Des Moines River Basin

March 2021

Des Moines River Basin Watersheds Total Maximum Daily Loads

Des Moines River Headwaters, Lower Des Moines River, and East Fork Des Moines River Watersheds.

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Contents

List of Tables

List of Figures

Acronyms

AFO	Animal Feeding Operation
AU	Animal Unit
AUID	Assessment Unit ID
BMP	Best management practice
CAFO	Concentrated Animal Feeding Operation
cfs	Cubic foot per second
Chl-*a*	Chlorophyll-a
CWA	Clean Water Act
CWLA	Clean Water Legacy Act
CWP	Clean Water Partnership
DNR	Minnesota Department of Natural Resources
E. coli	*Escherichia coli*
EDA	Environmental Data Access
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
FWMC	Flow weighted mean concentration
HSPF	Hydrological Simulation Program-Fortran
HUC-08	8-digit hydrologic code unit
HUC-10	10-digit hydrologic code unit
ITPHS	Imminent Threat to Public Health and Safety
kg	Kilogram
km^2	Square kilometer
LA	Load allocation
Lb	Pound
lb/day	Pounds per day
lb/yr	Pounds per year
LC	Loading capacity
LDC	Load duration curve
LGU	Local Government Unit
m	Meter

MAWQCP	Minnesota Agricultural Water Quality Certification Program
mgd	Million gallons per day
mg/L	Milligrams per liter
mL	Milliliter
MOS	Margin of safety
MPCA	Minnesota Pollution Control Agency
MRLC	Multi-Resolution Land Characteristics
MS4	Municipal Separate Storm Sewer Systems
NGP	Northern Glaciated Plains
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint sources
NSE	Nash-Sutcliffe Efficiency
OLA	Open Lot Agreement
P	Phosphorus
PTMApp	Prioritize, Target, and Measure Application
RC	Reserve Capacity
SDS	State Disposal System
sq mi	Square miles
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TP	Total phosphorus
TSS	Total suspended solids
µg/L	Microgram per liter
WCBP	Western Corn Belt Plains
WLA	Wasteload allocation
WQBELs	Water Quality Based Effluent Limits
WRAPS	Watershed Restoration and Protection Strategy
WWTP	Wastewater treatment plant

Executive summary

Section 303(d) of the federal Clean Water Act (CWA) provides authority for completing Total Maximum Daily Loads (TMDLs) to achieve state water quality standards and/or designated uses. The TMDL establishes the maximum amount of a pollutant a waterbody can receive on a daily basis and still meet water quality standards. The TMDL is divided into wasteload allocations (WLA) for point or permitted sources, load allocations (LA) for nonpoint sources (NPS) and natural background plus a margin of safety (MOS).

This TMDL report addresses impaired stream reaches and lakes in the Des Moines River Basin listed on the 303(d) impaired waters list requiring a TMDL. The Des Moines River Basin in Minnesota encompasses portions of three 8-digit hydrologic code unit (HUC-08) watersheds, including all of the Des Moines River Headwaters (07100001) and portions of the Lower Des Moines River (07100002) and East Fork Des Moines River (07100003) watersheds. This TMDL report addresses one chloride impairment, two turbidity/total suspended solids (TSS) impairments, and 10 *Escherichia coli* bacteria (*E. coli*) impairments in 13 river reaches. Additionally, 23 excessive nutrients (phosphorus) impaired lakes are addressed in this TMDL report. Addressing multiple impairments in one TMDL report is consistent with Minnesota's Water Quality Framework that seeks to develop watershed-wide protection and restoration strategies rather than focus on individual reach impairments.

The Des Moines River Basin is in southwestern Minnesota and encompasses part of the Western Corn Belt Plains (WCBP) and the Northern Glaciated Plains (NGP) ecoregions. The watershed covers an area of 1,537 square miles (approximately 983,000 acres). The Des Moines River Basin boundaries presented in this TMDL report cover portions of seven counties in Minnesota, including Cottonwood, Jackson, Lyon, Martin, Murray, Nobles, and Pipestone. Only river reaches and lakes within the boundaries of Minnesota are included in this TMDL report, though the basin extends south into Iowa.

This TMDL report used a variety of methods to evaluate current loading contributions by the various pollutant sources, as well as the allowable pollutant loading capacity (LC) of the impaired water bodies. These methods include the Hydrological Simulation Program – FORTRAN (HSPF) model, the load duration curve (LDC) approach, and a stochastic version of the BATHTUB lake eutrophication model. This TMDL report addresses Des Moines River Basin impairments identified in the most recent monitoring and assessment cycle. The North and South Heron Lake TMDL is also revisited and revised in this report. Additional data and the availability of a watershed-wide HSPF model were not available when the first Heron Lake TMDL was written.

A general strategy and cost estimate for implementation to address the impairments are included. NPS will be the focus of implementation efforts. NPS contributions are not regulated and implementation efforts will need to be addressed on a voluntary basis. Permitted point sources will be addressed through the Minnesota Pollution Control Agency's (MPCA) National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Permit (Permit) programs.

1. Project overview

1.1 Purpose

The federal CWA Section 303(d) requires that states publish a list of surface waters that do not meet water quality standards, and therefore do not support their designated use(s). These waters are then classified as impaired and placed on the impaired waters list, which dictates that a TMDL must be completed. The TMDL calculates the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and allocates pollutant loads across the sources of pollutants.

The passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and resources to state and local governments to accelerate efforts to monitor, assess, and restore impaired waters and to protect unimpaired waters. The result has been a comprehensive "watershed approach" that integrates water resource management efforts, local governments, and stakeholders to develop watershed-scale TMDL reports, restoration and protection strategies, and plans for each of Minnesota's 80 major watersheds. The information gained and strategies developed in the watershed approach are presented in major watershed-scale Watershed Restoration and Protection Strategy (WRAPS) reports, which guide restoration and protection of streams, lakes, and wetlands across the watershed, including those for which TMDL calculations are not made. Local watershed plans are then developed based on the WRAPS, including using the One Watershed, One Plan process. The Des Moines Basin was selected in 2020 for funding for this process.

This report addresses impaired stream reaches and lakes in the Des Moines River Basin listed on the 303(d) impaired waters list requiring a TMDL. The Des Moines River Basin in Minnesota encompasses portions of three 8-digit HUC-08 watersheds, including all of the Des Moines River Headwaters (07100001), parts of the Lower Des Moines River (07100002), and East Fork Des Moines River (07100003) watersheds. This TMDL report addresses one chloride impairment, two turbidity/TSS impairments, and 10 *E. coli* impairments in 13 stream reaches in the Des Moines River Basin. Additionally, 23 excessive nutrients (phosphorus) impaired lakes are addressed in this TMDL report. Although this report addresses many impaired streams and lakes, the biological impaired waterbodies are not addressed. These have been deferred to further investigate the impairments. An accounting of all impairments within the Des Moines River Basin is found in **Appendix E**. The Des Moines River Basin boundaries presented in this TMDL report cover portions of seven counties in Minnesota including Cottonwood, Jackson, Lyon, Martin, Murray, Nobles, and Pipestone. Only river reaches and lakes within the boundaries of Minnesota are included in this TMDL report, though the basin continues south into Iowa. This TMDL report also revisits and revises the North and South Heron Lakes TMDLs. The TMDLs are being revised due to additional data and the availability of a watershed-wide HSPF model (see **Section 4.2.1**). Two reach designations (Assessment Unit Identifications (AUID) 07100001 -501 and -527) are impaired by total phosphorus (TP) and are addressed in the *Des Moines River Basin River Eutrophication TMDL*, which was developed concurrently with this TMDL report. The purpose of this TMDL report is to quantify the pollutant reductions needed to meet state water quality standards for turbidity, phosphorus (P), nutrients, *E. coli*, and chloride for river reaches and lakes identified in **Tables 1** and **2** and **Figure 1** through **Figure 3**. This TMDL report is developed and established in accordance with Section 303(d) of the CWA and provides WLAs and LAs for the watershed as appropriate.

One TMDL report was completed in the Des Moines River Basin prior to this TMDL report. The previous TMDL report, West Fork Des Moines River Watershed Total Maximum Daily Load Final Report: Excess Nutrients (North and South Heron Lakes), Turbidity, and Fecal Coliform Bacteria Impairments (MPCA 2008), was approved by U.S. Environmental Protection Agency (EPA) in 2008 and an implementation plan, the West Fork Des Moines River and Heron Lake TMDL Implementation Plan (HLWD 2009), was approved by the MPCA in 2009. The previous report addressed a total of 33 impairments covering lake nutrients, turbidity, fecal coliform bacteria, and pH in the Des Moines River Headwaters and Lower Des Moines River watersheds. Since the approval of this TMDL report and implementation plan, a watershed-wide HSPF model has been developed. New lake data is available and new processes of completing lake TMDLs have been implemented that better reflect the lake conditions. The North Heron Lake TMDL and South Heron Lake TMDL completed within this report will replace the 2008 North and South Heron Lake TMDL. All other existing TMDLs from the previous report will not be revised.

1.2 Identification of waterbodies

This TMDL report addresses 13 impairments in 13 stream reaches and 23 lakes listed on the 2018 303(d) impaired waterbodies list for the Des Moines River Basin. The stream impairments include:

- 10 *E. coli* impairments, not supporting aquatic recreation use;
- 2 Turbidity impairments, not supporting aquatic life use; and
- 1 Chloride impairment, not supporting aquatic life use.

The lake impairments are all for excessive nutrients/eutrophication indicators, not supporting aquatic recreation use.

Tables 1 and **2** below summarize the Des Moines River Basin impairments addressed in this TMDL report. **Table 1** provides the impaired stream reaches and **Table 2** provides the impaired lakes. **Figure 1** shows the location of impaired waters addressed in this TMDL report for the Des Moines River Headwaters Watershed. **Figure 2** shows the location of impaired waters addressed in this TMDL report for the Lower Des Moines River Watershed, and **Figure 3** shows the location of impaired waters addressed in this TMDL report for the East Fork Des Moines River Watershed. It should be noted that as of 2015, the turbidity standard was replaced with a TSS standard. TSS is a surrogate for all turbidity impairments and the turbidity impairments will be referred to as TSS impairments for the remainder of this TMDL report.

Table 1. Stream reach impairments addressed in this TMDL report.

Watershed (HUC-08)	Assessment Unit ID	Waterbody	Impairment/ Parameter	Designated Class	Beneficial Use[1]	Listing Year
Des Moines River Headwaters (07100001)	07100001-512	Okabena Creek, Unnamed cr to T102 R38W S6, north line	*Escherichia coli*	7	LRV	2010
	07100001-524	Des Moines River, Heron Lk outlet to Windom Dam	*Escherichia coli*	2Bg, 3C	AQR	2018
	07100001-527	Heron Lake Outlet, Heron Lk (32-0057-01) to Des Moines R	*Escherichia coli*	2Bg, 3C	AQR	2018
	07100001-551	Unnamed creek, String Lk to Des Moines R	Turbidity	2Bg, 3C	AQL	2008
	07100001-564	Unnamed creek, Unnamed ditch to Jack Cr	*Escherichia coli*	2Bg, 3C	AQR	2018
	07100001-602	Okabena Creek, Elk Cr to Division Cr	Chloride	2Bg, 3C	AQL	2018
	07100001-652	Jack Creek, North Branch, JD 12 to Jack Cr	*Escherichia coli*	2Bg, 3C	AQR	2018
Lower Des Moines River (07100002)	07100002-505	Judicial Ditch 56, Unnamed cr to Des Moines R	Turbidity	2Bg, 3C	AQL	2008
East Fork Des Moines River (07100003)	07100003-503	County Ditch 11, Headwaters to E Fk Des Moines R	*Escherichia coli*	7	LRV	2018
	07100003-510	Fourmile Creek, JD 105 to Des Moines R	*Escherichia coli*	2Bg, 3C	AQR	2018
	07100003-515	County Ditch 1/Judicial Ditch 50, Unnamed cr to CD 11	*Escherichia coli*	2Bm, 3C	AQR	2018
	07100003-525	Des Moines River, East Branch, Unnamed cr to CD 11	*Escherichia coli*	2Bg, 3C	AQR	2018
	07100003-527	Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk	*Escherichia coli*	2Bg, 3C	AQR	2018

[1]Beneficial Uses: LRV = Limited Resource Value, AQR = Aquatic Recreation, AQL = Aquatic Life.

Table 2. Lake impairments addressed in this TMDL report.

Watershed (HUC-08)	Assessment Unit ID	Waterbody	Impairment/Parameter	Designated Class	Beneficial Use[1]	Listing Year	Ecoregion
Des Moines River Headwaters (07100001)	17-0044-00	North Oaks	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	17-0060-00	Talcot	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2010	WCBP
	32-0015-00	Boot	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	32-0045-00	Flahtery	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2010	WCBP
	32-0053-00	Teal	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	32-0057-02	Heron (Duck)	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2002	WCBP
	32-0057-05	North Heron Lake	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2002	WCBP
	32-0057-07	South Heron Lake	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2002	WCBP
	32-0058-00	Timber	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	42-0047-00	Yankton	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2010	NGP
	51-0024-00	Lime	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2010	WCBP
	51-0040-00	Bloody	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2010	WCBP
	51-0043-00	Fox	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	51-0046-00	Shetek	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2006	WCBP
	51-0054-00	Corabelle	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	51-0063-00	Sarah	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2006	NGP
	51-0082-00	Currant	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2008	NGP
	53-0020-00	East Graham	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2008	WCBP
	53-0021-00	West Graham	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2008	WCBP
East Fork Des Moines River (07100003)	46-0052-00	Bright	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	46-0076-00	Pierce	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	46-0103-00	Temperance	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2018	WCBP
	46-0051-00	Okamanpeedan	Nutrient/eutrophication biological indicators	2B, 3C	AQR	2010	WCBP

[1]Beneficial Uses: AQR = Aquatic Recreation.

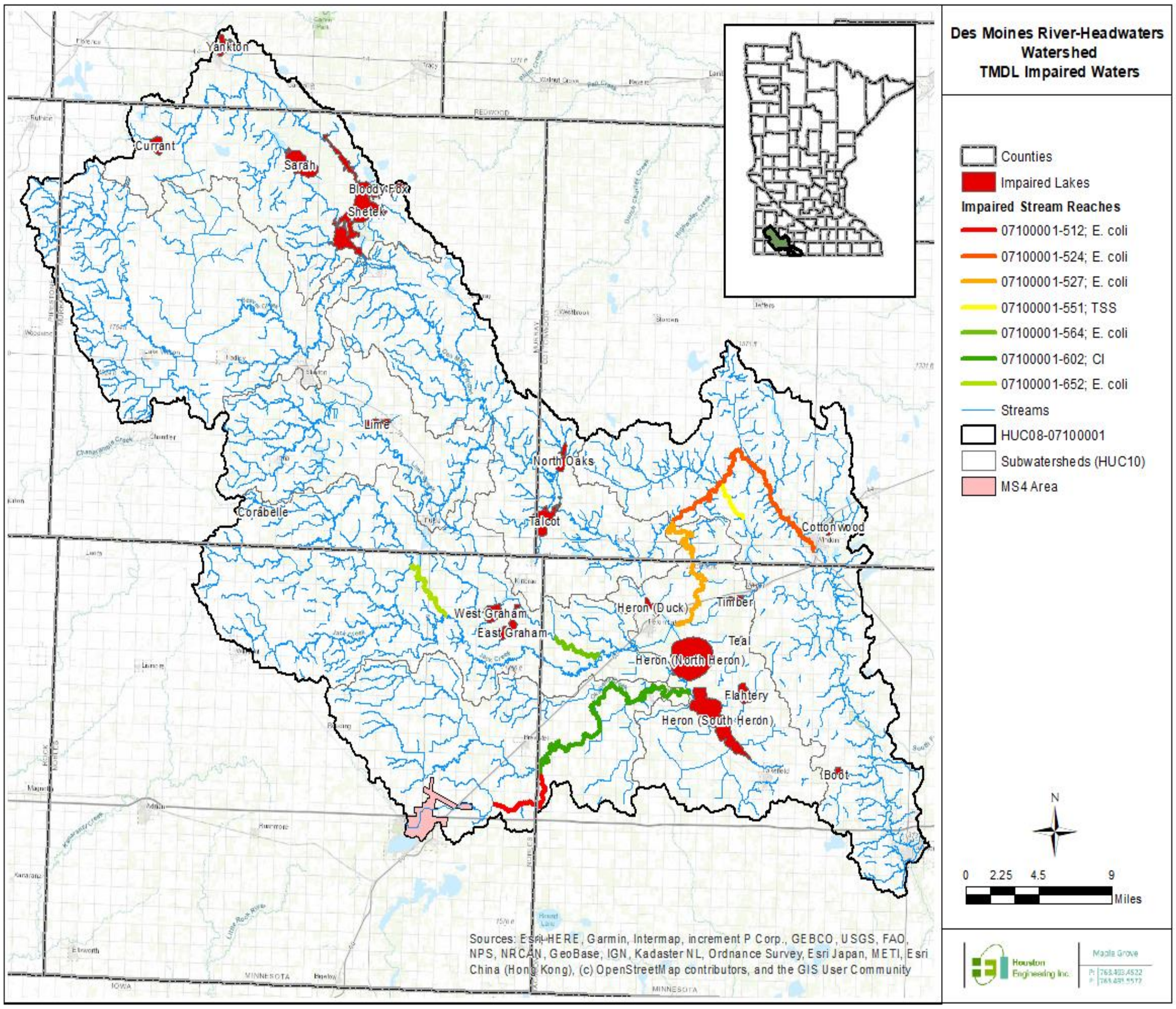

Figure 1. Impaired waters in the Des Moines River Headwaters Watershed of the Des Moines River Basin addressed in this TMDL report.

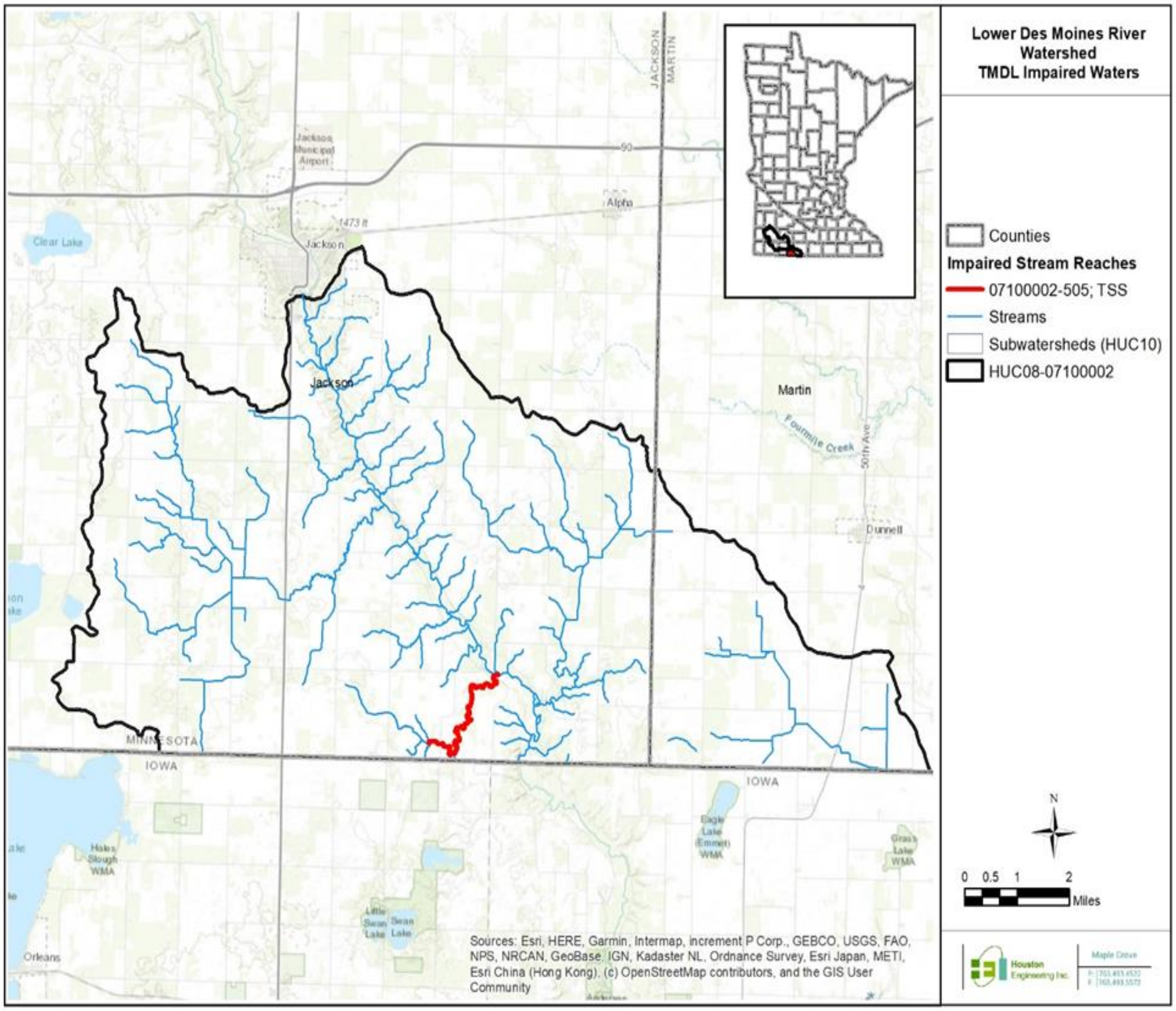

Figure 2. Impaired waters in the Lower Des Moines River Watershed of the Des Moines River Basin addressed in this TMDL report. Only the portions of water bodies and watersheds within Minnesota are addressed in this

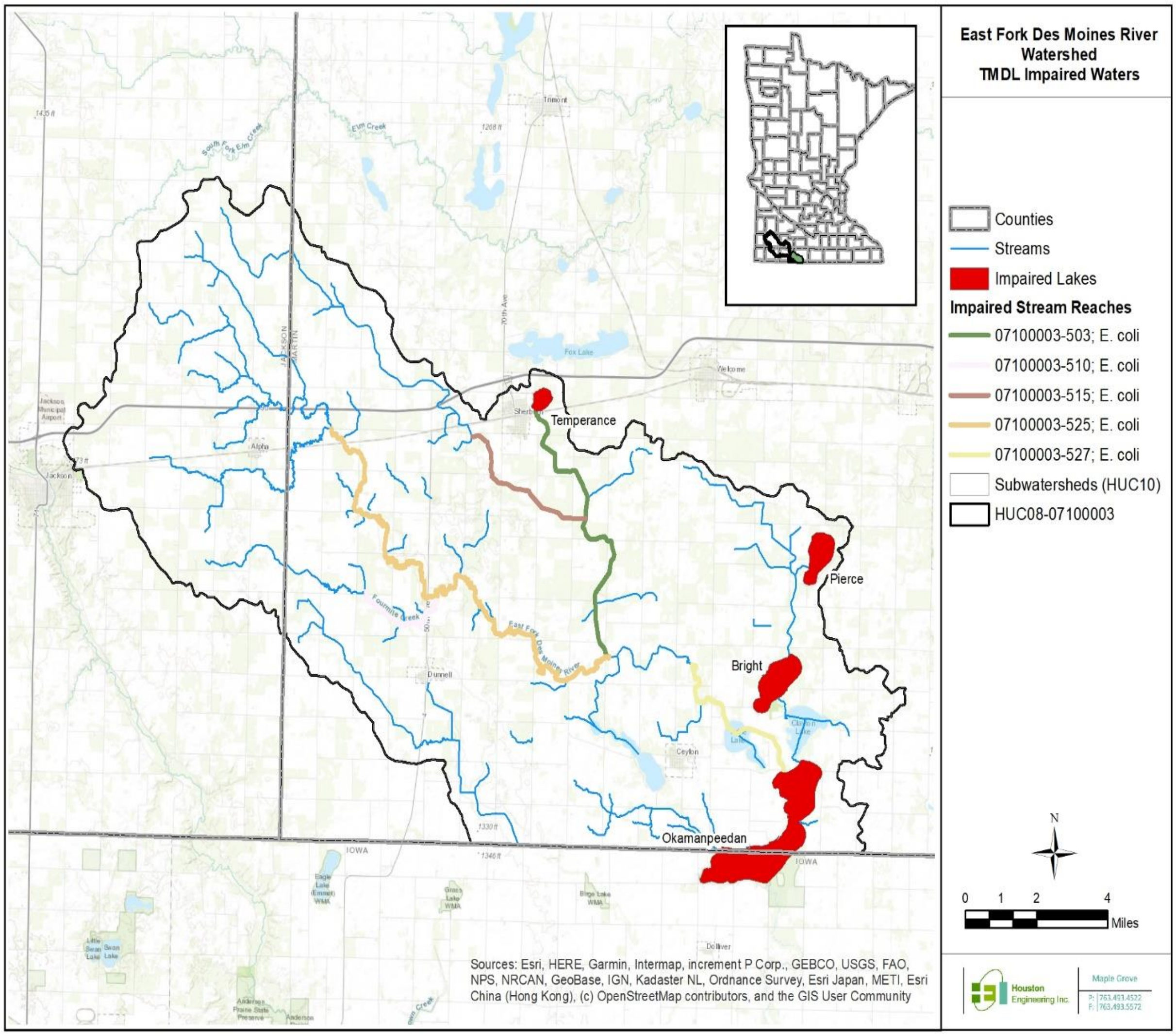

Figure 3. Impaired waters in the East Fork Des Moines River Watershed of the Des Moines River Basin addressed in this TMDL report. Only the portions of water bodies and watersheds within Minnesota are addressed in this

1.3 Priority ranking

The MPCA's schedule for TMDL completions, as indicated on Minnesota's Section 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL report. The MPCA has aligned TMDL priorities with the watershed approach. The schedule for TMDL completion corresponds to the WRAPS report completion on the 10-year cycle. The MPCA developed a state plan, Minnesota's TMDL Priority Framework Report, to meet the needs of EPA's national measure (WQ-27) under EPA's Long-Term Vision for Assessment, Restoration, and Protection under the CWA Section 303(d) Program. As part of these efforts, the MPCA identified water quality impaired segments that will be addressed by TMDLs by 2022. The Des Moines River Basin waters addressed by this TMDL report are part of that MPCA prioritization plan to meet EPA's national measure.

2. Applicable water quality standards and numeric water quality targets

The criteria used to determine stream and lake impairments are outlined in the MPCA's document *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List* (MPCA 2018). Minn. R. ch. 7050.0470 lists waterbody classifications and Minn. R. ch. 7050.0220 lists applicable water quality standards.

The Minnesota narrative water quality standard for all Class 2 waters (Minn. R. 7050.0150, subp. 3) states that:

> *The aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments, and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters.*

The impaired waters covered in this TMDL report are classified as Class 2B and 7. Relative to aquatic life and recreation, the designated beneficial uses for the most stringent classifications, 2B and 7 waters, are:

> **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 aquatic biota, and their habitats according to the definitions in subpart 4c. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface water is not protected as a source of drinking water* (Minn R. ch. 7050.0222, subp. 4).

> **Class 7 waters; limited resource value waters** – *The quality of class 7 waters of the state shall be such as to protect aesthetic qualities, secondary body contact use, and groundwater for use as a potable water supply.* (Minn. R. ch. 7050.0227, subp. 2)

The water quality standards shown in **Table 3** and **Table 4** are the numeric water quality target for each parameter shown. For more detailed information refer to the *MPCA TMDL Policies and Guidance*. It should be noted that if Minnesota water quality standards are met for streams and lakes, then those streams and lakes should not contribute to any downstream impairments.

2.1 Streams

Applicable water quality standards for impaired streams in this TMDL report are shown in **Table 3**, while **Table 1** shows the specific waterbodies.

Table 3. Surface water quality standards for Des Moines River Basin stream reaches addressed in this TMDL report.

Parameter	Water Quality Standard	Units	Criteria	Period of Time Standard Applies
Chloride	Not to exceed 230	mg/L	No more than 3 exceedances in 3 years	Year round
Escherichia coli (*E. coli*)-Aquatic Recreation (Class 2B)	Not to exceed 126	org/100 mL	Monthly geometric mean	April 1-October 31
	Not to exceed 1,260	org/100 mL	Upper 10th percentile	
Escherichia coli (*E. coli*)-Limited Resource Value (Class 7)	Not to exceed 630	org/100 mL	Monthly geometric mean	May 1-October 31
	Not to exceed 1,260	org/100 mL	Upper 10th percentile	
Total suspended solids (TSS)-Southern River Nutrient Region	Not to exceed 65	mg/L	Upper 10th percentile	April 1 – September 30

Chloride

Chloride can be a good general indicator of human impacts on water quality and high levels of chloride can harm aquatic organisms, possibly interfering with the organism's osmoregulatory capabilities. The Class 2 chronic standard for chloride is 230 milligrams per liter (mg/L) and applies year-round.

***Escherichia coli* (*E. coli*)**

Minnesota changed from a fecal coliform standard to an *E. coli* standard for bacteria impairments in 2008. The bacteria standard change is supported by an EPA guidance document on bacteriological criteria (EPA 1986). Minn. R. 7050.0222 Class 2B water quality standards for *E. coli* states:

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

For Class 7 water quality standard for *E. coli*, Minn. R. 7050.0227 states:

> *Escherichia (E.) coli - Not to exceed 630 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between May 1 and October 31.*

Although surface water quality standards are based on *E. coli*, wastewater treatment plants (WWTPs) are permitted based on fecal coliform concentrations. A conversion factor of 126 *E. coli* organisms per 100 mL for every 200 fecal coliforms per 100 mL is assumed (MPCA 2009). The *E. coli* standard is based on the geometric mean of water quality observations. Geometric mean is used in place of arithmetic mean in order to describe the central tendency of the data, dampening the effect that very high or very low values have on arithmetic means. The *Guidance Manual for Assessing the Quality of Minnesota*

Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List (MPCA 2018) provides details regarding how waters are assessed for conformance to the *E. coli* standard.

Total Suspended Solids

In January of 2015, the EPA issued an approval of the adopted amendments to the State Water Quality Standards, replacing the previous turbidity standard with TSS standards. The TSS standards are now used instead of turbidity standards as TMDL endpoints for impairments of this nature. Therefore, this TMDL report will treat turbidity impairments in the Des Moines River Basin as TSS impairments. Previously approved turbidity TMDLs are not impacted by the adoption of TSS standards.

TSS is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water (MPCA 2018). The Minnesota State TSS standards are based upon river nutrient regions, which are loosely based on ecoregions (MPCA 2019a). The Des Moines River Basin is located in the Southern River Nutrient Region. The state TSS standard for this region is 65 mg/L (MPCA 2018).

2.2 Lakes

Lake eutrophication standards are written to protect lakes and their designated beneficial use. The lakes of the Des Moines River Basin are considered Class 2B waters, which are protected for aquatic life and recreation. Minnesota categorizes its lake water quality standards by ecoregion and depth classification. Lakes in the Des Moines River Basin are in the WCBP and NGP ecoregions. All 23 impaired lakes are classified as shallow (maximum depth less than 15 feet or greater than 80% of the lake is part of the littoral zone). **Table 4** displays the standards for the WCBP and NGP ecoregions. Standards for NGP are identical to those for WCBP lakes.

Table 4. Minnesota's lake water quality standards by ecoregion.

Eco-region	TP [µg/L]	Chl-*a* [µg/L]	Secchi Disk Depth [m]
Western Corn Belt Plains - Shallow Lakes	<90	<30	>0.7
Northern Glacial Plains - Shallow Lakes	<90	<30	>0.7

The MPCA considers a lake impaired when TP and at least one of the response variables, chlorophyll-a (Chl-*a*) or Secchi depth, fail to demonstrate compliance with the standards (MPCA 2018). In addition to meeting TP limits, Chl-*a* and Secchi depth standards must also be met for the resource to be considered "fully supporting" its designated use. In developing the lake nutrient standards for Minnesota lakes (Minn. R. ch. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (MPCA 2005). Clear relationships were established between the causal factor TP and the response variables Chl-*a* and Secchi transparency. Based on these relationships it is expected that by meeting the P target in each lake, the Chl-*a* and Secchi standards will likewise be met.

3. Watershed and waterbody characterization

The Des Moines River Basin is in southwestern Minnesota and encompasses part of the WCBP and the NGP ecoregions. The watershed covers an area of 1,537 square miles (approximately 983,000 acres) and extends across seven counties: Cottonwood, Jackson, Lyon, Martin, Murray, Nobles, and Pipestone. The headwaters of the Des Moines River originate in the northwestern part of the watershed in a poorly drained region, from its principal source, Lake Shetek. The Des Moines River flows from the Lake Shetek outlet southeasterly for 94 miles to the Minnesota/Iowa border, through Des Moines, Iowa, and eventually drains to the Mississippi River at Keokuk, Iowa. No part of the Des Moines River Basin in Minnesota is located within the boundary of a Native American Reservation. This TMDL does not allocate pollutant load to any federally recognized Indian tribe.

The watershed lies on the Coteau des Prairies, a prominent upland in southern Minnesota with a flat iron-shaped plateau that rises to an altitude of more than 1,900 feet (579 m) within the watershed. The western boundary was formed during the late Wisconsin Glaciation and is a terminal moraine. The northern and eastern boundaries of the watershed are also morainic highs formed during recession of the Des Moines lobe during the late Wisconsin Glaciation. The Des Moines River Basin is comprised of glacial deposits reaching a thickness of approximately 900 feet (275 m), with numerous small glacial lakes.

The geology of the Des Moines River Basin directly affected the historic native vegetation. The NGP soils are very fertile, composed of glacial till, and the increased sand and loess composition historically supported a transitional grassland containing both tallgrass and shortgrass prairie species. The sub-humid conditions of the gently rolling hills were also marked by temporary and seasonal wetlands that supported waterfowl migration and nesting. Soils and annual climactic variation historically drove the vegetation. The WCBP in the southeast region of the watershed is comprised of gently rolling glaciated till plains and hilly loess plains. The till plains are comprised of heavier soils that supported tallgrass prairies that transitioned to cordgrass sloughs in depressions and swales. Depressions throughout the till plains of the Des Moines lobe also supported migrating and nesting waterfowl, while uplands supported highly productive tallgrass prairies.

Figure 4 shows the pre-European settlement vegetation in the Des Moines River Basin (DNR 1994) with the main pre-European settlement vegetation classified as prairie. The Des Moines River Basin was largely settled by Europeans between the 1850s and the 1870s, with the majority of the land use improvements occurring since this settlement. Additional land use conversion has continued with approximately 85% of the watershed in row crop agriculture, approximately 10% in pasture or grassland, 3% in waterbodies or marshes, approximately 1.5% urban, and less than a percent forested. Lands adjacent to the Des Moines River are heavily utilized for pasture, cropland, and urban development, with a narrow riparian corridor. These changes have resulted in the loss of more than 95% of the historic prairie and wetland communities within the Des Moines River Basin.

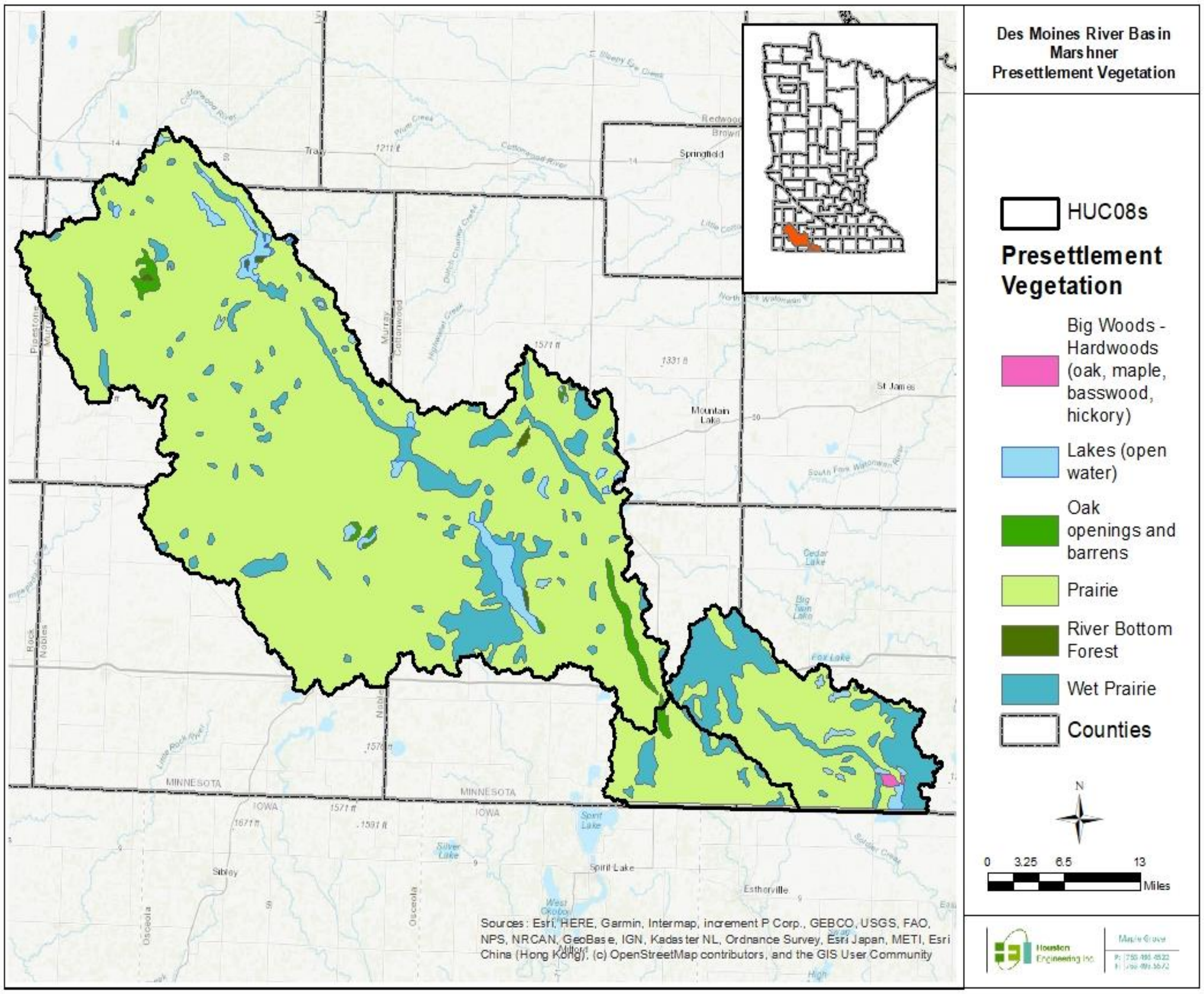

Figure 4. Pre-European settlement vegetation for the Des Moines River Basin.

3.1 Lakes

There are 23 impaired lakes in the Des Moines River Basin addressed in this TMDL report. All lakes in this region are shallow lakes, less than 15 feet maximum depth, and cover approximately 29 square miles or 18,939 acres of open water total. Most lakes lie within the WCBP ecoregion, with the exception of Yankton Lake, Sarah Lake, and Currant Lake, which are located in the NGP ecoregion. The majority of lakes' watersheds lie entirely within Minnesota. However, Okamanpeedan Lake lies on the Minnesota-Iowa border (designated Tuttle Lake in Iowa), and is listed as impaired in both states. Okamanpeedan Lake requires a TMDL in Minnesota and has a completed TMDL in Iowa[1]. The Iowa TMDL was completed with a higher P target value, which requires Minnesota to complete a TMDL as well to meet Minnesota standards. The MPCA assumes that by meeting the WCBP eutrophication targets for Okamanpeedan Lake that the Okamanpeedan Lake TMDL will meet the Iowa's Tuttle Lake eutrophication target.

[1] https://www.iowadnr.gov/Environmental-Protection/Water-Quality/Watershed-Improvement/Water-Improvement-Plans/Public-Meetings-Plans

Lake morphometry and watershed information for each impaired lake in the Des Moines River Basin are presented in **Table 5**. Locations of the impaired lakes are shown in **Figure 1** for the Des Moines River Headwaters Watershed and **Figure 3** for the East Fork Des Moines River Watershed.

Table 5. Morphometry and watershed area of lakes addressed in this TMDL report.

Watershed (HUC-08)	Lake Name	DNR Lake #	Surface Area [acres]	Average Depth [feet]	Lakeshed Area - direct drainage [acres]	Lakeshed Area - Total drainage [acres]	Lakeshed Area: Surface Area Ratio
Des Moines River Headwaters (07100001)	North Oaks	17-0044-00	333	6	5,440	5,440	16.3
	Talcot	17-0060-00	844	6	7,296	332,416	393.9
	Boot	32-0015-00	151	6	486.4	486.4	3.2
	Flahtery	32-0045-00	417	6	4,352	4,352	10.4
	Teal	32-0053-00	90	8	1,024	1,024	11.4
	Heron (Duck)	32-0057-02	307	8	4,736	4,736	15.4
	Heron (North)	32-0057-05	3,204	4[1]	8,859	234,492	73.2
	Heron (South)	32-0057-07	2,670	3	16,116	43,618	16.3
	Timber	32-0058-00	194	8	1,344	1,344	16.3
	Yankton	42-0047-00	396	8	1,184	1,184	6.9
	Lime	51-0024-00	318	6	1,920	37,696	3.0
	Bloody	51-0040-00	257	11	896	1,472	119
	Fox	51-0043-00	180	9	576	576	5.7
	Shetek	51-0046-00	3477	10	10,880	83,136	3.2
	Corabelle	51-0054-00	104	8	512	512	23.9
	Sarah	51-0063-00	1164	4	4,672	12,800	4.9
	Currant	51-0082-00	391	8	1,536	1,920	11.0
	East Graham	53-0020-00	469	8	3,584	23,360	4.9
	West Graham	53-0021-00	519	8	1,792	11,776	49.8
East Fork Des Moines River (07100003)	Bright	46-0052-00	639	5	2,304	12,992	22.7
	Pierce	46-0076-00	429	8	1,280	1,280	20.3
	Temperance	46-0103-00	153	5	960	960	3.0
	Okamanpeedan	46-0051-00	2233	7	10240	125,568	6.3

[1]Assumed as 80% of maximum depth

3.2 Streams

Thirteen impaired stream reaches in the Des Moines River Basin addressed in this TMDL report cover approximately 148 river-miles, and cumulatively drain approximately 1,537 square miles or 983,680 acres in Minnesota. Judicial Ditch 56 (07100002-505) lies on the Minnesota-Iowa border, with approximately 13,350 acres draining from Iowa to Judicial Ditch 56 in Minnesota (about 87% of the catchment surface area). This TMDL report does not address any Iowa impaired reaches that contribute to Minnesota impaired reaches. Reach information for each impaired stream in the Des Moines River Basin are presented in **Table 6** for this TMDL report.

Table 6. Approximate drainage area of impaired stream reaches.

Watershed (HUC-08)	Stream/Reach Name	Assessment Unit ID #	Total Drainage Area [sq mi]	Reach Length [miles]
Des Moines River Headwaters (07100001)	Okabena Creek, Unnamed cr to T102 R38W S6, north line	07100001-512	14.3	7.98
	Des Moines River, Heron Lk outlet to Windom Dam	07100001-524	1,137	18.1
	Heron Lake Outlet, Heron Lk (32-0057-01) to Des Moines R	07100001-527	444	13.61
	Unnamed creek, String Lk to Des Moines R	07100001-551	7.7	2.62
	Unnamed creek, Unnamed ditch to Jack Cr	07100001-564	36.5	4.29
	Okabena Creek, Elk Cr to Division Cr	07100001-602	82.6	24.66
	Jack Creek, North Branch, JD 12 to Jack Cr	07100001-652	65.4	7.12
Lower Des Moines River (07100002)	Judicial Ditch 56, Unnamed cr to Des Moines R	07100002-505	23.8	3.65
East Fork Des Moines River (07100003)	County Ditch 11, Headwaters to E Fk Des Moines R	07100003-503	1.5	8
	Fourmile Creek, JD 105 to Des Moines R	07100003-510	15.6	4.14
	County Ditch 1/Judicial Ditch 50, Unnamed cr to CD 11	07100003-515	24.5	4.36
	Des Moines River, East Branch, Unnamed cr to CD 11	07100003-525	35.9	19.5
	Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk	07100003-527	122	5.07

3.3 Subwatersheds

Minnesota’s portion of the Des Moines River Basin includes part of or all of three HUC-08 watersheds: Des Moines River Headwaters (07100001), Lower Des Moines River (07100002), and East Fork Des Moines River (07100003).

The Des Moines River Headwaters Watershed drains approximately 798,600 acres of seven counties (Cottonwood, Jackson, Lyon, Martin, Murray, Nobles, and Pipestone). There are 14 communities in the watershed, the largest of which are the cities of Worthington, Slayton, Windom, Lakefield, Heron Lake, and Fulda. Heron, Shetek, and Sarah Lakes are in this watershed. Larger streams and rivers include Okabena Creek, Elk Creek, Jack Creek, Beaver Creek, Lime Creek, and the West Fork Des Moines River. The outlet of the Des Moines River Headwaters (07100001) flows into the Lower Des Moines River (07100002) in Jackson, Minnesota.

The Des Moines River Headwaters contains eight HUC-10 subwatersheds. The headwaters of the Des Moines River flows southeast from Shetek Lake Watershed (0710000102) through watersheds with prominent shallow, natural lakes. The Shetek Lake Watershed is first joined by Beaver Creek (0710000101) and becomes the Talcot Lake-Des Moines River (0710000108). Several HUC-10 watersheds in the southern tier of counties then join the Des Moines River, including Lime Creek (0710000104), Okabena Creek (0710000107), Jack Creek (0710000107), and Heron Lake (0710000108) prior to becoming the City of Windom-Des Moines River (0710000108).

Near Jackson, Minnesota, the Des Moines River then flows into the Lower Des Moines River Watershed (07100002) and flows into Iowa. The Lower Des Moines River Watershed drains approximately 55,720 acres in Jackson and Martin Counties. The Minnesota portion of the Lower Des Moines River Watershed includes only one HUC-10 subwatershed (Brown Creek-Des Moines River; 0710000201).

Adjacent to the east of the Lower Des Moines River Watershed is the East Fork Des Moines River Watershed (07100003). The East Fork Des Moines River Watershed is located in Martin and Jackson Counties and drains approximately 129,400 acres in Minnesota. Communities in the watershed include Alpha, Sherburn, Dunnell, Ceylon, and Wilbert. The East Fork Des Moines River flows southeast for about 30 miles before entering Okamanpeedan Lake on the Minnesota-Iowa border. Other lakes include Bright and Pierce. Several shallow waterfowl lakes are also located in the southern part of the watershed. The Minnesota portion of the East Fork Des Moines River Watershed encompasses one HUC-10 subwatershed (Headwaters East Fork Des Moines River; 0710000301).

The Lower Des Moines River and East Fork Des Moines River join near Dakota City, Iowa and ultimately flow into the Mississippi River near Keokuk, Iowa. **Figure 5** through **Figure 7** show the HUC-10 subwatersheds for the Des Moines River Headwaters, Lower Des Moines River, and East Fork Des Moines River watersheds, respectively. **Table 7** provides a list of impairments addressed in this TMDL report located in each HUC-10 subwatershed.

Table 7. Impairments in each HUC-10 subwatershed.

Watershed (HUC-08)	Subwatershed (HUC-10)	Waterbody	AUID/ DNR Lake ID	Impairment/ Parameter
Des Moines River Headwaters (07100001)	Lake Shetek (0710000102)	Yankton	42-0047-00	Nutrient/eutrophication biological indicators
		Bloody	51-0040-00	Nutrient/eutrophication biological indicators
		Fox	51-0043-00	Nutrient/eutrophication biological indicators
		Shetek	51-0046-00	Nutrient/eutrophication biological indicators
		Sarah	51-0063-00	Nutrient/eutrophication biological indicators
		Currant	51-0082-00	Nutrient/eutrophication biological indicators
	Lime Creek (0710000103)	Lime	51-0024-00	Nutrient/eutrophication biological indicators
	Talcot Lake-Des Moines River (0710000104)	North Oaks	17-0044-00	Nutrient/eutrophication biological indicators
		Talcot	17-0060-00	Nutrient/eutrophication biological indicators
	Okabena Creek (0710000105)	Okabena Creek, Unnamed cr to T102 R38W S6, north line	07100001-512	*Escherichia coli*
		Okabena Creek, Elk Cr to Division Cr	07100001-602	Chloride
	Jack Creek (0710000106)	Corabelle	51-0054-00	Nutrient/eutrophication biological indicators
		East Graham	53-0020-00	Nutrient/eutrophication biological indicators
		West Graham	53-0021-00	Nutrient/eutrophication biological indicators
		Unnamed creek, Unnamed ditch to Jack Cr	07100001-564	*Escherichia coli*
		Jack Creek, North Branch, JD 12 to Jack Cr	07100001-652	*Escherichia coli*
	Heron Lake (0710000107)	Flahtery	32-0045-00	Nutrient/eutrophication biological indicators
		Teal	32-0053-00	Nutrient/eutrophication biological indicators

Watershed (HUC-08)	Subwatershed (HUC-10)	Waterbody	AUID/ DNR Lake ID	Impairment/ Parameter
		Heron (Duck)	32-0057-02	Nutrient/eutrophication biological indicators
		Heron (North)	32-0057-05	Nutrient/eutrophication biological indicators
		Heron (South)	32-0057-07	Nutrient/eutrophication biological indicators
		Timber	32-0058-00	Nutrient/eutrophication biological indicators
		Heron Lake Outlet, Heron Lk (32-0057-01) to Des Moines R	07100001-527	*Escherichia coli*
	City of Windom-Des Moines River (0710000108)	Boot	32-0015-00	Nutrient/eutrophication biological indicators
		Des Moines River, Heron Lk outlet to Windom Dam	07100001-524	*Escherichia coli*
		Unnamed creek, String Lk to Des Moines R	07100001-551	Turbidity
Lower Des Moines River (07100002)	Brown Creek-Des Moines River (0710000201)	Judicial Ditch 56, Unnamed cr to Des Moines R	07100002-505	Turbidity
East Fork Des Moines River (07100003)	Headwaters East Fork Des Moines River (0710000301)	Bright	46-0052-00	Nutrient/eutrophication biological indicators
		Pierce	46-0076-00	Nutrient/eutrophication biological indicators
		Temperance	46-0103-00	Nutrient/eutrophication biological indicators
		Okamanpeedan	46-0051-00	Nutrient/eutrophication biological indicators
		County Ditch 11, Headwaters to E Fk Des Moines R	07100003-503	*Escherichia coli*
		Fourmile Creek, JD 105 to Des Moines R	07100003-510	*Escherichia coli*
		County Ditch 1/Judicial Ditch 50, Unnamed cr to CD 11	07100003-515	*Escherichia coli*
		Des Moines River, East Branch, Unnamed cr to CD 11	07100003-525	*Escherichia coli*
		Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk	07100003-527	*Escherichia coli*

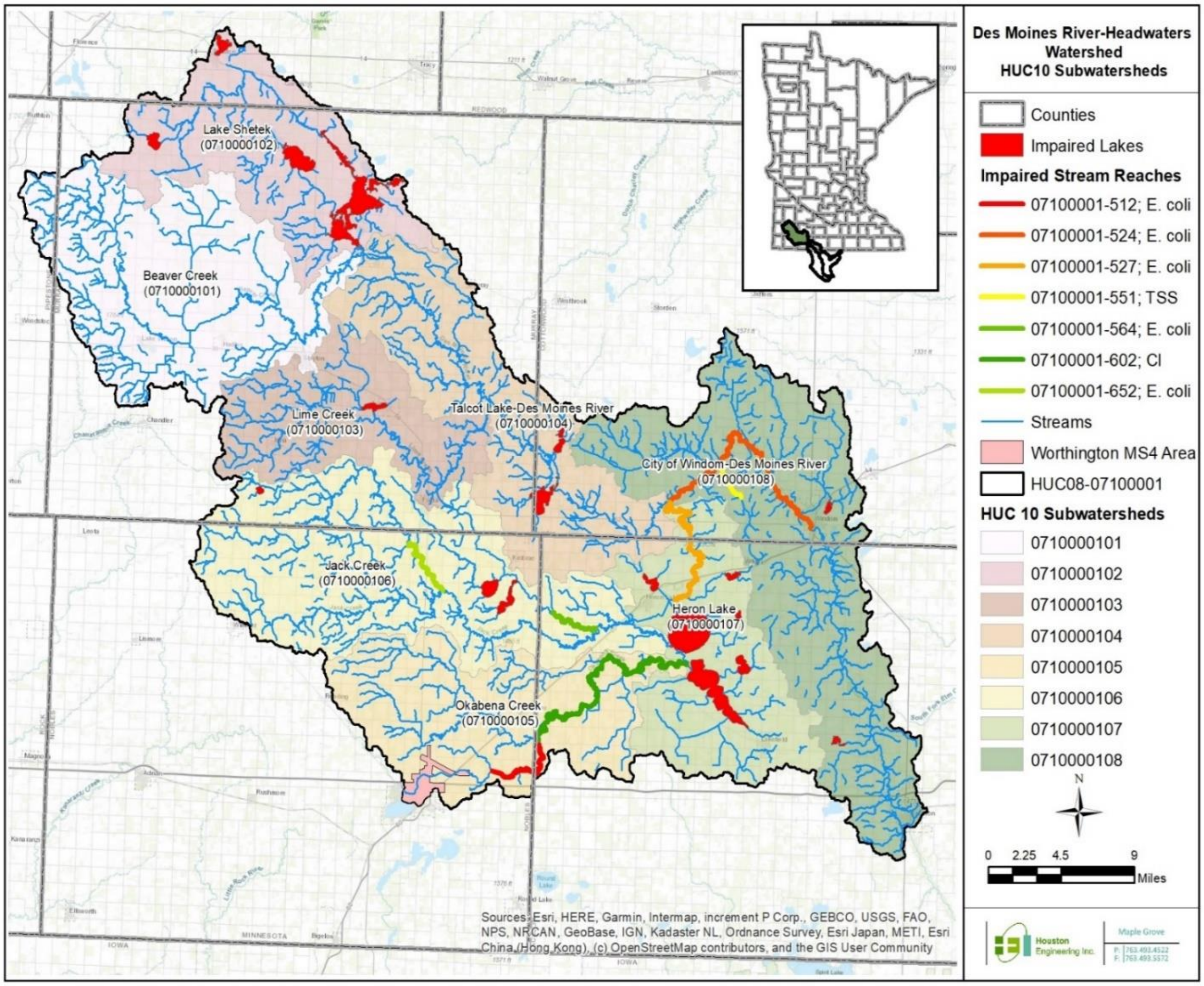

Figure 5. Des Moines River Headwaters Watershed HUC-10 subwatersheds.

