West Fork Des Moines River Watershed Total Maximum Daily Load Final Report: Excess Nutrients (North and South Heron Lake), Turbidity, and Fecal Coliform Bacteria Impairments

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TMDL SUMMARY

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Executive Summary

The Clean Water Act, Section 303(d), requires that every two years states publish a list of waters that do not meet water quality standards and do not support their designated uses. These waters are then considered to be “impaired”. Once a waterbody is placed on the impaired waters list, a Total Maximum Daily Load (TMDL) must be developed. The TMDL provides a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. It is the sum of the individual wasteload allocations (WLAs) for point or permitted sources, load allocations (LAs) for nonpoint or nonpermitted sources and natural background, plus a margin of safety (MOS).

The Minnesota Pollution Control Agency (MPCA) listed 15 stream reaches in the West Fork Des Moines River (WFDMR) watershed as impaired for excess fecal coliform bacteria (a human health concern that limits recreational use of the water) and 15 stream reaches for excess turbidity (a measure of cloudiness of water that affects aquatic life). (Some of these reaches were listed for both impairments and some were listed for either fecal coliform or turbidity.) In addition, the MPCA listed North and South Heron Lake as impaired due to excess nutrients (which limits both its recreational use and ecological/wildlife function). Related to the Heron Lake problem is a listing for pH within the Heron Lake Outlet. All of these impairments are addressed in this study for the following reasons: 1) they share some common contributing sources; 2) it is more efficient from administrative and cost standpoints to address multiple impairments in the same effort rather than separately; and 3) a watershed-wide approach makes the most sense to addressing some of the long-standing nonpoint pollution issues in this region. It should be noted that there are some more recent listings that could not be incorporated into this project due mainly to budget constraints, but up until separate TMDL studies are done on those waters it is likely that the broad-based efforts that will come out of this study should help to improve those waters as well.

The WFDMR watershed is located in southwestern Minnesota and is a part of the Western Corn Belt Plains and Northern Glaciated Plains ecoregions. The watershed extends across seven counties: Murray, Cottonwood, Jackson, and Nobles and a small portion of Pipestone, Lyon, and Martin. It covers an area of 1,333 square miles. The watershed consists of five subwatersheds: Lake Shetek (128 square miles), Beaver Creek (178 square miles), Heron Lake (467 square miles), the West Fork mainstem (473 square miles), and the Lower Des Moines (87 square miles). The river originates in the northwestern part of the watershed from several lakes including its principal source, Lake Shetek. The river flows from the Lake Shetek outlet near Currie in a southeasterly direction for 94 miles to the Minnesota/Iowa border and eventually enters the Mississippi River at Keokuk, Iowa. Land use is dominated by agricultural cropping and animal production. Point sources (permitted municipal and industrial dischargers) and a small number of unsewered communities also exist in the watershed.

This study used a variety of methods to evaluate the current loading, contributions by the various pollutant sources, as well as the allowable pollutant loading capacity of the impaired reaches and North and South Heron Lake. These methods included the load duration curve approach for reaches impaired by fecal coliform bacteria and turbidity and the BATHTUB model for North and South Heron Lake excess nutrients. It is estimated that the overall magnitude of reduction needed to meet water quality standards ranges from 10 to 86 percent for fecal coliform bacteria, 50 to 80 percent for turbidity levels, and 87 percent for North and South Heron Lake excess nutrients.

The primary contributing sources to fecal coliform bacteria were found to be livestock on overgrazed riparian pasture, surface-applied manure on cropland, feedlots lacking adequate runoff controls and inadequate septic systems. The primary contributing sources to the turbidity impairments were found to be streambank/bed erosion, row cropland, algae and, to a lesser extent, benthic feeders (e.g., carp), overgrazed pasture and inadequate buffers near streams and waterways. The primary contributing watershed sources to excess phosphorus in North and South Heron Lake were essentially found to be divided between point sources, primarily wastewater treatment facilities, and nonpoint sources, including cropland/pasture runoff and streambank erosion. Under current conditions, internal phosphorus loading to North and South Heron Lake from sediment phosphorus release, wind resuspension, and benthic fish represent a larger source of phosphorus (more than 75 percent overall) than the watershed loading to the lakes.

A general strategy for implementation of nonpoint source-related actions to address the impairments is provided in this document (a more specific implementation plan will be developed and will be available as a separate report). Nonpoint contributions are not regulated and, therefore, reductions will need to proceed on a voluntary basis. For North and South Heron Lake considerations for reductions of internal phosphorus loading are described. Needed reductions from permitted point sources related to the North and South Heron Lake TMDL are described in this TMDL report. These will be addressed through the MPCA’s National Pollutant Discharge Elimination System (NPDES) permit programs.

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act provides authority for completing Total Maximum Daily Loads (TMDLs) to achieve state water quality standards and/or designated uses.

A TMDL is a calculation of the maximum amount of pollutant that a waterbody can receive and still meet water quality standards and/or designated uses. It is the sum of the loads of a single pollutant from all contributing point and nonpoint sources. TMDLs are approved by the U.S. Environmental Protection Agency (EPA) based on the following elements:

1. They are designed to implement applicable water quality criteria;
2. Include a total allowable load as well as individual 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; and
8. Have a reasonable assurance that the TMDL can be met.

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

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

Where:

WLA = wasteload 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 of 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 (USEPA, 1999); and

RC = reserve capacity, an allocation for future growth. This is an MPCA-required element, if applicable, for TMDLs.

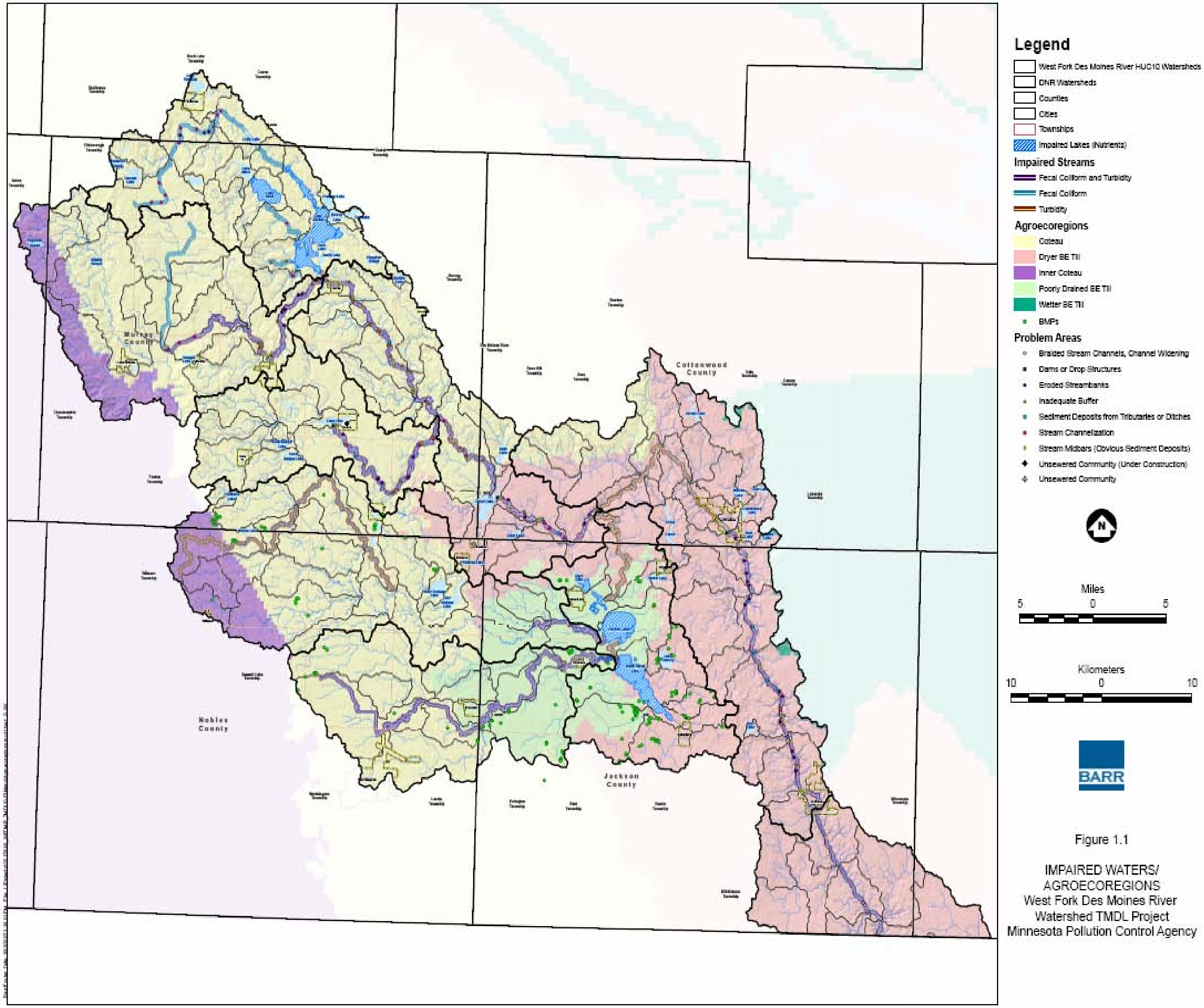
This TMDL report applies to 15 stream reaches in the WFDMR watershed as impaired for excess fecal coliform bacteria, 15 stream reaches for excess turbidity, North and South Heron Lake for excess nutrients and one reach (the Heron Lake Outlet) for pH, which will be addressed via the Heron Lake excess nutrient evaluation. These impairments are currently on the 2008 303(d) list of impaired waters and are shown in Table 1.1 and Figure 1.1.

TABLE 1.1. WFDMR watershed 303(d) impairments addressed in this report.

REACH	DESCRIPTION	YEAR LISTED	ASSESSMENT UNIT ID / DNR LAKE #	AFFECTED USE	POLLUTANT OR STRESSOR
Beaver Creek	CD 20 to Des Moines R	02	07100001-503	Aquatic recreation	Fecal coliform
Beaver Creek	CD 20 to Des Moines R	04	07100001-503	Aquatic life	Turbidity
County Ditch 20	Headwaters to Beaver Cr	02	07100001-504	Aquatic recreation	Fecal coliform
Des Moines River	Beaver Cr to Lime Cr	04	07100001-546	Aquatic recreation	Fecal coliform
Des Moines River	Beaver Cr to Lime Cr	04	07100001-546	Aquatic life	Turbidity
Des Moines River	Lime Cr to Heron Lk Outlet	04	07100001-533	Aquatic recreation	Fecal coliform
Des Moines River	Lime Cr to Heron Lk Outlet	04	07100001-533	Aquatic life	Turbidity
Des Moines River	Windom Dam to Jackson Dam	04	07100001-501	Aquatic recreation	Fecal coliform
Des Moines River	Windom Dam to Jackson Dam	98	07100001-501	Aquatic life	Turbidity
Des Moines River	Jackson Dam to JD 66	02	07100001-541	Aquatic life	Turbidity
Des Moines River	JD 66 to IA border	04	07100002-501	Aquatic recreation	Fecal coliform
Des Moines River	JD 66 to IA border	02	07100002-501	Aquatic life	Turbidity
Des Moines River	Heron Lk Outlet to Windom Dam	06	07100001-524	Aquatic life	Turbidity
Des Moines River	Lk Shetek to Beaver Cr	06	07100001-545	Aquatic life	Turbidity
Division Creek	Heron Lk to Okabena Cr	06	07100001-529	Aquatic life	Turbidity
Elk Creek	Headwaters to Okabena Cr	06	07100001-507	Aquatic life	Turbidity
Elk Creek	Headwaters to Okabena Cr	06	07100001-507	Aquatic recreation	Fecal coliform
Heron Lake Outlet	Heron Lk (32-0057-01) to Des Moines R	06	07100001-527	Aquatic life	pH
Heron Lake Outlet	Heron Lk (32-0057-01) to Des Moines R	06	07100001-527	Aquatic life	Turbidity
Jack Creek	JD 26 to Heron Lk	06	07100001-509	Aquatic life	Turbidity
Jack Creek	JD 26 to Heron Lk	06	07100001-509	Aquatic recreation	Fecal coliform
Jack Creek, North Branch	Headwaters to Jack Cr	06	07100001-505	Aquatic life	Turbidity
Lake Shetek Inlet	Headwaters to Lk Shetek	02	07100001-502	Aquatic recreation	Fecal coliform
Lime Creek	Lime Lk to Des Moines R	04	07100001-535	Aquatic recreation	Fecal coliform
Lime Creek	Lime Lk to Des Moines R	04	07100001-535	Aquatic life	Turbidity
Lower Lake Sarah Outlet	First Unnamed Cr on Lk Sarah Outlet stream to Lk Shetek inlet	02	07100001-508	Aquatic recreation	Fecal coliform
Okabena Creek	Elk Cr to South Heron Lk	06	07100001-506	Aquatic life	Turbidity
Okabena Creek	Elk Cr to South Heron Lk	06	07100001-506	Aquatic recreation	Fecal coliform
Unnamed Creek	Unnamed Cr to Lk Shetek	02	07100001-519	Aquatic recreation	Fecal coliform
Unnamed Creek	Unnamed Cr to Unnamed Cr	02	07100001-517	Aquatic recreation	Fecal coliform
Upper Lake Sarah Outlet	Lk Sarah Outlet to first Unnamed Cr	02	07100001-513	Aquatic recreation	Fecal coliform
Heron (North Heron)	Lake or Reservoir	02	32-0057-05	Aquatic recreation	Excess nutrients
Heron (South Heron)	Lake or Reservoir	02	32-0057-07	Aquatic recreation	Excess nutrients

The MPCA's projected schedule for TMDL completions, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. The project was scheduled to be completed in 2008. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

Figure 1.1. WFDMR watershed 303(d) impairments and land use.



In this report, the background information relevant to all impairment categories (fecal coliform, turbidity, excess nutrients in North and South Heron Lake and pH) is provided in Section 2.0, followed by the TMDL technical elements of each impairment category provided separately in Sections 3.0 through 5.0. For follow-up monitoring, implementation, reasonable assurance and public participation all impairment categories are addressed together in Sections 6.0 through 9.0.

2.0 BACKGROUND INFORMATION

2.1 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 TMDLs addressed in this report.

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

According to Minn. Rules Ch. 7050.0470, the impaired waters covered in this TMDL are classified as Class 2B or 2C, 3B, 3C, 4A, 4B, 5 and 6. Relative to aquatic life and recreation the designated beneficial uses for 2B and 2C waters are as follows:

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

Fecal coliform bacteria

Fecal coliform bacteria are an indicator organism, meaning that not all the species of bacteria of this category are harmful but are usually associated with harmful organisms transmitted by fecal contamination. They are found in the intestines of warm-blooded animals, including humans. The presence of fecal coliform bacteria in water suggests the presence of fecal matter and associated harmful bacteria (e.g., some strains of *E. coli*), viruses and protozoa (e.g., *Giardia* and *Cryptosporidium*) that are pathogenic to humans when ingested (USEPA, 2001). While Minnesota currently uses fecal coliform bacteria as its standard the MPCA is changing this to an *E. coli* standard (see Section 3.3 for further discussion).

Minn. Rules Ch. 7050.0222, fecal coliform water quality standard for Class 2B and 2C waters, states that fecal coliform concentrations shall "not exceed 200 organisms per 100 milliliters as a geometric mean[1] of not less than five samples in any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms per 100 milliliters. The standard applies only between April 1 and October 31". The designated use that this standard protects is aquatic recreation. Impairment assessment is based on the procedures contained in The Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment (MPCA, 2007).

Turbidity

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

Minn. Rules Ch. 7050.0222, turbidity water quality standard for Class 2B and 2C waters is 25 nephelometric turbidity units (NTUs). The designated use that this standard protects is aquatic life. Impairment assessment procedures for turbidity are provided in the guidance manual cited above. Essentially, listings occur when greater than ten percent of data points collected within the previous ten-year period exceed the 25 NTU standard (or equivalent values for total suspended solids or transparency tube data).

Excess nutrients

In Minnesota, excess nutrients from anthropogenic sources contribute to cultural eutrophication of lakes. Excessive nutrient loads, in particular total phosphorus (TP), lead to increased algae blooms and reduced transparency – both of which may significantly impair or prohibit the designated use of aquatic recreation. According to Minn. Rules Ch. 7050.0222, shallow lake water quality standards for Class 2B waters, and the MPCA's assessment guidance (MPCA, 2007), there are three lake water quality criteria for excess nutrients that must be met on an average summer (June-September) basis in the Western Corn Belt Plains (WCBP) ecoregion (which includes the Heron Lake watershed): total phosphorus concentration less than or equal to 90 µg/L, chlorophyll-*a* concentration less than or equal to 32 µg/L, and Secchi disc transparency greater than or equal to 0.7 meters (2.3 feet). Impaired water listings occur for lakes in the WCBP ecoregion when these criteria are not being met based on the long-term mean from the past ten years of monitoring data (with a minimum of 10 data points; MPCA, 2007).

[1] Geometric means are used throughout this report. It is a type of average that is appropriate for summarizing the central tendency of environmental data that is not normally distributed (Helsel and Hirsch, 1991). Unlike arithmetic means, geometric means tend to dampen the effect of very high or very low values. They are calculated by taking the n^{th} root of the product of n numbers (or by taking the antilog of the arithmetic mean of log-transformed numbers).

pH

The pH of water is a measure of the degree of its acid or alkaline reaction. pH water quality standards are provided in Minn. Rules Ch. 7050.0222 for Class 2B and 2C waters and are further describe in the MPCA's assessment guidance (MPCA, 2007) as follows: "the applicable pH standard for most Class 2 waters is a minimum of 6.5 and a maximum of 8.5, based on the more stringent of the standards for the applicable multiple beneficial uses. The pH values that are either too high or too low can be harmful to aquatic organisms". Thus, the designated use that this standard protects is aquatic life.

While natural waters can exhibit pH values outside the 6.5 to 8.5 range, the high pH documented within the Heron Lake Outlet appears to be directly the result of eutrophication (high algal production) in North and South Heron Lakes. In his description of inorganic carbon chemical processes in fresh water systems, Wetzel (2001) includes the relationship of carbon dioxide dissolution, carbon dioxide utilization (during photosynthesis) and pH. Specifically, atmospheric carbon dioxide dissolves in water and is in equilibrium with the hydrated dissolved carbon product carbonic acid. During rapid photosynthesis (e.g., resulting from abundant algal production) the dissolved carbon dioxide concentration is rapidly reduced, which in turn reduces the carbonic acid concentration and raises the pH. High pH in highly eutrophic lakes has been commonly observed in Minnesota (Bruce Wilson, MPCA, 2007; personal communication). For these reasons a separate TMDL analysis for the pH listing for the Heron Lake outlet will not be done and instead will be addressed via the Heron Lake excess nutrient TMDL analysis. (A summary and discussion of existing pH data in the outlet and Heron Lake is provided in Section 5.0.)

2.2 General Watershed Characteristics

The WFDMR watershed is located in southwestern Minnesota and is a part of the Western Corn Belt Plains and Northern Glaciated Plains ecoregions. The watershed extends across seven counties: Murray, Cottonwood, Jackson, and Nobles and a small portion of Pipestone, Lyon, and Martin. It covers an area of 1,333 square miles. The watershed consists of five subwatersheds: Lake Shetek (128 square miles), Beaver Creek (178 square miles), Heron Lake (467 square miles), the West Fork mainstem (473 square miles), and the Lower Des Moines (87 square miles).

The river originates in the northwestern part of the watershed from several lakes including its principal source Lake Shetek. The headwaters of the river are the Lake Shetek and Beaver Creek watersheds. The river flows from the Lake Shetek outlet near Currie in a southeasterly direction for 94 miles to the Minnesota/Iowa border and eventually enters the Mississippi River at Keokuk, Iowa.

Although the river has not gone through significant channelization, other alterations to the waterbody have occurred in the form of dams, which are located at several locations along the river. These include mainstem dams at the lower ends of Lake Shetek and Talcot lake and in the cities of Windom and Jackson. Smaller dams include those at North Heron lake, Fulda lake, the Graham lakes, and a fish barrier on the Heron lake outlet. The river is mainly slow flat water except for some moderate rapids near Kilen Woods State Park. The overall gradient from the Talcot dam to Jackson is approximately 2.1 feet per mile. The river is used for fishing, hunting, and canoeing in the summer and snowmobiling and ice fishing in the winter.

The dominant land use in the WFDMR watershed is row crop agriculture (approximately 85.5 percent), with 9.5 percent pasture/open, 3 percent water/marsh, 1.5 percent urban, and 0.5 percent forested. Land adjacent to the stream is utilized for pasture, cropland, urban development and recreation. The annual average precipitation on the watershed ranges from 25 to 29 inches along the northwest to northeast gradient. Runoff patterns also increase along the same gradient.

David Mulla of the Department of Soil, Water, and Climate of the University of Minnesota has described the state's land area in terms of "agroecoregions", in which each agroecoregion is associated with a specific combination of soil types, landscape and climatic features, and land use. The WFDMR watershed is predominantly made up of three agroecoregions: the Coteau (in the western half of the watershed), the Poorly Drained Blue Earth Till (in the lowest portion of the Heron Lake subwatershed drainage), and Dryer Blue Earth Till (in the eastern portion of the watershed); see Figure 1.1. These agroecoregions are described as follows:

Coteau

This agroecoregion consists of fine-textured morainal soils such as the Barnes, Clarion, Flom, and Forman. Soils are generally well drained, and are located on moderately steep slopes. Water and wind erosion potentials can be moderate to severe. Many intermittent streams exist in this agroecoregion. There is a moderate risk for loss of phosphorus to streams by erosion and runoff.

Original vegetation was prairie. Nearly all of the Coteau is in cropland or is used for animal production. Corn and soybeans are grown on 45 and 49 percent of the cropland, respectively. Cattle, hogs, and turkeys are the major animals produced, representing 5, 8, and 2 percent of the statewide production, respectively. Within this agroecoregion cattle account for 63 percent of the animal units (AUs) raised, hogs account for 35 percent of the AUs, and turkeys account for 1.5 percent of the AUs. Rates of phosphorus and nitrogen applied to cropland from manure and fertilizer average 29 lb/acre and 131 lb/acre, respectively.

Poorly Drained Blue Earth Till

This agroecoregion consists of fine textured soils from the Collinwood, Lura, Waldorf, and Spicer series developed in lacustrine deposits. Soils are very flat and are poorly drained. These soils have a moderate potential for erosion by wind and water, and for phosphorus transport to surface waters.

Original vegetation was prairie and wet prairie. Cropland accounts for 93 percent of the land use in this agroecoregion, while wetlands account for 3 percent. Corn and soybeans are grown on 48 and 50 percent of the cropland, respectively. Rates of phosphorus and nitrogen applied to cropland from fertilizer average 23 lb/acre and 107 lb/acre, respectively.

Dryer Blue Earth Till

This agroecoregion consists of fine-textured soils such as the Canisteo, Ves, Normania, and Webster series developed from calcareous glacial till. Soils tend to be basic in pH. Soils are generally poorly or moderately well drained, and are located on flat to moderately steep slopes. Water and wind erosion potentials can be moderate to high. There is a moderate risk for losses of phosphorus to streams by erosion and runoff.

Original vegetation was prairie and wet prairie. Nearly all of the land use in this agroecoregion is accounted for by cropland and animal production. Corn and soybeans are grown on 45 and 49 percent of the cropland, respectively. About 13 percent of the hogs, five percent of the cattle, and four percent of the turkeys grown statewide are raised in this agroecoregion. Within this agroecoregion hogs account for 49 percent of the AUs raised, cattle account for 48 percent of the AUs, and turkeys account for two percent of the AUs. Rates of phosphorus and nitrogen applied to cropland from manure and fertilizer average 32 lb/acre and 148 lb/acre, respectively.

Agricultural production is a dominant and vital part of the economy for this region. According to Minnesota Agricultural Water Resources Coalition, the corn, soybean, beef and swine production in the four counties that make up the majority of the watershed (Cottonwood, Jackson, Murray and Nobles) generate more than $750 million annually.

North and South Heron Lake and its contributing watershed have undergone significant transformation over the decades. The Minnesota Department of Natural Resources describes the changes as follows:

> The Heron Lake watershed was once blessed with rich natural resources including clean water, fertile prairie soil, lush vegetation and abundant wildlife. Gradually, however, the landscape began to change: wetlands were drained, streams were channelized, and croplands replaced prairie grasses and wetlands for intensive modern agricultural production. As a result, the frequency and extent of flooding increased and water became polluted. Dikes built around Heron Lake to contain fluctuating water levels reduced its area by one quarter. This reduction in lake area has led to a loss of habitat and degraded plant and wildlife communities.
> (http://www.dnr.state.mn.us/rprp/heronlake/place_context.html)

North and South Heron Lakes were once a nationally recognized migratory waterfowl habitat with over 700,000 staging canvasbacks, 50,000 nesting Franklin's gulls, and large numbers of other birds. Today the lake is primarily used by smaller flocks of mallards and other puddle ducks mainly for refuge during migration.

3.0 FECAL COLIFORM BACTERIA

3.1 Surface Water Quality Conditions

Many factors affect the quantity of fecal coliform bacteria (and associated pathogens) in water bodies. The delivery of fecal matter to surface water is discussed later in this report. The factors affecting survivability of fecal coliform bacteria once they get into surface water include: sunlight, temperature, settling, and presence of nutrients and organic matter (USEPA, 2001).

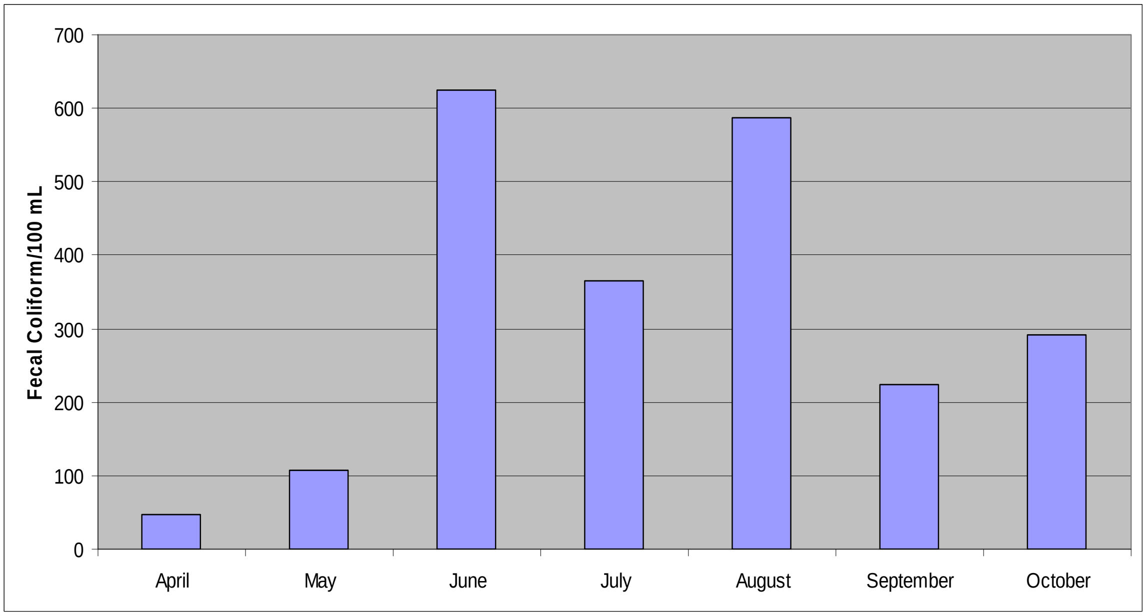
A summary of the fecal coliform data used in this report is provided in Table 3.1. The data used was from 1994 through 2003 with the different reaches having been sampled for only some of the years within this time period (due to the data being collected by different organizations/ projects over the years). To gain insight into seasonal differences data were separated into "spring" (April-May) and "summer" (June-October) on Table 3.1. To evaluate the effects of runoff-producing rainfall, data were also separated into "wet" and "dry" categories. Because many landscape, climatic, and other site-specific factors affect the occurrence and degree of runoff, determining what is wet versus dry could be a very involved undertaking on its own. The goal of this analysis is only to gain some general insights; therefore, wet and dry are defined in a fairly simplistic way. Wet sample days are those in which either 0.5 inches or more of total rain fell within 24 hours prior to sampling or 1.0 inches or more of total rain fell within the previous 48 hours. Dry samples are those with less than these rainfall totals. (Some minor exceptions were made to these guidelines based on closer review of the data, i.e., some more intense rain events falling under these amounts were considered to be "wet".) In Table 3.1, exceedences of the 200 organisms/100 ml geometric mean standard are shown in gray.

A summary of monthly geometric means across all sites is provided in Figure 3.1. Additional reach-specific analysis, through interpretation of load duration curves, is provided for each impaired reach in Sections 3.4.1 through 3.4.15).

TABLE 3.1. Summary of fecal coliform data for the WFDMR watershed based on season and runoff conditions. Shaded boxes exceed 200 orgs/100 ml geometric mean. Fewer than five data points are generally not a reliable geometric mean (values in italics).

	Monitoring station(s) STORET #	Years monitored	SPRING						SUMMER						SPRING THROUGH SUMMER						
			Wet		Dry		All		Wet		Dry		All		Wet		Dry		All		Percent samples >2000
			Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	
Beaver Ck. Subwatershed:																					
Beaver Creek; CD 20 to Des Moines R (07100001-503)	S002-005 S001-555	94, 01-03	*3057*	3	104	20	162	23	2584	14	487	36	777	50	2662	17	281	56	474	73	23
County Ditch 20; Headwaters to Beaver Cr (07100001-504)	S001-545	94	*1400*	1	*20*	2	*81*	3	30129	5	210	7	1662	12	18065	6	124	9	909	15	27
Lake Shetek Subwatershed:																					
Lake Shetek Inlet; Headwaters to Lk Shetek (07100001-502)	S001-546	94, 00	*100*	1	*50*	4	58	5	505	8	66	9	172	17	422	9	61	13	134	22	14
Lower Lake Sarah Outlet; First Unnamed Cr on Lk Sarah Outlet stream to Lk Shetek inlet (07100001-508)	S001-547	94, 00	*119*	3	*179*	4	150	7	2142	10	882	8	1444	18	1100	13	518	12	766	25	28
Unnamed Creek; Unnamed Cr to Unnamed Cr (07100001-517)	S001-548	94, 00	*134*	3	*207*	4	172	7	2276	10	542	7	1260	17	1184	13	382	11	705	24	29
Unnamed Creek; Unnamed Cr to Lk Shetek (07100001-519)	S001-549	94, 00	*110*	3	*46*	4	67	7	2393	10	732	8	1414	18	1176	13	292	12	602	25	24
Upper Lake Sarah Outlet; Lk Sarah Outlet to Unnamed Cr (07100001-513)	S001-551	94	*1*	1	*8*	2	*4*	3	1910	5	419	6	835	11	542	6	155	8	265	14	29
Middle Des Moines Subwatershed:																					
Des Moines River; Beaver Cr to Lime Cr (07100001-546)	S002-008	01-03	*1083*	3	97	17	139	20	1414	9	561	32	687	41	1323	12	305	49	407	61	13
Lime Creek; Lime Lk to Des Moines R (07100001-535)	S002-007	01-03	*1578*	4	47	16	94	20	1854	11	331	27	545	38	1776	15	159	43	297	58	14
Des Moines River; Lime Cr to Heron Lk Outlet (07100001-533)	S001-363	01-03	*408*	4	38	16	61	20	1159	10	202	32	306	42	861	14	115	48	182	62	10
Des Moines River; Windom Dam to Jackson Dam (07100001-501)	S000-027 S000-894 S000-481	01-03	151	11	43	34	58	45	895	23	91	81	151	104	503	34	73	115	113	149	5
Heron Lake Subwatershed:																					
Okabena Creek; Elk Cr to South Heron Lk (07100001-506)	S001-568	97-03	*213*	2	38	12	49	14	1786	8	273	30	406	38	1168	10	156	42	229	52	10
Jack Creek; JD 26 to Heron Lk (07100001-509)	S001-557	97-03	*280*	1	40	13	46	14	1953	7	364	25	525	32	1532	8	171	38	251	46	15
Elk Creek; Headwaters to Okabena Cr (07100001-507)	S000-232	97, 99-02		0	93	5	93	5	*5027*	4	509	15	825	19	5027	4	333	20	523	24	25
Lower Des Moines Subwatershed:																					
Des Moines River; JD 66 to IA border (07100002-501)	S000-156	01-02	*417*	2	73	8	104	10	1732	6	257	18	414	24	1213	8	174	26	275	34	15

Figure 3.1. Monthly geometric means for fecal coliform bacteria for all sites in WFDMR watershed.



In drawing conclusions from Table 3.1 it is important to note that there are fewer spring than summer samples and that some sites had far fewer samples than others. In spite of these limitations some important conclusions can be drawn from the data:

- The dominant factors for levels of fecal coliform bacteria are time of year and occurrence of runoff-producing rainfall events. Both summer samples and wet samples are much higher than spring samples and dry samples, respectively, often 5 – 10 times higher.
- Regarding the seasonal differences spring geometric means are well below the 200 organisms/100 ml standard and summer values are generally above it. (Note: two reaches in Table 3.1 show values below the standard for the summer; data from individual months does show exceedences of the standard for these reaches, however.) Explanations for seasonal differences likely include: 1) a greater percentage of wet sampling days during summer vs. spring, 2) growth of bacteria in sediments and riparian areas during summer months owing to the warmer temperatures.
- In the summer even dry samples are elevated (i.e., above 200) for most sampling locations. Elevated summer-dry values are possibly indicative of contributions by a more continuous type source that is present mainly in the summer (e.g., cattle in/near streams) and/or warmer temperatures. Further discussion of potential sources is discussed in the next section.
- Comparisons across sampling locations are difficult to reliably make due to inherent variability in bacterial data and also the fact that the data was generated over different years for many of the sites. Additional reach-specific data analysis is provided in Sections 3.4.1 through 3.4.15.
- When looking at the aggregate data for each sampling location, many locations show significant percent exceedence of the 2000 organisms/100 ml portion of the standard.

3.2 Fecal Coliform Sources and Current Contribution

Conclusions regarding fecal coliform sources and estimates of current loading are based on: 1) interpreting the water quality data presented in the previous section and other MPCA information, and 2) simple modeling via inventorying sources and estimating delivery of bacteria to the water. This modeling is described in Appendix A and is adapted from the 2002 version of the “Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota” (MPCA, 2002). It represents a means to roughly approximate the magnitude of the current loadings of the various fecal coliform source categories and subcategories. It starts with an estimated inventory of all the fecal coliform producers in the given land area, then considers where and how the fecal waste is distributed on the landscape (or other intermediate location prior to delivery to surface water), then applies various “delivery potentials” to the fecal waste to estimate the relative amount of fecal material getting into the surface water. A separate analysis was done for each of the four counties that make up most of the watershed— Nobles, Cottonwood, Jackson and Murray (Figure 1.1)—in order to provide some sense of the geographic differences. Counties were used (rather than subwatersheds or some other land unit) because the data inputs and information are most readily available at the county level. Only the portion of the county within the WFDMR watershed boundary is used in the analysis.

The fecal coliform producers of this watershed are livestock (primarily beef and dairy cattle, swine, sheep, horses and poultry), humans, wildlife and pets. Based on an inventory of these sources the breakdown of total fecal coliform production in the four counties is shown in Figures 3.2 - 3.5 (data based on Table A-1 from Appendix A).

Figure 3.2. Estimated fecal coliform produced by source in Nobles Co.

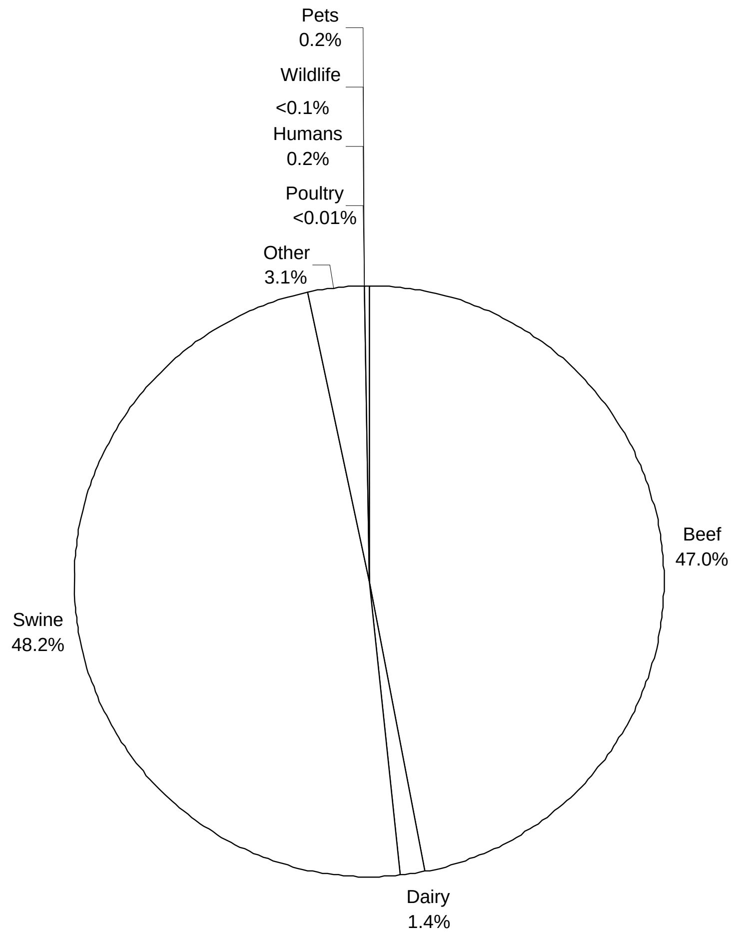


Figure 3.3. Estimated fecal coliform produced by source in Cottonwood Co.

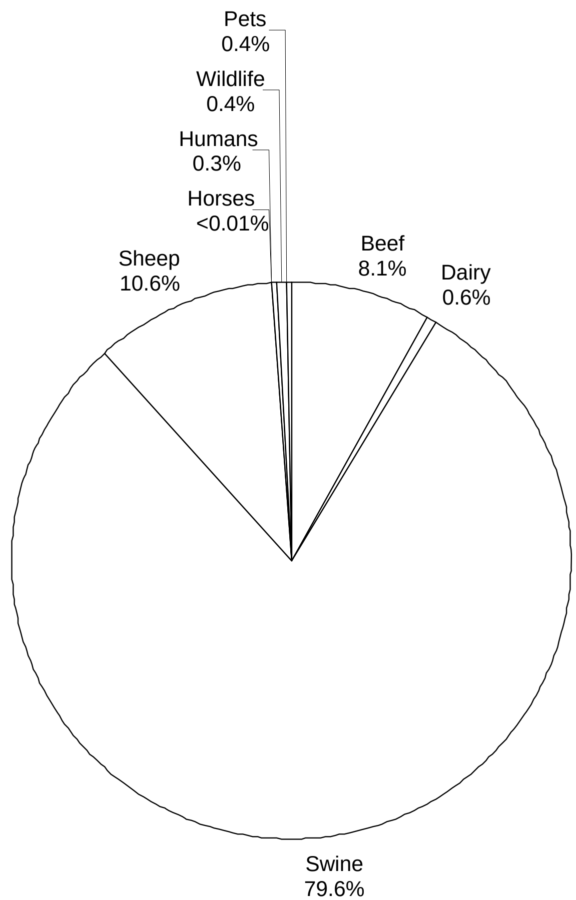


Figure 3.4. Estimated fecal coliform produced by source in Jackson Co.

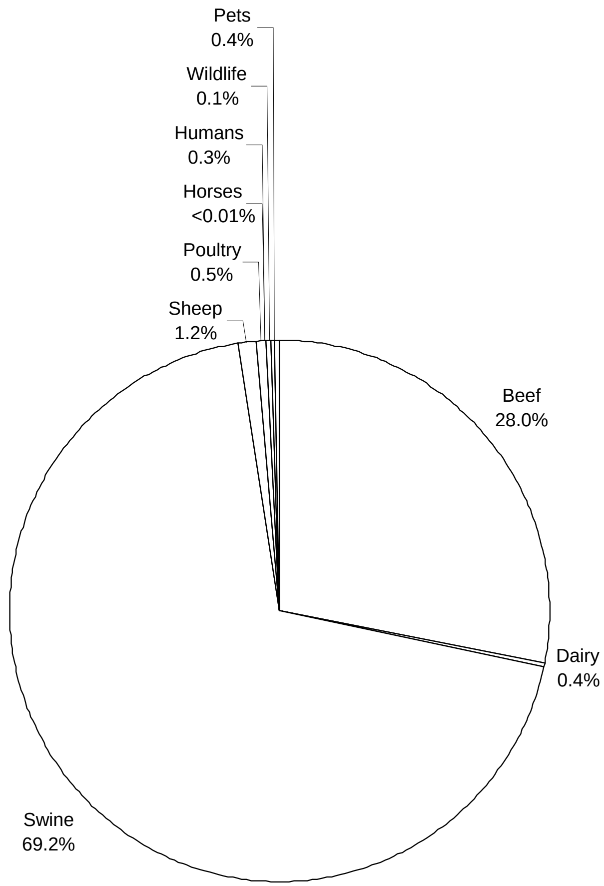
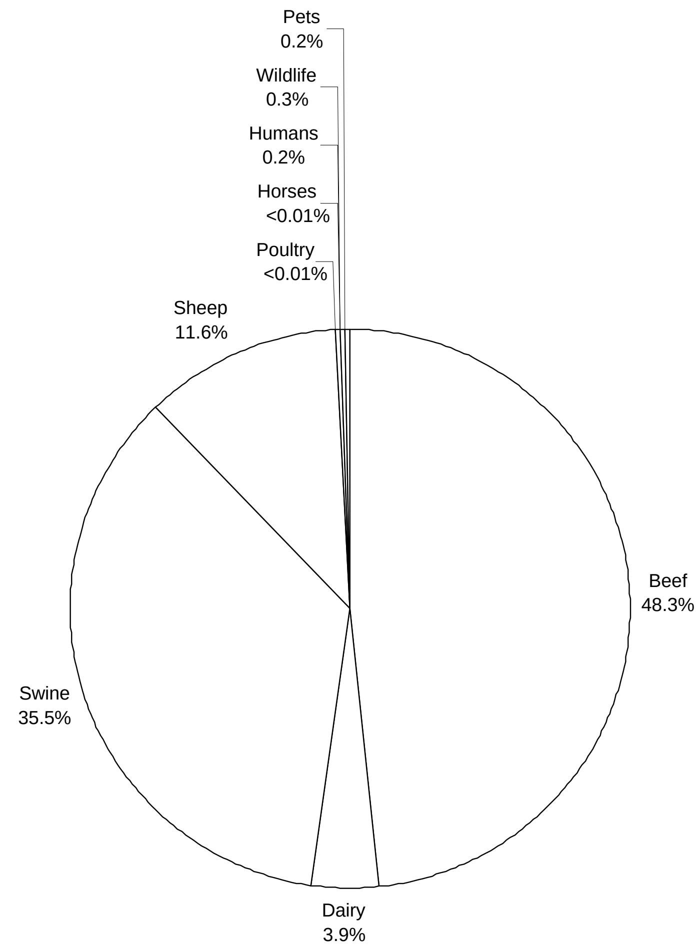


Figure 3.5. Estimated fecal coliform produced by source in Murray Co.



The following sections provide estimates of relative contribution and further discussion of these sources.

Livestock

From Figures 3.2 – 3.5 it is clear that the dominant producer of fecal coliform in the watershed is livestock and that most of this livestock are swine and beef cattle. (For actual estimated numbers of each livestock type see Tables A.2 – A.5 in Appendix A.) The magnitude of fecal coliform contribution to surface water from feedlots/stockpiles, manure-applied fields and pastures was estimated and presented in Appendix A and is summarized below.

The category of *feedlots or stockpiles without adequate runoff controls* appears to provide a high relative contribution during spring and summer wet conditions for all counties except Murray County, which showed a moderate contribution. In all four counties, it appears that cattle operations were judged by local staff to be most lacking in adequate runoff controls. While swine make up much of the livestock in the watershed those operations are primarily indoor confinement.

