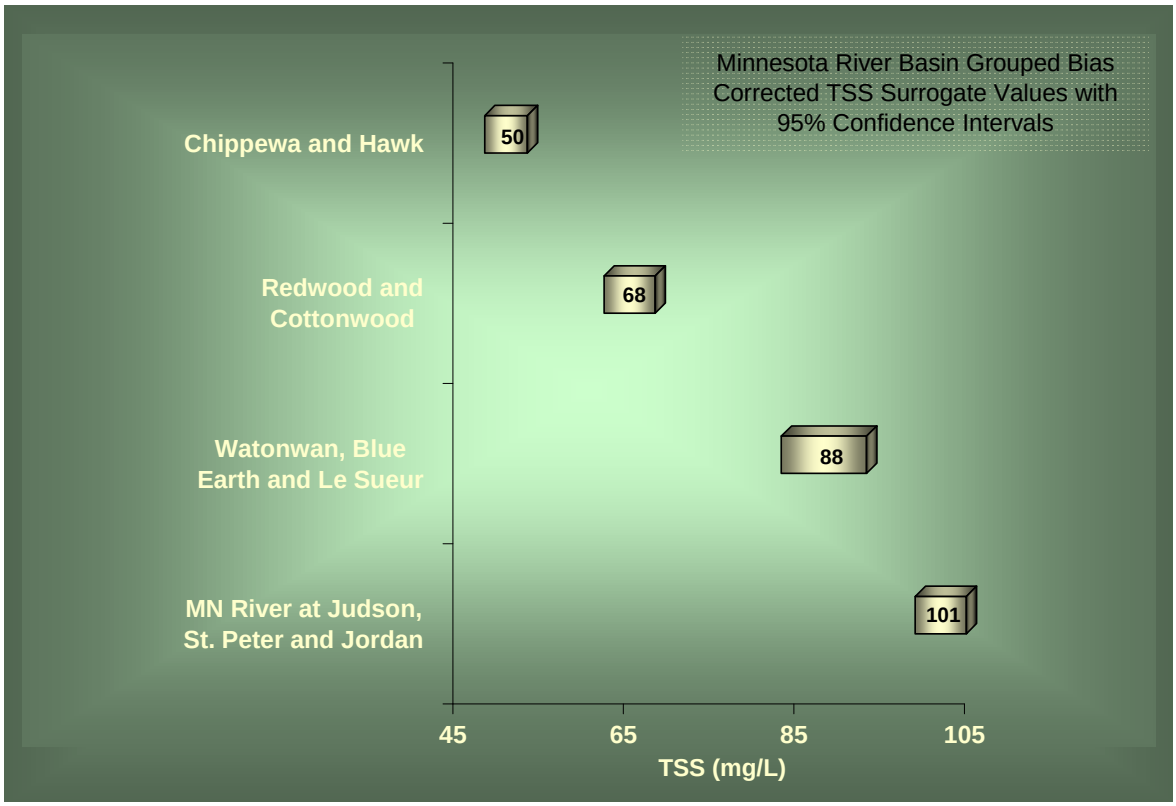


Figure B-17: Grouped bias corrected TSS surrogate values with 95% confidence intervals

V. Discussion of Surrogate Value Variability and Algal Influence

There are numerous likely and potential reasons for the differences in the TSS surrogate values among the different watersheds. While every attempt was made to account for differences in meter type, reporting units and lab analysis techniques, this may still be a significant "hidden" source of the variability. To the extent that more consistent approaches are developed over time in these areas, this variability will be reduced. The other major source of variability is the host of physical differences that exist throughout the basin. Everything from the rainfall patterns, soil types, and land slopes of the watersheds and rivers, to the size, width, depth, and nutrient status of the rivers, may affect the relationship between TSS and turbidity.