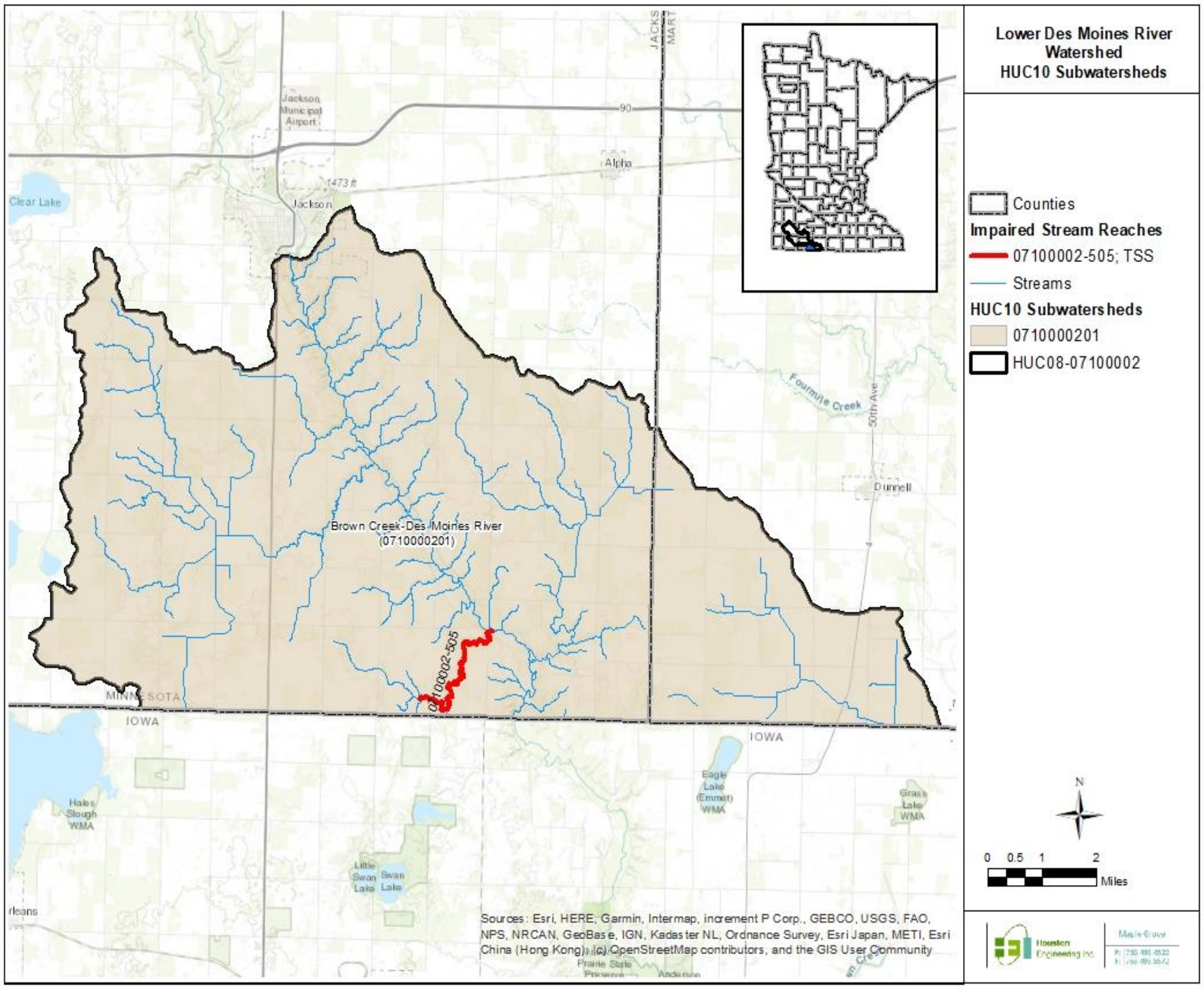

Figure 6. Lower Des Moines River Watershed HUC-10 subwatersheds. Only the portions of water bodies and watersheds located within Minnesota are addressed in this report.

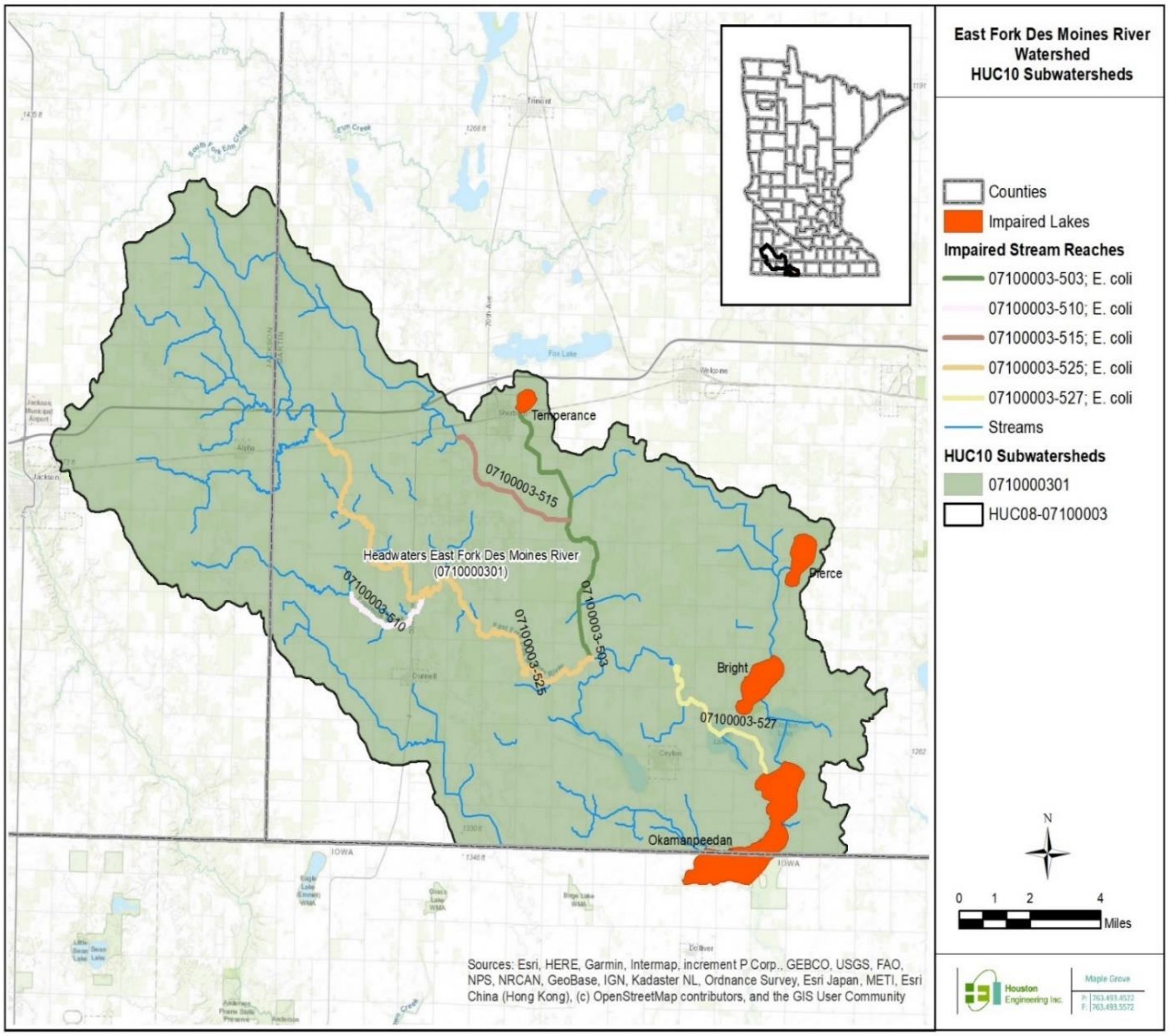

Figure 7. East Fork Des Moines River Watershed HUC-10 subwatersheds. Only the portions of water bodies and watersheds located within Minnesota are addressed in this report.

3.4 Land use

The land use for the entire watershed and HUC-10 subwatersheds are summarized in **Table 8** and shown in **Figures 8** through **10**. Multi-Resolution Land Characteristics (MRLC) data was used to characterize land use. Portions of Iowa that drain to an impaired reach are also included in the figures to show all land use in an impaired waters' drainage area. Row crop is the largest land use in each subwatershed, and the basin as a whole, with wetlands and lakes more common in low-relief subwatersheds. Drainage is prominent in the Beaver Creek, Okabena Creek, Heron Lake, and Upper East Fork Des Moines subwatersheds where upland sloughs were historically prominent. However, drainage throughout the entirety of the Des Moines River Basin is common. The conversion of native vegetation to agricultural lands has resulted in increased overland flow, decreased groundwater recharge (lower groundwater infiltration), and increased the nonpoint source transport of sediment, nutrients, chemicals (agricultural and residential), and feedlot runoff.

Groundwater recharge in the region is slow and varies from zero to six inches per year (MPCA 2017a). High agricultural land use contributes to high nutrient, sediment, and bacterial export as well, which can impact both surface waters and aquifers. Agricultural land use exceeds 80% in each HUC-08 watershed of the Des Moines River Basin, and receiving surface- and ground- water reflect these uses with elevated nutrient and bacterial loading common throughout the watershed.

Table 8. Land cover (MRLC 2011) percentages in the Des Moines River Headwaters, East Fork Des Moines River, and Lower Des Moines River.

HUC-08/HUC-10 Subwatershed[1]	Cropland [%]	Rangeland [%]	Developed [%]	Wetland [%]	Open Water [%]	Forest/ Shrub [%]	Barren/ Mining [%]
Des Moines River Headwaters (07100001)	**81.1**	**5.9**	**6.0**	**3.1**	**2.9**	**1.1**	**0.03**
Beaver Creek (0710000101)	82.2	9.8	5.1	1.8	0.6	0.4	0.02
Lake Shetek (0710000102)	72.0	8.7	5.4	3.2	10.3	0.3	0.04
Lime Creek (0710000103)	83.5	4.4	6.4	3.4	1.7	0.5	0.01
Talcot Lake-Des Moines River (0710000104)	80	6.3	4.7	5.5	2.9	0.4	0.07
Okabena Creek (0710000105)	88.1	1.7	8.2	1.2	0.2	0.6	0.02
Jack Creek (0710000106)	87.9	2.3	5.2	2.3	1.4	0.9	0.02
Heron Lake (0710000107)	76.7	2.1	6.1	5.6	7.8	1.7	0.02
City of Windom-Des Moines River (0710000108)	76.6	9.4	6.9	2.8	1.4	2.9	0.04
Lower Des Moines River (07100002)	**84.3**	**5.2**	**6.0**	**2.2**	**1.1**	**0.7**	**0.1**
Brown Creek-Des Moines River (0710000201) MN only	85.7	4.9	4.9	1.0	0.5	3.0	0.1
East Fork Des Moines River (07100003)	**87.2**	**3.3**	**6.3**	**1.9**	**0.8**	**0.5**	**0.03**
Headwaters East Fork Des Moines River (0710000301) MN only	85.2	1.9	6.1	2.4	3.3	1.1	0.02

[1]Totals of percentages may not equal 100% due to rounding.

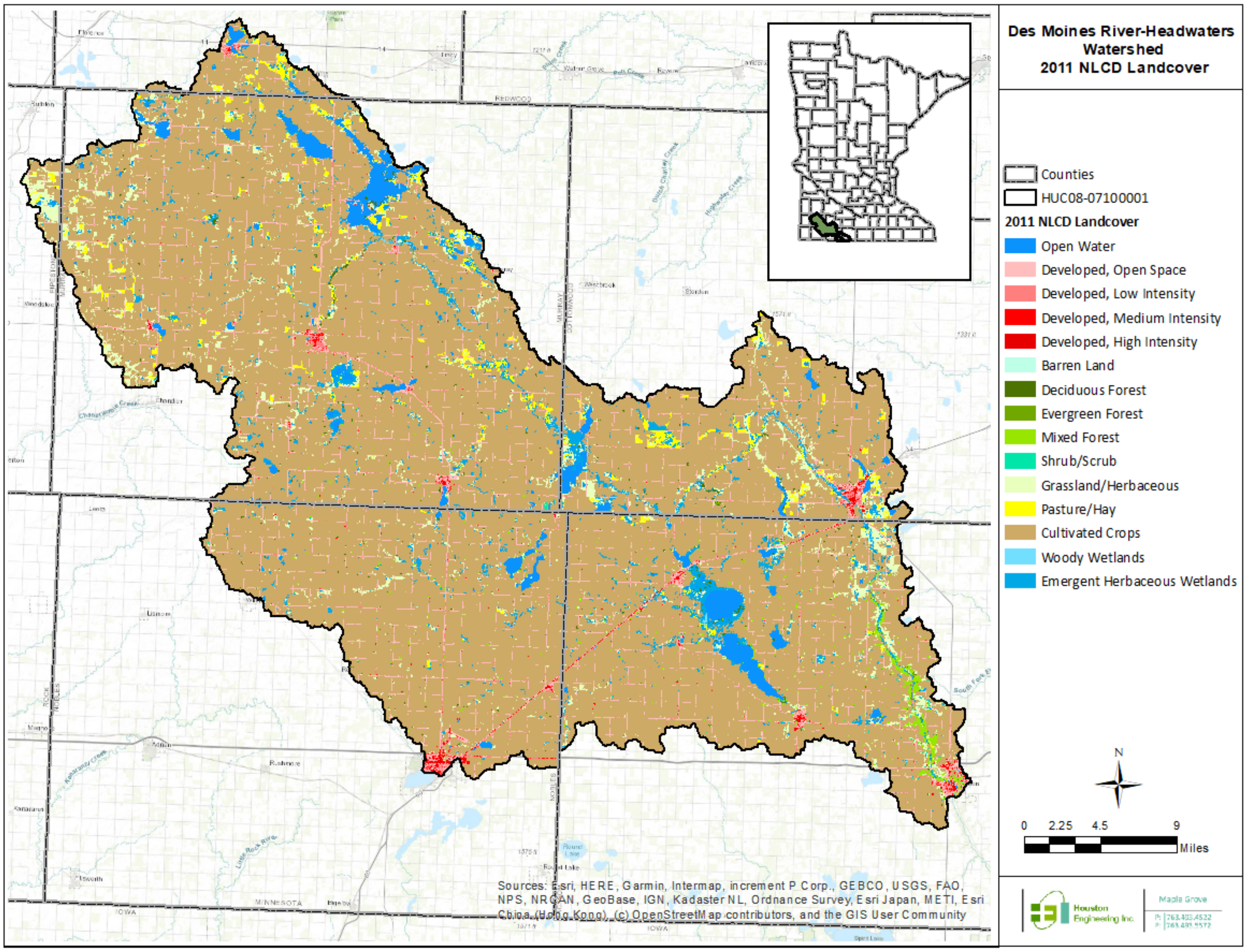

Figure 8. Land use/Land cover (MRLC 2011) in the Des Moines River Headwaters Watershed.

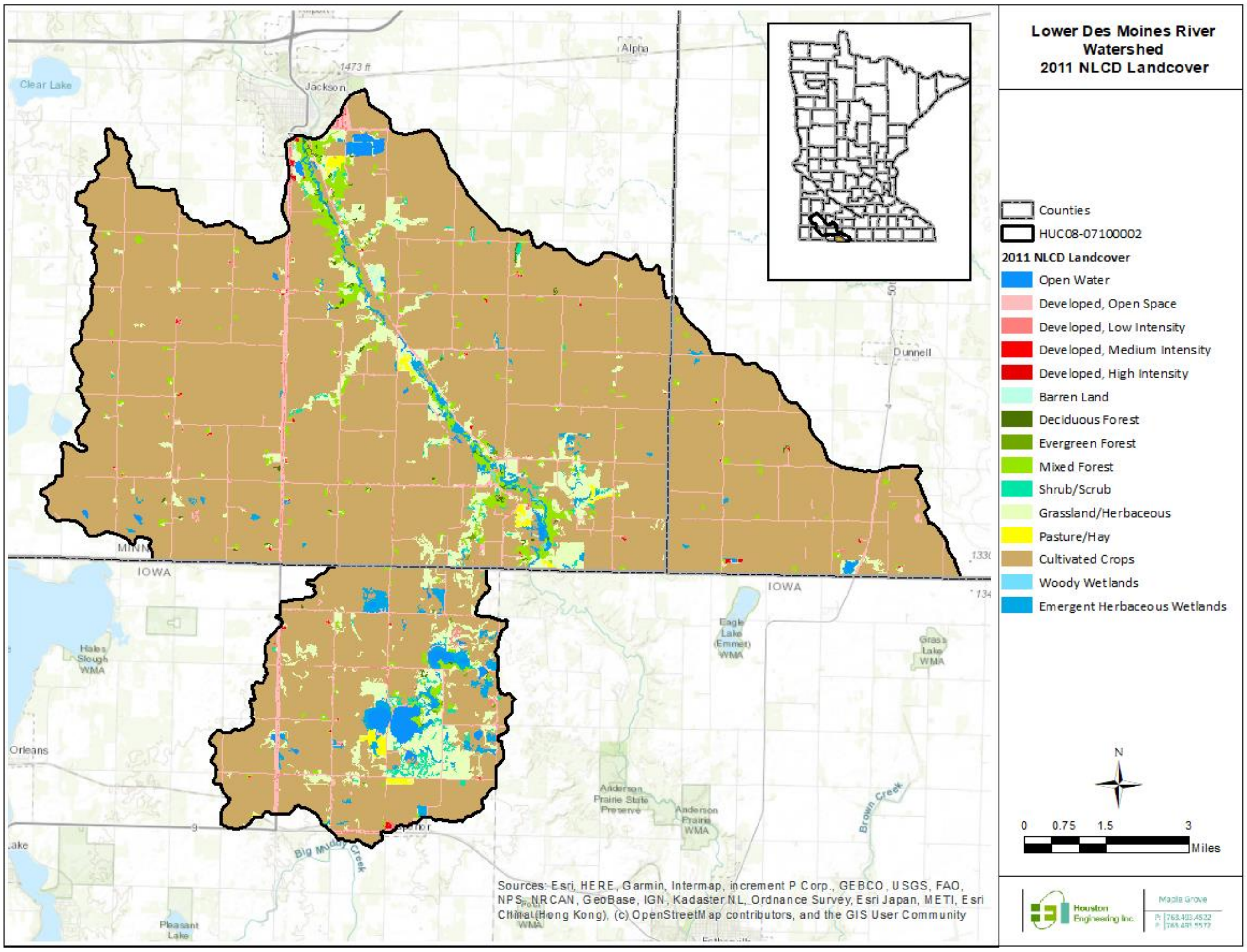

Figure 9. Land use/Land cover (MRLC 2011) in the Lower Des Moines River Watershed.

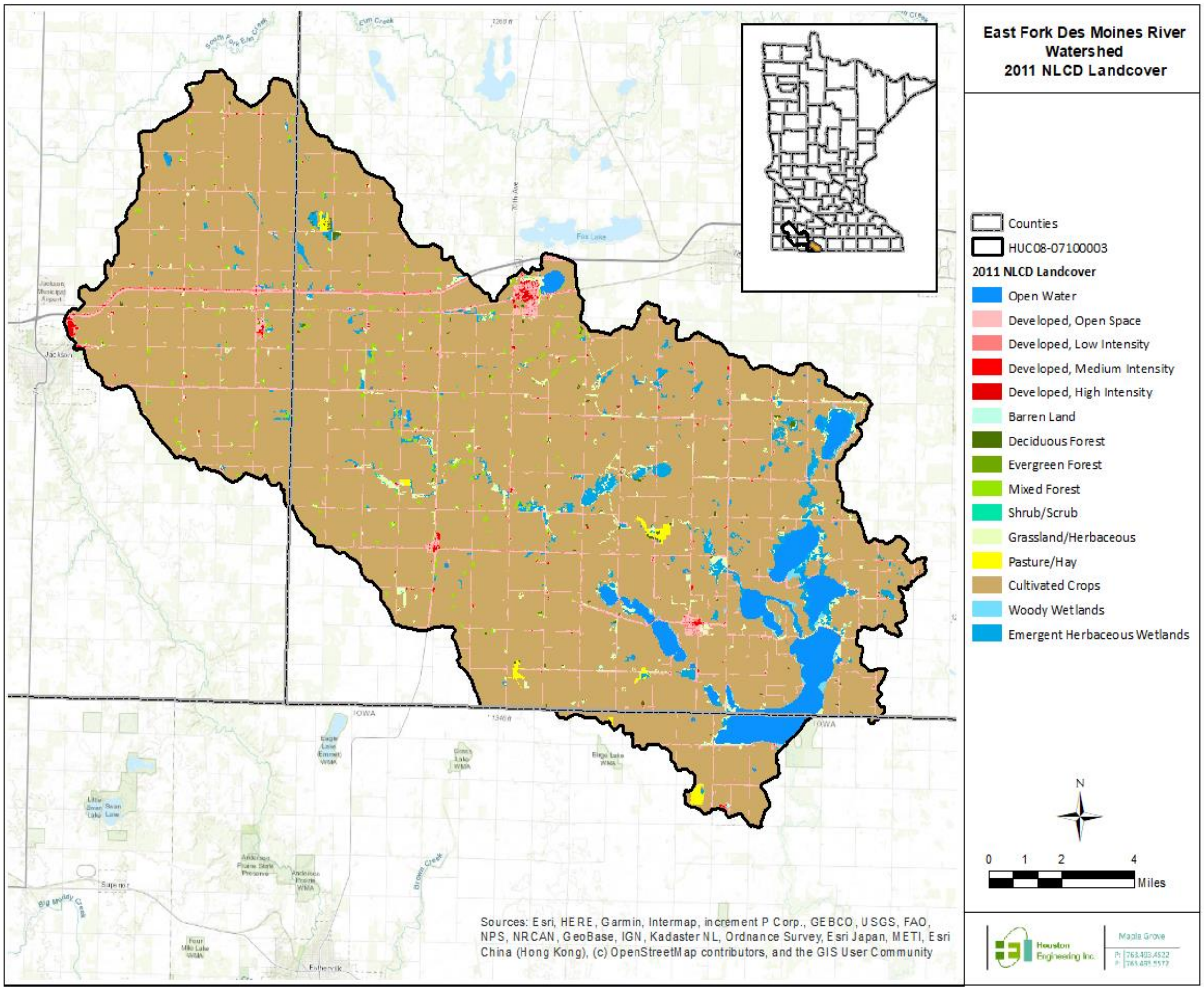

Figure 10. Land use/Land cover (MRLC 2011) in the East Fork Des Moines River Watershed.

3.5 Current/historical water quality

Existing water quality conditions are described using data downloaded from the MPCA's Environmental Quality Information System (EQuIS) database[2]. EQuIS stores data collected by the MPCA, partner agencies, grantees, and citizen volunteers. All water quality sampling data utilized for assessments, modeling, and data analyses for this TMDL report and reference reports, are stored in this database and are accessible through the MPCA's Environmental Data Access (EDA) website[2].

Various agencies and local partners, such as the MPCA, Soil and Water Conservation Districts (SWCD), local watershed districts, and volunteer monitoring programs, collected data used to develop this TMDL report (see **Section 7** for more information on monitoring). In most stream reaches flow information used to develop the TMDLs were available from 1994 through 2014. In order to have at least 10 years of flow data to develop the LDCs (see **Section 4.3.1**), water quality data used was from 2005 to 2017 to

[2] https://www.pca.state.mn.us/environmental-data

show current water quality conditions, and to calculate the TMDLs. Although data prior to 2005 exists, the more recent data better represents the current conditions in the waterbody.

For *E. coli*, data collected during the months of April through October were used for Class 2B streams and May through October for Class 7 streams. For the TSS standard, data collected from April through September were used.

Monitoring locations used for this TMDL report are shown in **Figure 11** through **Figure 13** by watershed and summarized in **Table 9** through **Table 12**.

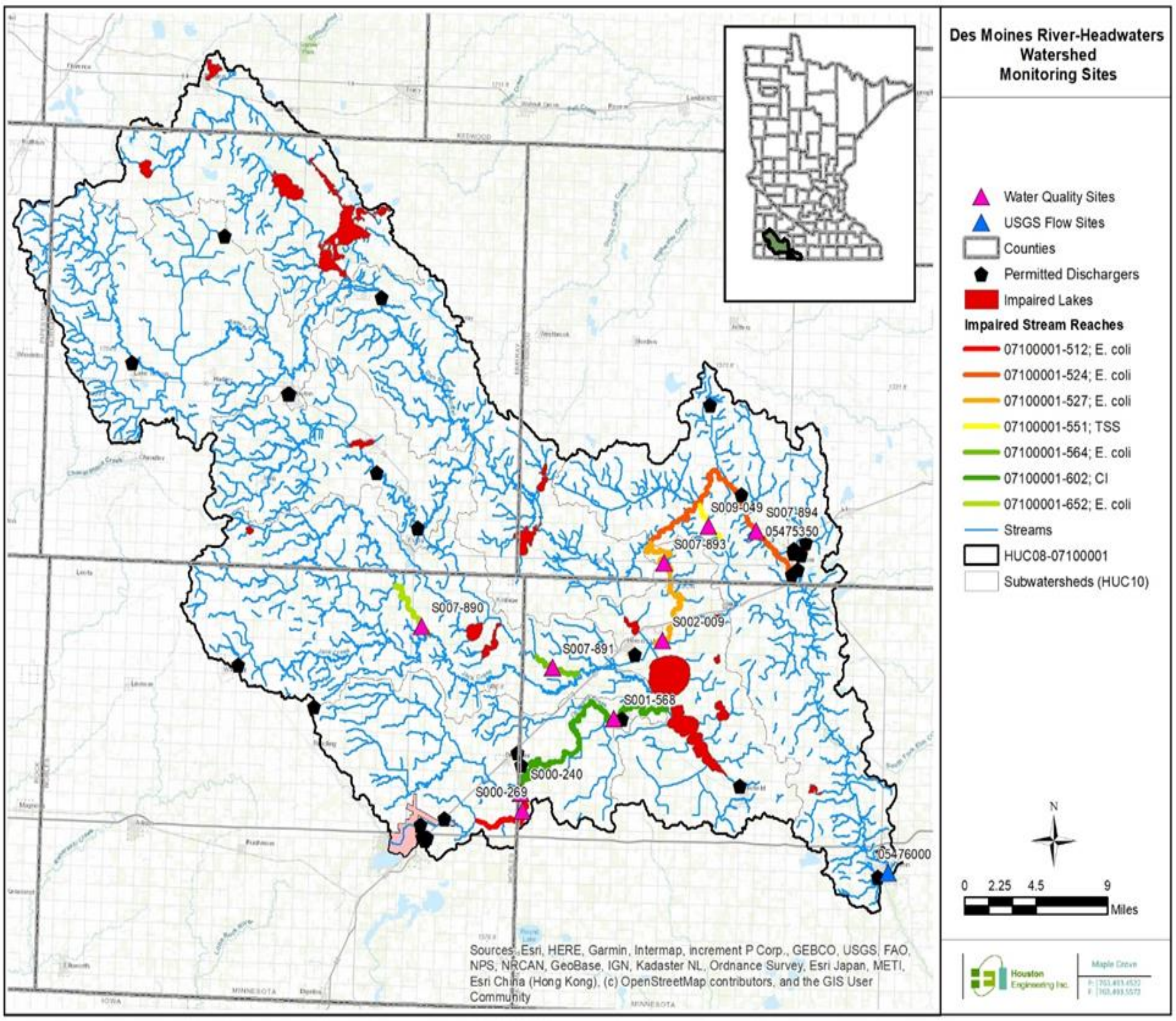

Figure 11. Monitoring locations in the Des Moines River Headwaters Watershed used in this TMDL report.

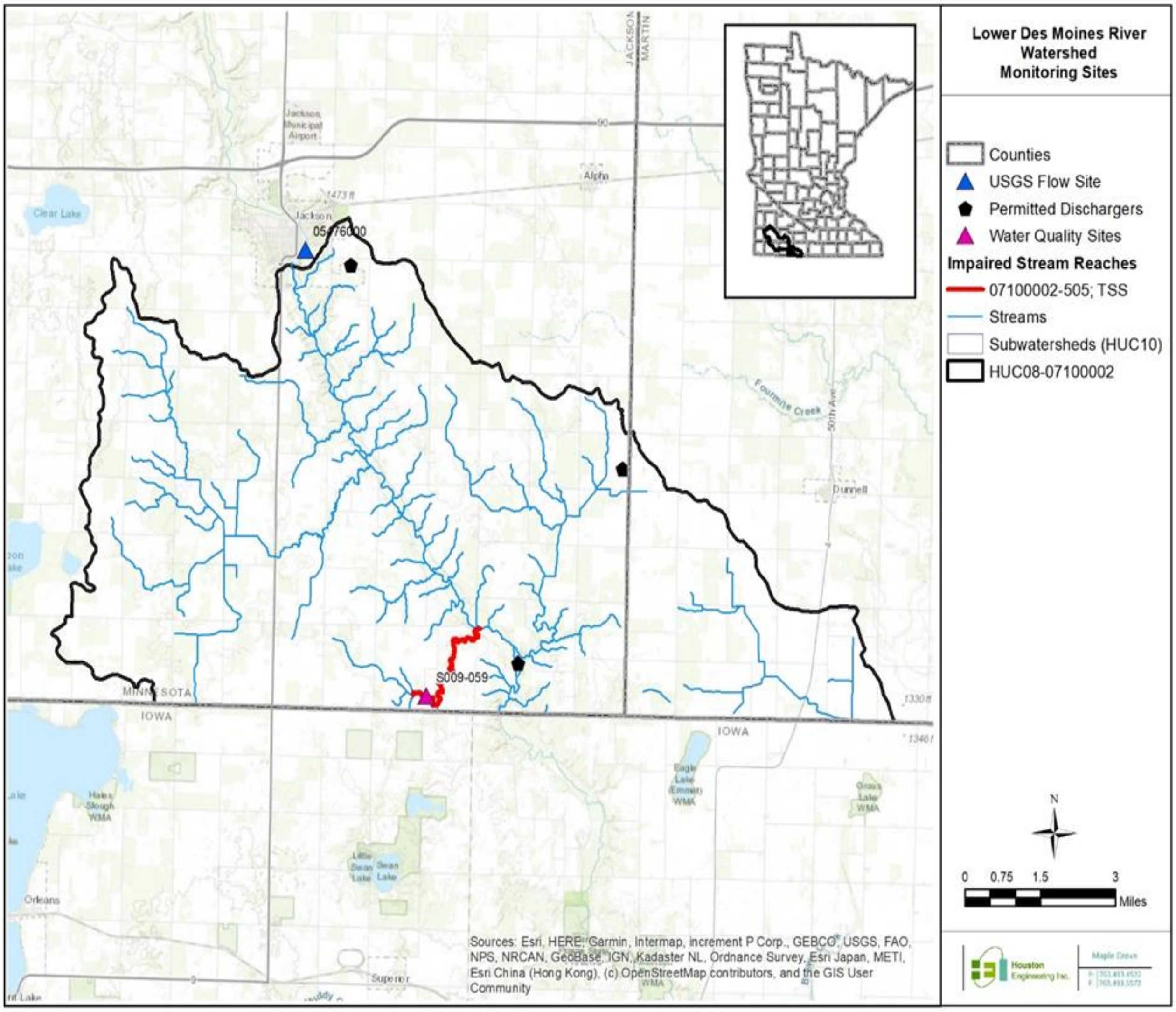

Figure 12. Monitoring locations in the Lower Des Moines River Watershed used in this TMDL report.

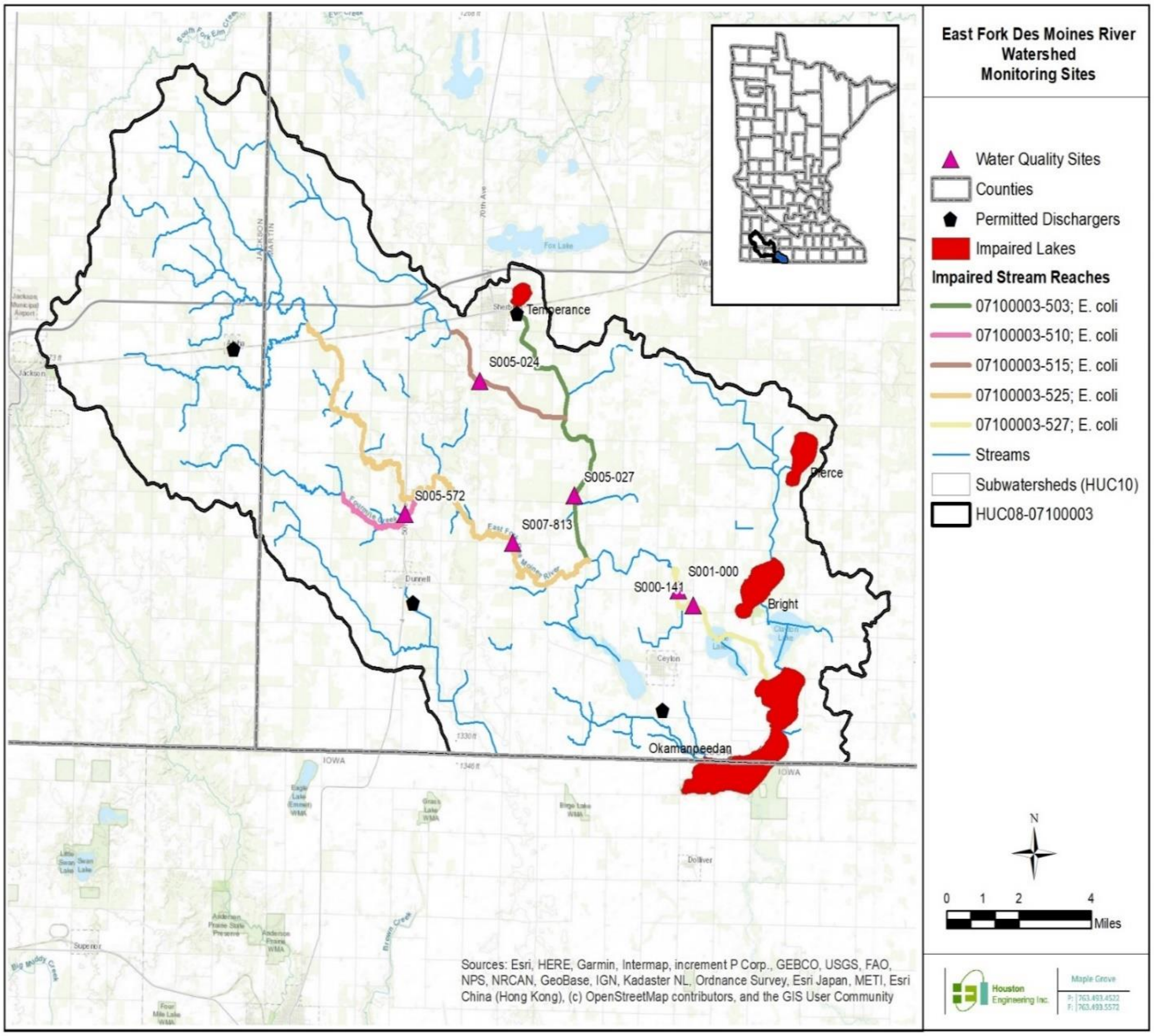

Figure 13. Monitoring locations in the East Fork Des Moines River Watershed used in this TMDL report.

3.5.1 Chloride

Ambient chloride data for the impaired stream reach 07100001-602 was compiled to understand current water quality. As stated in **Section 2**, the chronic chloride standard of 230 mg/L has been applied as the numeric criterion. **Table 9** provides a summary of the water quality sampling in the impaired reach, including the number of samples, the average of all samples, the number of samples above the chronic criteria of 230 mg/L, and the number of samples above the acute criteria of 860 mg/L. All chloride samples were taken in 2014 and the exceeding samples were recorded in late summer/early fall (August through September) during low flow conditions.

Table 9. Chloride impairment and water quality sites in the Des Moines River Basin.

Watershed	AUID	Station	Number of Samples	Average of Sampled Days [mg/L]	Number of Days exceeding 230 mg/L Chronic Criteria	Number of Days exceeding 860 mg/L Acute Criteria
Des Moines River Headwaters (07100001)	07100001-602	S001-568	10	184	3	0

3.5.2 *Escherichia coli*

Minn. R. 7050 sets standards as described in **Section 2.1**. The standard for *E. coli* is to not exceed a geometric mean of 126 organisms per 100 mL for one or more months from April through October for Class 2B streams. For Class 7 streams, the standard is a geometric mean of 630 organisms per 100 mL per month during the assessment window (May through October). Geometric means require no less than five samples per month. In addition, a water body that exceeds a concentration of 1,260 organisms per 100 mL for more than 10% of individual samples during any calendar month is also identified as impaired. The geometric mean is used to describe bacterial data as the geometric mean better normalizes data with different ranges, as may occur during storm events, and allows a percentage change to be made equally to the geometric mean across watersheds. The geometric mean can be calculated using the following function:

$$\text{Geometric mean} = \sqrt[n]{x_1 * x_2 * \ldots x_n}$$

Where $x_1, x_2, \ldots, x_n$ are *E. coli* concentrations for each sampling month.

Table 10 shows monthly *E. coli* by AUID and sampling station reported as monthly count, geometric mean and percent exceedances of the standard of 1,260 org/100mL.

Table 10. Current condition in *Escherichia coli* impairments and water quality sites in the Des Moines River.

Watershed		Des Moines River Headwaters (07100001)							East Fork Des Moines River (07100003)					
AUID		07100001-512		07100001-524	07100001-527		07100001-564	07100001-652	07100003-503	07100003-510	07100003-515	07100003-525	07100003-527	
Station(s)		S000-240	S000-269	S007-894	S002-009	S007-893	S007-891	S007-890	S005-027	S005-572	S005-024	S007-813	S000-141	S001-000
Years		2006-2008	2014-2015	2014-2015	2009-2017	2014-2015	2014-2015	2014-2015	2008-2015	2008-2009	2008-2009	2014-2015	2006-2008	2014-2015
April	**n**	2			13				11	8	3		2	
	Geo[1]	912			28				44	37	12		79	
	%n> 1,260	50%			0%				0%	13%	0		0	
May	**n**	2			20				8	5	2		2	
	Geo[1]	416			12				86	447	220		79	
	%n> 1,260	50%			0%				0%	20%	0		0	
June	**n**	2	5	6	37	6	7	6	18	11	2	5	2	5
	Geo[1]	990	1143	292	64	83	205	680	428	735	1,160	495	469	351
	%n> 1,260	0%	60%	0%	3%	0%	0%	17%	17%	18%	50%	0	0	0
July	**n**	2	5	5	28	5	4	6	14	7	3	5	2	5
	Geo[1]	599	430	41	159	78	170	460	317	1,932	947	260	582	160
	%n> 1,260	0%	0%	0%	4%	20%	0%	0%	14%	100%	33%	0	0	0
August	**n**	2	5	5	17	5	7	7	14	7	4	5	2	5
	Geo[1]	1942	268	41	231	52	60	210	218	197	429	329	408	202
	%n> 1,260	100%	0%	0%	12%	0%	0%	29%	7%	29%	0	0	0	0
September	**n**	2			11				6	5	1		2	
	Geo[1]	1,051			337				385	502	108		205	
	%n> 1,260	50%			18%				17%	40%	0		0	
October	**n**	2			6				3	3	3		2	
	Geo[1]	505			422				315	2420	458		36	
	%n> 1,260	0%			17%				0%	100%	0		0	

[1]Geo = geometric mean and has units of org/100 mL.

3.5.3 Total Suspended Solids

TSS data was summarized by watershed, AUID, and station for each TSS impaired stream in the Des Moines River Basin in **Table 11**. The TSS TMDLs are based on the current TSS standard for the Southern Rivers Nutrient Region of 65 mg/L. Variation of TSS, based on flow conditions, can be seen in the TSS LDCs (**Figures 34** and **35**).

Table 11. Current condition in TSS impairments and water quality sites in the Des Moines River Basin.

Watershed	AUID	Station	Period	Number of samples	90th Percentile [mg/L]	Number of Exceedances
Des Moines River Headwaters (07100001)	07100001-551	S009-049	2016	8	99.0	7
Lower Des Moines River (07100002)	07100002-505	S009-059	2016	8	121.0	4

3.5.4 Lake Nutrients

In general, historical in-lake water quality data collected from the period 1998 through 2015 were reviewed and summarized for use in this TMDL report. **Table 12** provides the number of samples and average (mean) during the summer (June through September) for TP, Chl-*a*, and Secchi Disk depths.

Table 12. Lake nutrients impairment and water quality sites in the Des Moines River Basin.

Lake Name	AUID	Observation Period	TP (WQ Standard : <90 µg/L)		Chl-*a* (WQ Standard: <30 µg/L)		Secchi Disk Depth (WQ Standard: > 0.7 m)	
			n	Mean [µg/L]	n	Mean [µg/L]	n	Mean [m]
North Oaks	17-0044-00	2014-2015	8	248.9	8	160.2	8	0.34
Talcot	17-0060-00	2002-2014	13	408.5	13	183.0	14	0.23
Boot	32-0015-00	2006-2015	11	207.4	5	25.7	10	1.05
Flahtery	32-0045-00	2001-2008	19	189.5	17	104.7	18	0.39
Teal	32-0053-00	2001-2012	29	218.2	29	152.6	24	0.44
Heron (Duck)	32-0057-02	2001-2010	13	214.9	11	96.5	5	0.25
Heron (North)	32-0057-02	2005-2014	14	350	12	161	10	0.205
Heron (South)	32-0057-02	2005-2014	14	373	12	105	0	

Lake Name	AUID	Observation Period	TP (WQ Standard : <90 µg/L)		Chl-*a* (WQ Standard: <30 µg/L)		Secchi Disk Depth (WQ Standard: > 0.7 m)	
			n	Mean [µg/L]	n	Mean [µg/L]	n	Mean [m]
Timber	32-0058-00	2001-2010	12	197.8	12	90.6	8	0.25
Yankton	42-0047-00	2002-2014	17	132.9	16	105.1	24	0.33
Okamanpeedan	46-0051-00	1998-2014	13	211.9	13	171.3	11	0.26
Bright	46-0052-00	2007-2015	9	148.6	9	146.0	9	0.17
Pierce	46-0076-00	2014-2015	8	264.4	5	66.1	7	0.46
Temperance	46-0103-00	2009-2015	9	231.9	8	56.9	6	0.16
Lime	51-0024-00	2002-2014	15	212.2	13	176.8	12	0.22
Bloody	51-0040-00	1994-2013	24	101.8	23	50.4	383	0.72
Fox	51-0043-00	2006-2015	9	96.6	8	143.2	4	0.30
Shetek	51-0046-00	1994-2015	40	122.1	26	76.8	342	0.48
Corabelle	51-0054-00	2000-2010	20	180.6	18	71.3	10	0.35
Sarah	51-0063-00	1994-2013	35	132.9	22	225.6	92	0.59
Currant	51-0082-00	2002-2011	22	137.6	8	81.7	29	0.35
East Graham	53-0020-00	1997-2016	47	172.2	36	73.8	20	0.32
West Graham	53-0021-00	1997-2016	48	158.1	35	54.0	20	1.06

3.6 Pollutant source summary

3.6.1 Chloride

Exposure to elevated chloride, even in small concentrations, can affect aquatic species, disrupting blood pH by impacting the buffering capacity of sodium bicarbonate. In animals, exposure can cause gastrointestinal irritation, respiratory distress, and eventually death if exposure is sustained. Chloride loading to streams commonly occurs from road salt or brine applications to roadways, treatment of potable waters supplies in water softeners, and from fertilizer, manure, and dust suppressants. A conceptual model shown in **Figure 14** shows the potential sources of chloride**.**

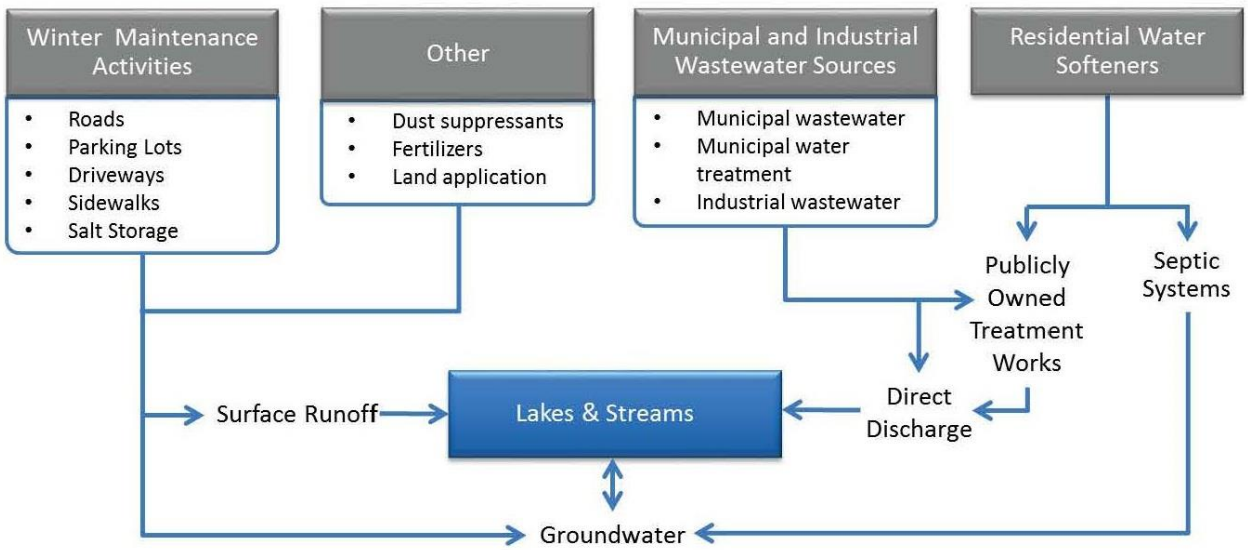

Figure 14. Conceptual model of anthropogenic sources of chloride and pathways (MPCA 2016).

In Okabena Creek (07100001-602), the main driver of the high chloride levels can be attributed to discharge of municipal WWTPs (e.g., Brewster, Okabena, Worthington Industrial, and Worthington WWTPs) during low flow periods. This can be seen by looking at the monitoring data and flow in Okabena Creek (**Figures 15** and **16).**

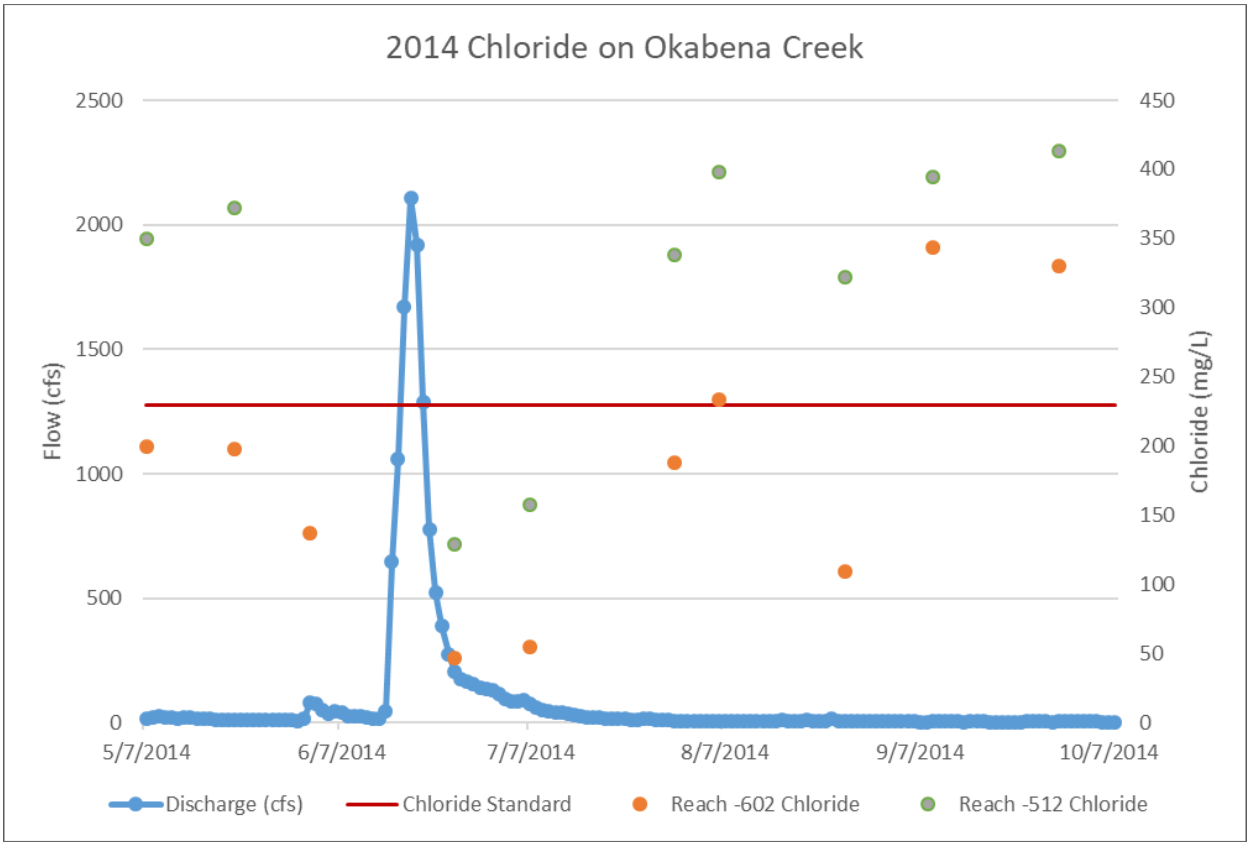

Figure 15. Chloride concentrations and flow in Okabena Creek in 2014.