Surface-applied manure was found to provide a high and moderate-high relative contribution under spring and summer wet conditions seasons, respectively. The type of livestock manure that makes up this contribution is a function of both the amount of manure produced and the fraction of this that is surface-applied (versus incorporated), which varies geographically. Based on this, it appears that beef cattle and swine make up significant portions of the surface-applied manure contribution to surface water for all four counties. For Cottonwood and Murray counties, sheep manure also appears to provide a significant contribution. The category *incorporated/injected manure* shows much lower potential contributions, as would be expected since this is the desired best management practice (BMP) for field-applied manure. There is some potential off-field movement of fecal bacteria for this practice, however. As referenced in the Blue Earth River Fecal Coliform TMDL (MPCA, 2006) sampling of fecal coliform from tile lines in fields with injected manure did, at times, indicate relatively high bacterial levels. Movement of the bacteria through macropores was identified as the likely pathway.

Overgrazed pasture near streams or waterways appears to provide a high relative fecal coliform contribution across all counties during dry times, but varies by county during wet times. The high late season fecal coliform numbers as described in Section 3.1 are consistent with the conclusion that overgrazed areas may be a significant source, since it is those summer months when overgrazing may be most likely to occur (which reduces the ability of the surface to slow or prevent runoff during even light rainfall conditions). Also, this is when cattle use the stream to cool off.

Humans

The human-derived sources of fecal coliform are from inadequate subsurface sewage treatment systems (SSTSs) and the wastewater treatment facilities in the watershed.

County staff conferred with for this project provided the information shown in Table 3.2 regarding the state of SSTSs.

TABLE 3.2. SSTS status for four main counties in WFDMR watershed.

COUNTY	SSTS STATUS/INFORMATION
Nobles	Estimate of SSTSs noncompliant or failing: 70% Direct-to-tile systems exist, but we do not have numbers or locations of these.
Cottonwood	Estimate of SSTSs noncompliant or failing: 44% Of noncompliant systems approximately 90% are believed to be direct-to-tile, while the remaining 10% are surface systems with the slight potential for other noncomplying systems to exist. Approximately 200 systems have been upgraded through 2005. Approximately 11 systems per year are upgraded within the WFDMR watershed.
Jackson	Estimate of SSTSs noncompliant or failing: 70% Of noncompliant systems, probably 75% of those systems may be “straight-pipe” systems (direct to tile or surface discharge). Since 1997, there have been 251 septic system upgrades. Roughly 25 systems are upgraded per year in the WFDMR watershed. There are roughly 1000 households in the watershed, so approximately 750 that may need upgrades.
Murray	Estimate of SSTSs noncompliant or failing: 80% Of noncompliant systems, 75% are direct-to-tile and/or surface discharge and 25% fail to meet state requirements. Since 2000, 217 systems have been upgraded. 15-20% of systems in WFDMR watershed meet compliance Approximately 50 systems are upgraded per year.

This information provides a clear indication that inadequate SSTSs may be contributing a significant fecal coliform bacteria load to surface waters in the watershed. The modeling exercise summarized in Appendix A coincides with this finding, particularly during dry times when runoff is not a factor. It should be pointed out that most direct-to-tile septic systems likely have some type of rudimentary collection/settling component, so not all the waste is necessarily entering the tile line.

Efforts to address unsewered communities are ongoing with the MPCA and other organizations (see MPCA, 2008). Those identified in 2007 in the WFDMR watershed include Hadley, Lime Creek, Kinbrae, Wilder and Dundee. These are very small communities ranging in population from 18 to about 100.

Most of the watershed's population is serviced by wastewater treatment facilities. A summary of these (including one industrial facility) is provided in Table 3.3 and are separated by facility type. Mechanical systems discharge on a daily basis; facilities utilizing stabilization ponds are permitted to discharge from April 1 through June 15 and September 15 through December 15 in this part of the state. According to state rule, a discharger is required to meet a discharge limit of 200 organisms/100 ml concentration (monthly geometric mean). The number of months with violations of this requirement is provided in Table 3.3.

TABLE 3.3. NPDES-permitted wastewater treatment facilities discharging in the WFDMR watershed.

CITY-FACILITY	NPDES PERMIT #	NUMBER OF FECAL COLIFORM VIOLATIONS 2000-2006
Stabilization Pond Systems		
Lake Wilson	MNG580061	0
Slayton	MN0024911	3
Fulda	MN0023507	6
Brewster	MN0021750	0
Okabena	MN0050288	0
Currie	MN0025682	1
Heron Lake	MN0023655	0
Jackson	MNG580063	0
Mechanical Systems		
Worthington-municipal	MN0031186	0
Worthington-industrial	MN0031178	1
Windom	MN0022217	0
Lakefield	MN0020427	0

In addition to exceedences occurring during normal operation, occasional emergency bypasses at wastewater treatment facilities are an additional source of bacteria and other pollutants. Wastewater treatment plants and sanitary sewer systems are designed to handle at least 100 gallons of water per person per day as well as the additional flow generated by commercial and industrial establishments. If the amount of water entering a system exceeds the design capacity of the system, some of the untreated wastewater is discharged to the environment. This event is called a bypass, because the wastewater has bypassed part or all of the treatment process.

Bypasses may occur during certain weather conditions, such as heavy rain events or flooding or in case of emergency because of equipment failure or when a pipe breaks. These diversions of wastewater are necessary in order to protect public health by preventing sewage from backing up into the streets and basements of homes and businesses. They are also necessary at times to prevent serious property damage that could result in the costly losses of equipment and the systems' ability to provide adequate treatment.

The MPCA considers all bypass events to be serious and expects treatment system operators to employ all reasonable measures to avoid bypassing. When that is not possible, the MPCA requires the operators to take whatever steps necessary to protect the public health and to minimize impacts on the environment. Additionally, operators are required to notify state and local governments within one hour of the onset of a bypass event, to sample and monitor the bypass discharge and to submit a detailed written report concerning the bypass. Intentional unreported bypasses are regarded as serious violations of Minnesota statute and rule and can result in the imposition of civil or criminal penalties. In cases where frequent bypasses have occurred, the MPCA imposes Schedules of Compliance requiring the system operator to correct the problem within a specified period of time. In such cases, the MPCA also places a moratorium on the issuance of sewer extension permits to prevent the introduction of additional flow to the system until the system has adequate capacity.

Based on a review of the available wastewater treatment records for the facilities in this watershed, it appears that they collectively contribute a very low amount of fecal coliform bacteria.

Wildlife and Pets

Estimating the contributions from wildlife (which provides natural background levels) and pets is difficult. The modeling exercise in Appendix A used fairly crude numbers and assumptions regarding availability and delivery of the waste to surface water. It showed that under dry conditions wildlife may contribute a low to moderate relative contribution. Because large flocks of waterfowl are known to gather and use the river they could be a factor during some times of the year. The contribution from pets appears to be from negligible to relatively minor and is generally limited to the portions of the watershed where delivery would occur via stormwater runoff from paved surfaces.

3.3 Methodology for Load Allocations, Wasteload Allocations and Margins of Safety

The TMDLs developed for the fifteen reaches in this report consist of three main components: WLA, LA, and MOS as defined in Section 1.0. The WLA includes four subcategories: Permitted wastewater treatment facilities, livestock facilities requiring NPDES permits, the one city subject to Stormwater Municipal Separate Storm Sewer Systems (MS4) NPDES permit requirements (Worthington), and "straight pipe" septic systems. The LA, reported as a single category, includes manure runoff from farm fields, pastures, and smaller non-NPDES permitted feedlots; stormwater runoff from the cities not subject to Stormwater MS4 NPDES permit requirements other nonpermitted areas with impervious surfaces; and fecal coliform contributions from wildlife. The LA includes land-applied manure from livestock facilities requiring NPDES permits, provided the manure is applied in accordance with the permit. The third component, MOS, is the part of the allocation that accounts for uncertainty that the allocations will result in attainment of water quality standards.

The three components (WLA, LA, and MOS) were calculated as average total daily load of fecal organisms (with the average being met over a calendar month). The methodology to derive and express these load components is referred to as the duration curve approach. It was used in the "Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (Jan 2006) and is described more fully in Appendix B.

Allocations in the duration curve approach for each impaired stream reach are developed for the full range of flows in the watershed using daily flow records at either project-related or US Geological Survey (USGS) gage stations. For the USGS gage station at Jackson (#5476000), it was decided to limit flow data from 1980 to 2006 in order to have a closer reflection of hydrologic conditions occurring under "recent" land use. For those reaches that are ungaged, flow estimates were made by assuming that the ungaged reach flows are proportional to the gaged reach flows based on respective drainage areas. For reaches using flow data from project gages four to five years of daily flow data was available. While that does not provide a long-term flow record, which is the desired intent for duration curves, that period of record contains both wet and dry years and a comparison with the long-term record shows good alignment when superimposing the two duration curves (see illustration in Appendix B).

For each impaired reach, the total loading capacity or "TMDL" was divided into its component WLA, LA, and MOS. The process was as follows:

Wasteload Allocation

- For wastewater treatment facilities with pond systems the WLA was determined based on their permitted discharge volume from their secondary pond(s) (based on six inches per day drawdown) and their permitted concentration limit (200 organisms/100 ml). Although a daily WLA is assigned to these facilities, it is important to note that discharge occurs only during specified days during the year (April 1 through June 15 and September 15 through December 15). For wastewater treatment facilities using mechanical treatment, the permitted average wet weather design flow is used as the discharge volume to calculate the WLA.
- Livestock facilities that have been issued NPDES permits are assigned a zero WLA. This is consistent with the conditions of the permits, which allow no pollutant discharge from the livestock housing facilities and associated sites. Discharge of fecal coliform from fields where manure has been land-applied may occur at times. Such discharges are covered under the LA portion of the TMDLs,

provided the manure is applied in accordance with the permit. (In this watershed nearly all of these NPDES permitted livestock facilities are confined swine operations.)

- Straight-pipe septic systems are illegal and unpermitted, and as such are assigned a zero WLA.
- The allocation for communities subject to MS4 NPDES stormwater permit requirements is made after the WLA for wastewater treatment facilities and the MOS are subtracted from the total loading capacity. That remaining capacity is divided up between the permitted MS4s and all of the nonpoint sources (the LA) based on the percentage of the land area in the impaired reach watershed that the MS4 permit covers. For this TMDL the only permitted MS4 community is the city of Worthington. The city land area falling in the WFDMR watershed is four square miles.
- The total daily loading capacities in the dry and low flow zone for some reaches are very small due to the occurrence of very low flows in the flow record. Consequently, for some of the impaired reaches the permitted wastewater treatment facility design flows are close to or exceed the stream flow at these flow zones. This translates to these point sources appearing to use all (or more than) the available loading capacity, based on the method described here to calculate the TMDL components. Of course actual treatment facility flow can never exceed stream flow as it is a component of stream flow. 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 200 organisms/100 ml

  In essence, this assigns a concentration-based limit to the LA sources for these lower flow zones. The WLAs for straight pipe septic systems and NPDES-permitted livestock operations remain at zero. (This is the same procedure employed for three reaches with similar situations in the “Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota” (Jan 2006)).

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 is applied. This is expected to provide an adequate accounting of uncertainty, especially given that wastewater treatment facilities have generally demonstrated consistent meeting of fecal coliform discharge limits (and often well below these limits) and in the case of wastewater facilities with pond systems, discharge only during spring and fall windows (i.e., before June 15 and after September 15). Also, a wide range of agricultural BMPs have been identified and shown to be effective at reducing pathogens from livestock sources (University of Minnesota Extension, 2007). Follow-up effectiveness monitoring will provide a means to evaluate installed BMPs in terms of compliance with WLAs and progress or achievement of the TMDL. To accommodate the potential for the five small unsewered communities that exist in the WFDMR watershed (see section 3.2) to upgrade to adequate wastewater systems, a small (but difficult to quantify) portion of the MOS can serve as reserve capacity should there be the need to provide wastewater facilities that involve a discharge.

- For the impaired reaches in which the allocations under low flow conditions required use of an alternative method of calculation, i.e., a concentration-based limit, an implicit MOS was used. An implicit MOS means that conservative assumptions were built in to the TMDL and/or allocations. In these instances, the reaches are expected to meet the TMDL because external inputs are limited to the standard and the stream flow itself is primarily being fed by groundwater at these low flows, which is believed to convey very little, if any, fecal coliform bacteria. An additional conservative assumption relates to reaches with discharges from wastewater facilities with pond systems that discharge only in spring and fall, as indicated above, meaning that a significant portion of the year a significant fraction of the WLA is not being used.

Load Allocations

- Once the WLA and MOS were determined for a given reach and flow zone, the remaining loading capacity was considered LA. The LA includes nonpoint pollution sources that are not subject to NPDES permit requirements, as well as "natural background" sources such as wildlife. The nonpoint pollution sources are largely related to livestock manure, inadequate human wastewater treatment (non-straight-pipes), and city stormwater runoff.

Additional Daily Loading Capacity and Allocations

- The TMDLs and allocations are "average daily loading values calculated within a calendar month" based on the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml. For the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml an additional allocation requirement is made. Specifically, the loading capacity and allocations must also meet a maximum single day load that is no more than ten times the listed average daily loading values. (This relates to the 2000 numerical standard being a factor of 10 times the 200 numerical standard.)

Change of Standard to E. coli

- Presently, changes to some of the water quality standards in Minn. Rules Ch. 7050 are in the process of being approved. Among those changes are shifting from fecal coliform to *E. coli*, which is being set at an equivalent level to provide an equivalent level of protection. Specifically, the change takes into account water analysis studies that show an average of 63 percent of fecal coliform bacteria to be *E. coli* and, thereby, sets *E. coli* standards, for most situations, at that percentage of the current fecal coliform standard (e.g., monthly geometric mean of 126 *E. coli* bacteria/100 ml). Therefore, to adapt the fecal coliform TMDL allocations in this section to the future *E. coli* standards those values can be multiplied by 0.63.

3.4 TMDL Allocations for Individual Impaired Reaches

In Sections 3.4.1 through 3.4.15 below TMDL allocations are provided for the individual impaired reaches. Please note the following explanations and clarifications for portions of presented information in these sections:

- Calculations for the TMDL, LA, WLA and MOS consider the total drainage area represented by the end of each listed reach. As such, listed reaches lower in the watershed will have allocations for the same sources covered in listed reaches upstream. In terms of actual load contributions, some upstream sources may not be as significant as those sources within or close to the downstream listed reaches due to the potential for die-off of bacteria within the lakes or reservoirs that the river flows through in some parts of the watershed.

- Tables showing the fecal coliform loading capacities and allocations are provided and illustrate the TMDL, WLA, LA and MOS for the midpoints of five flow zones. (Due to rounding the WLA, LA, and MOS may not exactly add up to the loading capacities for some flow zones.)

- An estimated reduction percentage is provided for each listed reach (where sufficient data are available) to indicate how much of a decrease from summer geometric means are needed to meet the water quality standard (i.e., 200 organisms/100 ml). The calculation is as follows:

  (summer geometric mean – 200) / summer geometric mean

  The resulting reduction percentage is only intended as a rough approximation, as it does not account for flow and since bacterial data is inherently highly variable. Reduction percentages are not a required element of a TMDL (and do not supersede the allocations provided), but are included here to provide a starting point to assess the magnitude of the effort needed in the watershed to achieve the standard.

- Load duration curves are also provided for each listed reach. These figures provide a graphic representation of the allowable loading capacity across all flows as well as a means to interpreting collected water quality samples as they relate to the stream flow at the time of collection. (A more complete explanation of load duration curves and how they were derived is provided in Appendix B.) The curve (labeled “target”) represents the allowable loading capacity. For each impaired reach, the total loading capacity or “TMDL” is provided in units of billions of organisms per day. Samples on or below the load duration curve meet the target; those above the curve exceed it. Samples highlighted in red represent samples that were taken at flows in which over 50 percent of the flow is due to a storm event, or flow primarily of relatively rapid surface runoff. Samples with a “+” were taken before July (in an attempt to distinguish pre-canopy from post-canopy samples). Note that the “moist” and “dry” conditions shown, which are describing flow levels or “zones”, are not necessarily equated with the “wet” and “dry” samples of Table 3.1, which are describing previous rainfall events.

3.4.1 Beaver Creek; CD 20 to Des Moines R (AUID: 07100001-503)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was monitoring conducted under the Lake Shetek Clean Water Partnership (CWP) Project and the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 177 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There are two wastewater treatment facilities within the land area that drains to this listed reach (Table 3.4). There are five livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.5).

Table 3.6 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. The loading capacities for the five flow zones were developed using flow data from 1994 and 2001-2004 from a MPCA-installed flow gage near the mouth of Beaver Creek.

TABLE 3.4. Wastewater treatment facilities and associated WLAs (AUID: 07100001-503).

FACILITY	NPDES PERMIT #	DISCHARGE, MGD	WLA, BILLIONS/DAY
Lake Wilson	MNG580061	*	4
Slayton	MN0024911	*	15

* - Seasonal discharge.

TABLE 3.5. Livestock facilities with NPDES permits (AUID: 07100001-503).

FACILITY	NPDES PERMIT #
Grandy Pork LLP	MNG440141
Green Prairie Coop - Sec 23	MNG440346
James R & Robert E Buldhaupt Farm	MNG440142
Mark Buldhaupt Farm	MNG440143
Vander Wal Brothers	MNG440347

TABLE 3.6. Fecal coliform loading capacities and allocations (AUID: 07100001-503).

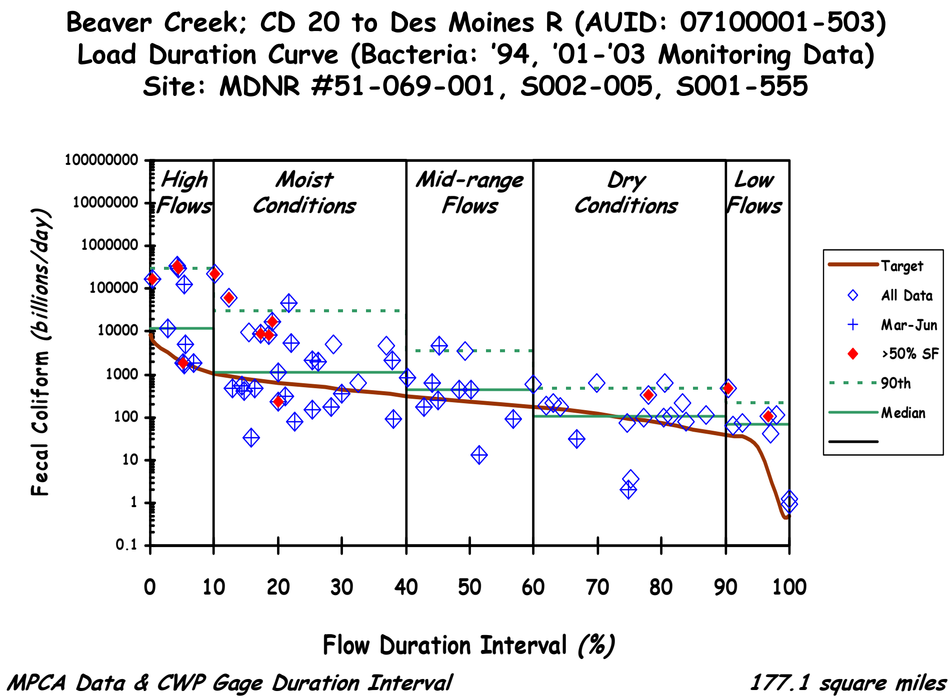
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	1925	533	227	88	20
Wasteload Allocation*					
Wastewater Treatment Facilities	19	19	19	19	19
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	1713	461	185	60	**
Margin of Safety	193	53	23	9	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	1%	4%	8%	22%	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	89%	86%	82%	68%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Tables 3.4 and 3.5.
** See Section 3.3 for allocations for these specific categories in these flow zones.

The summer month geometric mean for this reach for the years with available monitoring data (from Table 3.1) is 777. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 74 percent.

The load duration curve (Figure 3.6) for the available dataset indicates exceedence of the target across the range of flows recorded. A large proportion of late season samples exceed the target, as do samples collected following significant stormwater runoff.

Figure 3.6. Fecal coliform load duration curve (AUID: 07100001-503).



3.4.2 County Ditch 20; Headwaters to Beaver Cr (AUID: 07100001-504)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was monitoring conducted under the Lake Shetek CWP Project.

The drainage area to the downstream end of this impaired reach is about 40 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There are no wastewater treatment facilities within the land area that drains to this listed reach. There are three livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.7).

Table 3.8 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily

loading values in this table. Because this reach has not been monitored for flow the flow data from a MPCA-installed flow gage downstream of the listed reach near the mouth of Beaver Creek was used to develop the loading capacities (same gage and flow record as was used for AUID: 07100001-503).

TABLE 3.7. Livestock facilities with NPDES permits (AUID: 07100001-504).

FACILITY	NPDES PERMIT #
Grandy Pork LLP	MNG440141
James R & Robert E Buldhaupt Farm	MNG440142
Mark Buldhaupt Farm	MNG440143

TABLE 3.8. Fecal coliform loading capacities and allocations (AUID: 07100001-504).

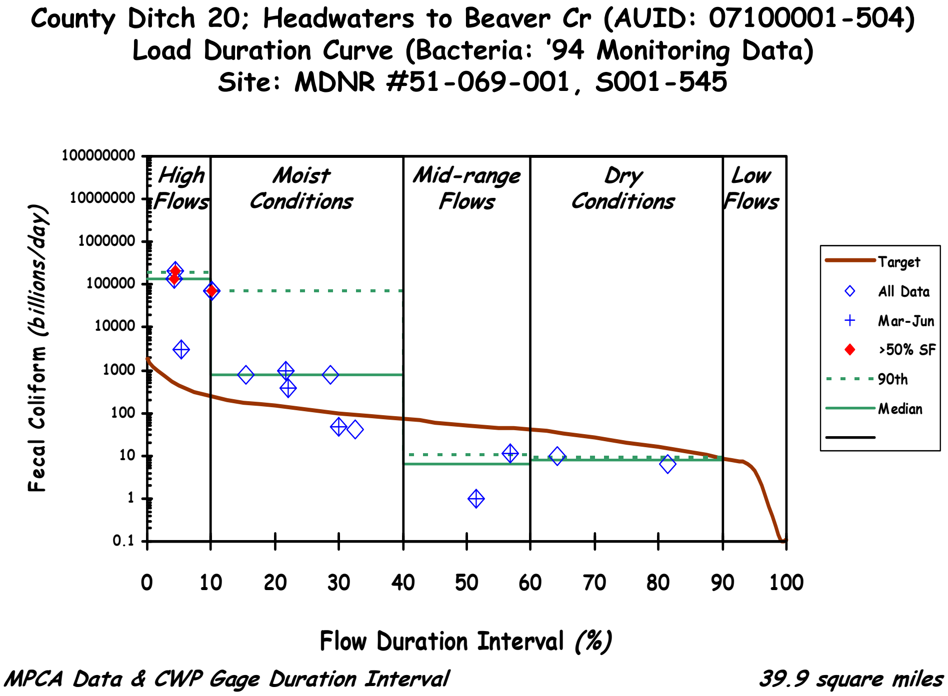
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	434	120	51	20	4.5
Wasteload Allocation*					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	390	108	46	18	4
Margin of Safety	43	12	5	2	0.5
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

* The individual facilities are listed in Table 3.7.

This reach was monitored for fecal coliform bacteria for only one year (1994). Given the limited amount of the data as well as its age, calculating a percent reduction needed to achieve the standard would be of limited value. Evaluation of level of effort to achieve the standard will need to be done during the implementation phase.

The load duration curve is shown in Figure 3.7. Again, with a limited dataset it is difficult to make specific conclusions. What data is available shows exceedences during higher flow zones only.

Figure 3.7. Fecal coliform load duration curve (AUID: 07100001-504).



3.4.3 Lake Shetek Inlet; Headwaters to Lk Shetek (AUID: 07100001-502)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was monitoring conducted under the Lake Shetek CWP Project.

The drainage area to the downstream end of this impaired reach is about 62 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Lyon and Murray Counties. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There are no wastewater treatment facilities within the land area that drains to this listed reach. There are two livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.9).

Table 3.10 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. Because this reach has only very limited direct flow data associated with it flow data from a MPCA-installed flow gage downstream of the listed reach at the outlet of Lake Shetek with data from 1994 and 2001 to 2004 was used to develop the loading capacities. Due to many zero flow days in the flow record the duration curve methodology shows no available loading capacity for the low flow zone.

TABLE 3.9. Livestock facilities with NPDES permits (AUID: 07100001-502).

FACILITY	NPDES PERMIT #
Schultz Hog Farms Inc	MNG440140
James Tutt Farm	MNG440139

TABLE 3.10. Fecal coliform loading capacities and allocations (AUID: 07100001-502).

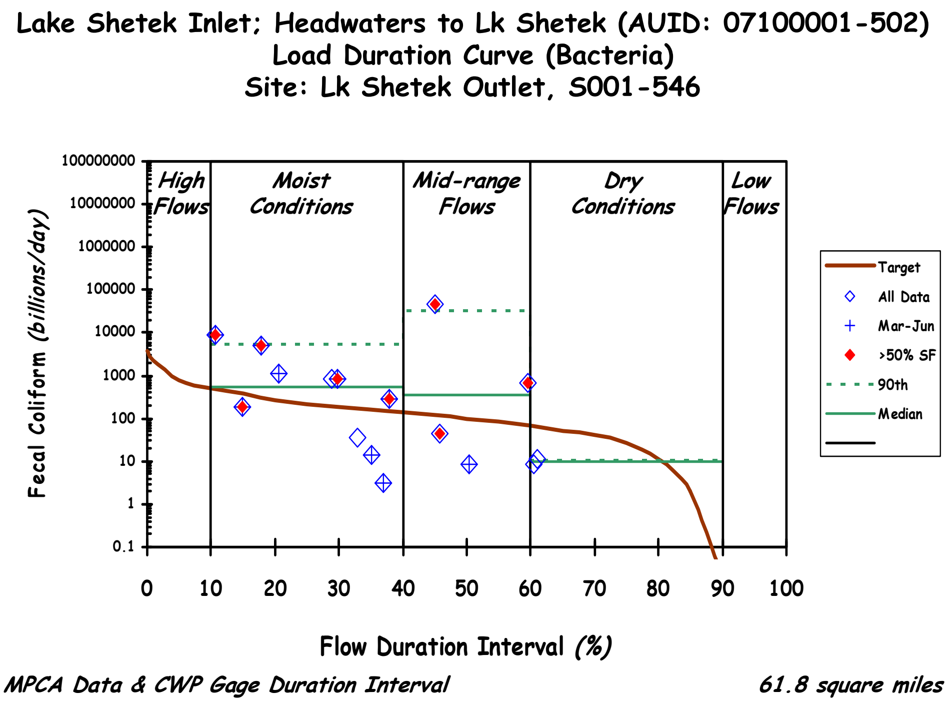
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	993	232	87	10	0
Wasteload Allocation*					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	893	209	78	9	0
Margin of Safety	99	23	9	1	0
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	0%
Wasteload Allocation*					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	90%	90%	90%	90%	0%
Margin of Safety	10%	10%	10%	10%	0%

* The individual facilities are listed in Table 3.9.

The summer month geometric mean for this reach for the two years with available monitoring data (from Table 3.1) is actually below the target standard. The listing was based on exceedence during individual months, for which only the needed minimum number of data for listing exists. However, this is not sufficient data to provide a reliable estimated reduction percentage for those months. Evaluation of level of effort to achieve the standard will need to be done during the implementation phase.

The load duration curve is shown in Figure 3.8. Again, with a limited dataset it is difficult to make specific conclusions. What data is available shows exceedence of the target mainly following significant stormwater runoff.

Figure 3.8. Fecal coliform load duration curve (AUID: 07100001-502).



3.4.4 Lower Lake Sarah Outlet; First Unnamed Cr on Lk Sarah Outlet stream to Lk Shetek inlet (AUID: 07100001-508)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was monitoring conducted under the Lake Shetek CWP Project.

The drainage area to the downstream end of this impaired reach is about 26 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There are no wastewater treatment facilities or livestock facilities with NPDES permits within the land area that drains to this listed reach.

Table 3.11 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. Because this reach has only very limited direct flow data associated with it flow data from a MPCA-installed flow gage downstream of the listed reach at the outlet of Lake Shetek with data from 1994 and 2001 to 2004 was used to develop the loading capacities. Due to many zero flow days in the flow record the duration curve methodology shows no available loading capacity for the low flow zone.

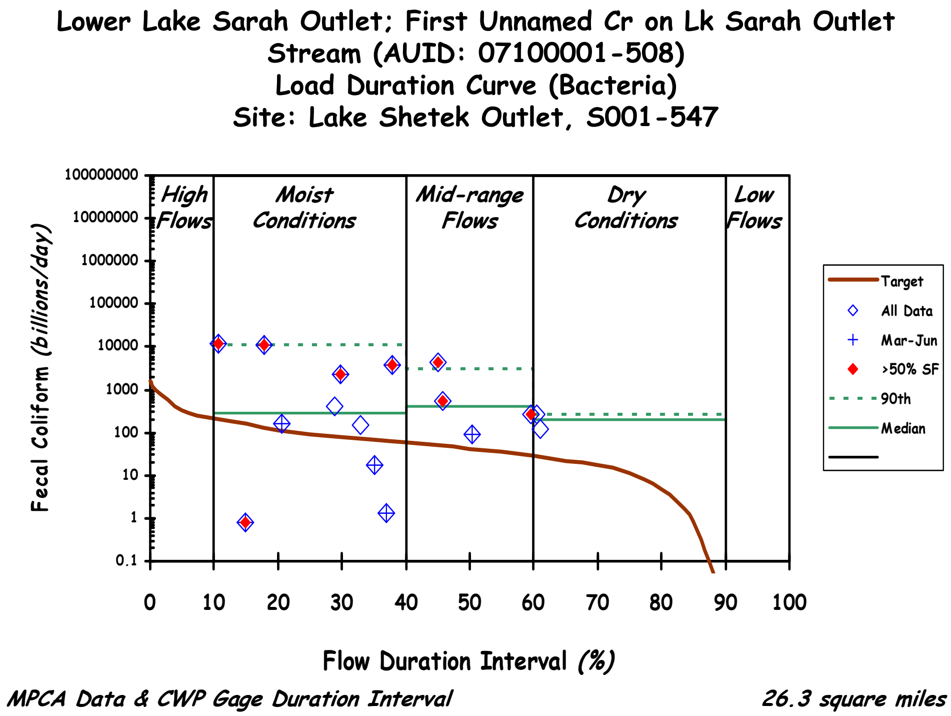
TABLE 3.11. Fecal coliform loading capacities and allocations (AUID: 07100001-508).

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	422	99	37	4.1	0
Wasteload Allocation					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	NA	NA	NA	NA	NA
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	380	89	33	3.7	0
Margin of Safety	42	10	4	0.4	0
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	NA	NA	NA	NA	NA
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	90%	90%	90%	90%	0%
Margin of Safety	10%	10%	10%	10%	0%

The summer month geometric mean for this reach for the two years (1994 and 2000) with available monitoring data (from Table 3.1) is 1444. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 86 percent. However, given the limited amount of the data as well as its age it would be prudent to further evaluate the level of effort needed to achieve the standard during the implementation phase.

The load duration curve is shown in Figure 3.9. Again, with a limited dataset it is difficult to make specific conclusions. What data is available shows exceedence of the target mainly following significant stormwater runoff and in the later part of the season.

Figure 3.9. Fecal coliform load duration curve (AUID: 07100001-508).



3.4.5 Unnamed Creek; Unnamed Creek to Unnamed Creek (AUID: 07100001-517)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. It represents the drainage area monitored at Site I3 (as it was known in the Lake Shetek Clean Water Partnership Project sponsored by Murray County and others) and flows to an unnamed creek that enters Lake Shetek on its western shore. The primary source of data that led to this listing was the monitoring conducted under the Lake Shetek Clean Water Partnership Project.

The drainage area to the downstream end of this impaired reach is about two square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There are no wastewater treatment facilities or livestock facilities with NPDES permits within the land area that drains to this listed reach.

Table 3.12 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. Because this reach has only very limited direct flow data associated with it flow data from a MPCA-installed flow gage downstream of the listed reach at the outlet of Lake Shetek with data from 1994 and 2001 to 2004 was used to develop the loading capacities. Due to many zero flow days in the flow record the duration curve methodology shows no available loading capacity for the low flow zone.

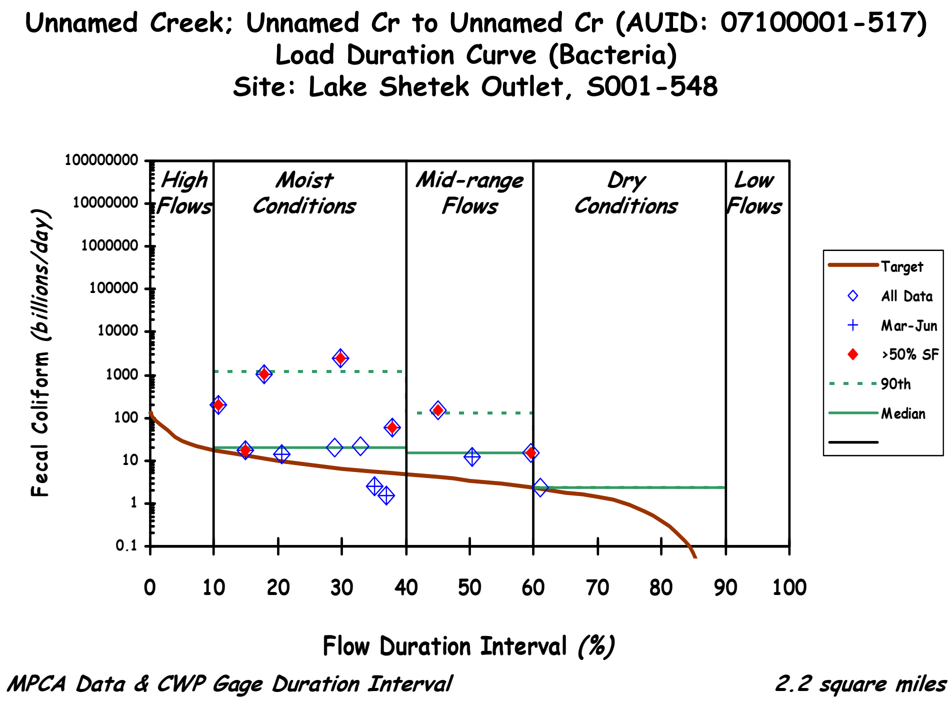
TABLE 3.12. Fecal coliform loading capacities and allocations (AUID: 07100001-517).

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	35	8	3.1	0.35	0
Wasteload Allocation					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	NA	NA	NA	NA	NA
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	32	7	2.8	0.31	0
Margin of Safety	4	1	0.3	0.03	0
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	0%
Wasteload Allocation					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	NA	NA	NA	NA	NA
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	90%	90%	90%	90%	0%
Margin of Safety	10%	10%	10%	10%	0%

The summer month geometric mean for this reach for the two years (1994 and 2000) with available monitoring data (from Table 3.1) is 1260. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 84 percent. However, given the limited amount of the data as well as its age it would be prudent to further evaluate the level of effort needed to achieve the standard during the implementation phase.

The load duration curve is shown in Figure 3.10. What data is available shows exceedence of the target mainly following significant stormwater runoff and in the later part of the season.

Figure 3.10. Fecal coliform load duration curve (AUID: 07100001-517).



3.4.6 Unnamed Creek; Unnamed Creek to Lk Shetek (AUID: 07100001-519)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. It represents the drainage area monitored at Site I4 (as it was known in the Lake Shetek Clean Water Partnership Project sponsored by Murray County and others) and enters Lake Shetek on its southwestern shore. The primary source of data that led to this listing was monitoring conducted under the Lake Shetek CWP Project.

The drainage area to the downstream end of this impaired reach is about five square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There are no wastewater treatment facilities or livestock facilities with NPDES permits within the land area that drains to this listed reach.

Table 3.13 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. Because this reach has only very limited direct flow data associated with it flow data from a MPCA-installed flow gage downstream of the listed reach at the outlet of Lake Shetek with data from 1994 and 2001 to 2004 was used to develop the loading capacities. Due to many zero flow days in the flow record the duration curve methodology shows no available loading capacity for the low flow zone.

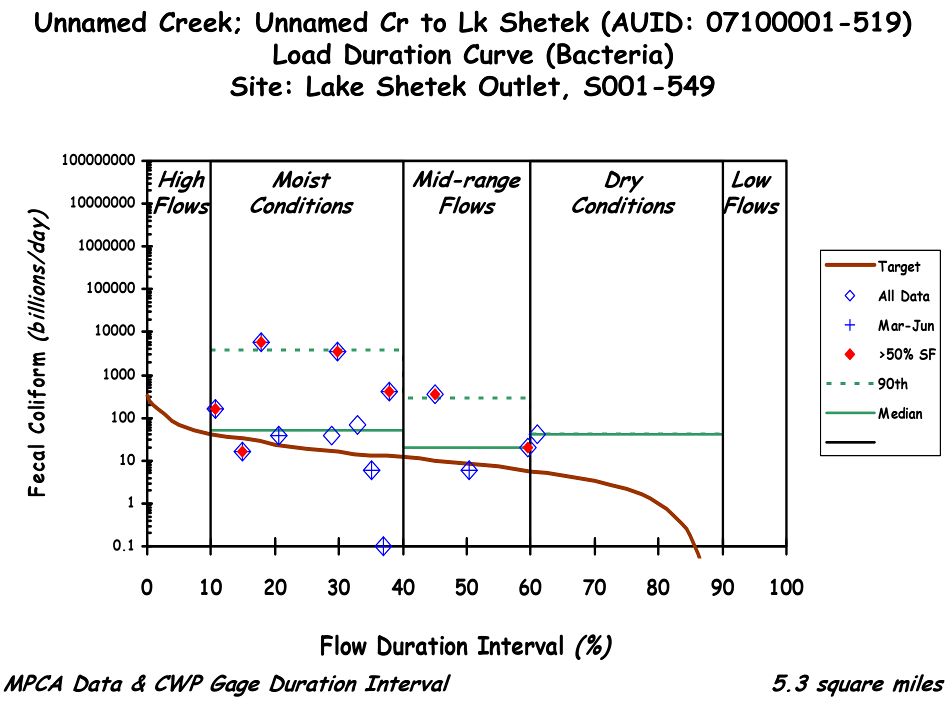
TABLE 3.13. Fecal coliform loading capacities and allocations (AUID: 07100001-519).

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	85	20	7.5	0.8	0
Wasteload Allocation					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	NA	NA	NA	NA	NA
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	77	18	6.7	0.7	0
Margin of Safety	9	2	0.7	0.1	0
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	0%
Wasteload Allocation					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	NA	NA	NA	NA	NA
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	90%	90%	90%	90%	0%
Margin of Safety	10%	10%	10%	10%	0%

The summer month geometric mean for this reach for the two years (1994 and 2000) with available monitoring data (from Table 3.1) is 1414. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 86 percent. However, given the limited amount of the data as well as its age it would be prudent to further evaluate the level of effort needed to achieve the standard during the implementation phase.

The load duration curve is shown in Figure 3.11. What data is available shows exceedence of the target mainly following significant stormwater runoff and in the later part of the season.

Figure 3.11. Fecal coliform load duration curve (AUID: 07100001-519).



3.4.7 Upper Lake Sarah Outlet; Lk Sarah Outlet to Unnamed Creek (AUID: 07100001-513)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was monitoring conducted under the Lake Shetek CWP Project.

The drainage area to the downstream end of this impaired reach is about 20 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There are no wastewater treatment facilities or livestock facilities with NPDES permits within the land area that drains to this listed reach.

Table 3.14 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily

loading values in this table. Because this reach has only very limited direct flow data associated with it flow data from a MPCA-installed flow gage downstream of the listed reach at the outlet of Lake Shetek with data from 1994 and 2001 to 2004 was used to develop the loading capacities. Due to many zero flow days in the flow record the duration curve methodology shows no available loading capacity for the low flow zone.

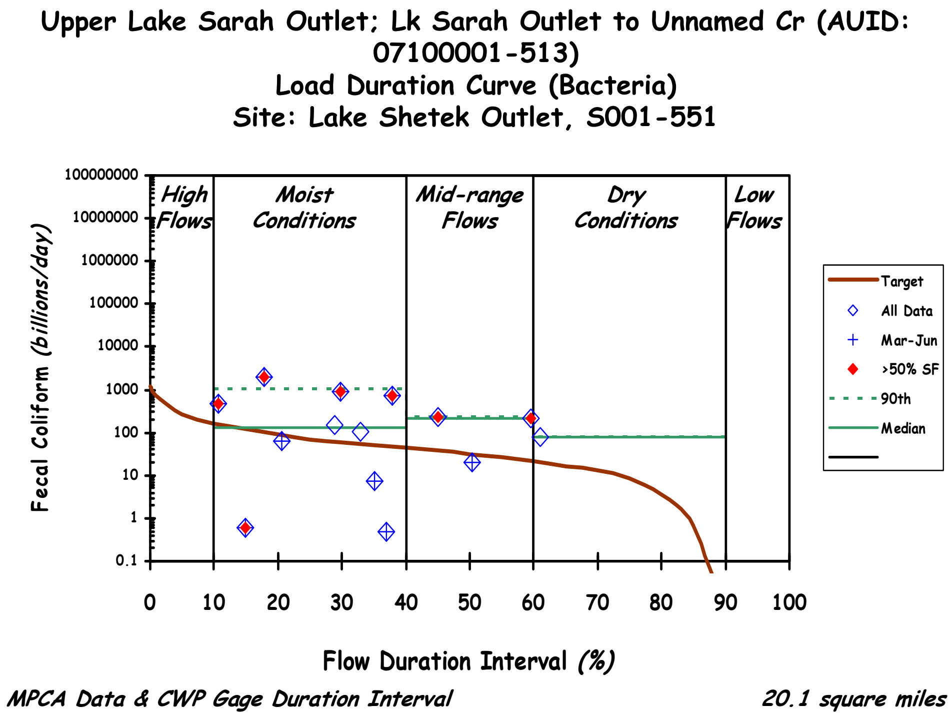
TABLE 3.14. Fecal coliform loading capacities and allocations (AUID: 07100001-513).

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	323	76	28	3.2	0
Wasteload Allocation					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	NA	NA	NA	NA	NA
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	291	68	26	2.8	0
Margin of Safety	32	8	3	0.3	0
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	0%
Wasteload Allocation					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	NA	NA	NA	NA	NA
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	90%	90%	90%	90%	0%
Margin of Safety	10%	10%	10%	10%	0%

This reach was monitored for only one year (1994). Given the limited amount of the data as well as its age calculating a percent reduction needed to achieve the standard would be of limited value. Evaluation of level of effort to achieve the standard will need to be done during the implementation phase.

The load duration curve is shown in Figure 3.12. What data is available shows exceedence of the target mainly following significant stormwater runoff and in the later part of the season.

Figure 3.12. Fecal coliform load duration curve (AUID: 07100001-513).



3.4.8 Des Moines River; Beaver Cr to Lime Cr (AUID: 07100001-546)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 355 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There are three wastewater treatment facilities within the land area that drains to this listed reach (Table 3.15). There are eight livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.16).

Table 3.17 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily

loading values in this table. The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage near the end of the listed reach.

TABLE 3.15. Wastewater treatment facilities and associated WLAs (AUID: 07100001-546).

FACILITY	NPDES PERMIT #	DISCHARGE, MGD	WLA, BILLIONS/DAY
Lake Wilson	MNG580061	*	4
Slayton	MN0024911	*	15
Currie	MN0025682	*	18

* - Seasonal discharge.

TABLE 3.16. Livestock facilities with NPDES permits (AUID: 07100001-546).

FACILITY	NPDES PERMIT #
Schultz Hog Farms Inc	MNG440140
James Tutt Farm	MNG440139
Grandy Pork LLP	MNG440141
Green Prairie Coop - Sec 23	MNG440346
James R & Robert E Buldhaupt Farm	MNG440142
Mark Buldhaupt Farm	MNG440143
Vander Wal Brothers	MNG440347
Gervais Brothers II	MNG440321

TABLE 3.17. Fecal coliform loading capacities and allocations (AUID: 07100001-546).