One of the most obvious physical causes of variability in the relationship is the particle-size distribution of the TSS. Finer (e.g. clay) particles have the potential to cause more turbidity per unit mass than coarser (e.g. sand, some algae) particles. Particle size, in turn, is influenced by both watershed characteristics such as soil types and sediment sources, and by river characteristics such as depth and gradient. A case could be made that the greater significance of non-field (ravine, bluff, and streambank) sediment sources in the eastern portion of the basin result in a coarser particle size distribution in TSS samples. Higher stream gradients can also produce a coarser particle size distribution in TSS samples. Both of these situations would result in higher TSS surrogate values. Unfortunately, limited data that includes particle size, turbidity, and TSS for a given water sample exist to test these ideas. At this time, we believe it is prudent for this project to utilize the grouped surrogate values shown in Figures B-16 and B-17. The analysis of the data supports these differences being real, even if the reasons cannot be fully explained.

In addition to (and related to) particle size distribution, there are both volatile (organic) and non-volatile (inorganic) components of TSS. Volatile solids include live and dead algae, and detritus that may influence turbidity differently from non-volatile solids. The algal component has been of particular interest from the standpoint of understanding whether on-going or future phosphorus reduction strategies will also reduce turbidity by limiting algae production. However, a thorough investigation of the relationships between turbidity, TSS and chlorophyll-*a* completed in the Phase I Report of the Lower Vermillion River Watershed Turbidity TMDL Project (Tetra Tech, 2004), concluded that algae do not play a major role in the observed turbidity. The Vermillion Study settled on a simple TSS regression as the best overall predictor of turbidity. At this time, we believe a similar approach is warranted in this project. Algae, other volatile solids, and non-volatile solids are all component parts of TSS, and contribute more or less to turbidity. A TMDL effort directed at TSS will encompass all three components. Some watershed management activities will impact all three components, and some may impact one more than others. As a more sophisticated understanding of turbidity emerges, some management activities could be directed at a specific component of TSS.

References

Campbell, Eileen. 2008. Personal communication with David Fuchs, MCES Assistant Lab Manager.

Christopherson, David. 2008. "The MPCA Water Quality Assessment Process." Presentation. Minnesota Pollution Control Agency internal Lakes, Streams, Wetlands and Groundwater Meeting. February 2008.

Hach Company. 2008. 2100 Series Laboratory Turbidimeters Data Sheet.

Johnson, Greg. 2007. Evaluation of "Paired" Turbidity Measurements from Two Turbidimeters for Use in Two TMDL Projects. December 13, 2007. Appendix to the Draft West Fork Des Moines River Watershed Total Maximum Daily Load Report: Excess Nutrients (North and South Heron Lake), Turbidity and Fecal Coliform Bacteria Impairments. Minnesota Pollution Control Agency.

Johnson, Greg, 2007. Personal communication with Jason Smith, MVTL Lab Manager.

Johnson, Greg. 2008. Personal communication. E-mail on bias corrections.

Minnesota Pollution Control Agency. 2005. Minnesota River Basin TMDL Project for Turbidity. Water Quality/Basins Fact Sheet 3.33. June 2005.

Minnesota Pollution Control Agency. 2006. Minnesota River Turbidity TMDL Work Plan.

Minnesota Pollution Control Agency. 2007. Turbidity TMDL Protocols and Submittal Requirements.

Minnesota Pollution Control Agency. 2007. Guidance Manual for Assessing the Quality of Minnesota Surface Waters.

SYSTAT 12. Version 12.00.08. SYSTAT Software, Inc., 2007.

Tetra Tech. Inc. 2004. Phase I Report: Data Gathering and Conceptual Model Development. Lower Vermillion River Watershed TMDL Project.

USGS. 2007. Turbidity codes. http://water.usgs.gov/owq/turbidity_codes.xls. Version: January 2007.

Zar, Jerrold H, 1996. *Biostatistical Analysis. 3rd Edition.* Englewood Cliffs, NJ. Prentice-Hall.