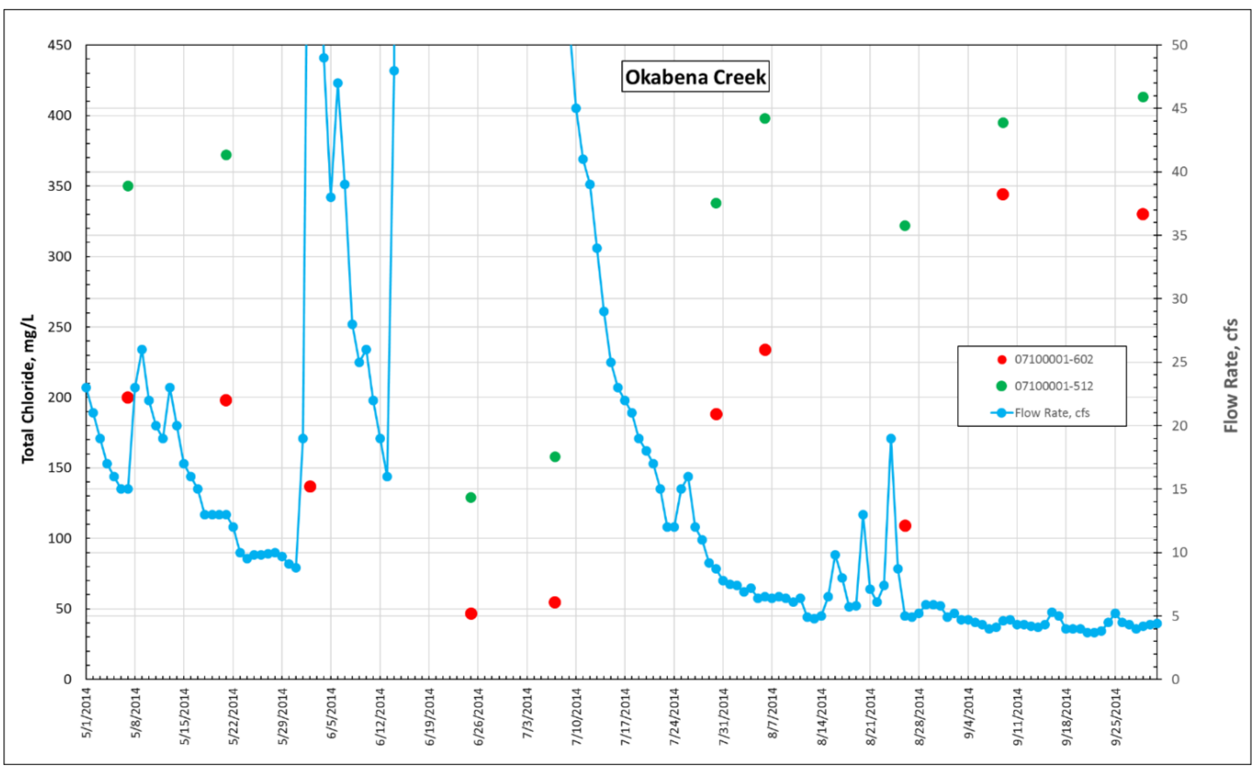

Figure 16. Closer look at chloride concentrations and low flows in Okabena Creek.

Figure 15 shows the recent chloride monitoring data with the chronic chloride standard of 230 mg/L shown as the red line. **Figure 16** shows a closer look at low flows for the same period, showing flows less than 50 cfs. The chloride data is shown for reach 07100001-602 (the impaired reach shown as red dots; S001-568) and reach 07100001-512 (green dots; S000-269), which is a Class 7 upstream of the impairment.

Looking at the flow/chloride response in **Figure 16**, it can be seen that:

- The chloride concentration dips from 200 mg/L to 140 mg/L due to the 1.2-inch rainfall event on June 1, and then falls down to 50 to 60 mg/L due to the large three-inch rainfall event.
- The chloride concentration recovers and rises to exceeding the chronic standard of 230 mg/L on August 6 as the flow rate in the creek falls to 6 cfs.
- A series of 0.25 to 0.5-inch rainfall events in mid-August generates a small runoff response and a drop-in chloride concentration to 109 mg /L.
- Few rainfall events in September, and none over 0.3 inches produce little or no flow response in the creek, and the flow rate hovers just below 5 cfs.
- During September, the chloride concentration rose to 344 mg/L on September 9 and 330 mg/L on September 29.

Some conclusions from the monitoring data include:

- For the 2014 monitoring data set, the chloride chronic standard is exceeded on three occasions, at flow rates of 6.5, 4.6, and 4.2 cfs.
- The chloride concentration at S001-568 exhibits a clear flow response, with concentrations falling during periods of increasing flow rate, and rising during periods of decreasing flow rate.
- During the one-month period of relatively constant low flow of near 5 cfs, the two samples have very similar elevated chloride concentrations.
- Based upon the observations, it can be concluded that the elevated chloride concentrations at monitoring site S001–568 occur during low flow conditions, and therefore the low flow condition at or near 6 cfs is the critical flow condition.
- Surface runoff is not the primary source since concentrations drop during increased runoff. Typically, chloride loading in surface runoff peaks during winter and spring months. WWTP discharges during low flow conditions or groundwater sources are most likely the main source of the impairment.

Permitted sources

Wastewater Sources

The major source of chloride in wastewater discharges is from residential and commercial water softeners and food processing industries. Salt is expensive to remove and is not currently treated for in WWTPs in the Des Moines River Basin. **Figure 17** shows the chloride concentrations in the effluent of Worthington's domestic WWTP. The mean effluent concentration of chloride is 365 mg/L, well above the chronic standard of 230 mg/L. **Figure 18** shows the chloride concentrations in the effluent of the

Worthington Industrial WWTP, which treats waste from food processing industries and its mean effluent concentration of chloride is 385 mg/L, well above the chronic standard for chloride.

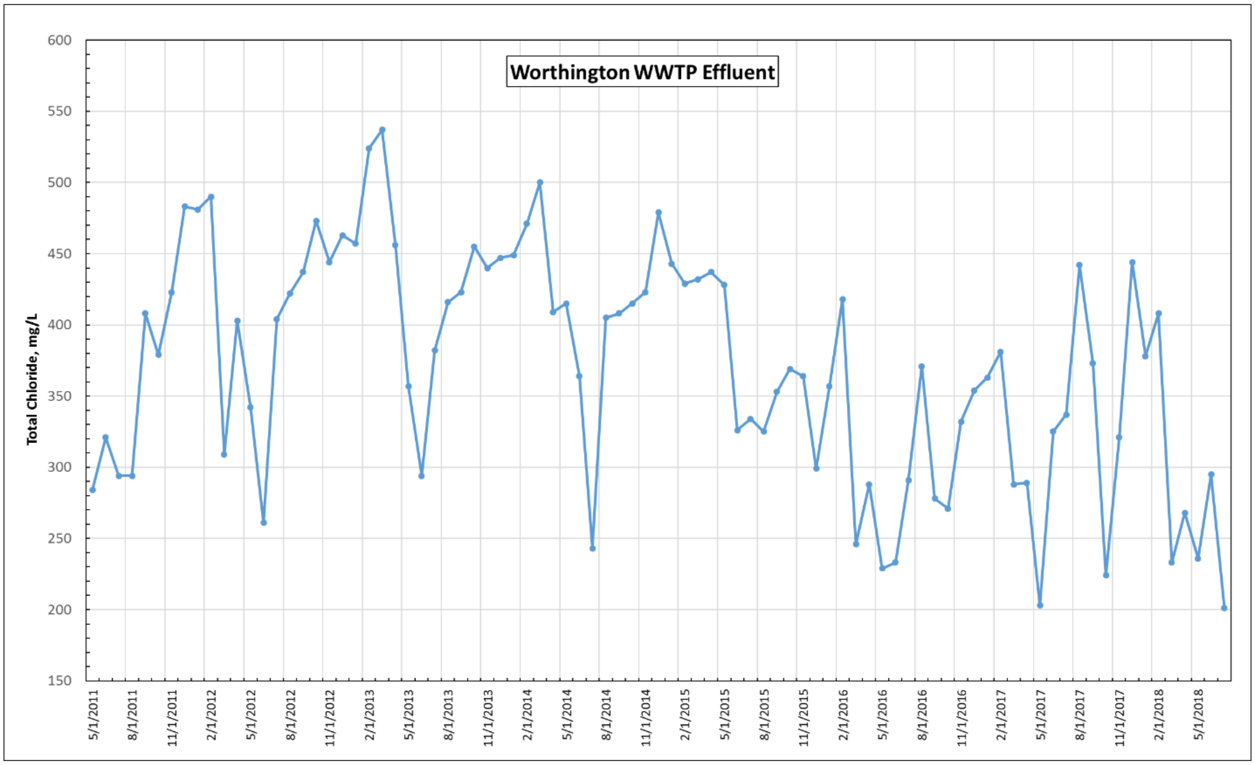

Figure 17. Chloride concentrations in Worthington WWTP effluent.

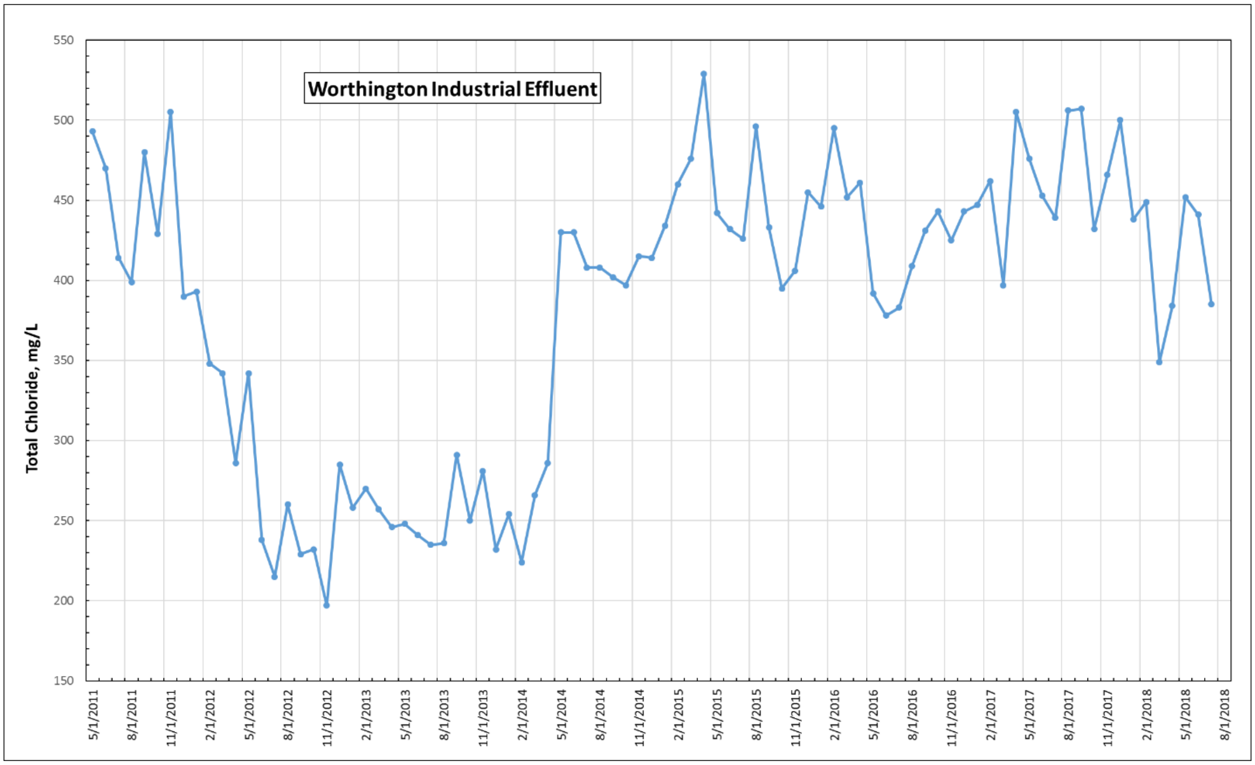

Figure 18. Chloride concentrations in Worthington Industrial WWTP effluent.

As shown in **Table 13**, evaluating the WWTP loads before and during the 9/9/2014 chloride standard exceedance event show that the sum of the effluent chloride load of the two discharging WWTPs (Worthington WWTP and Worthington Industrial WWTP) exceeds the total chloride load at the monitoring site, under the assumptions that 1) conservation of mass during transport, which is a fair assumption for chloride; 2) zero flow transmission loss, and 3) ignoring additional inflows from three streams between the WWTPs and the downstream monitoring site, which, under low flow may contribute negligible chloride mass. The chloride mass rate from the two continuous WWTP discharges exceeds the chloride mass rate at the downstream monitoring site, which tends to confirm that under low flow conditions and when the concentrations in the reach exceed the standard, WWTPs are the dominant chloride source. WWTPs are provided with WLAs and further discussed in **Section 4.3.3**

Table 13. Okabena Creek and WWTP flows and chloride loads for 9/9/2014.

Date	Station	Chloride, mg/L	Flow Rate, mgd	Flow Rate, cfs	Chloride Load, tons/day
9/9/2014	Okabena Creek 1 mile W of Okabena	344		4.60	4.27
9/9/2014	Worthington WWTP	408	1.18	1.83	2.01
9/9/2014	Worthington Industrial WWTP	402	1.5	2.32	2.52
9/9/2014	Brewster WWTP		0		
	Okabena WWTP[1]	--	--	--	--
	WWTP Totals			4.15	4.52

[1] Okabena WWTP discharges below the flow gauge site and is therefore not included in this analysis.

Municipal Separate Storm Sewer System (MS4) Winter Maintenance

MS4s can be a source of chloride through winter maintenance activities. Winter maintenance activities include snow and ice removal. Application of deicing and anti-icing chemicals, primarily salt, is common. Salt is applied to a variety of surfaces such as roads, parking lots, driveways, and sidewalks. The chemical properties of sodium chloride, most commonly salt, make it effective at melting ice, but these properties also result in chloride dissolving in water and being transported with snow melt and stormwater runoff to lakes, streams and wetlands. Because the chloride exceedances were seen during warm months and low flows, it is not believed that chloride from road salt is a significant source for the impairment.

Non-permitted sources

Non-permitted sources refer to sources not under the jurisdiction of regulatory permits and can include winter maintenance activities outside MS4-permitted areas, residential water softeners, agricultural runoff, natural sources, and many others.

Residential Water Softeners

Water softeners can be a source of chloride through the required use of water softener salt. The use of water softeners is common in areas where the water supply is considered to be “hard”. Hardness is a measure of the calcium and magnesium carbonate concentration in water. Most water softeners use chloride ions to replace calcium and magnesium ions. Chloride from this salt is delivered to the environment either through discharge to a septic system or by delivery to a WWTP. Septic systems become more prevalent in the rural areas where wastewater collection systems do not exist. The chloride that comes from septic systems enters either the shallow groundwater or local streams through subsurface flow. Chloride loading from any individual home water softener is dependent on many variables and is specific to the individual home's water chemistry, water use, hardness preferences, and softener efficiency. At this time, chloride loading estimates from residential water softeners in the Okabena Creek Watershed are not available.

Agriculture

Agricultural crop land may be a source of chloride to lakes and streams through the use of fertilizers and biosolids from food processing and publicly owned treatment works. The application of fertilizers and biosolids on crop land can result in chlorides being transported to lakes and streams through surface runoff, as well as infiltration into shallow groundwater and subsequent recharge of lakes and streams. Potassium chloride is the most commonly used fertilizer containing chloride. While not currently suspected to be a significant source of chloride, estimates of the amount of chloride in land-applied fertilizers and biosolids in the Des Moines River Basin are not available. An on-going evaluation by North Dakota State University – Department of Agriculture and Biosystems Engineering indicates that chloride concentrations from agricultural drainage can range from 8.6 mg/L to 37.4 mg/L (MPCA 2016).

Subsurface and Natural Sources

Groundwater and subsurface flow can be a source of chloride. Older groundwater, generally in deeper aquifers, tends to trend toward greater chloride concentration. In far western Minnesota, sodium chloride rich groundwater occurs in complex vertical and areal relationships. Paleozoic brines can have chloride concentrations up to 100,000 mg/L. The Paleozoic and Cretaceous rocks contain highly soluble minerals which contribute to the high salinity of the water and over time can reach surface waters through wells and groundwater seeps.

While the Des Moines River Basin is south of the area described above, it is important to note that saline seeps and groundwater in wells is possible and should not be overlooked. Natural background levels of chloride in surface runoff and groundwater vary depending on the geology of the watershed. Natural background was assumed to have a concentration of 18.7 mg/L (Stefan et al 2008) to represent the chloride from subsurface sources in the watershed.

3.6.2 Escherichia coli

Bacteria amounts produced in the Des Moines River Basin was estimated using available *E. coli* data on livestock and manure application, pasture, human populations (WWTPs and subsurface sewage treatment systems [SSTS]), pets, and wildlife populations based on literature rates from previous studies. Assessing the number of bacteria generated by major sources in the watershed can aid in implementing conservation activities to reduce bacteria loading to surface waters.

The greatest bacteria loading in the Des Moines River Basin is applied manure from animal feeding operations (AFOs). Surface and subsurface applied manure is attributed with 43% and 25% of *E. coli* loading respectively in the watershed. Human sources account for 11% of the *E. coli* loading. The remaining 21% of bacterial loading is estimated to come directly from AFO feedlots, pastures, pets, and environmental propagation of *E. coli*. Addressing inadequately treated waste, primarily SSTS, could reduce impairments during low flow conditions despite not being a major contributor in terms of relative production numbers. A general summary of the results and sources of bacteria in the Des Moines River Basin is given below.

Permitted sources

Feedlot Facilities

In Minnesota, AFOs are required to register with their respective delegated county or the state if they are 1) an animal feedlot capable of holding 50 or more animal units (AU), or a manure storage area capable of holding the manure produced by 50 or more AUs outside of shoreland; or 2) an animal feedlot capable of holding 10 or more AUs, or a manure storage area capable of holding the manure produced by 10 or more AUs, that is located within shoreland. Further explanation of registration requirements can be found in Minn. R. 7020.0350. Feedlots within delegated counties are registered through a County Feedlot Officer. Feedlots in non-delegated counties, all feedlots that are at or above 1,000 AU and all feedlots that meet the EPA definition of a Large Concentrated Animal Feeding Operations (CAFO) are registered directly with the MPCA.

CAFOs are defined by the EPA based on the number and type of animals. The MPCA currently uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the definition of AU. In Minnesota, the following types of livestock facilities are issued, and must operate under, a NPDES Permit or a state issued SDS Permit: a) all federally defined CAFOs which have had a discharge, some of which are under 1,000 AUs in size; and b) all CAFOs and non-CAFOs that have 1,000 or more AUs.

CAFOs and AFOs with 1,000 or more AUs must be designed to contain all manure and manure contaminated runoff from precipitation events of less than a 25-year - 24-hour storm event. Having and complying with an NPDES permit allows some enforcement protection if a facility discharges due to a 25-year - 24-hour precipitation event (approximately 5.2" in 24 hours) and the discharge does not contribute to a water quality impairment. Large CAFOs permitted with an SDS permit or those not covered by a permit must contain all runoff, regardless of the precipitation event. Therefore, many large CAFOs in Minnesota have chosen to have an NPDES permit, even if discharges have not occurred in the past at the facility. A current manure management plan, which complies with Minn. R. 7020.2225, and the respective permit is required for all CAFOs and AFOs with 1,000 or more AUs.

Permitted CAFOs are inspected by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved annually by the EPA. All large CAFOs (NPDES permitted, SDS permitted and not required to be permitted) are inspected by the MPCA on a routine basis with an appropriate mix of field inspections, offsite monitoring, and compliance assistance. The number of AUs by animal type registered with the MPCA feedlot database are used in this TMDL report.

A summary of the feedlots and permitted CAFOs in the Des Moines River Basin is provided in **Appendix D** by HUC-08 watershed. **Figure 19** shows the locations and AUs for registered feedlots and permitted CAFOs in the Des Moines River Headwaters Watershed, **Figure 20** shows the Lower Des Moines River Watershed, and **Figure 21** shows the East Fork Des Moines River Watershed. There are 647 AFOs with approximately 295,160 AUs in the Des Moines River Basin (MPCA Feedlot Program personal communication). A complete list of CAFOs by watershed and TMDL AUID is located in **Appendix D**. Of the 647, 84 are CAFOs. Fifty-two AFOs are located on shoreland, defined as within 1,000 feet of a lake or 300 feet of a stream or river. Open lots and those located near surface water bodies present a potential pollution hazard if runoff from the lot is not treated prior to reaching a surface water.

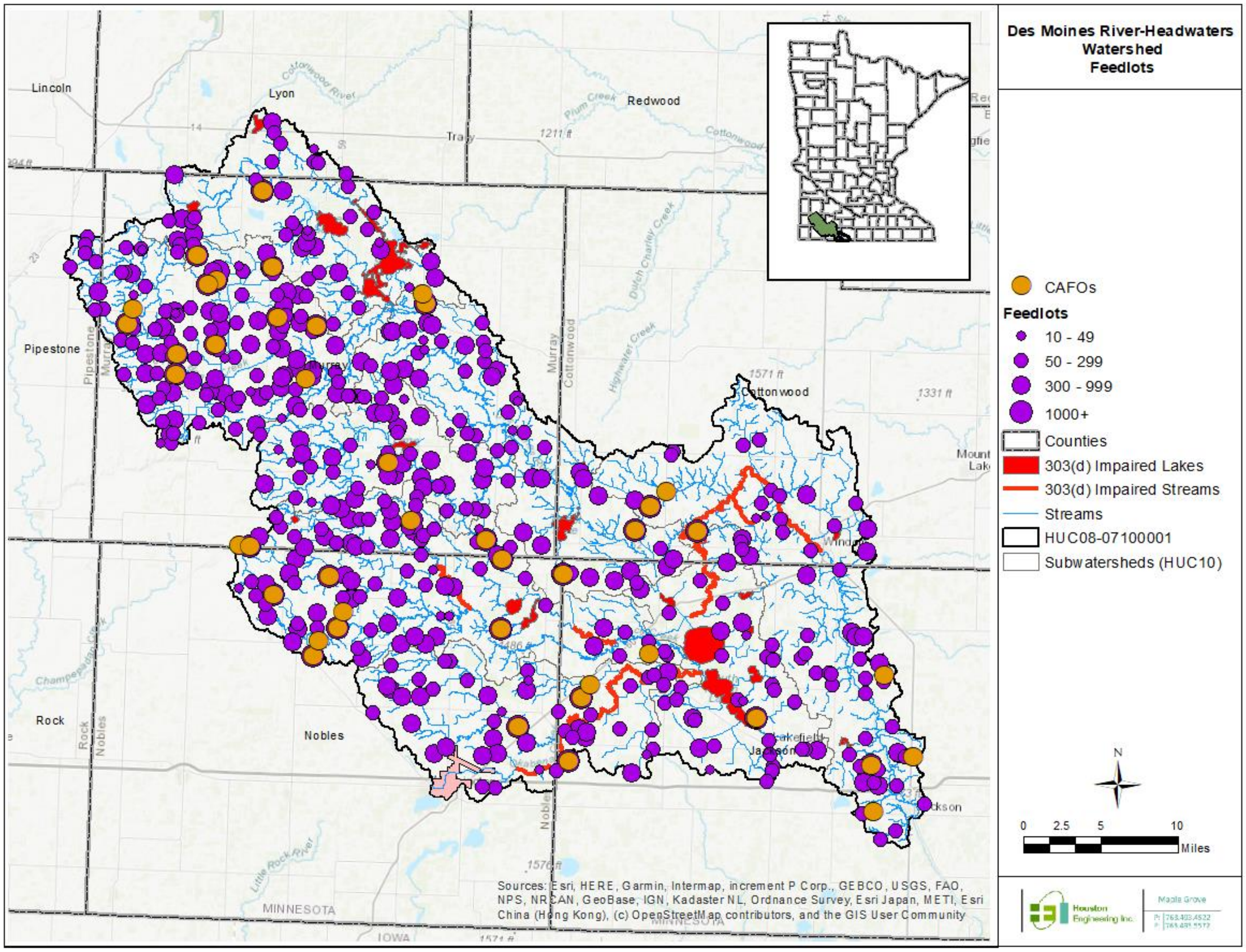

Figure 19. MPCA registered feedlots in the Des Moines River Headwaters Watershed.

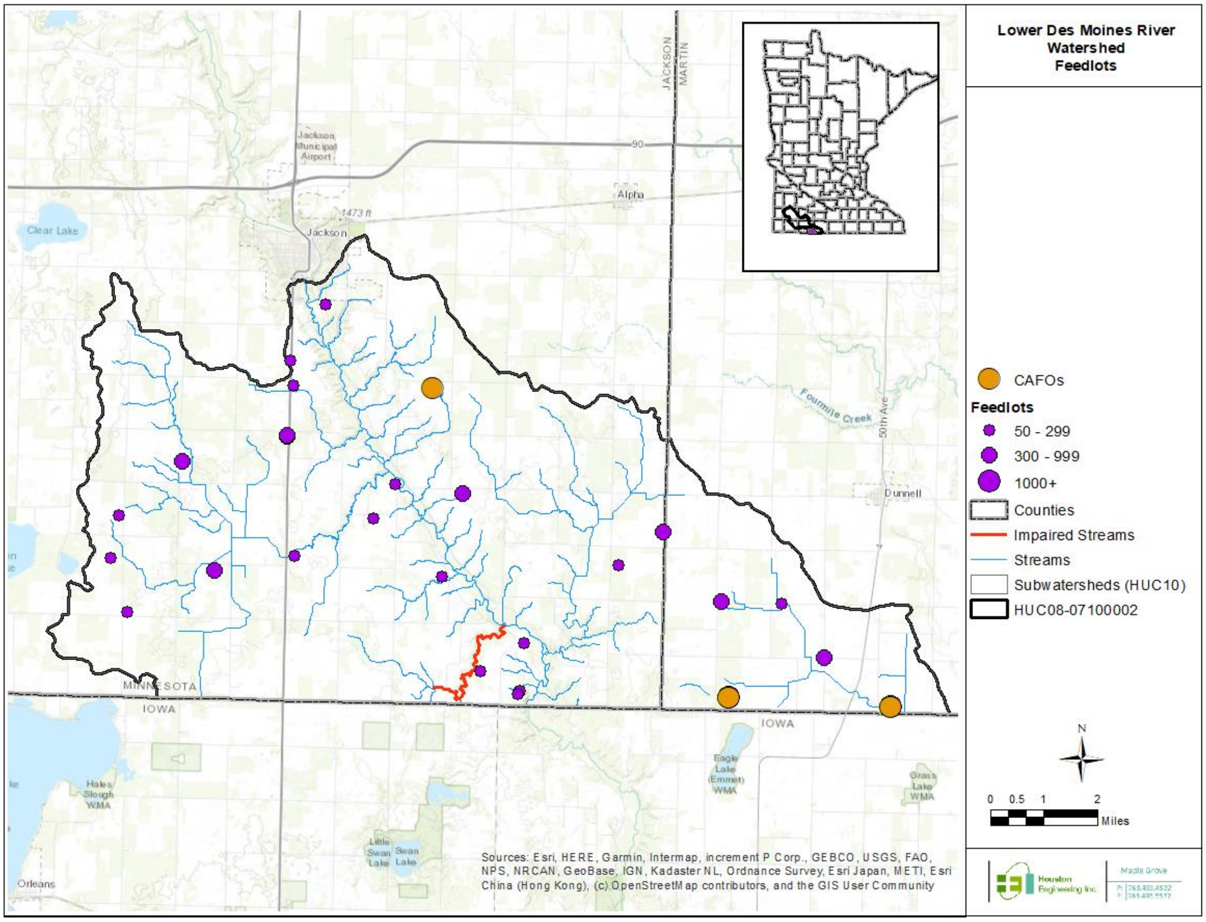

Figure 20. MPCA registered feedlots in the Lower Des Moines River Watershed.

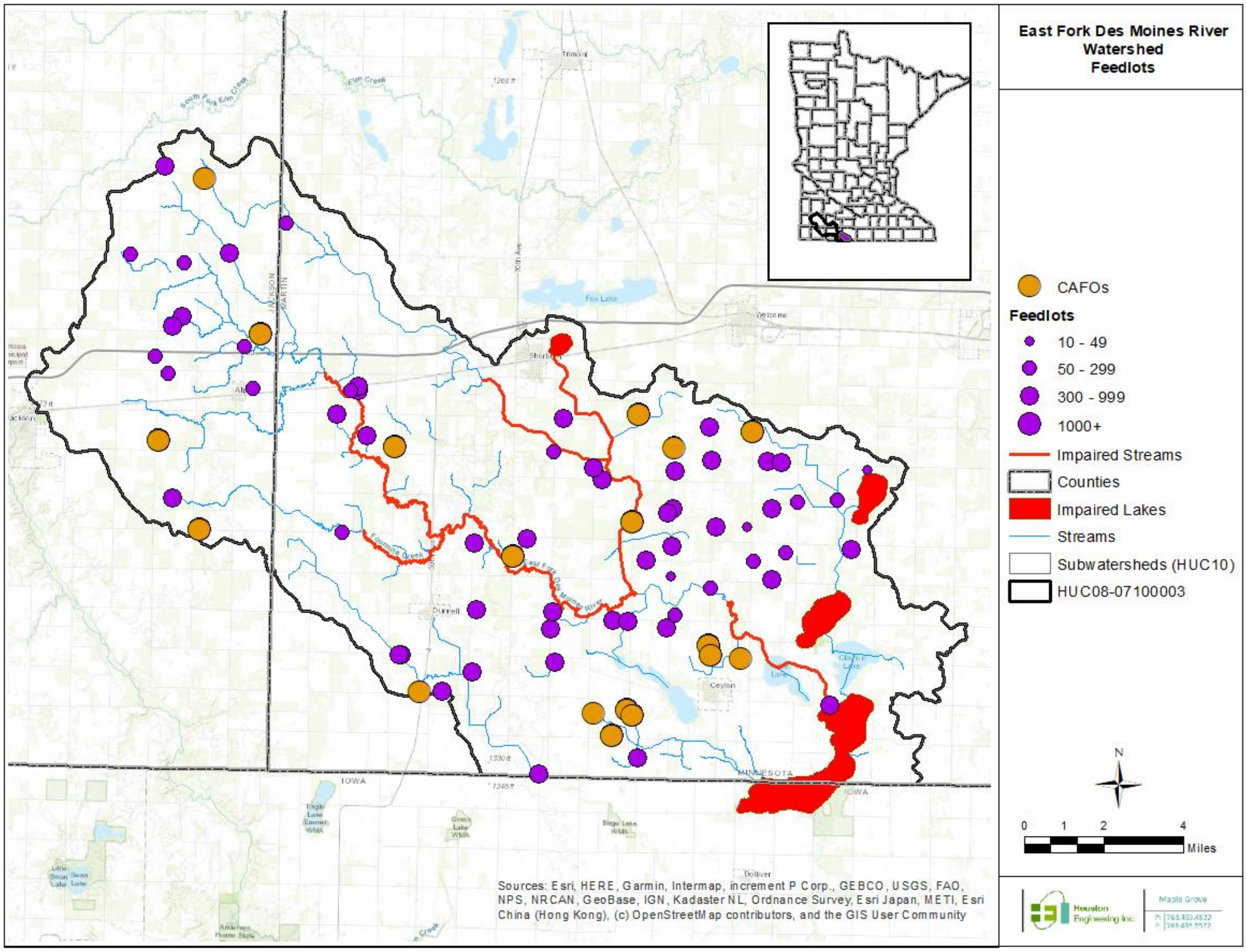

Figure 21. MPCA registered feedlots in the East Fork Des Moines River Headwaters Watershed.

Wastewater Treatment Plants

Human waste can be a significant source of *E. coli* during low flow periods. There are 27 NPDES wastewater permits in the Des Moines River Basin, consisting of 18 domestic wastewater permits and nine industrial permits. Of the 27 permits, 14 WWTPs discharge to impaired reaches and are sources of bacteria (see **Section 4.4.3**). Ten of these WWTPs have controlled discharge (pond) systems with discharge windows from March 1 to June 15 and September 15 to December 15. They can be a significant source if low flow conditions are occurring during discharge. Four of the WWTPs are continuous discharge systems, constantly releasing treated water, and are unlikely to be a primary source during low flows so long as the WWTP meets its permit levels. Fecal coliform effluent limits are intended to ensure that wastewater facilities effectively disinfect their effluents prior to discharge in months when the *E. coli* standard is in effect. Rarely, during extreme high flow conditions, WWTPs may also be a source if they become overloaded and have an emergency discharge of partially or untreated sewage, known as a release. All facilities within the Des Moines River Basin have adequate permit limits for *E. coli* and revisions are not required based on the TMDL analysis.

Municipal Stormwater Runoff

The city of Worthington (MS4 Permit #MS400257) covers 4.15 square miles in the drainage area of three impaired reaches (07100001-512, 07100001-524, and 07100001-527). Percentages covered by the MS4 area in each impaired reach watershed can be found in **Table 22** in **Section 4.4.3**. Urban areas may contribute bacteria to surface waters from pet waste and wildlife. Basin wide, pets contribute less than 1% of the total *E. coli* load in the Des Moines River Basin and wildlife accounts for 5% of bacteria.

Non-NPDES permitted sources

SSTS

Failing SSTS near waterways can be a source of bacteria to streams and lakes, especially during low flow periods when these sources continue to discharge, and runoff driven sources are not active. The MPCA differentiates between systems that are generally failing and those that are an imminent threat to public health or safety (ITPHS). Generally, failing systems are those that do not provide adequate treatment and may contaminate groundwater. For example, a system deemed failing to protect groundwater may have a functioning, intact tank and soil absorption system, but fails to protect ground water by providing less than sufficient amount of unsaturated soil between where the sewage is discharged and the ground water or bedrock. Systems that have been identified as an ITPHS may include systems that back up inside the house, discharge to the surface, unsecured or damaged maintenance hole covers, and "straight pipes" which may transport raw or partially treated sewage directly to a lake, a stream, a drainage system, or ground surface (Minn. Stat. 115.55, subd. 5).

Counties are required to submit annual reports to the MPCA regarding SSTS within their respective boundaries. Data reported is aggregate information by each county so the location of SSTSs are not known to the State of Minnesota. SSTS data from each county is shown in **Figure 22** and annual reports by counties within significant contributing areas to the watershed (Cottonwood, Jackson, Murray, Martin, and Nobles) indicate that failing SSTS have an ITPHS range from <1 to 5 systems per 1,000 acres (MPCA 2020a). These counties continue to invest in the education of landowners on the maintenance and impact failing systems can have on humans and wildlife.

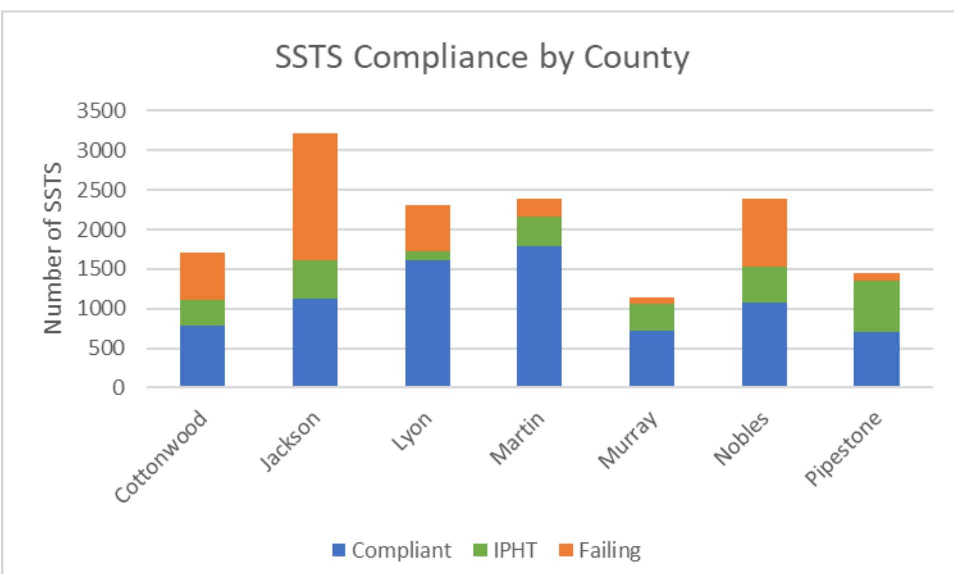

Figure 22. Individual subsurface sewage treatment systems by county in the Des Moines River Basin as of 2016.

Non-NPDES Permitted Feedlots and Manure Application

AFOs under 1,000 AUs and those that are not federally defined as CAFOS do not operate with permits. These facilities must operate their facilities in accordance with Minn. R. 7020.2000 through 7020.2150 to minimize their impact on water quality. AFOs may pose an environmental concern if the facilities are located near water and manure is inadequately managed, especially in open lot feedlots. There are 379 facilities in the Des Moines River Basin that have open lots. Of those with open lots, 45 are located within 1,000 feet of a lake or 300 feet of a stream. None of the feedlots within a shoreland are operating with an Open Lot Agreement (OLA) with the MPCA.

Approximately 66% of the AUs in the basin are swine and the majority of their manure is held in liquid manure storage areas. Another 33% of the AUs are cattle and their manure is held in either liquid manure storage areas or in stockpiles. When stored and applied properly, manure provides a natural nutrient source for crops.

Manure can be a significant source of bacteria. AFOs create a large amount of manure that is usually stored on site until field conditions and the crop rotation allow for land application of manure as a fertilizer. The timing of manure application can decrease the likelihood of bacteria loading to nearby water bodies. Specifically, the application of manure on frozen soil in the late-winter is likely to result in surface runoff with precipitation events and snow melt. Deferring manure application until soils have thawed decreases overland runoff associated with snow melt and large precipitation events. Injected or incorporated manure is a preferred best management practice (BMP) to reduce the runoff of waste and associated bacteria, as injected manure reduces the risk of surface runoff associated with large precipitation events.

Pasture

Livestock can contribute to bacteria loading to water bodies, from poorly managed pasture lands that are overgrazed or through the direct access of livestock to surface waters. Poorly maintained pasture can have significant overland surface flow during heavy precipitation events resulting in manure transport from the pasture. Livestock with direct access to streams and lakes can defecate directly into the water body resulting in direct contamination.

Natural Reproduction

Evidence suggests that *E. coli* bacteria have the ability to reproduce naturally in water and sediment, and therefore should be considered a self-propagating bacteria source. The relationship between bacterial sources and bacterial concentrations found in streams is complex, involving precipitation and flow, temperature, livestock management practices, wildlife activities, survival rates, land use practices, and other environmental factors. **Section 3.5.2** discussed possible sources of bacteria found in streams and highlighted the observation that *E. coli* populations can be naturalized in the sediment and persist over an extended period of time. Two Minnesota studies describe the presence and growth of "naturalized" or "indigenous" strains of *E. coli* in watershed soils (Ishii et al 2010), and ditch sediment and water (Sadowsky et al 2015). Sadowsky et al. concluded that approximately 36.5% of *E. coli* strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. The authors suggested that 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period. While these results may not be transferable to other locations, they do suggest the presence of background *E. coli* and a fraction of *E. coli* may be present regardless of the control measures taken by traditional implementation strategies. The following *E. coli* LAs include natural background.

Wildlife and Pets

Wildlife and pet waste can contribute bacteria to streams and lakes. Like livestock and humans, *E. coli* is present in the digestive tracts of wildlife and pets and as such, some *E. coli* may be present in the water from these sources. Wildlife and pets can be a contributor of *E. coli* in surface waters, directly or through surface runoff. It was determined that wildlife contribute about 5% of total *E. coli* load in the Des Moines River Basin and pets account for less than 1%.

3.6.3 Total Suspended Solids

TSS consist of soil particles, algae, and other materials that are suspended in water and cause a lack of water clarity. Excessive TSS can harm aquatic life and degrade aesthetic and recreational qualities. External sources of TSS to streams and lakes include sediment loading from permitted sources outside the stream such as construction, industrial, municipal stormwater runoff, and wastewater effluent, as well as non-permitted sources such as overland erosion and atmospheric deposition. Sources of TSS that occur internally within a stream include sediment from bank erosion, scouring, and in-channel algal production. Sources of TSS are variable seasonally as the majority of sediment loading to water bodies occurs during the spring snowmelt or precipitation events. Heavy precipitation during which soil is exposed is when erosion and sediment loss is most likely.

Permitted sources

Wastewater Treatment Plants

Human waste and permitted NPDES sites can be sources of TSS. Permitted sites have strict TSS restrictions that commonly contribute little to the permitted daily load. Neither of the two TSS impaired streams receive discharge from a permitted WWTP.

Construction Stormwater

Construction stormwater can be a source of TSS due to runoff from disturbed and easily erodible soils during construction activities. On average there are about 400 acres, or less than 0.1%, a year under a construction stormwater permit in the Des Moines River Basin. TSS from construction is not considered a significant contributor of TSS.

Industrial Stormwater

Industry can contribute to the TSS load of water bodies but there is very little industrial activity within either impaired stream reach.

Municipal Stormwater Runoff

There are no permitted MS4 areas draining to either impaired TSS stream addressed in this TMDL report.

Non-permitted sources

Overland Erosion

Overland runoff of sediment is assessed to be the greatest contributor of TSS to water bodies in the Des Moines River Basin, with 55% determined to come from crop surfaces, the equivalent of an average of 100 to 250 lbs of TSS per acre per year. High TSS can occur when heavy rains fall on unprotected soils, dislodging soil particles that are transported with surface runoff to adjacent water bodies. Losses are greatest during the spring, April through June, when vegetation is not yet actively growing, and rainfall is elevated. Ephemeral systems, streams, and gullies, are highly susceptible to intermittent flows and have high erosion potential in agricultural systems. Farming practices can exacerbate erosion in sensitive areas if soil is unprotected from rain and there is insufficient buffering of stream channels. Other overland erosion sources include sediment transported from upland fields through open intakes into subsurface tile drainage, sheet and rill runoff from upland fields, and livestock pastures in riparian zones.

Streambank Erosion

Streambank erosion can contribute significant amounts of sediment to streams. Unstable stream banks are common in the Des Moines River Basin, especially in the Des Moines River Headwaters and Lower Des Moines River watersheds where both impaired reaches considered in this TMDL report are located. Stream bed and bank erosion is estimated to be 40% of the annual TSS load, and is attributed to poor riparian vegetation management near stream channels and altered hydrology throughout the region. Altered hydrology has increased stream flows due to lower water storage from tiling, altered evapotranspiration cycles, and decreased water residence time in the stream channel due to straightening. Managing water on and below fields in addition to deep-rooted vegetation in the riparian zone can stabilize soil and decrease sediment loading, lowering TSS, in adjacent water bodies.

In-Channel Algae Production

Algae can be a source of TSS in streams. Algal growth in water bodies, commonly assessed as Chl-*a*, is naturally occurring, with highest growth commonly found in slow-moving streams or lakes with abundant nutrient supply. Neither stream has monitoring data for Chl-*a*, but both drain shallow lake systems that are highly productive. String Lake (17-0024-00) drains to Unnamed Creek (07100001-551) and from 2008 through 2017 was classified as highly eutrophic, with a 10-year average for transparency of 0 meters and Chl-*a* of 94 ug/L. Similarly, Judicial Ditch 56 (07100002-505) drains a series of shallow lakes and wetland complexes (Little Swan Lake, Swan Lake, and Christopherson Slough Complex), none of which are actively monitored, prior to becoming Judicial Ditch 23 in Iowa. The contribution of algal production to the TSS impairments for both reaches is not clear due to a lack of data. However, during low flow exceedances, algal production contribution increases in areas where livestock do not have access to streams.

Atmospheric Deposition

The atmosphere can contribute to stream TSS load. Average wind speeds in the Des Moines River Basin are greater than five miles per hour and strong seasonal winds are capable of transporting sediment from fields. Dust from industrial and construction sites, bare soils, and developed areas can all contribute TSS to surface waters. Windblown sediment is a likely source of TSS within the Des Moines River Basin but is likely a small percentage of total TSS in impaired streams.

3.6.4 Lake Nutrients

P and nitrogen (N) are the primary nutrients that, when present in excessive amounts, pollute lakes, streams, and wetlands. The limiting nutrient controlling algal production and excessive nutrient impairments in lakes of the Des Moines River Basin is P. P is an essential element for plant life, but when there is too much in the water growth of algae can be accelerated resulting in nuisance algae blooms. P is a common constituent of agricultural fertilizers, manure, and organic wastes in sewage and industrial effluent. P has an affinity to bind to soil particles, therefore, soil erosion is also a contributor. Streambank erosion occurring during flood events can transport P to streams and lakes.

According to the Des Moines River Basin HSPF model, the largest source of P in the Des Moines River Basin is cropland surface runoff at 38%, with cropland tile discharge coming in second at 23%. Groundwater contributes 10% of the P in the basin, followed by point sources estimated to be 9% of the watershed load. Near bank and in-channel sources account for 4%, and runoff from developed areas also contributes 4% of TP. Feedlot runoff account for 2% of P. The remaining 10% is attributed to other sources (MPCA 2020a).

Internal P cycles seasonally as the water in a lake turns over and P-rich water from the lake bottom mixes with surface waters, or through the disturbance of P-rich sediment disturbance by rough fish or wind-driven wave action. In shallow lakes that fully mix during these events, P from sediment is available to drive primary production. Internal loading and the effect of P made available varies yearly depending on environmental conditions.

Nutrient sources are described in more detail below by permitted and non-permitted sources.

Permitted sources

Wastewater Treatment Plants

WWTPs can contribute TP to lakes and streams. There are 16 NPDES permitted facilities upstream of nutrient- impaired lakes. Seven facilities are upstream of Talcot Lake, one discharges to South Heron Lake, five are upstream of North Heron Lake, and three facilities are upstream of Okamanpeedan Lake. Since the 2008 TMDL report, the MPCA has amended nutrient discharge limits in facility permits to address nutrient loading to lakes and rivers. Effluent limits continue to be reviewed every five years as part of the permit review process, but additional limits will be dependent on the water body receiving treated water and the broader watershed. All facilities in the Des Moines River Headwaters (07100001) and East Fork Des Moines River (07100003) watersheds have undergone a MPCA watershed phosphorus review. Watershed scale phosphorus effluent limit reviews are developed to establish the need for TP effluent limits and monitoring requirements for NPDES permitted wastewater treatment facilities. Phosphorus permit limits are based on the potential of a facility to contribute to a downstream water that exceeds lake or river eutrophication standards. Procedures for implementing river eutrophication standards in NPDES wastewater permits in Minnesota (MPCA 2015) outlines the analysis and calculations used to establish necessary P limits. A P effluent limit (MPCA 2017b) review for the Lower Des Moines River Watershed (07100002), which includes the Jackson WWTP (Permit No. MNG580063), was in progress at the time this TMDL report was written. P permit limits set for the lake eutrophication standards seek to protect waters downstream of an outfall without being overly stringent. Based on this TMDL, 8 of the 16 facilities will have a new or potentially revised TP permit limit (**Table 14**). A meeting was held with the permitted facilities to present the TMDLs and explain the impacts to the permit limits, see **Section 9**.

Table 14. Summary of permit status changes for permitted facilities in the Des Moines River Basin based on TP TMDLs.

Facility	New/Revised TP Permit Limit	Facility	New/Revised TP Permit Limit
Alpha WTP	Yes	Lake Wilson WWTP	Yes
Avoca & Iona WWTP[2]	No	Lakefield WWTP	No
Brewster WWTP	Yes[1]	Okabena WWTP	Yes[1]
Ceylon WWTP	No	Sherburn WWTP	No
Currie WWTP	No	Shetek Area Water & Sewer District WWTP	No
Dundee WWTP	No	Slayton WWTP	Yes
Fulda WWTP	No	Worthington Industrial WWTP	Yes[1]
Hubbard Feeds Inc - Worthington	Yes[2]	Worthington WWTP	Yes[1]

[1]Annual WLA will result in a new annul limit but the facility's permit already includes an equivalent TP concentration effluent limit.
[2]WLA may not result in new TP effluent limit if the discharge does not have reasonable potential to cause or contribute to the impairment. Reported TP effluent concentrations are always less than 0.1 mg/L.

Construction Stormwater

Construction stormwater can be a source of P due to runoff with P bound to disturbed and easily erodible soils during construction activities. On average there are about 400 acres, or less than 0.1%, a year under a construction stormwater permit in the Des Moines River Basin. P from construction is not considered a significant contributor.

Industrial Stormwater

Industrial stormwater can be a source of P. P-containing material that is handled, used, processed, or generated when exposed to stormwater may leak, leach, or decompose and be carried offsite. There are no NPDES permitted industrial stormwater sites in the drainage area of impaired lakes covered in this TMDL report.

Municipal Stormwater Runoff

P from sediment, grass clippings, leaves, fertilizers, and other P-containing materials can be conveyed through stormwater pipe networks to surface waters. The city of Worthington (MS4 Permit #MS400257) covers 4.15 square miles, less than 1% of the drainage area of North Heron Lake, which is the only lake it contributes to in the TMDL report.

Feedlot Facilities

Livestock AFOs can be a source of P to surface and ground water. Regulations regarding manure stockpiling or liquid manure storage areas on site decrease the likelihood of a direct release of manure, and associated nutrients, to water bodies. Temporary stockpiling of manure from feedlots, manure stored on fields prior to application to agricultural fields, are assessed as manure application (a non-permitted source). Permitted feedlot information can be found in **Section 3.6.2** and a list of permitted CAFOs in the basin is located in **Appendix D**.

Non-permitted sources

Upland Erosion

Soil erosion can be a source of nutrients because P often binds to sediment particles and is transported downstream. Upland P transport pathways include overland erosion, open tile intakes, and tile lines. In addition to sediment, organic materials often contain P and, much like sediment, organic materials can be transported across the landscape with runoff. Overland erosion can occur by sheet, rill, or gully modes of sediment transport that can convey P tightly bound to sediment to surface waters. Upon the formation of a gully, these areas are sensitive and highly susceptible to continued disturbance. Protecting sensitive areas with deep-rooted vegetation that stabilizes soils can help mitigate P loss. Minimizing the geographic extent and temporal duration of uncovered fields can also reduce the erosive power of heavy rain events.

P loading to lakes from upland sources is estimated to be 0.3-0.6 lbs/acre annually for the Des Moines River Headwaters Watershed (East Fork and Lower Des Moines River watersheds were not modeled). Overland runoff coupled with the high percentage of straightened stream channels, agricultural land use, loss of wetlands, and tiling – jointly indicating altered hydrology – increases the conveyance of P from the landscape to water bodies. Cropland surface runoff accounts for 38% of TP loading in the basin. Cropland tiling accounts for 23% of the TP load.