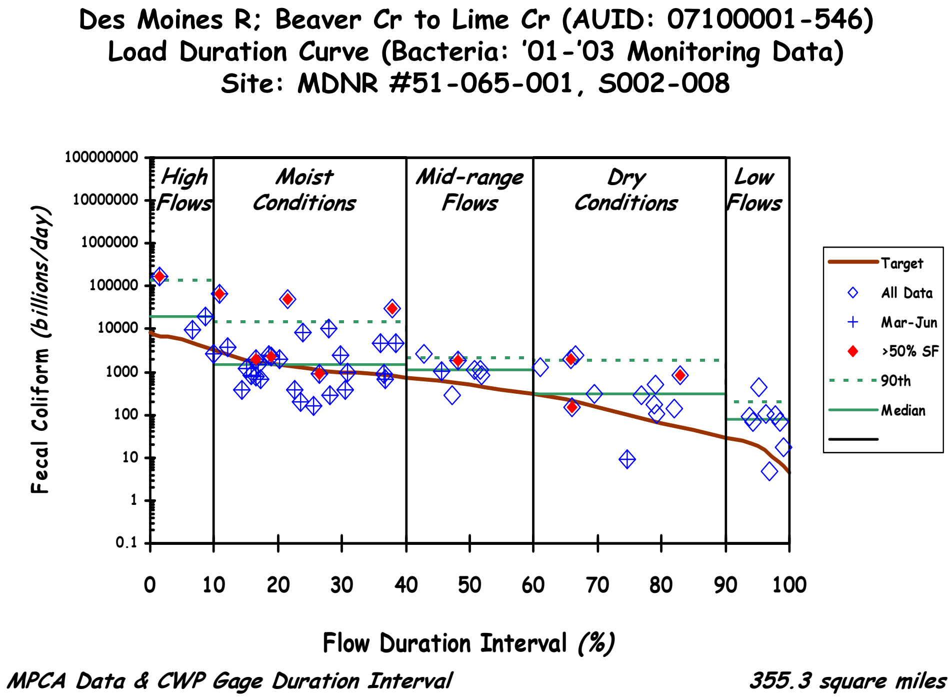
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	5629	1202	493	97	19
Wasteload Allocation*					
Wastewater Treatment Facilities	37	37	37	37	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	5029	1045	407	50	**
Margin of Safety	563	120	49	10	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	1%	3%	8%	39%	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	89%	87%	82%	51%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Tables 3.15 and 3.16.
** See Section 3.3 for allocations for these specific categories in these flow zones.

The summer month geometric mean for this reach for the years with available monitoring data (from Table 3.1) is 687. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 71 percent.

The load duration curve (Figure 3.13) for the available dataset indicates exceedence of the target across the range of flows recorded. A large proportion of late season samples exceed the target, as do samples collected following significant stormwater runoff.

Figure 3.13. Fecal coliform load duration curve (AUID: 07100001-546).



3.4.9 Lime Creek; Lime Lk to Des Moines R (AUID: 07100001-535)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 98 square miles. The listed reach exists within the Coteau and the Dryer Blue Earth Till agroecoregions, previously described, and Murray County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways and, to a lesser extent, feedlots or stockpiles without adequate runoff controls and surface-applied manure.

There is one wastewater treatment facility within the land area that drains to this listed reach: city of Fulda (MN0023507). There is one livestock facilities with a NPDES permit located within the land area that drains to this listed reach: Kramer Swine Finishing (MNG440396).

Table 3.18 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily

loading values in this table. The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage near the end of the listed reach.

TABLE 3.18. Fecal coliform loading capacities and allocations (AUID: 07100001-535).

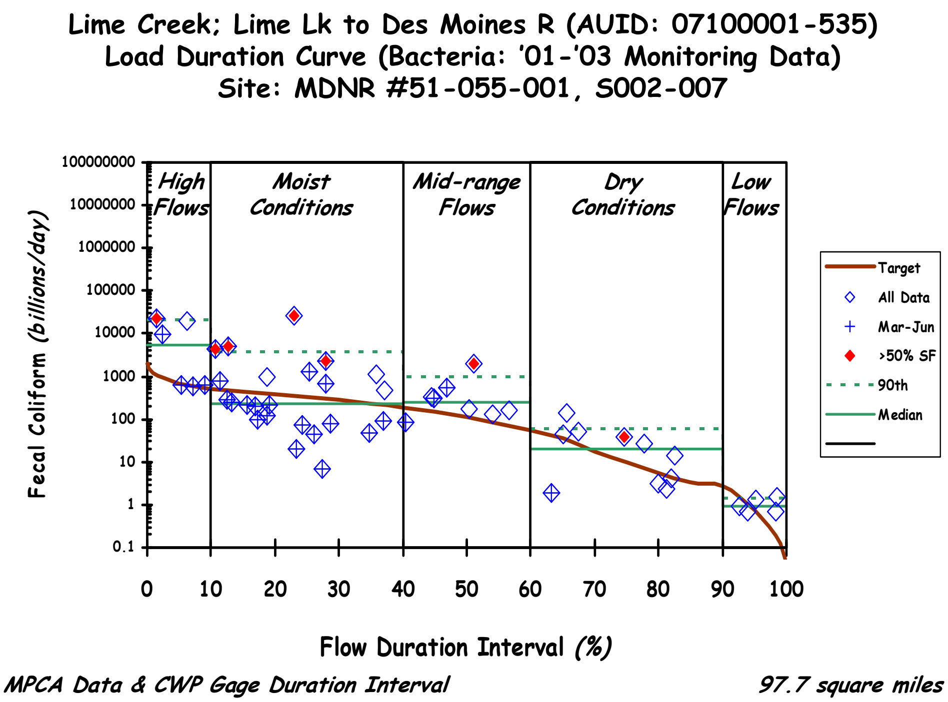
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	671	328	110	10	1
Wasteload Allocation*					
Wastewater Treatment Facilities	7	7	7	7	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	597	288	93	2	**
Margin of Safety	67	33	11	1	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	1%	2%	6%	67%	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	89%	88%	84%	23%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in the text.
** See Section 3.3 for allocations for these specific categories in these flow zones.

The summer month geometric mean for this reach for the years with available monitoring data (from Table 3.1) is 545. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 63 percent.

The load duration curve (Figure 3.14) for the available dataset indicates exceedence of the target across the range of flows recorded. A large proportion of late season samples exceed the target, as do samples collected following significant stormwater runoff.

Figure 3.14. Fecal coliform load duration curve (AUID: 07100001-535).



3.4.10 Des Moines River; Lime Cr to Heron Lk Outlet (AUID: 07100001-533)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 716 square miles. The listed reach exists within the Coteau and the Dryer Blue Earth Till agroecoregions, previously described, and Murray and Cottonwood Counties. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways, feedlots or stockpiles without adequate runoff controls, surface-applied manure and during dryer conditions, failing or inadequate SSTSs.

There are four wastewater treatment facilities within the land area that drains to this listed reach (Table 3.19). There are ten livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.20).

Table 3.21 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily

loading values in this table. The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage near the end of the listed reach.

TABLE 3.19. Wastewater treatment facilities and associated WLAs (AUID: 07100001-533).

FACILITY	NPDES PERMIT #	DISCHARGE, MGD	WLA, BILLIONS/DAY
Lake Wilson	MNG580061	*	4
Slayton	MN0024911	*	15
Currie	MN0025682	*	18
Fulda	MN0023507	*	7

* - Seasonal discharge.

TABLE 3.20. Livestock facilities with NPDES permits (AUID: 07100001-533).

FACILITY	NPDES PERMIT #
Schultz Hog Farms Inc	MNG440140
James Tutt Farm	MNG440139
Grandy Pork LLP	MNG440141
Green Prairie Coop - Sec 23	MNG440346
James R & Robert E Buldhaupt Farm	MNG440142
Mark Buldhaupt Farm	MNG440143
Vander Wal Brothers	MNG440347
Gervais Brothers II	MNG440321
Kramer Swine Finishing	MNG440396
Steve Rasche Farm	MNG440010

TABLE 3.21. Fecal coliform loading capacities and allocations (AUID: 07100001-533).

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	7564	1425	435	174	42
Wasteload Allocation*					
Wastewater Treatment Facilities	44	44	44	44	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	6764	1238	347	112	**
Margin of Safety	756	142	43	17	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	1%	3%	10%	25%	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	89%	87%	80%	65%	**
Margin of Safety	10%	10%	10%	10%	Implicit

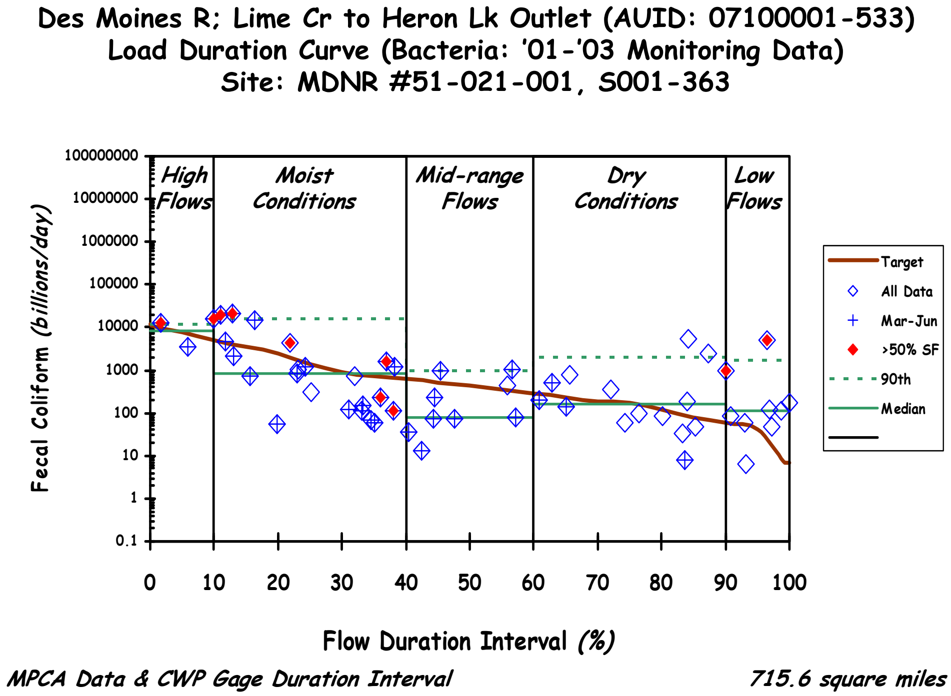
* The individual facilities are listed in Tables 3.19 and 3.20.

** See Section 3.3 for allocations for these specific categories in these flow zones.

The summer month geometric mean for this reach for the years with available monitoring data (from Table 3.1) is 306. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 35 percent.

The load duration curve (Figure 3.15) for the available dataset indicates exceedence of the target across the range of flows recorded. Many of the late season samples exceed the target, as do samples collected following significant stormwater runoff.

Figure 3.15. Fecal coliform load duration curve (AUID: 07100001-533).



3.4.11 Des Moines River; Windom Dam to Jackson Dam (AUID: 07100001-501)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 1240 square miles. The listed reach exists within the Dryer Blue Earth Till agroecoregions, previously described, and primarily Jackson County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely feedlots or stockpiles without adequate runoff controls, surface-applied manure and during dryer conditions, failing or inadequate SSTSs. There is limited riparian pasture area along this main stem reach and, therefore, is not likely to be a significant source. Also, waterfowl (often in the reservoir above this reach) may be a factor, although overall the monitored levels of fecal coliform bacteria are relatively low in this reach (additional discussion below).

There are 11 wastewater treatment facilities within the land area that drains to this listed reach (Table 3.22). There are 19 livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.23), as well as four square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements.

Table 3.24 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. The loading capacities for the five flow zones were developed using flow data from 1980-2006 from the USGS gage site at Jackson (#5476000).

TABLE 3.22. Wastewater treatment facilities and associated WLAs (AUID: 07100001-501).

FACILITY	NPDES PERMIT #	DISCHARGE, MGD	WLA, BILLIONS/DAY
Lake Wilson	MNG580061	*	4
Slayton	MN0024911	*	15
Fulda	MN0023507	*	7
Brewster	MN0021750	*	16
Worthington-municipal	MN0031186	4.0	30
Worthington-industrial	MN0031178	2.04	15
Okabena	MN0050288	*	2
Currie	MN0025682	*	18
Windom	MN0022217	1.83	14
Heron Lake	MN0023655	*	6
Lakefield	MN0020427	0.58	4

* - Seasonal discharge.

TABLE 3.23. Livestock facilities with NPDES permits (AUID: 07100001-501).

FACILITY	NPDES PERMIT #
Schultz Hog Farms Inc	MNG440140
James Tutt Farm	MNG440139
Grandy Pork LLP	MNG440141
Green Prairie Coop - Sec 23	MNG440346
James R & Robert E Buldhaupt Farm	MNG440142
Mark Buldhaupt Farm	MNG440143
Vander Wal Brothers	MNG440347
Gervais Brothers II	MNG440321
Kramer Swine Finishing	MNG440396
Brake Beef Yard	MN0066265
Southwest Prairie Pork	MNG440370
Double K - Finishing Site	MNG440273
Double K - Farrowing Site	MNG440273
Highway 60 Pork	MNG440278
Green Prairie Coop - Sec 7	MNG440337
Lake Shore Pork	MNG440055
Steve Rasche Farm	MNG440010
Christensen Family Farms Site C-13	MNG440063
Douglas Lusk Farm	MNG440047

TABLE 3.24. Fecal coliform loading capacities and allocations (AUID: 07100001-501).

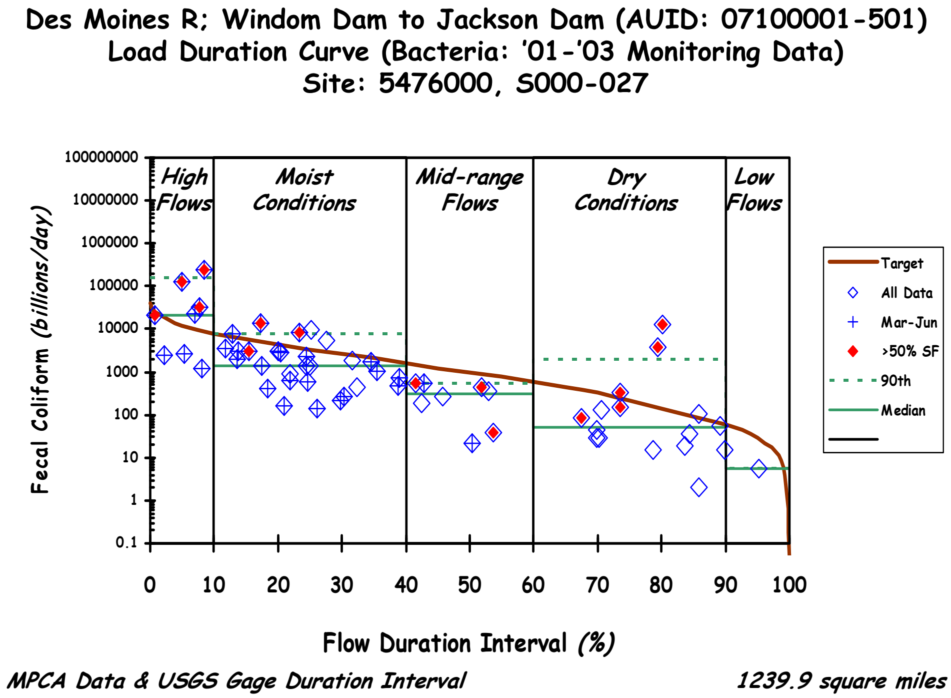
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	11986	3302	964	220	29
Wasteload Allocation*					
Wastewater Treatment Facilities	131	131	131	131	**
Communities Subject to MS4 NPDES Requirements	34	9	2	0.2	**
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	10622	2831	734	66	**
Margin of Safety	1199	330	96	22	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	1%	4%	14%	60%	**
Communities Subject to MS4 NPDES Requirements	0.3%	0.3%	0.2%	0.1%	**
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	89%	86%	76%	30%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Tables 3.22 and 3.23.
** See Section 3.3 for allocations for these specific categories in these flow zones.

The summer month geometric mean for this reach for the two years with available monitoring data (from Table 3.1) is actually below the target standard. The listing was based on exceedence during individual months, for which only the needed minimum of data for listing exists. Based on a review of the monthly data the highest month was June, showing a geometric mean of 223. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 10 percent.

The load duration curve (Figure 3.16) for the available dataset indicates exceedence of the target mainly following significant stormwater runoff, primarily in the later part of the season.

Figure 3.16. Fecal coliform load duration curve (AUID: 07100001-501).



3.4.12 Okabena Creek; Elk Cr to South Heron Lk (AUID: 07100001-506)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 133 square miles. The listed reach exists within the Poorly Drained Blue Earth Till and Coteau agroecoregions, previously described, and Jackson and Nobles Counties. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways, feedlots or stockpiles without adequate runoff controls, surface-applied manure and during dryer conditions, failing or inadequate SSTSs.

There are four wastewater treatment facilities within the land area that drains to this listed reach (Table 3.25). There are two livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.26), as well as approximately 3.6 square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements.

Table 3.27 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. The loading capacities for the five flow zones were developed using flow data from 2003-2006 from the USGS gage #5474915 near the end of the listed reach.

TABLE 3.25. Wastewater treatment facilities and associated WLAs (AUID: 07100001-506).

FACILITY	NPDES PERMIT #	DISCHARGE, MGD	WLA, BILLIONS/DAY
Brewster	MN0021750	*	16
Worthington-municipal	MN0031186	4.0	30
Worthington-industrial	MN0031178	2.04	15
Okabena	MN0050288	*	2

* - Seasonal discharge.

TABLE 3.26. Livestock facilities with NPDES permits (AUID: 07100001-506).

FACILITY	NPDES PERMIT #
Highway 60 Pork	MNG440278
Green Prairie Coop - Sec 7	MNG440337

TABLE 3.27. Fecal coliform loading capacities and allocations (AUID: 07100001-506).

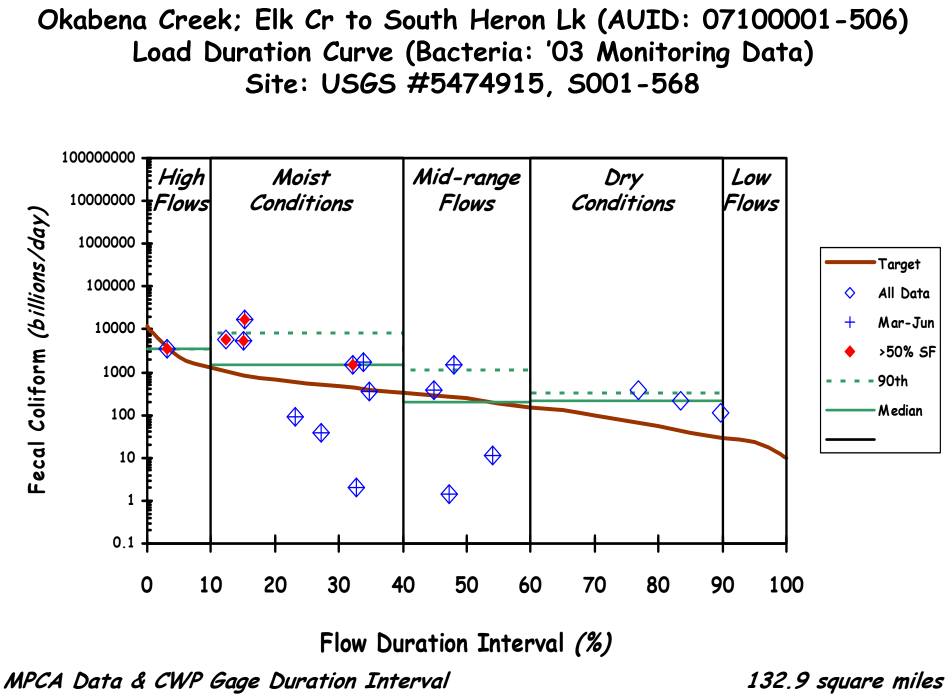
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	2299	550	254	75	23
Wasteload Allocation*					
Wastewater Treatment Facilities	63	63	63	63	**
Communities Subject to MS4 NPDES Requirements	55	12	5	0.1	**
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	1951	420	161	4	**
Margin of Safety	230	55	25	7	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	3%	12%	25%	85%	**
Communities Subject to MS4 NPDES Requirements	2%	2%	2%	0.1%	**
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	85%	76%	63%	5%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Tables 3.25 and 3.26.
** See Section 3.3 for allocations for these specific categories in these flow zones.

The summer month geometric mean for this reach for the years with available monitoring data (from Table 3.1) is 406. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 51 percent.

The load duration curve is shown in Figure 3.17. However, only one year of bacteria sampling occurred during the time flow was monitored so it is difficult to make specific conclusions. Of the limited data that is available it appears that late season samples exceed the target, as do samples collected following significant stormwater runoff.

Figure 3.17. Fecal coliform load duration curve (AUID: 07100001-506).



3.4.13 Jack Creek; JD 26 to Heron Lk (AUID: 07100001-509)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 205 square miles. The listed reach exists within the Poorly Drained Blue Earth Till agroecoregion, previously described, and Jackson County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways, feedlots or stockpiles without adequate runoff controls, surface-applied manure and during dryer conditions, failing or inadequate SSTSs.

There are no wastewater treatment facilities within the land area that drains to this listed reach. There are four livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.28).

Table 3.29 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. The loading capacities for the five flow zones were developed using flow data from 1987-1994 and 2003-2006 from USGS gage #5474975 near the end of the listed reach.

TABLE 3.28. Livestock facilities with NPDES permits (AUID: 07100001-509).

FACILITY	NPDES PERMIT #
Brake Beef Yard	MN0066265
Southwest Prairie Pork	MNG440370
Double K - Finishing Site	MNG440273
Double K - Farrowing Site	MNG440273

TABLE 3.29. Fecal coliform loading capacities and allocations (AUID: 07100001-509).

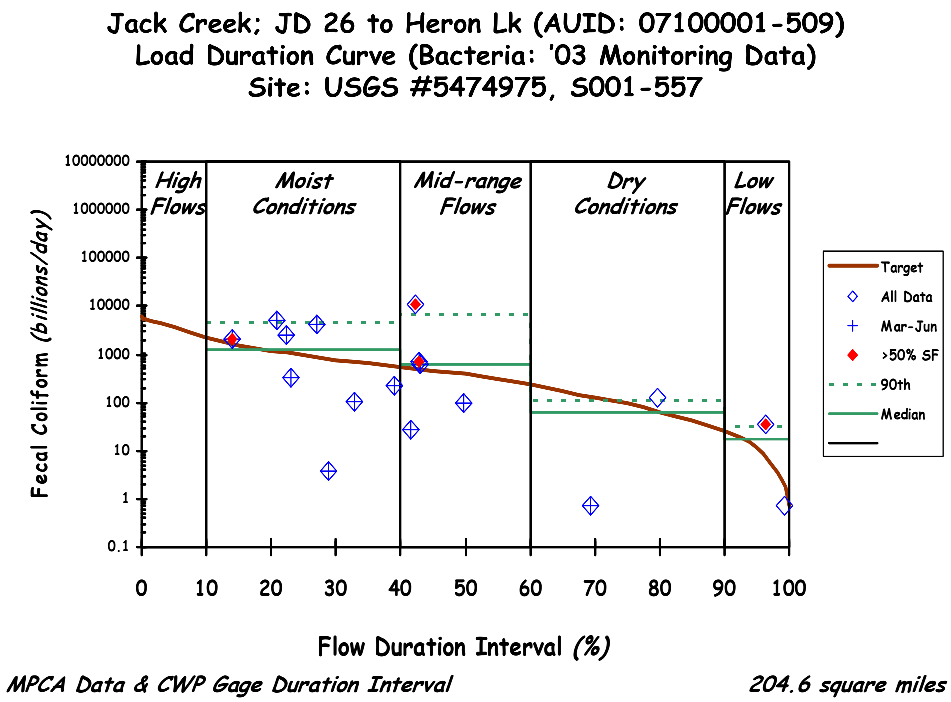
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	3583	940	388	98	12
Wasteload Allocation*					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	3225	846	350	88	11
Margin of Safety	358	94	39	10	1
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

* The individual facilities are listed in Table 3.28.

The summer month geometric mean for this reach for the years with available monitoring data (from Table 3.1) is 525. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 62 percent.

The load duration curve is shown in Figure 3.18. However, only one year of bacteria sampling occurred during the time flow was monitored so it is difficult to make specific conclusions. Of the limited data that is available it appears that samples collected following significant stormwater runoff are most likely to show exceedences.

Figure 3.18. Fecal coliform load duration curve (AUID: 07100001-509).



3.4.14 Elk Creek; Headwaters to Okabena Cr (AUID: 07100001-507)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 70 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Nobles County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways, feedlots or stockpiles without adequate runoff controls, and during dryer conditions, failing or inadequate SSTSs. Surface-applied manure also appears to be a source during wet weather conditions but to a lesser extent than the other sources.

There are no wastewater treatment facilities within the land area that drains to this listed reach. There is one livestock facility with a NPDES permit located within the land area that drains to this listed reach, Highway 60 Pork (MNG440278), as well as approximately 0.4 square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements.

Table 3.30 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. Because this reach has not been monitored for flow the flow data from the USGS gage downstream of the listed reach was used to develop the loading capacities (same gage and flow record as was used for AUID: 07100001-506).

TABLE 3.30. Fecal coliform loading capacities and allocations (AUID: 07100001-507).

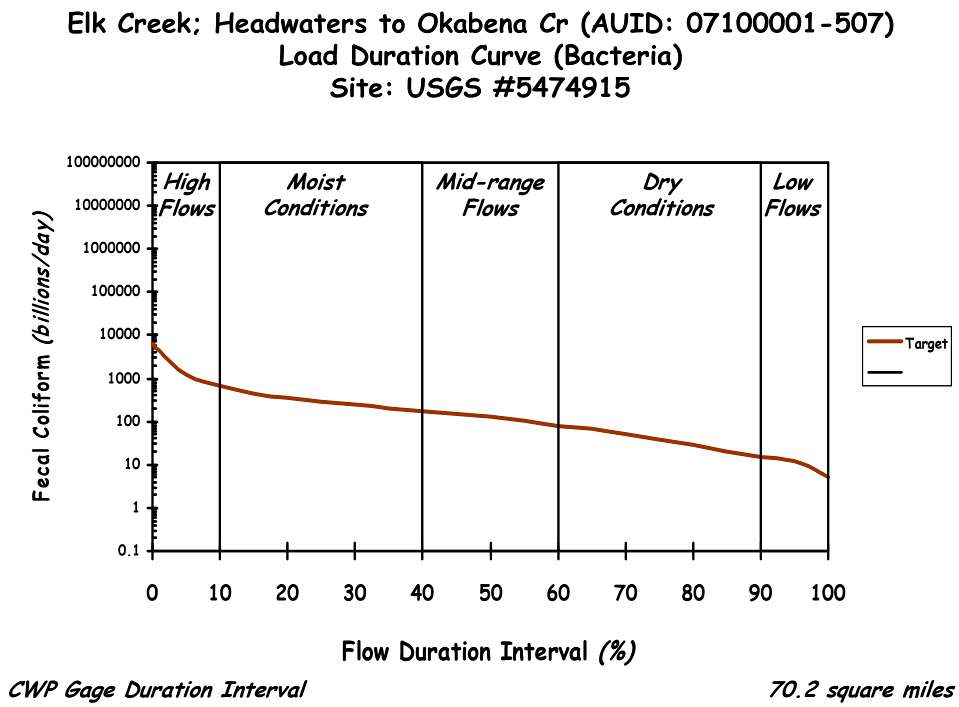
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	1214	291	134	39	12
Wasteload Allocation*					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	6	1	0.7	0.2	0.06
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	1087	260	120	35	11
Margin of Safety	121	29	13	4	1
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	0.5%	0.5%	0.5%	0.5%	0.5%
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

* The individual facilities are listed in the text.

The summer month geometric mean for this reach for the years with available monitoring data (from Table 3.1) is 825. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 76 percent.

The load duration curve is shown in Figure 3.19. However, no bacteria sampling occurred during the time flow was monitored so it is not possible to make specific conclusions regarding bacteria levels as influenced by flow.

Figure 3.19. Fecal coliform load duration curve (AUID: 07100001-507).



3.4.15 Des Moines River; JD 66 to IA border (AUID: 07100002-501)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 1333 square miles. The listed reach exists within the Dryer Blue Earth Till agroecoregion, previously described, and Jackson County. Based on the analysis provided in Section 3.2, primary sources contributing within those areas are likely overgrazed pasture near streams and waterways, feedlots or stockpiles without adequate runoff controls, surface-applied manure and during dryer conditions, failing or inadequate SSTSs.

There are 12 wastewater treatment facilities within the land area that drains to this listed reach (Table 3.31). There are 19 livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 3.32), as well as four square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements.

Table 3.33 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below

200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. Because this reach has not been monitored for flow the flow data from the USGS gage upstream of the listed reach was used to develop the loading capacities (same gage and flow record as was used for AUID: 07100001-501).

TABLE 3.31. Wastewater treatment facilities and associated WLAs (AUID: 07100002-501).

FACILITY	NPDES PERMIT #	DISCHARGE, MGD	WLA, BILLIONS/DAY
Lake Wilson	MNG580061	*	4
Slayton	MN0024911	*	15
Fulda	MN0023507	*	7
Brewster	MN0021750	*	16
Worthington-municipal	MN0031186	4.0	30
Worthington-industrial	MN0031178	2.04	15
Okabena	MN0050288	*	2
Currie	MN0025682	*	18
Windom	MN0022217	1.83	14
Heron Lake	MN0023655	*	6
Lakefield	MN0020427	0.58	4
Jackson	MNG580063	*	78

* - Seasonal discharge.

TABLE 3.32. Livestock facilities with NPDES permits (AUID: 07100002-501).

FACILITY	NPDES PERMIT #
Schultz Hog Farms Inc	MNG440140
James Tutt Farm	MNG440139
Grandy Pork LLP	MNG440141
Green Prairie Coop - Sec 23	MNG440346
James R & Robert E Buldhaupt Farm	MNG440142
Mark Buldhaupt Farm	MNG440143
Vander Wal Brothers	MNG440347
Gervais Brothers II	MNG440321
Kramer Swine Finishing	MNG440396
Brake Beef Yard	MN0066265
Southwest Prairie Pork	MNG440370
Double K - Finishing Site	MNG440273
Double K - Farrowing Site	MNG440273
Highway 60 Pork	MNG440278
Green Prairie Coop - Sec 7	MNG440337
Lake Shore Pork	MNG440055
Steve Rasche Farm	MNG440010
Christensen Family Farms Site C-13	MNG440063
Douglas Lusk Farm	MNG440047

TABLE 3.33. Fecal coliform loading capacities and allocations (AUID: 07100002-501).

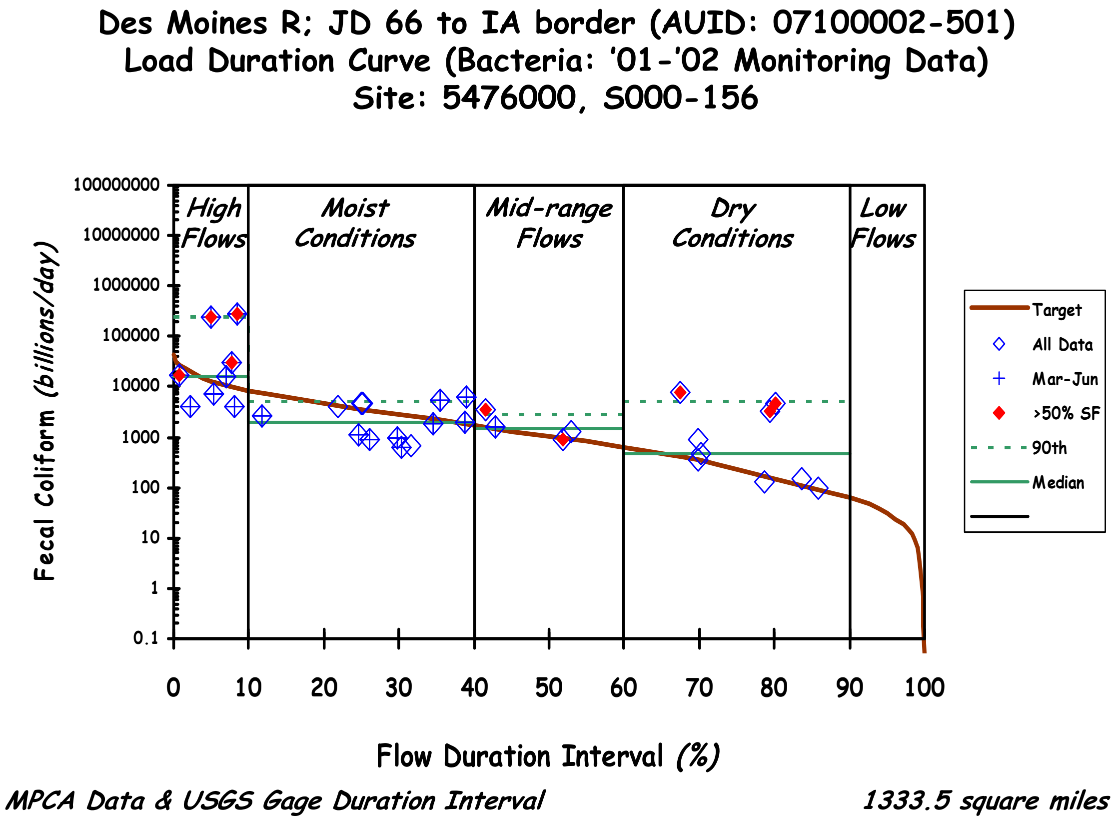
	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	12891	3552	1037	237	31
Wasteload Allocation*					
Wastewater Treatment Facilities	209	209	209	209	**
Communities Subject to MS4 NPDES Requirements	34	9	2	0.01	**
Livestock Facilities Requiring NPDES Permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	11358	2978	721	4	**
Margin of Safety	1289	355	104	24	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation*					
Wastewater Treatment Facilities	2%	6%	20%	88%	**
Communities Subject to MS4 NPDES Requirements	0.3%	0.3%	0.2%	0.005%	**
Livestock Facilities Requiring NPDES Permits	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	88%	84%	70%	2%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Tables 3.31 and 3.32.
** See Section 3.3 for allocations for these specific categories in these flow zones.

The summer month geometric mean for this reach for the two years (2001 and 2002) with available monitoring data (from Table 3.1) is 414. Therefore, the estimated reduction to achieve the 200 organisms/100 ml standard is approximately 52 percent. In spite of the limited amount of data this reduction percentage is within the same range of other main stem reaches.

The load duration curve (Figure 3.20) for the available dataset indicates exceedence of the target mainly following significant stormwater runoff, primarily in the later part of the season.

Figure 3.20. Fecal coliform load duration curve (AUID: 07100002-501).



3.5 Critical Conditions and Seasonal Variation

EPA states that the critical condition *"…can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence"* (USEPA, 1999). Fecal coliform levels are generally at their worst following significant storm events during the summer months, as described in Section 3.1. This section further spelled out overall seasonal variation, indicating that the fecal coliform levels appear to be below standard in April and May and above the standard from June through October. Such conditions and variation are fully captured in the duration curve methodology used in this TMDL.

3.6 Consideration of Growth on TMDL

As a result of population growth, changes in the agricultural sector, and other land use changes in the WFDMR watershed, sources and pathways of bacteria to surface waters will not remain constant over time.

Regarding population changes, flows at some wastewater treatment facilities are likely to increase over time with increases in the population they serve. This is not likely to have an impact on any of the impaired reaches provided discharge limits are met. This is because increased flows from wastewater treatment facilities add to the overall loading capacity by increasing river flows. This also applies to the potential for the five small unsewered communities that exist in the WFDMR watershed to upgrade to adequate wastewater systems (that may involve a discharge). However, as indicated previously, a small portion of the MOS as reserve capacity can account for this potential slightly increased load as well.

The allocations for nonpoint sources are for all current *and* future sources. This means that any expansion of nonpoint sources will need to comply with the LA provided in this report. Additional nonpoint sources (e.g., livestock) could very well make meeting the TMDL more difficult over time. Therefore, continued efforts over time to prevent fecal delivery to the stream will be critical.

4.0 TURBIDITY

4.1 Surface Water Quality Conditions

Turbidity is a parameter that has a significant amount of variability associated with the measurement values reported. Unlike many water quality parameters which are a measurement of mass of constituents in a volume of water, turbidity is a measure of the optical properties of a water sample which causes light to be scattered and absorbed (Federal Water Pollution Control Administration, 1968). Differences in the constituents' response to light contribute to the variability in turbidity readings. Adding to this variability, differences between turbidity meter types can result in different turbidity values being measured for the same water samples.

The MPCA's Turbidity TMDL Protocol (MPCA, 2007b) identified the need to use the turbidity reporting units/categories adopted by the United States Geological Survey (USGS) to differentiate data sets by type of turbidity meter. The MPCA began using the reporting categories for data being entered into STORET in 2005. The protocol identified a list of options/recommendations to use/follow when a project has one or more types of turbidity data. The difficulty of selecting a "method" from this list of options became apparent fairly quickly for various reasons in developing the TMDLs for this project. In this case, the water samples from two different watershed projects were analyzed by different laboratories – one being the Minnesota Valley Testing Laboratory (MVTL) measuring turbidity as NTU for samples collected within the Heron Lake watershed and the other being the MDH Lab measuring turbidity as NTRU for samples collected elsewhere in the WFDMR watershed. Fortunately, both turbidimeters had previously been used to test some of the same samples as part of the Minnesota River Turbidity TMDL project. Appendix C describes and fully documents the statistical relationship between the paired data to provide a "conversion" factor for estimating NTU values from measured NTRU values for use in this project given the absence of paired measurements with each meter.

Turbidity in streams is derived from suspended sediments, organic material, dissolved salts and stains. This analysis will focus primarily on the suspended sediment and organic material components, as they appear to be the primary factors of turbidity in this watershed. In order to evaluate and establish loads the surrogate measure of total suspended solids (TSS) is used. This parameter shows a good correlation with turbidity, based on regressions done on the monitoring data for each of the impaired stream reaches for this project (R-squared values ranging from 0.75 to 0.93; Table 4.1). Table 4.1 shows how the turbidity standard of 25 NTU is equivalent to TSS concentrations that range from 50 to 73 mg/L for these datasets, after applying the conversion factor described in Appendix C (where necessary) to each of the turbidity-TSS regression equations. Table 4.1 shows that the TSS concentrations that were corrected for the NTRU turbidity units are much more similar to the estimated TSS equivalents obtained for the turbidity samples collected in the Heron Lake watershed and analyzed as NTU.

Table 4.1 also shows that for three of the turbidity-impaired stream reaches, which were listed based on transparency tube readings, the TSS concentration equivalent to the 25 NTU turbidity standard was estimated based on the TSS regression equivalents from adjacent watersheds or upstream/downstream reaches. Regressions done on the TSS and volatile suspended solids (VSS) data were also done to determine the relative amounts of organic and mineral forms of the suspended solids. Table 4.1 shows that, with the exception of the Heron Lake outlet, between 10 to 15 percent of the TSS is made up of organic material in all of the impaired streams. The data from the Heron Lake outlet indicates that algae are contributing to a much higher organic proportion (23%) of the TSS load. It is noted that while the algal and organic forms of suspended solids do not represent the majority of the TSS mass they may represent a significantly higher proportion of the turbidity due to the way in which light is scattered.

Section 4.4 discusses the TMDL allocations for TSS loading for each of the individual impaired reaches. As described in Section 2.1, each stream reach is listed as impaired for turbidity when greater than ten percent of the data points collected in the previous ten-year period exceed the 25 NTU standard. Based on a review of the turbidity data, approximately 15 percent of the samples taken from the Lake Shetek outlet (AUID: 07100001-545) and 30 percent of the samples from Beaver Creek (AUID: 07100001-503) exceeded the turbidity standard, while between 50 and 70 percent of the samples obtained from the remaining impaired reaches exceeded the turbidity standard.

TABLE 4.1. Relationships between turbidity, total suspended solids and volatile suspended solids for impaired stream reaches

			Results of TSS-Turbidity Regressions			Results of TSS-VSS Regressions	
Impaired Stream Reach	Assessment Unit ID #	Lab/Units/Turbidimeter	Estimated TSS Conc. (mg/L) for Turbidity of 25 NTU (or NTRU)*	R^2	Corrected TSS Conc. (mg/L) for Turbidity of 25 NTU**	Volatile Suspended Solids (VSS) as a Percentage of TSS	R^2
Okabena Creek; Elk Creek to South Heron Lk	07100001-506	MVTL--NTU-Hach 2100A	62	0.750	NA	15%	0.924
Jack Creek; JD 26 to Heron Lk	07100001-509	MVTL--NTU-Hach 2100A	59	0.796	NA	12%	0.896
Heron Lake Outlet; Heron Lk to Des Moines R	07100001-527	MVTL--NTU-Hach 2100A	59	0.791	NA	23%	0.599
Des Moines River; Windom dam to JD 66	07100001-501,541	MDH--NTRU-Hach 2100AN	32	0.779	50	10%	0.563
Lime Creek; Lime Lk to Des Moines R	07100001-535	MDH--NTRU-Hach 2100AN	35	0.797	54	11%	0.770
Beaver Creek; CD 20 to Des Moines R	07100001-503	MDH--NTRU-Hach 2100AN	46	0.848	71	12%	0.979
Des Moines River; Beaver Cr to Lime Cr	07100001-546	MDH--NTRU-Hach 2100AN	46	0.848	73	12%	0.895
Des Moines River; Lime Cr to Heron Lk Outlet	07100001-533	MDH--NTRU-Hach 2100AN	37	0.842	58	12%	0.417
Des Moines River; Lk Shetek to Beaver Cr	07100001-545	MDH--NTRU-Hach 2100AN	38	0.837	60	15%	0.619
Elk Creek; Headwaters to Okabena Cr	07100001-507	MVTL--NTU-Hach 2100A	62	0.928	NA		
Des Moines River; JD 66 to IA border	07100002-501	MDH--NTRU-Hach 2100AN	42	0.883	66		
Des Moines River; Heron Lk Outlet to Windom Dam	07100001-524				54		
Division Creek; Heron Lk to Okabena Cr	07100001-529				62		
Jack Creek, North Branch; Headwaters to Jack Cr	07100001-505				57		

NOTES: * - Refers to turbidity units of NTRU for streams using MDH lab.
** - Except for the three reaches that did not have turbidity measurements. These sites 07100001-524, 529, 505 used the TSS concentration based on adjacent watersheds. AUID 07100001-524 used the average of 07100001-533, 5.01 and 541. AUID 07100001-529 used the same value as 7100001-506. AUID 07100001-505 used the average of AUID of 07100001-535, and 509

4.2 Turbidity Sources and Current Contribution

Conclusions regarding turbidity sources and current loading are based largely on analysis/interpretation of the available data and information. Various sources of information are used in the analysis including water quality data collected and other MPCA information, soil and land use information.

A simplified turbidity conceptual model is presented in Figure 4.1 that shows several possible candidate sources. This figure illustrates both potential sources and pathways for sediment and phosphorus. Phosphorus is included since it can contribute to turbidity through production of algae during lower flow periods or in low-gradient/low-velocity portions of the streams or in lakes and reservoirs. Both "external" and "internal" sources are illustrated in this figure. Most point and nonpoint sources are typically considered external in that they are located in the watershed outside of the stream or river channel yet contribute TSS and turbidity in some manner. Internal sources typically encompass processes that occur within the channel (including the bed and banks) or the floodplain of a waterway, stream, or river. Such processes include channel and floodplain erosion or scour, and bank slumping. Algae growth and decay could be considered an internal process though the phosphorus that drives its production is generally from external sources. The components of this conceptual model, as they pertain to this watershed, are evaluated below.

Feedlots with pollution hazards

Feedlots near streams and watercourses with pollution hazards can contribute to excess turbidity via soil and phosphorus runoff. Overall, this source appears to represent a relatively low contribution in this watershed. However, on a site-specific basis some of these facilities may be a contributor to the problem and should be addressed.