Stream Bank Erosion

Like overland erosion, P can be bound to sediment in streambanks and transported downstream when erosion occurs. During large precipitation events or during spring snow melt, streams can convey water at high velocity with significant stream energy. High stream power values commonly observed in the Des Moines River Basin can exceed the stress stream banks can withstand. This leads to bank failure and stream bank erosion with sediment and bound P being transported downstream. The removal of natural vegetation can exacerbate streambank erosion along a channel. In addition, alterations to the stream reaches, e.g. channel straightening, further increase stream energy and likelihood of streambank erosion. Near streambank and channel erosion accounts for 4% of TP loading in the Des Moines River Basin.

Non-NPDES Permitted Feedlots and Manure Application

AFOs under 1,000 AUs and those that are not federally defined as CAFOS do not operate with permits. These facilities must operate in accordance with Minn. R. 7020.2000 through 7020.2150 to minimize their impact on water quality. AFOs may pose an environmental concern if the facilities are located near water and manure is inadequately managed, especially in open lot feedlots. Information about AFO numbers is located in **Section 3.6.2**.

Manure is a by-product of animal production and large numbers of animals create large quantities of manure. This manure is usually stockpiled or held in liquid manure storage areas, and then spread over agricultural fields. The majority of liquid manure is immediately incorporated during application while solid manure is surface applied with varying amounts of incorporation at the time of application.

Manure can have a high content of P per unit of manure. Since manure can have different ratios of nitrogen to P content, deliberate manure management measures must be employed to ensure excessive P application does not occur if manure is applied based on nitrogen rates. There is potentially a significant amount of winter application of manure onto snow covered or frozen soils based on MPCA feedlot staff observation. High intensity precipitation events during the spring can cause erosion of both the soil as well as the manure that is applied onto the soil, leading to high P loads making their way to streams and lakes. Land applied manure from all AFOs must comply with Minn. R. 7020.2225.

Internal Loading

Internal loading can be a significant source in lakes, especially if the lake has a long history of excessive external P loading. Lake bed sediments can be high P contributors as organic material and sediment fall out of the water column, settling on the bottom of a lake. Disturbance of sediment on a lake bottom from carp and other rough fish can resuspend sediment and lead to the release of P to the water column. In addition, anoxic conditions can break the bonds holding the P in the sediment and re-release it into the water column, exacerbating already high P levels. Although internal loading can be a significant source of P, there is no information on specific internal loading rates in the lakes of the Des Moines River Basin.

SSTS

Failing SSTS with an insufficient dry zone between the leach field and bedrock or saturated zone, or improperly designed SSTS, can result in the transport of P to groundwater and surface waters. The large number of failing SSTS in the Des Moines River Basin, estimated to be between one and five systems per 1,000 acres (numbers by county are found in **Section 3.6.2**), can contribute increased P loads to surface waters. Counties in the watershed continue to improve SSTS assessment and conduct outreach to the public regarding system maintenance.

Atmospheric Deposition

Atmospheric deposition to the surface of lakes can be a source of P, including pollen, soil (aeolian particulates), oil, coal particulate matter, and fertilizers. Regional P loading for the region is modeled to be 45 kg/km^2/year which is 0.4 lbs/acre/year (Barr 2007).

4. TMDL development

A TMDL represents the maximum mass of a pollutant that can be assimilated by a receiving waterbody without causing an impairment in that receiving waterbody. TMDLs are developed based on the following equation:

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

Where:

LC = loading capacity, or the greatest amount of a pollutant a waterbody can receive and still meet water quality standards (see **Section 4.2.1**);

WLA = Wasteload allocation, or the portion of the LC allocated to existing or future permitted point sources (see **Section 4.2.3**);

LA = load allocation, or the portion of the LC allocated for existing or future NPS (see **Section 4.2.2**);

MOS = margin of safety, or accounting for any uncertainty associated with attaining the water quality standard. The MOS may be explicitly stated as an added, separate quantity in the TMDL calculation or may be implicit, as in a conservative assumption (EPA 2007) (see **Section 4.2.4**);

RC = reserve capacity, or the portion of the TMDL that accommodates for future loads. (see **Section 4.6.5**).

Per Code of Federal Regulations (40 CFR 130.2(1)), TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measures. For this TMDL report, the TMDLs, allocations, and margins of safety are expressed in mass/day. Each TMDL component is explained in greater detail below.

4.1 Natural background consideration

Natural background was given consideration in the development of LA in this TMDL. Natural background is the landscape condition that occurs outside of human influence. Minn. R. 7050.0150, subp. 4, defines the term "natural causes" as the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence. Natural background conditions refer to inputs of pollution that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, loading from forested land, and wildlife, etc. For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment and therefore natural background is accounted for and addressed through the MPCA's waterbody assessment process. Natural background conditions were evaluated, where possible, within the modeling and source assessment. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, WWTPs, failing SSTSs, and other anthropogenic sources.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the waterbodies' ability to meet state water quality standards. For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment. Federal law instructs an agency to distinguish between natural and nonpoint source loads "[w]herever possible." 40 C.F.R. § 130.2(g). However, Minnesota law[3] does not compel the MPCA to develop a separate LA for natural background sources, distinct from NPS.

[3] The MPCA is not required to designate a separate LA for natural background (Matter of Decision to Deny Petitions for a Contested Case Hearing, 924 N.W.2d 638 (Minn. Ct. App. 2019), review denied (Apr. 24, 2019)).

4.2 Data Sources

4.2.1 Hydrological Simulation Program-Fortran (HSPF)

The HSPF model is a comprehensive package for simulation of watershed hydrology and water quality for conventional and toxic organic pollutants. HSPF incorporates watershed-scale Agricultural Runoff Model (ARM) and NPS models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at the outlet of any subwatershed.

An HSPF model was developed in 2016 for Minnesota's portion of the Des Moines River Basin. The HSPF models predict the range of flows that have historically occurred in the modeled area and the load contributions from a variety of point and NPS in a watershed. Multiple memos are available which discuss modeling methodologies, data used, and calibration results for the three major watersheds in the basin (Tetra Tech 2016). The HSPF models simulate hydrology and water quality for the period 1993 to 2014.

4.2.2 Environmental Quality Information Systems

The MPCA uses a system called EQuIS to store water quality data from more than 17,000 sampling locations across the state. All discreet water quality sampling data utilized for assessments and data analysis for this TMDL report are stored in this accessible database: *Environmental Data Access* (MPCA 2020b). The EQuIS locations used are provided in **Table 9** through **Table 12** and **Figure 11** through **Figure 13** in **Section 3.5**.

4.3 Chloride

4.3.1 Loading capacity methodology

The loading capacities for impaired stream reaches were determined using the LDC approach. A LDC is developed by combining the (simulated or observed) river/stream flow at the downstream end of the AUID with the observed/measured parameter data available within the segment. Methods detailed in the EPA document *An Approach for Using Load Duration Curves in the Development of TMDLs* were used in creating the curves (EPA 2007).

A stream's water quality often varies based on flow regime, with elevated pollutant loadings sometimes occurring more frequently under one regime or another. Loading dynamics during certain flow conditions can be indicative of the type of pollutant source causing an exceedance (i.e., point sources contributing more loading under low flow conditions). The LDC approach identifies these flow regimes and presents the observed and "allowable" loading within each regime, to compute necessary load reductions. To represent different types of flow events, and pollutant loading during these events, five flow regimes were identified based on percent exceedance: Very High Flow (0% to 10%), High Flow (10% to 40%), Mid Flow (40% to 60%), Low Flow (60% to 90%), and Very Low Flow (90% to 100%).

Benefits of LDC analysis include: (1) the loading capacities are calculated for multiple flow regimes, not just a single point; (2) use of the method helps identify specific flow regimes and hydrologic processes/patterns where loading may be a concern; and (3) ensuring that the applicable water quality standards are protective across all flow regimes. Some limitations with the LDC approach exist: (1) the approach is limited in the ability to track individual loadings or relative source contributions and (2) is appropriate when a correlation between flow and water quality exists and flow is the driving force behind pollutant delivery mechanics.

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this TMDL report (see **Table 17** as example), only five points on the entire LC curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and it is what the EPA ultimately approves.

In the LDC, the percent likelihood of flow exceedance is shown on the x-axis, while the computed loading is shown on the y-axis. "Allowable" loadings under each flow condition, based on the water quality standards (both the geometric mean and instantaneous standards), is shown with a red and green line. Observed loads are also shown, indicated by points on the plot. The median loads for each flow regime are shown as a red dashed line for median existing loads ("observed") and a solid blue line for median "allowable" load (geometric mean) under each flow condition. Observed loads are broken out by station, allowing for a detailed examination of when and where loading exceedances have occurred. The "allowable" loads are the loading capacity of the stream reach.

Table 15 provides the methodology to convert flows and concentrations to chloride loads. For chloride, the LC was calculated using the standards of 230 mg/L. The water quality standards for chloride applies year-round. Loads are calculated as pounds per day.

Table 15. Converting flow and concentration into chloride load.

Load (lbs/day) = Standard (ug/L) * Flow (cfs) * Conversion Factor			
For each flow regime			
Multiply **flow** (cfs) by **28.31** (L/ft^3) and **86,400** (sec/day) to convert	cfs	→	L/day
Multiply **concentration** [**mg/L**] by **L/day** to convert	L/day	→	mg/day
Divide **mg/day** by **453,592** (mg/lbs) to convert	mg/day	→	lbs/day

4.3.2 Load allocation methodology

LAs represent the portion of the LC designated for NPS of chloride. The LA is the remaining load once the WLAs, RC, and MOS are determined and subtracted from the LC. The LA includes all sources of chloride that do not require NPDES permit coverage, including unregulated watershed runoff, internal loading, groundwater, atmospheric deposition and a consideration for "natural background" conditions as described in **Section 4.1**. Chloride is naturally present in Minnesota's groundwater due to glacial deposits from eroded igneous rocks and clay minerals containing chloride ions. Natural background levels of chloride in surface runoff and groundwater vary depending on the geology. Natural background was assumed to have a concentration of 18.7 mg/L (Stefan et al 2008) and given a separate LA in the TMDL table (**Table 17**). Additional NPS of chloride were previously discussed in **Section 3.6.1**.

4.3.3 Wasteload allocation methodology

WLAs are developed for any point source/permitted discharge in the drainage area of an impaired reach. These are discharges requiring an NPDES permit and typically include WWTPs, permitted MS4s, industrial discharges, construction stormwater, and permitted feedlots. WLAs for each AUID are provided in **Table 16**.

Wastewater Treatment Plants

WLAs for WWTPs are based on the reported maximum allowable discharge and the permitted concentration limits. The WWTPs, permit numbers, permitted flows, and WLAs are provided in **Table 16** as well as the AUIDs impacted by the WWTPs and potential new or revised permit limits. All facilities in the Okabena Creek subwatershed will receive a new or revised chloride permit limit. A meeting was held with the permitted facilities to present the TMDLs and explain the impacts to the permit limits, see **Section 9**.

Table 16. WLAs for NPDES permits in impaired reaches of the Des Moines River Basin.

Watershed (HUC-08)	WWTP	Permit Number	AUIDs	Flow [cfs]	WLA Concentration Assumption [mg/L]	Chloride [lbs/day][1]	New/Revised Chloride Permit Limit[2]
Des Moines River Headwaters (07100001)	Brewster WWTP	MN0021750	07100001-602	1.997	230	3,831	Yes
	Hubbard Feeds Inc - Worthington	MN0033375	07100001-602	0.009	230	17.3	Yes[3]
	Okabena WWTP	MN0050288	07100001-602	0.244	230	468	Yes
	Worthington Industrial WWTP	MN0031178	07100001-602	2.16	230	4,143	Yes
	Worthington WWTP	MN0031186	07100001-602	4	230	7,673	Yes

[1]WLA calculated using flow (cfs) * concentration (mg/L) * 8.34 (conversion factor) to get WLA (lbs/day)
[2]See Section 6.1.4 for discussion of municipal WWTPs and chloride management alternatives
[3]WLA may not result in new total chloride effluent limit if the discharge does not have reasonable potential to cause or contribute to the impairment.

Straight Pipe Septic Systems

Straight pipe septic systems are illegal and unpermitted, and as such, receive a WLA of zero.

Industrial and Construction Stormwater Permits

WLAs for regulated construction stormwater (MNR10001) were not developed since chloride is not a typical pollutant from construction sites. WLAs for regulated industrial stormwater were also not developed. Industrial stormwater must receive a WLA only if the pollutant is part of benchmark monitoring for an industrial site in the watershed of an impaired waterbody. There are no chloride benchmarks associated with the Industrial Stormwater Permit (MNR050000).

Municipal Separate Storm Sewer System (MS4)

The WLA for communities subjected to MS4 NPDES stormwater permit requirements is taken as a percentage of the LC based on the percentage of area in the impaired reach that the MS4 permit area covers. The only MS4 area within the Des Moines River Basin is the city of Worthington (MS4 Permit #MS400257) and covers about 4.15 square miles within the watershed (total area of 137.7 sq mi) or 3.02% of the watershed area. Since the chloride for the MS4 is primarily from road salt and spring melt runoff, the WLA for the MS4 was taken as 3.02% of the LC during the Very High flow conditions (when most spring melt flows occur). The MS4 will now have to assess and document winter maintenance BMPs to address the chloride WLA as stated in their permit.

Livestock Facilities

NPDEs permitted feedlot facilities are assigned a zero WLA. This is consistent with the conditions of the permit, which allows no pollutant discharge from livestock housing facilities and associated sites. Discharge of chloride from fields where manure has been land-applied may occur during runoff events, but those discharges are covered under the LA portion of the TMDL and do not require an additional WLA. A list of CAFOs by AUID reach can be found in **Appendix D**.

WLA during low flows

The total daily LC of some stream reaches during low and very low flow regimes are very small due to the occurrence of very low flows in the stream/river. Consequently, for some of the impaired reaches the permitted wastewater design discharge is close to or higher than the streamflow during these flow regimes. This translates to these point sources appearing to use all of, or exceeding, the LC during these flow periods. In reality, this will never occur as the discharge is a part of the streamflow and can never exceed total streamflow. To account for these unique situations, the WLA (and LA) are expressed as an equation rather than an absolute number. The equation is:

Allocation = Point Source Discharge X Water Quality Standard Concentration

Consistent units are used to obtain the load. This assigns a concentration-based limit to the WLA for these lower flow rates.

4.3.4 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% of the LC MOS was applied to each flow regime for all LDCs developed for this TMDL report. The explicit 10% MOS accounts for:

- Uncertainty in the observed daily flow record;
- Uncertainty in the simulated flow data from the HSPF model;
- Uncertainty in the observed water quality data;
- Allocations and loading capacities are based on flow, which varies from very high to very low. This variability is accounted for using the five flow regimes and the LDCs.

The majority of the MOS is apportioned to uncertainty related to the HSPF model. The hydrologic validation statistics for the HSPF model at the Des Moines River at Jackson, Minnesota (USGS station ID 05476000) were:

- -9.33% Error in total flow volume;
- 3.68% Error in bottom 50% low flows;
- -8.93% Error in the top 10% high flows;

- A Nash-Sutcliffe coefficient of model fit efficiency (NSE) of 0.72 for daily flows;
- And, a Nash-Sutcliffe Efficiency (NSE) of 0.79 for monthly flows.

Overall, the HSPF model calibration and outputs were determined to be "Good". There is no reason to believe a 10% MOS is inappropriate as it is consistent with HSPF modeling errors, and the HSPF model is a valid representation of hydrological and chemical conditions in the watershed. More information on the calibration of the HSPF model can be found in Tetra Tech (2016).

4.3.5 Seasonal variation

The TMDL developed for AUID 07100001-602 considered chloride sources from both seasonal sources, such as spring snowmelt and runoff, as well as continuous year-round sources, such as WWTP's flow. Both seasonal variation and critical conditions are accounted for in this TMDL report through the application of LDCs. LDCs evaluate water quality conditions across all flow conditions, including high flows, runoff conditions, and low flows. As shown in **Figure 23** (and **Figures 15** and **16** in **Section 3.6.1**), the high chloride concentrations, and therefore the critical conditions, are present during low flows, occurring in late summer/early fall (August and September) when flows are below 12 cfs.

4.3.6 TMDL summary

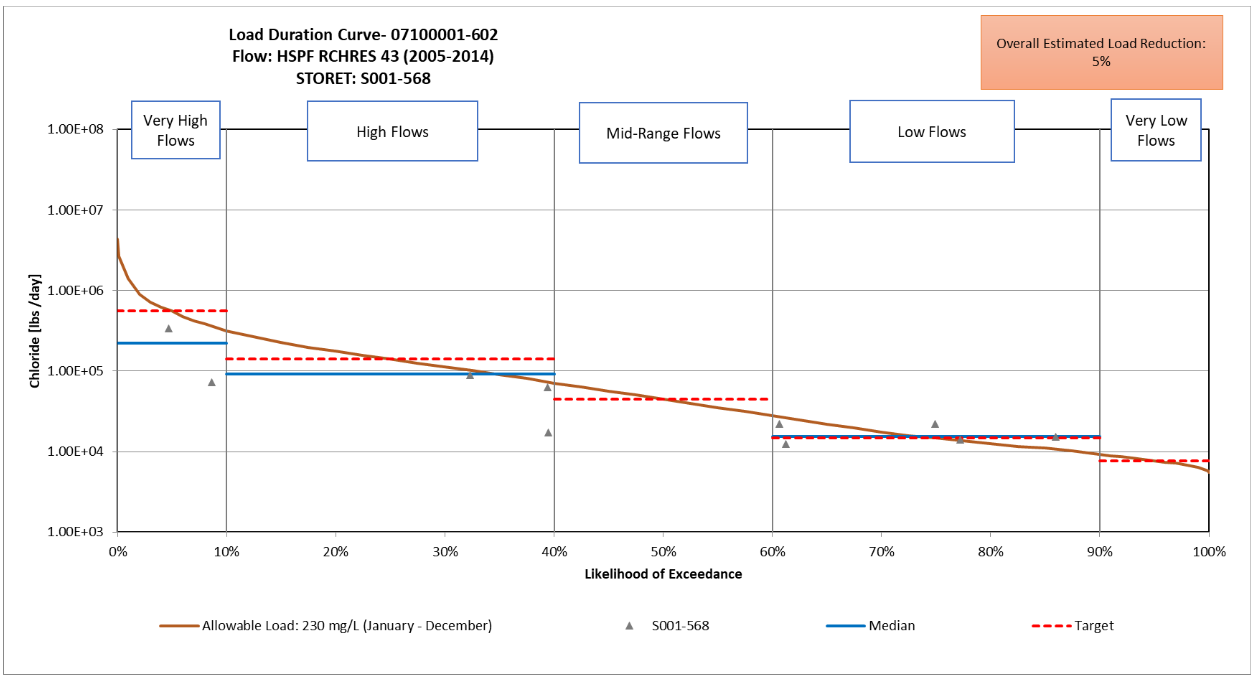

Figure 23. Okabena Creek, Elk Cr to Division Cr (AUID 07100001-602) Chloride LDC.

Table 17. Allocations for Okabena Creek, Elk Cr to Division Cr (AUID 07100001-602) Chloride TMDL.

Chloride		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[lbs /day]				
Wasteload Allocation	**Total WLA**	**32,860**	**32,860**	**32,860**	**###[1]**	**###[1]**
	Brewster WWTP	3,831	3,831	3,831	**###[1]**	**###[1]**
	Hubbard Feeds Inc — Worthington	17	17	17	**###[1]**	**###[1]**
	Okabena WWTP	468	468	468	**###[1]**	**###[1]**
	Worthington Industrial WWTP	4,143	4,143	4,143	**###[1]**	**###[1]**
	Worthington WWTP	7,673	7,673	7,673	**###[1]**	**###[1]**
	Worthington MS400257[2]	16,728	16,728	16,728		
Load Allocation	**Total LA**	**465,665**	**93,213**	**7,097**	**###[3]**	**###[3]**
	Nonpoint Sources	420,629	81,824	3,487	**###[3]**	**###[3]**
	Natural Background	45,036	11,389	3,610	1,202	625
Margin of Safety (MOS)		**55,392**	**14,008**	**4,440**	**1,478**	**769**
Loading Capacity		**553,917**	**140,081**	**44,397**	**14,780**	**7,691**
Average concentration during low flows (mg/L)		**241**				
Overall estimated percent reduction		**4.6%**				

[1]### = The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number, see section 4.3.3.

[2]MS4 WLA set to 3.02% of LC, see Section 4.3.3. Only applies during Very high to Mid-range flows (flows common with snowmelt).

[3]WLA exceeded load capacity for this zone, therefore LA for nonpoint sources are determined by the formula: Allocation = (flow from a given source) X (Chloride concentration standard). The resulting Total LA is then the summation of the nonpoint sources formula and the natural background value.

4.4 *Escherichia coli*

4.4.1 Loading capacity methodology

Like chloride, LDCs were used to represent the LC for each E. coli impaired reach. Description of the LDC methodology can be found in Section 4.3.1. Table 18 provides the methodology to convert flows and concentrations to bacteria loads. The LC was calculated using both the instantaneous standard of 1,260 organisms/100 mL and the geometric mean (i.e., geomean) standard of 126 organisms/100 mL (630 organisms/100 mL for Class 7 waters). The water quality standards for E. coli applies during April to October (May to October for Class 7 waters). Loads are calculated as organisms per day and reported as billions of organisms/day.

Load (org/day) = *E. coli* Standard (organisms/100mL) * Flow (cfs) * Factor			
Multiply by **28.316** to convert	ft^3 per second	→	L/sec
Multiply by **1,000** to convert	Liters per second	→	mL/sec
Divide by **100** to convert	Milliliters per second	→	organisms/sec
Multiply by **86,400** to convert	organisms per second	→	organisms/day

Table 18. Converting flow and concentration into bacterial load.

Assessments for *E. coli* divide the observed data by month and assess each month individually. A LDC combines all months and divides the data based on the flow regime when the data was measured. These differences sometimes lead to an LDC not showing a needed reduction, even though exceedances can be seen and the AUID reach is still impaired**.** In these cases, the loading capacity is still correct and valid, other methods are needed to estimate a required load reduction. This will be further explained in the TMDL document for any AUID where this special case exists.

4.4.2 Load allocation methodology

LAs represent the portion of the LC designated for NPS of *E. coli*. The LA is the remaining load once the waste LA and MOS are determined and subtracted from the LC. The LA includes all sources of *E. coli* that do not require NPDES permit coverage, including unregulated watershed runoff, wildlife sources, and a consideration for "natural background" conditions as described in **Section 4.1.** NPS of *E. coli* were previously discussed in **Section 3.6.2**.

4.4.3 Wasteload allocation methodology

WLAs are developed for any point source/permitted discharge in the drainage area of an impaired reach. These are discharges requiring an NPDES permit and typically include wastewater treatment facilities, permitted MS4s, industrial discharges, construction stormwater, and permitted feedlots. WLAs for each AUID are provided in the TMDL table in **Section 4.4.6**.

Wastewater Treatment Plants

WLAs for WWTPs are based on the reported maximum allowable discharge and converted permitted concentration limits. The permitted bacteria limits for fecal coliform and a ratio of 200 fecal coliform to 126 *E. coli* is used to convert fecal coliform to *E. coli*. **Table 19** provides the methodology to convert maximum daily flow and permitted limits to the WLA in organisms per day. The WWTPs, permit numbers, flow type, and impacted AUIDs are provided in **Table 20**. The permitted flows and WLAs are provide in **Table 21** as well as the AUIDs impacted by the WWTPs.

Table 19. Converting flow and permit limit concentrations into bacterial loads.

Waste Load (org/day) = *E. coli* Limit (126 organisms/100mL) * Flow (mgd) * Factor			
Convert Fecal to *E. coli*	200 (Fecal):126 (*E. coli*)	→	organisms per 100 mL
Multiply by **10** to convert	organisms per 100 mL	→	organisms per Liter
Multiply by **3.785** to convert	organisms per Liter	→	organisms per gallon
Multiply by **1,000,000** to convert	organisms per gallon	→	organisms per million gallons
Multiply by flow (mgd)	organisms per mg	→	organisms per day

Table 20. WWTPs in *E. coli* impaired reaches of the Des Moines River Basin.

Watershed (HUC-08)	WWTP	Permit Number	Station	Flow Type	AUIDs
Des Moines River Headwaters (07100001)	Avoca & Iona WWTP	MNG580165	SD 001	Controlled	07100001-524
	Brewster WWTP	MN0021750	SD 001	Controlled	07100001-524, 07100001-527
	Currie WWTP	MNG580221	SD 002	Controlled	07100001-524
	Dundee WWTP	MN0070271	SD 001	Controlled	07100001-524
	Fulda WWTP	MNG580188	SD 002	Controlled	07100001-524
	Heron Lake WWTP	MNG580189	SD 001	Controlled	07100001-524, 07100001-527
	Lake Wilson WWTP	MNG580061	SD 002	Controlled	07100001-524
	Lakefield WWTP	MN0020427	SD 002	Continuous	07100001-524, 07100001-527
	Okabena WWTP	MN0050288	SD 001	Controlled	07100001-524, 07100001-527
	Shetek Area Water & Sewer District WWTP	MN0070947	SD 002	Controlled	07100001-524
	Slayton WWTP	MNG580191	SD 002	Controlled	07100001-524
	Worthington Industrial WWTP	MN0031178	SD 002	Continuous	07100001-512, 07100001-524, 07100001-527
	Worthington WWTP	MN0031186	SD 001	Continuous	07100001-512, 07100001-524, 07100001-527
East Fork Des Moines River (07100003)	Sherburn WWTP	MN0024872	SD 002	Continuous	07100003-503, 07100003-527

Table 21. WLA for NPDES permits in impaired reaches of the Des Moines River Basin.

Watershed (HUC-08)	WWTP	Permit Limit (as *E. coli*)				Max Daily Flow (mgd)	*E. coli* WLAs	
		org/ 100 mL	org/L	org/ Gal	org/mg		org/day	billion org/day
Des Moines River Headwaters (07100001)	Avoca & Iona WWTP	126	1260	4769.1	4.7691E+09	0.805	3,838,424,577	3.838
	Brewster WWTP	126	1260	4769.1	4.7691E+09	1.997	9,526,130,629	9.526
	Currie WWTP	126	1260	4769.1	4.7691E+09	0.927	4,421,181,344	4.421
	Dundee WWTP	126	1260	4769.1	4.7691E+09	0.121	574,986,677	0.575
	Fulda WWTP	126	1260	4769.1	4.7691E+09	0.880	4,195,848,727	4.196
	Heron Lake WWTP	126	1260	4769.1	4.7691E+09	0.766	3,651,942,411	3.652
	Lake Wilson WWTP	126	1260	4769.1	4.7691E+09	0.512	2,439,808,334	2.440
	Lakefield WWTP	126	1260	4769.1	4.7691E+09	0.582	2,775,616,200	2.776
	Okabena WWTP	126	1260	4769.1	4.7691E+09	0.244	1,165,513,535	1.166
	Shetek Area Water & Sewer District WWTP	126	1260	4769.1	4.7691E+09	3.617	17,249,600,324	17.250
	Slayton WWTP	126	1260	4769.1	4.7691E+09	2.028	9,673,762,344	9.674
	Worthington Industrial WWTP	126	1260	4769.1	4.7691E+09	2.160	10,301,256,000	10.301
	Worthington WWTP	126	1260	4769.1	4.7691E+09	4.000	19,076,400,000	19.076
East Fork Des Moines River (07100003)	Sherburn WWTP	126	1260	4769.1	4.7691E+09	0.332	1,583,341,200	1.583

Straight Pipe Septic Systems

Straight pipe septic systems are illegal and unpermitted, and as such, receive a WLA of zero.

Industrial and Construction Permits

WLAs for permitted construction stormwater (permit# MNR100001) were not developed for *E. coli*, since *E. coli* is not a typical pollutant associated with construction sites. Industrial stormwater receives a WLA only if bacteria or *E. coli* is part of benchmark monitoring for an industrial site in the drainage area of an impaired water body. There are no bacteria or *E. coli* benchmarks associated with any Industrial Stormwater Permits (permit# MNR050000) in the impaired watersheds. Therefore, no industrial stormwater *E. coli* WLAs were assigned.

Municipal Separate Storm Sewer System (MS4)

The WLA for communities subjected to MS4 NPDES stormwater permit requirements is taken as a percentage of the LC based on the percentage of drainage area in the impaired reach that the MS4 permit area covers. The only MS4 area within the Des Moines River Basin is the city of Worthington (MS4 Permit #MS400257) and covers about 4.15 square miles within the watershed. The MS4 is included in three *E. coli* impaired reaches as shown in **Table 22**. **Table 22** provides the drainage area of the impaired reaches, the MS4 area, percent of drainage area covered by the MS4, and percent of LC allocated to the MS4.

Table 22. Percentage of drainage areas covered by MS4 in *E. coli* impaired streams.

AUID	Drainage Area [sq mi]	MS4 Area [sq mi]	Percentage of Drainage Area	Percentage of Loading Capacity
07100001-512	21.4	4.15	19.39%	19.39%
07100001-524	1,137.4	4.15	0.365%	0.36%
07100001-527	466.9	4.15	0.89%	0.889%

Livestock Facilities

NPDES permitted feedlot facilities 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 bacteria (*E. coli*) from fields where manure has been land-applied may occur during runoff events, but those discharges are covered under the LA portion of the TMDL and do not require an additional WLA. A list of CAFOs by AUID reach can be found in **Appendix D**.

WLA during low flows

The total daily LC of some stream reaches during low and very low flow regimes are very small due to the occurrence of very low flows in the stream/river. Consequently, for some of the impaired reaches the permitted wastewater design discharge is close to or higher than the streamflow during these flow regimes. This translates to these point sources appearing to use all of, or exceeding, the LC during these flow periods. In reality, this will never occur as the discharge is a part of the streamflow and can never exceed total streamflow. To account for these unique situations, the WLA (and LA) are expressed as an equation rather than an absolute number. The equation is:

Allocation = Point Source Discharge X Water Quality Standard Concentration

Consistent units are used to obtain the load. This assigns a concentration-based limit to the WLA for these lower flow rates.

4.4.4 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% of the LC MOS was applied to each flow regime for all LDCs developed for this TMDL report. The explicit 10% MOS accounts for:

- Uncertainty in the observed daily flow record;
- Uncertainty in the simulated flow data from the HSPF model;
- Uncertainty in the observed water quality data;
- Uncertainty with regrowth in the sediment, die-off, and natural background levels of *E. coli*; and
- Allocations and loading capacities are based on flow, which varies from very high to very low. This variability is accounted for using the five flow regimes and the LDCs.

The majority of the MOS is apportioned to uncertainty related to the HSPF model. The hydrologic validation statistics for the HSPF model at the Des Moines River at Jackson, Minnesota (USGS station ID 05476000) were:

- -9.33% Error in total flow volume;
- 3.68% Error in bottom 50% low flows;

- -8.93% Error in the top 10% high flows;
- A Nash-Sutcliffe coefficient of model fit efficiency (NSE) of 0.72 for daily flows;
- And, an NSE of 0.79 for monthly flows.

Overall, the HSPF model calibration and outputs were determined to be "Good". The *E. coli* LDCs were developed using the HSPF modeled daily flow data from April to October (May to October for Class 7 streams). There is no reason to believe a 10% is inappropriate as it is consistent with HSPF modeling errors, and the HSPF model is a valid representation of hydrological and chemical conditions in the watershed. More information on the calibration of the HSPF model can be found in Tetra Tech (2016).

4.4.5 Seasonal variation

Geometric means for *E. coli* bacteria within the impaired reaches are often above the state chronic standard from April through October. Exceedances of the acute standard are also common in these reaches during this time period. Fecal bacteria are most productive at temperatures similar to their origination environment in animal digestive tracts. Thus, these organisms are expected to be at their highest concentrations during warmer summer months when stream flow is low and water temperatures are high. High *E. coli* concentrations in many of the reaches continue into the fall, which may be attributed to constant sources of *E. coli* (such as failing SSTS and animal access to the stream) and less flow for dilution. However, some of the data may be skewed as more samples were collected in the summer months than in October. Seasonal and annual variations are accounted for by setting the TMDL across the entire flow record using the load duration method.

4.4.6 TMDL summary

The *E. coli* LDCs and tables follow. The following rounding conventions were used in the TMDL tables:

- Values ≥10 reported in mass/day have been rounded to the nearest mass.
- Values <10 and ≥1 reported in mass/day have been rounded to the nearest tenth of a mass.
- Values ≥0.01 reported in mass/day have been rounded to the nearest hundredth of a mass.
- Values <0.01 reported in mass/day have been rounded to enough significant digits so that the value is greater than zero and a number is displayed in the table.
- While some of the numbers in the tables show multiple digits, they are not intended to imply great precision.
- Some small arithmetic errors may exist; this is due to rounding errors.
- Mass refers to billions of organisms for *E. coli*.

Each table provides a representative load reduction to provide watershed planners a single target reduction to aid in planning that is not dependent on flow conditions. A single, representative load reduction (overall stream reduction, not individual source) is easier for watershed planners to translate into annual load reductions when developing restoration and protection plans to improve water quality in the basin. Since *E. coli* is assessed by month, a flow weighted average of the monthly geometric means was used to determine the representative existing condition. The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard. Load reductions for each flow regime can be found in **Appendix A**.

Des Moines River Headwaters *E. coli* TMDLs

Okabena Creek, Unnamed cr to T102 R38W S6, north line (AUID 07100001-512)

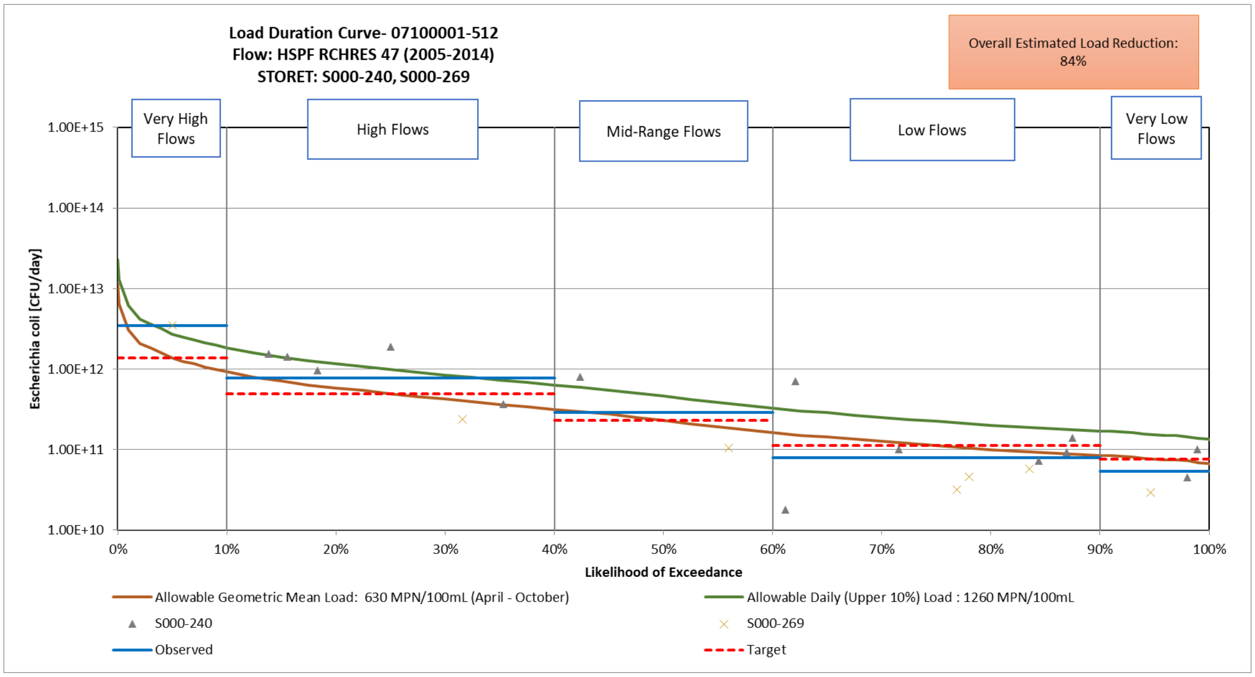

Figure 24. Okabena Creek, Unnamed cr to T102 R38W S6, north line (AUID 07100001-512) *E. coli* LDC.

Table 23. *E. coli* Allocations for Okabena Creek, Unnamed cr to T102 R38W S6, north line (AUID 07100001-512).

Escherichia coli		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		Load [Billions org/day]				
Wasteload Allocation	**Total WLA**	**294**	**125**	**74**	**51**	**44**
	Worthington Industrial WWTP	10	10	10	10	10
	Worthington WWTP	19	19	19	19	19
	Worthington MS400257[1]	265	96	45	22	15
Load Allocation	**Total LA**	**936**	**320**	**136**	**51**	**25**
Margin of Safety (MOS)		**137**	**50**	**23**	**11**	**7.7**
Loading Capacity (TMDL)		**1,367**	**495**	**233**	**113**	**77**
Flow Weighted Geometric Mean (org/100 mL)		**805**				
Overall estimated percent reduction		**84%**				

[1]MS4 WLA is 19.4% of LC.

Des Moines River, Heron Lk outlet to Windom Dam (AUID 07100001-524)

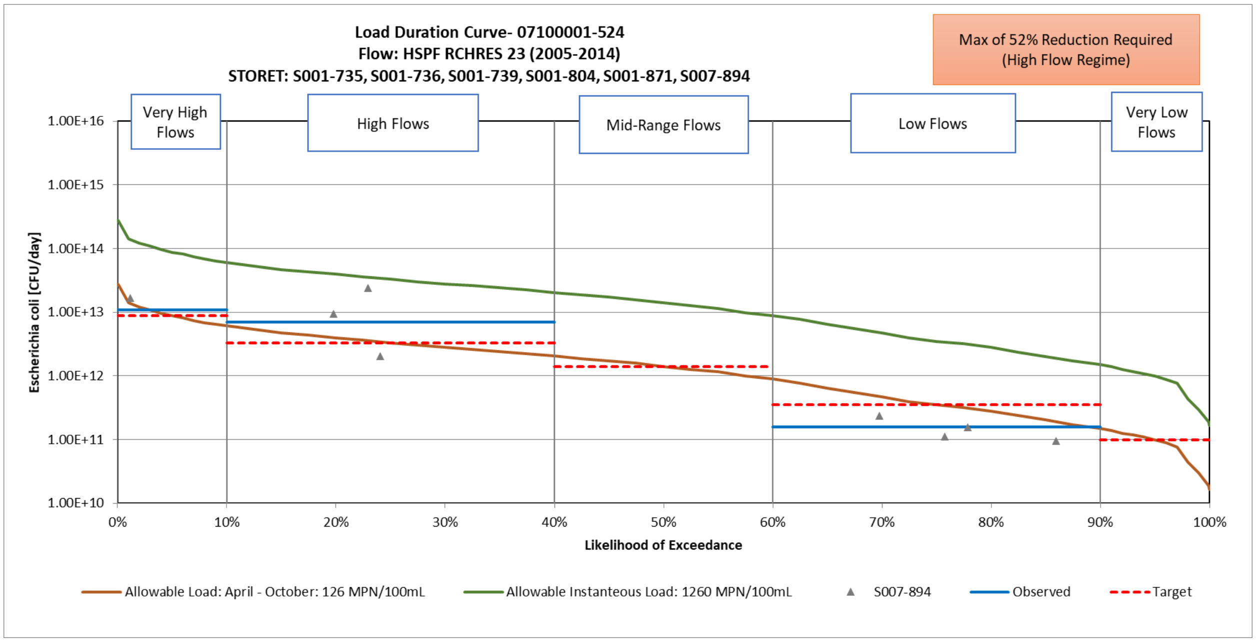

Figure 25. Des Moines River, Heron Lk outlet to Windom Dam (AUID 07100001-524) *E. coli* LDC.

Table 24. *E. coli* Allocations for Des Moines River, Heron Lk outlet to Windom Dam (AUID 07100001-524).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		Load [Billions org/day]				
Wasteload Allocation	**Total WLA**	**121**	**101**	**94**	**90**	**###[2]**
	Avoca & Iona WWTP	3.8	3.8	3.8	3.8	###[2]
	Brewster WWTP	9.5	9.5	9.5	9.5	###[2]
	Currie WWTP	4.4	4.4	4.4	4.4	###[2]
	Dundee WWTP	0.58	0.58	0.58	0.58	###[2]
	Fulda WWTP	4.2	4.2	4.2	4.2	###[2]
	Heron Lake WWTP	3.7	3.7	3.7	3.7	###[2]
	Lake Wilson WWTP	2.4	2.4	2.4	2.4	###[2]
	Lakefield WWTP	2.8	2.8	2.8	2.8	###[2]
	Okabena WWTP	1.2	1.2	1.2	1.2	###[2]
	Shetek Area Water & Sewer District WWTP	17	17	17	17	###[2]
	Slayton WWTP	9.7	9.7	9.7	9.7	###[2]
	Worthington Industrial WWTP	10	10	10	10	###[2]
	Worthington WWTP	19	19	19	19	###[2]
	Worthington MS400257[1]	32	12	5.1	1.3	###[2]
Load Allocation	**Total LA**	**7,726**	**2,883**	**1,171**	**225**	**###[3]**
Margin of Safety (MOS)		**872**	**332**	**141**	**35**	**9.9**
Loading Capacity (TMDL)		**8,719**	**3,316**	**1,405**	**350**	**99**
Flow Weighted Geometric Mean (org/100 mL)		**237**				
Overall estimated percent reduction		**47%**				

[1]MS4 WLA is 0.365% of LC

[2]### = The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number, see Section 4.4.3

[3]WLA exceeded load capacity for this zone, therefore LA is determined by the formula: Allocation = (flow from a given source) X (*E. coli* concentration standard).

Heron Lake Outlet, Heron Lk (32-0057-01) to Des Moines R (AUID 07100001-527)

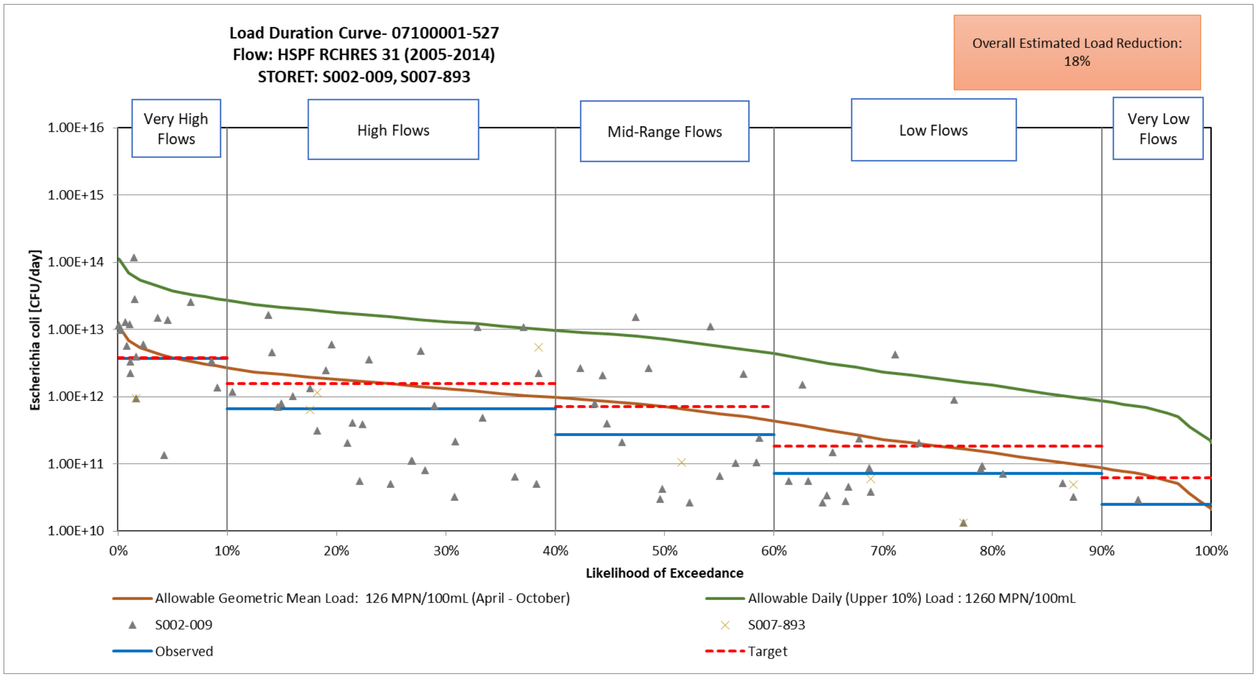

Figure 26. Heron Lake Outlet, Heron Lk (32-0057-01) to Des Moines R (AUID 07100001-527) *E. coli* LDC.

Table 25. *E. coli* Allocations for Heron Lake Outlet, Heron Lk (32-0057-01) to Des Moines R (AUID 07100001-527).

Escherichia coli		Flow Condition				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		Load [Billions org/day]				
Wasteload Allocation	**Total WLA**	**80**	**60**	**53**	**48**	**47**
	Brewster WWTP	9.5	9.5	9.5	9.5	9.5
	Heron Lake WWTP	3.7	3.7	3.7	3.7	3.7
	Lakefield WWTP	2.8	2.8	2.8	2.8	2.8
	Okabena WWTP	1.2	1.2	1.2	1.2	1.2
	Worthington Industrial WWTP	10	10	10	10	10
	Worthington WWTP	19	19	19	19	19
	Worthington MS400257[1]	33	14	6.4	1.6	0.56
Load Allocation	**Total LA**	**3,307**	**1,341**	**593**	**118**	**9.3**
Margin of Safety (MOS)		**376**	**156**	**72**	**18**	**6.3**
Loading Capacity (TMDL)		**3,763**	**1,557**	**718**	**184**	**63**
Flow Weighted Geometric Mean (org/100 mL)		154				
Overall estimated percent reduction		18%				

[1]MS4 WLA is 0.89% of LC

Unnamed creek, Unnamed ditch to Jack Cr (AUID 07100001-564)

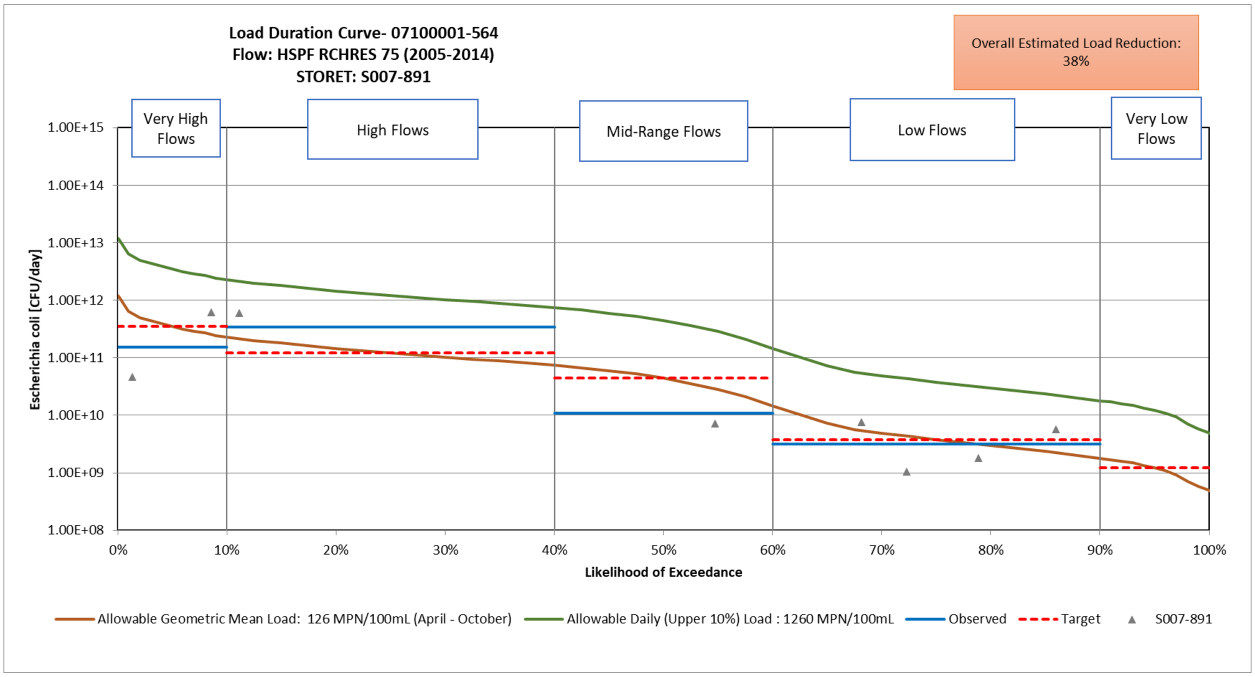

Figure 27. Unnamed creek, Unnamed ditch to Jack Cr (AUID 07100001-564) *E. coli* LDC.

Table 26. *E. coli* Allocations for Unnamed creek, Unnamed ditch to Jack Cr (AUID 07100001-564).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		Load [Billions org/day]				
Wasteload Allocation	Total WLA	0	0	0	0	0
Load Allocation	Total LA	314	109	40	3.3	1.1
Margin of Safety (MOS)		35	12	4.4	0.37	0.12
Loading Capacity (TMDL)		349	121	44	3.7	1.2
Flow Weighted Geometric Mean (org/100 mL)		202				
Overall estimated percent reduction		38%				

Jack Creek, North Branch, JD 12 to Jack Cr (AUID 07100001-652)

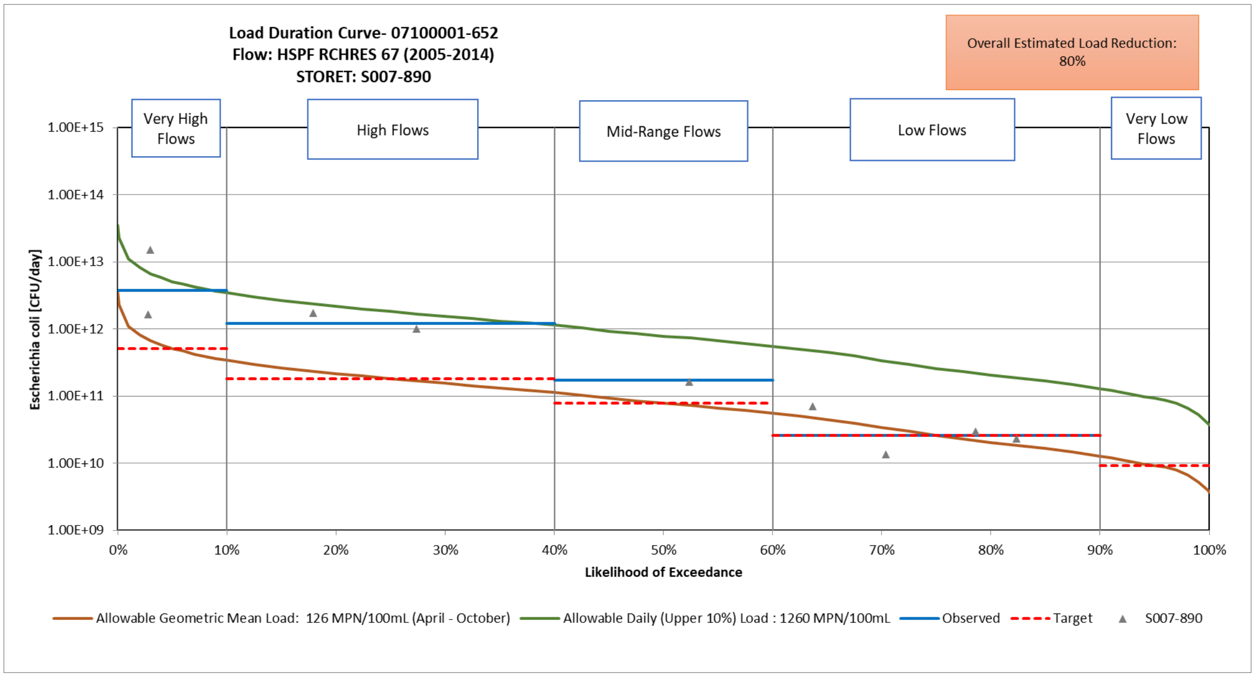

Figure 28. Jack Creek, North Branch, JD 12 to Jack Cr (AUID 07100001-652) *E. coli* LDC.