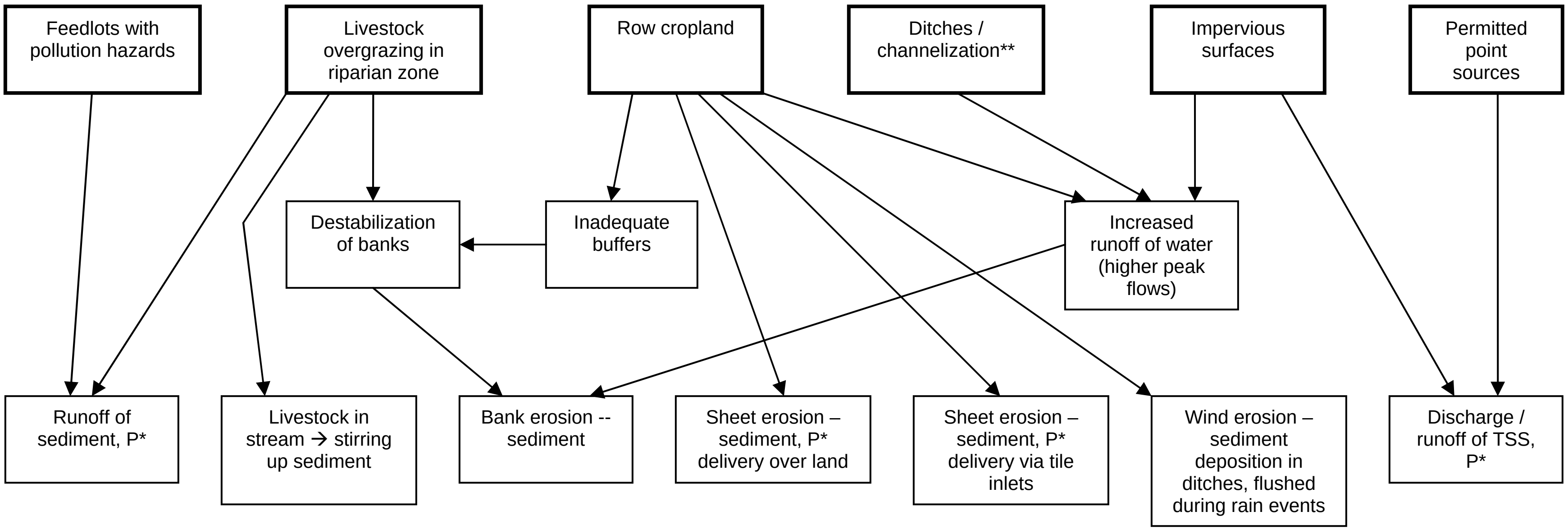
Livestock in riparian zone

Livestock overgrazing in riparian areas can contribute to excess turbidity via soil and phosphorus runoff directly from devegetated areas, resuspending of sediments by walking in the stream, and by destabilizing the banks leading to increased bank erosion or slumping. While it does not appear that overgrazing in riparian pastures is a widespread chronic problem in the watershed this source may be a concern and should be further identified and addressed.

Row cropland

Row cropland can contribute to excess turbidity via sheet/rill erosion of soil either overland or via surface tile intakes, wind-eroded soil settling in ditches that are then flushed during rain events, destabilization of banks (if inadequate buffers) leading to increased bank erosion, and also drainage alterations on cropped land can lead to increased flows which can then cause bank/bed erosion. Based on the National Land

Figure 4.1. Simplified turbidity conceptual model



* Phosphorus (P) can contribute to turbidity through production of algal blooms during lower flow periods or in low-gradient/low-velocity portions of stream.

** Ditches / channelization also can cause sediment delivery via:

- bank erosion as watercourses revert to original meandering
- steeper gradient can cause headward erosion and downcutting (nickpoints may form; channel erodes nickpoint resulting in upstream scour)
- ditch cleaning / dredging

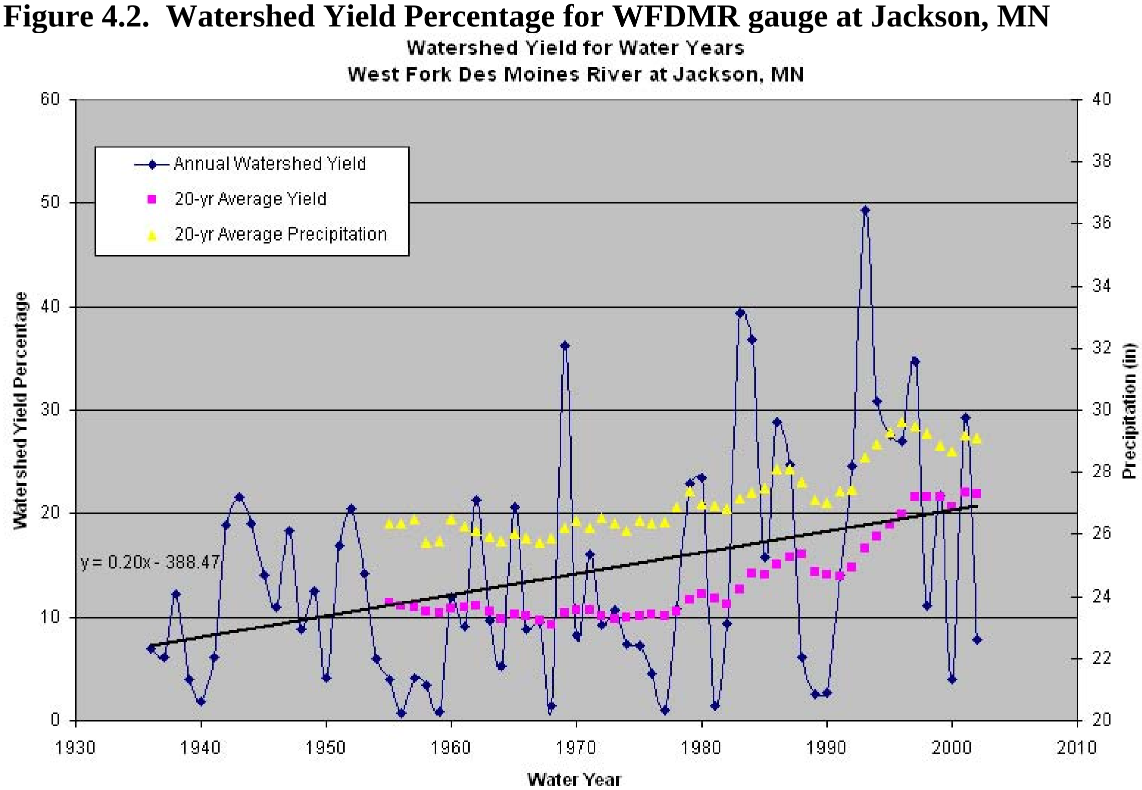
Cover Data (NLCD) 2001 land use coverage, row cropland includes both corn and soybean crops. The most recent crop survey statistics indicate corn and soybeans are grown on approximately 97 percent of the harvested cropland in the watershed.

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, 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. Release of sediments also occurs during ditch cleaning/dredging.

A full assessment of the influence of ditches/channelization in terms of turbidity is difficult and there is no specific monitoring data that provides a breakdown of contributions for upland erosion versus these near-channel sources. Barr Engineering recently completed a draft technical memorandum regarding the hydrologic trends, sources of additional runoff and implications for streambank erosion for each of the Minnesota basins, as a follow-up to the Detailed Phosphorus Assessment (Barr Engineering Company, 2004). Figure 4.2 shows the trend analysis done for the hydrologic data collected for the WFDMR watershed yield at Jackson.

Figure 4.2. Watershed Yield Percentage for WFDMR gauge at Jackson, MN



The upward trend in annual watershed yield is statistically significant over the period of record. As part of the analysis, stepwise multiple regressions were used to show that 60% of the trend can be attributed to climatic factors, while the remaining contribution is due to anthropogenic changes within the watershed. As a result, additional runoff associated with these anthropogenic changes, would account for an additional 12,000 tons of sediment per year due to increased streambank erosion within the Des Moines River basin during high flow conditions. This TSS loading rate exceeds the total allowable loading capacity for the West Fork Des Moines River at Jackson by approximately 60 percent.

Engstrom (2007) reported that 68, 82 and 89 percent of TSS loading from snowmelt runoff samples originated from riverine sources of sediment in the Cottonwood River, Watonwan River, and Blue Earth River watersheds, respectively, based on a sediment fingerprinting study conducted in the Minnesota River basin.

Impervious surfaces

Impervious surfaces (roads, parking lots, roofs, etc.) can contribute to excess turbidity directly via sediment and phosphorus delivery and indirectly via increased runoff of water leading to increased bank/bed erosion. In 1987 the federal Clean Water Act was amended to include provisions for a two-phase program to address stormwater runoff. The city of Worthington is the only MS4-permitted source of urban stormwater in the watershed, while the remaining municipalities have populations that are too small to require a MS4 permit. Overall, however, in this agricultural-dominated watershed there is relatively limited growth and development.

Point sources

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

The operation, location and other related information regarding the wastewater treatment facilities in the watershed was described in Section 3.0 and Table 3.3. Relative to turbidity and TSS each of the facilities NPDES permits have discharge limits of either 30 or 45 mg/L TSS as well as average and maximum daily loading limits per calendar week and month. A review of MPCA records since 1999 reveals 17 TSS-related violations for the stabilization pond systems and no violations for the mechanical systems. These violations appear to represent a small to perhaps moderate contribution to their respective receiving waters during the facilities' discharge windows (spring and fall). Ongoing efforts by the respective cities as well as continued regulatory oversight by MPCA are needed and should minimize this contribution.

Regarding construction, the MPCA issues construction permits for any construction activities disturbing: one acre or more of soil; less than one acre of soil if that activity is part of a “larger common plan of development or sale” that is greater than one acre; or less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. Although stormwater runoff at construction sites that do not have adequate runoff controls can be significant on a per acre basis (MPCA Stormwater web page, 2006), 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 very minor turbidity source.

Regarding MS4-permitted stormwater runoff, approximately 245 acres from the city of Worthington drains to Elk Creek while 2,315 acres drains to Okabena Creek from the city. Table 4.1 shows that discharge to both watersheds should meet the 25 NTU turbidity standard as long as the TSS concentration in the stormwater runoff remains at or below 62 mg/L. The MS4 wasteload allocations presented in Section 4.4 are based on the TSS concentration that corresponds to a turbidity reading of 25 NTU and the flow rates that correspond with each flow zone for each of the impaired reaches downstream of the city of Worthington.

Regarding industrial stormwater sources, there are four water discharge permit holders in the watershed according to the MPCA’s DELTA database. These do not appear to represent a TSS loading concern in this watershed. (For the purpose of the TMDL this source is lumped with construction stormwater into a categorical WLA.)

Other

One other potential turbidity contributor worth noting is carp and other benthic feeders that stir up fine sediments. It is difficult to gage the relative impact of this internal source, but fish monitoring by MPCA and the Minnesota Department of Natural Resources does show significant biomass of carp in several locations where sampling was conducted. For example, in a reach of the West Fork Des Moines River downstream of Talcot Lake, 116 carp were observed (ranging in size from 1 to 29 inches). The turbidity reading during the fish survey was 35 NTU and the total suspended solids concentration was 89 mg/L despite the fact that the observed flow rate was within the mid-range flow at this site. The Heron Lake outlet had 206 carp (ranging in size from 2 to 7 inches) observed during dry flow conditions with a turbidity reading of 27 NTU.

4.3 Methodology for Load Allocations, Wasteload Allocations and Margins of Safety

The TMDLs developed for the stream reaches in this report consist of three main components: WLA, LA, and MOS as defined in Section 1.0. The WLA includes three sub-categories: permitted wastewater and water treatment facilities with TSS limits, the MS4 permitted stormwater source category and a construction plus industrial permitted stormwater category. The LA, reported as a single category, includes the nonpoint sources described in the previous section, namely row cropland, overgrazed pastures, feedlots with pollution hazards, streambank/bed erosion, and stormwater runoff from impervious surfaces (in which no permit is required). The third component, MOS, is the part of the allocation that accounts for uncertainty that the allocations will result in attainment of water quality standards.

The three components (WLA, LA, and MOS) were calculated as total daily load of TSS. As described in Section 4.1 this parameter is used as a surrogate for turbidity based on a good correlation between the two. While it was noted that nutrients (i.e., phosphorus) may play a role in turbidity during portions of the year, we lack a robust enough dataset to establish an adequate correlation between nutrients, algae and turbidity upon which to base loading allocations. However, reducing the delivery of sediment will also reduce the delivery of nutrients.

As with the fecal coliform impairments (Section 3.0), the methodology to derive and express the TSS load components is the duration curve approach and is described in Appendix B. The same flow gage and flow records as with Section 3.0 were used here.

For each impaired reach and flow condition, the total loading capacity or "TMDL" was divided into its component WLA, LA, and MOS. The process was as follows:

Wasteload Allocation

- The permitted wastewater and water treatment facility WLAs were determined based on their permitted discharge design flow rates and their permitted TSS concentration limits or their permitted daily loading rates, whichever were higher.
- Construction stormwater and industrial stormwater are lumped together into a categorical WLA based on an approximation of the land area covered by those activities. MPCA construction stormwater permit application records over the last four years indicate approximately 0.04 percent of the acreage in Murray, Cottonwood, Jackson and Nobles counties is subject to construction on an annual basis. To account for industrial stormwater, which the MPCA does not have readily accessible acreage data (but is likely much smaller than construction), as well as reserve capacity (to allow for the potential of higher rates of construction and additional industrial facilities), this TMDL assumes 0.1 percent of the land area for a combined construction and industrial stormwater category. The allocation to this category is made after the WLA for water and wastewater treatment facilities and the MOS are subtracted from the total loading capacity. That remaining capacity is divided up between construction and industrial stormwater, permitted MS4s and all of the nonpoint sources (the LA) based on the percent land area covered.
- As indicated above the allocation for communities subject to MS4 NPDES stormwater permit requirements is made after the WLA for water and wastewater treatment facilities and the MOS are subtracted from the total loading capacity. The allocation for the MS4 is based on the percentage of the land area in the impaired reach watershed that the MS4 permit covers. For this TMDL the only permitted MS4 community is the city of Worthington. The city land area falling in

- As occurred in the calculations for the fecal coliform section (Section 3.0), the total daily loading capacities in the dry and low flow zone are 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 at the low flow zone. Of course actual treatment facility flow can never exceed stream flow as it is a component of stream flow. For the dry flow zone the calculated MOS would take up all of the remaining allocation capacity. 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 wastewater treatment facilities, 30 for Red Rock Rural Water System treatment facility and Hubbard Feeds, Inc. cooling water discharge, and for all other sources the corrected TSS concentration corresponding to 25 NTU in Table 4.1

  In essence, this assumption equates to assigning a concentration-based limit to the sources for the dry and low flow zone.

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 is applied. This is expected to provide an adequate accounting of uncertainty, especially given that wastewater treatment facilities have generally demonstrated consistent meeting of TSS discharge limits and in the case of wastewater facilities with pond systems, discharge only during spring and fall windows (i.e., before June 15 and after September 15). Also, the mechanisms for soil loss from agricultural sources and the factors that affect this have been extensively studied over the decades and are well understood. Much has been done to target agricultural BMPs for soil loss prevention (see section 7.0 and Appendix E). Follow-up effectiveness monitoring will provide a means to evaluate installed BMPs in terms of compliance with WLAs and progress or achievement of the TMDL. To accommodate the potential for the five small unsewered communities that exist in the WFDMR watershed (see section 3.2) to upgrade to adequate wastewater systems, a small (but difficult to quantify) portion of the MOS can serve as reserve capacity should there be the need to provide wastewater facilities that involve a discharge.
- For the impaired reaches in which the allocation for the dry and low flow zones required use of an alternative method of calculation, i.e., a concentration-based limit, an implicit MOS was used. An implicit MOS means that conservative assumptions were built in to the TMDL and/or allocations. In this instance the

reaches are expected to meet the TMDL because the permitted point source dischargers are limited to discharge concentrations below the TSS target, thereby providing additional capacity. In addition, the stream flow itself is primarily being fed by ground water at these low flows, which is believed to convey very little TSS. An additional conservative assumption relates to reaches with discharges from wastewater facilities with pond systems that discharge only in spring and fall, as indicated above, meaning that a significant portion of the year a significant fraction of the WLA is not being used.

Load Allocations

- Once the WLA and MOS were determined for a given reach and flow zone, the remaining loading capacity was considered LA. The LA includes nonpoint pollution sources that are not subject to NPDES permit requirements, as well as "natural background" sources such as low levels of soil/sediment erosion from both upland areas and the stream channel. The nonpoint pollution sources were described previously and include upland and riparian erosion and bank/bed erosion, as well as the other sources.

4.4 TMDL Allocations for Individual Impaired Reaches

In the sections below TMDL allocations are provided for the individual impaired reaches. Calculations for the TMDL, LA, WLA and MOS consider the total drainage area represented by the end of the listed reach. Load duration curves which integrate flow and the TSS equivalent to the turbidity standard to provide loading capacity across the flow record as well as comparisons to the loading capacity using collected water quality data are also included in each section (see previous explanation in Section 3.4 and also Appendix B). The TSS equivalent used in calculations was from Table 4.1. Specifically, for turbidity datasets analyzed with a Hach 2100A turbidimeter (NTU) the column labeled "Estimated TSS…" was used; for turbidity datasets analyzed with a Hach 2100AN turbidimeter (NTRU) the column labeled "Corrected TSS…" was used. Duration curves that integrate flow and the transparency tube equivalent to the turbidity standard are provided in the sections that discuss the reaches that were listed based on transparency tube readings.

4.4.1 Beaver Creek; CD 20 to Des Moines R (AUID: 07100001-503)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 177 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are row cropland and streambank/bed erosion and, to a lesser extent, overgrazed pasture and inadequate buffers near streams and waterways. In addition, the Beaver Creek system is unstable as a result of a drainage project that that converted 3,000 to 4,000 acres of a wetland/lake complex into farmland.

There are two wastewater treatment facilities within the land area that drains to this listed reach (Table 4.2). This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 4.3 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 71 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage near the mouth of Beaver Creek.

TABLE 4.2. Wastewater treatment facilities and associated WLAs (AUID: 07100001-503).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Lake Wilson	MNG580061	*	87
Slayton	MN0024911	*	345

* - Seasonal discharge.

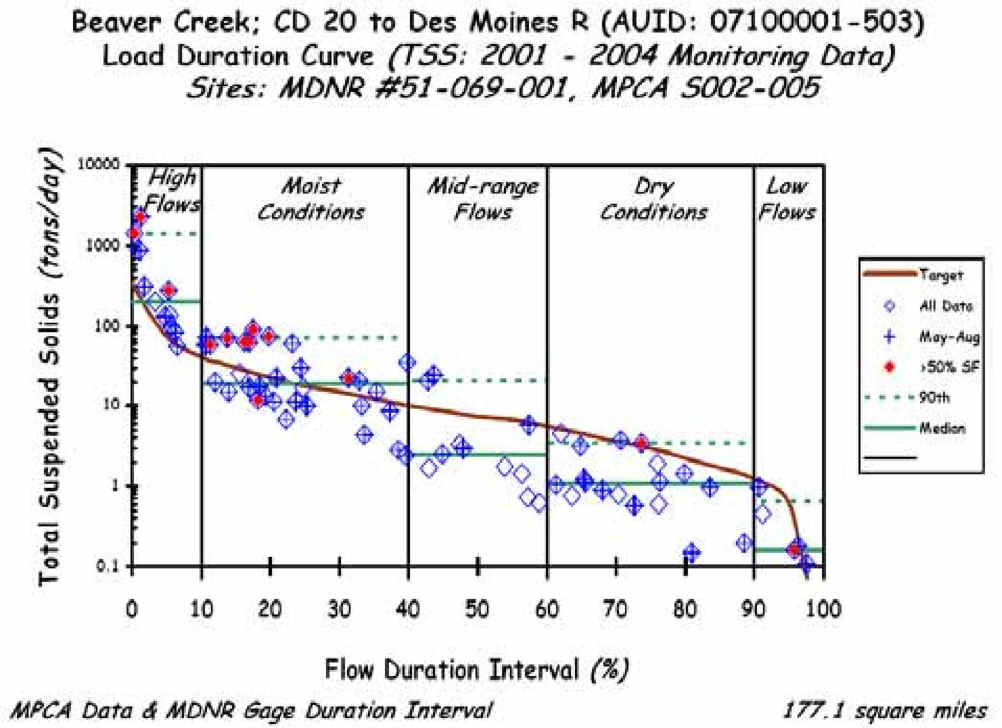
TABLE 4.3. Total suspended solids loading capacities and allocations (AUID: 07100001-503).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	75.86	18.08	7.50	2.95	0.61
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	0.48	0.48	0.48	0.48	0.48
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.07	0.02	0.006	0.002	<0.001
Load Allocation	67.73	15.78	6.27	2.17	0.07
Margin of Safety	7.59	1.81	0.75	0.29	0.06
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1%	3%	6%	16%	78%
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	<0.1%
Load Allocation	89%	87%	84%	74%	12%
Margin of Safety	10%	10%	10%	10%	10%

* The individual facilities are listed in Table 4.2.

The load duration curve (Figure 4.3) for the available dataset indicates exceedence of the target between the mid-range and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately 95 percent under high flows, 75 percent under moist conditions, and 65 percent under mid-range flows. A large proportion of samples that exceeded the target were collected following significant (greater than 50 percent) stormwater runoff. In particular, TSS concentration is positively correlated with storm flow percentage and storm systems that produced larger one-day increases in flow resulted in significantly higher TSS concentrations in Beaver Creek.

Figure 4.3. Total suspended solids load duration curve (AUID: 07100001-503).



4.4.2 Des Moines River; Lk Shetek to Beaver Cr (AUID: 07100001-545)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 129 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the monitoring data, it indicates that the primary sources contributing to the impairment include algae, dissolved organics from Lake Shetek, scour from the outlet channel and, to a less extent, inundation from Beaver Creek backflow.

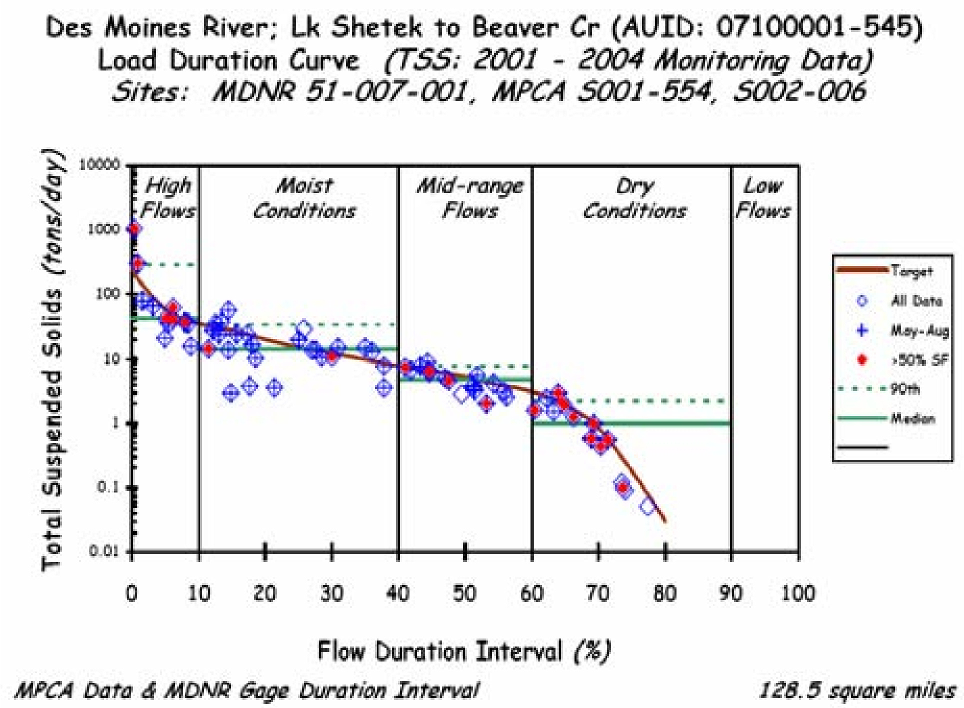
There are no wastewater treatment facilities within the land area that drains to this listed reach. Table 4.4 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 60 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage at the Lake Shetek outlet.

TABLE 4.4. Total suspended solids loading capacities and allocations (AUID: 07100001-545).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	61.11	15.18	5.24	0.18	0.002
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.06	0.01	0.005	<0.001	<0.001
Load Allocation	54.94	13.65	4.72	0.16	0.001
Margin of Safety	6.11	1.52	0.52	0.02	<0.001
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	0.1%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

The load duration curve (Figure 4.4) for the available dataset indicates exceedence of the target between the mid-range and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately 80 percent under high flows, 55 percent under moist conditions, and 30 percent under mid-range flows. The sample TSS concentrations were positively correlated with one-day increases in flow rate.

Figure 4.4. Total suspended solids load duration curve (AUID: 07100001-545).



4.4.3 Des Moines River; Beaver Cr to Lime Cr (AUID: 07100001-546)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 355 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are row cropland and streambank/bed erosion and, to a lesser extent, overgrazed pasture and inadequate buffers near streams and waterways. This stream segment also had several locations with sediment deposition in stream midbars.

There are three wastewater treatment facilities within the land area that drains to this listed reach (Table 4.5). This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 4.6 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 73 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage at CSAH 7.

TABLE 4.5. Wastewater treatment facilities and associated WLAs (AUID: 07100001-546).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Lake Wilson	MNG580061	*	87
Slayton	MN0024911	*	345
Currie	MN0025682	*	158

* - Seasonal discharge.

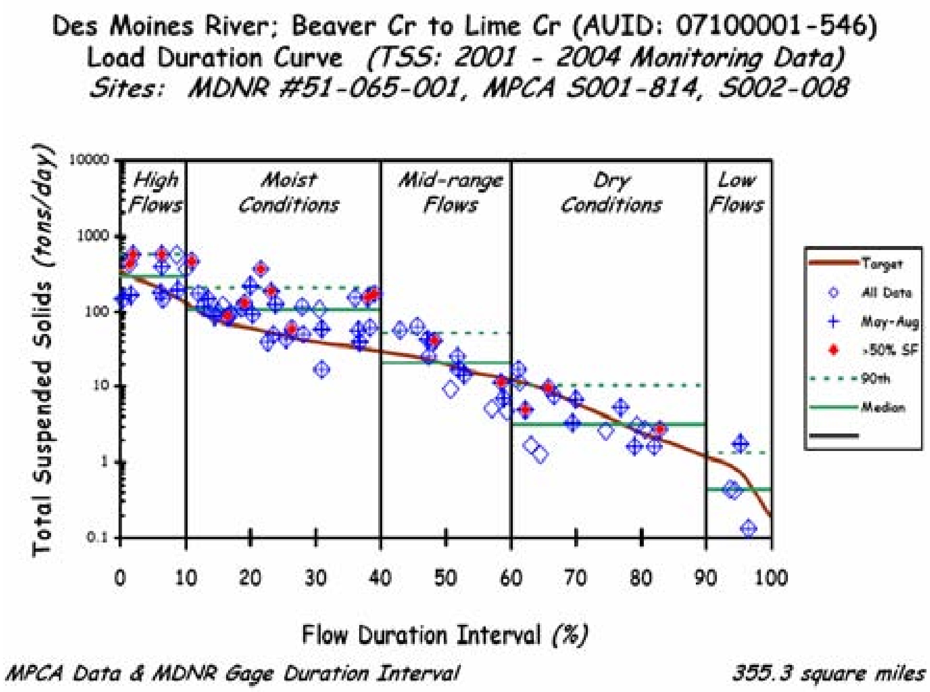
TABLE 4.6. Total suspended solids loading capacities and allocations (AUID: 07100001-546).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	226.47	48.38	19.85	3.91	0.75
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	0.65	0.65	0.65	0.65	0.65
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.20	0.04	0.02	0.003	<0.001
Load Allocation	202.97	42.85	17.20	2.86	0.02
Margin of Safety	22.65	4.84	1.98	0.39	0.08
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	0%	1%	3%	17%	87%
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	<0.1%
Load Allocation	90%	89%	87%	73%	3%
Margin of Safety	10%	10%	10%	10%	10%

* The individual facilities are listed in Table 4.5.

The load duration curve (Figure 4.5) for the available dataset indicates exceedence of the target between the dry conditions and high flows that have been recorded. With the exception of the low flows, the estimated load reduction to achieve the TSS (and turbidity) standard is between 60 to 75 percent for all of the remaining flow duration intervals. A large proportion of samples that exceeded the target were collected following significant (greater than 50 percent) stormwater runoff. In particular, TSS concentration is positively correlated with storm flow percentage and storm systems that produced larger one-day increases in flow resulted in significantly higher TSS concentrations.

Figure 4.5. Total suspended solids load duration curve (AUID: 07100001-546).



4.4.4 Lime Creek; Lime Lk to Des Moines R (AUID: 07100001-535)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 98 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Murray County. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are row cropland and streambank/bed erosion and, to a lesser extent, overgrazed pasture and inadequate buffers near streams and waterways.

There is one wastewater treatment facility within the land area that has seasonal discharge to this listed reach: city of Fulda (MN0023507). The WLA for the Fulda facility is 149.6 kg/day.

Table 4.7 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 54 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage near the end of the listed reach.

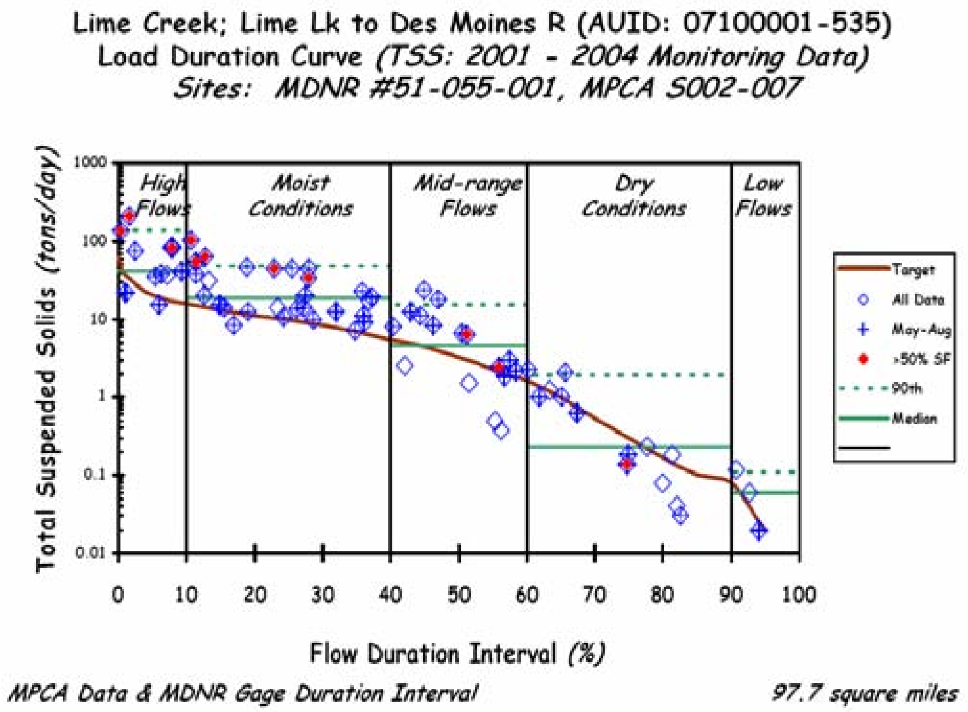
TABLE 4.7. Total suspended solids loading capacities and allocations (AUID: 07100001-535).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	19.96	9.75	3.28	0.29	0.02
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	0.16	0.16	0.16	0.16	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.02	0.009	0.003	<0.001	**
Load Allocation	17.78	8.61	2.79	0.10	**
Margin of Safety	2.00	0.98	0.33	0.03	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1%	2%	5%	56%	**
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	<0.1%	**
Load Allocation	89%	88%	85%	34%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in the text.
** See Section 4.3 for allocations for these specific categories in these flow zones.

The load duration curve (Figure 4.6) for the available dataset indicates exceedence of the target throughout the entire recorded flow regime. The estimated load reduction to achieve the TSS (and turbidity) standard is between 80 and 85 percent for all of the flow duration intervals. A large proportion of samples that exceeded the target were collected following significant (greater than 50 percent) stormwater runoff. In particular, TSS concentration is positively correlated with storm flow percentage. Also, the samples collected between May and August generally had higher TSS concentrations than the samples collected outside of the summer months. This corresponds with the results of a RUSLE2 simulation of a corn-soybean rotation in loam soils in southwest Minnesota which shows that the soil loss rates, on a long-term basis, are highest between May and August, with the highest rate occurring in June.

Figure 4.6. Total suspended solids load duration curve (AUID: 07100001-535).



4.4.5 Des Moines River; Lime Cr to Heron Lk Outlet (AUID: 07100001-533)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 716 square miles. The listed watershed exists within the Coteau and a small amount of the Dryer Blue Earth Till agroecoregions, previously described, and Murray and Cottonwood Counties. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are row cropland and streambank/bed erosion and, to a lesser extent, carp, overgrazed pasture and inadequate buffers near streams and waterways. This stream segment also had several locations with channelization and sediment deposition in stream midbars.

There are four wastewater treatment facilities within the land area that drains to this listed reach (Table 4.8). This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 4.9 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 58 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage near the end of the listed reach.

TABLE 4.8. Wastewater treatment facilities and associated WLAs (AUID: 07100001-533).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Lake Wilson	MNG580061	*	87
Slayton	MN0024911	*	345
Fulda	MN0023507	*	150
Currie	MN0025682	*	158

* - Seasonal discharge.

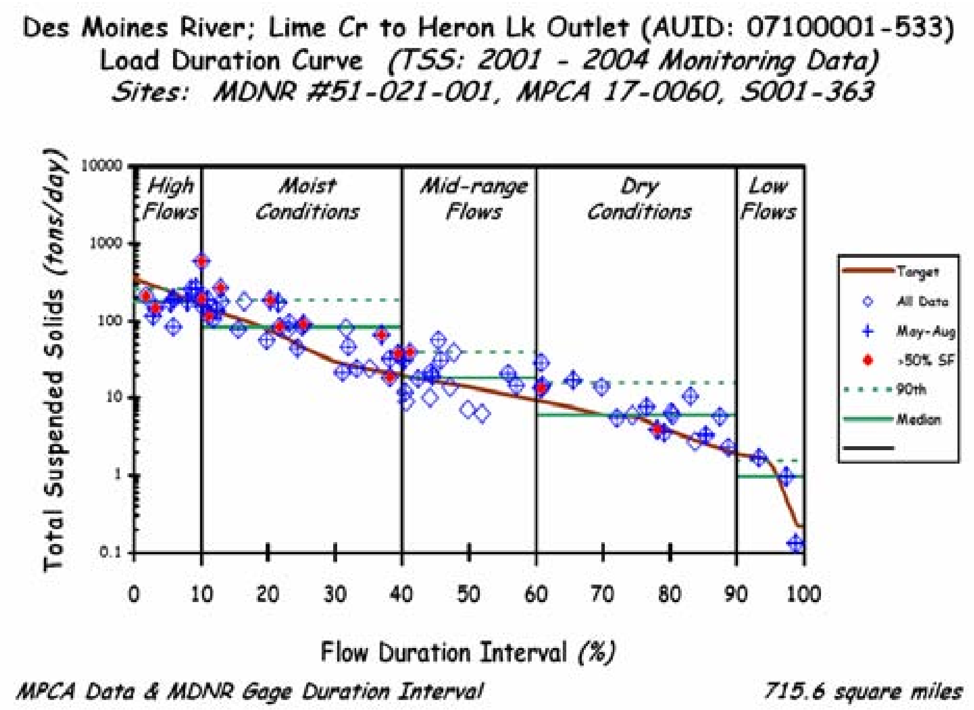
TABLE 4.9. Total suspended solids loading capacities and allocations (AUID: 07100001-533).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	241.80	45.55	13.90	5.56	1.36
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	0.82	0.82	0.82	0.82	0.82
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.22	0.04	0.01	0.004	<0.001
Load Allocation	216.59	40.14	11.68	4.18	0.40
Margin of Safety	24.18	4.56	1.39	0.56	0.14
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	0%	2%	6%	15%	60%
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	<0.1%
Load Allocation	90%	88%	84%	75%	30%
Margin of Safety	10%	10%	10%	10%	10%

* The individual facilities are listed in Table 4.8.

The load duration curve (Figure 4.7) for the available dataset indicates exceedence of the target between the dry conditions and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately five percent under high flows, 75 percent under moist conditions, and 65 percent under mid-range flows and dry conditions. A large proportion of samples that exceeded the target were collected following significant (greater than 50 percent) stormwater runoff. In particular, TSS concentration is positively correlated with storm flow percentage.

Figure 4.7. Total suspended solids load duration curve (AUID: 07100001-533).



4.4.6 Des Moines River; Heron Lk Outlet to Windom Dam (AUID: 07100001-524)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 1,136 square miles. The listed watershed exists within the Coteau, Dryer Blue Earth Till and Poorly Drained Blue Earth Till agroecoregions, previously described, and Murray, Cottonwood, Nobles and Jackson Counties. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are algae, row cropland and streambank/bed erosion and, to a lesser extent, overgrazed pasture and inadequate buffers near streams and waterways.

There are ten wastewater treatment facilities, a water treatment facility, and a cooling water discharge within the land area that drains to this listed reach (Table 4.10). There also is four square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 4.11 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 54 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2001-2004 from a MPCA-installed flow gage near the downstream end of the listed reach.

TABLE 4.10. Wastewater treatment facilities and associated WLAs (AUID: 07100001-524).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Lake Wilson	MNG580061	*	87
Slayton	MN0024911	*	345
Fulda	MN0023507	*	150
Currie	MN0025682	*	158
Brewster	MN0021750	*	356
Worthington Industrial	MN0031178	2.04	232
Worthington Municipal	MN0031186	4.00	454
Okabena	MN0050288	*	42
Hubbard Feeds Inc.	MN0033375	0.01	1
Lakefield	MN0020427	0.58	99
Heron Lake	MN0023655	*	131
Red Rock Rural WTP	MNG640077	0.25	28

* - Seasonal discharge.

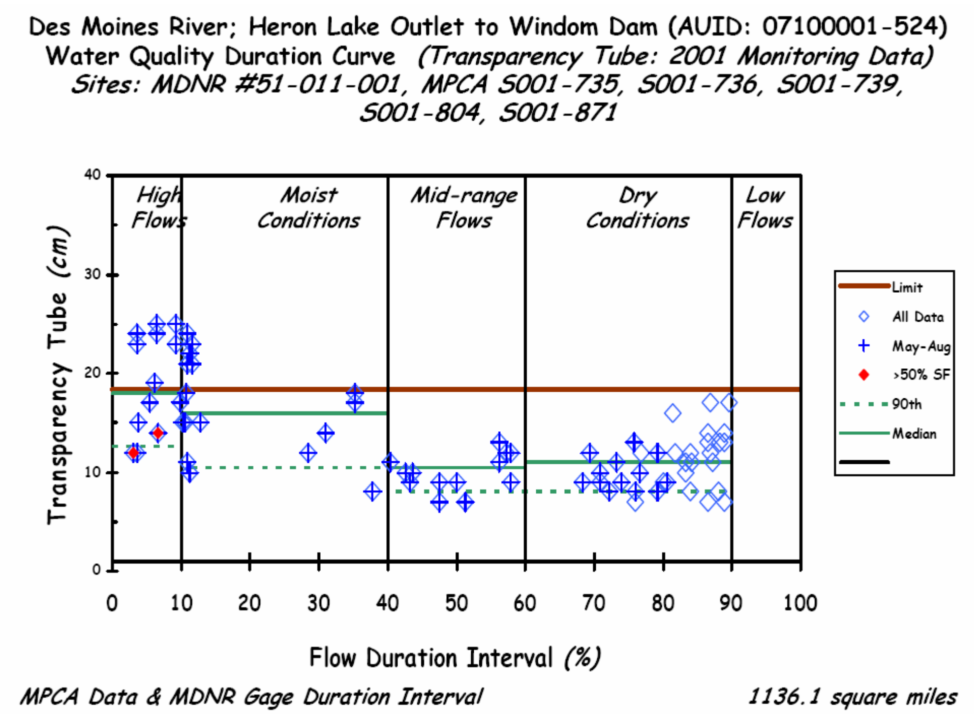
TABLE 4.11. Total suspended solids loading capacities and allocations (AUID: 07100001-524).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	231.53	81.95	37.82	8.87	3.20
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	2.30	2.30	2.30	2.30	2.30
Communities Subject to MS4 NPDES Requirements	0.73	0.25	0.11	0.02	0.002
Construction and Industrial Stormwater	0.21	0.07	0.03	0.006	0.001
Load Allocation	205.15	71.13	31.60	5.66	0.58
Margin of Safety	23.15	8.19	3.78	0.89	0.32
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1%	3%	6%	26%	72%
Communities Subject to MS4 NPDES Requirements	0.3%	0.3%	0.3%	0.2%	0.1%
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	<0.1%
Load Allocation	89%	87%	84%	64%	18%
Margin of Safety	10%	10%	10%	10%	10%

* The individual facilities are listed in Table 4.10.

The transparency tube duration curve (Figure 4.8) for the available dataset indicates noncompliance between the dry conditions and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity/transparency tube) standard is approximately 30 percent under high flows, 40 percent under moist conditions, and 55 percent under mid-range flows and dry conditions. The transparency tube 25 NTU-equivalent of 18 cm is based on the turbidity-transparency tube regression for the WFDMR watershed data described in the 2003 Diagnostic Study completed for the WFDMR Watershed CWP Project. A larger proportion of samples that did not comply with the transparency tube target were collected under mid-range and dry flow conditions. In particular, the transparency tube reading is negatively correlated with the flow duration interval, indicating that lower flow rates produced higher turbidity from algae. (Note: for transparency tube data there is an inverse relationship to turbidity, meaning that lower numbers correspond to higher turbidity.)

Figure 4.8. Transparency tube reading duration curve (AUID: 07100001-524).



4.4.7 Des Moines River; Windom Dam to Jackson Dam (AUID: 07100001-501)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 1998. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project and data collected by the USGS.

The drainage area to the downstream end of this impaired reach is about 1240 square miles. The listed watershed exists within the Coteau, Dryer Blue Earth Till and Poorly Drained Blue Earth Till agroecoregions, previously described, and Murray, Cottonwood, Nobles and Jackson Counties. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are algae, row cropland and streambank/bed erosion and, to a lesser extent, inadequate buffers near streams and waterways. The listed stream segment also had several locations with sediment deposition in stream midbars.

There are 11 wastewater treatment facilities, a water treatment facility, and a cooling water discharge within the land area that drains to this listed reach (Table 4.12). There also is four square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 4.13 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 50 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 1980-2006 from the USGS gage site at Jackson (#5476000).

TABLE 4.12. Wastewater treatment facilities and associated WLAs (AUID: 07100001-501).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Lake Wilson	MNG580061	*	87
Slayton	MN0024911	*	345
Fulda	MN0023507	*	150
Currie	MN0025682	*	158
Brewster	MN0021750	*	356
Worthington Industrial	MN0031178	2.04	232
Worthington Municipal	MN0031186	4.00	454
Okabena	MN0050288	*	42
Hubbard Feeds Inc.	MN0033375	0.01	1
Lakefield	MN0020427	0.58	99
Heron Lake	MN0023655	*	131
Red Rock Rural WTP	MNG640077	0.25	28
Windom	MN0022217	1.83	208

* - Seasonal discharge.