Table 27. *E. coli* Allocations for Jack Creek, North Branch, JD 12 to Jack Cr (AUID 07100001-652).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		Load [Billions org/day]				
Wasteload Allocation	Total WLA	0	0	0	0	0
Load Allocation	Total LA	459	164	71	23.1	8.4
Margin of Safety (MOS)		51	18	7.9	2.6	0.93
Loading Capacity (TMDL)		510	182	79	25.7	9.3
Flow Weighted Geometric Mean (org/100 mL)		630				
Overall estimated percent reduction		80%				

East Fork Des Moines River *E. coli* TMDLs

County Ditch 11, Headwaters to E Fk Des Moines R (AUID 07100003-503)

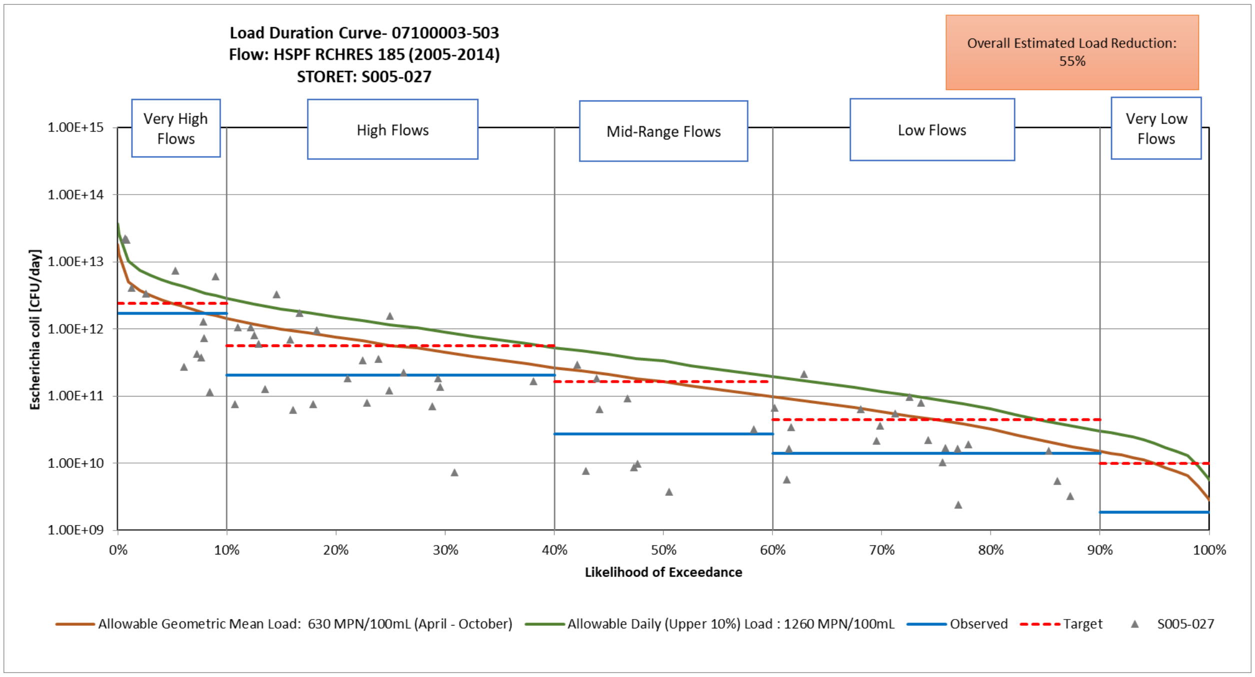

Figure 29. County Ditch 11, Headwaters to E Fk Des Moines R (AUID 07100003-503) *E. coli* LDC.

Table 28. *E. coli* Allocations for County Ditch 11, Headwaters to E Fk Des Moines R (AUID 07100003-503).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		Load [Billions org/day]				
Wasteload Allocation	Total WLA	1.6	1.6	1.6	1.6	1.6
	Sherburn WWTP	1.6	1.6	1.6	1.6	1.6
Load Allocation	Total LA	2,166	512	148	38	7.3
Margin of Safety (MOS)		241	57	17	4.4	0.99
Loading Capacity (TMDL)		2,408	571	166	44.2	9.9
Flow Weighted Geometric Mean (org/100 mL)		282				
Overall estimated percent reduction		55%				

Fourmile Creek, JD 105 to Des Moines R (AUID 07100003-510)

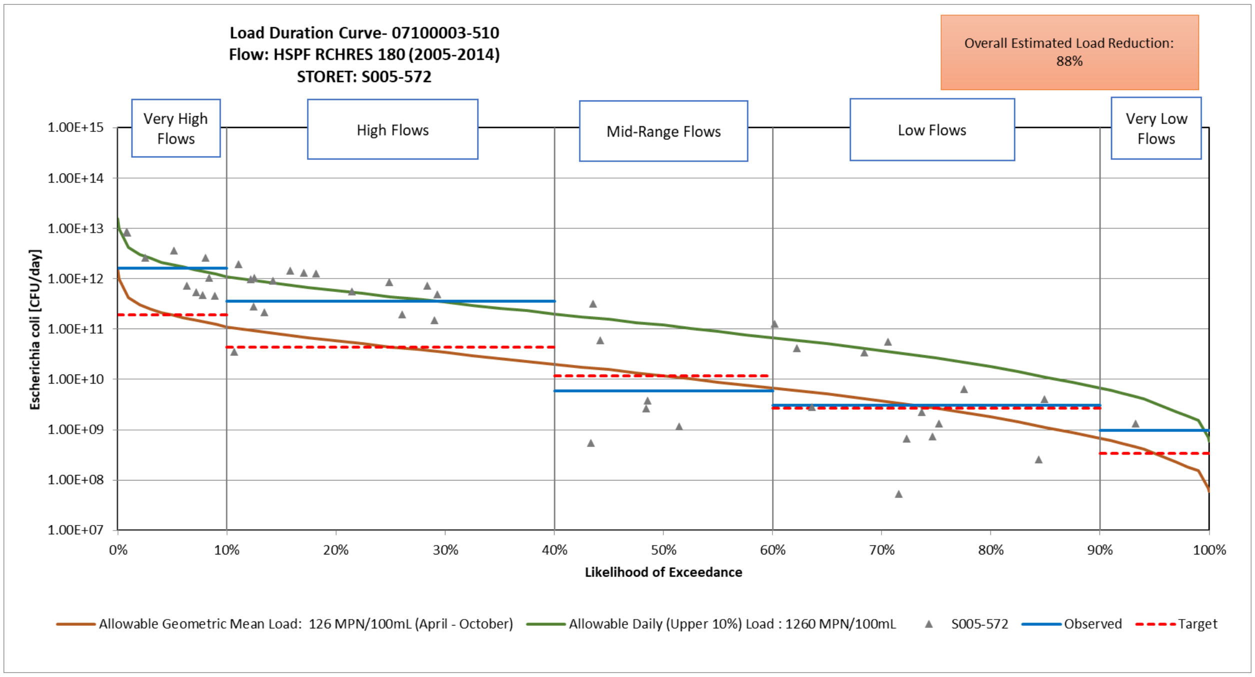

Figure 30. Fourmile Creek, JD 105 to Des Moines R (AUID 07100003-510) *E. coli* LDC.

Table 29. *E. coli* Allocations for Fourmile Creek, JD 105 to Des Moines R (AUID 07100003-510).

Escherichia coli		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		Load [Billions org/day]				
Wasteload Allocation	**Total WLA**	**0**	**0**	**0**	**0**	**0**
Load Allocation	**Total LA**	**172**	**40**	**11**	**2.4**	**0.27**
Margin of Safety (MOS)		**19**	**4.4**	**1.2**	**0.27**	**0.03**
Loading Capacity (TMDL)		**191**	**44**	**12**	**2.7**	**0.3**
Flow Weighted Geometric Mean (org/100 mL)		**1,037**				
Overall estimated percent reduction		**88%**				

County Ditch 1/Judicial Ditch 50, Unnamed cr to CD 11 (AUID 07100003-515)

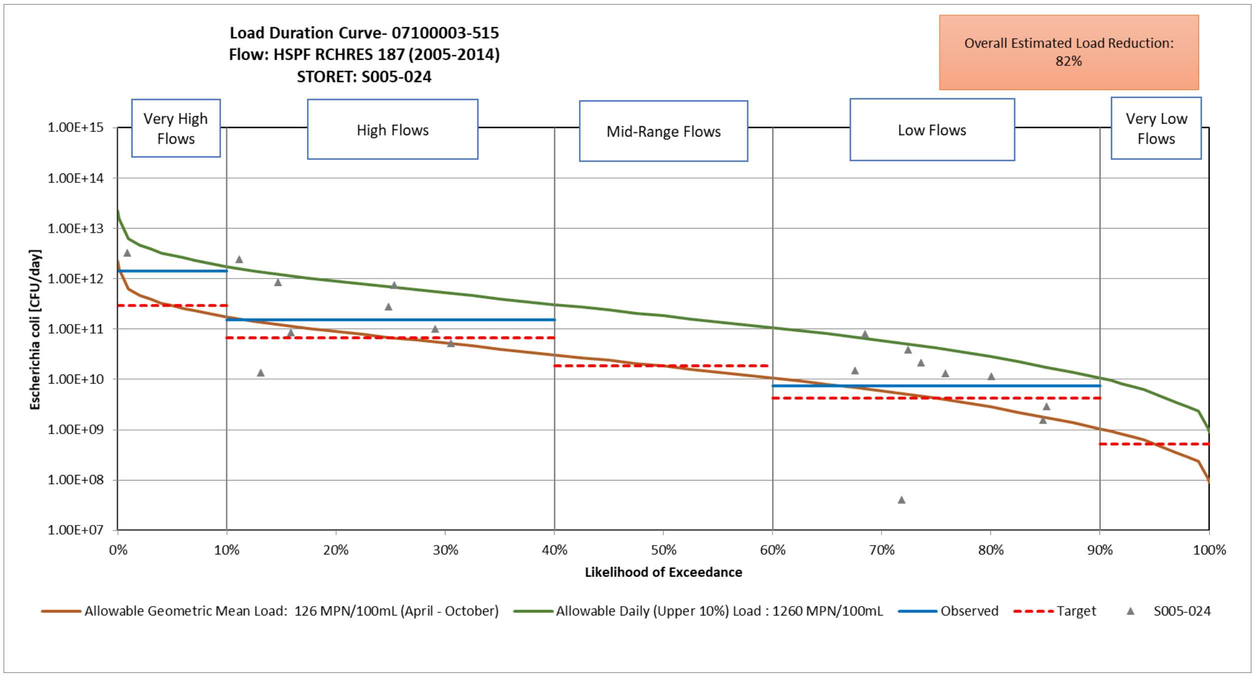

Figure 31. County Ditch 1/Judicial Ditch 50, Unnamed cr to CD 11 (AUID 07100003-515) *E. coli* LDC.

Table 30. *E. coli* Allocations for County Ditch 1/Judicial Ditch 50, Unnamed cr to CD 11 (AUID 07100003-515).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		Load [Billions org/day]				
Wasteload Allocation	Total WLA	0	0	0	0	0
Load Allocation	Total LA	265	61	17	3.8	0.45
Margin of Safety (MOS)		30	6.8	1.9	0.42	0.05
Loading Capacity (TMDL)		295	68	19	4.2	0.50
Flow Weighted Geometric Mean (org/100 mL)		706				
Overall estimated percent reduction		82%				

Des Moines River, East Branch, Unnamed cr to CD 11 (AUID 07100003-525)

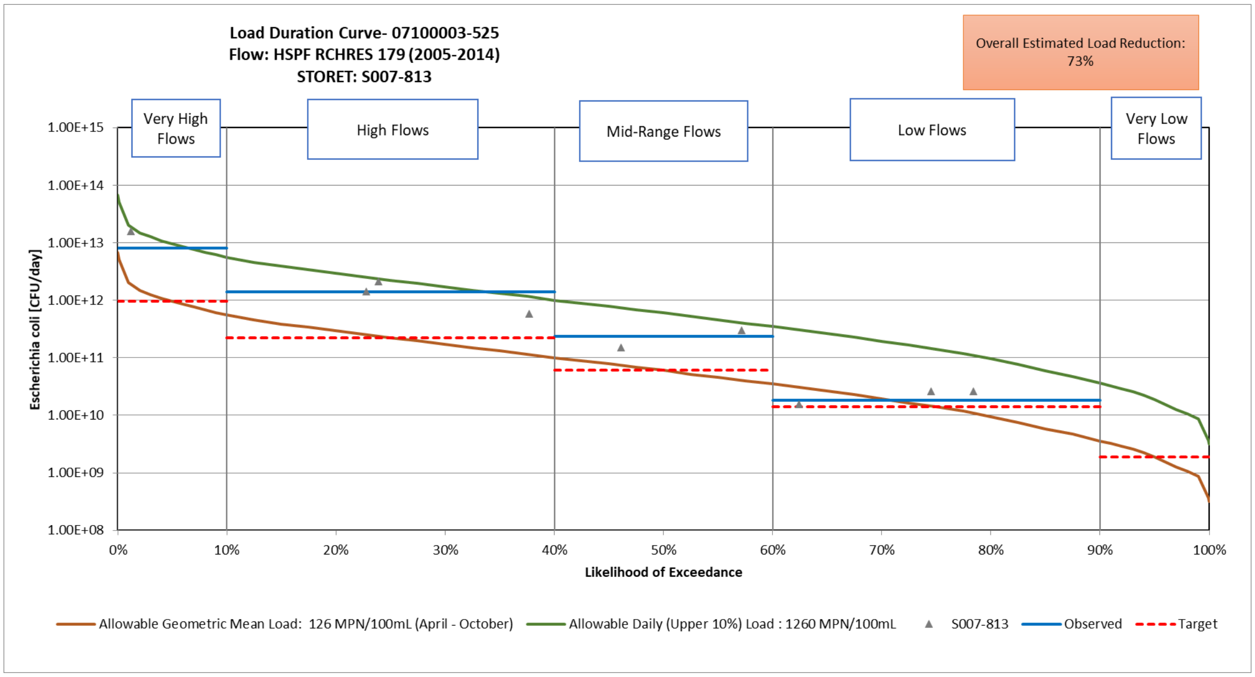

Figure 32. Des Moines River, East Branch, Unnamed cr to CD 11 (AUID 07100003-525) *E. coli* LDC.

Table 31. *E. coli* Allocations for Des Moines River, East Branch, Unnamed cr to CD 11 (AUID 07100003-525).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		Load [Billions org/day]				
Wasteload Allocation	Total WLA	0	0	0	0	0
Load Allocation	Total LA	862	199	54	13	1.7
Margin of Safety (MOS)		96	22	6.0	1.4	0.19
Loading Capacity (TMDL)		958	221	60	14	1.9
Flow Weighted Geometric Mean (org/100 mL)		474				
Overall estimated percent reduction		73%				

Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk (AUID 07100003-527)

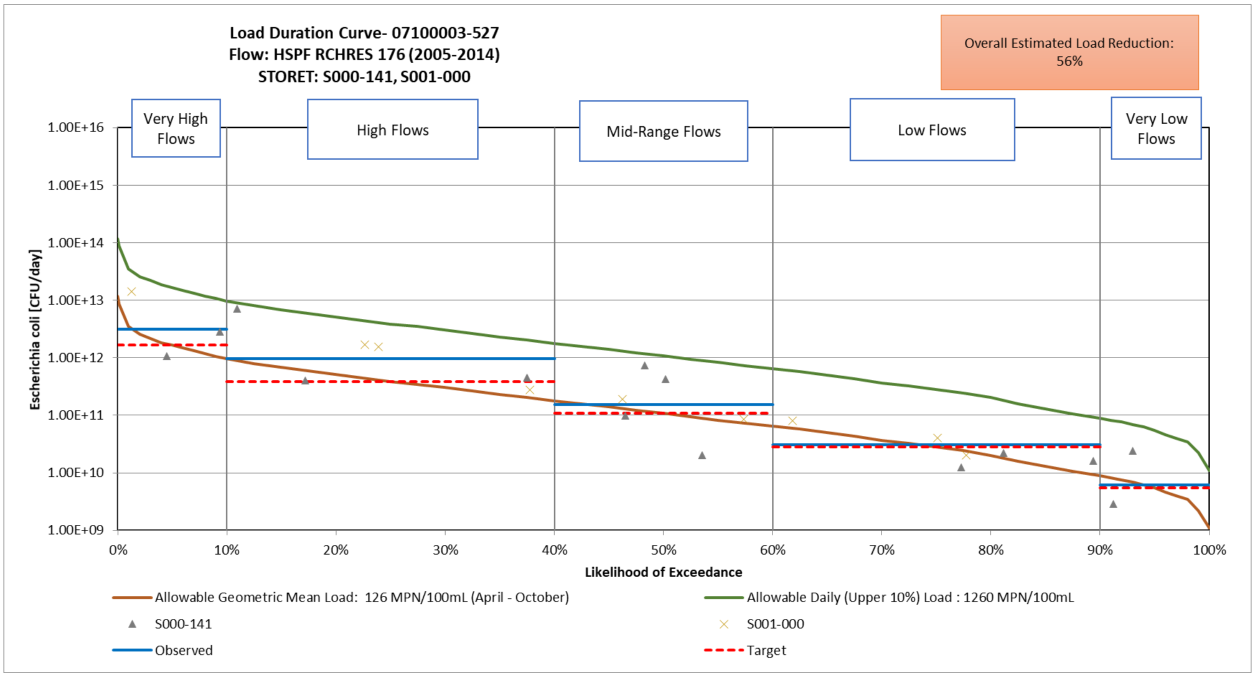

Figure 33. Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk (AUID 07100003-527) *E. coli* LDC.

Table 32. *E. coli* Allocations for Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk (AUID 07100003-527).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		Load [Billions org/day]				
Wasteload Allocation	Total WLA	1.6	1.6	1.6	1.6	1.6
	Sherburn WWTP	1.6	1.6	1.6	1.6	1.6
Load Allocation	Total LA	1,483	348	97	24	3.4
Margin of Safety (MOS)		165	38.8	11	2.8	0.50
Loading Capacity (TMDL)		1,650	388	110	28	5.5
Flow Weighted Geometric Mean (org/100 mL)		284				
Overall estimated percent reduction		56%				

4.5 Total Suspended Solids

4.5.1 Loading capacity methodology

Like *E. coli* and chloride, LDCs were used to represent the LC for each TSS impaired reach. Description of the LDC methodology can be found in **Section 4.3.1**. The LDCs are based on the HSPF simulated daily average flows (2005 through 2014) and the Southern River Nutrient Region TSS standard of 65 mg/L. TSS LDCs for each impaired reach are shown in **Section 4.5.6**. The red curve in these figures represents the allowable TSS LC of the reach for each daily flow. The median (or midpoint) load of each flow zone is used to represent the total load capacity in the TMDL tables.

Table 33 provides the methodology and conversion factors to transform flows and concentrations to loads. The TSS standard only applies during the months of April through September. Loads for TSS are calculated as tons/day.

Table 33. Converting flow and concentration to sediment load.

Load (tons/day) = TSS standard (mg/L) * Flow (cfs) * Conversion Factor			
For each flow regime			
Multiply **flow** (cfs) by **28.31** (L/ft^3) and **86,400** (sec/day) to convert	cfs	→	L/day
Multiply **TSS Standard** (65 mg/L) by **L/day** to convert	L/day	→	mg/day
Divide **mg/day** by **907,184,740** (mg/ton) to convert	mg/day	→	tons/day

It should be noted that no observed TSS data was collected during the period of available flows (2005 through 2014). The only observed TSS data in the impaired reaches was collected in 2016. Therefore, existing conditions could not be estimated without flow transfer to determine flow conditions on the days when samples were collected. A flow transfer was developed using the closest USGS gage (USGS# 05476000) with a sufficient data record to complete the flow transfer. The flow transfer was conducted by comparing the distributions of flows at the USGS gaging station and the simulated flows in the impaired reach for the LDC period (2005 through 2015), and developing a linear regression equation (**Table 34**). Once the regression equation was developed, the percent exceedance of the observed day was calculated and transformed using the regression equation. Then the absolute flow was estimated by finding the flow of the transfer flow exceedance using the simulated flow distribution (from HSPF).

Table 34. Flow transfer equations used to develop existing conditions in TSS TMDLs.

AUID	HSPF RCHRES ID	Transfer Flow Site (USGS ID)	Transfer Equation[1]	R^2
07100001-551	28	USG 05476000	%Model = 0.9444*%Obs	0.5809
07100002-505	4	USG 05476000	%Model = 0.9301*%Obs	0.4742

[1]%Model = the percent exceedance of the model flow, and %Obs = the percent exceedance of the observed flow.

Judicial Ditch 56 (07100002-505) is the only stream reach that drains a part of Iowa, therefore, a percentage of the load capacity to represent Minnesota's portion was used to develop the TMDL. To determine the percentage of the load capacity for Minnesota, the percentage of drainage area from Minnesota was calculated. Minnesota contributes 13% of the total drainage area, thus the TMDL is calculated at 13% of the total loading capacity.

4.5.2 Load allocation methodology

LAs represent the portion of the LC designated for NPS of TSS. The LA is the remaining load once the WLA, RC, and MOS are determined and subtracted from the LC. The LA includes all sources of TSS that do not require NPDES permit coverage, including unregulated watershed runoff and atmospheric deposition and a consideration for "natural background" conditions. "Natural background", as defined in Minn. R. 7050.0150, subp. 4, can be described as physical, chemical, or biological conditions that would exist in a waterbody that are not a result of human activity. NPS of TSS were previously discussed in **Section 3.6.3**.

4.5.3 Wasteload allocation methodology

WLAs are developed for any point source/permitted discharge in the drainage area of an impaired reach. These are discharges requiring an NPDES permit, and typically include wastewater treatment facilities, permitted MS4s, industrial discharges, construction stormwater, and permitted feedlots. WLAs for each AUID are provided in the TMDL tables in **Section 4.5.6**.

Wastewater Treatment Plants

There are no WWTPs in the TSS impaired reaches, therefore, no TSS WLAs for WWTPs were assigned.

Straight Pipe Septic Systems

Straight pipe septic systems are illegal and unpermitted and receive a WLA of zero.

Industrial and Construction Permits

WLAs for construction and industrial stormwater discharges that are covered by the state's general permits (permit # MNR100001 and MNR050000, respectively) were combined and addressed through a categorical allocation. Stormwater runoff from construction sites that disturb: (a) one acre of soil or more, (b) less than one acre of soil and are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but determined to pose a risk to water quality are regulated under the state's NPDES/SDS General Stormwater Permits for Construction Activity (MNR1000001). This permit requires and identifies BMPs to be implemented to protect water resources from mobilized sediment and other pollutants of concern. If the owner/operators of impacted construction sites obtain and abide by the NPDES/SDS General Construction Stormwater Permit, the stormwater discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Similar to construction activities, industrial sites are regulated under general permits, in this case either the NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or the NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying, and Hot Mix Asphalt Production facilities (MNG490000). Like the NPDES/SDS General Construction Stormwater Permit, these permits identify BMPs to be implemented to protect water resources from pollutant discharges at the site. If the owner/operators of industrial sites abide by the necessary NPDES/SDS General Stormwater Permits, the discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Due to the transient nature of construction activities and the minimal amount of industrial activity, it is assumed that 0.1% of the drainage area is under construction or industrial activities at any given time. Therefore, to calculate the WLAs for construction and industrial stormwater, this TMDL report assigns 0.1% of the load capacity for the stream reach to the construction/industrial stormwater WLA.

Municipal Separate Storm Sewer System (MS4)

There are no permitted MS4s in the TSS impaired reaches, therefore, no TSS WLAs for permitted MS4s were assigned

Livestock Facilities

NPDES permitted feedlot facilities 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.

4.5.4 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% of the LC MOS was applied to each flow regime for all LDCs developed for this TMDL report. The explicit 10% MOS accounts for:

- Uncertainty in the observed daily flow record;
- Uncertainty in the simulated flow data from the HSPF model;
- Uncertainty in the observed water quality data;
- Allocations and loading capacities are based on flow, which varies from very high to very low. This variability is accounted for using the five flow regimes and the LDCs.

The majority of the MOS is apportioned to uncertainty related to the HSPF model. The hydrologic validation statistics for the HSPF model at the Des Moines River at Jackson, Minnesota (USGS station ID 05476000) were:

- -9.33% Error in total flow volume;
- 3.68% Error in bottom 50% low flows;
- -8.93% Error in the top 10% high flows;
- A Nash-Sutcliffe coefficient of model fit efficiency (NSE) of 0.72 for daily flows;
- And, an NSE of 0.79 for monthly flows.

Overall, the HSPF model calibration and outputs were determined to be “Good”. The TSS LDCs were developed using the HSPF modeled daily flow data from April to September. There is no reason to believe a 10% MOS is inappropriate as it is consistent with HSPF modeling errors and the HSPF model is a valid representation of hydrological and chemical conditions in the watershed. More information on the calibration of the HSPF model can be found in Tetra Tech (2016).

4.5.5 Seasonal variation

Both seasonal variation and critical conditions are accounted for in this TMDL report through the application of LDCs. LDCs evaluate water quality conditions across all flow zones including high flow, runoff conditions where sediment transport tends to be greatest. Seasonality is accounted for by addressing all flow conditions in a given reach. The maximum load reduction for both TSS TMDLs occurs during high flow conditions.

4.5.6 TMDL summary

The TSS LDCs and tables follow.

The following rounding conventions were used in the TMDL tables:

- Values ≥10 reported in mass/day have been rounded to the nearest mass.
- Values <10 and ≥1 reported in mass/day have been rounded to the nearest tenth of a mass.
- Values ≥0.01 reported in mass/day have been rounded to the nearest hundredth of a mass
- Values <0.01 reported in mass/day have been rounded to enough significant digits so that the value is greater than zero and a number is displayed in the table.
- While some of the numbers in the tables show multiple digits, they are not intended to imply great precision.
- Some small arithmetic errors may exist; this is due to rounding errors.
- Mass refers to tons for TSS.

Each table provides a representative load reduction to provide watershed planners a single target reduction to aid in planning that is not dependent on flow conditions. A single, representative load reduction (overall stream reduction, not individual source) is easier for watershed planners to translate into annual load reductions when developing restoration and protection plans to improve water quality in the basin. For TSS, the representative existing condition is taken as the 90th percentile of the observed TSS concentrations. The overall estimated percent reduction is the reduction of the existing condition to meet the 65 mL standard. Load reductions for each flow regime can be found in **Appendix A**.

Des Moines River Headwaters TSS TMDL

Unnamed creek, String Lk to Des Moines R (AUID 07100001-551)

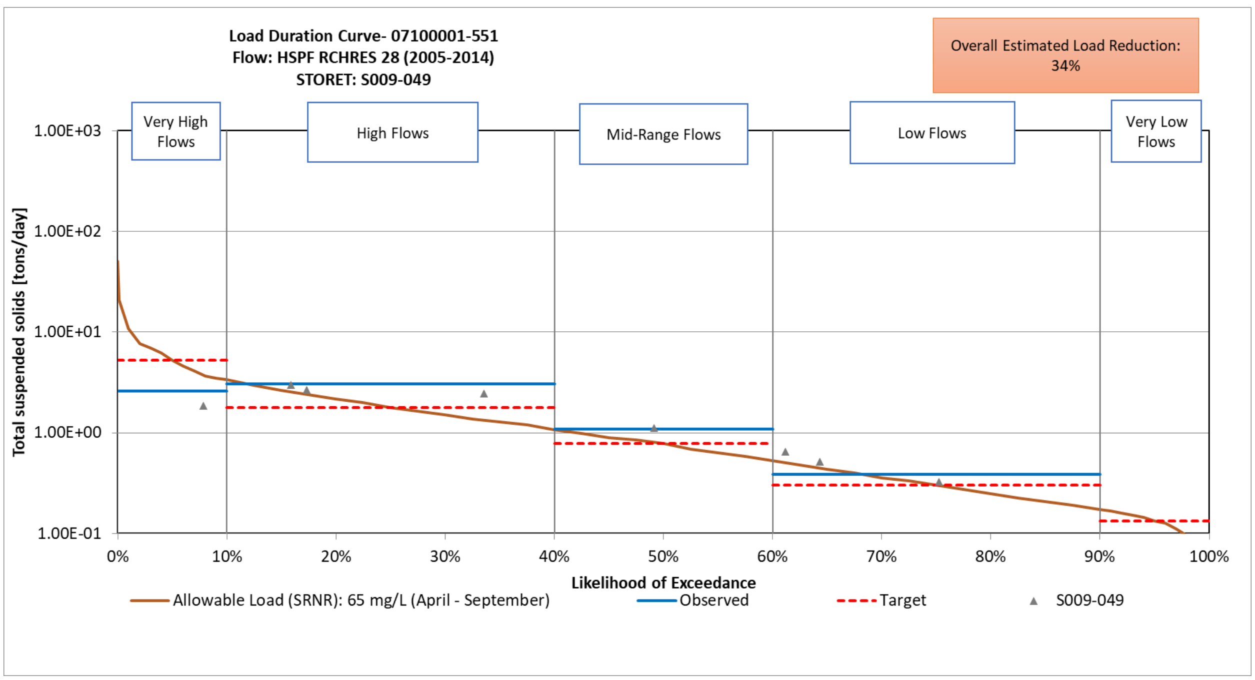

Figure 34. Unnamed creek, String Lk to Des Moines R (AUID 07100001-551) TSS LDC.

Table 35. TSS Allocations for Unnamed creek, String Lk to Des Moines R (AUID 07100001-551).

Total suspended solids		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[tons/day]				
Wasteload Allocation	**Total WLA**	**0.005**	**0.002**	**0.0008**	**0.0003**	**0.0001**
	Construction/Industrial Stormwater	0.005	0.002	0.0008	0.0003	0.0001
Load Allocation	**Total LA**	**4.7**	**1.6**	**0.70**	**0.27**	**0.12**
Margin of Safety (MOS)		**0.52**	**0.18**	**0.08**	**0.03**	**0.01**
Loading Capacity (Total Load)		**5.2**	**1.8**	**0.78**	**0.30**	**0.13**
Existing 90th percentile concentration (mg/L)		**99**				
Overall estimated percent reduction		**34%**				

Lower Des Moines River TSS TMDL

Judicial Ditch 56, Unnamed cr to Des Moines R (AUID 07100002-505)

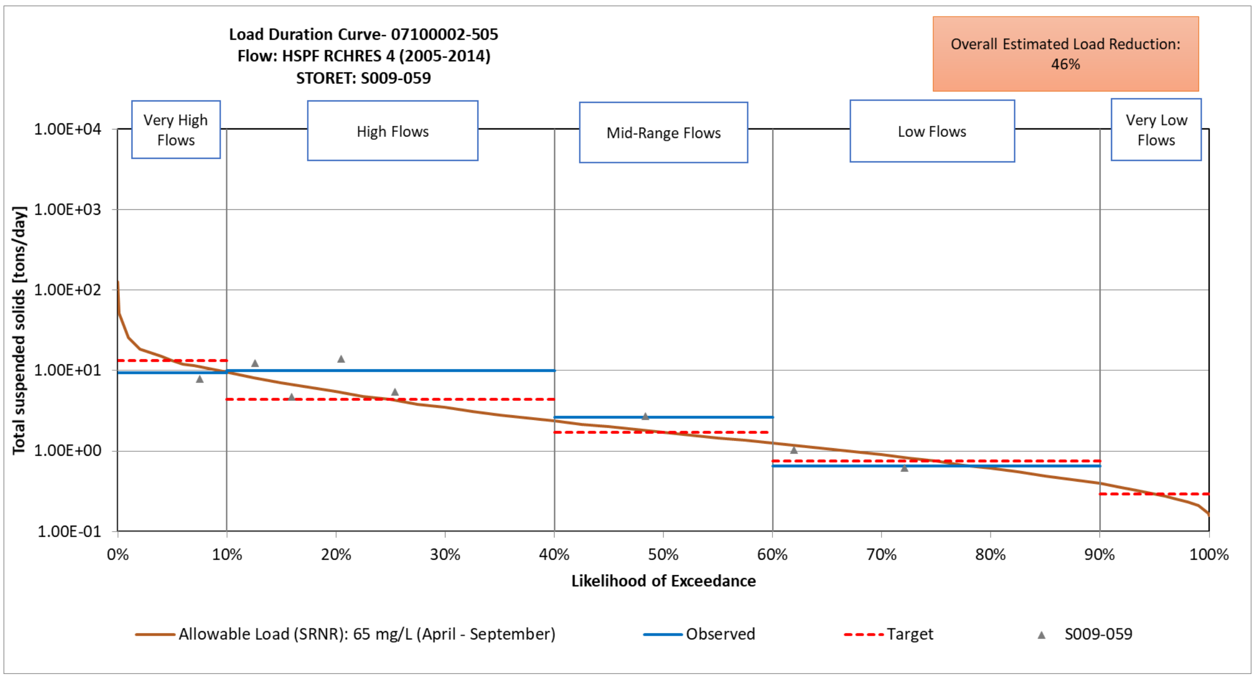

Figure 35. Judicial Ditch 56, Unnamed cr to Des Moines R (AUID 07100002-505) TSS LDC.

Table 36. Minnesota's percentage of the loading capacity for Judicial Ditch 56, Unnamed cr to Des Moines R (AUID 07100002-505).

MN's % of Load Capacity: 13%	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[tons/day]				
Total Load Capacity	13	4.4	1.7	0.75	0.29
MN Load Capacity	1.7	0.57	0.22	0.1	0.04

Table 37. TSS Allocations for Judicial Ditch 56, Unnamed cr to Des Moines R (AUID 07100002-505).

Total suspended solids		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[tons/day]				
Wasteload Allocation	Total WLA	0.002	0.0006	0.0002	0.0001	0.00004
	Construction/Industrial Stormwater	0.002	0.0006	0.0002	0.0001	0.00004
Load Allocation	Total LA	1.5	0.51	0.2	0.09	0.04
Margin of Safety (MOS)		0.2	0.06	0.02	0.01	0.004
Loading Capacity		1.7	0.57	0.22	0.1	0.04
Existing 90th percentile concentration (mg/L)[1]		121				
Overall estimated percent reduction[1]		46%				

[1]Overall reduction is calculated for entire watershed.

4.6 Lake Nutrients

4.6.1 Loading capacity methodology

The LC of a lake is the amount of P that can enter a lake over a defined amount of time (daily, annually, etc.) before it exceeds the numeric standard. The LC in impaired lakes in the Des Moines River Basin was determined using a spreadsheet version of the BATHTUB model currently available as a "beta" version from Dr. William W. Walker (https://www.oracle.com/applications/crystalball/). BATHTUB is steady-state model that simulates eutrophication-related water quality conditions in lakes and reservoirs. BATHTUB is designed to facilitate the application of empirical eutrophication models to reservoirs or lakes by formulating water and nutrient balances that account for advective transport, diffuse transport, and nutrient sedimentation.

The primary modification in the spreadsheet version of BATHUB is the ability to use a stochastic approach, via Monte Carlo simulation, which allows selected modeling inputs to vary, based upon known or assumed statistical distributions, and to be reflected in the forecasted results. The Monte Carlo simulation generates a statistical distribution of the yearly mean TP and Chl-*a* concentrations and Secchi Disk depth, reflecting the uncertainty in the model parameters and normal variability in inputs (e.g., annual TP load from surface runoff), as well as correlation among inputs (e.g., runoff and load). Crystal Ball (a proprietary software developed by Oracle; https://www.oracle.com/applications/crystalball/) was used to perform the Monte Carlo simulations in the spreadsheet version of BATHTUB. The benefit of using the stochastic approach is the presentation of model results in the form of a statistical distribution of responses, which steady state models cannot achieve.

Okamapeedan Lake (46-0051-00) is the only lake where a portion of the lake's watershed is drained from Iowa. Therefore, the TMDL was developed using a percentage of the loading capacity to represent Minnesota's portion. To determine the percentage of the loading capacity for Minnesota, the percentage of drainage area from Minnesota was calculated and that same percentage was applied to the loading capacity. Minnesota contributes 95% of the total drainage area, thus the TMDL is calculated at 95% of the total loading capacity.

Watershed Loading Rates

The overland flows and P loading rates were extracted from the Des Moines River Basin HSPF model (Tetra Tech 2016) and used in the BATHTUB models. The HSPF model simulates hydrology and water quality for the period 1993 through 2014. The BATHTUB models simulated water quality on either a seasonal (June to September) scale or an annual scale, depending on the hydraulic residence time, or the time it takes to completely replace the water in the lake.

Upstream Lakes

Some of the lakes have impaired lakes upstream, which are also addressed in this TMDL report. Meeting water quality standards is contingent on improving the water quality in upstream lakes. When estimating the needed load reduction to meet the water quality standard, tributary and overland loading were taken equally, and only the overall required load reduction was estimated. Improvements in upstream waterbodies, due to meeting water quality standards, were incorporated into the parceling of the LAs. The LA was divided into NPS, upstream lakes that could influence the lake, atmospheric deposition, and SSTS and load reductions were provided to NPS and upstream lakes. The upstream lakes were assumed to have a flow weighted mean concentration (FWMC) equal to their standard, based on HSPF model results, and provides their portion of the overall load reductions. Nonpoint source reductions were then adjusted to account for the reduction from upstream lakes to meet water quality standards.

Atmospheric Deposition

Atmospheric deposition refers to the P applied directly to the lakes surface from the atmosphere. The rates of atmospheric deposition (both wet and dry) of TP onto each of the simulated lakes use an estimated mean annual atmospheric deposition load of 45 $kg/km^2/year$ which is 0.4 lbs/acre/year (Barr 2007). When summer values are used, the ratio of summer precipitation to average annual precipitation is used to estimate the summer atmospheric deposition.

Internal Loading

Internal loading is the re-release of TP from sediments, usually due to anoxic conditions (dissolved oxygen concentrations < 2.0 mg/L) near the bed of the lake. Internal P loading can be a substantial part of the mass balance in a lake, especially in lakes with a history of high P loads. If a lake has a long history of high P concentrations, it is possible to have internal loading rates higher than external loads. There was no information on specific internal loading in lakes in the basin at the time of this TMDL report, therefore, internal loading rates (if needed) were determined using a mass balance approach.

Internal loading can be estimated using methodology developed by Nurnberg (1984). Internal loading is estimated by adding an internal loading term to the current models based on external loading and predicted retention (Nurnberg 1984):

$$TP = {}^{L_{ext}}/_{q_s}\left(1 - R_{pred}\right) + {}^{L_{int}}/_{q_s} \qquad [1]$$

where TP is the in-lake TP concentration (ug/L); L_{ext} is the external load (kg/yr), q_s is the lake outflow (hm^3/yr), R_{pred} is the predicted retention coefficient, and L_{int} is the internal loading (kg/yr). The retention coefficient can be estimated using:

$$R_{pred} = {15}/{(18 + {q_s}/{A})} \quad [2]$$

Where A = surface area of the lake (km^2). The only unknown in [1] and [2] is internal loading and it can be estimated by solving for L*int*.

Using [1] and [2], the potential for internal loading was checked for the modeled lakes. No lake requiring a TMDL showed the need for an explicit internal load. Thus, internal loading was assumed to be negligible for all lakes in this study.

It should be noted, the 2008 TMDL report (MPCA 2008) states in the Executive Summary:

> *"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."*

The modeling effort under this TMDL report could not confirm this and did not find a need for an explicit internal load rate for either North or South Heron lakes. This does not mean internal loading does not exist in either lake or any other lake in the Des Moines River Basin. It means that additional internal loading was not needed to calibrate the BATHTUB lake models to the observed lake water quality for lakes modeled in this TMDL report. We expect that internal loading is a source to the lakes based on shallow lake characteristics (potential factors include: intermittent stratification, carp, wind mixing, etc.), but that it was not explicitly quantified.

Therefore, although no information on internal loading exists, if any internal loading exists, it is assumed to be included in the nonpoint source loading and LA. However, BMPs to reduce internal loading could benefit the lakes in the Des Moines River Basin.

The MPCA recommends feasibility studies for any lakes in which water level drawdown or chemical treatment is considered. *The Minnesota State and Regional Government Review of Internal Phosphorus Load Control* (MPCA 2020d) paper provides more information on internal phosphorus load BMPs and considerations.

The stochastic BATHUB modeling

The benefit of using stochastic modeling over the traditional BATHTUB modeling is the ability to capture the natural variation in the forcing data. Stochastic modeling is an approach where model input values (e.g. terms in hydrologic budget) and model parameters used in the equations to compute the in-lake mean concentration of TP and Chl-*a* and Secchi Disk depth, are allowed to vary according to their observed statistical distribution, and therefore their probability of occurrence. This allows the effect of parameter uncertainty and normal variability in the inputs (e.g., amount of surface runoff and nutrient load, which varies depending upon the amount of precipitation) to be quantified when computing the in-lake mean concentration of TP, Chl-*a* and Secchi Disk depth.

Using the Crystal Ball software allowed for multiple probabilistic model computations. Many trial values (10,000 trials in this modeling effort) were generated with each trial representing a different permutation of model input values within the bounds established by the statistical distributions. The many trials resulted in a computed distribution of expected in-lake water quality for each lake rather than a single, deterministic output that was based upon only one possible combination of model inputs. Select inputs, primarily those components of the water budget or TP mass balance, were allowed to vary during the Monte Carlo simulation. The selected inputs are precipitation, evaporation, atmospheric deposition, direct drainage inflows and loadings, and tributary inflows and loadings.

Crystal Ball was used to develop the model input statistical distributions based on the previously mentioned HSPF hydrologic and TP loading seasonal or yearly values for the period 1994 through 2014. Crystal Ball was used to fit the data to distributions and provide correlations between statistical distributions to simulate natural conditions of the forcing data.

Once the BATHTUB models were built and calibrated, load reduction scenarios were developed to estimate the required load reduction to meet the water quality standard. The load reduction needed to meet the numeric water quality standard was calculated from the median (50^{th} percentile) lake concentration. Only load reductions in tributary flows and overland (direct) drainage were made to reach the target load reduction. No reduction to atmospheric deposition was considered. Modeling specifics for the lakes in this report can be found in **Appendix B and C**.

4.6.2 Load allocation methodology

LAs represent the portion of the LC designated for NPS of P. The LA is the remaining load once the WLA, RC, and MOS are determined and subtracted from the LC. The LA includes all sources of TP that do not require NPDES permit coverage, including unregulated watershed runoff, internal loading, groundwater, atmospheric deposition, and a consideration for "natural background" conditions. "Natural background", as defined in Minn. R. 7050.0150, subp. 4, can be described as physical, chemical, or biological conditions that would exist in a waterbody that are not a result of human activity. NPS of TP were previously discussed in **Section 3.6.4**.

4.6.3 Wasteload allocation methodology

WLAs were developed for any permitted discharge in the drainage area of an impaired lake. These are discharges requiring an NPDES permit, and typically include wastewater treatment facilities, municipal separate storm sewer systems (MS4s), industrial dischargers, construction sites managing for stormwater, and permitted feedlots. WLAs for each impaired lake are provided in the tables in **Section 4.6.7**. The WLAs for North Heron Lake and South Heron Lake as calculated below and presented in **Table 49** and **Table 50**, respectively, replace the WLAs developed in the 2008 *West Fork Des Moines River Watershed Total Maximum Daily Load Final Report: Excess Nutrients (North and South Heron Lakes), Turbidity, and Fecal Coliform Bacteria Impairments* (MPCA 2008).

Wastewater Treatment Plants

WLAs for WWTPs are based on the permit's maximum daily flow (industrial) or average wet weather design flow (municipal) and a phosphorus concentration variable. Future NPDES permits will include phosphorus effluent limits that are consistent with the TMDL's WLAs. Since existing loads are calculated using actual effluent flow and concentrations, it is not unusual for existing loads to be lower than the WLAs. It is anticipated that facilities whose existing loads are lower than their WLAs will maintain their performance, although permit limits will be equivalent to the TMDL's WLAs and will allow for increased effluent loads from these facilities. Facilities whose existing effluent loads exceed their WLAs will need to achieve effluent phosphorus load reductions, see **Table 14** for a list of the facilities. A meeting was held with the permitted facilities to present the TMDLs and explain the impacts to the permit limits, see

Section 9. The NPDES permits requiring a WLA for WWTPs in the drainage area for impaired lakes are provided in **Table 38**.

Table 38. NPDES permits in impaired lakes of the Des Moines River Basin.

Facility	Permit No.	Effluent Flow Type	Waterbody	Daily flow type for WLA calculation[3]	Average Wet Weather Design Flow/ Maximum Design Flow (mgd)
Alpha WTP[1]	MNG640102	Controlled	Okamanpeedan	AWW	0.015
Avoca & Iona WWTP	MNG580165	Controlled	Talcot	AWW	0.074
Brewster WWTP	MN0021750	Controlled	North Heron	AWW	0.191
Ceylon WWTP	MNG580006	Controlled	Okamanpeedan	AWW	0.061
Currie WWTP	MNG580221	Controlled	Talcot	AWW	0.328
Dundee WWTP	MN0070271	Controlled	Talcot	AWW	0.015
Fulda WWTP	MNG580188	Controlled	Talcot	AWW	0.178
Hubbard Feeds Inc - Worthington	MN0033375	Continuous	North Heron	MDF	0.009
Lake Wilson WWTP[2]	MNG580061	Controlled	Talcot	AWW	0.074
Lakefield WWTP	MN0020427	Continuous	South Heron	AWW	0.582
Okabena WWTP	MN0050288	Controlled	North Heron	AWW	0.0311
Sherburn WWTP	MN0024872	Continuous	Okamanpeedan	AWW	0.332
Shetek Area Water & Sewer District WWTP	MN0070947	Controlled	Talcot	AWW	0.241
Slayton WWTP	MNG580191	Controlled	Talcot	AWW	0.371
Worthington Industrial WWTP	MN0031178	Continuous	North Heron	MDF	2.16
Worthington WWTP	MN0031186	Continuous	North Heron	AWW	4

[1]Alpha WTP WLA assumes three 0.015 mgd discharges per month at 1 mg/L
[2]Lake Wilson WLA assumes 0.074 mgd x 2 mg/L x 365 days
[3]AWW is Average Wet Weather Design Flow; the flow value used to calculate permit load limits and WLAs for municipal facilities. MDF is Maximum Daily Flow; the permitted flow value used to calculate load limits and WLAs for industrial dischargers.

Stabilization Pond Discharge Rates

Controlled systems are designed to store 180 days' worth of flow and discharge during the spring and fall periods of relatively high stream flow and/or low receiving water temperatures. Their permits allow for the discharge of six inches of depth per day from their secondary ponds in the spring (March 1 to June 15) and fall (September 15 to December 31). Therefore, their daily phosphorus discharge rate is based on their maximum allowable flow of six inches per day of discharge (**Table 39**). The daily WLAs are specified in the TMDL summary tables (**Table 43** through **Table 66**).

Table 39. Daily phosphorus discharge rate calculation for controlled pond systems.

Facility	Secondary Pond (acres)	Maximum Permitted Flow (mgd)	TP Concertation Assumption (mg/L)	Conversion Factor	Daily Phosphorus Discharge Rate (lbs/day)
Avoca & Iona WWTP	4.94	0.805	2	8.34	13.43
Brewster WWTP	12.3	2.004	1	8.34	16.71
Ceylon WWTP	2.9	0.472	1	8.34	3.94
Currie WWTP	5.69	0.927	1	8.34	7.73
Dundee WWTP	0.74	0.121	1	8.34	1.01
Fulda WWTP	5.4	0.88	2	8.34	14.68
Lake Wilson WWTP[2]	3.14	0.512	2	8.34	8.53
Okabena WWTP	1.5	0.244	1	8.34	2.04
Shetek Area Water & Sewer District WWTP	22.2	3.617	1	8.34	30.17
Slayton WWTP	12.45	2.028	1	8.34	16.92

Annual and Seasonal WLAs

Table 40 provides the information used to calculate the annual and daily P WLA for each permitted WWTP receiving a WLA. The annual WLAs are based on either the average wet weather flow or the maximum daily design flow and an assumed discharge concentration of 1 mg/L or 2 mg/L. The daily flow [A] is multiplied by the assumed TP concentration [B] and a conversion factor [C] and converted to pounds per year [E] and pounds per day [F]. For TMDLs where the loads are expressed seasonally, the daily WLA in pounds per day was multiplied by 122 days for continuous WWTPs and an assumed 14 days of discharge at maximum daily flow (**Table 39**) for controlled WWTPs (see **Table 38** for flow type). Seasonal WLAs are only provided for WWTPs where they are needed (Talcot and Okamanpeedan Lakes) in **Table 40**. The annual NPDES permit limits (kg/year) are consistent with the assumptions and requirements of seasonal WLAs calculated for Talcot and Okamanpeedan Lakes.

Table 40. WLAs for NPDES permits in impaired lakes of the Des Moines River Basin.

Facility	Daily Flow (mgd)	TP Concentration Assumption (mg/L)	Conversion Factor (L/gal)	TP WLA (kg/year)	TP WLA (lbs/year)	Daily TP WLA (lbs/day)[4]	TP WLA (lbs/seas.)[5]
	[A]	[B]	[C]	[D=A*B*C*365]	[E]	[F]	[G]
Alpha WTP[1]	0.015	1	3.785	2	4.4	0.057	0.68
Avoca & Iona WWTP[2]	0.074	2	3.785	204	450	1.23	188.0
Brewster WWTP	0.191	1	3.785	264	582	1.59	
Ceylon WWTP[2]	0.061	1	3.785	84	185	0.51	55.2
Currie WWTP[2]	0.087	1	3.785	120	265	0.73	108
Dundee WWTP[2]	0.015	1	3.785	21	46	0.13	14.1
Fulda WWTP[2]	0.178	2	3.785	492	1,085	2.97	205.5
Hubbard Feeds Inc - Worthington	0.009	1	3.785	12	26	0.08	
Lake Wilson WWTP[2]	0.074	2	3.785	204	450	1.23	119
Lakefield WWTP	0.582	1	3.785	804	1,772	4.86	
Okabena WWTP	0.0311	1	3.785	43	95	0.26	
Sherburn WWTP[3]	0.332	1	3.785	459	1,012	2.77	338
Shetek Area Water & Sewer District WWTP[2]	0.241	1	3.785	333	734	2.01	422
Slayton WWTP[2]	0.371	1	3.785	513	1,131	3.10	237
Worthington Industrial WWTP	2.16	1	3.785	2,984	6,579	18.02	
Worthington WWTP	4	1	3.785	5,526	12,183	33.36	

[1]Alpha WTP WLA assumes three 0.015 mgd discharges per month at 1 mg/L, seasonal WLA based on 4 months of discharge.
[2]Controlled flow type, assumes 14 days of discharge during season at maximum daily discharge (Table 38).
[3]Continous discharge, assumes 122 days of discharge during season, only provided for relevant WWTPs.
[4]Taken as annual WLA divided by 365, except for Alpha WTP (see footnote 1).
[5]The seasonal TP WLA for controlled discharge WWTPs assumes the daily phosphorus discharge rate shown in Table 37 and 14 day of discharge from June 1st through September 30th.

Straight Pipe Septic Systems

Straight pipe septic systems are illegal and unpermitted and receive WLA of zero.

Municipal Separate Storm Sewer System (MS4)

The WLA for communities subjected to MS4 NPDES stormwater permit requirements is taken as a percentage of the LC based on the percentage of land area in the impaired reach that the MS4 permit area covers. There is one MS4 permitted area, the city of Worthington (MS4 Permit #MS400257), and it covers about 4.15 square miles within the drainage area of North Heron Lake. North Heron Lake's drainage area totals 428.9 square miles, therefore, the WLA for Worthington is 0.968% of the LC for North Heron Lake.

Industrial and Construction Permits

WLAs for construction and industrial stormwater discharges which are covered by the state's general permits were combined and addressed through a categorical allocation. Stormwater runoff from construction sites that disturb: (a) one acre of soil or more, (b) less than one acre of soil and are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but determined to pose a risk to water quality are regulated under the state's NPDES/SDS General Stormwater Permits for Construction Activity (MNR1000001). This permit requires and identifies BMPs to be implemented to protect water resources from mobilized sediment and other pollutants of concern. If the owner/operator of impacted construction sites, obtains and abides by the NPDES/SDS General Construction Stormwater Permit, the stormwater discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Similar to construction activities, industrial sites are regulated under general permits, in this case either the NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or the NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying, and Hot Mix Asphalt Production facilities (MNG490000). Like the NPDES/SDS General Construction Stormwater Permit, these permits identify BMPs to be implemented to protect water resources from pollutant discharges at the site. If the owner/operator of industrial sites abides by the necessary NPDES/SDS General Stormwater Permits, the discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Due to the transient nature of construction activities and the minimal amount industrial activity, it is assumed that 0.1% of the drainage area is under construction or industrial activities at any given time. Therefore, to calculate the WLA for construction and industrial stormwater, this TMDL report assigns 0.1% of the load capacity to the construction/industrial stormwater WLA.

Livestock Facilities

NPDES permitted feedlot facilities are assigned a WLA of zero. This is consistent with the conditions of the permits, which allow no pollutant discharge from the livestock housing facilities and associated sites. A list of CAFOs included in lake drainage areas can be found in **Appendix D**.

4.6.4 Margin of safety

The MOS accounts for uncertainty in the lake models, observed water quality data, and the HSPF model. The stochastic nature of the stochastic version of BATHUB model and using distributions for the forcing data accounts for the uncertainty in the forcing data. Each lake model was simulated for 10,000 runs to account for the variability in the forcing data (climate and loadings). The loading reductions needed to meet the water quality standard was assumed to occur when the models simulated TP concentration at the 50th percentile, meaning the lake will meet the water quality standard 50% of the time. To account for the uncertainty in the lake models, the load reductions needed to reach the water quality standard at the 90th percentile, meaning the water quality standard will be met 90% of the time was used to determine the MOS. The MOS was established as the difference between load reductions at the 50th percentile and 90th percentile. This accounts for the uncertainty within the lake models and forcing data. The MOS for each lake is provided in **Table 41**. In some lakes, the 90th percentile was influenced by extreme values in the distributions and lead to unrealistic MOS (>20%). Therefore, for some of the lakes, the 80th percentile was used to determine the MOS. It should be noted, the load reductions provided in

Table 41 are slightly different than the load reductions provided in the following TMDL tables. This is due to atmospheric deposition being held constant and the MOS not being included in the modeled load reduction calculations.

Table 41. Margin of Safety for modeled lakes in Des Moines River Basin.

Lake Name	AUID	Load Capacity [lbs/yr]	Load Reduction {B}	90th Percentile Load Reduction {A}	Margin of Safety {A-B}	Margin of Safety [lbs/yr]
North Oaks	17-0044-00	1,214	77%	83%	6%	72.9
Talcot[1,2]	17-0060-00	29,159	69%	82%	13%	3,791
Boot[1]	32-0015-00	128	72%	82%	10%	12.8
Flahtery	32-0045-00	1,050	69%	77%	8%	84
Teal[1]	32-0053-00	263	63%	72%	9%	23.6
Heron (Duck)	32-0057-02	1,221	70%	78%	8%	97.6
Heron (North)	32-0057-05	45,526	81%	88%	7%	3,187
Heron (South)	32-0057-07	8,909	82%	88%	6%	535
Timber	32-0058-00	258	64%	76%	12%	31.0
Yankton[1]	42-0047-00	523	54%	64%	10%	52.3
Okamanpeedan[2]	46-0051-00	14,439	56%	67%	11%	1,588
Bright[1,2]	46-0052-00	1,807	46%	57%	11%	199
Pierce[1]	46-0076-00	207	78%	90%	12%	24.8
Temperance	46-0103-00	174	73%	83%	10%	17.4
Lime[1,2]	51-0024-00	3,924	56%	71%	15%	589
Bloody[1]	51-0040-00	783	15%	28%	13%	101.9
Fox[1]	51-0043-00	292	11%	26%	15%	43.8
Shetek[1]	51-0046-00	45,184	34%	49%	15%	6,778
Corabelle	51-0054-00	165	44%	54%	10%	16.5
Sarah[1]	51-0063-00	7,320	47%	59%	12%	878
Currant	51-0082-00	761	52%	65%	13%	99
East Graham[1]	53-0020-00	2,902	49%	63%	14%	406
West Graham	53-0021-00	3,199	52%	65%	13%	415.8

[1]MOS estimated from the 80th percentile load reduction, due to influences of the forcing data distributions.
[2]Seasonal lake model (June-September). Units for load capacity and MOS are lbs/season

4.6.5 Reserve Capacity

The RC represents a set-aside for potential future loading sources. In this TMDL report, the RC accounts for currently “unsewered” communities that may become “sewered” and discharge to a WWTP in the future.

The potential need for RC for these situations has been estimated based on the assumption that 10% of the unsewered population within an impaired lake drainage basin may discharge to WWTPs in the future. The potential TP load from future WWTPs serving these populations has been calculated based on an assumption of 0.8 kg/capita/year of TP load to the WWTP and a reduction efficiency of 80% at the WWTP, resulting in a load to the receiving water of 0.16 kg/capita/year (MPCA 2012b).

A RC was allocated for Talcot Lake, Heron (North), and Okamanpeedan Lake. These lakes are most likely to have "unsewered" communities become "sewered" in the future. A summary of the RC calculations for future "sewered" communities is presented in **Table 42.**

Table 42. Reserve capacity for future "sewered" communities.

Lake (AUID)	Estimated population not currently connected to NPDES permitted WWTP	Estimated required future permit population[1]	Estimated untreated annual TP load[2]	Reserve Capacity [80% removal] (kg/yr)	Reserve Capacity [80% removal] (kg/day)	Reserve Capacity [80% removal] (lbs/day)
Talcot (17-0060-00)	3,211	321	257	51	0.14	0.31
Heron (North) (32-0057-05)	179	18	14	3	0.01	0.02
Okamanpeedan (46-0051-00)	1,172	117	94	19	0.05	0.11

[1]: Not currently connected to NPDES permitted WWTP that may require a TP WLA in the future (10%)
[2]: For population not currently connected to NPDES permitted WWTP that may require a TP WLA in the future (0.8 kg/capita/yr)

4.6.6 Seasonal variation

Lakes are generally not sensitive to short term changes in water quality, but rather respond to long-term changes and variation in seasonal and/or annual loads. Water quality monitoring suggests in-lake water quality varies over the course of the growing season and generally peaks in mid to late summer. The standard applies from June through September, and MPCA guidelines for assessing lake TP is defined as the June through September mean concentration. The BATHTUB models were used to calculate the load capacities for each lake, incorporating mean growing season TP values and seasonal or annual loads, depending on the hydrologic residence time. Calibration to the summer critical period provides adequate protection during times of the year with reduced loading.

4.6.7 TMDL summary

The allowable TP load (TMDL) for each lake was divided among the WLA, LA, and the MOS as described in the above sections. The following tables summarize the existing and allowable TP loads (Total Load and Load Capacity, respectively, in tables), the TMDL allocations (Wasteload and Load in tables) and required reductions for each lake.

The following rounding conventions were used in the TMDL tables:

- Values ≥10 reported in lbs/yr (or lbs/seas.) have been rounded to the nearest pound.
- Values <10 and ≥1 reported in lbs/yr (or lbs/seas.) have been rounded to the nearest tenth of a pound.
- Values ≥0.01 reported in lbs/day have been rounded to the nearest hundredth of a pound.

- Values <0.01 reported in lbs/day have been rounded to enough significant digits so that the value is greater than zero and a number is displayed in the table.
- While some of the numbers in the tables show multiple digits, they are not intended to imply great precision.
- Some small arithmetic errors may exist; this is due to rounding errors.

Some lake TMDL tables report annual loads and some report seasonal (June-September) loads. This was determined using the lake models and hydraulic residence time. If the hydraulic residence time, i.e. the time it takes the lake to fully replace its stored water, was smaller than half a year, a seasonal model was used. This was to remove the effects of annual spring flood, which might cause lower than expected summer in-lake concentrations because of the high volume of water, and better represent summer conditions in the lake model. Daily loads for lakes with annual models are calculated by dividing the annual loading by 365 days. For seasonal models, the seasonal loads are divided by 122 days (June 1 to September 30).

For lakes with impaired lakes upstream, a portion of the LAs were attributed to the improving water quality when those lakes meet water quality standards. The portion of the LA attributed to the improving water quality was determined using the HSPF model and setting the outflow from the upstream lake to their water quality standard. It should be noted, these loads and load reductions may not match the corresponding LC and load reductions in the upstream lakes' TMDL table. This is due to the loads and reductions coming from the lake's outflow and some processing of the P as it travels downstream.

Des Moines River Headwaters Lake Nutrient TMDLs

Table 43. North Oaks Lake (17-0044-00) TP TMDL.

North Oaks (17-0044-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day	lbs/yr	%
Wasteload Allocation	**Total WLA**	**1.2**	**1.2**	**0.003**	**0**	**0%**
	Construction/Industrial Stormwater[1]	1.2	1.2	0.003	0	0%
Load Allocation	**Total LA**	**4,829**	**1,140**	**3.1**	**3,689**	**76%**
	Nonpoint Sources[2]	4,695	1,006	2.8	3,689	79%
	Atmosphere	134	134	0.37	0	0%
Margin of Safety (MOS)[3]			**73**	**0.20**		
Total Load/Loading Capacity		**4,830**	**1,214**	**3.3**	**3,616**	**75%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any

[3]MOS is 6% of LC.

Table 44. Talcot Lake (17-0060-00) TP TMDL.

Talcot (17-0060-00)		Existing Phosphorus Load[1]	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/seas.[5]	lbs/seas.[5]	lbs/day	lbs/seas.	%
Wasteload Allocation	**Total WLA**	**604**	**1,322**	**92.9**	**0**	**0%**
	Avoca & Iona WWTP[6]	18	188	13.43	0	0%
	Currie WWTP[7]	25	108	7.7	0	0%
	Dundee WWTP[8]	NA	14	1.0	NA	NA
	Fulda WWTP[9]	252	205	15	47	19%
	Lake Wilson WWTP[10]	119	119	8.5	0	0%
	Shetek Area Water & Sewer District WWTP[11]	NA	422	30	NA	NA
	Slayton WWTP[12]	161	237	17	0	0%
	Construction/Industrial Stormwater[2]	29	29	0.24	0	0%
Load Allocation	**Total LA**	**93,085**	**24,008**	**114.8**	**69,078**	**74%**
	Atmosphere	168	168	1.4	0	0%
	Nonpoint Sources[3]	70,498	18,308	68.1	52,190	74%
	Lime Lake[13]	7,013	1,783	15	5,229	75%
	North Oaks Lake[13]	1,909	280	2.3	1,629	85%
	Shetek Lake[13]	13,497	3,469	28	10,028	74%
Margin of Safety (MOS)[4]			**3,791**	**31**		
Reserve Capacity			**38**	**0.31**		
Total Load/Loading Capacity		**93,689**	**29,159**	**239**	**64,529**	**69%**

[1]Existing conditions for permitted is calculated for 2012-2014.
[2]Based on assumption that 0.1% of watershed area is in construction/industrial activities at any given time. Assumes existing permits are being met with current BMPs.
[3]Includes any internal loading, if any exists.
[4]MOS is taken as 13% of LC.
[5]Hydraulic residence time (0.03 years) is on seasonal timescale, therefore existing and allowable loads developed using seasonal values (Jun-Sept). Season is 122 days long (June 1- Sept 30). Seasonal WLAs for controlled discharge WWTPs assume potential for 14 days of discharge during the summer season.
[6]Annual WLA is 451 lbs/yr for Avoca & Iona WWTP. Seasonal WLA based on 14 days of discharge at 0.80 mgd and 1 mg/L TP.
[7]Annual WLA is 265 lbs/yr for Currie WWTP. Seasonal WLA based on 14 days of discharge at 0.93 mgd and 1 mg/L TP.
[8]Facility initiated operations in 2014, thus no existing load was calculated. Annual WLA is 46 lbs/yr for Dundee WWTP. Seasonal WLA based on 14 days of discharge at 0.12 mgd and 1 mg/L TP.
[9]Annual WLA is 1,084 lbs/yr for Fulda WWTP. Seasonal WLA based on 14 days of discharge at 0.88 mgd and 2 mg/L TP.
[10]Annual WLA is 451 lbs/yr for Lake Wilson WWTP. Seasonal WLA based on 14 days of discharge at 0.51 mgd and 1 mg/L TP.
[11]Facility was part of the Currie WWTP permit until 2017, thus no existing load was calculated. Annual WLA is 734 lbs/yr for Shetek Area Water & Sewer District WWTP. Seasonal WLA based on 14 days of discharge at 3.62 mgd and 1 mg/L TP.
[12]Annual WLA is 1,130 lbs/yr for Slayton WWTP. Seasonal WLA based on 14 days of discharge at 2.03 mgd and 1 mg/L TP.
[13]Impaired upstream lake; LA assumes outflow from impaired lake meets water quality standards.

Table 45. Boot Lake (32-0015-00) TP TMDL.

Boot (32-0015-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.13**	**0.13**	**0.0004**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.13	0.13	0.0004	0	0%
Load Allocation	**Total LA**	**300**	**115**	**0.31**	**186**	**62%**
	Nonpoint Sources[2]	240	54	0.15	186	77%
	Atmosphere	61	61	0.17	0	0%
Margin of Safety (MOS)3			**13**	**0.035**		
Total Load/Loading Capacity		**301**	**128**	**0.35**	**173**	**57%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any

[3]MOS is 10% of LC.

[4]Daily loads are annual loads divided by 365

Table 46. Flahtery Lake (32-0045-00) TP TMDL.

Flahtery (32-0045-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**1.1**	**1.1**	**0.003**	**0**	**0%**
	Construction/Industrial Stormwater[1]	1.1	1.1	0.003	0	0%
Load Allocation	**Total LA**	**3,016**	**965**	**2.6**	**2,051**	**68%**
	Nonpoint Sources[2]	2,849	798	2.2	2,051	72%
	Atmosphere	167	167	0.46	0	0%
Margin of Safety (MOS)[3]			**84**	**0.23**		
Total Load/Loading Capacity		**3,017**	**1,050**	**2.9**	**1,967**	**65%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any

[3]MOS is 8% of LC.

[4]Daily loads are annual loads divided by 365

Table 47. Teal Lake (32-0053-00) TP TMDL.

Teal (32-0053-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.26**	**0.26**	**0.0007**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.26	0.26	0.0007	0	0%
Load Allocation	**Total LA**	**648**	**239**	**0.65**	**410**	**63%**
	Nonpoint Sources[2]	613	203	0.56	410	67%
	Atmosphere	36	36	0.10	0	0%
Margin of Safety (MOS)[3]			**24**	**0.065**		
Total Load/Loading Capacity		**649**	**263**	**0.72**	**386**	**60%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 9% of LC.

[4]Daily loads are annual loads divided by 365.

Table 48. Heron (Duck) Lake (32-0057-02) TP TMDL.

Heron (Duck) (32-0057-02)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**1.2**	**1.2**	**0.003**	**0**	**0%**
	Construction/Industrial Stormwater[1]	1.2	1.2	0.003	0	0%
Load Allocation	**Total LA**	**3,780**	**1,122**	**3.1**	**2,658**	**70%**
	Nonpoint Sources[2]	3,657	999	2.7	2,658	73%
	Atmosphere	123	123	0.34	0	0%
Margin of Safety (MOS)[3]			**98**	**0.27**		
Total Load/Loading Capacity		**3,781**	**1,221**	**3.3**	**2,561**	**68%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 8% of LC.

[4]Daily loads are annual loads divided by 365.

Table 49. Heron (North) Lake (32-0057-05) TP TMDL.

North Heron (32-0057-05)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[7]	lbs/yr	%
Wasteload Allocation	**Total WLA[1]**	**8,661**	**19,952**	**55**		
	Brewster WWTP[8]	311	582	1.6	0	0%
	Hubbard Feeds Inc – Worthington[8]	0.4	26	0.075	0	0%
	Okabena WWTP[8]	57	95	0.26	0	0%
	Worthington Industrial WWTP[8]	3,488	6,579	18	0	0%
	Worthington WWTP[8]	4,759	12,183	33	0	0%
	Worthington MS400257[2]		441	1.2	0	0%
	Construction/Industrial Stormwater[3]	46	46	0.13	0	0%
Load Allocation	**Total LA**	**219,473**	**22,381**	**61**	**197,093**	**90%**
	Atmosphere	1,281	1,281	3.5	0	0%
	Nonpoint Sources[4]	188,705	13,037	36	175,669	93%
	South Heron Lake[5,9]	24,904	5,874	16	19,030	76%
	East Graham Lake[9]	4,425	2,133	5.8	2,292	52%
	Corabelle Lake[9]	158	56	0.15	102	64%
Margin of Safety (MOS)[6]			**3,187**	**8.7**		
Reserve Capacity			**6.3**	**0.02**		
Loading Capacity/Total Load		**228,134**	**45,526**	**125**	**182,608**	**80%**

[1]Existing conditions for permitted WLA is included in the HSPF loads, therefore, included in the LA loading for existing conditions. Assumes existing permits are being met with current BMPs.
[2]WLA for Worthington MS4 area is taken as the 0.968% of the load capacity.
[3]Based on assumption that 0.1% of watershed area is in construction/industrial activities at any given time. Assumes existing permits are being met with current BMPs.
[4]Includes any internal loading, if any exists.
[5]Loading from South Heron Lake, including any groundwater dispersion, and based on CNET models.
[6]MOS is taken as 7% of LC.
[7]Based on 365-day year.
[8]Daily WLA based on Annual WLA divided by 365.
[9]Impaired upstream lake; LA assumes outflow from impaired lake meets water quality standards.

Table 50. Heron (South) Lake (32-0057-07) TP TMDL.

South Heron (32-0057-07)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr[6]	lbs/yr	lbs/day[6]	lbs/yr	%
Wasteload Allocation	**Total WLA[1]**	**847**	**1,781**	**4.9**	**0**	**0%**
	Lakefield WWTP[8]	838	1,772	4.9	0	0%
	Construction/Industrial Stormwater[2]	8.9	8.9	0.024	0	0%
Load Allocation	**Total LA**	**40,703**	**6,593**	**18**	**34,110**	**84%**
	Atmosphere	1,067	1,067	2.9	0	0%
	Okabena Creek Overflow[3]	7,292	1,386	3.8	5,907	81%
	Nonpoint Source[4]	29,863	3,793	10.4	26,069	87%
	Flahtery Lake[7]	2,481	347	1.0	2,134	86%
Margin of Safety (MOS)[5]			**535**	**1.5**		
Total Load (or Loading Capacity)		**41,550**	**8,909**	**24**	**32,641**	**79%**

[1] Existing WWTP loads from reported effluent loads (https://www.pca.state.mn.us/data/wastewater-data-browser.
[2]Based on assumption that 0.1% of watershed area is in construction/industrial activities at any given time.
[3]LA for Okabena Creek, assumed as 5% of annual TP in Okabena Creek.
[4]Includes any internal loading, if any exists.
[5]MOS is taken as 6% of LC.
[6]Based on 365-day year.
[7]Impaired upstream lake; LA assumes outflow from impaired lake meets water quality standards.
[8]Daily WLA based on Annual WLA divided by 365.

Table 51. Timber Lake (32-0058-00) TP TMDL.

Timber (32-0058-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.26**	**0.26**	**0.0007**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.26	0.26	0.0007	0	0%
Load Allocation	**Total LA**	**579**	**227**	**0.62**	**352**	**61%**
	Nonpoint Sources[2]	501	149	0.41	352	70%
	Atmosphere	77	77	0.21	0	0%
Margin of Safety (MOS)[3]			**31**	**0.085**		
Total Load/Loading Capacity		**579**	**258**	**0.71**	**321**	**55%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.
[2]Includes internal loading, if any.
[3]MOS is 12% of LC.
[4]Daily loads are annual loads divided by 365.

Table 52. Yankton Lake (42-0047-00) TP TMDL.

Yankton (42-0047-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.52**	**0.52**	**0.001**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.52	0.52	0.001	0	0%
Load Allocation	**Total LA**	**950**	**470**	**1.3**	**479**	**50%**
	Nonpoint Sources[2]	791	311	0.85	479	61%
	Atmosphere	159	159	0.44	0	0%
Margin of Safety (MOS)[3]			**52**	**0.14**		
Total Load/Loading Capacity		**950**	**523**	**1.4**	**427**	**45%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 10% of loading capacity.

[4]Daily loads are annual loads divided by 365.

Table 53. Lime Lake (51-0024-00) TP TMDL.

Lime (51-0024-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/ seas.[5]	lbs/ seas.[5]	lbs/day[4]	lbs/ seas.[5]	%
Wasteload Allocation	**Total WLA**	**3.9**	**3.9**	**0.032**	**0**	**0%**
	Construction/Industrial Stormwater[1]	3.9	3.9	0.032	0	0%
Load Allocation	**Total LA**	**8,835**	**3,331**	**27**	**5,504**	**62%**
	Nonpoint Sources[2]	8,773	3,269	27	5,504	63%
	Atmosphere	62	62	0.51	0	0%
Margin of Safety (MOS)[3]			**589**	**4.8**		
Total Load/Loading Capacity		**8,839**	**3,924**	**32**	**4,915**	**56%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 15% of loading capacity.

[4]Daily loads are annual loads divided by 122 days.

[5]Hydraulic residence time (0.11 yrs) is on seasonal timescale, therefore existing and allowable loads developed using seasonal values (Jun-Sept). Season is 122 days long (June 1- Sept 30).

Table 54. Bloody Lake (51-0040-00) TP TMDL.

Bloody (51-0040-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.78**	**0.78**	**0.002**	**0.00**	**0%**
	Construction/Industrial Stormwater[1]	0.78	0.78	0.002	0.00	0%
Load Allocation	**Total LA**	**903**	**681**	**1.9**	**222**	**25%**
	Nonpoint Sources[2]	553	481	1.3	71	13%
	Fox Lake[5]	250	99	0.27	151	60%
	Atmosphere	101	101	0.28	0	0%
Margin of Safety (MOS)[3]			**102**	**0.28**		
Loading Capacity/Total Load		**904**	**783**	**2.1**	**121**	**13%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 13% of loading capacity.

[4]Daily loads are annual loads divided by 365.

[5]Impaired upstream lake; LA assumes outflow from impaired lake meets water quality standards.

Table 55. Fox Lake (51-0043-00) TP TMDL.

Fox (51-0043-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.29**	**0.29**	**0.0008**	**0.00**	**0%**
	Construction/Industrial Stormwater[1]	0.29	0.29	0.0008	0.0	0%
Load Allocation	**Total LA**	**319**	**248**	**0.68**	**71**	**22%**
	Nonpoint Sources[2]	247	176	0.5	71	29%
	Atmosphere	72	72	0.20	0	0%
Margin of Safety (MOS)[3]			**44**	**0.12**		
Total Load/Loading Capacity		**319**	**292**	**0.80**	**27**	**9%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 15% of loading capacity.

[4]Daily loads are annual loads divided by 365.

Table 56. Shetek Lake (51-0046-00) TP TMDL.

Shetek (51-0046-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**45**	**45**	**0.12**	**0.00**	**0%**
	Construction/Industrial Stormwater[1]	45	45	0.12	0.00	0%
Load Allocation	**Total LA**	**67,714**	**38,361**	**105**	**29,353**	**43%**
	Atmosphere	1362	1362	3.7	0	0%
	Nonpoint Sources[2]	61,151	35,684	98	25,466	42%
	Bloody Lake[5]	526	57	0.16	470	89%
	Currant Lake[5]	467	71	0.19	397	85%
	Sarah Lake[5]	3,862	1,175	3.2	2,687	70%
	Yankton Lake[5]	345	12	0.03	333	97%
Margin of Safety (MOS)[3]			**6,778**	**19**		
Total Load/Loading Capacity		**67,759**	**45,184**	**124**	**22,575**	**33%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.
[2]Includes internal loading, if any.
[3]MOS is 15% of loading capacity.
[4]Daily loads are annual loads divided by 365.
[5]Impaired upstream lake; LA assumes outflow from impaired lake meets water quality standards.

Table 57. Corabelle Lake (51-0054-00) TP TMDL.

Corabelle (51-0054-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.17**	**0.17**	**0.0005**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.17	0.17	0.0005	0	0%
Load Allocation	**Total LA**	**262**	**148**	**0.41**	**114**	**43%**
	Nonpoint Sources[2]	221	107	0.29	114	52%
	Atmosphere	41	41	0.11	0	0%
Margin of Safety (MOS)[3]			**17**	**0.045**		
Total Load/Loading Capacity		**262**	**165**	**0.45**	**97**	**37%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.
[2]Includes internal loading, if any.
[3]MOS is 10% of loading capacity.
[4]Daily loads are annual loads divided by 365.

Table 58. Sarah Lake (51-0063-00) TP TMDL.

Sarah (51-0063-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**7.3**	**7.3**	**0.02**	**0**	**0%**
	Construction/Industrial Stormwater[1]	7.3	7.3	0.02	0	0%
Load Allocation	**Total LA**	**13,399**	**6,434**	**18**	**6,965**	**52%**
	Nonpoint Sources[2]	12,943	5,978	16	6,965	54%
	Atmosphere	456	456	1.2	0	0%
Margin of Safety (MOS)[3]			**878**	**2.405**		
Total Load/Loading Capacity		**13,406**	**7,320**	**20**	**6,087**	**45%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.
[2]Includes internal loading, if any.
[3]MOS is 12% of loading capacity.
[4]Daily loads are annual loads divided by 365.

Table 59. Currant Lake (51-0082-00) TP TMDL.

Currant (51-0082-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.76**	**0.76**	**0.002**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.76	0.76	0.002	0	0%
Load Allocation	**Total LA**	**1,418**	**661**	**1.8**	**757**	**53%**
	Nonpoint Sources[2]	1,265	508	1.4	757	60%
	Atmosphere	153	153	0.42	0	0%
Margin of Safety (MOS)[3]			**98.9**	**0.27**		
Total Load/Loading Capacity		**1,419**	**761**	**2.1**	**658**	**46%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.
[2]Includes internal loading, if any.
[3]MOS is 13% of loading capacity.
[4]Daily loads are annual loads divided by 365.

Table 60. East Graham Lake (53-0020-00) TP TMDL.

East Graham (53-0020-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/seas.[6]	lbs/seas.[6]	lbs/day[4]	lbs/seas.[6]	%
Wasteload Allocation	**Total WLA**	**2.9**	**2.9**	**0.024**	**0**	**0%**
	Construction/Industrial Stormwater[1]	2.9	2.9	0.024	0	0%
Load Allocation	**Total LA**	**5,599**	**2,493**	**20**	**3,107**	**55%**
	Nonpoint Sources[2]	4,969	1,995	16	2,975	60%
	West Graham Lake[5]	539	407	3.3	132	24%
	Atmosphere	91	91	0.74	0	0%
Margin of Safety (MOS)[3]			**406**	**3.3**		
Total Load/Loading Capacity		**5,603**	**2,902**	**24**	**2,701**	**48%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 14% of loading capacity.

[4]Daily loads are annual loads divided by 122 days.

[5]Impaired upstream lake; LA assumes outflow from impaired lake meets water quality standards.

[6]Hydraulic residence time (0.33 yrs) is on seasonal timescale, therefore existing and allowable loads developed using seasonal values (Jun-Sept). Season is 122 days long (June 1- Sept 30).

Table 61. West Graham Lake (53-0021-00) TP TMDL.

West Graham (53-0021-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**3.2**	**3.2**	**0.009**	**0**	**0%**
	Construction/Industrial Stormwater[1]	3.2	3.2	0.009	0	0%
Load Allocation	**Total LA**	**6,510**	**2,780**	**7.6**	**3,730**	**57%**
	Nonpoint Sources[2]	6,371	2,641	7.2	3,730	59%
	Atmosphere	139	139	0.38	0	0%
Margin of Safety (MOS)[3]			**416**	**1.1**		
Total Load/Loading Capacity		**6,513**	**3,199**	**8.8**	**3,315**	**51%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 13% of loading capacity.

[4]Daily loads are annual loads divided by 365.

East Fork Des Moines River Lake Nutrient TMDLs

Table 62. Bright Lake (46-0052-00) TP TMDL.

Bright (46-0052-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/seas.[6]	lbs/seas.[6]	lbs/day[4]	lbs/seas.[6]	%
Wasteload Allocation	**Total WLA**	**1.8**	**1.8**	**0.015**	**0**	**0%**
	Construction/Industrial Stormwater[1]	1.8	1.8	0.015	0	0%
Load Allocation	**Total LA**	**3,238**	**1,607**	**13**	**1,631**	**50%**
	Nonpoint Sources[2]	2,819	1,409	12	1,410	50%
	Pierce Lake[5]	293	72	0.59	221	76%
	Atmosphere	126	126	1.0	0	0%
Margin of Safety (MOS)[3]			**199**	**1.6**		
Total Load/Loading Capacity		**3,240**	**1,807**	**15**	**1,432**	**44%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.
[2]Includes internal loading, if any.
[3]MOS is 11% of loading capacity.
[4]Daily loads are annual loads divided by 122 days.
[5]Impaired upstream lake; LA assumes outflow from impaired lake meets water quality standards.
[6]Hydraulic residence time (0.36 yrs) is on seasonal timescale, therefore existing and allowable loads developed using seasonal values (Jun-Sept). Season is 122 days long (June 1- Sept 30).

Table 63. Pierce Lake (46-0076-00) TP TMDL.

Pierce (46-0076-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.21**	**0.21**	**0.0006**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.21	0.21	0.0006	0	0%
Load Allocation	**Total LA**	**533**	**182**	**0.50**	**351**	**66%**
	Nonpoint Sources[2]	418	67	0.18	351	84%
	Atmosphere	115	115	0.32	0	0%
Margin of Safety (MOS)[3]			**25**	**0.068**		
Total Load/Loading Capacity		**534**	**207**	**0.57**	**326**	**61%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.
[2]Includes internal loading, if any.
[3]MOS is 12% of loading capacity.
[4]Daily loads are annual loads divided by 365.

Table 64. Temperance Lake (46-0103-00) TP TMDL.

Temperance (46-0103-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/yr	lbs/day[4]	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.17**	**0.17**	**0.0005**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.17	0.17	0.0005	0	0%
Load Allocation	**Total LA**	**478**	**156**	**0.43**	**322**	**67%**
	Nonpoint Sources[2]	417	95	0.26	322	77%
	Atmosphere	61	61	0.17	0	0%
Margin of Safety (MOS)[3]			**17**	**0.048**		
Total Load/Loading Capacity		**478**	**174**	**0.48**	**304**	**64%**

[1]Assumes 0.1% of Allowable Total Load/Load Capacity. Assumes existing permits are being met with current BMPs.

[2]Includes internal loading, if any.

[3]MOS is 10% of loading capacity.

[4]Daily loads are annual loads divided by 365.

Table 65. Minnesota's percentage of the loading capacity for Okamanpeedan Lake (46-0051-00).

MN's % of Loading Capacity: 95%	Existing Phosphorus Load	Allowable Phosphorus Load	
	lbs/seas.	lbs/seas.	lbs/day
Total Load Capacity	32,250	14,439	118
MN Load Capacity	30,638	13,717	112

Table 66. Okamanpeedan Lake (46-0051-00) TP TMDL.

Okamanpeedan (46-0051-00)		Existing Phosphorus Load	Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/ seas.[5]	lbs/ seas.[5]	lbs/day[10]	lbs/ seas.[5]	%
Wasteload Allocation	**Total WLA[1]**	**179**	**408**	**6.9**	**0**	**0%**
	Alpha WTP[6]	0.025	0.68	0.057	0	0%
	Ceylon WWTP[7]	2.8	55	3.9	0	0%
	Sherburn WWTP[8]	162	338	2.8	0	0%
	Construction/Industrial Stormwater[2]	14	14	0.11	0	0%
Load Allocation	**Total LA**	**30,459**	**11,779**	**93**	**18,680**	**61%**
	Atmosphere	201	201	1.7	0	0%
	Nonpoint Sources[3]	27,860	10,873	86	16,987	61%
	Bright Lake[9]	2,208	621	5.1	1,587	72%
	Temperance Lake[9]	190	84	0.69	106	56%
Margin of Safety (MOS)[4]			**1,517**	**12**		
Reserve Capacity			**13**	**0.11**		
Total Load/Loading Capacity		**30,638**	**13,717**	**112**	**16,921**	**55%**

[1]Existing conditions for permitted WWTP WLA is included in the HSPF loads, therefore, included in the LA loading for existing conditions.
[2]Based on assumption that 0.1% of watershed area is in construction/industrial activities at any given time. Assumes existing permits are being met with current BMPs.
[3]Includes any internal loading, if any exists.
[4]MOS is taken as 11% of loading capacity.
[5]Hydraulic residence time (0.03 years) is on seasonal timescale, therefore existing and allowable loads developed using seasonal values (Jun-Sept). Season is 122 days long (June 1- Sept 30). This does not mean TMDL only applies seasonally, just that daily loads were determined from seasonal loads.
[6]Annual WLA is 4.4 lbs/yr for Alpha WTP, based on three 0.015 mgd discharges per month at 1 mg/L.. Seasonal WLA based on four months of three 0.015 mgd discharges per month at 1 mg/L.
[7]Annual WLA is 186 lbs/yr for Ceylon WWTP. Seasonal WLA based on 14 days of discharge at 0.47 mgd and 1 mg/L TP, Table 38.
[8]Annual WLA is 1,011 lbs/yr for Sherburn WWTP. Seasonal WLA based on 122 days of discharge at 0.332 mgd and 1 mg/L TP.
[9]Impaired upstream lake; LA assumes outflow from impaired lake meets water quality standards.
[10]Convential daily load rate is calculated by taking the lbs/season divided by the days in the season (e.g.122 days). Alpha WTP and Ceylon WWTP discharge on a subset of the 122 days in the season as defined by their permits, resulting in the daily total WLA not calculated by the 122 averaging period, which may cause a difference from daily WLA in Table 39. These WLAs based on permits were used to calculate daily total LA and adjust the daily NPSs allocations.

5. Future growth considerations

According to the Minnesota State Demographic Center (MDA 2015), over the next 20 years (2015 to 2035), the populations in the Des Moines River Basin are projected to decrease in all counties (Cottonwood -15%, Lyon -3.1%; Martin -9.3%; Murray -10.7%; Nobles -0.4%; Pipestone -13.8%), except Jackson (1.5%). Like most of Minnesota's counties, this loss of population will likely occur in the rural areas and small towns and will result in a negligible amount of change in land use. The overall population projection for all seven counties is -5.0%. The MPCA does not anticipate significant population growth within the Des Moines River Basin in Minnesota.

5.1 New or expanding permitted MS4 WLA transfer process

Future transfer of watershed runoff loads in this TMDL report may be necessary if any of the following scenarios occur within the project watershed boundaries.

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an urban area at the time the TMDL report was completed but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES Permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL report. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

5.2 New or expanding wastewater (TSS and *E. coli* TMDLs only)

The MPCA, in coordination with the EPA Region 5, has developed a streamlined process for setting or revising WLAs for new or expanding wastewater discharges to waterbodies with an EPA approved TMDL (MPCA 2012b). This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target and will ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying any and all WLAs will be handled by the MPCA, with input and involvement by the EPA, once a permit request or reissuance is submitted. The overall process will use the permitting public notice process to allow for the public and EPA to comment on the permit changes based on the proposed WLA modification(s). Once any comments or concerns are addressed, and the MPCA determines that the new or expanded wastewater discharge is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made.

For more information on the overall process, visit the MPCA's TMDL Policy and Guidance webpage.

5.3 New or expanding wastewater; Reserve Capacity (Nutrient TMDLs only)

A small RC was set aside for Talcot and Okamanpeedan Lakes for future treatment of "unsewered" communities. Because P loading must be reduced substantially to these lakes, there is little capacity for new sources that will result in more P being added. For this reason, only a small RC is available to establish WLAs for the conversion of existing P loads; it is not intended to provide WLAs for new and expanding industrial or municipal discharges. The RC will support projects that address failing or nonconforming septic systems and "unsewered" communities, and will be made available only to new WWTPs or existing WWTPs that provide service to existing populations with failing or nonconforming systems.

6. Reasonable assurance

A TMDL report needs to provide reasonable assurance that water quality targets will be achieved through the specified combination of point and nonpoint source reductions reflected in the LAs and WLAs. According to EPA guidance (EPA 2002), "When a TMDL is developed for waters impaired by both point and NPS, and the WLA is based on an assumption that nonpoint-source load reductions will occur... the TMDL should provide reasonable assurances that nonpoint-source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for the EPA to determine that the TMDL, including the LA and WLAs, has been established at a level necessary to achieve water quality standards". In the Des Moines River Basin considerable reductions in NPS are required.

The MPCA will:

- Evaluate existing programmatic, funding, and technical capacity to implement basin and watershed strategies.
- Identify gaps in current programs, funding, and local capacity to achieve the needed controls.
- Build program capacity for short-term and long-term goals. Demonstrate increased implementation and/or pollutant reductions.
- Commit to track/monitor/assess and report progress at set regular times.

6.1 Regulatory

6.1.1 Construction Stormwater

State implementation of the TMDL report will be through action on NPDES Permits for regulated construction stormwater. To meet the WLA for construction stormwater, construction stormwater activities are required to meet the conditions of the 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 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.

6.1.2 Industrial Stormwater

To meet the WLA for industrial stormwater, industrial stormwater activities are required to meet the conditions of the industrial stormwater general permit or Nonmetallic Mining & Associated Activities general permit (MNG49) under the NPDES program and properly select, install, and maintain all BMPs required under the permit.

6.1.3 Municipal Separate Storm Sewer System (MS4) Permits

Stormwater discharges associated with permitted MS4s are regulated through NPDES/SDS Permits. The Stormwater Program for permitted MS4s is designed to reduce the amount of sediment and pollution that enters surface and ground water from storm sewer systems to the maximum extent practicable. The MS4 permits require the implementation of BMPs to address WLAs. The permit holder must identify BMPs and measurable goals associated with each minimum control measure. NPDES Phase II MS4 Stormwater Permits are in place for approximately 4.15 square miles of the city of Worthington that flows to Okabena Creek in the Des Moines River Headwaters Watershed. Under the Stormwater Program, permit holders are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP must cover six minimum control measures:

- Public education and outreach;
- Public participation/involvement;
- Illicit discharge, detection, and elimination;
- Construction site runoff control;
- Post-construction site runoff controls;
- Pollution prevention/good housekeeping.

The MPCA's MS4 general permit requires MS4 permittees to provide reasonable assurances that progress is being made toward achieving all WLAs in TMDLs approved by the EPA prior to the effective date of the permit. The current permit has been in effect since August, 2013. The MPCA is currently updating the permit and will likely become effective in 2020. MS4 permittees must meet TMDL-related permit requirements for all TMDL WLAs approved by the EPA prior to the effective date of the permit. In doing so, they must determine if they are currently meeting their WLA(s). If the WLA is not being achieved for TSS and TP at the time of application, a compliance schedule is required that includes proposed BMPs or progress toward implementation of BMPs to be achieved during the permit term, the year each BMP is expected to be implemented, a target year the applicable WLA(s) will be achieved, and a cumulative estimate of TSS and TP load reductions (in pounds) to be achieved during the permit term.

If a permitted MS4 has an approved chloride WLA before the effective date of the permit, the new draft MS4 permit language includes requirements to document winter maintenance practices, establish goals for improving winter maintenance practices, and track improvements. The expectation is for permitted MS4s to track progress from the year that implementation of salt reducing BMPs began and report that progress to the MPCA as part of their annual reporting.

There are also some additional draft permit requirements related to chloride that would apply to all permittees. These include requiring permittees to properly store salt, train employees that apply salt, develop a model snow and ice policy, and distribute educational materials related to salt.

The new draft MS4 permit language would require MS4 permittees with a bacteria WLA (approved by the EPA prior to the effective date of the permit) to maintain a written or mapped inventory of potential areas and sources of bacteria (e.g., dense populations of waterfowl or other bird, dog parks). The permittee must also maintain a written plan to prioritize reduction activities to address the areas and sources identified in the inventory. The written plan must include BMPs the permittee will implement over the permit term to reduce bacteria.

There are also some additional draft permit requirements related to bacteria that would apply to all permittees. These include requiring permittees to distribute educational materials focused on pet waste to residents and would also require the permittee's regulatory mechanism to require owners or custodians of pets to remove and properly dispose of feces.

6.1.4 Wastewater NPDES and SDS Permits

The MPCA issues permits for WWTPs and industrial facilities that discharge into waters of the state. Permits have site specific effluent limits for TSS and bacteria (if necessary) that are protective of applicable water quality standards. WWTPs discharging into impaired reaches did not require changes to their discharge permit limits due to the WLAs calculated in this TMDL report for TSS and bacteria. Changes may be necessary by facilities to address TP and chloride on a case-by-case basis. A meeting was held with the permitted facilities to present the TMDLs and explain the impacts to the permit limits, see **Section 9**. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every WWTP treats wastewater. In addition, NPDES and SDS permits set limits and establish controls for land application of waste and byproducts. Since 1996, the MPCA southwest wastewater staff have helped 21 small communities upgrade their sewer systems throughout the region that includes the Des Moines River Basin. Permits for municipal and industrial wastewater dischargers that are found to cause or have a reasonable potential to cause or contribute to the exceedance of a nutrient/eutrophication water quality standard must contain TP effluent limits. Limits must be derived from the standard and consistent with the assumptions and requirements of EPA approved TMDLs.

Permits issued under the NPDES program are required to have effluent limits consistent with the assumptions and requirements of the WLAs in this TMDL report. Attaining the WLAs, as developed and presented in this TMDL report, is assumed to ensure meeting the water quality standards for all of the chloride 303(d) listings. During the permit issuance or reissuance process, wastewater discharges will be evaluated for the potential to cause or contribute to violations of chloride water quality standards. Water Quality Based Effluent Limits (WQBELs) will be developed for facilities whose discharges are found to have a reasonable potential to cause or contribute to chloride above the water quality standards. The WQBELs will be calculated based on low flow conditions, may vary slightly from the TMDL WLAs and will include concentration based effluent limitations.

For municipal WWTPs, technologies capable of removing chloride from wastewater at the WWTP are cost-prohibitive. Some cities may be able to achieve compliance with the final chloride effluent limit by installing centralized softening and taking action to remove chloride sources, which may include encouraging or requiring removal of in home ion-exchange water softeners or the replacement of in home ion-exchange softeners with high efficiency softeners.

For cities who identify a viable path to compliance (whether via wastewater treatment upgrades, central softening, or removal of chloride sources), compliance schedules will be included in their NPDES/SDS permits giving them time to take the necessary actions to comply with the final limit. For cities where compliance would result in substantial and widespread economic and social impact, a city may qualify for a variance (40 CFR 131.14 and 131.10(g)(6) and Minn. R. 7050.0190). A variance would provide time for the respective city to work on identifying sources of chloride, making source reductions (including nonpoint reductions), and evaluating treatment options while still being required to comply with an alternate effluent limit (a limit set to ensure that chloride levels do not increase). Variances are re-evaluated every five years to ensure that complying with the limit would still result in substantial and widespread economic and social impact and that the alternate effluent limit is representative of the highest quality effluent that is attainable by the permittee. The permittee is required to comply with the final limit for total chloride at the end of the variance term.

6.1.5 Subsurface Sewage Treatment Systems Program

SSTS, commonly known as septic systems, are regulated by Minn. Stat. §§ 115.55 and 115.56. Counties and other local government units (LGUs) that regulate SSTS must meet the requirements for local SSTS programs in Minn. R. ch. 7082. Counties and other LGUs must adopt and implement SSTS ordinances in compliance with Minn. R. chs. 7080 through 7083.

These regulations detail:

- Minimum technical standards for individual and mid-size SSTS;
- A framework for LGUs to administer SSTS programs; and
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee.

Compliance inspections by counties and other LGUs are required by Minnesota Rule for all new construction and for existing systems if the LGU issues a permit for the addition of a bedroom. In order to increase the number of compliance inspections, the MPCA has developed and administers several grants to LGUs for various ordinances. Additional grant dollars are awarded to counties that have additional provisions in their ordinance above the minimum program requirements. The MPCA has worked with counties through the SSTS Implementation and Enforcement Task Force to identify the most beneficial way to use these funds to accelerate SSTS compliance statewide. **Figure 36** shows the number of SSTS replaced in the counties that are included in Minnesota’s portion of Des Moines River Basin between 2002 and 2016.

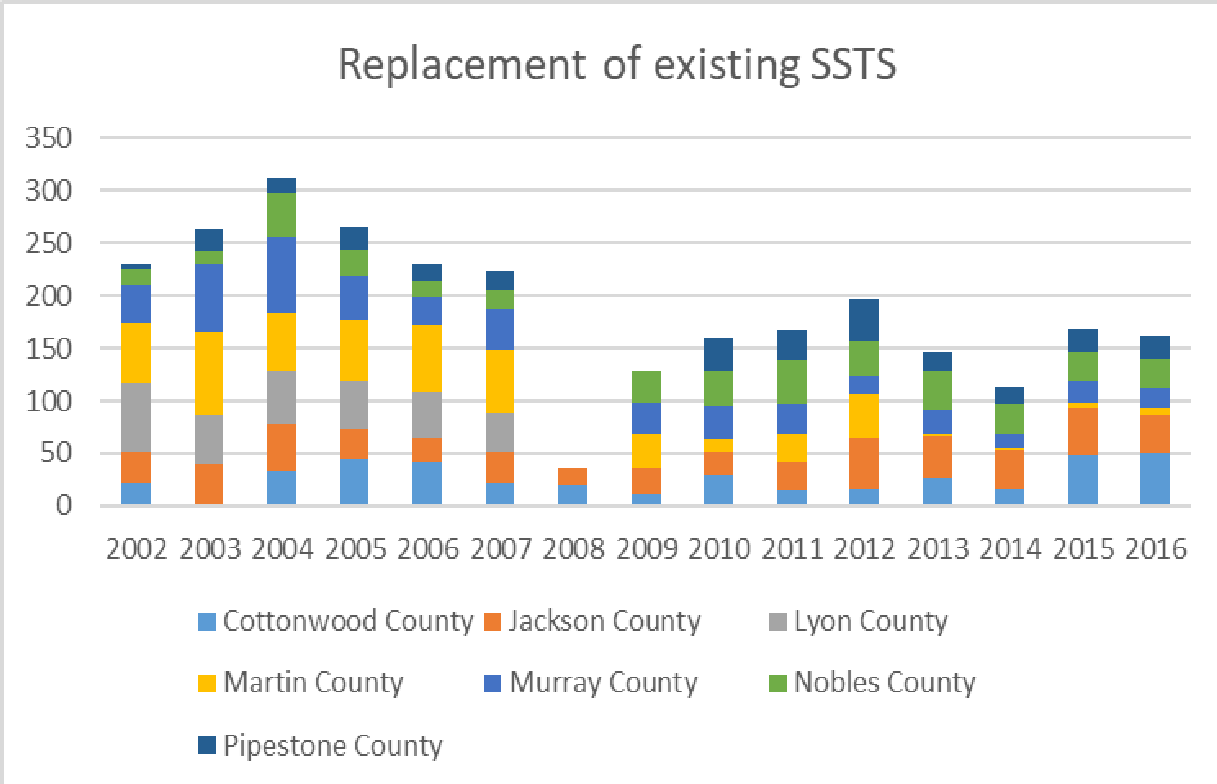

Figure 36. SSTS replacements in the Des Moines River Basin counties between 2002 and 2016.

The MPCA staff keeps a statewide database of potentially unsewered or undersewered areas that could include ITPHS systems. Some of those systems potentially could be straight pipe systems. The counties and LGUs are working on assessing these areas and determining if any individual straight pipes exist. Upon confirmation of a straight pipe system, the county sends out a notice of non-compliance, which starts a 10-month deadline to bring the system into compliance.

6.1.6 Feedlots

All feedlots in Minnesota are regulated by Minn. R. ch. 7020. The MPCA has regulatory authority of feedlots but counties may choose to participate in a delegation of the feedlot regulatory authority to the LGU. Delegated counties are then able to enforce Minn. R. ch. 7020 (along with any other local rules and regulations) within their respective counties for facilities that are under the CAFO threshold. In the Des Moines River Basin, the counties of Cottonwood, Jackson, Lyon, Martin, Murray, Nobles, and Pipestone are delegated the feedlot regulatory authority. The counties will continue to implement the feedlot program and work with producers on manure management plans.

The MPCA regulates the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation waste. The MPCA Feedlot Program implements rules governing these activities and provides assistance to counties and the livestock industry. The feedlot rules apply to most aspects of livestock waste management including the location, design, construction, operation and management of feedlots and manure handling facilities.

There are two primary concerns about feedlots in protecting water:

- Ensuring that manure on a feedlot or manure storage area does not run into water.

- Ensuring that manure is applied to cropland at a rate, time, and method that prevents bacteria and other possible contaminants from entering streams, lakes, and ground water.

6.1.7 Nonpoint Sources

Existing regulations on NPS of pollution are limited. The following are the current, existing nonpoint source statutes/rules in Minnesota:

- 50-foot buffer required for the shore impact zone of streams classified as protected waters (Minn. Stat. § 103F.201) for agricultural land uses. November 1, 2017 was the deadline for compliance. Currently, compliance with the buffer law in the Des Moines River Basin ranges from 80% to 100% (BWSR 2020b).
- 16.5-foot minimum width buffer required on public drainage ditches (Minn. Stat. § 103E.021). November 1, 2018 was the deadline for compliance.
- Protecting highly erodible land within the 300-foot shoreland district (Minn. Stat. § 103F.201).
- Excessive soil loss statute (Minn. Stat. § 103F.415).
- Nuisance nonpoint source pollution (Minn. R. 7050.0210, subp. 2).

6.2 Non-regulatory

6.2.1 Pollutant Load Reduction

Reliable means of reducing nonpoint source pollutant loads are fully addressed in the WRAPS report (MPCA 2020a), a document that is written as a companion to this TMDL report. In order for the impaired waters to meet water quality standards, the majority of pollutant reductions in the Des Moines River Basin will need to come from NPS. Agricultural drainage and surface runoff are major contributors of nutrients, bacteria, sediment, and increased flows throughout the watershed. The BMPs selected in the WRAPS report strategies tables have demonstrated effectiveness in reducing contributions of pollutants to surface water. The Strategies Table A (to meet the full goals) was synthesized from multiple lines of model evidence, including P-BMP, N-BMP, HSPF-SAM, and other models developed for Southern Minnesota. The strategies included in Strategies Table B (to meet the 10-year targets) were developed by the WRAPS Local Work Group, and the BMP efficiencies used to estimate the adoption rates were derived from BMP effectiveness studies such as those summarized in the Minnesota Ag BMP handbook. The Local Work Group selected these strategies based on their local professional knowledge of the watershed in combination with BMP effectiveness and model scenario data.