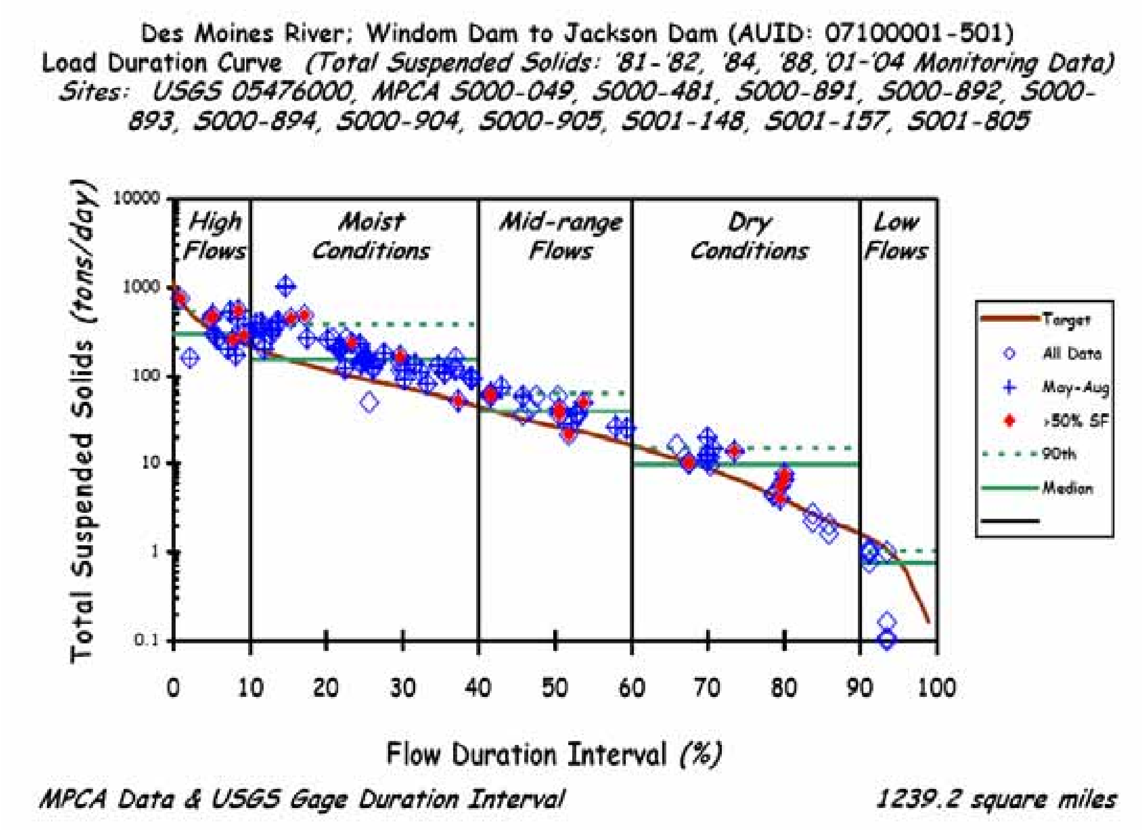
TABLE 4.13. Total suspended solids loading capacities and allocations (AUID: 07100001-501).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	330.31	91.00	26.56	6.07	0.80
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	2.52	2.52	2.52	2.52	**
Communities Subject to MS4 NPDES Requirements	0.95	0.26	0.07	0.009	**
Construction and Industrial Stormwater	0.29	0.08	0.02	0.003	**
Load Allocation	293.51	79.04	21.29	2.92	**
Margin of Safety	33.03	9.10	2.66	0.61	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1%	3%	10%	42%	**
Communities Subject to MS4 NPDES Requirements	0.3%	0.3%	0.3%	0.2%	**
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	<0.1%	**
Load Allocation	89%	87%	80%	48%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Table 4.12.
** See Section 4.3 for allocations for these specific categories in these flow zones.

The load duration curve (Figure 4.9) for the available dataset indicates exceedence of the target between the dry conditions and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately 40 percent under high flows, 80 percent under moist conditions, and 60 percent under mid-range flows and dry conditions. TSS concentration is negatively correlated with the flow duration interval, indicating that higher flow rates produced higher turbidity.

Figure 4.9. Total suspended solids load duration curve (AUID: 07100001-501).



4.4.8 Des Moines River; Jackson Dam to JD 66 (AUID: 07100001-541)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 1247 square miles. The listed watershed exists within the Coteau, Dryer Blue Earth Till and Poorly Drained Blue Earth Till agroecoregions, previously described, and Murray, Cottonwood, Nobles and Jackson Counties. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are algae, row cropland and streambank/bed erosion and, to a lesser extent, inadequate buffers near streams and waterways.

There are 11 wastewater treatment facilities, a water treatment facility, and a cooling water discharge within the land area that drains to this listed reach (Table 4.14). There also is four square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 4.15 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 50 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 1980-2006 from the USGS gage site at Jackson (#5476000).

TABLE 4.14. Wastewater treatment facilities and associated WLAs (AUID: 07100001-541).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Lake Wilson	MNG580061	*	87
Slayton	MN0024911	*	345
Fulda	MN0023507	*	150
Currie	MN0025682	*	158
Brewster	MN0021750	*	356
Worthington Industrial	MN0031178	2.04	232
Worthington Municipal	MN0031186	4.00	454
Okabena	MN0050288	*	42
Hubbard Feeds Inc.	MN0033375	0.01	1
Lakefield	MN0020427	0.58	99
Heron Lake	MN0023655	*	131
Red Rock Rural WTP	MNG640077	0.25	28
Windom	MN0022217	1.83	208

* - Seasonal discharge.

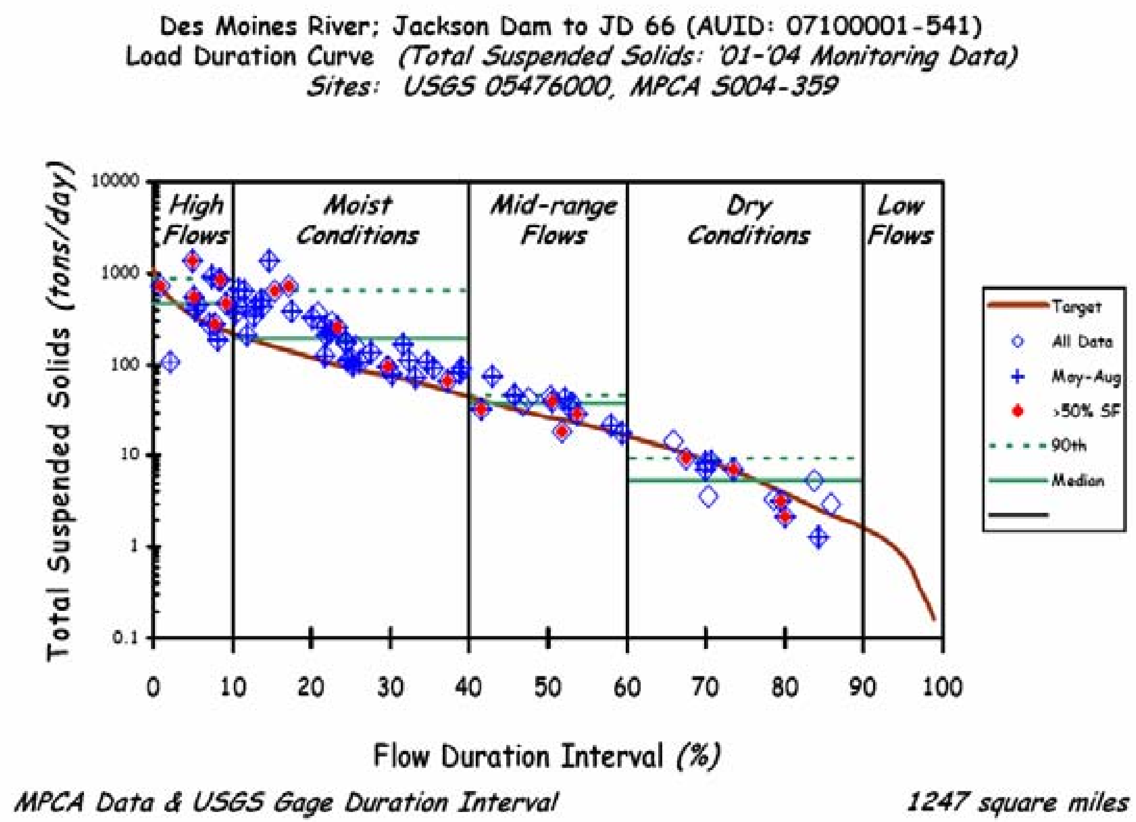
TABLE 4.15. Total suspended solids loading capacities and allocations (AUID: 07100001-541).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	332.07	91.49	26.70	6.10	0.80
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	2.52	2.52	2.52	2.52	**
Communities Subject to MS4 NPDES Requirements	0.95	0.26	0.07	0.01	**
Construction and Industrial Stormwater	0.30	0.08	0.02	0.003	**
Load Allocation	295.09	79.48	21.42	2.95	**
Margin of Safety	33.21	9.15	2.67	0.61	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1%	3%	9%	41%	**
Communities Subject to MS4 NPDES Requirements	0.3%	0.3%	0.3%	0.2%	**
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	<0.1%	**
Load Allocation	89%	87%	80%	48%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Table 4.14.
** See Section 4.3 for allocations for these specific categories in these flow zones.

The load duration curve (Figure 4.10) for the available dataset indicates exceedence of the target between the mid-range and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately 60 percent under high flows, 90 percent under moist conditions, and 40 percent under mid-range flows and dry conditions. TSS concentration is negatively correlated with the flow duration interval, indicating that higher flow rates produced higher turbidity. Significantly, higher TSS concentrations were observed during the highest 20th percentile flow rates.

Figure 4.10. Total suspended solids load duration curve (AUID: 07100001-541).



4.4.9 Elk Creek; Headwaters to Okabena Cr (AUID: 07100001-507)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 61 square miles. The listed reach exists within the Coteau agroecoregion, previously described, and Nobles County. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are row cropland and streambank/bed erosion and, to a lesser extent, overgrazed pasture and inadequate buffers near streams and waterways. There are significant stretches of the Elk Creek that have been channelized.

There are no wastewater treatment facilities within the land area that drains to this listed reach. There is approximately 0.4 square miles of the city of Worthington that drains to this listed reach, which is subject to Stormwater MS4 NPDES permit requirements.

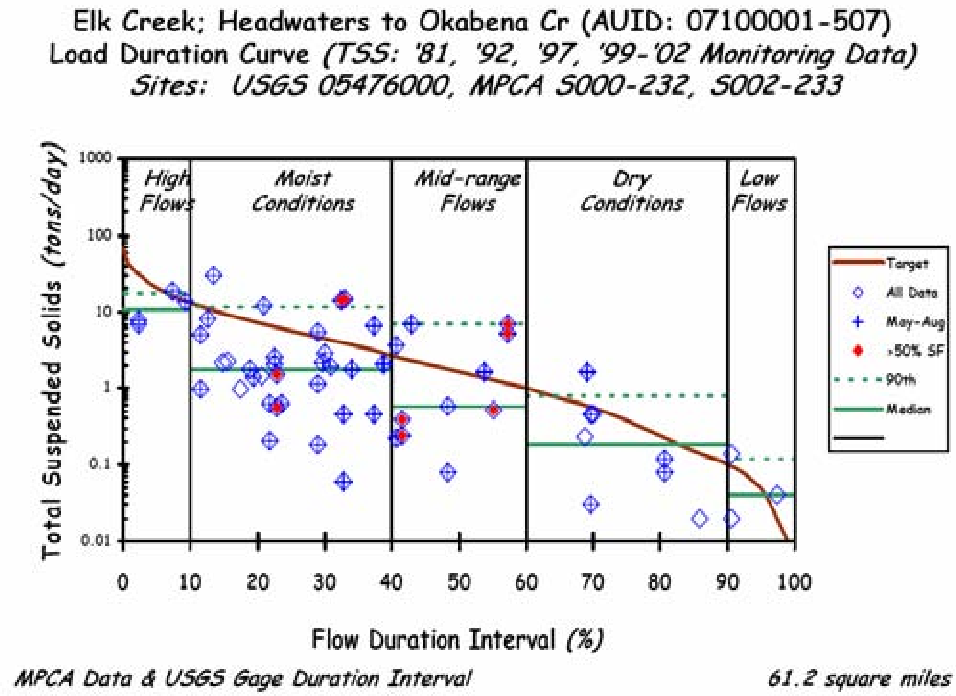
Table 4.16 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 62 mg/L (from Table 4.1). Because this reach has not been monitored for flow, the flow data from the USGS gage at Jackson was used to develop the loading capacities (same gage and flow record as was used for AUID: 07100001-501) because it was the only flow gaging record that corresponded with the Elk Creek sampling record.

TABLE 4.16. Total suspended solids loading capacities and allocations (AUID: 07100001-507).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	20.22	5.57	1.63	0.37	0.05
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	0.11	0.03	0.009	0.002	<0.001
Construction and Industrial Stormwater	0.02	0.005	0.001	<0.001	<0.001
Load Allocation	18.06	4.98	1.45	0.33	0.04
Margin of Safety	2.02	0.56	0.16	0.04	0.005
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	1%	1%	1%	1%	1%
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	0.1%
Load Allocation	89%	89%	89%	89%	89%
Margin of Safety	10%	10%	10%	10%	10%

The load duration curve (Figure 4.11) for the available dataset indicates exceedence of the target between the moist conditions and low flows that have been estimated. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately 50 percent under moist and dry conditions, 75 percent under mid-range flows and 60 percent under low flows. The observed TSS concentration has a strong positive correlation with storm flow percentage and runoff events that produced larger one-day increases in flow resulted in significantly higher TSS concentrations.

Figure 4.11. Total suspended solids load duration curve (AUID: 07100001-507).



4.4.10 Okabena Creek; Elk Cr to South Heron Lk (AUID: 07100001-506)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 133 square miles. The listed reach exists within the Poorly Drained Blue Earth Till and Coteau agroecoregions, previously described, and Jackson and Nobles Counties. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are row cropland and streambank/bed erosion and, to a lesser extent, algae, overgrazed pasture and inadequate buffers near streams and waterways.

There are four wastewater treatment facilities and a cooling water discharge within the land area that drains to this listed reach (Table 4.17). There is approximately 3.6 square miles of the city of Worthington that drains to this listed reach, which is subject to Stormwater MS4 NPDES permit requirements.

Table 4.18 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 62 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2003-2006 from the USGS gage (#5474915) near the downstream portion of the listed reach and flow estimated from the USGS gage at Jackson for the time period between 1992 and 2003.

TABLE 4.17. Wastewater treatment facilities and associated WLAs (AUID: 07100001-506).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Brewster	MN0021750	*	356
Worthington Industrial	MN0031178	2.04	232
Worthington Municipal	MN0031186	4.00	454
Okabena	MN0050288	*	42
Hubbard Feeds Inc.	MN0033375	0.01	1

* - Seasonal discharge.

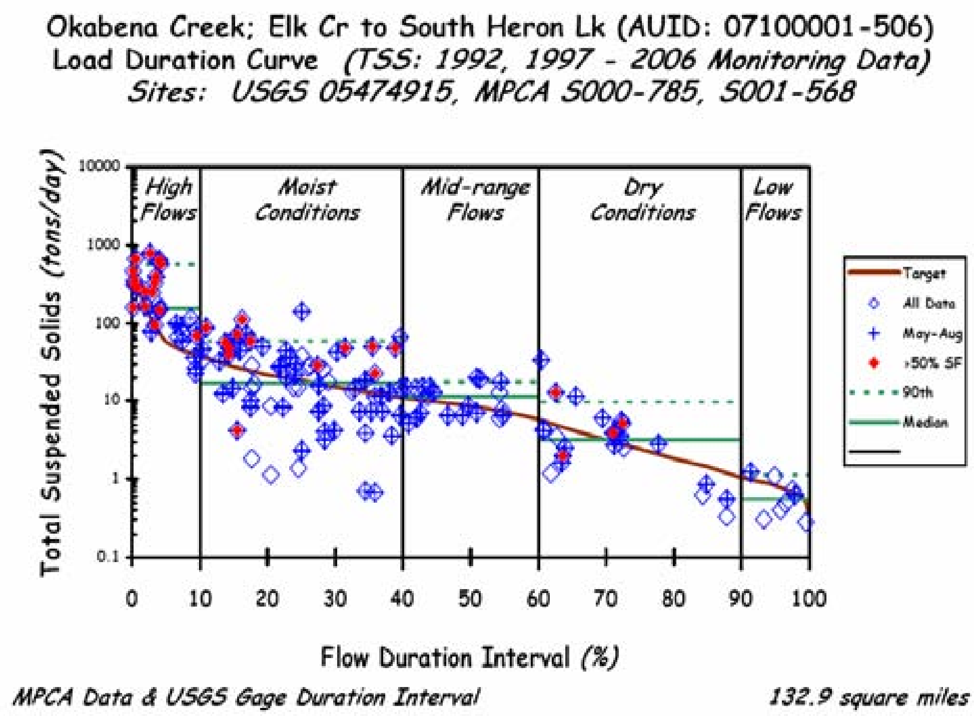
TABLE 4.18. Total suspended solids loading capacities and allocations (AUID: 07100001-506).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	58.41	18.24	8.79	2.38	0.84
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1.20	1.20	1.20	1.20	**
Communities Subject to MS4 NPDES Requirements	1.35	0.40	0.18	0.02	**
Construction and Industrial Stormwater	0.05	0.02	0.007	0.001	**
Load Allocation	49.97	14.80	6.53	0.92	**
Margin of Safety	5.84	1.82	0.88	0.24	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	2%	7%	14%	50%	**
Communities Subject to MS4 NPDES Requirements	2.3%	2.2%	2.0%	1.0%	**
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	<0.1%	**
Load Allocation	86%	81%	74%	39%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Table 4.17.
** See Section 4.3 for allocations for these specific categories in these flow zones.

The load duration curve (Figure 4.12) for the available dataset indicates exceedence of the target between the dry conditions and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately 90 percent under high flows, 70 percent under moist conditions, 50 percent under mid-range flows, 75 percent under dry conditions, and 25 percent under low flows. TSS concentration is negatively correlated with the flow duration interval, indicating that higher flow rates produced higher turbidity. A large proportion of samples that exceeded the target were collected following significant (greater than 50 percent) stormwater runoff. In particular, TSS concentration is positively correlated with storm flow percentage.

Figure 4.12. Total suspended solids load duration curve (AUID: 07100001-506).



4.4.11 Jack Creek, North Branch; Headwaters to Jack Cr (AUID: 07100001-505)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 70 square miles. The listed reach exists within the Inner Coteau and Coteau agroecoregions, previously described, and Nobles and Murray Counties. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are row cropland and streambank/bed erosion and, to a lesser extent, overgrazed pasture and inadequate buffers near streams and waterways.

There are no wastewater treatment facilities within the land area that drains to this listed reach. Table 4.19 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 57 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from

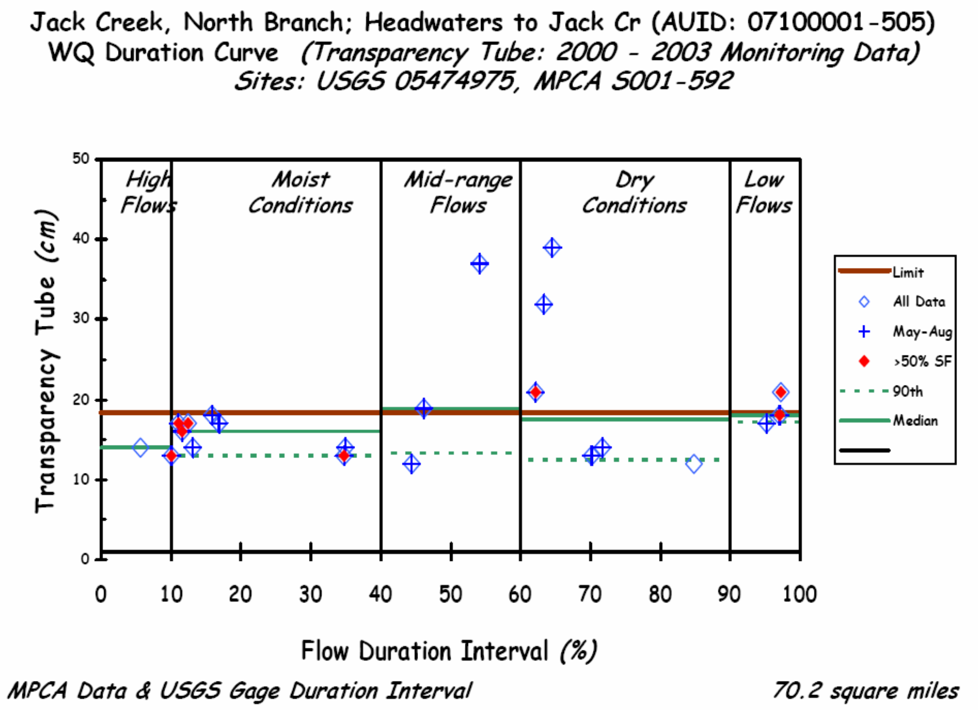
1987-1994 and 2003-2006 from USGS gage #5474975 near the downstream portion of the listed reach and flow estimated from the USGS gage at Jackson for the time period between 2000 and 2002.

TABLE 4.19. Total suspended solids loading capacities and allocations (AUID: 07100001-505).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	31.01	7.80	3.23	0.69	0.14
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.03	0.007	0.003	0.001	<0.001
Load Allocation	27.88	7.02	2.91	0.62	0.13
Margin of Safety	3.10	0.78	0.32	0.07	0.01
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	0.1%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

The transparency tube duration curve (Figure 4.13) for the available dataset indicates noncompliance throughout the flow regime. The estimated load reduction to achieve the TSS (and turbidity/transparency tube) standard is approximately 20 percent under high flows, 30 percent under moist conditions, mid-range flows and dry conditions. The transparency tube 25 NTU-equivalent of 18 cm is based on the turbidity-transparency tube regression for the WFDMR watershed data described in the 2003 Diagnostic Study completed for the WFDMR Watershed CWP Project. (Note: for transparency tube data there is an inverse relationship to turbidity, meaning that lower numbers correspond to higher turbidity.)

Figure 4.13. Transparency tube reading duration curve (AUID: 07100001-505).



4.4.12 Jack Creek; JD 26 to Heron Lk (AUID: 07100001-509)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 205 square miles. The listed reach exists within the Poorly Drained Blue Earth Till agroecoregion, previously described, and Jackson County. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are row cropland and streambank/bed erosion and, to a lesser extent, overgrazed pasture and inadequate buffers near streams and waterways.

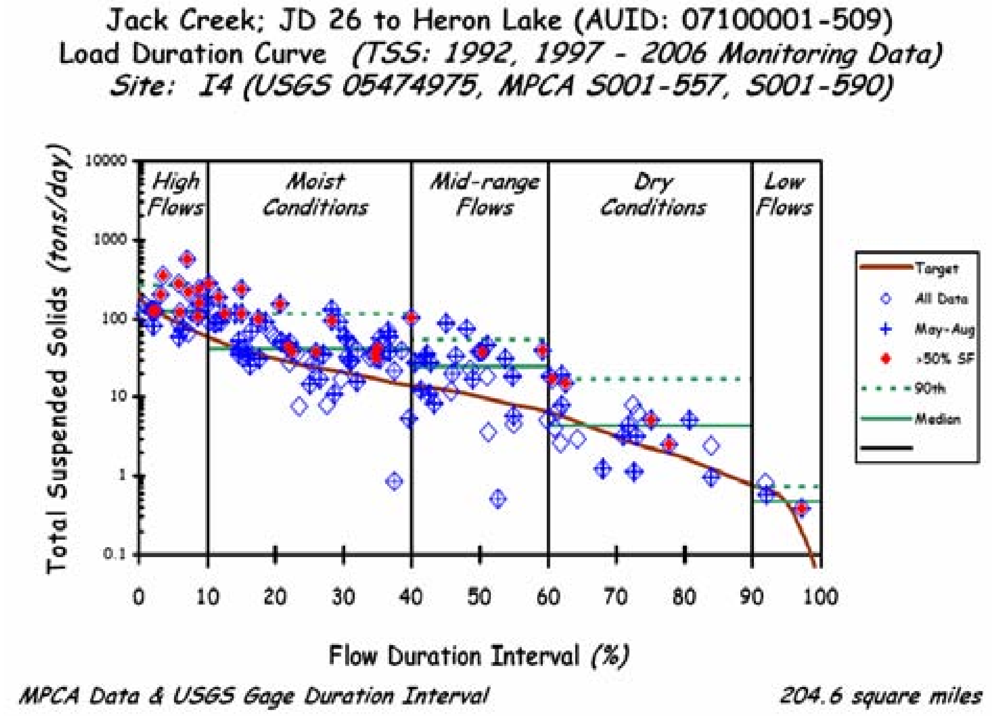
There are no wastewater treatment facilities within the land area that drains to this listed reach. Table 4.20 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 59 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 1987-1994 and 2003-2006 from USGS gage #5474975 near the downstream portion of the listed reach and flow estimated from the USGS gage at Jackson for the time period between 1997 and 2002.

TABLE 4.20. Total suspended solids loading capacities and allocations (AUID: 07100001-509).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	95.65	24.07	9.97	2.13	0.45
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.09	0.02	0.01	0.002	<0.001
Load Allocation	86.00	21.65	8.96	1.91	0.40
Margin of Safety	9.56	2.41	1.00	0.21	0.05
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	NA	NA	NA	NA	NA
Communities Subject to MS4 NPDES Requirements	NA	NA	NA	NA	NA
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	0.1%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

The load duration curve (Figure 4.14) for the available dataset indicates exceedence of the target between the dry conditions and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately 65 percent under high flows, 80 percent under moist conditions and mid-range flows, 90 percent under dry conditions, and 40 percent under low flows. A large proportion of samples that exceeded the target were collected following significant (greater than 50 percent) stormwater runoff. In particular, TSS concentration is positively correlated with storm flow percentage. Also, runoff events that produced larger one-day increases in flow resulted in significantly higher TSS concentrations.

Figure 4.14. Total suspended solids load duration curve (AUID: 07100001-509).



4.4.13 Division Creek; Heron Lk to Okabena Cr (AUID: 07100001-529)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 206 square miles. The listed reach exists within the Poorly Drained Blue Earth Till agroecoregion, previously described, and Jackson County. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are algae and, to a lesser extent, carp, row cropland and streambank/bed erosion.

There are five wastewater treatment facilities and a cooling water discharge within the land area that drains to this listed reach (Table 4.21). There is approximately four square miles of the city of Worthington that drains to this listed reach, which is subject to Stormwater MS4 NPDES permit requirements.

Table 4.22 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 62 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2003-2006 from USGS gage #5475000 near the downstream portion of the listed reach and flow estimated from the USGS gage at Jackson for 2002.

TABLE 4.21. Wastewater treatment facilities and associated WLAs (AUID: 07100001-529).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Brewster	MN0021750	*	356
Worthington Industrial	MN0031178	2.04	232
Worthington Municipal	MN0031186	4.00	454
Okabena	MN0050288	*	42
Hubbard Feeds Inc.	MN0033375	0.01	1
Lakefield	MN0020427	0.58	99

* - Seasonal discharge.

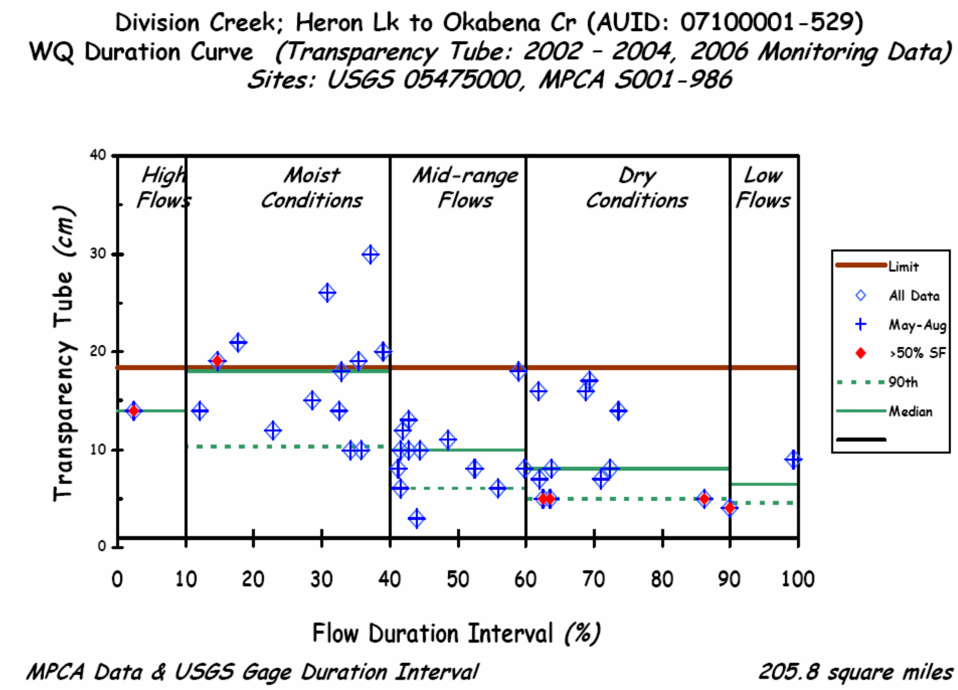
TABLE 4.22. Total suspended solids loading capacities and allocations (AUID: 07100001-529).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	63.78	26.96	14.91	3.29	0.03
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1.30	1.30	1.30	1.30	**
Communities Subject to MS4 NPDES Requirements	1.09	0.45	0.24	0.03	**
Construction and Industrial Stormwater	0.06	0.02	0.01	0.002	**
Load Allocation	54.95	22.49	11.87	1.62	**
Margin of Safety	6.38	2.70	1.49	0.33	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	2%	5%	9%	40%	**
Communities Subject to MS4 NPDES Requirements	1.7%	1.7%	1.6%	1.0%	**
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	**
Load Allocation	86%	83%	80%	49%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Table 4.21.
** See Section 4.3 for allocations for these specific categories in these flow zones.

The transparency tube duration curve (Figure 4.15) for the available dataset indicates noncompliance between the dry conditions and high flows that have been recorded. The estimated load reductions necessary to achieve the TSS (and turbidity/transparency tube) standard is approximately 20 percent under high flows, 40 percent under moist conditions, 70 percent under mid-range flows and dry conditions, and 75 percent under low flows. The transparency tube 25 NTU-equivalent of 18 cm is based on the turbidity-transparency tube regression for the WFDMR watershed data described in the 2003 Diagnostic Study completed for the WFDMR Watershed CWP Project. A larger proportion of samples that did not comply with the transparency tube target were collected under mid-range and dry flow conditions. In particular, the transparency tube reading is negatively correlated with the flow duration interval, indicating that lower flow rates produced higher turbidity from algae. (Note: for transparency tube data there is an inverse relationship to turbidity, meaning that lower numbers correspond to higher turbidity.)

Figure 4.15. Transparency tube reading duration curve (AUID: 07100001-529).



4.4.14 Heron Lake Outlet; Heron Lk to Des Moines R (AUID: 07100001-527)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 467 square miles. The listed reach exists within the Poorly Drained Blue Earth Till agroecoregion, previously described, and Jackson County. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are algae and, to a lesser extent, carp, wind resuspension within Heron Lake, and row cropland and streambank/bed erosion from the Heron Lake watershed.

There are six wastewater treatment facilities and a cooling water discharge within the land area that drains to this listed reach (Table 4.23). There is approximately four square miles of the city of Worthington that drains to this listed reach, which is subject to Stormwater MS4 NPDES permit requirements.
Table 4.24 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration

equivalent to 25 NTU used for these calculations was 59 mg/L (from Table 4.1). The loading capacities for the five flow zones were developed using flow data from 2003-2006 from USGS gage #5475000 near the downstream portion of the listed reach and flow estimated from the USGS gage at Jackson for the time period between 1992 and 2002.

TABLE 4.23. Wastewater treatment facilities and associated WLAs (AUID: 07100001-527).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Brewster	MN0021750	*	356
Worthington Industrial	MN0031178	2.04	232
Worthington Municipal	MN0031186	4.00	454
Okabena	MN0050288	*	42
Hubbard Feeds Inc.	MN0033375	0.01	1
Lakefield	MN0020427	0.58	99
Heron Lake	MN0023655	*	131

* - Seasonal discharge.

TABLE 4.24. Total suspended solids loading capacities and allocations (AUID: 07100001-527).

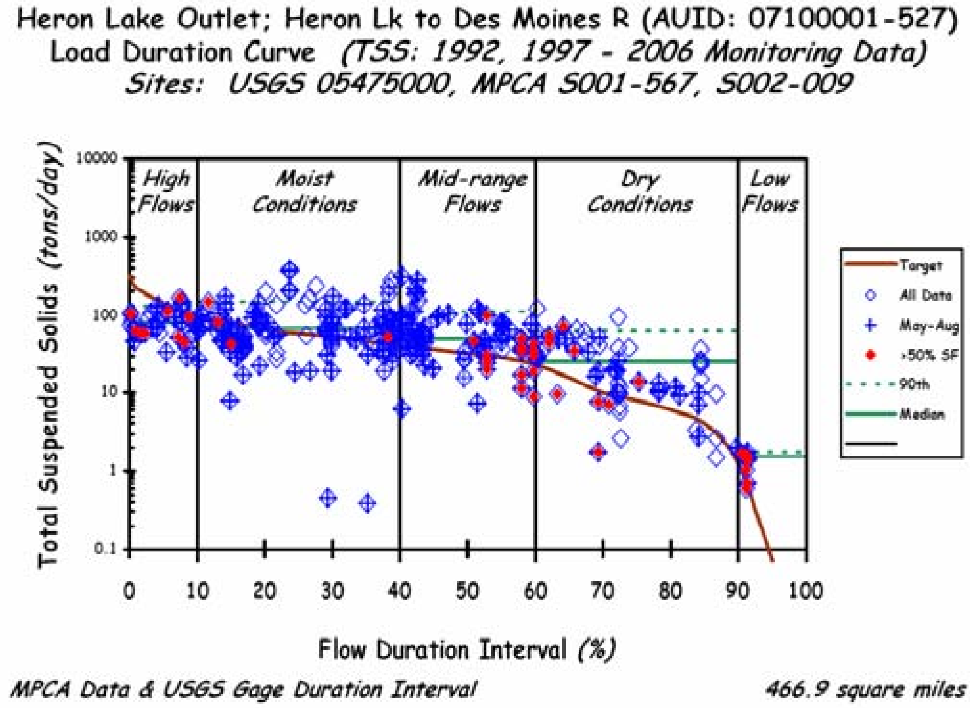
	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	137.69	58.21	32.20	7.10	0.07
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1.45	1.45	1.45	1.45	**
Communities Subject to MS4 NPDES Requirements	1.05	0.44	0.24	0.04	**
Construction and Industrial Stormwater	0.12	0.05	0.03	0.005	**
Load Allocation	121.30	50.45	27.26	4.89	**
Margin of Safety	13.77	5.82	3.22	0.71	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1%	2%	4%	20%	**
Communities Subject to MS4 NPDES Requirements	0.8%	0.7%	0.7%	0.6%	**
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	**
Load Allocation	88%	87%	85%	69%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Table 4.23.
** See Section 4.3 for allocations for these specific categories in these flow zones.

The load duration curve (Figure 4.16) for the available TSS dataset indicates noncompliance between the moist conditions and low flows that have been recorded. The estimated load reductions necessary to achieve the TSS standard is approximately

60 percent under moist conditions, 70 percent under mid-range flows, 90 percent under dry conditions, and 95 percent under low flows. A larger proportion of samples that did not comply with the target were collected under mid-range and dry flow conditions. In particular, the TSS concentrations are positively correlated with the flow duration interval, indicating that lower flow rates produced higher turbidity from algae.

Figure 4.16. Total suspended solids load duration curve (AUID: 07100001-527).



4.4.15 Des Moines River; JD 66 to IA border (AUID: 07100002-501)

This reach was added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was monitoring conducted under the WFDMR Watershed CWP Project.

The drainage area to the downstream end of this impaired reach is about 1334 square miles. The listed reach exists within the Dryer Blue Earth Till agroecoregion, previously described, and Jackson County. Based on the analysis provided in Section 4.2, primary sources contributing TSS within this area are algae, row cropland and streambank/bed erosion and, to a lesser extent, inadequate buffers near streams and waterways.

There are 12 wastewater treatment facilities, a water treatment facility, and a cooling water discharge within the land area that drains to this listed reach (Table 4.25). There also is four square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 4.26 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS. The TSS concentration equivalent to 25 NTU used for these calculations was 66 mg/L (from Table 4.1). Because this reach has not been monitored for flow, the flow data from the USGS gage upstream of the listed reach was used to develop the loading capacities (same gage and flow record as was used for AUID: 07100001-501).

TABLE 4.25. Wastewater treatment facilities and associated WLAs (AUID: 07100002-501).

Facility	NPDES Permit #	Discharge, mgd	WLA, kg/day
Lake Wilson	MNG580061	*	87
Slayton	MN0024911	*	345
Fulda	MN0023507	*	150
Currie	MN0025682	*	158
Brewster	MN0021750	*	356
Worthington Industrial	MN0031178	2.04	232
Worthington Municipal	MN0031186	4.00	454
Okabena	MN0050288	*	42
Hubbard Feeds Inc.	MN0033375	0.01	1
Lakefield	MN0020427	0.58	99
Heron Lake	MN0023655	*	131
Red Rock Rural WTP	MNG640077	0.25	28
Windom	MN0022217	1.83	208
Jackson	MNG580063	*	1330

* - Seasonal discharge.

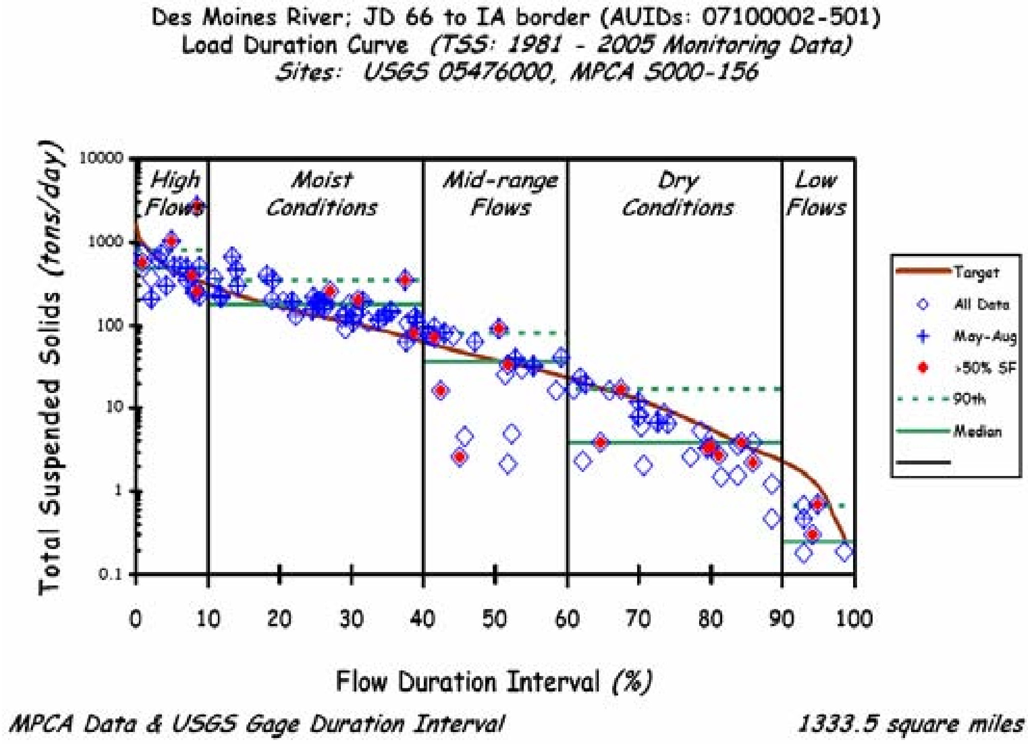
TABLE 4.26. Total suspended solids loading capacities and allocations (AUID: 07100002-501).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY L0ADING CAPACITY	471.14	129.80	37.88	8.65	1.13
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	3.99	3.99	3.99	3.99	**
Communities Subject to MS4 NPDES Requirements	1.25	0.34	0.09	0.01	**
Construction and Industrial Stormwater	0.42	0.11	0.03	0.004	**
Load Allocation	418.36	112.38	29.98	3.78	**
Margin of Safety	47.11	12.98	3.79	0.87	Implicit
	Percent of total daily loading capacity				
TOTAL DAILY L0ADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities*	1%	3%	11%	46%	**
Communities Subject to MS4 NPDES Requirements	0.3%	0.3%	0.2%	0.1%	**
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	<0.1%	**
Load Allocation	89%	87%	79%	44%	**
Margin of Safety	10%	10%	10%	10%	Implicit

* The individual facilities are listed in Table 4.25.
** See Section 4.3 for allocations for these specific categories in these flow zones.

The load duration curve (Figure 4.17) for the available dataset indicates exceedence of the target between the dry conditions and high flows that have been recorded. The estimated load reduction to achieve the TSS (and turbidity) standard is approximately 40 percent under high flows, 60 percent under moist conditions, 55 percent under mid-range flows and 50 percent under dry conditions. TSS concentration is negatively correlated with the flow duration interval, indicating that higher flow rates produced higher turbidity, while the sample TSS concentrations were positively correlated with one-day increases in flow rate.

Figure 4.17. Total suspended solids load duration curve (AUID: 07100002-501).



4.5 Overall Conclusions from Turbidity-Related Monitoring and Required Load Reductions

Some of the conclusions to be drawn from the project monitoring experience, data and assessments discussed in Sections 4.1, 4.2 and Sections 4.4.1 through 4.4.15 are the following:

- Based on the available data the turbidity impairment in the watershed appears to be "significant" when viewed across the entire sampling season. A majority of the time turbidity readings are above the standard; however, some site differences do exist.
- There is a significant increasing trend in the long-term water yield from the WFDMR watershed at Jackson. Approximately 40 percent of this increasing trend can be attributed to anthropogenic changes, which has significant implications for sediment delivery and streambank erosion within the watershed.
- In general, the long-term dataset for TSS and turbidity indicates no significant increasing or decreasing trend. The turbidity data from the Heron Lake Outlet has a statistically significant decreasing trend since 1999, likely due to decreasing phosphorus loadings to Heron Lake from the wastewater treatment facilities. There are significant increasing trends for turbidity in the WFDMR discharge from the Shetek Lake outlet, as well as the USGS gage site at Jackson, since 2001.

- Primary sources contributing TSS within this watershed are likely streambank/bed erosion, row cropland, algae and, to a lesser extent, carp, overgrazed pasture and inadequate buffers near streams and waterways. Algae contributions to turbidity are likely more important in both the Shetek and Heron Lake outflows and Division Creek, as well as the WFDMR from the Heron Lake outlet to the Jackson dam.
- Loading via runoff is suggested by storm event samples at several sites that consistently showed high loading contributions during higher flows, even during the late-season. In Lime Creek, in particular, the samples collected between May and August generally had higher TSS concentrations than the samples collected outside of the summer months. This corresponds with the results of a RUSLE2 simulation of a corn-soybean rotation in loam soils in southwest Minnesota which shows that the soil loss rates, on a long-term basis, are highest between May and August. Some of the increased late-season turbidity could also be due to increased algae growth in the heat of the summer. This was particularly true of Division Creek, the Heron Lake outlet and the WFDMR between the Heron Lake outlet and Windom dam.
- Flow data indicates flashy hydrology in the headwater portions of the watershed—flow rises sharply following significant rain and then decreases rapidly. As a result, a large proportion of the samples that exceeded the target TSS concentrations were collected following significant (greater than 50 percent) stormwater runoff. In general, sample TSS concentration was positively correlated with storm flow percentage and/or one-day increases in flow rate in several main stem portions of the WFDMR watershed, as well as the headwater reaches. In contrast, higher sample TSS concentrations occurred under lower flow conditions at Division Creek, Heron Lake outlet and WFDMR between the Heron Lake outlet and the Windom dam.
- An estimate for an overall load reduction percentage can be made using the existing dataset. To do so it makes sense to consider the listing/delisting criteria for turbidity, which is based on whether or not ten percent of the data points within a dataset exceed the 25 NTU standard. Therefore, to meet the standard 90 percent of the time would mean reducing the 90^{th} percentile value from the dataset down to 25 NTU. Based on the monitoring data, it is estimated that the overall magnitude of reduction needed to the meet the turbidity standard for each impaired reach is between 50 and 80 percent, based on an average of all flow duration intervals. This reduction percentage is only intended as a rough approximation, as it does not account for flow, and is not a required element of a TMDL. It serves to provide a starting point based on available water quality data for assessing the magnitude of the effort needed in the watershed to achieve the standard. This reduction percentage does not supersede the allocations provided for each flow duration interval.

4.6 Critical Conditions and Seasonal Variation

The EPA definition of “critical conditions” was provided in Section 3.5. Turbidity levels are generally at their worst following significant storm events during the spring and summer months, as described in Section 4.1. This section also addressed seasonal variation, which was somewhat more difficult to generalize given reach-specific differences. Regardless, such conditions and variation are fully captured in the duration curve methodology used in this TMDL.

4.7 Consideration of Growth on TMDL

Regarding population changes and contributions from industrial discharges, flows at some wastewater treatment facilities are likely to increase over time with increases in the population they serve. This is not likely to have an impact on any of the impaired reaches provided discharge limits are met. This is because increased flows from wastewater treatment facilities add to the overall loading capacity by increasing river flows.

The allocations for nonpoint sources are for all current *and* future sources. This means that any expansion of nonpoint sources will need to comply with the LA provided in this report. Additional nonpoint sources (e.g., shifting grassland to row cropland) could very well make meeting the TMDL more difficult over time. Therefore, continued efforts over time to prevent soil/sediment delivery to the stream will be critical.

5.0 NORTH AND SOUTH HERON LAKE EXCESS NUTRIENTS AND pH IMPAIRMENTS

It should be noted that when North and South Heron Lakes were originally placed on the 303(d) list of impaired waters in 2002 they were listed together simply as “Heron Lake” with lake ID 32-0057-00. On the 2008 list these lakes are listed separately as “Heron (North Heron)” with lake ID 32-0057-05 and “Heron (South Heron)” with lake ID 32-0057-07. In addition, the water bodies known as the North Marsh and Duck Lake are now shown on the 2008 list as “Heron (North Marsh)” and “Heron (Duck)”. This TMDL study is limited to the nutrient impairments on North and South Heron Lake only based on the scope of the original contracting for this project and the availability of data for lake modeling. Also, because of the interrelationships between North and South Heron Lakes they are combined into one modeling effort and set of TMDL allocations.

5.1 Surface Water Quality Conditions for Excess Nutrients

Excessive total phosphorus (TP) loads lead to increased algae blooms and reduced transparency – each of which may significantly impair or prohibit the use of lakes for ecological and recreational use. The MPCA’s Citizen’s Board approved adoption of water quality rule amendments on December 18, 2007 that apply the following lake water quality criteria for excess nutrients to be met on an average summer (June-September) basis for shallow lakes (maximum depth less than 15 feet) in the Western Corn Belt Plains (WCBP) ecoregion (which includes the Heron Lake watershed): TP concentration less than or equal to 90 µg/L, chlorophyll-*a* concentration less than or equal to 30 (32 is the criteria for making the impaired waters list as mentioned earlier in this document) µg/L, and Secchi disc transparency greater than or equal to 0.7 meters (2.3 feet). Both North Heron Lake and South Heron Lake are shallow lakes; North Heron Lake is less than five feet deep, while South Heron Lake does not exceed 12 feet deep.

Problems associated with these lakes include severe algae blooms, loss of rooted aquatic vegetation, loss of migratory waterfowl, rough fish impacts, water clarity, and flooding. Historical information suggests that both basins were originally a macrophyte dominated system; whereas, they are now dominated by algae. Both lake basins are listed as impaired based on excessive nutrient levels. Water quality monitoring data collected in 1992 in the Heron Lake watershed (as summarized in the Middle Des Moines Watershed Restoration Project Diagnostic Study, 1995) indicated North and South Heron Lakes to be in a hypereutrophic state due to loading of TP from point and nonpoint sources. TP levels were well in excess of Western Corn Belt Plains Ecoregion norms. This TMDL project directly addresses the reduction of total phosphorus and chlorophyll-*a* which will consequently improve Secchi depth measurements. The return of aquatic plants will require an improvement in the trophic status of the lake along with minimizing water level fluctuations and control of rough fish. The mechanisms required to “switch” the lake to a clear state dominated by macrophytes is evident, but not fully understood in Minnesota at this time (MPCA, 2005). The BATHTUB model does not predict the recovery of vegetation, but can be used to predict TP, chlorophyll-*a*, and Secchi depth.

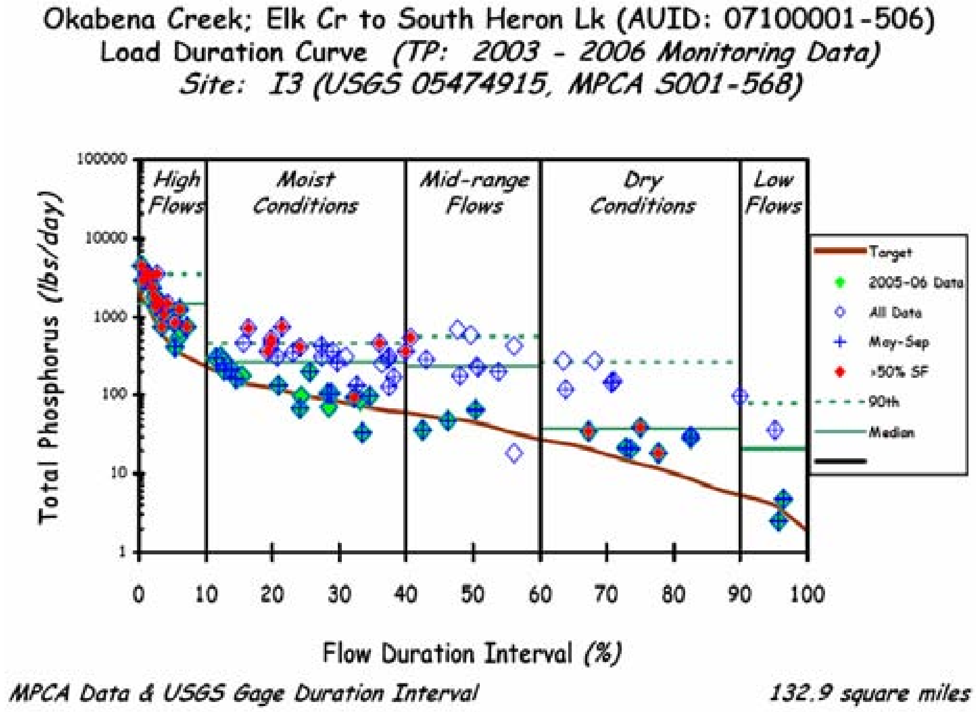
More recent monitoring show even higher TP levels—the summer averages of TP from 1997-2002 for North Heron Lake and South Heron Lake are 558 μg/L and 689 μg/L, respectively. In April, 2002 and October, 2004, the respective Worthington Municipal and Industrial WWTPs began attainment of the 1 mg/L TP discharge limit for their discharges to Okabena Creek and ultimate delivery to Heron Lake. This resulted in slight improvements in water quality as Table 5.1 shows that the summer averages of TP from 2006 for North Heron Lake and South Heron Lake were 358 μg/L and 507 μg/L, respectively. The current TP, chlorophyll-*a* and Secchi disc transparency data still fall considerably short of the respective water quality standards for the Western Corn Belt Plains ecoregion. The higher late-season TP concentrations indicate that internal phosphorus loading is a significant contributor in both lake basins. Based on the 2006 average water quality data, the respective Carlson TSI (Carlson, 1977) values calculated for TP, chlorophyll-*a* and Secchi disc transparency are 89, 79, and 79 for North Heron Lake and 94, 78, and 82 for South Heron Lake. This data indicates that the TP concentrations in both lake basins would support significantly worse water quality than what exists for chlorophyll-*a* and Secchi disc transparency. This is likely due to self-shading provided by the high algal populations and/or high turbidity from inorganic solids in each basin.

TABLE 5.1. 2006 Heron Lake Water Quality Monitoring Data.

	Date mm/dd/yy	Secchi (ft)	TSS mg/L	TURB NTU	CHL-a ug/L	TP mg/L	OP mg/L	TKN Mg/L	VSS mg/L
South Heron Lake	5/31/2006	1.2	32	20	88	0.117	0.003	2.9	27
	6/13/2006	0.92	52	44		0.196	0.024	2.7	34
	8/21/2006	0.5	104	93	149	0.718	0.114	8.3	86
	9/13/2006	0.25	200	180	141	0.995	0.124	9.8	112
North Heron Lake	5/31/2006	1	34	21	122	0.127	0.022	3.3	29
	6/13/2006	0.58	75	82	108	0.446	0.035	4.9	51
	7/20/2006	1.08	9	7		0.180	0.095	1.6	6
	8/22/2006	1.5	120	81	196	0.483	0.092	4.4	48
	9/13/2006	0.25	180	73	156	0.554	0.066	5.6	112

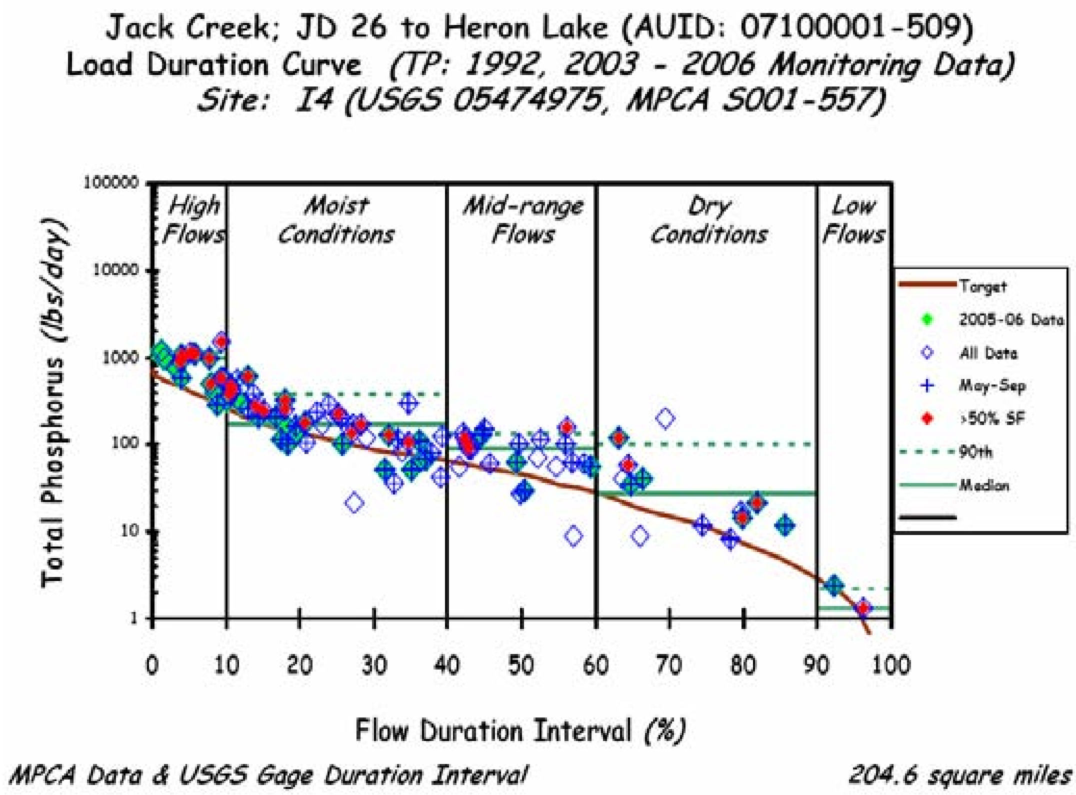
The load duration curve (Figure 5.1) for the available Okabena Creek TP dataset indicates exceedence of the target load throughout the recorded flow regimes, with flow monitoring typically occurring between April and October each year. The target is consistent with the total daily loading capacity for meeting the 90 μg/L TP standard in both North and South Heron Lake. Figure 5.1 also shows that there are proportionally higher exceedances of the target TP loading under lower flows when considering the data prior to 2005. The 2005 and 2006 data shows that the TP concentrations in Okabena Creek dropped significantly (99% confidence level) between the low flows and moist conditions flow duration intervals when compared to the older monitoring data.

Figure 5.1. Total phosphorus load duration curve (AUID: 07100001-506).



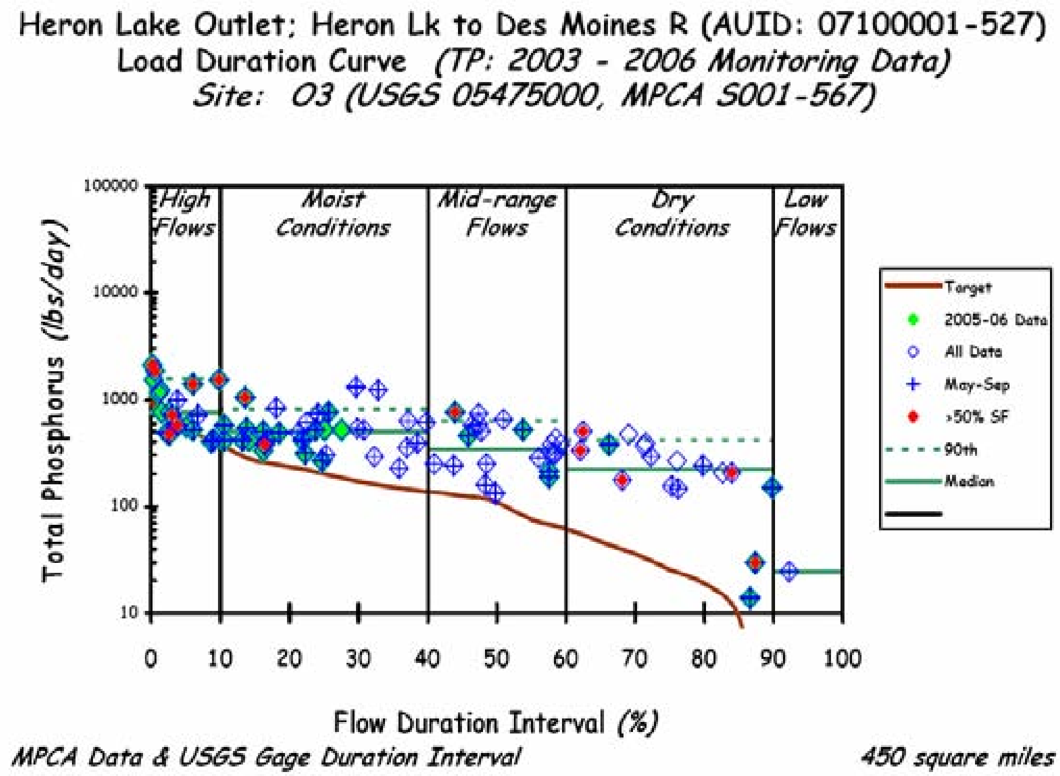
The load duration curve (Figure 5.2) for the available Jack Creek TP dataset indicates exceedence of the target load throughout the recorded flow regimes. A large proportion of samples that exceeded the target were collected following significant (greater than 50 percent) stormwater runoff. In particular, TP concentration is positively correlated with storm flow percentage. Also, runoff events that produced larger one-day increases in flow resulted in significantly higher TP concentrations. There is no significant time trend (90% confidence level or higher) for the Jack Creek TP concentrations during the period of record.

Figure 5.2. Total phosphorus load duration curve (AUID: 07100001-509).



The load duration curve (Figure 5.3) for the available Heron Lake outlet TP dataset indicates exceedence of the target load throughout the recorded flow regimes. Figure 5.3 also shows that there are proportionally higher exceedances of the target TP loading under lower flows. TP concentration is positively correlated with storm flow percentage. Also, runoff events that produced larger one-day increases in flow resulted in significantly higher TP concentrations during 2005 and 2006. Unlike Okabena Creek, where the 2005 and 2006 data (Figure 5.1) shows that the TP concentrations dropped significantly when compared to the older monitoring data, Figure 5.3 shows that the TP concentrations in the flow out of the Heron Lake system were not significantly lower in 2005 and 2006 than prior years (less than 90% confidence level). This indicates that internal phosphorus loading continues to be a significant problem for Heron Lake. Under current conditions, internal phosphorus loading to North and South Heron Lake represents a larger source of phosphorus (more than 75 percent overall) than the watershed loading to the lakes during the growing season. The BATHTUB model does not allow us to predict future reductions in internal loading after implementation of external load reductions.

Figure 5.3. Total phosphorus load duration curve (AUID: 07100001-527).



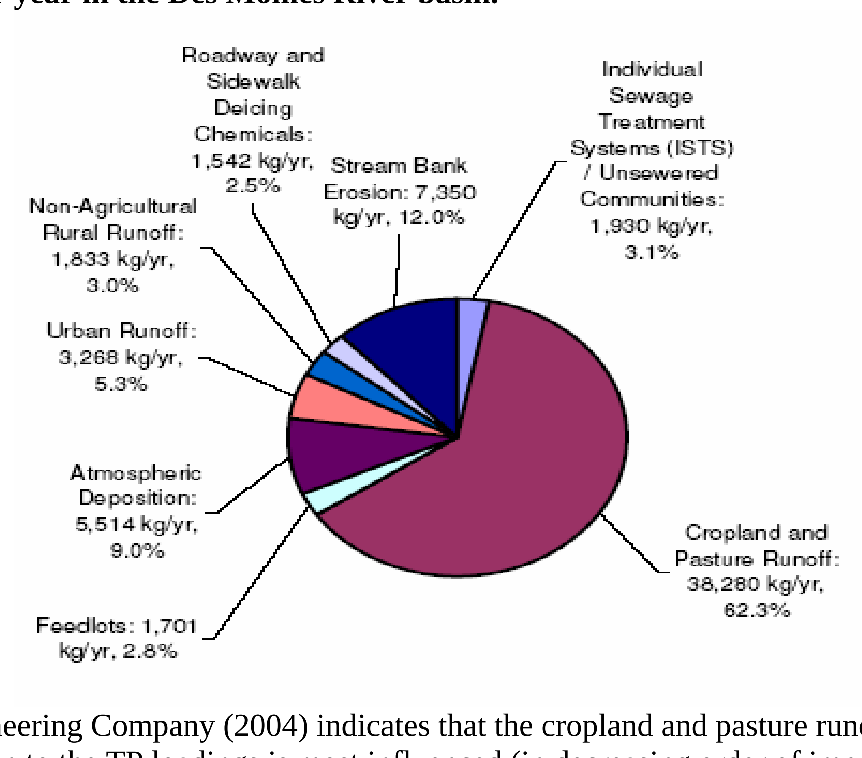
5.2 Phosphorus Sources and Current Contributions

Conclusions regarding phosphorus sources and estimates of current loading are based on: 1) analyzing/interpreting the water quality data presented in the previous section and other available data and information, and 2) simple modeling to estimate in-lake and watershed sources and delivery of phosphorus to the surface waters in the watershed. This modeling is described in further detail in Section 5.3. It represents a means to roughly approximate the magnitude of the current loadings of the various phosphorus source categories. Section 4.2 also describes the interrelationship between phosphorus sources and turbidity. The following sections provide estimates of relative contribution and further discussion of these sources.

As discussed in Section 3.2, most of the watershed's population and a significant portion of the commercial and industrial dischargers are serviced by wastewater treatment facilities. Currently, the Brewster, Worthington Industrial and Worthington Municipal wastewater treatment plants (WWTPs) are the only facilities with discharge limits for phosphorus (1 mg/L monthly average maximum), but all of the facilities in the Heron Lake watershed (including Lakefield and Okabena) have Discharge Monitoring Report (DMR) data for TP. All five WWTPs discharge to South Heron Lake. The operation, location and other related information regarding the wastewater treatment facilities in the watershed was described in Section 3.0 and Table 3.3. A review of MPCA records since 1999 does not reveal any TP-related violations for the WWTPs.

The MPCA's Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (Barr Engineering Company, 2004) provided estimates for source contributions from both wastewater treatment facilities and other sources of phosphorus in the Minnesota portion of the Des Moines River Basin during dry, average and wet flow conditions. The relative contributions of the remaining phosphorus sources in this study are expected to be directly applicable to the Heron Lake watershed. The estimated relative TP contributions, other than WWTPs, during an average year (Figure 5.4) show that cropland and pasture runoff accounts for a significant portion of the TP load during an average year. Barr Engineering Company (2004) determined that SSTS (5.2%), urban runoff (7.6%), atmospheric deposition (12.5%), and agricultural runoff (67%) become more prominent sources of phosphorus during a dry year, while streambank erosion (33%) becomes more prominent during a wet year in the Des Moines River basin, compared to the percentages shown in Figure 5.4. As discussed in Section 4.2, there is an increasing trend in annual watershed yield that is expected to add significantly to the sediment loading (25% during an average year), as well as the streambank erosion TP loadings presented in the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (3% and 8% additional load for average and wet years, respectively).

Figure 5.4. Estimated non-WWTP total phosphorus contributions for an average flow water year in the Des Moines River basin.



Barr Engineering Company (2004) indicates that the cropland and pasture runoff contribution to the TP loadings is most influenced (in decreasing order of importance) by the soil erosion rate, the percentage of cropland and pasture within 300 feet of a watercourse (ditches, streams, lakes, wetlands, etc.), agricultural or commercial phosphorus fertilizer application rate, and manure application method. The Detailed Assessment of Phosphorus Sources to Minnesota Watersheds did not specifically account for the phosphorus load associated with surface and subsurface tile drainage in the

Des Moines River basin, but this phosphorus source is estimated to contribute 11 percent of the TP load in the adjacent Minnesota River basin during an average year, or about a quarter of the TP load coming from cropland and pasture runoff.

Point sources, for the purpose of this TMDL, are those facilities/entities that discharge or potentially discharge phosphorus to surface water or otherwise contribute to excess nutrients and require a water quality permit from the MPCA. In this watershed the potential point source categories are: permitted wastewater treatment facilities, construction stormwater requiring NPDES permits, industrial stormwater requiring NPDES permits, livestock facilities requiring NPDES permits, communities subject to MS4 NPDES permit requirements (City of Worthington), and “straight pipe” septic systems.

Regarding construction, the MPCA issues construction permits for any construction activities disturbing: one acre or more of soil; less than one acre of soil if that activity is part of a “larger common plan of development or sale” that is greater than one acre, or less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. Although stormwater runoff at construction sites that do not have adequate runoff controls can be significant on a per acre basis (MPCA Stormwater web page, 2006), 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 very minor phosphorus source.

Regarding municipal stormwater runoff, approximately 245 acres from the city of Worthington drains to Elk Creek while 2,315 acres drains to Okabena Creek from the city. The MS4 wasteload allocations presented in Section 5.4 are based on the Okabena Creek TP concentration that corresponds to a TP concentration of 90 μg/L in both Heron Lake basins.

Regarding industrial stormwater sources, there are four water discharge permit holders in the watershed according to the MPCA’s DELTA database. These do not appear to represent a TP loading concern in this watershed. (For the purpose of the TMDL this source is lumped with construction stormwater into a categorical WLA.)

Livestock facilities that have been issued NPDES permits are not allowed, as a condition of the permits, any pollutant discharge from the livestock housing facilities and associated sites. Discharge of phosphorus from fields where manure has been land-applied may occur at times. Such discharges are covered under the LA portion of the TMDLs, provided the manure is applied in accordance with the permit. (In this watershed nearly all of these NPDES permitted livestock facilities are confined swine operations.)

Straight-pipe septic systems are illegal and unpermitted, but do exist in the watershed, as discussed in Table 3.2. This information, combined with the information in Figure 5.4, indicates that inadequate SSTSs may be contributing a small portion of the phosphorus load to surface waters in the watershed.

Other sources of phosphorus loading to Heron Lake include internal sediment phosphorus release, wind resuspension, carp and other benthic feeders that stir up fine sediments. It is difficult to gage the relative impact of these internal sources, but under current conditions these sources as a whole represent a larger source of phosphorus than the watershed loading to the lakes. In the late 1990s, the Minnesota Department of Natural Resources (MDNR) removed more than 200,000 pounds of carp from Heron Lake. The current (1999) MDNR fisheries survey for South Heron Lake provides the following information:

- South Heron Lake is managed primarily for northern pike and secondarily for yellow perch.
- Common carp invaded the lake in 1918 and have made it difficult to maintain production of aquatic vegetation for northern pike spawning and for waterfowl foraging.
- A fish kill was conducted during the winter of 1997-98 with only partial success due in part to an unseasonable thaw which caused dilution of toxicant.
- Northern pike were first stocked in 1998. Stocking reports indicate that northern pike were also stocked in 1999 and 2006.
- Fishing for northern pike can be done on South Heron Lake but “catch and release” is encouraged.
- The common carp catch rate in 1999 was more than seven times the upper expected range.
- The black bullhead catch rate in 1999 was near the upper normal range.
- Common carp and black bullhead catch rates in 1999 were three times higher than the 1997 catch rates.

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

The TMDL developed for North and South Heron Lake in this report consist of three main components: WLA, LA, and MOS as defined in Section 1.0. The WLA includes six subcategories: Permitted wastewater treatment facilities, construction stormwater requiring NPDES permits, industrial stormwater requiring NPDES permits, livestock facilities requiring NPDES permits, communities subject to MS4 NPDES permit requirements (city of Worthington), and “straight pipe” septic systems. The LA, reported as a single category, includes nonpoint pollution sources that are not subject to NPDES permit requirements, as well as “natural background” sources such as wildlife. The nonpoint pollution sources are largely related to soil erosion, phosphorus fertilizer, manure application, tile drainage, atmospheric deposition, inadequate human wastewater treatment (non-straight-pipes), non-MS4 stormwater runoff, and internal loading.

The LA includes land-applied manure from livestock facilities requiring NPDES permits, provided the manure is applied in accordance with the permit. The third component, MOS, is the part of the allocation that accounts for uncertainty that the allocations will result in attainment of water quality standards.

The three components (WLA, LA, and MOS) were calculated as average total daily loads of total phosphorus (with the average being met over the summer [May-September] months). The methodology to derive and express these load components is based on determining the total loading capacity necessary to ensure that the 90 µg/L summer average total phosphorus concentration will be met in both Heron Lake basins. The following process was used to complete the various components of the modeling for use in setting the Heron Lake TMDL:

- The continuous flow and water quality grab sample data was used to complete FLUX modeling for the Okabena and Jack Creek tributary stations and the Heron Lake outlet. The 2006 data was chosen because it provided representative current-day loadings of the WWTPs in the watershed, there was corresponding in-lake monitoring data for four to five summer dates in each lake basin, and it was a wet year that produced higher TP concentrations from the nonpoint sources of runoff in the watershed.
- The 2006 DMR data was compiled for the four WWTPs in the watershed and subtracted from the FLUX modeling results to estimate the nonpoint TP source loadings in the Okabena Creek subwatershed.
- Since the unmonitored portion of the watershed more closely matches the watershed characteristics of the Okabena Creek subwatershed, the nonpoint TP loading rate from Okabena Creek was entered into the BATHTUB model for the unmonitored portions of the watershed.
- The BATHTUB model was set up for North and South Heron Lake, North Marsh, the watershed inputs, and calibrated to the available FLUX modeling and monitoring data.
- The calibrated BATHTUB model was run with the TP loading that is currently permitted for all of the WWTPs in the watershed to determine the necessary load reductions to meet the TMDL, based on the assumption that future growth would be accommodated by further reductions in the permitted effluent concentrations from wastewater treatment facilities.
- Five percent of the total loading capacity in the BATHTUB model was set aside for the MOS and the remainder of the TMDL was divided between the WWTPs and the remaining sources of phosphorus, based on the May-September, 2006 conditions.

The BATHTUB modeling inputs resulting from this analysis are shown Appendix D. For TP in Heron Lake, the total loading capacity or “TMDL” was divided into its component WLA, LA, and MOS. The process was as follows:

Wasteload Allocation

- For wastewater treatment facilities with pond systems, their WLA was determined based on their design capacity and a proposed permitted concentration limit of 0.4 mg/L. Although a daily WLA is assigned to these facilities, it is important to note that discharge occurs only during specified days during the year (April 1 through June 15 and September 15 through December 15). For wastewater treatment facilities using mechanical treatment, the permitted average wet weather design flow is used with the same proposed permitted concentration limit to calculate their WLA. The applicable time frame for the allocations was conservatively estimated to ensure that the water quality standard would be met during the pertinent June through September time period. The allocations for the remainder of the year were set to the current discharge limits for the WWTPs.
- Construction stormwater and industrial stormwater are lumped together into a categorical WLA based on an approximation of the land area covered by those activities. MPCA construction stormwater permit application records over the last four years indicate approximately 0.04 percent of the acreage in Murray, Cottonwood, Jackson and Nobles counties is subject to construction on an annual basis. To account for industrial stormwater, which the MPCA does not have readily accessible acreage data (but is likely much smaller than construction), as well as reserve capacity (to allow for the potential of higher rates of construction and additional industrial facilities), this TMDL assumes 0.1 percent of the land area for a combined construction and industrial stormwater category. The allocation to this category is made after the WLA for wastewater treatment facilities and the MOS are subtracted from the total loading capacity. That remaining capacity is divided up between construction and industrial stormwater, permitted MS4s and all of the nonpoint sources (the LA) based on the percent land area covered.
- Livestock facilities that have been issued NPDES permits are assigned a zero WLA. This is consistent with the conditions of the permits, which allow no pollutant discharge from the livestock housing facilities and associated sites. Discharge of phosphorus from fields where manure has been land-applied may occur at times. Such discharges are covered under the LA portion of the TMDLs, provided the manure is applied in accordance with the permit. (In this watershed nearly all of these NPDES permitted livestock facilities are confined swine operations.)
- Straight-pipe septic systems are illegal and unpermitted, and as such are assigned a zero WLA.
- As indicated above the allocation for communities subject to MS4 NPDES stormwater permit requirements is made after the WLA for wastewater treatment facilities and the MOS are subtracted from the total loading capacity. The allocation for the MS4 is based on the percentage of the land area in the impaired reach watershed that the MS4 permit covers. For this TMDL the only permitted MS4 community is the city of Worthington. The city land area falling in the WFDMR watershed is four square miles.

Margin of Safety

- The purpose of the MOS is to account for uncertainty that the allocations will result in attainment of water quality standards. As a result, the allocations are a direct function of the spatial and seasonal TP variability and the prediction error resulting from limits in the available monitoring data and models. Both Heron Lake and the two major tributaries have been monitored for flow and phosphorus during a minimum of five of the last ten years. For this TMDL, it is estimated that 95 percent of the summer watershed loading to the lake was monitored during 2006, based on the combined FLUX modeling results from the Okabena Creek and Jack Creek subwatershed monitoring data. Also, both Heron Lake basins and the Heron Lake outlet were monitored during the growing season, which provided all of the monitoring data necessary to calibrate the BATHTUB model and estimate the internal phosphorus loading contributions. The TMDL allocations reflect an explicit margin of safety of 5%. This margin of safety is further reinforced by an implicit margin of safety produced from calibrating the BATHTUB model to the 2006 data, a wet year that produced higher TP concentrations from the nonpoint sources of runoff in the watershed.

Load Allocations

- Once the WLA and MOS were determined for each lake basin, the remaining loading capacity was considered LA. The LA includes nonpoint pollution sources that are not subject to NPDES permit requirements, as well as "natural background" sources such as wildlife. The nonpoint pollution sources are largely related to soil erosion, phosphorus fertilizer, manure application, tile drainage, atmospheric deposition, inadequate human wastewater treatment (non-straight-pipes), non-MS4 stormwater runoff, and internal loading.

5.4 Phosphorus TMDL Allocations for North and South Heron Lakes (Lake IDs: 32-0057-05 and 32-0057-07)

North and South Heron Lake were added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was monitoring conducted under the Heron Lake Watershed CWP Project.

The drainage area to the downstream end of this impaired lake is about 438 square miles. The impaired watershed exists within the Poorly Drained Blue Earth Till agroecoregion, previously described, and Jackson, Nobles and Murray Counties. Based on the analysis provided in Section 5.2, primary sources contributing TP to Heron Lake include cropland and pasture runoff, streambank/bed erosion and internal loading from sediment phosphorus release, wind resuspension, carp and other benthic feeders that stir up fine sediments.

There are five wastewater treatment facilities within the land area that drains to this listed waterbody (Table 5.2). There are six livestock facilities with NPDES permits located within the land area that drains to this listed reach (Table 5.3), as well as approximately four square miles of the city of Worthington, which is subject to Stormwater MS4 NPDES permit requirements.

Table 5.4 provides the average daily TP loading capacity for Heron Lake to meet the 90 µg/L water quality standard, as a growing season (June through September) average, along with the component WLAs, LAs and MOS. As discussed in Section 5.3, the applicable time frame for the WWTP WLA allocations was conservatively estimated to ensure that the water quality standard would be met during the pertinent May through September time period. The watershed flow records were reviewed and used to model the period between October 2005 and April 2006 for hydraulic and total phosphorus residence time to obtain a conservative estimate of how long it takes for phosphorus discharged from the Worthington Municipal WWTP to travel through Okabena Creek and both basins of Heron Lake before it is flushed from the system. The result was a total phosphorus residence time estimate of 85 days for the Heron Lake system. Three months were tacked onto the beginning of the May through September model averaging period to establish the time frame for the 0.4 mg/L phosphorus permit effluent limit (resulting from the BATHTUB modeling of the total loading capacity of the lake). The allocations for the remainder of the year were set to the current discharge limits for the WWTPs, resulting in a 1 mg/L phosphorus permit effluent limit between October and January, that will continue to be applied to existing permits to minimize the potential for internal phosphorus loading, consistent with the rules being applied to the discharge of effluent that affects a shallow lake.

TABLE 5.2. Wastewater treatment facilities and associated WLAs.

Facility	NPDES Permit #	Discharge, mgd	Feb.-Sept. WLA, kg/day	Oct.-Jan. WLA, kg/day
Brewster	MN0021750	*	0.29	0.72
Worthington Industrial	MN0031178	2.04	3.2	8.0
Worthington Municipal	MN0031186	4.00	6.0	15.0
Okabena	MN0050288	*	0.05	0.11
Lakefield	MN0020427	0.58	0.88	2.2

* - Seasonal discharge.

TABLE 5.3. Livestock facilities with NPDES permits.

FACILITY	NPDES PERMIT #
Brake Beef Yard	MN0066265
Southwest Prairie Pork	MNG440370
Double K - Finishing Site	MNG440273
Double K - Farrowing Site	MNG440273
Highway 60 Pork	MNG440278
Green Prairie Coop - Sec 7	MNG440337

TABLE 5.4. Total phosphorus loading capacity and allocations.

	FEBRUARY—SEPTEMBER	OCTOBER—JANUARY
	kg per day	
Average Total Daily Loading Capacity	75.50	75.50
Wasteload Allocation*		
Wastewater Treatment Facilities	10.42	26.03
Communities Subject to MS4 NPDES Requirements	0.56	0.42
Construction and Industrial Stormwater	0.07	0.05
Livestock Facilities Requiring NPDES Permits	0	0
"Straight Pipe" Septic Systems	0	0
Load Allocation	60.67	45.22
Margin of Safety	3.78	3.78
	Percent of total daily loading capacity	
Average Total Daily Loading Capacity	100%	100%
Wasteload Allocation*		
Wastewater Treatment Facilities	13.8%	34.4%
Communities Subject to MS4 NPDES Requirements	0.7%	0.6%
Construction and Industrial Stormwater	0.1%	0.1%
Livestock Facilities Requiring NPDES Permits	0%	0%
"Straight Pipe" Septic Systems	0%	0%
Load Allocation	80.4%	59.9%
Margin of Safety	5%	5%

* The individual facilities are listed in Table 5.2 and 5.3.

5.5 Critical Conditions and Seasonal Variation

The index period for lake eutrophication standards is the summer season—June through September. This is the critical period in which the frequency and severity of nuisance algal growth are greatest. Therefore, seasonal variation is accounted for by developing targets for this critical period.

5.6 Consideration of Growth on TMDL

Regarding population changes and contributions from future industrial discharges, contributions of phosphorus from wastewater treatment facilities could increase over time and, therefore, this would have an impact on the TMDL. Options to address this would be to either hold some of the current capacity as “reserve capacity” or to require pollutant trading among phosphorus sources so that there would be no net increase in phosphorus contributed. Because the magnitude of reduction called for in this TMDL is already substantial it would be an additional burden to current dischargers to hold some allocation as reserve capacity. Therefore, this TMDL assumes pollutant trading would be used to address future growth.

The allocations for nonpoint sources are for all current *and* future sources. This means that any expansion of nonpoint sources will need to comply with the LA provided in this report. Additional nonpoint sources (e.g., shifting grassland to row cropland) could very well make meeting the TMDL more difficult over time. Therefore, continued efforts over time to prevent phosphorus delivery to the stream will be critical.

5.7 pH for Heron Lake Outlet (AUID: 07100001-527)

The Heron Lake Outlet (from North Heron Lake to the Des Moines River) is listed as impaired for high pH. As indicated previously this can be attributed to the excessive production of algae due to excess phosphorus in North and South Heron Lakes. Tables 5.5 and 5.6 further establish this linkage. Table 5.5 shows available pH data for the outlet (monitoring station S002-009). Although there are fewer in-lake pH data (Table 5.6), what is available is elevated for nearly all sampling dates. Chlorophyll-*a* and phosphorus data are also shown in Table 5.6 and likewise show elevated values.

By addressing eutrophication in North and South Heron Lakes via the excess nutrients TMDL described in Sections 5.1 through 5.6, the pH impairment in the outlet will be addressed. Accordingly, the MPCA considers TP as a surrogate for pH and the TP TMDL allocations for North and South Heron Lakes provided in Table 5.4 apply to this pH impairment as well. A separate TMDL exercise for the pH listing alone is not needed.

TABLE 5.5. pH data for Heron Lake Outlet 2001-2004. Shaded fields indicate exceedence of pH 8.5 for streams.

DATE	PH		DATE	PH		DATE	PH		DATE	PH
5/21/2001	8.2		6/12/2002	9.3		4/14/2003	8.5		4/19/2004	8.8
5/22/2001	8.4		6/20/2002	9.1		4/21/2003	8.9		4/21/2004	8.9
5/30/2001	8.7		6/25/2002	9.4		4/23/2003	8.4		4/27/2004	8.7
6/13/2001	8.3		7/11/2002	8.5		5/13/2003	8.4		5/11/2004	8.7
6/14/2001	8.0		8/6/2002	7.4		5/20/2003	8.9		5/17/2004	9.4
7/25/2001	8.5		8/7/2002	9.1		6/10/2003	8.9		5/20/2004	9.5
7/31/2001	8.3		8/26/2002	8.8		7/28/2003	9.5		5/27/2004	9.2
8/22/2001	8.6					8/6/2003	8.2		6/1/2004	8.5
9/18/2001	8.5								6/21/2004	8.7
10/17/2001	8.6								9/21/2004	8.1

TABLE 5.6. pH, chlorophyll-*a* and phosphorus data for North and South Heron Lakes (2001).

DATE	PH	CHLOROPHYLL-*A*, µG/L	PHOSPHORUS, MG/L
North Heron Lake			
5/9/2001	8.6	29	0.345
6/6/2001	9.1	121	0.241
7/11/2001	9.3	51	0.599
8/8/2001	9.3	290	1.04
9/6/2001	8.9	238	1.41
South Heron Lake			
5/8/2001	9.0	200	0.251
6/6/2001	9.5	162	0.214
7/11/2001	9.7	63	0.604
8/8/2001	9.0	334	0.975
9/6/2001	8.9	427	1.05
10/16/2001	8.2	235	0.712

6.0 MONITORING

The goals of follow-up monitoring are generally to both evaluate progress toward the water quality targets provided in the TMDL and to inform and guide implementation activities. More specific monitoring plan(s) will be developed as part of implementation efforts. The impaired waterbodies will remain listed until water quality standards are met. Monitoring will primarily be conducted by local staff with funding likely from state sources.

E. coli

For the purpose of the fecal coliform impairments any follow-up monitoring should use *E. coli* as the analysis parameter (due to the change to this water quality standard in Minn. Rules Ch. 7050 described in Section 3.0). At a minimum monitoring will be done at the same sites that were monitored for assessment/study purposes and will be done five times per month from April 1 through October 31. What year this monitoring should start will need to be determined on a reach-by-reach basis. Factors to consider will include availability of funding and the extent of implementation that has occurred in the drainage area. Additional more intensive monitoring may be considered for some areas in order to inform and guide implementation efforts. For example, synoptic surveys involving several water samples taken along a reach within a single day, could better identify potential source areas in which to focus BMP activities.

Turbidity

At a minimum monitoring will be done at the same sites that were monitored for assessment/study purposes. This monitoring will occur during the open water season and at a frequency and timing similar to previous turbidity assessment monitoring. What year this monitoring should start will need to be determined on a reach-by-reach basis. Factors to consider will include availability of funding and the extent of implementation that has occurred in the drainage area. Laboratory measurement for turbidity (using a Hach 2100A turbidimeter or equivalent) will be used for this monitoring, but synoptic surveys could employ use of transparency tubes as a cost-savings measure and to allow real-time evaluation for sampling locations. Also, continuous measurements using turbidity probes may be useful at selected locations. In addition to turbidity, other parameters including TSS, total suspended volatile solids and chlorophyll-*a* should be considered at selected sites to evaluate mineral versus algal sources of suspended solids in order to better target implementation efforts.

North and South Heron Lakes excess nutrients

The approach to monitor the different phosphorus sources and associated loading on phosphorus levels in Heron Lake is as follows:

- Monitor flow, total and dissolved phosphorus, TSS, VSS, turbidity and pH at the traditional Okabena Creek (S001-568) and Jack Creek (S001-590) inlets to

Heron Lake, as well as Division Creek (S001-986) and the Heron Lake outlet (S002-009) from March through October.

- Collecting a minimum of 12 surface water samples during the growing season and analyzing for TP, total dissolved phosphorus (TDP), pH, TSS, VSS, turbidity and chlorophyll-*a*. Bottom water (above the sediment surface) samples will be collected and analyzed for TP and TDP. Profile data will also be collected during each sampling event and will include standard parameters such as dissolved oxygen, temperature and conductivity. Secchi depth and lake level will be measured during each sampling event as well. Monitoring should start in April (or immediately after ice-out) and continue through October each year for both lake basins (32-0057-05 and 32-0057-07). In addition, at least one season of the aforementioned lake monitoring should be conducted during the winter months of November through March, resulting in a minimum of six sampling events.
- Comprehensive phytoplankton, zooplankton, macrophyte and fisheries surveys should be conducted in both lake basins during at least one of the years that surface water quality monitoring is being accomplished. Carp populations should be enumerated by size class using a catch-tag-release-recapture method or similar approach for producing reliable estimates of fish populations.

This monitoring will be done for a minimum of three seasons and should begin as soon as possible since there is very little data to:

- Evaluate the phosphorus dynamics in Heron Lake since the Worthington Industrial WWTP began treatment down to the 1 mg/L TP concentration in the effluent.
- Specifically document the internal loading impacts from sediment phosphorus release, wind resuspension and benthic fish.

7.0 IMPLEMENTATION

This section provides an overview of implementation options and considerations to primarily address nonpoint sources of fecal coliform bacteria, turbidity and excess nutrients for these TMDLs.

Point sources with required effluent monitoring will be addressed through NPDES permit programs within the MPCA. Activities within those programs include establishment of effluent limits, compliance tracking and enforcement, including requiring corrective action. Construction stormwater activities are considered in compliance with provisions of the turbidity and excess nutrients TMDLs 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.

Regarding the nonpoint sources of pollutants, a more detailed implementation plan addressing those sources will be developed following approval of this TMDL study. Because fecal coliform bacteria, turbidity and nutrients have several sources and delivery pathways in common it will make sense to address implementation efforts together. Furthermore, many agricultural best management practices (BMPs) address a range of pollutants.

The University of Minnesota Extension Service recently developed a bulletin entitled "Best Management Practices for Pathogen Control in Manure Management Systems" (University of Minnesota Extension, 2007). This publication identifies three basic points in the manure management cycle where producers can implement BMPs: 1) in the animal, 2) during manure collection, and 3) during land application of manure. Management options for these categories are described and a checklist is included that provides 27 BMPs for pathogen reduction.

An additional reference for agricultural BMP implementation options is provided in Appendix E. This information is in a matrix format and was developed by David Mulla of the Department of Soil, Water, and Climate of the University of Minnesota. It was designed to provide options on an agroecoregion basis and is focused on turbidity impairments, though it appears to have applicability to other runoff-driven pollutants. The West Fork Des Moines River watershed is predominantly in the Coteau and Dryer Blue Earth Till agroecoregions (see Figure 1.1). The following narratives, provided by David Mulla, discuss these agroecoregions and provide summaries of appropriate BMPs for the range of agricultural-related water quality impacts that occur there.

Coteau
Nutrient management practices are recommended to reduce the risk of phosphorus transport to streams. Livestock should be excluded from streambanks, and liquid manure storage facilities should be properly sited and designed. Control of water erosion and reduced delivery of sediment into numerous creeks and streams are important, primarily through the use of conservation tillage techniques, and contour farming, strip cropping or terracing where feasible. Excessive runoff and flooding are a major concern in the Coteau. Streambank stabilization and flood control are priorities.