Selection of sites for BMPs will be led by LGUs, including SWCDs, watershed districts, and counties, with support from state and federal agencies. The Des Moines Basin was selected in 2020 for funding for a One Watershed One Plan planning process grant. These BMPs are supported by programs administered by the SWCDs and the Natural Resource Conservation Service (NRCS). Local resource managers are well-trained in promoting, placing, and installing these BMPs. Some counties within the basin have shown significant levels of adoption of these practices. State and local agencies will need to work with landowners to identify priority areas for BMPs and practices that will help reduce nutrient runoff, as well as streambank and overland erosion. Agencies, organizations, LGUs, and citizens alike need to recognize that resigning waters to an impaired condition is not acceptable. Throughout the course of the WRAPS and TMDL meetings, local stakeholders endorsed the BMPs selected in the WRAPS report. These BMPs reduce pollutant loads from runoff (i.e. P, sediment and pathogens) and loads delivered through drainage tiles or groundwater flow.

From 2004 to 2019, over 4,000 BMPs were installed in the Des Moines River Basin by local partners (MPCA 2020c). **Figure 37** depicts the number of BMPs per subwatershed in the Des Moines River Basin Watersheds. Additional information about the BMPs may be found on the [MPCA's Healthier Watershed website.]

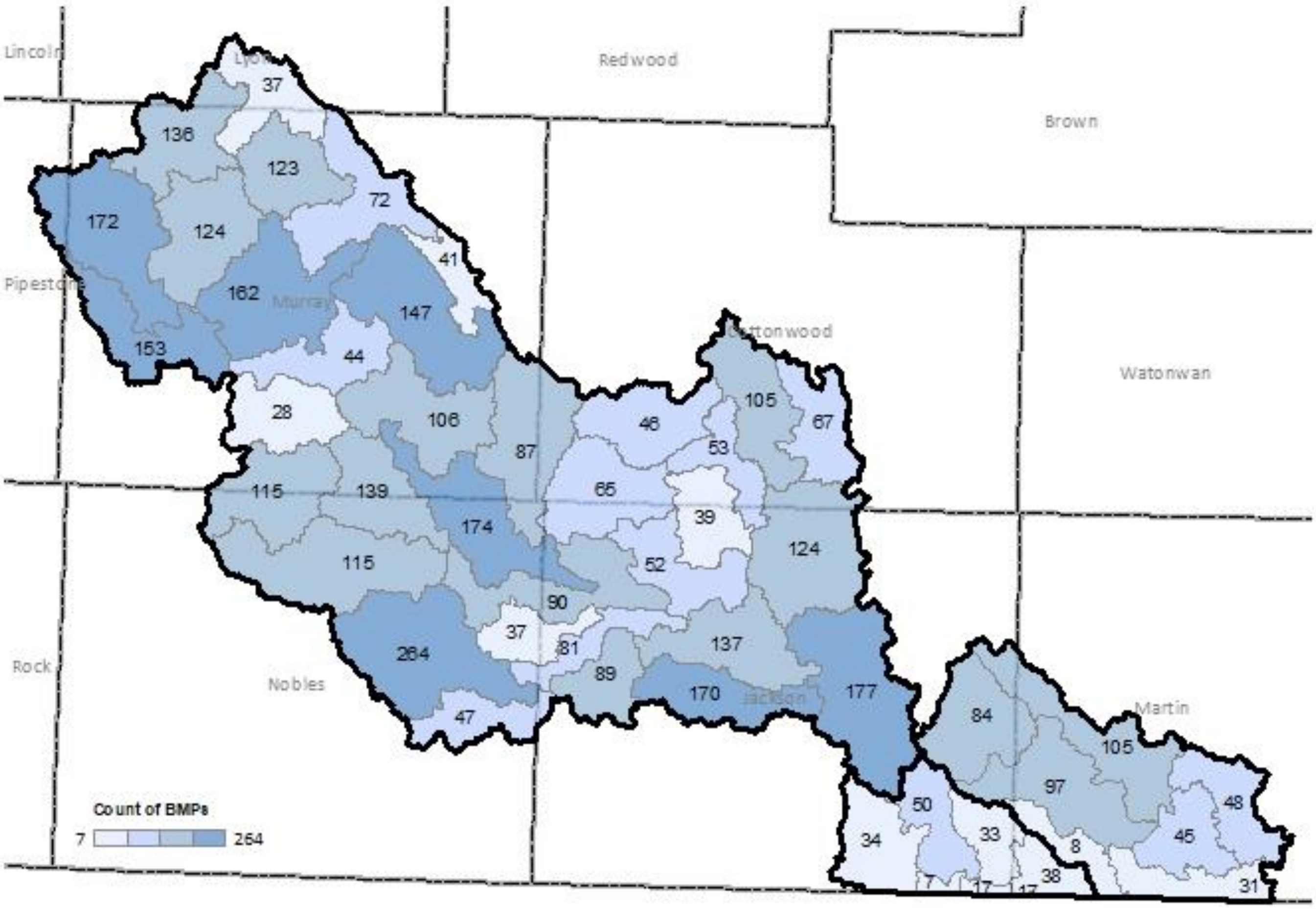

Figure 37. The number of reported BMPs installed by subwatershed in the Des Moines River Basin.

To help achieve nonpoint source reductions, a large emphasis has been placed on public participation, where the citizens and communities that hold the power to improve water quality conditions are involved in discussions and decision-making. The watershed's citizens and communities will need to voluntarily adopt the practices at the necessary scale and rates to achieve the 10-year targets presented in the Des Moines River Basin WRAPS Report. The WRAPS report also presents the pollutant goals and targets to the primary sources and the estimated years to meet the goals developed by the WRAPS Local Work Group. The strategies identified and relative adoption rates developed by the WRAPS Local Work Group were used to calculate the adoption rates needed to meet the pollutant 10-year targets. In addition to public participation, several government programs are in place to support a political and social infrastructure that aims to increase the adoption of strategies that will improve watershed conditions and reduce loading from NPS. **Section 6.2.3** provides funding spent in the basin through these government programs as well as local and landowner contributions.

Minnesota Nutrient Reduction Strategy

The *Minnesota Nutrient Reduction Strategy* (MPCA & Tetra Tech 2014) and the *5-year Progress Report on Minnesota's Nutrient Reduction Strategy* (MPCA et al 2020) guides activities that support nitrogen and P reductions in Minnesota waterbodies and those downstream of the state (e.g., Lake Winnipeg, Lake Superior, and the Gulf of Mexico). The Nutrient Reduction Strategy was developed by an interagency coordination team with help from public input. Fundamental elements of the Nutrient Reduction Strategy include:

- Defining progress with clear goals.
- Building on current strategies and success.
- Prioritizing problems and solutions.
- Supporting local planning and implementation.

Included within the strategy discussion are alternatives and tools for consideration by drainage authorities, information on available tools and approaches for identifying areas of P and nitrogen loading and tracking efforts within a watershed, and additional research priorities. The Nutrient Reduction Strategy is focused on incremental progress and provides meaningful and achievable nutrient load reduction milestones that allow for better understanding of incremental and adaptive progress toward final goals. It has set a reduction of 45% for both P and nitrogen in the Mississippi River, downstream of the Des Moines River Basin.

Successful implementation of the Nutrient Reduction Strategy will require broad support, coordination, and collaboration among agencies, academia, local government, and private industry. The MPCA is implementing a framework to integrate its water quality management programs on a major watershed scale, a process that includes:

- Intensive watershed monitoring.
- Assessment of watershed health.
- Development of WRAPS reports.
- Management of NPDES and other regulatory and assistance programs.

This framework will result in nutrient reduction for the basin as a whole and the major watersheds within the basin.

Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites notes that sites across Minnesota, including the Des Moines River Basin, show reductions over the period of record for TSS, P, ammonia, and biochemical oxygen demand (MPCA 2014). The Minnesota NRS documented a 33% reduction of the P load leaving the state via the Mississippi River from the pre-2000 baseline to current (MPCA 2015). These reports generally agree that while further reductions are needed, municipal and industrial P loads as well as loads of runoff-driven pollutants (i.e. TSS and TP) are decreasing; a conclusion that lends assurance that the Des Moines River Basin WRAPS and TMDL P goals and strategies are reasonable and that long-term, enduring efforts to decrease erosion and nutrient loading to surface waters have the potential to reduce pollutant loads.

Agricultural Water Quality Certification Program

The Minnesota Agricultural Water Quality Certification Program is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect waters. Those who implement and maintain approved farm management practices are certified and in turn obtain regulatory certainty for a period of 10 years.

Through this program, certified producers receive:

- **Regulatory certainty**: Certified producers are deemed to be in compliance with any new water quality rules or laws during the period of certification.
- **Recognition**: Certified producers may use their status to promote their business as protective of water quality.
- **Priority for assistance**: Producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality.

Through this program, the public receives assurance that certified producers are using conservation practices to protect Minnesota's lakes, rivers, and streams. Since the start of the program in 2014, the Ag Water Quality Certification Program as of June 2020 has state-wide:

- Enrolled over 620,000 acres;
- Included over 900 producers;
- Added more than 1,800 new conservation practices;
- Kept over 84 million pounds of sediment out of Minnesota rivers;
- Saved over 230 million pounds of soil and over 46,000 pounds of P on farms; and

As of November 2020, there were 25,209 acres certified in the Des Moines River Basin.

Other NPS Implementation Programs

Federal Section 319 grants and state Clean Water Partnership (CWP) loans have been utilized within the Des Moines River Basin. Section 319 grants are utilized by LGU to work with citizens and landowners to implement nonpoint source conservation practices. These funds also help with education and public participation to help promote the voluntary practices and educate on water quality. CWP grants were also awarded to LGU to implement conservation practices and fund education and public participation activities. CWP loans are loaned out to LGUs and have primarily been utilized to upgrade septic systems within the basin. Section 319 grants are continuing in the South Heron Lake Subwatershed and loans are continuing for septic system upgrades throughout the watershed.

Conservation easements, both permanent and temporary, are a critical component of the state's efforts to improve water quality by reducing soil erosion, P and nitrogen loading, and improving wildlife habitat and flood attenuation on private lands. Easements protect the state's water and soil resources by permanently restoring wetlands, adjacent native grassland wildlife habitat complexes and permanent riparian buffers. In cooperation with county SWCDs and the USDA NRCS, Board of Water and Soil Resources (BWSR) programs compensate landowners for granting conservation easements and establishing native vegetation habitat on economically marginal, flood-prone, environmentally sensitive or highly erodible lands. These easements vary in length of time from 10 years to permanent/perpetual easements. Types of conservation easements in Minnesota include: Conservation Reserve Program (CRP); Conservation Reserve Enhancement Program (CREP); Reinvest in Minnesota (RIM); and the Wetland Reserve Program (WRP) or Permanent Wetland Preserve (PWP) and are implemented throughout Minnesota (**Figure 38**). As of August 2020, in the counties of Cottonwood, Jackson, Lyon, Martin, Murray, Nobles, and Pipestone, there were 70,832 acres of short-term conservation easements such as CRP and 36,179 acres of long term or permanent easements (CREP, RIM, WRP; BWSR 2020a).

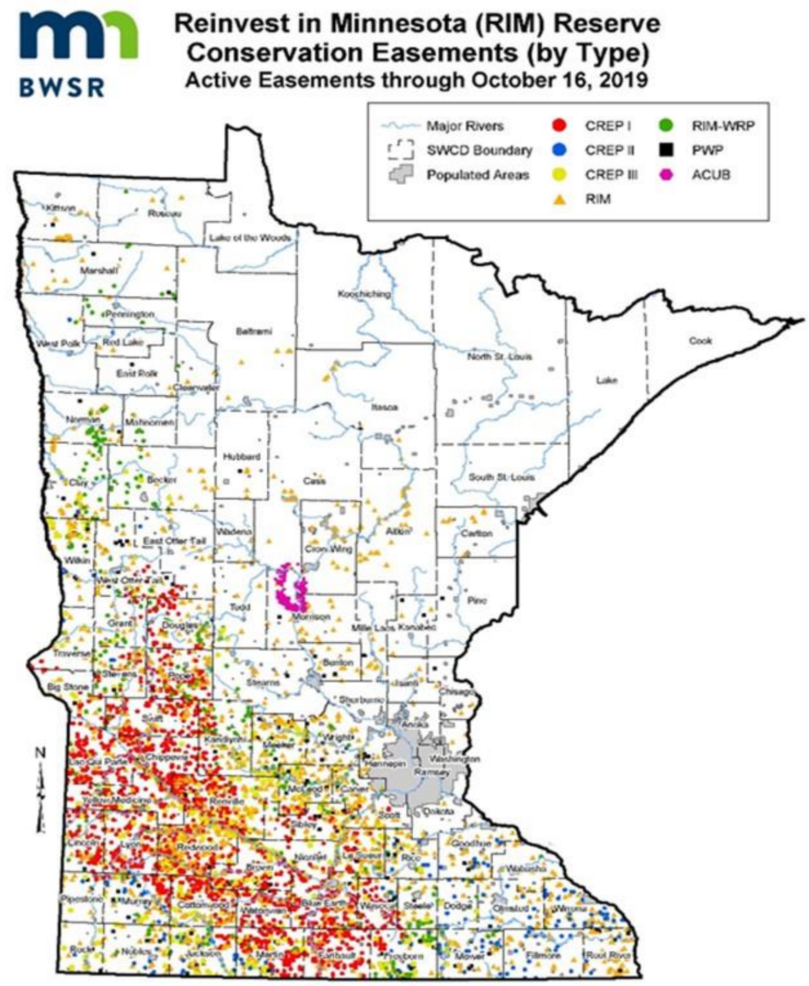

Figure 38. Reinvest in Minnesota Reserve Conservation Easements by county in Minnesota broken out by type.

6.2.2 Prioritization

The Des Moines River Basin WRAPS Report details a number of tools that provide means for identifying priority pollutant sources and implementation work in the watershed. Further, LGUs in the Des Moines River Basin often employ their own local analysis for determining priorities for work.

Light Detection and Ranging (LIDAR) data is available for all of the Des Moines River Basin within Minnesota. It is being increasingly used by LGUs to examine landscapes, understand watershed hydrology, and prioritize BMP targeting.

A Prioritize, Target, and Measure Application (PTMApp) was developed for the Des Moines River Headwaters and Lower Des Moines River watersheds which produced a data set that includes the most cost-effective BMP implementation for identified priority resources, including impaired waters. The PTMApp is being used by LGUs in watershed planning efforts.

6.2.3 Funding

On November 4, 2008, Minnesota voters approved the Clean Water, Land, and Legacy Amendment to the constitution to:

- protect drinking water sources;
- protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat;
- preserve arts and cultural heritage;
- support parks and trails; and
- protect, enhance, and restore lakes, rivers, streams, and groundwater.

This is a secure funding mechanism with the explicit purpose of supporting water quality improvement projects.

Additionally, there are many other funding sources for nonpoint pollutant reduction work; they include but are not limited to CWA Section 319 grant programs, BWSR state Clean Water Fund implementation funding, and NRCS incentive programs. Programs and activities are also occurring at the local government level, where county staff, commissioners, and residents work together to address water quality issues.

Since 2004, over $143 million dollars have been spent addressing water quality issues in the Des Moines River Basin (**Figure 39**). Additional information about funding may be found on the MPCA's Healthier Watersheds website.

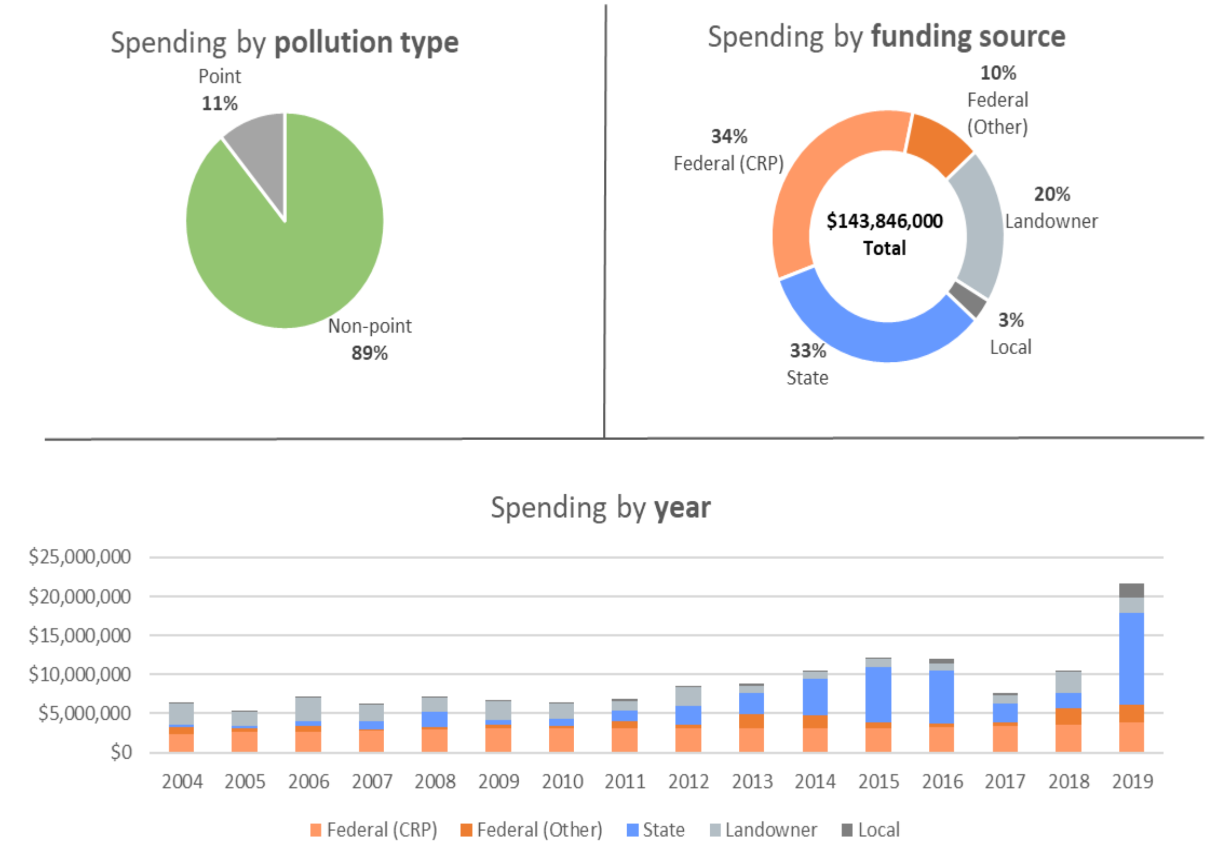

Figure 39. Funds spent in the Des Moines River Headwaters Watershed for conservation practices, shown by pollution type, funding sources and year, according to the MPCA Healthier Watersheds website (MPCA 2020c).

6.2.4 Planning and Implementation

The WRAPS, TMDLs, and all the supporting documents provide a foundation for planning and implementation. Subsequent planning, including imminent development of a "One Watershed-One Plan" for the Des Moines River Basin, will draw on the goals, technical information, and tools to describe in detail strategies for implementation. For the purposes of reasonable assurance, the WRAPS report is sufficient in that it provides strategies for achieving pollutant reduction goals. However, many of the goals outlined in this TMDL report are very similar to objectives outlined in the County Water Plans. These county plans have the same goal of removing streams from the 303(d) impaired waters list. These plans provide watershed specific strategies for addressing water quality issues. In addition, the commitment and support from the LGU will ensure that this TMDL project is carried successfully through implementation.

6.3 Reasonable Assurance Summary

In summary, significant time and resources have been devoted to identifying the best BMPs, providing means of focusing them in the Des Moines River Basin, and supporting their implementation via state initiatives and dedicated funding. The Des Moines River Basin WRAPS and TMDLs process engaged partners to arrive at reasonable examples of BMP combinations that attain pollutant reduction goals. Minnesota is a leader in watershed planning as well as monitoring and tracking progress toward water quality goals and pollutant load reductions. Finally, examples cited herein confirm that BMPs and restoration projects have proven to be effective over time and as stated by the State of Minnesota Court of Appeals in A15-1622 MCEA vs MPCA and MCES.

One stream reach and one lake have contributing areas in Iowa, however, this TMDL Report focuses on Minnesota contributions. It should be noted that Iowa does have planning efforts in place to address NPSs such as Iowa's Nonpoint Source Management Plan (IA DNR 2018). A project was also completed in the Okamanpeedan Lake Watershed (known as Tuttle Lake in Iowa) that installed grassed waterways, filter strips and a wetland restoration resulting in a phosphorus reduction of 85 pounds per year from reaching the lake.

We conclude that substantial evidence exists to conclude that voluntary reductions from NPS have occurred in the past and can be reasonably expected to occur in the future. The Nutrient Reduction Strategy (MPCA & Tetra Tech 2014) provides substantial evidence of existing state programs designed to achieve reductions in nonpoint source pollution as evidence that reductions in nonpoint pollution have been achieved and can reasonably be expected to continue to occur.

7. Monitoring plan

Data from water quality monitoring programs enables water quality condition assessment and creates a long-term data set to track progress towards water quality goals. BMPs implemented by LGUs will be tracked through BWSR's e-Link system. These programs will continue to collect and analyze data in the Des Moines River Basin as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. These monitoring programs are summarized below:

Intensive Watershed Monitoring (MPCA 2012a) data provides a periodic but intensive "snapshot" of water quality throughout the watershed. This program collects water quality and biological data at stream and lake monitoring stations across the basin in one to two years, every ten years. To measure pollutants across the basin, the MPCA will re-visit and re-assess the basin, as well as have capacity to visit new sites in areas with BMP implementation activity. This work is scheduled to start its second iteration in the Des Moines River Basin in 2024.

Watershed Pollutant Load Monitoring Network (MPCA 2013b) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment, and nutrient loads. In the Des Moines River Basin, there is a basin site for the Des Moines River at Jackson, Minnesota and one subwatershed site on the West Fork Des Moines River near Avoca.

Citizen Stream and Lake Monitoring Program (MPCA 2013a) data provide a continuous record of waterbody transparency throughout much of the watershed. This program relies on a network of private citizen volunteers who take monthly lake and river measurements annually. In the last 10 years, there have been 16 volunteer-monitored sites throughout the basin. This has declined to five volunteer-monitored stream locations and no lake locations in 2017.

Local water quality monitoring programs are also utilized to track progress towards water quality goals. The Heron Lake Watershed District's monitoring plan provides long-term data on three streams and six lakes. Water quality sampling, stream elevation gages and discharge measurements are collected yearly to calculate nutrient loads at each stream site. Water quality samples are collected on the lakes once every three years to maintain long-term records. One monitoring site is located on Heron Lake Outlet while the remaining sites are upstream of this reach.

BMPs implemented by LGU will be tracked through BWSR's e-Link system.

8. Implementation strategy summary

The strategies described in this section are potential strategies to reduce chloride, bacteria (*E. coli*), TSS, and lake nutrients (TP) in the three major watersheds of the Des Moines River Basin in Minnesota. A more detailed discussion on implementation strategies can be found in the *Des Moines River Basin WRAPS Report* (MPCA 2020a).

8.1 Permitted sources

8.1.1 Construction stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites with one or more acres expected to be active in the watershed at any one time, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs, and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report. All local construction stormwater requirements must be met.

8.1.2 Industrial stormwater

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

8.1.3 MS4

The General NPDES/SDS Permit requirements must be consistent with the assumptions and requirements of an approved TMDL and associated WLAs. The BMP stormwater control measure requirements are defined in the State's General Stormwater NPDES/SDS Permit (MNR040000). For the purposes of this TMDL report, the baseline year for implementation will be the mid-range year of the data years used for to develop LDCs (2005 through 2014; 2005 represents the median flow conditions). The baseline year for bacteria impairments is 2005. The rationale for developing a baseline year is that projects undertaken recently may take a few years to influence water quality. Any wasteload-reducing BMP implemented since the baseline year will be eligible to “count” toward an MS4’s load reductions. If a BMP was implemented during or just prior to the baseline year, the MPCA is open to presentation of evidence by the MS4 Permit holder to demonstrate that it should be considered as a credit.

8.1.4 Wastewater

The MPCA issues permits for WWTPs that discharge into waters of the state. The permits have site specific limits that are based on water quality standards. WWTPs discharging into impaired reaches did not require any changes to their discharge permit limits due to the WLAs calculated in this TMDL report. Permits regulate discharges with the goals of protecting public health and aquatic life and assuring that every WWTP treats wastewater. In addition, SDS Permits set limits and establish controls for land application of sewage.

For chloride, the impairment is driven by point sources and WWTPs do not currently have permit limits for chloride. Permit limits for chloride will have to be added to new and existing permits to regulate the discharge of chloride into the streams to reduce chloride loads and protect public health and aquatic life.

8.2 Non-permitted sources

A summary of potential BMPs to reduce NPS organized by land use is provided in **Table 67**. Social strategies are also important to improving water quality throughout the basin. These strategies can include education and outreach, improved programs and funding to promote BMPs, collaboration between different groups, and a change of ordinances or rules. Potential BMPs and implementation strategies are explored more thoroughly in the *Des Moines River Basin WRAPS Report* (MPCA 2020a).

Table 67. Summary of BMPs by land use and source type and their primary targeted pollutants.

Land use/Source Type	Des Moines River Watersheds Restoration Strategies and associated BMPs	Targeted Pollutants			
		Sediment	Phosphorus	Bacteria	Chloride
Cultivated Crops	**Add cover crops for living cover in fall/spring**: cover crops on corn/beans, cover crops on early-harvest (canning) crops	x	x	x	
	Decrease tillage: conservation tillage, no-till, strip till, ridge till	x	x	x	
	Decrease fertilizer use: nutrient management, reduced rates, targeted/measured application		x		
	Reduce and treat cropland surface runoff: water and sediment control basins, retention ponds, treatment wetlands, stormwater control structures, field buffers	x	x	x	
	Diversify crops: conversion to small grains, perennial crops, and well-managed pasture	x	x	x	
	Replace or buffer open tile intakes: blind, rock, sand filter intakes, vegetative buffer	x	x	x	
	Reduce and treat cropland tile drainage: Bioreactors, treatment wetlands, saturated buffers, limit new tiles	x	x		
	Convert/protect land for critical habitat (replacing marginally productive and high risk cropped areas): Restore wetlands, conservation cover/CRP, prairie, habitat management, native shrub hedgerows	x	x	x	
Feedlots	**Optimize siting of manure storage**: rainwater diversion (prevent from entering manure storage system) to water source, feedlot manure storage addition, add farm infrastructure to achieve storage/runoff reduction goals (machinery, buildings, roads)		x	x	
	Reduce/treat feedlot runoff: targeting smaller and unpermitted facilities		x	x	
	Optimize feedlot siting: increase distance between livestock and water, move feedlots out of sensitive areas		x	x	
	Smaller facilities and transition to more grazing: encourage small scale facilities and more conservation and cover crop grazing		x	x	
Manure Application	**Improve manure application**: improve placement/setbacks, no application draining to open intakes, equipment upgrades to variable applicators		x	x	

Land use/Source Type	Des Moines River Watersheds Restoration Strategies and associated BMPs	Targeted Pollutants			
		Sediment	Phosphorus	Bacteria	Chloride
Pastures	**Improve pasture/grazing management**: managed/rotational grazing, graze cover crops, remote watering facilities and fencing	x	x	x	
	Restrict livestock access to water bodies: exclusions/fencing, watering facilities	x	x	x	
Stream, ditches, and riparian	**Stream channel, bank, and habitat projects**: stream stabilization, re-connect/ restore flood plains, re-meander channelized stream reaches, and/or stream habitat improvement and management on selected locations within assessed stream miles	x	x	x	
	Reduce ditch impacts: reduce ditch clean-outs, ditch improvements projects include additional water storage practices to mitigate impacts, 2-stage ditches	x	x	x	
	Enhance/improve buffers: improve required buffers with native plants	x	x	x	
Lakes, wetlands, and shoreland	**Restore/protect shoreland**: stabilize/restore shoreline with native vegetation and/or increase distance (buffer) between waterbody and impacts at selected locations within assessed lakes	x	x		
	Manage in-lake/wetland: Drawdowns, wetland enhancements	x	x		
City and residential	**Increase stormwater treatment and storage:** Stormwater ponds, swales, rain gardens/barrels, wetlands, applicable parties follow SWPPPs	x	x	x	
	Improve vegetation: Add and diversify trees, native landscaping, rain gardens	x	x	x	
	Improve road management: Road salt management/education, street sweeping, smart snow stockpiling	x	x	x	x
	Nutrient management: Proper/reduced use of lawn fertilizer, pet waste management		x	x	
	Water softener upgrades				x
Septics/SSTS	**Eliminate unsewered areas and straight pipes**: systems discharging to streams/land surfaces are redirected per SSTS rules		x	x	
	Maintenance and replacement: scheduled maintenance and replace failing systems		x	x	

8.3 Cost

The CWLA requires that a TMDL report include an overall approximation of the cost to implement a TMDL [Minn. Stat. 2007 § 114D.25]. The costs to implement the activities outlined in the *Des Moines River Basin WRAPS* (MPCA 2020a) are approximately $25 to $45 million over the next 20 years. This range reflects the level of uncertainty in the source assessment and addresses the high priority sources identified in **Section 3.6**. The cost includes increasing local capacity to oversee implementation in the watershed and the voluntary actions needed to achieve reductions. Required buffer installation and replacement of ITPHS systems, as legal requirements, are not included.

8.4 Adaptive management

Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using new data and information to reduce uncertainty and adjust implementation activities. The state of Minnesota has a unique opportunity to adaptively manage water resource plans and implementation activities, resulting from a voter-approved tax increase to improve state waters. The resulting interagency coordination effort is referred to as Minnesota Water Quality Framework, which works to monitor and assess Minnesota's major watersheds every 10 years. This Framework supports ongoing implementation and adaptive management of conservation activities and watershed-based local planning efforts utilizing regulatory and non-regulatory means to achieve water quality standards.

Implementation of TMDL related activities can take many years, and water quality benefits associated with these activities can also take many years. As the pollutant source dynamics within the watershed are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reaches and lakes. The follow up water monitoring program outlined in **Section 7** will be integral to the adaptive management approach, providing assurance that implementation measures are succeeding in achieving water quality standards. Adaptive management does not include changes to water quality standards or LC. Any changes to water quality standards or LC must be preceded by appropriate administrative processes, including public notice and an opportunity for public review and comment.

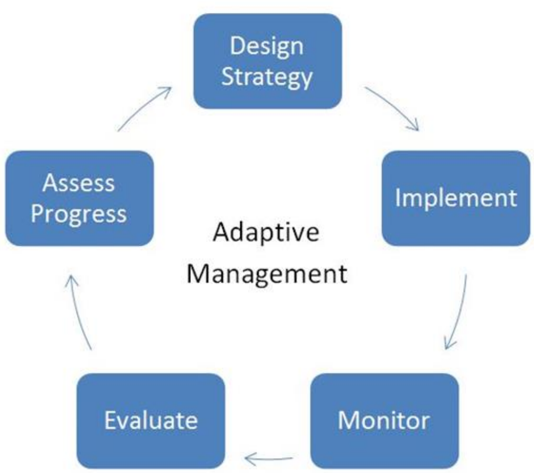

Figure 40. Adaptive management.

A list of implementation strategies in the WRAPS report prepared in conjunction with this TMDL report will focus on adaptive management (**Figure 40**). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for achieving the water quality goals established in this TMDL report. Management activities will be changed or refined to efficiently meet the TMDLs and lay the groundwork for de-listing the impaired water bodies.

9. Public participation

Public participation was a major focus during the Des Moines River Basin project related to WRAPS and the TMDL study. The MPCA worked with county and SWCD staff, the Heron Lake Watershed District, citizens, and other state agency staff in the seven counties to help with education on water quality on impaired reaches and survey citizens regarding water quality issues. Work group involvement related to the TMDL included report development and editing and setting pollution reduction goals. The Iowa Department of Natural Resources was involved with updates of the project and review of the report.

Local partners, state agency staff and consultants worked on two projects to promote public participation and collaboration related to WRAPS and TMDL work in the area. Complete final reports and attachments can be found in the Des River Basin Civic Engagement Project Summary (MPCA 2019b). The following are brief summaries of public participation activities completed within the Des Moines River Basin.

East Fork Des Moines River Watershed Priority Management Zone Strategy

The purpose of this project was to identify community/landowner opportunities, obstacles, and opinions on land management and water quality in the East Fork Des Moines River Watershed and assist in data collection in the East and West Fork Des Moines River Watersheds. Ultimately, this work will help identify land management options for the purposes of surface water quality restoration and protection within the East Fork Des Moines River Watershed. The findings from this project informed the development of the TMDL and WRAPS reports, and can be used in the One Watershed-One Plan process.

West Fork Des Moines River Major Watershed Project

During this project it was determined that civic engagement activities needed to focus on two areas: gathering information from and sharing information with the public and public education in regards to water quality and impaired waters. This was accomplished through citizen surveys, sharing information through social media, and education at six events held throughout the watershed. Information gathered through this project informed the development of the TMDL and WRAPS reports, and can be used in the One Watershed-One Plan process.

Update for municipal wastewater discharge permit holders

A meeting was held in November 2019 with Des Moines Watershed NPDES/SDS permit holders. The purpose of the meeting was to explain existing and new standards and how TMDLs will impact their facilities. TSS, bacteria and P limits where discussed along with how the respective TMDLs will impact NPDES permits. This meeting allowed an opportunity for permit holders to ask questions about TMDL Reports and their specific permits. A follow up email was sent to facilities to provide information that was presented at the meeting.

Public notice

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from December 7, 2020 through January 6, 2021. There were two comment letters received and responded to as a result of the public comment period.

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Appendices

Appendix A: Stream Load Calculations

Loading Capacity Methodology

Data

Observed daily flow data are limited within the DMRB. There is only one USGS station with continuous daily flow data in AUID 07100001-501. Simulated daily mean flows from the DMRB HSPF model (TetraTech 2016) were used to create the LDCs for the remaining AUIDs. The HSPF model simulates flows from 1995-2014. In order to best capture the flow regimes of each AUID, the period 2005 – 2014 was used in development of the LDCs. For AUID 07100001-501, the period 2008-2017 was used to capture the most recent assessment period, since flows during the 2015-2017 period are available. The water quality data used to develop the LDCs were obtained from the MPCA through their EQuIS database and Environmental Data Application (EDA) data portal (https://www.pca.state.mn.us/quick-links/eda-surface-water-data). For the purposes of creating the LDCs, water quality data for 2005-2014 (2008-2017 for AUID 07100001-501) were used to correspond to the flow data. **Table 1A** provides a list of available water quality stations and flow stations or HSPF reaches used to develop the LDCs. It should be noted that not all water quality stations listed in **Table 1A** have data during the time period used to develop the LDCs but are only the water quality sites located in the AUID. Stations with water quality data during the LDC time period are listed in the LDCs and highlighted in **BOLD** in **Table 1A**.

Table 1A. AUIDs with developed LDCs, stressors and data used.

AUID	Pollutant/Stressor	Flow Station USGS or HSPF ID	Available Water Quality Stations
07100001-512	Escherichia coli	HSPF RCHRES 47	**S000-240**, S000-241, S000-242, **S000-269**, S000-270, S000-271
07100001-524	Escherichia coli	HSPF RCHRES 23	S001-735, S001-736, S001-739, S001-804, S001-871, **S007-894**
07100001-527	Escherichia coli	HSPF RCHRES 31	S001-870, **S002-009**, **S007-893**
07100001-551	Turbidity	HSPF RCHRES 28	S001-789, **S009-049** (2016 data only))
07100001-564	Escherichia coli	HSPF RCHRES 75	**S007-891**
07100001-602	Chloride	HSPF RCHRES 43	S000-239, S000-298, S000-786, S000-787, S000-788, **S001-568**, S001-987
07100001-652	Escherichia coli	HSPF RCHRES 67	**S007-890**
07100002-505	Turbidity	HSPF RCHRES 4	S001-875, **S009-059** (2016 data only))
07100003-503	Escherichia coli	HSPF RCHRES 185	**S005-027**
07100003-510	Escherichia coli	HSPF RCHRES 180	**S005-572**, S009-038
07100003-515	Escherichia coli	HSPF RCHRES 187	**S005-024**
07100003-525	Escherichia coli	HSPF RCHRES 179	**S007-813**, S009-278
07100003-527	Escherichia coli, Turbidity	HSPF RCHRES 176	**S000-141**, S000-998, **S001-000**, S005-940

Flow Regimes and Reductions

The existing load, remaining capacity (if any), and percentage of load reduction needed to meet the water quality standard is provided, if available, in **Table 2A** through **Table 15A**. If the existing load is blank for a specific flow regime, there was no water quality data for that load regime. The remaining capacity is the load remaining if the existing load is less than the load capacity of a specific flow regime. If no observed data is available during any of the flow regimes, the existing load, remaining load, and/or estimated load reduction is left blank.

Chloride

Table 2A. Chloride loading capacity for Okabena Creek, Elk Cr to Division Cr (AUID 07100001-602).

Chloride	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[lbs /day]				
Loading Capacity	553,917	140,081	44,397	14,780	7,691
Existing Load	220,965	91,905		15,487	
Remaining Capacity	332,953	48,176		0.0	
Estimated Load Reduction	0%	0%		4.6%	

Escherichia coli

Table 3A. *E. coli* loading capacity for Okabena Creek, Unnamed cr to T102 R38W S6, north line (AUID 07100001-512).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	1,367	495	233	112.7	76.5
Existing Load	3,488	777	287	79.6	53.7
Remaining Capacity	0.00	0.00	0.00	33.1	22.8
Estimated Load Reduction	61%	36%	19%	0%	0%

Table 4A. *E. coli* loading capacity for Des Moines River, Heron Lk outlet to Windom Dam (AUID 07100001-524).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	8,719	3,316	1,405	350.0	99.2
Existing Load	10,795	6,906	11.1	157.2	
Remaining Capacity	0.00	0.00	1,393	192.8	
Estimated Load Reduction	19%	52%	0%	0%	

Table 5A. *E. coli* loading capacity for Heron Lake Outlet, Heron Lk (32-0057-01) to Des Moines R (AUID 07100001-527).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	3,763	1,557	718	184.2	62.6
Existing Load	3,757	668	273	73.0	25.3
Remaining Capacity	6.5	889.3	445.4	111.2	37.3
Estimated Load Reduction	0%	0%	0%	0%	0%

Table 6A. *E. coli* loading capacity for Unnamed creek, Unnamed ditch to Jack Cr (AUID 07100001-564).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	349	121	44	3.7	1.2
Existing Load	153	346	11	3.1	
Remaining Capacity	196.0	0.0	33.4	0.6	
Estimated Load Reduction	0%	65%	0%	0%	

Table 7A. *E. coli* loading capacity for Jack Creek, North Branch, JD 12 to Jack Cr (AUID 07100001-652).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	510	182	79	25.7	9.3
Existing Load	3,714	1,214	174	25.9	
Remaining Capacity	0.0	0.0	0.0	0.0	
Estimated Load Reduction	86%	85%	55%	1%	

Table 8A. *E. coli* loading capacity for County Ditch 11, Headwaters to E Fk Des Moines R (AUID 07100003-503).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	2,408	571	166	44.2	9.9
Existing Load	1,730	204	27	14.0	1.9
Remaining Capacity	678.0	367.2	139.1	30.2	8.0
Estimated Load Reduction	0%	0%	0%	0%	0%

Table 9A. *E. coli* loading capacity for Fourmile Creek, JD 105 to Des Moines R (AUID 07100003-510).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	191	44	12	2.7	0.3
Existing Load	1,631	361	6	3.1	1.0
Remaining Capacity	0.0	0.0	6.0	0.0	0.0
Estimated Load Reduction	88%	88%	0%	14%	66%

Table 10A. *E. coli* loading capacity for County Ditch 1/Judicial Ditch 50, Unnamed cr to CD 11 (AUID 07100003-515).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	295	68	19	4.2	0.5
Existing Load	1,436	154		7.4	
Remaining Capacity	0.0	0.0		0.0	
Estimated Load Reduction	79%	56%		43%	

Table 11A. *E. coli* loading capacity for Des Moines River, East Branch, Unnamed cr to CD 11 (AUID 07100003-525).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	958	221	60	14.0	1.9
Existing Load	7,985	1,391	235	18.2	
Remaining Capacity	0.0	0.0	0.0	0.0	
Estimated Load Reduction	88%	84%	74%	23%	

Table 12A. *E. coli* loading capacity for Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk (AUID 07100003-527).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[CFU/day]				
Loading Capacity	1,650	388	110	28.0	5.5
Existing Load	3,150	957	152	30.9	6.1
Remaining Capacity	0.0	0.0	0.0	0.0	0.0
Estimated Load Reduction	48%	59%	28%	9%	9%

Total Suspended Sediment (Turbidity)

Table 13A. TSS loading capacity for Unnamed creek, String Lk to Des Moines R (AUID 07100001-551).

Total suspended solids	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[tons/day]				
Loading Capacity	5.24	1.77	0.78	0.30	0.13
Existing Load					
Remaining Capacity					
Estimated Load Reduction					

Table 14A. TSS loading capacity for Judicial Ditch 56, Unnamed cr to Des Moines R (AUID 07100002-505).

Total suspended solids	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[tons/day]				
Loading Capacity	13.35	4.35	1.72	0.75	0.29
Existing Load					
Remaining Capacity					
Estimated Load Reduction					

Table 15A. TSS loading capacity for Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk (AUID 07100003-527).

Total suspended solids	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[tons/day]				
Loading Capacity	101.24	24.08	6.99	1.94	0.40
Existing Load		17.3	2.1	1.0	0.3
Unallocated Load		6.7	4.9	1.0	0.0
Estimated Load Reduction		0%	0%	0%	0%

Appendix B: Lake Modeling

Introduction

The CNET models were calibrated to the assumed average condition in each lake using the mean observed in-lake water quality condition and watershed inputs (flow and TP loading) from twenty-one years (1994-2014) simulated in the DMRB Hydrologic Simulation Program Fortran (HSPF) model (TetraTech, 2016). Following calibration, the models were used for stochastic simulations using Crystal Ball^{TM}, a Monte Carlo simulator. The stochastic simulations result in distributions of in-lake eutrophication conditions based on statistical distributions of input parameters. The stochastic modeling approach reflects the variability in forcing data (e.g., the terms in the hydrologic budget and mass balance) and model parameters used to represent processes in natural systems (e.g., nitrification rate). This allows for a more realistic prediction of long-term water quality condition. Finally, load reduction scenarios were developed for each lake to estimate the required load reduction needed to meet current lake eutrophication water quality standards. This analysis used the best available data at the time of this study.

Lake Morphology

The required inputs to the CNET model, for each lake simulation, include basic morphology characteristics such as: surface area, mean depth, direct drainage area, and total drainage area. **Table 1B** lists the required morphometric characteristics for the modeled lakes in the DMRB. The morphometric characteristics displayed in **Table 1B** are in U.S. customary units and are converted to the international system of units (SI) (i.e., the metric system) for use in the CNET models.

For the purposes of this report, direct drainage area is defined as the area that contributes water directly to the lake via overland flow in the absence of a defined tributary. Total drainage area is the total area that contributes water to the lake and includes areas that drain into the lake through upstream tributaries and non-contributing areas, for example.

The primary data sources used for lake morphometric characteristics were the MN DNR LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html) and the *Des Moines River Basins in Minnesota Monitoring and Assessment Report* (MPCA 2017).

Table 1B: Morphometric characteristics of modeled lakes.

Lake Name	AUID	HUC08	Surface Area [acres]	Mean Depth [ft]	Direct Drainage Area [sq-mi]	Total Drainage Area [sq-mi]
North Oaks	17-0044-00	07100001	333	6.0	8.5	8.5
Talcot	17-0060-00	07100001	844	6	11.4	519.4
Boot	32-0015-00	07100001	151	6	0.76	0.76
Flahtery	32-0045-00	07100001	417	6	6.8	6.8
Teal	32-0053-00	07100001	90	8.0	1.6	1.6
Heron (Duck)	32-0057-02	07100001	307	8	7.4	7.4
Timber	32-0058-00	07100001	194	8.0	2.1	2.1

Lake Name	AUID	HUC08	Surface Area [acres]	Mean Depth [ft]	Direct Drainage Area [sq-mi]	Total Drainage Area [sq-mi]
Yankton	42-0047-00	07100001	396	8	1.85	1.85
Okamanpeedan	46-0051-00	07100003	2233	7	16	196.2
Bright	46-0052-00	07100003	639	5.0	3.6	20.3
Pierce	46-0076-00	07100003	429	8.0	2.0	2.0
Temperance	46-0103-00	07100003	153	5.0	1.5	1.5
Lime	51-0024-00	07100001	318	6	3	58.9
Bloody	51-0040-00	07100001	257	11	1.4	2.3
Fox	51-0043-00	07100001	180	9	0.90	0.90
Shetek	51-0046-00	07100001	3477	10	17	129.9
Corabelle	51-0054-00	07100001	104	8.0	0.8	0.8
Sarah	51-0063-00	07100001	1164	4	7.3	20
Currant	51-0082-00	07100001	391	8	2.4	3
East Graham	53-0020-00	07100001	469	8	5.6	36.5
West Graham	53-0021-00	07100001	519	8	2.8	18.4

Water Budget

A lake's water budget is an accounting of the amount of water entering and leaving a lake over a given time period. This modeling effort assumes a seasonal (summer months, June to September) time period for modeling the lakes if the hydrologic residence time is less than one year and assumes an annual time period if the hydrologic residence time of the lake is greater than a year. The amount of water moving in and out of a system varies from year-to-year, dictated primarily by the seasonal variation of precipitation occurring in the area. It is important to quantify the water budget because different sources of water can contain different quantities of pollutants and the amount of water entering and leaving the lake determines the hydraulic residence time, which impacts the lake's eutrophication response. Additionally, the water budget is important because it is used during hydrologic and water quality modeling for model calibration and validation purposes. A water budget accounts for "gains" in water to the lake (including precipitation, surface water runoff, tributary inflow, and groundwater inflow) as well as "losses" (including evaporation, surface outflow, and groundwater outflow). Each of these affects the volume of water in the lake (i.e. storage).

The water budget components accounted for in this study are: **Precipitation**, the amount of water entering the lake directly from precipitation landing on the lake's surface; **Direct drainage inflow**, the water flowing to the lake from the contributing drainage area, including both surface and groundwater inputs; **Tributary inflow**, the amount of water flowing into the lake from upstream basins, usually from stream sources; **Evaporation**, the water leaving the surface of the lake through evaporative processes; **Surface outflow**, the water leaving the lake through surface outlets (usually a stream); and **Storage**, the change in the water stored in the lake due to lake level increases or decreases. Any groundwater flows are lumped into direct drainage, tributary flow, and/or outflow.

The average annual water budgets for the modeled lakes of the DMRB were estimated by using climate forcing data and flow data from the DMRB's HSPF model. A brief discussion about the DMRB HSPF model is provided in the ***Model Development and Application*** section. CNET/BATHTUB is a steady-state model, assuming no change in average lake storage during a time step. This simply means that the elevation of the lake at the beginning of each year is the same, on average. As such, the simulated change in the storage term was assumed to be zero in the models created. The average water budgets for the modeled lakes are shown in **Table 2B**, using units of acre-feet per year (ac-ft/yr).

Table 2B. Average water budgets for the modeled lakes in the Des Moines River Basin.

Lake Name	AUID	Inflows [ac-ft/yr]			Outflows [ac-ft/yr]	
		Precipitation	Direct Drainage Inflow	Tributary Inflow	Evaporation	Outflow
North Oaks	17-0044-00	794	2,790	0	1,001	2,583
Talcot	17-0060-00	2,045	7,288	179,934	3,924	185,344
Boot	32-0015-00	361	277	0	400	238
Flahtery	32-0045-00	1,004	2,324	0	1,478	1,851
Teal	32-0053-00	216	626	0	319	523
Heron (Duck)	32-0057-02	735	2,882	0	1,088	2,529
Timber	32-0058-00	461	758	0	505	714
Yankton	42-0047-00	925	550	0	1,402	73
Okamanpeedan	46-0051-00	2,724	2,870	32,966	4,593	33,968
Bright	46-0052-00	1,571	1,505	8,110	2,210	8,976
Pierce	46-0076-00	1,054	821	0	1,367	507
Temperance	46-0103-00	371	729	0	477	624
Lime	51-0024-00	769	1,018	17,346	1,125	18,008
Bloody	51-0040-00	599	387	403	910	480
Fox	51-0043-00	420	403	0	604	219
Shetek	51-0046-00	8,112	5,132	44,999	12,311	45,932
Corabelle	51-0054-00	246	283	0	263	266
Sarah	51-0063-00	2,715	2,367	5,600	4,121	6,561
Currant	51-0082-00	912	763	247	1,384	538
East Graham	53-0020-00	1,123	1,706	10,304	1,679	11,455
West Graham	53-0021-00	1,275	744	5,446	1,839	5,627

Total Phosphorus Mass Balance

Similar to a water budget, a TP mass balance accounts for the amount of TP entering and exiting a lake over a given time period. TP amounts are expressed as loads, in units of mass per time, or for the purposes of this study, kilograms per year (kg/yr). The nutrient loads are estimated by considering the concentration of TP in the water and the amount of water entering and exiting the lake over the time period. The TP mass balance accounts for both “gains” (e.g., surface water runoff) as well as “losses” (e.g., outflows) from the lake. A typical lake TP mass balance accounts for direct drainage area loading, tributary loading, atmospheric deposition, internal loading, sedimentation/retention, and outflow. Groundwater outflow mass is assumed to be equal to inflow mass. Each of the TP balance components is explained in more detail below.

In the case of the DMRB lakes, TP mass balances were estimated using the DMRB HSPF model results. The average annual TP mass balances, as calculated by the CNET models, are provided in **Table 3B**. Most lakes in the DMRB retain (Sedimentation column in **Table 3B**) a large portion of their TP loading.

Table 3B. Average annual TP nutrient mass balances for modeled lakes in the Des Moines River Basin.

Lake Name	AUID	Gains [kg/yr]			Losses [kg/yr]	
		Atmospheric Deposition	Direct Drainage Load	Tributary Load	Sedimentation	Outflow Load
North Oaks	17-0044-00	40	1,896	0	1,141	796
Talcot	17-0060-00	102	2,699	3	3,670	85,390
Boot	32-0015-00	18	109	0	66	61
Flahtery	32-0045-00	51	1,282	0	900	432
Teal	32-0053-00	11	276	0	146	141
Heron (Duck)	32-0057-02	37	1,646	0	1,012	671
Timber	32-0058-00	24	227	0	75	175
Yankton	42-0047-00	48	354	0	390	12
Okamanpeedan	46-0051-00	134	243	2,642	1,160	1,859
Bright	46-0052-00	78	590	2,806	1,542	1,931
Pierce	46-0076-00	52	187	0	170	69
Temperance	46-0103-00	19	190	0	30	179
Lime	51-0024-00	39	515	9,052	3,993	5,612

Lake Name	AUID	Gains [kg/yr]			Losses [kg/yr]	
		Atmospheric Deposition	Direct Drainage Load	Tributary Load	Sedimentation	Outflow Load
Bloody	51-0040-00	30	250	112	332	61
Fox	51-0043-00	22	112	0	108	26
Shetek	51-0046-00	411	3,694	25,930	23,128	6,907
Corabelle	51-0054-00	13	130	0	83	59
Sarah	51-0063-00	138	1,831	3,980	4,870	1,079
Currant	51-0082-00	46	501	67	522	92
East Graham	53-0020-00	57	1,073	3,941	2,210	2,861
West Graham	53-0021-00	63	489	2,407	1,860	1,098

Direct Drainage Loading

The amount of TP entering each lake from its direct drainage was estimated using the outputs of the DMRB HSPF model. Phosphorus values for the sub-basins containing each lake were extracted from the model. Since all modeled lakes were explicitly modeled in the HSPF model, the TP loadings were extracted from the inflows to the RCHRES (the modeling unit for waterbodies in HSPF) using the PLANK parameter group.