Dryer Blue Earth Till
Nutrient management practices to properly manage animals and manure are recommended. The Manure Application Planner is recommended where animal manure is applied to land. University guidelines for fertilizer applications should be closely followed. Realistic yield goals and nitrogen credits should be established. Livestock should be excluded from streams. Forest and grass buffer strips are recommended along streams, while steep highly erodible land should be placed in the Conservation Reserve Program.

Poorly Drained Blue Earth Till
Practices to control erosion are encouraged, including field windbreaks and conservation tillage practices that leave crop residue and maintain surface roughness. Filter strips are recommended where there is overland flow to surface waters. Grass plantings in upland areas are recommended to restore habitat for migratory wildfowl.

Inner Coteau
Good animal and manure management practices include livestock exclusion from streams, improved pasture management, and limiting manure applications to frozen ground. Liquid manure waste holding facilities should be properly sited and designed to minimize seepage and overflow. The Manure Application Planner is recommended for nutrient management. Conservation tillage and conservation crop rotations are recommended to reduce soil erosion. Protection of ground water quality from nitrate contamination is a high priority in this agroecoregion. Nitrogen fertilizer applications should be based on realistic crop yield goals, nitrogen credits from legumes and manure, and an N soil test.

Wetter Blue Earth Till
This agroecoregion occupies a negligible portion of the WFDMR watershed.

Specific to improved pasture management the use of rotational grazing is an appropriate practice to be used in this watershed. With rotational grazing, only one portion of the pasture is grazed at a time. This is accomplished by dividing the pasture into paddocks and by moving livestock from one paddock to another before the forage is overgrazed. Rotationally grazed pastures have several environmental advantages to tilled land or to continuously grazed pastures: they dramatically decrease soil erosion potential, require minimal pesticides and fertilizers, and decrease the amount of fecal coliform and nutrient runoff. Grazing management that encourages tall, vigorous growing vegetation will result in higher water infiltration into the soil, thus reducing runoff losses. When grazing along streams, rotational grazing can be used as a tool to manage livestock activity for maintaining healthy stream bank vegetative cover while controlling unwanted plant species.

Additional actions to specifically address the fecal coliform impact include upgrading of noncompliant septic systems and correction of feedlots with runoff problems. Current programs/efforts should be further reviewed during the implementation planning process.

Streambank erosion was identified as an important contributing source to the turbidity problem. It is not clear to what extent streambank restoration will be pursued in this watershed. Due to potential high cost any streambank restoration projects should be prioritized based on magnitude of apparent contribution.

Regarding the internal nutrient sources and the role of benthic feeders in the Heron Lake basins, Sorensen and Bajer (2007) indicates that common carp comprises over half the fish in as many as a third of the Minnesota lakes at a density that can explain both the turbidity and phosphorus levels in these systems and their lack of aquatic plants (Parkos et al., 2003; Lougheed et al., 1998; Chumchal et al., 2005). The same research indicates that young carp usually do not survive past the first year of life due to natural processes that can be controlled. Preliminary analysis of five populations of carp suggests that there are only a few surviving age classes of carp that were born immediately after the studied lakes experienced winterkills in which large numbers of fish died due to low oxygen levels. Sorensen and Bajer (2007) hypothesize that winterkills promote carp recruitment because they eliminate predatory gamefish in shallow marshy areas in which carp spawn, so a solution to the carp problem would involve introduction of gamefish, elimination of winterkill, and/or removal of recruits. South Heron Lake has experienced several winterkill and summerkill events in the past. As a result, implementation of a lake aeration system, gamefish stocking, and carp removal should be considered as options to reduce turbidity and phosphorus levels in Heron Lake, improve the growth of aquatic plants, and minimize sediment phosphorus release and wind resuspension of lake sediments.

The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL [Minn. Statutes 2007, section 114D.25]. Based on cost estimates made in 2004 by a state-level interagency working group which assessed restoration costs for several TMDLs including this one, the initial estimate for implementing the WFDMR TMDL ranged from approximately $140 to $170 million. (Note: this estimate included two impairments not in the current scope - low dissolved oxygen and ammonia.) This estimate will be refined when the detailed implementation plan is developed, following approval of the TMDL study.

8.0 REASONABLE ASSURANCE

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

- The BMPs and other actions outlined in Section 6.0 have all been demonstrated to be effective in reducing transport of pollutants to surface water. Also, many of these actions are currently being promoted by local resource managers with some local efforts showing significant levels of adoption of these BMPS and actions by landowners.
- The advisory committee formed to provide feedback and input into the project had broad representation from government, citizens, and agricultural experts.
- Monitoring will be conducted to track progress and suggest adjustment in the implementation approach.
- The NPDES permits for the wastewater treatment facilities in the Heron Lake watershed will have limits both for mass loading on a daily basis and maximum monthly average concentrations.
- The MPCA's MS4 Permit requires MS4s to provide reasonable assurances that if an EPA-approved TMDL has been developed, they must review the adequacy of their Storm Water Pollution Prevention Program to meet the TMDL's WLA set for stormwater sources. If the Storm Water Pollution Prevention Program is not meeting the applicable requirements, schedules and objectives of the TMDL, they must modify their Storm Water Pollution Prevention Program, as appropriate, within 18 months after the TMDL is approved.

9.0 PUBLIC PARTICIPATION

Over the course of this project a variety of public participation and outreach efforts have been conducted:

- An advisory group was assembled and in addition to the project team included members representing from agricultural interests, wildlife interests, local government and state government. Four advisory group meetings were held.
- A public meeting was held approximately midway through the project to present key findings, outline future actions and address questions and concerns. It was widely advertised and 57 people attended, representing a variety of interests. An additional public meeting is planned for April 2008 to present the draft TMDL results.
- Cottonwood County, with the assistance of Heron Lake Watershed District (HLWD), created a website that was uploaded in June 2006 (www.dmr-tmdl.com). As of September 17, 2007, the website had 295 visitors from Iowa and Minnesota. The five most popular pages, in order of most viewed to least viewed are Publications, Home Page, Links, History, and Contact Information.

- Display boards featuring project information were created and used at fairs and other locations including:
    - Jackson County Fair in July 2006.
    - Cottonwood County Fair in August 2006.
    - Windom Farm and Home Show in March 2007.
    - Bank Midwest – Windom office in July 2007.
    - Jackson County Fair in August 2007.
    - Nobles County Fair in August 2007.
    - Murray County Fair in August 2007.
    - Cottonwood County Fair in August 2007.
- A PowerPoint presentation regarding the TMDL study was developed by HLWD and was presented on eight separate occasions to audiences which included county commissioners, city councils, and the HLWD board.
- MPCA and Barr Engineering met with representatives of the cities of Brewster, Okabena, Lakefield, and Worthington to present preliminary findings of the TMDL study indicating the need for phosphorus reductions and to discuss options.
- An opportunity for further public comment of the TMDL draft was done through a public notice in the State Register of a 30-day comment period that occurred from August 11 to September 10, 2008.

References

Barr Engineering Company. 2004. *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds.* Prepared for the Minnesota Pollution Control Agency.

Blue Earth River fecal coliform draft TMDL (MPCA, 2006).

Carlson, R.E. 1977. A Trophic State Index for Lakes. *Limnol. Oceangr.* 22: 361-369.

Chumchal, M.M., W.H. Nowlin and R.W. Drenner. 2005. Biomass dependent effects of common carp on water quality in shallow ponds. *Hydrobiologia* 545:271-277.

Cleland, B.R. November 2002. *TMDL Development From the "Bottom Up" – Part II: Using Duration Curves to Connect the Pieces*. National TMDL Science and Policy – WEF Specialty Conference. Phoenix, AZ.

Cottonwood County Environmental Office. 2003. *West Fork Des Moines River Clean Water Partnership Phase 1-Diagnostic Study Final Report.*

Engstrom, D. 2007. *A New Method for Fingerprinting Riverine Suspended Sediments.* Prepared by Shawn Schottler, Dylan Blumentritt, and Daniel Engstrom. St. Croix Watershed Research Station, Science Museum of Minnesota. Presented at the December 2007 Lake Pepin TMDL Stakeholder Advisory Committee Meeting. "Sources of Sediment in the LeSueur River".

Federal Water Pollution Control Administration. 1968. Water Quality Criteria: Report of the National Technical Advisory Committee to the Secretary of the Interior.

Helsel, D.R. and R.M. Hirsh. 1991. *Statistical Methods in Water Resources.* Techniques of Water-Resources Investigations of the USGS Book 4.

Lougheed, V.L., B. Crosbie and P. Chow-Fraser. 1998. Predictions on the Effect of Common Carp (*Cyprinus carpio*) Exclusion on Water Quality, Zooplankton, and Submergent Macrophytes in a Great Lakes Wetland. *Can. J. Fish. Aquat. Sci.* 55: 1189-1197.

Mankato State University. *1995. Middle Des Moines Watershed Restoration Project-Diagnostic Study and Implementation Plan.*

Minnesota Pollution Control Agency. 2002. *Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota.*

Minnesota Pollution Control Agency. 2005. *Interrelationships Among Water Quality, Lake Morphometry, Rooted Plants and Related Factors for Selected Shallow Lakes of West-Central Minnesota.*

Minnesota Pollution Control Agency. 2006. *Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota.*

Minnesota Pollution Control Agency. 2006. *Stormwater Program for Construction Activity* web page http://www.pca.state.mn.us/water/stormwater/stormwater-c.html

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

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

Minnesota Pollution Control Agency. 2008. *Small Community Wastewater Needs in Minnesota* web page http://www.pca.state.mn.us/publications/wq-wwtp1-06.pdf

Parkos, III, J.J., V.J. Santucci, Jr. and D.H. Wahl. 2003. Effects of Adult Common Carp (*Cyprinus carpio*) on Multiple Trophic Levels in Shallow Mesocosms. *Can. J. Fish. Aquat. Sci.* 60: 182-192.

Sorensen, P.W. and P.G. Bajer. 2007. *Accelerating Plans for Integrated Control of the Common Carp.* 2008 LCCMR Proposal.

University of Minnesota Extension. 2007. *Best Management Practices for Pathogen Control in Manure Management Systems.*

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

US Environmental Protection Agency. 2001. *Protocol for Developing Pathogen TMDLs.* EPA 841-R-00-002. Office of Water (4503F). United States Environmental Protection Agency, Washington, DC.

Wetzel, R.G. 2001. *Limnology: Lake and River Systems.* Academic Press.

APPENDICES

Appendix A. Fecal Coliform Current Loading by Source: Methodology and Estimates of Relative Contribution

The methodology outlined here is adapted from the 2002 version of the “Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota” (MPCA, 2002). It represents a means to estimate the current loadings of the various fecal coliform source categories and subcategories. It is only a very rough approximation for several reasons including: 1) flow is not accounted for; 2) the dynamics of fecal coliform growth/die-off in the environment and such factors as resuspension in the stream are not rigorously factored in; and 3) very general percentages for availability and delivery (based largely on professional judgment rather than research-derived estimates) are used. Because of these factors the relative contributions of the various sources are ultimately expressed in more of a qualitative manner (i.e., low, moderate, high) rather than precise percentages or loads. Despite the shortcomings, this method can help to understand delivery mechanisms and indicate the general magnitude of the various contributing sources.

For this analysis the land area was divided up into the four main counties that make up the watershed - Nobles, Cottonwood, Jackson and Murray. This was done because the data inputs and information are most readily available at the county level. The data and information gathering was done in 2006 and was coordinated by Karen Boysen of Cottonwood County Environmental Office. The county staff who provided the data inputs and information were: Al Langseth and Wayne Smith (Nobles County Environmental Office, Worthington), Mike Hanson and Marlene Smith (Cottonwood County Environmental Office, Windom), Ben Crowell (Jackson County Environmental Office, Jackson), and Chris Hanson (Murray County Environmental Office, Slayton). The data provided are for only the portion of the respective county that is in the West Fork Des Moines watershed (and are highlighted in yellow in the tables below).

Step 1. Estimating fecal coliform produced per animal group per day.

For use in subsequent steps it is necessary to start with estimates of fecal production by animal type. Table A-1 provides numbers obtained from the literature.

TABLE A-1. Fecal coliform produced per animal and animal unit per day.

	FC ORGS/ANIMAL/DAY			WEIGHT, LBS.	FC ORGS / AU / DAY
	Source 1*	**Source 2***	**Average**		
Dairy		1.00E+11	1.00E+11	1400	7.14E+10
Beef		1.00E+11	1.00E+11	1000	1.00E+11
Swine	8.90E+09	1.10E+10	9.95E+09	140	7.11E+10
Chickens	2.40E+08	1.40E+08	1.90E+08	4	4.75E+10
Turkeys	1.30E+08	9.50E+07	1.13E+08	18	6.25E+09
Horses		4.20E+08	4.20E+08	1000	4.20E+08
Sheep	1.80E+10	1.20E+10	1.50E+10	100	1.50E+11
Deer**	5.00E+08		5.00E+08		
Geese***	1.04E+07		1.04E+07		
People	2.00E+09		2.00E+09		
Dogs/cats****	5.00E+09		5.00E+09		

* Source 1: Metcalf and Eddy, 1991; source 2: ASAE, 1998

** interpolated from Metcalf and Eddy, 1991 (in Dry Creek Watershed TMDL, Alabama, 2001)

*** from Alderisio, K.A. and N. DeLuca, 1999. Applied and Env. Microb. (assumes 1.5 lbs. waste/goose/day)

**** from Horsley and Witten, 1996

Tables A-2 through A-5 summarizes the total fecal coliform production by all animal type groups for each county. Livestock numbers were based on feedlot inventory data. The number of people using septic systems and those served by wastewater treatment plants is based on census data and sorting out by municipal boundaries. Adequate vs. inadequate septic systems is based on professional judgment and experience with upgrade efforts. Deer numbers are approximate and based on local DNR office estimates. In the absence of reliable data for other wildlife, an equivalency to deer is assumed. The estimated number of dogs and cats are based on American Veterinary Medicine Association data that indicates 0.58 dogs and 0.66 cats per household (see: http://www.avma.org/membshp/marketstats/formulas.asp#households1) and the assumption of 2.5 people per household. For dogs and cats in the city, it is assumed that ten percent of the pets' waste is not properly managed, i.e., not collected and disposed of. It is assumed that the waste of rural pets is not collected.

Table A-2. This table provides total FC produced per animal type Nobles County.

	Subcategory	AUs or #s	FC/unit/d	Total FC/d	% of total
Livestock	Beef, AUs	13,855	1.00E+11	1.39E+15	99.6
	Dairy, AUs	560	7.14E+10	4.00E+13	
	Swine, AUs	20,000	7.11E+10	1.42E+15	
	Other, AUs *	600	1.50E+11	9.00E+13	
	Turkeys, AUs	20	6.25E+09	1.25E+11	
	Chickens, AUs	0	4.75E+10	0.00E+00	
	Horses, AUs	0	4.20E+08	0.00E+00	
Humans	Popn w/ inadeq septic	1378	2.00E+09	2.76E+12	0.2
	Popn w/ adeq septic	460	2.00E+09	9.20E+11	
	Popn served by WWTP	502	2.00E+09	1.00E+12	
Wildlife	Deer	714	5.00E+08	3.57E+11	0.0
	Other wildlife	Unknown	Unknown	3.57E+11	
	Total wildlife			7.14E+11	

Pets	Dogs+cats in city--uncollected	25	5.00E+09	1.24E+11	0.2
	Dogs+cats in city--collected	224	5.00E+09	1.12E+12	
	Dogs+cats outside city	912	5.00E+09	4.56E+12	
Total				2.95E+15	

* Other = mix of sheep, horses, goats and buffalo (sheep fecal production # used)

Table A-3. This table provides total FC produced per animal type in Cottonwood County.

	Subcategory	AUs or #s	FC/unit/d	Total FC/d	% of total
Livestock	Beef, AUs	2,775	1.00E+11	2.77E+14	98.9
	Dairy, AUs	281	7.14E+10	2.01E+13	
	Swine, AUs	38,330	7.11E+10	2.72E+15	
	Sheep, AUs	2410	1.50E+11	3.62E+14	
	Turkeys, AUs		6.25E+09	0.00E+00	
	Chickens, AUs		4.75E+10	0.00E+00	
	Horses, AUs	37	4.20E+08	1.55E+10	
Humans	Popn w/ inadeq septic	390	2.00E+09	7.80E+11	0.3
	Popn w/ adeq septic	520	2.00E+09	1.04E+12	
	Popn served by WWTP	4490	2.00E+09	8.98E+12	
Wildlife	Deer	6670	5.00E+08	3.34E+12	0.4
	Other wildlife	Unknown	Unknown	3.34E+12	
	Total wildlife			6.67E+12	
Pets	Dogs+cats in city--uncollected	223	5.00E+09	1.11E+12	0.4
	Dogs+cats in city--collected	2004	5.00E+09	1.00E+13	
	Dogs+cats outside city	451	5.00E+09	2.26E+12	
Total				3.42E+15	

Table A-4. This table provides total FC produced per animal type in Jackson County.

	Subcategory	AUs or #s	FC/unit/d	Total FC/d	% of total
Livestock	Beef, AUs	12,185	1.00E+11	1.22E+15	99.2
	Dairy, AUs	231	7.14E+10	1.65E+13	
	Swine, AUs	42,325	7.11E+10	3.01E+15	
	Sheep, AUs	336.8	1.50E+11	5.05E+13	
	Turkeys, AUs	369	6.25E+09	2.31E+12	
	Chickens, AUs*	367	4.75E+10	1.74E+13	
	Horses, AUs	648	4.20E+08	2.72E+11	
Humans	Popn w/ inadeq septic	410	2.00E+09	8.20E+11	0.3
	Popn w/ adeq septic	180	2.00E+09	3.60E+11	
	Popn served by WWTP	6250	2.00E+09	1.25E+13	
Wildlife	Deer	2600	5.00E+08	1.30E+12	0.1
	Other wildlife	Unknown	Unknown	1.30E+12	
	Total wildlife			2.60E+12	
Pets	Dogs+cats in city--uncollected	310	5.00E+09	1.55E+12	0.4
	Dogs+cats in city--collected	2790	5.00E+09	1.40E+13	
	Dogs+cats outside city	293	5.00E+09	1.46E+12	
Total				4.35E+15	

* includes "fowl"

Table A-5. This table provides total FC produced per animal type in Murray County.					
	Subcategory	AUs or #s	FC/unit/d	Total FC/d	% of total
Livestock	Beef, AUs	41,491	1.00E+11	4.15E+15	99.3
	Dairy, AUs	4,707	7.14E+10	3.36E+14	
	Swine, AUs	42,824	7.11E+10	3.04E+15	
	Sheep, AUs	6630	1.50E+11	9.95E+14	
	Turkeys, AUs	479	6.25E+09	2.99E+12	
	Chickens, AUs	0	4.75E+10	0.00E+00	
	Horses, AUs	700	4.20E+08	2.94E+11	
Humans	Popn w/ inadeq septic	2771	2.00E+09	5.54E+12	0.2
	Popn w/ adeq septic	677	2.00E+09	1.35E+12	
	Popn served by WWTP	4041	2.00E+09	8.08E+12	
Wildlife	Deer	12000	5.00E+08	6.00E+12	0.3
	Other wildlife	Unknown	Unknown	6.00E+12	
	Total wildlife			1.20E+13	
Pets	Dogs+cats in city--uncollected	200	5.00E+09	1.00E+12	0.2
	Dogs+cats in city--collected	1804	5.00E+09	9.02E+12	
	Dogs+cats outside city	1710	5.00E+09	8.55E+12	
Total				8.58E+15	

Step 2. Estimating fecal coliform produced within livestock subcategories that is available for potential runoff.

In order to assess potential contributions of fecal coliform from livestock, a number of assumptions were made regarding where the fecal coliform bacteria “start out”, i.e., where they are deposited or otherwise reside on the landscape, and would subsequently be available to some degree of runoff. The possibilities considered for where manure (and, therefore, fecal coliform) exists during various times of the year in this watershed are as follows:

- Feedlots or stockpiles without runoff controls
- Overgrazed pasture near streams or waterways
- Other pasture
- Surface-applied manure to fields
- Incorporated / injected manure in fields

Estimates of the percent of feedlots/stockpiles with and without runoff controls for the different livestock types are provided in Tables A-6 through A-9. These and all other estimates for this step in the process are based on the professional judgment of staff.

Table A-6. Estimates of the percent (expressed as decimal percent) of feedlots/stockpiles with and without runoff controls for Nobles County.						
	Beef	Dairy	Swine	Other	Poultry	Horses
Feedlots or stockpiles without runoff controls	0.6	0.7	0.2	0.9	0.99	0.9
Feedlots or stockpiles with runoff controls	0.4	0.3	0.8	0.1	0.01	0.1
Total	1	1	1	1	1	1

Table A-7. Estimates of the percent (expressed as decimal percent) of feedlots/stockpiles with and without runoff controls for Cottonwood County.						
	Beef	Dairy	Swine	Sheep	Poultry	Horses
Feedlots or stockpiles without runoff controls	0.05	0.01	0.01	0.1	0.01	0.1
Feedlots or stockpiles with runoff controls	0.95	0.99	0.99	0.9	0.99	0.9
Total	1	1	1	1	1	1

Table A-8. Estimates of the percent (expressed as decimal percent) of feedlots/stockpiles with and without runoff controls for Jackson County.						
	Beef	Dairy	Swine	Sheep	Poultry	Horses
Feedlots or stockpiles without runoff controls	0.1	0.5	0.01	0.25	0.01	0.25
Feedlots or stockpiles with runoff controls	0.9	0.5	0.99	0.75	0.99	0.75
Total	1	1	1	1	1	1

Table A-9. Estimates of the percent (expressed as decimal percent) of feedlots/stockpiles with and without runoff controls for Murray County.						
	Beef	Dairy	Swine	Sheep	Poultry	Horses
Feedlots or stockpiles without runoff controls	0.1	0.02	0.01	0.01	0	0.01
Feedlots or stockpiles with runoff controls	0.9	0.98	0.99	0.99	1	0.99
Total	1	1	1	1	1	1

Estimates of the percent of manure that is applied/deposited in pasture settings and fields are provided in Table A-10 through A-13.

Table A-10. Estimates of the percent (expressed as decimal percent) of manure that is applied/deposited in pastures and fields for Nobles County.						
	Beef	Dairy	Swine	Other	Poultry	Horses
Overgrazed pasture near streams or waterways	0.05	0.18		0.54		0.54
Other pasture	0.21	0.14	0.01	0.19		0.19
Surface-applied*	0.66	0.51	0.64	0.27	0.5	0.27
Incorporated/injected**	0.08	0.17	0.35	0	0.5	0
Total	1	1	1	1	1	1

Table A-11. Estimates of the percent (expressed as decimal percent) of manure that is applied/deposited in pastures and fields for Cottonwood County.						
	Beef	Dairy	Swine	Sheep	Poultry	Horses
Overgrazed pasture near streams or waterways	0.1	0.05				
Other pasture	0.15	0.05		0.15		0.15
Surface-applied*	0.65	0.75	0.1	0.8	1	0.8
Incorporated/injected**	0.1	0.15	0.9	0.05		0.05
Total	1	1	1	1	1	1

Table A-12. Estimates of the percent (expressed as decimal percent) of manure that is applied/deposited in pastures and fields for Jackson County.						
	Beef	Dairy	Swine	Sheep	Poultry	Horses
Overgrazed pasture near streams or waterways	0.01	0.01		0.01		0.01
Other pasture	0.04	0.04		0.04		0.04
Surface-applied*	0.8	0.8	0.05	0.9	0.5	0.9
Incorporated/injected**	0.15	0.15	0.95	0.05	0.5	0.05
Total	1	1	1	1	1	1

Table A-13. Estimates of the percent (expressed as decimal percent) of manure that is applied/deposited in pastures and fields for Murray County.						
	Beef	Dairy	Swine	Sheep	Poultry	Horses
Overgrazed pasture near streams or waterways	0.25	0.05				
Other pasture	0.1	0.05		0.2		0.2
Surface-applied*	0.6	0.45	0.1	0.7	1	0.7
Incorporated/injected**	0.05	0.45	0.9	0.1	0	0.1
Total	1	1	1	1	1	1

Tables A-14 and A-15 indicate the approximate percentage of field-applied manure applied in the fall though spring vs. the summer

Table A-14. Approximate percentage of manure applied by season for Nobles, Cottonwood and Jackson Counties.		
	Surface-applied	Incorporated/injected
Fall through spring	0.9	1
Summer	0.1	0
Total	1	1

Table A-15. Approximate percentage of manure applied by season for Murray County.		
	Surface-applied	Incorporated/injected
Fall thru spring	0.9	0.95
Summer	0.1	0.05
Total	1	1

Combining the information in the above tables results in Tables A-16 through A-19, which provide estimates of fecal coliform available for potential runoff for the various “sources” or settings in which manures exist during various times during the year.

Table A-16. This table breaks down the livestock contribution of FC further and provides the total FC potentially available for runoff within the source categories for Nobles County.

Source	Animal type	Total FC/d	proportion available	Total FC avail/d	Source total FC avail/d
Feedlots or stockpiles without runoff controls	Beef	1.39E+15	0.6	8.31E+14	1.22E+15
	Dairy	4.00E+13	0.7	2.80E+13	
	Swine	1.42E+15	0.2	2.84E+14	
	Sheep	9.00E+13	0.9	8.10E+13	
	Poultry	1.25E+11	0.99	1.24E+11	
	Horses	0.00E+00	0.9	0.00E+00	
Overgrazed pasture near streams or waterways	Beef	1.39E+15	0.05	6.93E+13	1.25E+14
	Dairy	4.00E+13	0.18	7.20E+12	
	Sheep	9.00E+13	0.54	4.86E+13	
	Horses	0.00E+00	0.54	0.00E+00	
Other pasture	Beef	1.39E+15	0.21	2.91E+14	3.14E+14
	Dairy	4.00E+13	0.14	5.60E+12	
	Sheep	9.00E+13	0.19	1.71E+13	
	Horses	0.00E+00	0.19	0.00E+00	
Surface-applied	Beef	1.39E+15	0.66	9.14E+14	1.87E+15
	Dairy	4.00E+13	0.51	2.04E+13	
	Swine	1.42E+15	0.64	9.10E+14	
	Sheep	9.00E+13	0.27	2.43E+13	
	Poultry	1.25E+11	0.5	6.25E+10	
	Horses	0.00E+00	0.27	0.00E+00	
Incorporated / injected	Beef	1.39E+15	0.08	1.11E+14	6.15E+14
	Dairy	4.00E+13	0.17	6.80E+12	
	Swine	1.42E+15	0.35	4.98E+14	
	Sheep	9.00E+13	0	0.00E+00	
	Poultry	1.25E+11	0.5	6.25E+10	
	Horses	0.00E+00	0	0.00E+00	

Table A-17. This table breaks down the livestock contribution of FC further and provides the total FC potentially available for runoff within the source categories for Cottonwood County.

Source	Animal type	Total FC/d	proportion available	Total FC avail/d	Source total FC avail/d
Feedlots or stockpiles without runoff controls	Beef	2.77E+14	0.05	1.39E+13	7.75E+13
	Dairy	2.01E+13	0.01	2.01E+11	
	Swine	2.72E+15	0.01	2.72E+13	
	Sheep	3.62E+14	0.1	3.62E+13	
	Poultry	0.00E+00	0.01	0.00E+00	
	Horses	1.55E+10	0.1	1.55E+09	
Overgrazed pasture near streams or waterways	Beef	2.77E+14	0.1	2.77E+13	2.88E+13
	Dairy	2.01E+13	0.05	1.01E+12	
	Sheep	3.62E+14	0	0.00E+00	

	Horses	1.55E+10	0	0.00E+00	
Other pasture	Beef	2.77E+14	0.15	4.16E+13	9.68E+13
	Dairy	2.01E+13	0.05	1.01E+12	
	Sheep	3.62E+14	0.15	5.42E+13	
	Horses	1.55E+10	0.15	2.33E+09	
Surface-applied	Beef	2.77E+14	0.65	1.80E+14	7.57E+14
	Dairy	2.01E+13	0.75	1.51E+13	
	Swine	2.72E+15	0.1	2.72E+14	
	Sheep	3.62E+14	0.8	2.89E+14	
	Poultry	0.00E+00	1	0.00E+00	
	Horses	1.55E+10	0.8	1.24E+10	
Incorporated / injected	Beef	2.77E+14	0.1	2.77E+13	2.50E+15
	Dairy	2.01E+13	0.15	3.02E+12	
	Swine	2.72E+15	0.9	2.45E+15	
	Sheep	3.62E+14	0.05	1.81E+13	
	Poultry	0.00E+00	0	0.00E+00	
	Horses	1.55E+10	0.05	7.77E+08	

Table A-18. This table breaks down the livestock contribution of FC further and provides the total FC potentially available for runoff within the source categories for Jackson County.

Source	Animal type	Total FC/d	proportion available	Total FC avail/d	Source total FC avail/d
Feedlots or stockpiles without runoff controls	Beef	1.22E+15	0.1	1.22E+14	1.73E+14
	Dairy	1.65E+13	0.5	8.25E+12	
	Swine	3.01E+15	0.01	3.01E+13	
	Sheep	5.05E+13	0.25	1.26E+13	
	Poultry	1.97E+13	0.01	1.97E+11	
	Horses	2.72E+11	0.25	6.80E+10	
Overgrazed pasture near streams or waterways	Beef	1.22E+15	0.01	1.22E+13	1.29E+13
	Dairy	1.65E+13	0.01	1.65E+11	
	Sheep	5.05E+13	0.01	5.05E+11	
	Horses	2.72E+11	0.01	2.72E+09	
Other pasture	Beef	1.22E+15	0.04	4.87E+13	5.14E+13
	Dairy	1.65E+13	0.04	6.60E+11	
	Sheep	5.05E+13	0.04	2.02E+12	
	Horses	2.72E+11	0.04	1.09E+10	
Surface-applied	Beef	1.22E+15	0.8	9.75E+14	1.19E+15
	Dairy	1.65E+13	0.8	1.32E+13	
	Swine	3.01E+15	0.05	1.50E+14	
	Sheep	5.05E+13	0.9	4.55E+13	
	Poultry	1.97E+13	0.5	9.87E+12	
	Horses	2.72E+11	0.9	2.45E+11	
Incorporated / injected	Beef	1.22E+15	0.15	1.83E+14	3.06E+15
	Dairy	1.65E+13	0.15	2.48E+12	
	Swine	3.01E+15	0.95	2.86E+15	
	Sheep	5.05E+13	0.05	2.53E+12	
	Poultry	1.97E+13	0.5	9.87E+12	
	Horses	2.72E+11	0.05	1.36E+10	

Table A-19. This table breaks down the livestock contribution of FC further and provides the total FC potentially available for runoff within the source categories for Murray County.					
Source	Animal type	Total FC/d	proportion available	Total FC avail/d	Source total FC avail/d
Feedlots or stockpiles without runoff controls	Beef	4.15E+15	0.1	4.15E+14	4.62E+14
	Dairy	3.36E+14	0.02	6.72E+12	
	Swine	3.04E+15	0.01	3.04E+13	
	Sheep	9.95E+14	0.01	9.95E+12	
	Poultry	2.99E+12	0	0.00E+00	
	Horses	2.94E+11	0.01	2.94E+09	
Overgrazed pasture near streams or waterways	Beef	4.15E+15	0.25	1.04E+15	1.05E+15
	Dairy	3.36E+14	0.05	1.68E+13	
	Sheep	9.95E+14	0	0.00E+00	
	Horses	2.94E+11	0	0.00E+00	
Other pasture	Beef	4.15E+15	0.1	4.15E+14	6.31E+14
	Dairy	3.36E+14	0.05	1.68E+13	
	Sheep	9.95E+14	0.2	1.99E+14	
	Horses	2.94E+11	0.2	5.88E+10	
Surface-applied	Beef	4.15E+15	0.6	2.49E+15	3.64E+15
	Dairy	3.36E+14	0.45	1.51E+14	
	Swine	3.04E+15	0.1	3.04E+14	
	Sheep	9.95E+14	0.7	6.96E+14	
	Poultry	2.99E+12	1	2.99E+12	
	Horses	2.94E+11	0.7	2.06E+11	
Incorporated / injected	Beef	4.15E+15	0.05	2.07E+14	3.20E+15
	Dairy	3.36E+14	0.45	1.51E+14	
	Swine	3.04E+15	0.9	2.74E+15	
	Sheep	9.95E+14	0.1	9.95E+13	
	Poultry	2.99E+12	0	0.00E+00	
	Horses	2.94E+11	0.1	2.94E+10	

Step 3. Estimating fecal coliform delivery potential

To estimate actual delivery from the various sources to the surface water of the watershed, an additional set of assumptions needs to be applied.

Table A-20 shows estimated fecal coliform "delivery potential" expressed in both a qualitative and quantitative fashion. Sources of fecal coliform and delivery potential vary both with season and weather. In the table this variability is reflected by different values for spring and summer as well as wet and dry conditions. While this is a bit of an oversimplification, it does recognize that certain sources are not "active" under dry conditions (i.e., no surface runoff).

TABLE A-20. Estimated fecal coliform delivery potential.

SOURCE	ESTIMATED DELIVERY POTENTIAL			
	Spring (wet)	**Spring (dry)**	**Summer (wet)**	**Summer (dry)**
Feedlots or stockpiles without runoff controls	High (4%)		Moderate (2%)	
Overgrazed pasture near streams or waterways	High (4%)	Low (1%)	High (4%)	Low (1%)
Other pasture	Very low (0.1%)		Very low (0.1%)	
Surface-applied manure	Low (1%)		Low (1%)	
Incorporated / injected manure	Very low (0.1%)		Very low (0.1%)	
Failing / inadequate septic systems	Very high (8%)	Very high (8%)	Very high (8%)	Very high (8%)
Deer and other wildlife	Low (1%)	Low (1%)	Low (1%)	Low (1%)
Dogs and cats in city—waste not collected	High (4%)		High (4%)	
Dogs and cats outside city	Very low (0.1%)		Very low (0.1%)	

The concept for the qualitative and quantitative fecal coliform delivery potential shown in this table came from Mulla et al. (Mulla, D.J., A.S. Birr, G. Randall, J. Moncrief, M. Schmitt, A. Sekely and E. Kerre. Technical Work Paper: Impacts of Animal Agriculture on Water Quality. University of Minnesota Department of Soil, Water and Climate. April 3, 2001), which describes water quality risk associated with different types of livestock, animal housing operations, and land application practices on a 1-5 scale (1 = very low risk, 5 = very high risk). Following the methodology of the 2002 version of the "Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (MPCA, 2002), a similar scale (very low to very high) was used to describe fecal coliform delivery potential and takes into account in a general way the various physical, microbiological, climatic and other factors at play. These qualitative rankings were translated into delivery percentages. One percent is considered a low delivery percentage and the percentage is doubled for each step up the scale (moderate = 2%, high = 4%). The exception to this is that for some sources a delivery of 0.1% was assigned, an order of magnitude below 1%, to reflect the very low delivery expected with those (see source-specific discussion below). Discussion of the estimated delivery and the likely delivery mechanisms associated with each of the sources is provided below.

<u>Livestock</u>

Runoff from feedlots and pastures has the potential to be a significant source of fecal coliform bacteria and other pollutants. Owing largely to the close proximity of many feedlots to the creek and waterways, runoff from "feedlots or stockpiles without runoff controls" under wet conditions is estimated as high during the spring. The summertime wet estimate is reduced to moderate to account for the filtering effect of vegetation growth. A high delivery potential is assumed during wet conditions for "overgrazed pasture near streams or waterways" due to proximity as well as limited protective cover, or even bare soil, which results from overgrazing. Under dry conditions, a low level of delivery is assumed to occur by direct deposit of manure from livestock standing in the water. For "other pasture" (i.e., further upland or otherwise properly managed pasture) very little delivery under wet conditions is expected to occur due to the effects of vegetative cover and no delivery is expected under dry conditions.

Land application of manure can also be a significant source of nonpoint pollution runoff. Much depends on how the manure application is managed – the rate, timing and method of application, observance of setbacks from surface water, timely incorporation to avoid major runoff following a major rain, use of riparian buffer strips, residue management to retard surface runoff and other practices. Runoff of applied manure only occurs during wet conditions. Unlike some feedlots and overgrazed pasture areas, there is generally some separation between manured fields and streams and waterways. Also, the soils of much of this watershed, particularly in the bottomlands, are of very low slope. As such, delivery potential is considered low relative to the other manure sources. Compared to surface-applied manure, the delivery potential of injected or incorporated manure is considered very low.

Failing or inadequate septic systems

Failing or inadequate septic systems are estimated to have a very high delivery potential during wet and dry conditions. These estimates assume waste delivery primarily via runoff and particularly those that are direct-to-tile systems, which some of the counties report as being common.

Wildlife

The estimated delivery potential of deer and other wildlife is believed to be low during all conditions. It is assumed that deer waste is deposited mainly in well-vegetated areas, but that they also spend time near the creek and waterways, as those are their water source.

Pets

The delivery of pet waste is assumed only to occur during wet conditions. For "dogs and cats in city - waste not collected" a high delivery is estimated due to stormwater runoff via impervious surfaces and storm sewers. Outside the city, the delivery potential is consider very low as it assumed the waste is deposited mainly in well-vegetated areas.

Step 4. Estimating fecal coliform current loading

To estimate loading for each source or source category the previous estimates of available fecal coliform are multiplied by the delivery percentages in Table A-20. This yields estimated daily loading for wet and dry conditions in the spring and summer seasons. Results are shown in Tables A-21 through A-24.

Table A-21. This table is the *estimated* current daily FC load delivered by source for Nobles County.				
	Spr-wet	Spr-dry	Sum-wet	Sum-dry
Feedlots or stockpiles without runoff controls	4.90E+13		2.45E+13	
Overgrazed pasture near streams or waterways	5.00E+12	1.25E+12	5.00E+12	1.25E+12
Other pasture	3.14E+11		3.14E+11	
Surface-applied manure	1.68E+13		1.87E+12	
Incorporated / injected manure	6.15E+11		0.00E+00	
Failing / inadequate septic systems	2.20E+11	2.20E+11	2.20E+11	2.20E+11
Deer + other wildlife	7.14E+09	7.14E+09	7.14E+09	7.14E+09
Dogs+cats in city—waste not collected	4.98E+09		4.98E+09	
Dogs and cats outside city	4.56E+09		4.56E+09	
TOTAL ESTIMATED	7.20E+13	1.48E+12	3.19E+13	1.48E+12

Table A-22. This table is the *estimated* current daily FC load delivered by source for Cottonwood County.				
	Spr-wet	Spr-dry	Sum-wet	Sum-dry
Feedlots or stockpiles without runoff controls	3.10E+12		1.55E+12	
Overgrazed pasture near streams or waterways	1.15E+12	2.88E+11	1.15E+12	2.88E+11
Other pasture	9.68E+10		9.68E+10	
Surface-applied manure	6.81E+12		7.57E+11	
Incorporated / injected manure	2.50E+12		0.00E+00	
Failing / inadequate septic systems	6.24E+10	6.24E+10	6.24E+10	6.24E+10
Deer + other wildlife	6.67E+10	6.67E+10	6.67E+10	6.67E+10
Dogs+cats in city—waste not collected	4.45E+10		4.45E+10	
Dogs and cats outside city	2.26E+09		2.26E+09	
TOTAL ESTIMATED	1.38E+13	4.17E+11	3.73E+12	4.17E+11

Table A-23. This table is the *estimated* current daily FC load delivered by source for Jackson County.				
	Spr-wet	Spr-dry	Sum-wet	Sum-dry
Feedlots or stockpiles without runoff controls	6.92E+12		3.46E+12	
Overgrazed pasture near streams or waterways	5.14E+11	1.29E+11	5.14E+11	1.29E+11
Other pasture	5.14E+10		5.14E+10	
Surface-applied manure	1.07E+13		1.19E+12	
Incorporated / injected manure	3.06E+12		0.00E+00	
Failing / inadequate septic systems	6.56E+10	6.56E+10	6.56E+10	6.56E+10
Deer+other wildlife	2.60E+10	2.60E+10	2.60E+10	2.60E+10
Dogs+cats in city—waste not collected	6.20E+10		6.20E+10	
Dogs and cats outside city	1.46E+09		1.46E+09	
TOTAL ESTIMATED	2.14E+13	2.20E+11	5.38E+12	2.20E+11

Table A-24. This table is the *estimated* current daily FC load delivered by source for Murray County.				
	Spr-wet	Spr-dry	Sum-wet	Sum-dry
Feedlots or stockpiles without runoff controls	1.85E+13		9.24E+12	
Overgrazed pasture near streams or waterways	4.22E+13	1.05E+13	4.22E+13	1.05E+13
Other pasture	6.31E+11		6.31E+11	
Surface-applied manure	3.28E+13		3.64E+12	
Incorporated / injected manure	3.04E+12		1.60E+11	
Failing / inadequate septic systems	4.43E+11	4.43E+11	4.43E+11	4.43E+11
Deer+other wildlife	1.20E+11	1.20E+11	1.20E+11	1.20E+11
Dogs+cats in city—waste not collected	4.01E+10		4.01E+10	
Dogs and cats outside city	8.55E+09		8.55E+09	
TOTAL ESTIMATED	9.77E+13	1.11E+13	5.65E+13	1.11E+13

To translate this information into a simpler format, we can convert the numbers in Tables A-21 through A-24 to percentages of the total load and then express the results in terms the categories below. The results are shown in Tables A-25 through A-28.

"very low to none" (less than 1%)	
"low" (1-5%)	
"moderate" (5-20%)	
"high" (greater than 20%)	

Table A-25. This table is the *estimated* current daily FC load delivered by source expressed as a percent of the estimated total daily load for Nobles County.				
Source	Spr-wet	Spr-dry	Sum-wet	Sum-dry
Feedlots or stockpiles without runoff controls				
Overgrazed pasture near streams or waterways				
Other pasture				
Surface-applied manure				
Incorporated / injected manure				
Failing / inadequate septic systems				
Deer + other wildlife				
Dogs+cats in city—waste not collected				
Dogs and cats outside city				

Table A-26. This table is the *estimated* current daily FC load delivered by source expressed as a percent of the estimated total daily load for Cottonwood County.

Source	Spr-wet	Spr-dry	Sum-wet	Sum-dry
Feedlots or stockpiles without runoff controls				
Overgrazed pasture near streams or waterways				
Other pasture				
Surface-applied manure				
Incorporated / injected manure				
Failing / inadequate septic systems				
Deer + other wildlife				
Dogs+cats in city—waste not collected				
Dogs and cats outside city				

Table A-27. This table is the *estimated* current daily FC load delivered by source expressed as a percent of the estimated total daily load for Jackson County.

Source	Spr-wet	Spr-dry	Sum-wet	Sum-dry
Feedlots or stockpiles without runoff controls				
Overgrazed pasture near streams or waterways				
Other pasture				
Surface-applied manure				
Incorporated / injected manure				
Failing / inadequate septic systems				
Deer + other wildlife				
Dogs+cats in city—waste not collected				
Dogs and cats outside city				

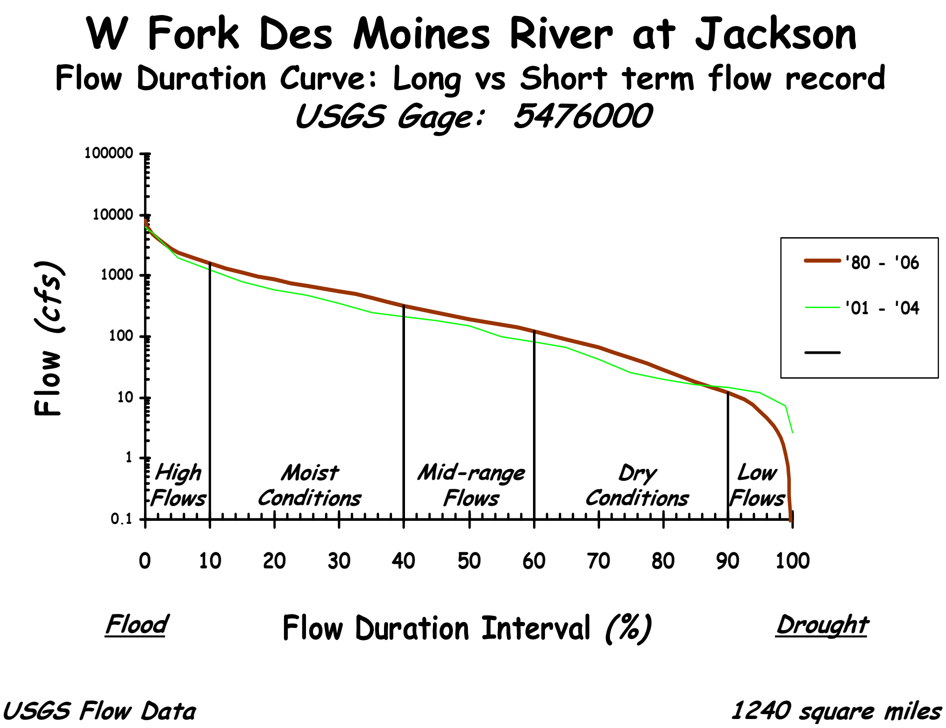
Table A-28. This table is the *estimated* current daily FC load delivered by source expressed as a percent of the estimated total daily load for Murray County.

Source	Spr-wet	Spr-dry	Sum-wet	Sum-dry
Feedlots or stockpiles without runoff controls				
Overgrazed pasture near streams or waterways				
Other pasture				
Surface-applied manure				
Incorporated / injected manure				
Failing / inadequate septic systems				
Deer + other wildlife				
Dogs+cats in city—waste not collected				
Dogs and cats outside city				

Appendix B. Methodology for Fecal Coliform and Turbidity TMDL Equations and Load Duration Curves

The loading capacity determination used for this report is based on the process developed for the "Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (Jan 2006). This process is known as the "Duration Curve" method.

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, but for some reaches of this TMDL a long-term record was not available. The flow record for those reaches was generally from 2001-2004. However, when examining the flow duration curves for that period vs. the long-term record (1980-2006) at the USGS gage at Jackson it appears that these curves are reasonably well-aligned (see graph below). This is likely the case because the short-term record included both wet and dry years.



Loading capacities for specific pollutants 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 is then created (where a flow at the Xth percentile means X% of all measured flows equal or exceed that flow). Five flow zones are illustrated in this approach: "high" (0-10th percentile), "moist" (10th- 40th percentile), "mid-range" (40th-60th percentile), "dry" (60th-90th percentile) and "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. For example, if the "mid-range" (50th percentile) flow is 100 cubic feet/sec, the loading capacity for fecal coliform bacteria would be:

100 cu ft/sec x 200 organisms/100 ml x 28,312 ml/cu ft x 86,400 sec/day ÷ 1 billion = 489 billion fecal coliform bacteria per day

For turbidity, the total suspended solids (TSS) equivalent to the turbidity standard is used. (A regression is used to determine the TSS equivalent.) For example, if the equivalent to 25 NTU was determined to be 50 mg/L TSS, then for the flow zone example above the TMDL for TSS would be:

100 cubic feet/sec x 50 mg/L TSS x 28.31 L/cubic ft x 86,400 s/day ÷ 907,184,740 mg/ton = 13.4 tons TSS/day

TMDLs were calculated for all the flow zones for each listed reach of the project. The TMDLs were then divided into a Margin of Safety (MOS), Wasteload Allocations (WLAs) and a Load Allocation (LA).

For this TMDL an explicit ten percent MOS was used. The next step in the process was determining the WLAs for point sources with specific discharge limits.

The permitted wastewater and water treatment facility WLAs were determined based on their permitted discharge design flow rates and their permitted TSS concentration limits or their permitted daily loading rates, whichever were higher. For fecal coliform bacteria the permitted concentration limit of 200 organisms/100 mls was used. Example calculations for the WLA for a wastewater treatment facility discharging 3,000,000 gallons of effluent per day with a 200 organisms/100 ml and a 45 mg/L TSS concentration limit are as follows:

3,000,000 gallons/day x 200 organisms/100 ml x 3785 ml/gallon ÷ 1 billion = 23 billion fecal coliform bacteria per day

3,000,000 gallons/day x 45 mg/L TSS x 3.785 L/gallon ÷ 907,184,740 mg/ton = 0.56 tons TSS/day

The WLA for a given wastewater treatment facility will be the same under all flow zones since its allocation is based on the volume it is permitted to discharge.

The WLAs for these dischargers with specific discharge limits and the MOS were subtracted from the total available loading capacity. The remaining capacity was then divided up based on land area between the nonpoint sources, i.e., the LA category, and communities subject to Stormwater MS4 permit requirements. For example, if 5% of the watershed is covered by communities subject to MS4 permit requirements, then 5% of the available loading capacity is assigned to those communities and 95% is assigned to the LA. (For turbidity, permitted construction stormwater and industrial stormwater were also provided WLAs based on an estimated land area covered (0.1 %)).

Load duration curves shown in the report display the allowable load across the range of flows in the timeframe selected. The loads represented by grab samples were calculated and plotted. 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.

Appendix C. Evaluation of "Paired" Turbidity Measurements from Two Turbidimeters for Use in Two TMDL Projects

December 13, 2007

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Watershed Section – Technical Assistance Unit

Background

Turbidity is a parameter that has a significant amount of variability associated with the measurement values reported. Unlike many water quality parameters which are a measurement of a mass of constituents in a volume of water, turbidity is a measure of the optical properties of a water sample which causes light to be scattered and absorbed (Federal Water Pollution Control Administration, 1968). The optical properties are affected by the biological, physical and chemical components in the water. Differences in the constituents' response to light contribute to this variability. Adding to this variability, differences between turbidity meter types can result in different turbidity values being measured for the same water samples. The USGS and others have published papers documenting the variation in turbidity measurements that can occur due to different sensor configurations, detector angle, and light wavelength used (Pavelich 2002, Ankcorn 2003, Anderson 2005). While the manufactured meters comply with standard method requirements of the EPA, different results may occur when using different types of turbidity meters and sensors. The variation occurs across different manufacturing company sensors and even within different generations of the same model sensor within a company. To address this issue, the United States Geological Survey (USGS) developed a reporting unit/category system to distinguish between the different sensor groups (Miller 2004, Anderson 2005).

Differences in turbidity values between meters have been observed in Minnesota through various monitoring efforts.

With the development of turbidity (and other variables) TMDLs well under way in Minnesota, the Minnesota Pollution Control Agency (MPCA) developed a Turbidity TMDL Protocol (MPCA 2007) as guidance to assist projects in completing the work needed for a turbidity TMDL. The issue of differences in measurements of turbidity between different meters was addressed in two ways. First, the protocol identified the need to use the turbidity reporting units/categories adopted by the USGS to differentiate data sets by type of turbidity meter. The MPCA began using the reporting categories for data being entered into STORET in 2005.

Secondly, the protocol identified a list of options/recommendations to use/follow when a project has one or more types of turbidity data. At the time of the protocol development, it was envisioned that use of this list would be sufficient in the short term as paired measurements of the data types were made and compared. The list of options assumed that the type of data present in a project would largely determine which reporting unit would be used in evaluating the data against the turbidity standards of 10 or 25 NTU. This, in essence, is what has been done for the turbidity TMDLs that have been approved by EPA prior to 2008.

The difficulty of selecting a "method" from this list of options became apparent fairly quickly for various reasons in three projects. In the Minnesota River Turbidity TMDL project, a difference in turbidity values between the MPCA and Metropolitan Council Environmental Services (MCES) monitoring programs had been recognized and discussed prior to and following the completion of the protocol. The primary differences are likely due to the use of different turbidimeters in the two labs. The MCES lab used a Hach 2100A meter to measure turbidity (J. Klang, personal communication, 2006). This meter measures turbidity via a single white light source and a single light detector located at 90 degrees to the light source. The USGS unit reporting category for this meter is NTU. The MDH lab used a Hach 2100AN meter to measure turbidity. This meter is set to measure turbidity utilizing a single white light source and two (multiple) light detectors. One detector is located at 90 degrees to the light source and the second light detector is located at a wider angle with a "ratio" compensation being made between the two (J. Klang, personal communication, 2006). The USGS unit reporting category for this meter is NTRU.

The protocol includes a description of the differences. The impact of the difference was thought to be important, but a decision on which to use in evaluating the standard was not made until the project timeline required a decision be made to identify a target for the HSPF modeling of the basin. The MPCA technical team for the project decided to use the NTU reporting category and, hence, the MCES turbidity data in the targeting work. The difference between the data sets was shown in a small set of paired (same water samples) turbidity measurements made by the MCES and Minnesota Department of Health (MDH) Laboratories where a "difference factor" of 0.55 was estimated in some way, but not formally documented.

The next turbidity project to face a decision on what and/or how to deal with turbidity data with different reporting units was the West Fork Des Moines River Turbidity TMDL project. In this case, the initial analysis and evaluation of the turbidity data combined together resulted in an apparent difference in the sediment reduction needed between two watersheds in the project. In working to document this unexpected difference, it was determined that the water samples from two watershed projects were analyzed by different laboratories – one being the MDH Lab measuring turbidity as NTRU and the other being the Minnesota Valley Testing Laboratory (MVTL) measuring turbidity as NTU. In discussing a means in which to "correct" the data, the project team decided to make the assumption that the difference between the two measurement types was the same as for the paired-data set of MCES and MDH turbidity measurements completed as part of a river remote sensing and monitoring project conducted in 2004. Subsequent estimates of load reductions needed in the two watersheds were very similar, as expected given the similarity of the watersheds. However, the relationship between the paired data had not been fully completed and documented, so MPCA staff began completing the data analysis with this document describing the results of the work.

A third turbidity TMDL project to encounter a problem related to a difference between reporting unit values was the Pipestone Creek Turbidity TMDL. In this project, the TMDL was originally developed with a lower TSS target. During the TMDL review, MPCA reviewed the calculation of the TMDL target for TSS. By going back to the water quality data documentation for the monitoring done in the project, it was determined that all of the turbidity data was measured as NTRU by the MDH Lab rather than as NTU, resulting in an overly stringent TSS target. Subsequent use of the initial ratio between NTRU and NTU in the paired data set provided a “better” / “more representative” evaluation of the current conditions to the turbidity standard.

Methods

With these issues and situations at the forefront of needs in completing turbidity TMDLs, this document presents a statistical evaluation of the paired data set for application in the Minnesota River, West Fork Des Moines River, and Pipestone Creek Turbidity TMDLs. The paired data are from water quality monitoring conducted as part of a river remote sensing study in 2004 by MPCA staff.

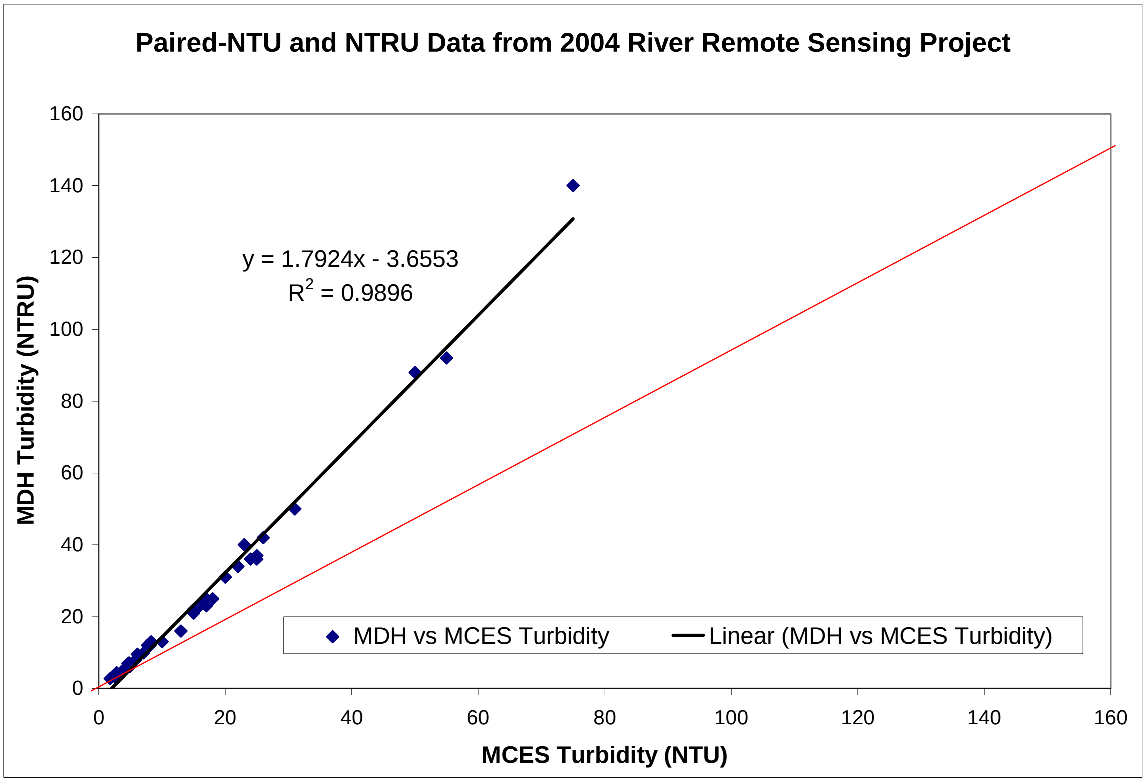
Excel and Minitab were used to analyze the paired laboratory turbidity data. The goal of the analysis was to use appropriate statistical methods to provide a “conversion” factor for estimating NTU values from measured NTRU values for use in the West Fork Des Moines River and Pipestone Creek Turbidity TMDLs given the absence of paired measurements from those project areas.

Summary statistics, tests for normality, linear regression, and paired-t tests and a nonparametric test parallel to a t-test were used for the analyses. The data and selected analyses are included at the end of this appendix.

Results

Linear regression of the raw data was initially completed to check if the initial difference factor of 0.55 was determined in this way (Figure 1). The results appear to indicate that this is the means in which the initial number was determined. However, summary statistics and histograms in Excel and tests for normality in Minitab indicate that the data is not normally distributed; such that parametric statistics (i.e., linear regression) should not be used on the raw data.

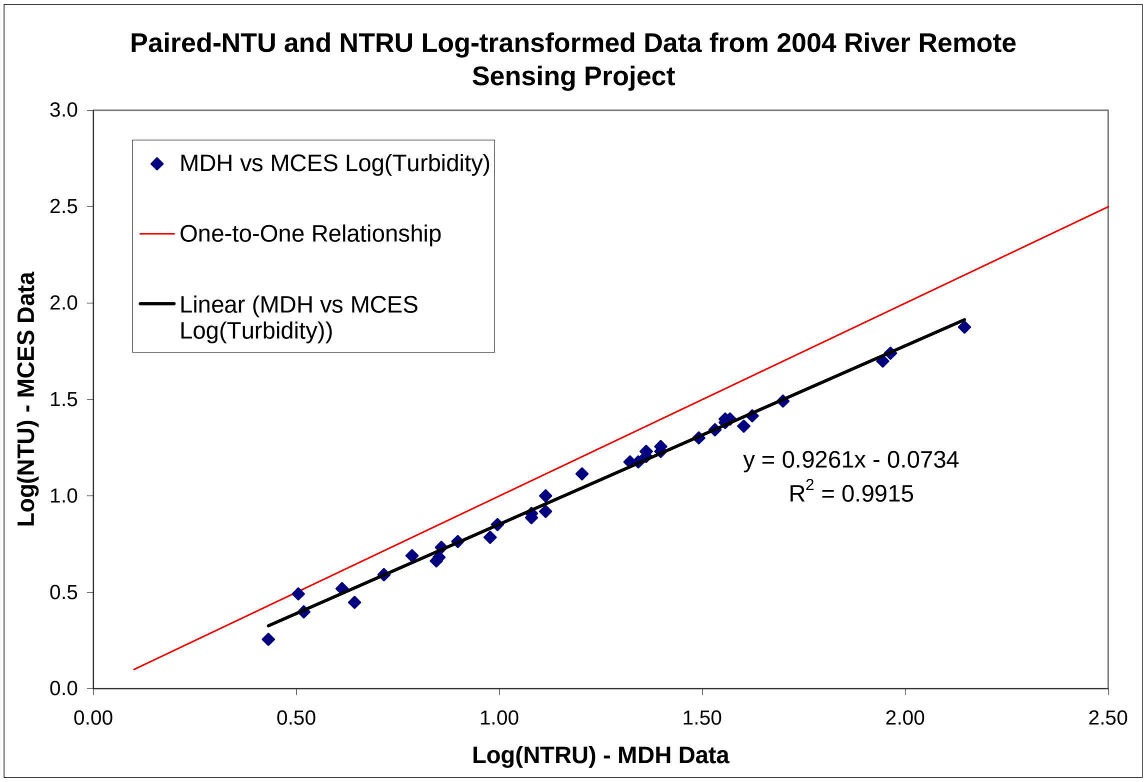
Figure 1.



The data were then log-transformed and evaluated to see if the log-transformed data were normally distributed. Summary statistics and histograms in Excel and tests for normality in Minitab indicate that the transformed data are nearly and acceptably normally distributed, respectively.

Linear regression analyses were then completed on the log-transformed data. The Excel regressions were done assigning the NTU data as the independent variable and the NTRU data as the dependent variable. The resulting regression equation resulted in the predicted y-variable being NTRU rather than NTU; therefore, the equation had to mathematically be solved for NTU. To reduce the chance of making a mistake in solving the equation for NTU, the Minitab regressions were run with the independent variable as NTRU and dependent variables as NTU. The resulting equation provided the predicted y-variable directly as NTU values. The switch to this approach occurred when a mistake in the math was found in the intermediate analysis work.

Figure 2.



Converting the predicted log-transformed value back to standard units (NTU) is done by taking the anti-log of the predicted number. Statistical analyses are often stopped at this point, especially in the natural sciences. However, statistical research has demonstrated that doing so results in a biased retransformation estimate. To correct this bias, there are various bias-correction factor procedures available for use. For this data, the Duan's Smearing Estimator (USGS, undated) was used. The effect of the bias-correction in this data was minimal; however, it is still the method of choice in this evaluation to complete the analyses following formal statistical procedures.

The final regression analysis and retransformation of the predicted variable in units of NTU resulted in the equation:

NTU = 10^(-0.0734+0.926*LOG(NTRU))/1.003635.

It is important to note when using this approach to "convert" NTRU to NTU values that the variability in measurements and characteristics of the water is probably much greater than the "accuracy" inferred by the significant digits used in this analysis. The estimated NTU turbidity values are best reported as integers, except for values less than ten where a single decimal place is adequate.

Table 1 provides a comparison of NTRU values to the predicted NTU values along with the ratio between the predicted NTU and observed NTRU values. Given the log-transformation and retransformation, the ratio between the values varies from low to high values with the difference between predicted NTU and measured NTRU being the least (highest ratio) at lower turbidity levels and greatest (lowest ratio) at higher turbidity levels. The ratio ranges from 0.6 to 0.65 for estimated turbidities (NTU) between 100 and 20, respectively. The ratio between the predicted and measured values at 25 NTU is 0.64.

Table 1. NTRU and "Estimated NTU" values based on regression of paired turbidity data from the 2004 River Remote Sensing Project.

NTRU	"Estimated NTU"	Ratio
1	0.84	0.84
5	3.74	0.75
10	7.1	0.71
15	10.33	0.70
20	13.48	0.67
25	16.58	0.66
30	19.63	0.65
35	22.64	0.65
39	**25.02**	**0.64**
40	25.62	0.64
45	28.57	0.64
100	59.84	0.60

Given the differences in the standard procedures for the two meters and the relatively wide geographic range of the remote sensing study rivers, a visual check of regressions using two subsets of the paired data was performed. A subset of data less than 40 NTU was selected to check for a possible affect on the relationship due to dilution of samples for turbidities greater than 40 when using Standard Methods with a Hach 2100A turbidimeter. The second subset to be checked was data from the Blue Earth River Basin assuming that its location was "most similar" to that of the Des Moines River and Pipestone Creek. Figure 3 plots these with the "all data" regression. They show little difference between them, so the "all data" regression equation was used in calculating NTU values from the measured NTRU values in the turbidity TMDLs for the West Fork Des Moines River and Pipestone Creek.

Figure 4 plots the estimated NTU values versus a range of NTRU values based on the final regression analysis of the paired data set.

Figure 3.

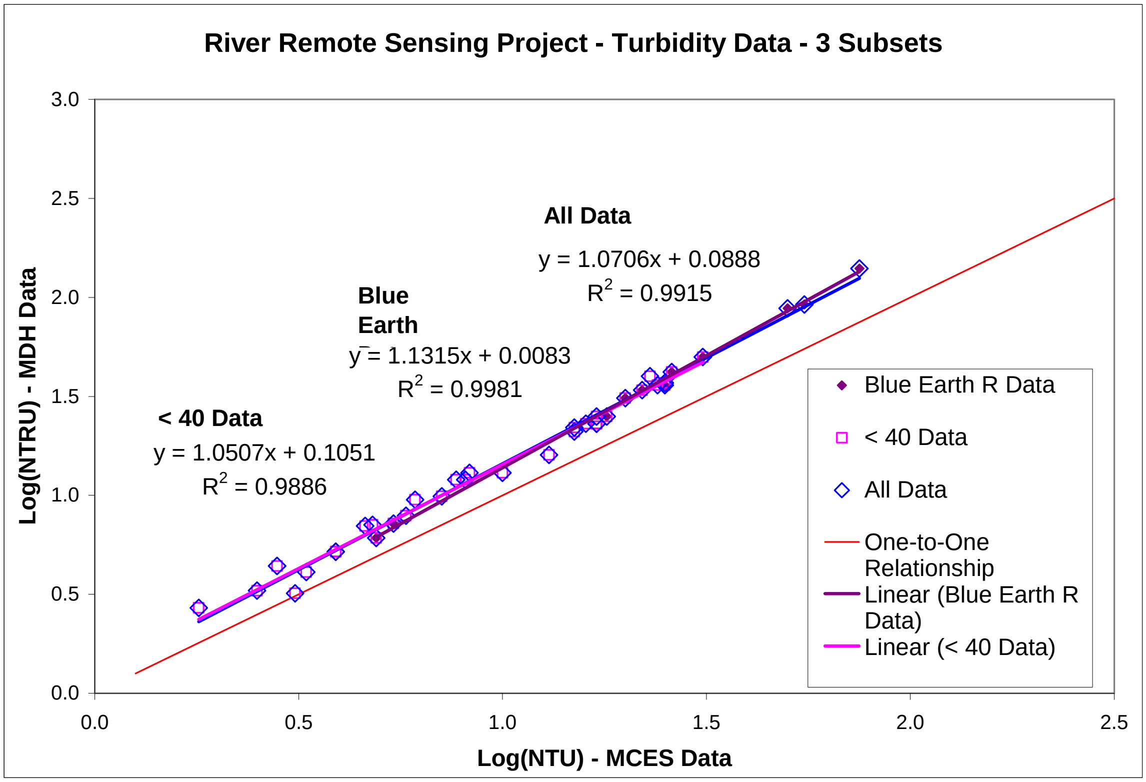
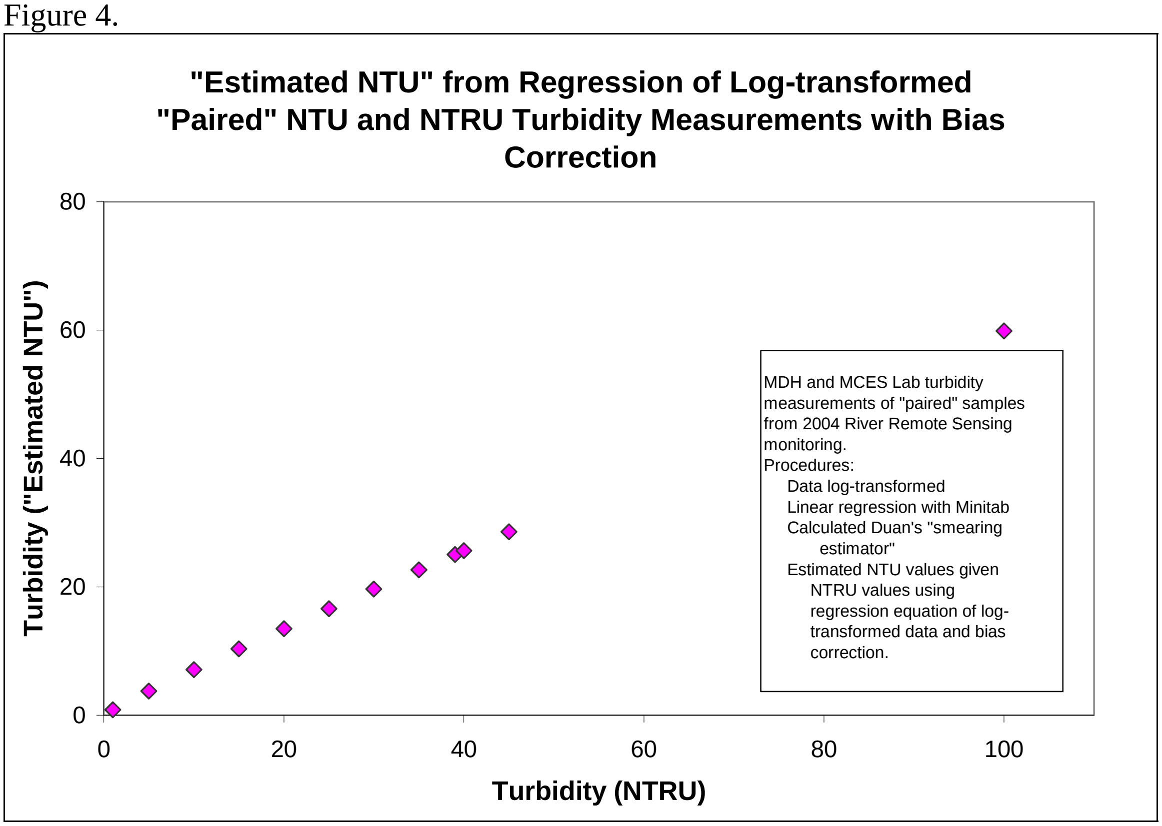


Figure 4.



References

Anderson, C.W., September 2005, Turbidity (version 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., section 6.7, accessed Dec. 13, 2007 from http://pubs.water.usgs.gov/twri9A6/.

Ankcorn, P.D. 2003. Clarifying Turbidity – The Potential and Limitations of Turbidity as a Surrogate for Water-Quality Monitoring. Proceedings of the 2003 Georgia Water Resources Conference, held April 23–24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Federal Water Pollution Control Administration. 1968. Water Quality Criteria: Report of the National Technical Advisory Committee to the Secretary of the Interior.

Miller, T.L. 2004. Revision of National Field Manual Chapter 6, Section 6.7--USGS Water-Quality Technical Memorandum 2004.03 http://water.usgs.gov/admin/memo/QW/qw04.03.html

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

Pavelich, P. 2002. Turbidity Studies at the National Water Quality Laboratory. Proceedings of the Federal Interagency Workshop on Turbidity and other Sediment Surrogates, April 30-May 2, 2002, Reno, Nevada. J.R. Gray and G.D. Glysson, editors. U.S. Geological Survey Circular 1250. [http://pubs.water.usgs.gov/circ1250]

USGS. Undated. Bias Correction Factor. Suspended-Sediment Database – Daily Values of Suspended Sediment and Ancillary Data. Accessed December 13, 2007 at http://co.water.usgs.gov/sediment/bias.frame.html.

River Remote Sensing Project

MCES and MDH Laboratory Analytical Data for Turbidity

All samples were collected on August 19, 2004

Site Description	Basin ID	Time	NTU	NTRU
LeSueur River at Hwy 66 Bridge in South Bend Twp.	LESUEUR	9:15	75	140
Minnesota River at Co Rd 42 Bridge in Judson	MINNESOTA	8:45	50	88
Blue Earth River at Hwy 169 Bridge in Mankato	BLUEEARTH	14:30	55	92
Blue Earth River Upstream of the Confluence with the LeSueur	BLUEEARTH	10:00	26	42
LeSueur River (Gravel Pit) Upstream of the Confluence with the Blue Earth	LESUEUR	9:30	4.9	6.1
Blue Earth River at Rapidan Dam	BLUEEARTH	8:25	22	34
Blue Earth River Upstream of the Confluence with Watonwan	BLUEEARTH	11:30	31	50
Watonwan River Upstream of Confluence with Blue Earth	WANTONWAN	11:40	5.4	7.2
Blue Earth River Upstream of the Pool Created by the Rapidan Dam	BLUEEARTH	12:00	18	25
Center of the Pool on the Blue Earth River Upstream of the Rapidan Dam	BLUEEARTH	12:50	20	31
Crow River at Hwy 55 Bridge in Rockford	CROW_R	8:30	15	22
North Fork of Crow River at Farmington Ave Bridge	CROW_R	9:00	17	23
South Fork of Crow River at Farmington Ave Bridge	CROW_R	9:25	7.1	9.9
Rum River at Main Street Bridge in Anoka	RUM	7:15	5.8	7.9
Mississippi River at Hwy 169 Bridge near Anoka	MISSISSIPPI	10:20	3.1	3.2
Mississippi River 250m Upstream of Confluence with the Crow River	MISSISSIPPI	13:20	2.5	3.3
Crow River at River Road Bridge near the Confluence with the Mississippi River	CROW_R	13:45	6.1	9.5
Mississippi River Downstream of Goodin Island - Right Descending Bank	MISSISSIPPI	14:45	3.9	5.2
Mississippi River Downstream of Goodin Island - Left Descending Bank	MISSISSIPPI	15:00	2.8	4.4
Mississippi River Downstream of Cloquet Island - Center Channel	MISSISSIPPI	10:50	3.3	4.1
Mississippi River at Hwy 5 Bridge	MISSISSIPPI	12:43	4.6	7
Mississippi River side of Pike Island	MISSISSIPPI	13:10	4.8	7.1
Minnesota River side of Pike Island	MINNESOTA	13:50	25	37
Minnesota River at Fort Snelling between I494 and Hwy 55	MINNESOTA	13:35	24	36
Mississippi River at I35E Bridge - Right Descending Bank	MISSISSIPPI	14:54	7.7	12
Mississippi River at I35E Bridge - Left Descending Bank	MISSISSIPPI	14:42	23	40
Mississippi River at Smith Ave High Bridge in St. Paul - Right Descending Bank	MISSISSIPPI	14:15	15	21
Mississippi River at Smith Ave High Bridge in St. Paul - Left Descending Bank	MISSISSIPPI	14:25	17	23
Mississippi River at Lock and Dam No. 2	MISSISSIPPI	9:00	16	23
Mississippi River downstream of Hwy 61 Bridge near Hastings	MISSISSIPPI	8:47	17	25
St. Croix River at Hwy 10 Bridge near Prescott	ST_CROIX	9:15	1.8	2.7
Mississippi River One-Half Mile Downstream of Prescott Island - Right Descending Bank	MISSISSIPPI	9:41	10	13
Mississippi River One-Half Mile Downstream of Prescott Island - Left Descending Bank	MISSISSIPPI	9:55	13	16
Mississippi River Three Miles Downstream from Prescott Island - Right Descending Bank	MISSISSIPPI	10:11	8.1	12
Mississippi River Three Miles Downstream from Prescott Island - Left Descending Bank	MISSISSIPPI	10:21	8.3	13
Minnesota River at Sibley Park	MINNESOTA	14:45	25	36
Mississippi River at Hayden Creek Confluence	MISSISSIPPI	9:50	3.9	5.2

Appendix D. Heron Lake BATHTUB Modeling Inputs

Heron Lake
File: C:\bath\heronlake_CB04_may-sep_TMDL2.btb
Description:
May thru Sep 2006

Global Variables	Mean	CV
Averaging Period (yrs)	0.4192	0.0
Precipitation (m)	0.397	0.0
Evaporation (m)	0.64	0.0
Storage Increase (m)	-0.97	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	24.5	0.00
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	4	CANF &BACH, RESERV
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	2	P, LIGHT, T
Secchi Depth	1	VS. CHLA & TURBIDITY
Dispersion	0	NONE
Phosphorus Calibration	0	NONE
Nitrogen Calibration	0	NONE
Error Analysis	2	MODEL ONLY
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	South Heron Lake	2	1	10.4	0.59	8.4	0	0	0	0	0.08	0	0	0	0	0	0	0
2	North Heron Lake	3	2	8.2	0.37	3.65	0	0	0	0	0.08	0	0	0	0	0	0	0
3	North Marsh	0	3	1.6	0.5	2.4	0	0	0	0	0.08	0	0	0	0	0	0	0
4	Duck Lake	3	4	2.4	0.5	2	0	0	0	0	0.08	0	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	507	0	0	0	126	0	0.22	0	0	0	426	0	0	0	0	0
2	0	0	358	0	0	0	146	0	0.27	0	0	0	296	0	0	0	0	0
3	0	0	182	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Okabena Creek 1	1	1	344.2	5.29	0	0	0	164	0	0	0	0	0	0	0
2	Jack Creek	2	1	529.9	96.1	0	0	0	105	0	0	0	0	0	0	0
3	Unmonitored Area to South He	1	3	162.4	30.3	0	0	0	105	0	0	0	0	0	0	0
4	Unmonitored Area to North He	2	3	64.8	11.8	0	0	0	105	0	0	0	0	0	0	0
5	Okabena Creek 2	2	1	344.2	67.68	0	0	0	166	0	0	0	0	0	0	0
6	Unmonitored Area to Duck Lak	4	3	16.8	3.1	0	0	0	105	0	0	0	0	0	0	0
7	Unmonitored Area to North M	3	3	17.3	3.1	0	0	0	105	0	0	0	0	0	0	0
8	Heron Lake WWTP	3	3	0	0.126	0	0	0	1000	0	0	0	0	0	0	0
9	Lakefield WWTP	1	1	0	0.825	0	0	0	600	0	0	0	0	0	0	0

Transport Channels

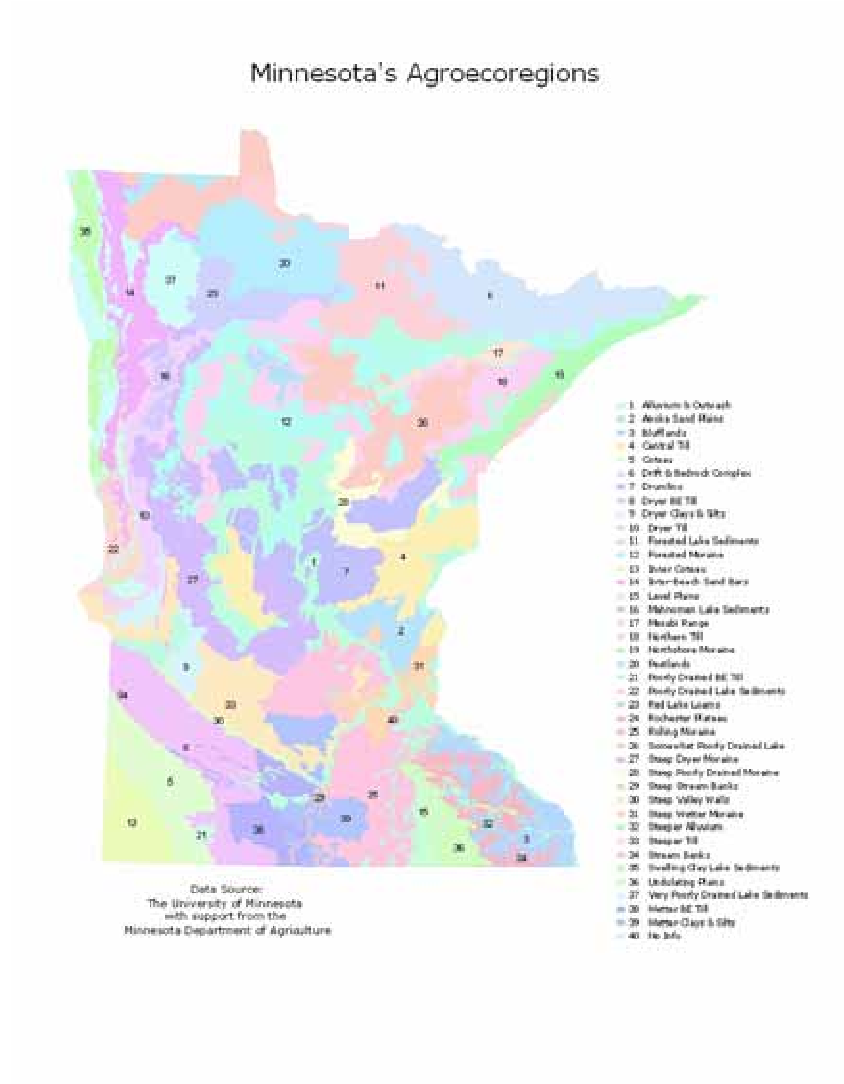
		Source	Downstr.	Adv.Flow (hm^3/yr)		Diffusive Flow (hm^3/yr)	
Chan	Name	Segment	Segment	Mean	CV	Mean	CV
1	Ditch 1	1	2	0	0	0	0
2	Ditch 2	2	3	0	0	0	0
3	Ditch 3	4	3	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Appendix E. Agroecoregion BMP Matrix

The matrix below was developed by David Mulla of the Department of Soil, Water, and Climate of the University of Minnesota and provides Best Management Practice (BMP) options based on agroecoregion. These agroecoregions for Minnesota are shown in the figure to the right. The agroecoregions for the WFDMR watershed are shown in Figure 1.1.

Ratings in the table that follows are High (H), Medium (M) and Low (L). High means a practice that will be very effective over a large area. Low means a practice that will be very effective, but is suitable only for small portions of the agroecoregion.



NRCS #	Conservation Practices	Alluvium & Outwash	Anoka Sand Plains	Blufflands	Central Till	Coteau	Drumlins	Dryer Blue Earth Till	Dryer Clays & Silts	Dryer Till	Inner Coteau	Inter-Beach Sand Bars	Level Plains	Mahnomen Lake Sediments	Poorly Drained Blue Earth Till	Poorly Drained Lake Sediments	Rochester Plateau	Rolling Moraine	Somewhat Poorly Drained Lake	Steep Dryer Moraine	Steep Stream Banks	Steep Valley Walls	Steep Wetter Moraine	Steeper Alluvium	Steeper Till	Stream Banks	Swelling Clay Lake Sediments	Undulating Plains	Very Poorly Drained Lake Sediments	Wetter Blue Earth Till	Wetter Clays & Silts
	Riparian																														
393	**Grass Filter Strip**[1]	M	L	M-H		M	L	M-H		H	L	M	H	L	L	L	M	H	L	H	H	M	H	H	M	H	M	M	L	H	L
391	**Riparian Forest Buffer**	M	L	M-H		L	L			L		M	M			L	M	L	H	M	M	H	H		L	L		M	L	L	
580	**Streambank & Shoreline Protection**	L		H		H		L-M					L			M	M	M	L	H	H	H	H	M	M	H	M	L	L	M	M
657	**Wetland Restoration**[2] *	L	L				M	H				L	L	L	M	H		L	H	M		M	M		L		M		M	H	M
659	**Wetland Enhancement**						M	H								M			H												M
	Upland																														
328	**Conservation Crop Rotation**[3]	M	L	H		H	M	M	M	H	M	L	M	L	M	M	H	H	L	M	H	M	H	M	L	L		L	M	L	L
329	**Conservation Tillage**[4]	M	L	H		H	M	H	M	M	M	M	M	L	M		H	H	L	H	H	L	H	M	H	H		M		H	M
	Primary Crop																										L		L		
	Secondary Crop																										M		M		
332	**Contour Buffer Strip**					H				M	L		M				M	M		H			L					M		L	
330	**Contour Farming**		L	H		H	M	L		H	M		M				H	**H**	**L**	**H**			**H**	**M**	**L**			**M**		**M**	
340	**Cover Crop**	M	M	L		L		L-M			M											L	L		L			L		L	L
342	**Critical Area Planting**	M	M	L		L		L				M			L		L	M		M	H	H	M	H	L	H		L		M	
643	**Declining Habitat Restoration & Mgt**[5]*							M-H			M			L	M	L			H	M		M					M		M		L
362	**Diversion**					H											M	L			M									M	

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554	Drainage Water Mgnt[6]							M-H					M	M	M-H	H		M	M						M		H	L	M	M	H
	Field Border																														L
655	Forest Harvest Trails & Landings						M												H	M									M		
666	Forest Stand Improvement						M												H	M									M		
	Gully Erosion	L		H		H		L									H	H		M	H	H	M		M	M		L		M	L
410	Grade Stabilization			H		H											H					M	M		L			L		M	L
412	Grass Waterway			M		H		L		M	M						H	M		M	H		M		L			L		M	L
600	Terrace			M		H				L	M						H	M					L		L			M		L	
638	Water and Sediment Control Basin			H		H		L		L							H	H		M	H		H		M			L		M	L
	Grass Cover (CRP only) [7]*	M	L	H		H	L	L		H	L	M					H	H		H	M	H	H	L	M	M	M	L	L	H	L
512	Pasture & Hayland Planting	M	M	H		H	H	L-M		M	M						H	H	M	H			M		L	M		L		L	L
528A	Prescribed Grazing	M	L	M-H		H	H	L-M			L						M	M	M	M			M		L	M		L		L	L
350	Sediment Basin	M	L	M		M	L	L									M	H		M	H		H		M			L		M	
725	Sinkhole Treatment[8]			M													H											L			
585	Stripcropping[9]			H		M					M		M				H			M								L		L	
612	Tree/Shrub Planting *						M									L			M	M		M	M	L		M			M		
472/ 382	Use Exclusion / Fencing	M	L	L		H	H	L			H		L				M	L	M	M		L	M		L	H		M	M	L	
645	Upland Wildlife Habitat Management[10]*			M		M		M-H		H	M				M	L	M		M	M		M	L				L		M		L
658	Wetland Creation							H								L			H												
657	Wetland Restoration[11]	L	L				M	H				L	M	M	M	H		L	H	M		L	M		L		M	L	H	M	H
	Wind Erosion																														

NRCS #	Conservation Practices	Alluvium & Outwash	Anoka Sand Plains	Blufflands	Central Till	Coteau	Drumlins	Dryer Blue Earth Till	Dryer Clays & Silts	Dryer Till	Inner Coteau	Inter-Beach Sand Bars	Level Plains	Mahnomen Lake Sediments	Poorly Drained Blue Earth Till	Poorly Drained Lake Sediments	Rochester Plateau	Rolling Moraine	Somewhat Poorly Drained Lake	Steep Dryer Moraine	Steep Stream Banks	Steep Valley Walls	Steep Wetter Moraine	Steeper Alluvium	Steeper Till	Stream Banks	Swelling Clay Lake Sediments	Undulating Plains	Very Poorly Drained Lake Sediments	Wetter Blue Earth Till	Wetter Clays & Silts
589	**Cross-Wind Ridges / X-Wind Stripcropping / X-Wind Trap Strips**	L	M					M	H	L		H		M	L-M	M			M	L							H		M		
422	**Hedgerow/ Herbaceous Wind Barrier**	L	M						H	L		H		M	L-M	M			M	L							H		M		
380/ 650	**Windbreak / Shelterbelt / Living Snow Fence** *	L	M						H	L		H		M	L-M	M			M	L							H		M		

* A common CRP cover type in Minnesota

[1] Effectiveness depends on complementary upland practices (which may be true for several other practices in this table as well)
[2] In riparian zones, this means floodplain wetlands
[3] Refers to the addition of at least a third crop—one that is resource-conserving and regionally appropriate—to an existing 2-crop rotation.
[4] Refers to NRCS Standards 329A-329C (Residue Management) which encompass No-Till, Strip-Till, Mulch-Till and Ridge-Till
[5] When the habitat being restored is native prairie, this is effectively an enhanced version of a typical CRP grass stand.
[6] Refers to a range of "conservation drainage" practices, some currently in Mn-NRCS Standard 554 Drainage Water Management and many not; examples include blind inlets, rock inlets, and tile spacing and depth.
[7] Some CRP grass stands are planted with special attention to use of native species, while others are not (need to specify if there is a significant difference in terms of water quality).
[8] Treatment is typically with filter strips and/or diversions
[9] Includes contour stripcropping as well as stripcropping on flatter land
[10] In the Northern Tallgrass Prairie region, this often consists of grassland restoration
11 In uplands (esp. in the Northern Tallgrass Prairie region), depressional "prairie potholes" are often the type of wetlands being restored