Tributary Loading

TP entering a lake, from upstream lakes and/or sub-basins, and transported by a stream or river, is known as tributary loading. Tributary loadings were extracted from the outflows of the modeled tributary RCHRES.

Atmospheric Loading

The rates of atmospheric deposition of TP onto each of the simulated lakes were set equal to those used in the Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) modeling program. MINLEAP is a program developed by Wilson and Walker (1989) to provide predictive techniques to assess common lake problems based on ecoregion. The lakes in the DMRB use an estimated mean annual atmospheric deposition load of 30 kg/km^2/year. When summer values are used, the ratio of summer precipitation to average annual precipitation is used to estimate the summer atmospheric deposition.

Potential Internal Loading

Internal loading is the re-release of TP from sediments, usually due to anoxic conditions (dissolved oxygen concentrations < 2.0 mg/L) near the bed of the lake. Internal phosphorus loading can be a substantial part of the mass balance in a lake, especially in lakes with a history of high phosphorus loads. If a lake has a long history of high phosphorus concentrations, it is possible to have internal loading rates higher than external loads.

Internal loading can be estimated using methodology developed by Nurnberg (1984, 1988, 2009). Internal loading is estimated by adding an internal loading term to the current models based on external loading and predicted retention (Nurnberg 1984):

$$TP = {}^{L_{ext}}/_{q_s}\left(1 - R_{pred}\right) + {}^{L_{int}}/_{q_s} \qquad [1]$$

where TP is the in-lake TP concentration (ug/L); L_{ext} is the external load (kg/yr), q_s is the lake outflow (hm^3/yr), R_{pred} is the predicted retention coefficient, and L_{int} is the internal loading (kg/yr). The retention coefficient can be estimated using:

$$R_{pred} = {}^{15}\Big/\left(18 + {}^{q_s}/_{A}\right) \qquad [2]$$

Where A = surface area of the lake (km^2). The only unknown in [1] and [2] is internal loading and it can be estimated by solving for L*int*.

Using [1] and [2], the potential for internal loading was checked for the modeled lakes. No lake in the DMRB showed any signs of substantial internal loading rates. This makes sense since all the lakes are shallow and have a short hydrologic residence time. Internal loading is most often found in deeper lakes, where stratification over long periods can create the anoxic conditions needed for sediment release.

Retained Mass & Error

Other in-lake processes (sedimentation, nutrient uptake, etc.) were not explicitly accounted for in the TP balances, but rather lumped into a retained mass and error term (sedimentation in **Table 3B**). The retained mass and error term is the difference between TP inputs and TP outputs (i.e., retained mass + error = TP inputs – TP outputs).

Surface Outflow Loading

The amount of TP exiting each lake through surface water outflow is known as surface outflow load and was calculated (using CNET) by taking the in-lake TP concentration and applying it to the lake's outflow. The average surface water outflow loadings computed for each lake, in kg/yr, are given in **Table 3B**.

Model Development and Application

Two models were used to develop the TMDL components for lakes in the DMRB, HSPF and CNET. The HSPF model was used to estimate precipitation, evaporation, surface runoff, and TP loadings for drainage areas to each lake. A complete description of the HSPF model can be found in the modeling report for the DMRB HSPF model (TetraTech, 2016).

The in-lake water quality model CNET is a modified version of the BATHTUB model developed for use with a spreadsheet program (e.g. Microsoft Office Excel). This spreadsheet version allows for the use of Crystal Ball^{TM}, a Monte Carlo simulator, to create stochastic simulations and develop distributions of in-lake eutrophication conditions based on statistical distributions of input parameters. The stochastic modeling approach reflects the variability in forcing data (e.g., the terms in the hydrologic budget and mass balance) and model parameters used to represent processes in natural systems (e.g., nitrification rate). This allows for a more realistic prediction of long-term water quality conditions. CNET models provide a summary of the predicted distributions of mean annual TP, Chl-*a*, and Secchi disk depths in the lakes. Load reduction scenarios were developed for each lake to estimate the required load reduction needed to meet current lake water quality eutrophication standards.

Watershed Modeling

Modeling results from the DMRB's HSPF model (TetraTech, 2016) were used to develop the inputs to the in-lake water quality CNET models. The hydrologic/TP budget components taken from the HSPF model include precipitation, potential evapotranspiration (assumed to be equal to evaporation), contributing drainage area runoff volume, contributing drainage area TP load, tributary flow, and tributary TP load. Data from the DMRB's HSPF model were available from 1993 through 2014 for daily, monthly, and annual timescales at the sub-basin scale. In order to include as much climate and loading variability into the lake models, the whole modeling period 1994-2014 was used. The first year, 1993, was used as a model warm-up period (TetraTech, 2016). Therefore, it was not used in the lakes modeling effort.

HSPF model results for RCHRES inflows are reported as total inflows of water and nutrients (e.g., runoff is reported in acre-feet and TP loading is reported as pounds per year). To use the outputs from HSPF in CNET, a few unit transformations were necessary. For precipitation and evaporation, CNET uses per unit area values and only required a unit transformation from inches to meters per year. For the contributing drainage area contributions (surface water and tributary flows and loads), units were transformed from acre-feet per year for hydrology and pounds per year for TP to cubic hectometers per year and kilograms per year, respectively.

Table 4B contains a summary of the contributing drainage areas (direct and tributary) feeding into each lake and the HSPF sub-basin (RCHRES ID) that each modeled lake lies within.

Table 4B: HSPF sub-basin IDs for modeled lakes in the Des Moines River Basin.

Lake Name	AUID	Total Drainage Area [km^2]	Direct Drainage Area [km^2]	HSPF Sub-basin ID	HSPF Sub-basin ID(s) for Tributary inflows
North Oaks	17-0044-00	22.12	22.12	153	NA
Talcot	17-0060-00	1,345	29.5	90	91, 92
Boot	32-0015-00	1.96	1.96	15	NA
Flahtery	32-0045-00	18	17.6	39	NA
Teal	32-0053-00	4.14	4.14	36	NA
Heron (Duck)	32-0057-02	19	19.3	83	NA
Timber	32-0058-00	5.31	5.31	33	NA
Yankton	42-0047-00	4.8	4.8	146	NA
Okamanpeedan	46-0051-00	508.2	41.5	171	172, 173, 176, 190
Bright	46-0052-00	52.49	9.23	191	192
Pierce	46-0076-00	5.06	5.06	194	NA

Lake Name	AUID	Total Drainage Area [km²]	Direct Drainage Area [km²]	HSPF Sub-basin ID	HSPF Sub-basin ID(s) for Tributary inflows
Temperance	46-0103-00	4.01	4.01	189	NA
Lime	51-0024-00	152.6	7.7	95	96, 103
Bloody	51-0040-00	6	3.7	148	149
Fox	51-0043-00	2.33	2.33	149	NA
Shetek	51-0046-00	336.4	44	126	127, 128, 129, 130,134, 147, 148
Corabelle	51-0054-00	1.98	1.98	74	NA
Sarah	51-0063-00	51.7	18.9	131	132
Currant	51-0082-00	7.8	6.3	143	144
East Graham	53-0020-00	94.7	14.4	76	77, 81
West Graham	53-0021-00	47.7	7.3	77	78

The average hydrology and TP balances from the HSPF model for the modeled lakes are given in **Tables 2B** and **3B**; results are shown as average volumes/loads as calculated by the CNET models.

In-Lake Water Quality Modeling

In-lake water quality was simulated using the CNET program. CNET is a spreadsheet version of the BATHTUB model currently available as a “beta” version from Dr. William W. Walker (URL: http://www.wwwalker.net/bathtub/index.htm). BATHTUB and CNET are steady-state models that simulate eutrophication-related water quality conditions in lakes and reservoirs. BATHTUB is designed to facilitate the application of empirical eutrophication models to reservoirs or lakes. It is a 1-D steady state model that formulates water and nutrient balances that account for advective transport, diffuse transport, and nutrient sedimentation.

The primary modification to BATHUB to develop the CNET model was the implementation of a Monte Carlo approach, which allowed selected modeling inputs to vary, based upon known or assumed statistical distributions, and to be reflected in the forecasted results. The Monte Carlo approach generates a statistical distribution of the yearly mean TP and Chl-*a* concentrations and Secchi disk depth, reflecting the uncertainty in the model parameters and normal variability in inputs (e.g., annual TP load from surface runoff) as well as correlation among inputs (e.g., runoff and load). Crystal Ball (a proprietary software developed by Oracle; https://www.oracle.com/applications/crystalball/) was used to perform the Monte Carlo simulations. A benefit of using the stochastic approach is the addition of probabilistic variability to forcing data to compile a distribution of responses that cannot usually be achieved in a steady-state model.

CNET Model Calibration

The modeling period for the CNET models was 1994-2014. All available in-lake water quality data was used in calibrating the CNET models and the models were calibrated to the period-averaged condition. Individual years were used to validate the models.

The CNET model relies on a variety of sub-models (i.e., empirical equations for estimating sedimentation) for computing eutrophication dynamics within a lake and to provide the ability to simulate eutrophication dynamics in lakes with differing in-lake processes. The first step in calibrating the CNET models was to select the best (sub-) model for simulating in-lake TP, Chl-*a*, and Secchi depths. The "best" (sub-) models were determined by finding the model with its calibration coefficient closest to 1.

The selected models varied from lake to lake; the following were used in the DMRW lakes:

- Total Phosphorus Models
  - Model 4: Canfield & Bachman (1981), Reservoirs,
  - Model 5: Vollenweider (1976), Northern Lakes,
  - Model 7: First Order Settling,
  - Model 8: Canfield & Bachman (1981), Natural Lakes, or
  - Model 9: Canfield & Bachman (1981), Reservoirs + Lakes
- Chl-*a* Models
  - Model 2: P, Light, Flushing, or
  - Model 5: P, Exponential, Jones & Bachman (1976)
- Secchi Disk Models
  - Model 1: Secchi vs Chl-*a* and Turbidity, or
  - Model 4: Carlson TSI (1977), Lakes

Full descriptions of each (sub-) model can be found in the BATHUB documentation (Walker 2014). The type of sub-model used for each lake, the associated calibration coefficients, and comparisons between observed and modeled TP, chl-a, and Secchi disk depth are provided in the lake summaries in the Appendices.

Sometimes the calibration coefficients are outside of the expected range (0.5-2). These higher/lower than expected calibration coefficients are likely caused by one or a combination of factors:

1. lack of extensive observed in-lake water quality data;
2. uncertainty within the HSPF model results;
3. the false assumption that the average loading used for calibration correlates to the average
    a. observed in-lake water quality data;
4. differences between the lakes used to develop the empirical eutrophication response models and
    a. the lake being modeled; and/or
5. lack of internal loading data.

The quality of each lake's CNET model calibration (i.e., the final values of the calibration coefficients) was considered when interpreting the results of the modeling, including the recommended TP load reductions.

Stochastic Simulations

The benefit of using CNET over the traditional BATHTUB model is the ability to perform stochastic simulations. Stochastic modeling is an approach where model input values (e.g. terms in hydrologic budget) and model parameters used in the equations to compute the in-lake mean concentration of TP and Chl-*a* and Secchi disk depth, are allowed to vary according to their observed statistical distribution and therefore their probability of occurrence. This allows the effect of parameter uncertainty and normal variability in the inputs (e.g., amount of surface runoff and nutrient load, which varies depending upon the amount of precipitation) to be quantified when computing the in-lake mean concentration of TP, Chl-*a* and Secchi disk depth.

Using the Crystal Ball software allowed for multiple probabilistic model computations. Many trial values (10,000 trials in this modeling effort) were generated with each trial representing a different permutation of model input values within the bounds established by the statistical distributions. The many trials resulted in a computed distribution of expected in-lake water quality for each lake rather than a single, deterministic output that was based upon only one possible combination of model inputs. Select inputs, primarily those components of the water budget or TP mass balance, were allowed to vary during the Monte Carlo simulation. The selected inputs are precipitation, evaporation, atmospheric deposition, direct drainage inflows and loadings, and tributary inflows and loadings.

Crystal Ball was used to develop the model input statistical distributions based on the previously mentioned HSPF hydrologic and TP loading yearly values for the period 1994-2014. Crystal Ball was used to choose the distribution based on the best fit of the data for most parameters. In addition to the probability distributions correlation coefficients were added to account for links between certain hydrologic and loading parameters (e.g., direct drainage inflow is driven by and, therefore, correlated to precipitation). Correlations between precipitation and evaporation, atmospheric deposition, direct drainage runoff and loadings, and tributary runoff and loadings were applied. Direct loading and tributary flows and loadings were correlated to direct inflow. Tributary flows were correlated to tributary loadings.

When appropriate, the model input statistical distributions were truncated to prevent erroneous values and/or modeling errors (e.g., negative TP loading rates). These truncations included: minimum values of precipitation, maximum values of evaporation, and minimum values of inflows and loadings. The minimum and/or maximum allowable values were set to the minimum or maximum values during the period of record (1994-2014) used to construct the distribution.

Eutrophication Response, Loading Capacity, & Recommended Reductions

Load Reduction Scenarios

The benefit of using CNET over the traditional BATHTUB model is the ability to perform stochastic simulations. Stochastic modeling is an approach where model input values (e.g. terms in hydrologic budget) and model parameters used in the equations to compute the in-lake mean concentration of TP and Chl-*a* and Secchi disk depth, are allowed to vary according to their observed statistical distribution and therefore their probability of occurrence. This allows the effect of parameter uncertainty and normal variability in the inputs (e.g., amount of surface runoff and nutrient load, which varies depending upon the amount of precipitation) to be quantified when computing the in-lake mean concentration of TP, Chl-*a* and Secchi disk depth.

Using the Crystal Ball software allowed for multiple probabilistic model computations. Many trial values (10,000 trials in this modeling effort) were generated with each trial representing a different permutation of model input values within the bounds established by the statistical distributions. The many trials resulted in a computed distribution of expected in-lake water quality for each lake rather than a single, deterministic output that was based upon only one possible combination of model inputs. Select inputs, primarily those components of the water budget or TP mass balance, were allowed to vary during the Monte Carlo simulation. The selected inputs are precipitation, evaporation, atmospheric deposition, direct drainage inflows and loadings, and tributary inflows and loadings.

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When appropriate, the model input statistical distributions were truncated to prevent erroneous values and/or modeling errors (e.g., negative TP loading rates). These truncations included: minimum values of precipitation, maximum values of evaporation, and minimum values of inflows and loadings. The minimum and/or maximum allowable values were set to the minimum or maximum values during the period of record (1994-2014) used to construct the distribution.

This approach is consistent with MPCA guidance (MPCA, 2007), which assumes that if a lake meets the state's TP water quality standard that Chl-*a* and Secchi disk depth within the system will respond accordingly and eventually also reach the state-defined goals (even if the results of the CNET modeling do not predict this result). This approach assumes that data collected and extensively analyzed by the MPCA during standards development provides a more accurate estimate of how lakes will respond when moved from an impaired to unimpaired state than the relationships that exist within the CNET program. This reduction process was applied to all lakes and results are summarized below and detailed results are provided by lake in the Appendices.

Eutrophication Response

The CNET modeling provides a range of eutrophication results. An example of these responses is provided here. Actual results from the various lake models is provided in the Appendices. **Figure 1B** shows an example of the frequency distribution of TP concentrations and **Table 5B** shows the numeric values used to construct the figure**. Figure 1B** and **Table 5B** illustrate the results of incrementally reducing loads within the CNET model. This example is taken from analysis for Talcot Lake. The reduced loads were assumed to come from contributing drainage area loading and any tributary loading. However, the same response would occur regardless of the sources (e.g., including internal load). Each line in **Figure 1B** represents a different loading scenario and the red dashed line represents the TP water quality standard target. It is assumed the lake will meet the water quality standard if the in-lake TP concentrations are lower than the water quality standard 50 percent of the time.

For the example, the median initial in-lake TP concentration is 252.3 µg/L and the TP loading is 40,096 kg/yr. **Figure 1B** and **Table 8** show a reduction of 64 percent is needed to meet the water quality standard of 90 µg/L 50 percent of the time. This results in a load reduction of 25,661 kg/yr, a loading capacity of 24,058 kg/yr, and an in-lake TP concentration of 90.0 µg/L (**Table 8**).

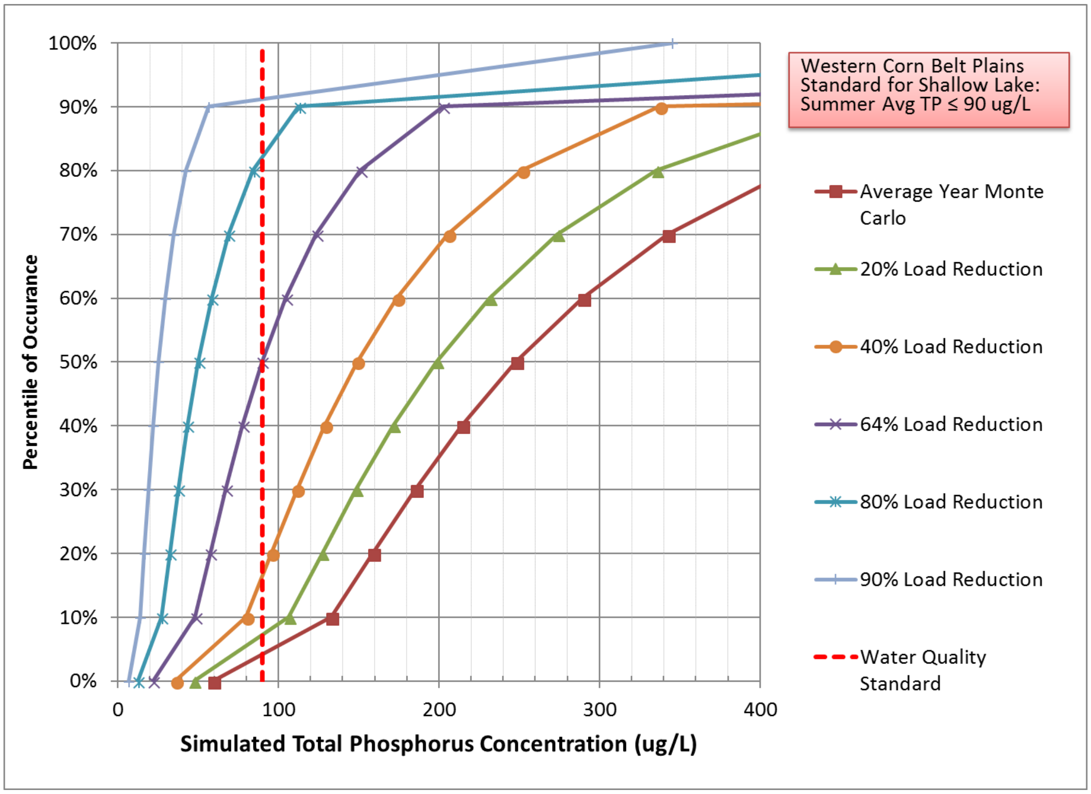

Figure 1B. Example of the frequency distribution of mean annual TP concentrations resulting from select load reduction scenarios.

Table 5B. Example of Monte Carlo simulation TP loading reduction results (µg/L)

Non-Exceedance Percentile	Average Year Monte Carlo	20% Load Reduction	40% Load Reduction	64% Load Reduction	80% Load Reduction	90% Load Reduction
TP Total Load	40,096 kg/yr	32,077 kg/yr	24,058 kg/yr	14,435 kg/yr	8,019 kg/yr	4,010 kg/yr
0%	76.2	61.4	46.6	26.6	16.9	9.5
10%	140.6	113.6	87.1	50.6	32.9	18.6
20%	165.3	133.8	102.3	59.8	39.0	22.3
30%	190.6	154.1	117.6	68.3	44.6	25.6
40%	220.5	177.6	135.0	77.5	50.1	28.7
50%	252.3	203.2	154.2	87.8	56.0	31.9
60%	291.3	234.2	176.9	100.2	63.7	35.7
70%	345.7	277.4	209.7	117.6	73.4	40.4
80%	422.4	338.7	255.1	142.9	88.7	47.7
90%	566.2	453.4	341.6	189.9	116.8	61.3
100%	3041.5	2433.8	1826.0	1005.5	610.5	306.6

In some cases, not all of the frequency distribution for a given load reduction is shown on the graph. **Figure 1B** is a good example of this. In these cases, extreme values in the distribution, typically resulting from combinations of very high runoff, precipitation, and/or other parameters, lead to occurrences with very high concentrations. The x-axis display scale was chosen to ensure all load reduction scenarios and the average year scenarios were clearly displayed up to the point of expected maximum TP concentration within reason.

The results of the CNET modeling and load reduction scenarios for each of the impaired lakes are summarized in **Table 6B**. **Table 6B** includes the specific TP water quality standard that applies to the individual lake, the simulated existing conditions TP concentration and loading into the lake as estimated by the average condition, the absolute load reduction (in kilograms per year) required to meet the TP water quality standard, the percent load reduction required to meet the TP water quality standard, and the loading capacity of the lake (i.e., the TP loading when the water quality standard is met).

These results provide the loading capacity of the lake to meet water quality standards. It is important to note that the simulated initial mean TP concentration values presented in **Table 6B** are those computed under the Monte Carlo simulations. In most cases, these values are higher than those that were observed and to which the models were calibrated, due to the fact that the values in **Table 6B** are based on distributions of model inputs and not limited by the observed dataset.

Table 6B: Results of the load reduction scenarios for modeled lakes in the Des Moines River Basin.

Lake Name	AUID	TP Standard [µg/L]	Simulated Initial Mean In-Lake TP Conc. [µg/L]	Existing Conditions TP Load (kg/yr)	Absolute TP Load Reduction [kg/yr]	TP Load Reduction [%]	Loading Capacity [kg/yr]
North Oaks	17-0044-00	90	249.7	1936.4	1491.0	77%	445.4
Talcot	17-0060-00	90	408.6	89,059	27,608	31%	61,451
Boot	32-0015-00	90	206.4	126.9	86.3	68%	40.6
Flahtery	32-0045-00	90	189.4	706.6	473.4	67%	233.2
Teal	32-0053-00	90	218.7	286.7	177.7	62%	108.9
Heron (Duck)	32-0057-02	90	215.2	1,683	1,161	69%	521.8
Timber	32-0058-00	90	199.0	250.1	152.6	61%	97.5
Yankton	42-0047-00	90	134.0	401.6	204.8	51%	196.8
Okamanpeedan	46-0051-00	90	212.4	34,992	19,596	56%	15,397
Bright	46-0052-00	90	149.2	3,473	1,598	46%	1,876
Pierce	46-0076-00	90	193.3	239.3	55.0	23%	184.2
Temperance	46-0103-00	90	233.0	209.0	146.3	70%	62.7
Lime	51-0024-00	90	212.5	9,606	5,475	57%	4,130
Bloody	51-0040-00	90	102.4	392.8	58.9	15%	333.9
Fox	51-0043-00	90	97.1	134.1	12.1	9%	122.0
Shetek	51-0046-00	90	121.9	30,035	10,212	34%	19,823
Corabelle	51-0054-00	90	180.8	142.2	58.3	41%	83.9

Lake Name	AUID	TP Standard [µg/L]	Simulated Initial Mean In-Lake TP Conc. [µg/L]	Existing Conditions TP Load (kg/yr)	Absolute TP Load Reduction [kg/yr]	TP Load Reduction [%]	Loading Capacity [kg/yr]
Sarah	51-0063-00	90	133.3	5,949	2,736	46%	3,212
Currant	51-0082-00	90	138.8	613.9	313.1	51%	300.8
East Graham	53-0020-00	90	172.6	5,071	2,485	49%	2,586
West Graham	53-0021-00	90	158.2	2,959	1,539	52%	1,420

The TP load reductions range from 9% to 77% (**Table 6B**). The modeling results may be influenced by one or a combination of factors:

1. lack of extensive observed in-lake water quality data;
2. uncertainty within the HSPF model results;
3. the assumption that the mean annual loading used for calibration correlates to the mean observed
    a. in-lake water quality data (only available for two years);
4. simulated hydrology and TP loadings form 1994-2014 can be representative of observed water
    a. quality from the same period; and/or
5. unknown sources/sinks of phosphorus or inflows.

To account for this uncertainty in the development of the TMDL, a margin of safety was added.

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Appendix C: Heron Lake Modeling

Heron Lakes

Heron Lakes consists of a chain of four lakes: North Heron, South Heron, Heron (Duck), and Heron (Marsh) Lakes. Three of the four lakes (North, South, and Duck) are listed on the MPCA's 303(d) list of impaired waters for excessive nutrients. This modeling effort focuses on two of the Heron Lakes, North Heron (32-0057-05) and South Heron (32-0057-07). North Heron and South Heron Lakes are located in the Des Moines River Headwaters 8-digit hydrologic unit code (HUC08) 07100001, in southwestern Minnesota. The drainage areas for both lakes are shown in **Figure 1C**, along with major point sources.

In 2008, a TMDL was completed for both North Heron Lake and South Heron Lake in the *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* (MPCA, 2008). The MPCA wanted to revisit the TMDLs for North and South Heron Lake due to the completion of the Des Moines River Basin (DMRB) Hydrologic Simulation Program-Fortran (HSPF) model and updated in-lake water quality data.

For each lake simulation, the required inputs to the CNET lake eutrophication model include basic morphology characteristics such as: lake surface area, mean depth, direct drainage area, and total drainage area. **Table1C** lists the morphometric characteristics for the modeled lakes. The morphometric characteristics displayed in **Table1C** are in U.S. customary units and are converted to the international system of units (SI) (i.e., the metric system) for use in the CNET models. For the purposes of this TM, direct drainage area is defined as the area that contributes water directly to the lake via overland flow in the absence of a defined tributary. Total drainage area is the total area that contributes water to the lake and includes areas that drain into the lake through upstream tributaries and non-contributing areas, for example. The primary data sources used for lake morphometric characteristics (**Table1C**) were the MN DNR LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html) and the *Des Moines River Basins in Minnesota Monitoring and Assessment Report* (MPCA 2017).

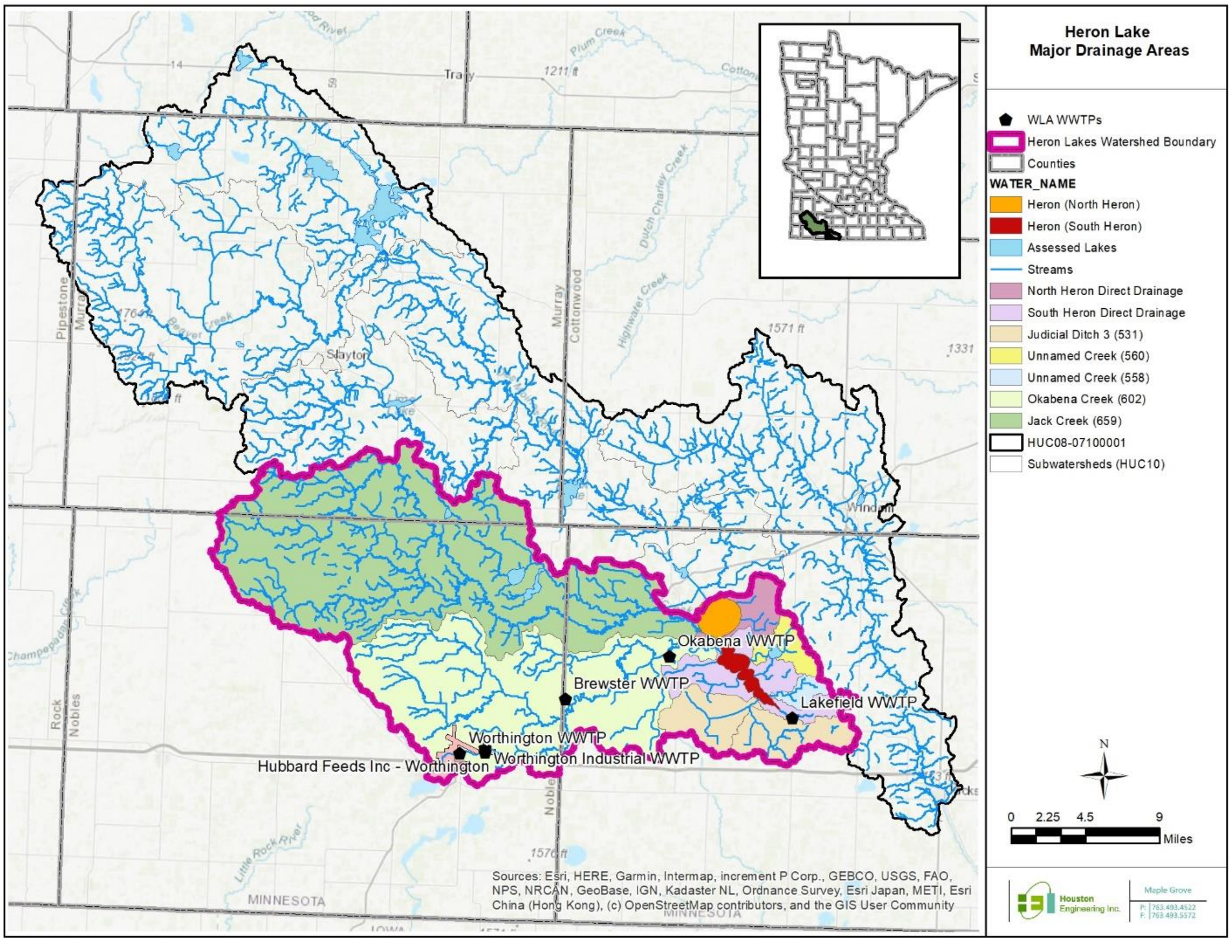

Figure 1C. Drainage areas and point sources for North Heron and South Heron Lakes.

Table 1C. Morphometric characteristics for North Heron and South Heron Lakes.

Lake Name	AUID	Surface Area [acres]	Max Depth [ft]	Direct Drainage Area [sq-mi]	Total Drainage Area [sq-mi]	Surface Area: Drainage Area
North Heron	32-0057-05	3,204	5	13.8	428.9	0.012
South Heron	32-0057-07	2,670	5	25.2	68.2	0.061

Table2C provides the drainage areas of the major tributaries to North Heron and South Heron Lakes and their percentage of total watershed area. South Heron Lake drains 68.2 square miles and has 3 major tributaries: Unnamed Creek, Unnamed Creek, and Judicial Ditch 3. North Heron Lake total drainage area is 428.9 square miles and has 2 major tributaries (Okabena Creek and Jack Creek) and generally receives the outflow from South Heron Lake.

Table 2C. Drainage areas of major tributaries.

Drainage Area (Last 3 digits of AUID)		Area [acres]	Area [sqmi]	Percent of Watershed
South Heron Lake (32-0057-07)	Direct Drainage	16,116	25.2	36.9%
	Unnamed Ck (560)	5,133	8.0	11.8%
	Unnamed Ck (558)	2,489	3.9	5.7%
	Judicial Ditch 3 (531)	19,880	31.1	45.6%
	Total Drainage Area	**43,618**	**68.2**	
North Heron Lake (32-0057-05)	Direct Drainage	8,859	13.8	3.2%
	Okabena Ck (602)	88,106	137.7	32.1%
	Jack Cr (659)	133,908	209.2	48.8%
	South Heron Lake	43,618	68.2	15.9%
	Total Drainage Area	**274,492**	**428.9**	

The drainage pattern between North and South Heron Lakes is complicated. Okabena Creek generally flows into North Heron Lake but passes nearby South Heron Lake. During high flows, Okabena Creek will spill over into South Heron Lake. In addition, there is significant marshland between the two lakes and they are hydrologically connected through groundwater flow. The difference in water surface elevations between the two lakes is generally one foot. During high flow events, flows between the lakes and Okabena Creek can be muddled. For modeling purposes, it is assumed 5% of the flow and TP loading from Okabena Creek enters South Heron Lake and the remainder enters North Heron Lake.

Current Water Quality Conditions

In-lake Water Quality

Water quality data for North Heron and South Heron Lakes were obtained from the MPCA through their EQuIS database and Environmental Data Application (EDA) data portal (https://www.pca.state.mn.us/quick-links/eda-surface-water-data). The average water quality conditions are provided in **Table 3C** and include both a summary of all existing data and the data used to calibrate the CNET models. The average water quality condition for the modeling was taken as the period from 2005-2014, a ten-year period for the last year of loads from the HSPF model. This period was used instead of the current assessment period (2007-2016) to have consistency with the runoff and TP loadings data from the HSPF model that were used in the CNET models. For purposes of this study, the average water quality condition is defined as the mean of all available data. In addition to the average water quality conditions, **Table 3C** shows the observation period and the number of observations for each lake eutrophication parameter used in computing the average condition.

Table 3C. Current and modeling period water quality conditions for Heron Lakes.

Lake Name	AUID	Observation Period		TP n	TP Mean [µg/L]	Chl-*a* n	Chl-*a* Mean [µg/L]	Secchi Disk Depth n	Secchi Disk Depth Mean [m]
North Heron	32-0057-05	Available data	2005-2014	14	350	12	161	10	0.205
		Modeling Period	1989-2016	42	477	30	152	33	0.304
South Heron	32-0057-07	Available data	2005-2014	14	373	12	105	0	
		Modeling Period	1989-2016	78	671	63	155	28	0.526

Watershed Loading

Watershed loading was extracted from the DMRB's HSPF watershed model (TetraTech, 2016). The HSPF model is a comprehensive package for the simulation of watershed hydrology, sediment transportation, and water quality for conventional and toxic organic pollutants. HSPF incorporates the watershed-scale Agricultural Runoff Model (ARM) and NPS models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes, and in-stream hydraulic and sediment-chemical interactions.

Precipitation, evaporation, runoff/flow, and phosphorus loading were extracted from the HSPF model. Data from the DMRB's HSPF model were available from 1993 through 2014 for daily, monthly, and annual timescales at a sub-basin spatial scale. In order to include as much climate and loading variability into the lake models, the whole modeling period 1994-2014 was used. The first year, 1993, was used as a model warm-up period (TetraTech, 2016). Therefore, it was not used in the lakes modeling effort.

Figure 2C and **3C** show the distribution of TP loading to South Heron Lake and North Heron Lake, respectively, by major tributary and source. **Table 4C** provides the annual and seasonal (June-September) total flows and TP loading for each lake and major tributary or source. In addition to flow and TP loading, the flow-weighted mean concentration (FWMC) for each source/tributary is given.

For South Heron Lake (**Figure 2C**), the distribution of TP loading generally follows the distribution of drainage area (see **Table 2C**Table). Lakefield Wastewater Treatment Plant (WWTP) outflows directly into South Heron Lake, therefore, is considered a major source and contributes about 2.2% of the total TP load. Atmospheric deposition contributes about 2.6%.

For North Heron Lake (**Figure 3C**), the majority of phosphorus comes from Okabena Creek, due to a large load from the WWTPs in the drainage area. Unlike Lakefield WWTP in South Heron Lake, the WWTPs that outflow into Okabena Creek are included in the HSPF loads for Okabena Creek. According to the HSPF model, point sources contribute about 28% of the load to North Heron Lake, with most of the remaining load coming from cropland runoff (~67%). About 11% of the load to North Heron Lake comes from South Heron Lake, with the remaining TP load to North Heron Lake coming from various other sources.

Many of the tributaries to both lakes have high annual FWMCs, ranging from 312 ug/L in Jack Creek to 759 ug/L in Okabena Creek.

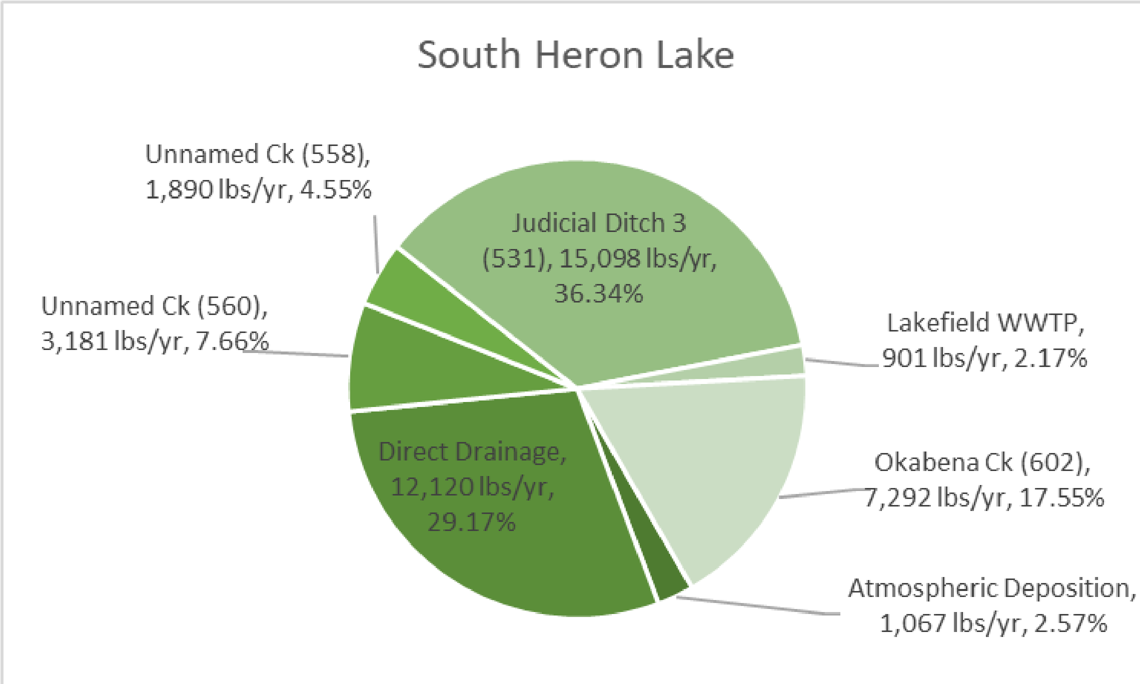

Figure 2C. TP load distribution to South Heron Lake (32-0057-07) by major tributary/source.

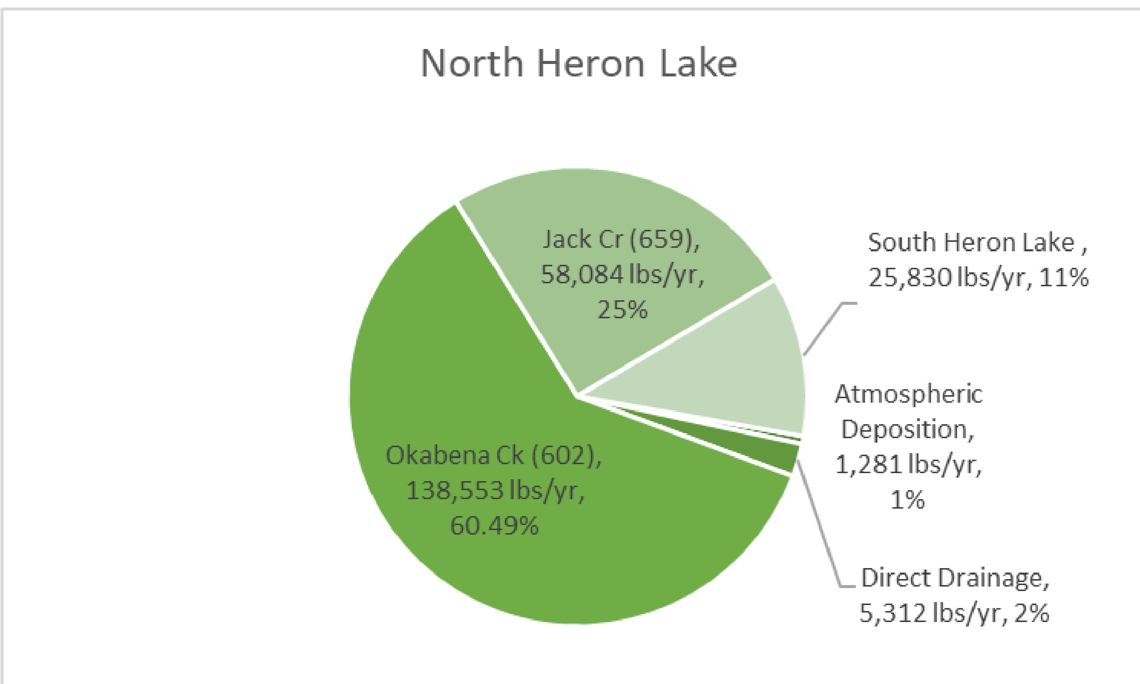

Figure 3C. TP load distribution to North Heron Lake (32-0057-05) by major tributary/source.

Table 4C. Existing annual and seasonal TP loads by major tributary to North Heron and South Heron Lakes.

Lake/Source		Average Annual Loads			Average Seasonal Loads (Jun-Sept)		
		Runoff	TP	FWMC TP	Runoff	TP	FWMC TP
		[acre-ft/ yr.]	[lbs./yr.]	ug/L	[acre-ft/ seas.]	[lbs./seas.]	ug/L
South Heron Lake (32-0057-07)	Precipitation/Atmospheric Deposition	6,394	1,067		6,394	545	
	Direct Drainage	7,968	12,120	559	3,674	5,693	570
	Unnamed Ck (560)	2,312	3,181	506	960	1,363	522
	Unnamed Ck (558)	1,504	1,890	462	701	1,024	537
	Judicial Ditch 3 (531)	11,685	15,098	475	5,445	8,109	548
	Lakefield WWTP	232	901	1431	85	315	1362
	Okabena Ck (602)[2]	3,534	7,292	759	1,455	2,890	731
	Total Loading	**33,629**	**41,550**	**454***	**18,714**	**19,938**	**392***
North Heron Lake (32-0057-05)	Atmospheric Deposition	7,673	1,281		3,916	654	
	Direct Drainage	4,086	5,312	478	1,792	2,593	532
	Okabena Ck (602)	67,148	138,553	759	27,638	54,911	731
	Jack Cr (659)	68,448	58,084	312	26,861	25,279	346
	South Heron Lake[1]	25,153	25,830	378	12,137	10,233	310
	Total Loading	**172,508**	**229,060**	**488***	**72,345**	**93,670**	**476***

[1]Outflows for South Heron Lake taken from the CNET model.
[2]Assumed 5% of runoff/load spill into South Heron Lake.
* Overall FWMC

CNET Modeling

In-lake water quality was simulated using the CNET program. CNET is a spreadsheet version of the BATHTUB model currently available as a "beta" version from Dr. William W. Walker (URL: http://www.wwwalker.net/bathtub/index.htm). BATHTUB and CNET are steady-state models that simulate eutrophication-related water quality conditions in lakes and reservoirs. BATHTUB is designed to facilitate the application of empirical eutrophication models to reservoirs or lakes. It formulates water and nutrient balances that account for advective transport, diffuse transport, and nutrient sedimentation. A more detail discussion of the CNET can be found in the technical memorandum "Des Moines River Basin Lake Modeling", dated June 7, 2018 (HEI, 2018). This TM is supplemental to it.

Eutrophication Response, Loading Capacity, & Recommended Reductions

The results of the CNET modeling are summarized in **Table 5C**, including the specific TP water quality standard that applies to each lake, the simulated existing TP concentration and loading into the lake as estimated by the average condition, the absolute load reduction (in pounds per year) required to meet the TP water quality standard, the percent load reduction required to meet the TP water quality standard, and the loading capacity of the lake (i.e., the TP loading when the water quality standard is met).

These results provide the loading capacity of the lake to meet water quality standards and are the basis for the TMDL. It should be noted that the absolute load reduction is taken as the difference between the existing loading conditions and the load capacity, but are not equal to the existing conditions multiplied by the load reduction percent. This is due to loads that are included in the existing load calculation but are not subject to the load reductions, such as atmospheric deposition and outflow from Lakefield WWTP (set to a 1 mg/L concentration).

Table 5C. TP load capacity and load reductions based on CNET modeling effort.

Lake Name	AUID	TP Standard [µg/L]	Simulated Initial Mean In-Lake TP Conc. [µg/L]	Existing Conditions TP Load (lbs./yr.)	TP Load Reduction [%]	Absolute TP Load Reduction [lbs./yr.][1]	Loading Capacity [lbs./yr.]
North Heron	32-0057-05	90	393.2	228,134	81%	182,608	45,526
South Heron	32-0057-07	90	404.1	41,550	82%	32,641	8,909

[1]Absolute load reduction taken as the difference between loading capacity and existing load, not the percent load reduction. Difference exist due to loads where the load reduction is not applied, such as atmospheric deposition and loading from Lakefield WWTP.

Table 6C provides the load by major tributary or source as modeled in the CNET models, and the estimated load reductions within each tributary or source. It should be noted; the estimated load reduction is applied across all loads to the lake. Results shown in **Table 6C**Table provide what the load reduction would be if applied equally across the watershed. In reality, it doesn't matter where the load reductions are made as long as the targeted total load reduction is achieved.

Table 6C. TP load reduction by major tributary.

Lake/Source		Current TP Loads [lbs./yr.]	Load Reduction [%]	Estimated Load Capacity [lbs./yr.]	Estimated TP FWMC at Load Capacity [ug/L]	Estimated Margin of Safety		Estimated Load Reduction [lbs./yr.]
						[%]	[lbs./yr.]	
South Heron Lake (32-0057-07)	Atmospheric Deposition	1,067		1,067				0
	Direct Drainage	12,120	82%	2,182	103	6%	131	9,808
	Unnamed Ck (560)	3,181	82%	573	93	6%	34	2,574
	Unnamed Ck (558)	1,890	82%	340	85	6%	20	1,529
	Judicial Ditch 3 (531)	15,098	82%	2,718	87	6%	163	12,217
	Lakefield WWTP[2]	901	31%	618	1,000	6%	37	246
	Okabena Ck (602)	7,292	81%	1,386	147	6%	83	5,824
	Total Loading	**41,550**	**78.6%**	**8,881**		**6%**	**469**	**32,199**
North Heron Lake (32-0057-05)	Atmospheric Deposition	1,281		1,281				0
	Direct Drainage	5,312	81%	1,009	93	7%	71	4,232
	Okabena Ck (602)	138,553	81%	26,325	147	7%	1843	110,385
	Jack Cr (659)	58,084	81%	11,036	60	7%	773	46,276
	South Heron Lake[1]	24,904	40%	14,926	231			9,977
	Total Loading	**228,134**	**80%**	**54,578**		**6%**	**86%**	**170,871**

[1]Loading form South Heron Lake is taken from the CNET model, based on the response from the average annual loads.
[2]Assumed 1 mg/L effluent for load capacity calculation.

It should be noted, slight differences between the loading capacity in **Table 6C** and **Table 5C** (and the TMDL tables). The loading capacity calculated in **Table 6C** is based the existing conditions and the percent load reduction found with the CNET scenarios. The loading capacities in **Table 5C** are based on the CNET model and stochastic simulations. The load capacity for the TMDLs is based on the CNET models and stochastic simulations (**Table 5C**). Individual loading from the tributaries for each loading scenario were not reported during the stochastic simulations and **Table 6C** is provided to show a rough estimate of load reduction by major tributary or source if uniform reductions were made across the subwatersheds.

Loading Capacity

The loading capacity of a lake is the amount of phosphorus that can enter the lake over a defined amount of time (daily, annually, etc.) before it exceeds the numeric water quality standard. The loading capacity of impaired lakes in the DMRB were determined using a spreadsheet version of the BATHTUB model currently available as a "beta" version from Dr. William W. Walker (URL: http://www.wwwalker.net/bathtub/index.htm). The primary modification in the spreadsheet version of BATHUB is the ability to use a stochastic approach via Monte Carlo simulation, which allows selected modeling inputs to vary based upon known or assumed statistical distributions, and to have that variability be reflected in the forecasted results. The Monte Carlo simulation generates a statistical distribution of the yearly mean TP and Chl-*a* concentrations along with Secchi Disk depth, reflecting the uncertainty in the model parameters, normal variability in inputs (e.g., annual TP load from surface runoff), as well as correlation among inputs (e.g., runoff and load). Crystal Ball (a proprietary software developed by Oracle; https://www.oracle.com/applications/crystalball/) was used to perform the Monte Carlo simulations in the spreadsheet version of BATHTUB. The benefit of using the stochastic approach is the presentation of model results in the form of a statistical distribution of responses, which steady state models cannot achieve.

Watershed Loading Rates

The overland flows and phosphorus loading rates were extracted from the DMRB HSPF model (Tetra Tech, 2016) and used in the BATHTUB models. The HSPF model simulates hydrology and water quality for the period 1993-2014. The CNET models were developed for both seasonal loading and annual loading. Based on the hydraulic residence time of each lake. North Heron flushes on a monthly timeframe and South Heron Lake on a half-year timeframe. Both the seasonal and annual models showed the same reduction in phosphorus needed to meet water quality standards and similar MOS. Therefore, it was determined that annual loads and the annual model would be used to develop the TMDLs.

Hydrologic Connection

The hydrologic connection between North Heron and South Heron Lakes is complicated. South Heron Lake outflows into North Heron Lake. South Heron Lake's ordinary high-water level (OHW) is 1403 ft; North Heron Lake's OWH is 1401 feet[1]. There are wetlands between the lakes, and it is assumed with their close proximity, there is significant groundwater flow between the lakes. Therefore, some dispersion was added to the lake models (and mass balances) to account for groundwater dispersion due to differences in in-lake TP concentrations. In addition, Okabena Creek flows pass South Heron Lake and flows into North Heron Lake. During times of high flow, Okabena Creek will flow into South Heron Lake. It is assumed that 5% of the flow and TP loading in Okabena Creek overflows into South Heron Lake. This was determined to be sufficient to represent annual conditions during calibration of the lake models.

[1] https://www.dnr.state.mn.us/lakefind/index.html

Atmospheric Deposition

Atmospheric deposition refers to the phosphorus inputs to the lake surface directly from the atmosphere. The rates of atmospheric deposition of TP (both wet and dry) onto each of the simulated lakes were set equal to those used in the Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) modeling program. MINLEAP is a program developed by Wilson and Walker (1989) to provide predictive techniques to assess common lake problems based on eco-region. The lakes in the DMRB receive an estimated mean annual atmospheric deposition load of 44.8 kg/km^2/year (Barr, 2007). To allow variation in the atmospheric deposition rates in the CNET models, atmospheric deposition was allowed to vary based on the variation form the average annual precipitation, e.g. the rate of 44.8 kg/km^2/year occurs when the average annual precipitation occurs, lower with less precipitation, higher with higher precipitation.

Internal Loading

Internal loading is the re-release of TP from sediments, usually due to anoxic conditions (dissolved oxygen concentrations < 2.0 mg/L) near the bed of the lake. Internal phosphorus loading can be a substantial part of the mass balance in a lake, especially in lakes with a history of high phosphorus loads. If a lake has a long history of high phosphorus concentrations, it is possible to have internal loading rates higher than external loads. There was no information on specific internal loading in lakes in the basin at the time of this TMDL study, therefore, internal loading rates (if needed) were determined using a mass balance approach. Using equations developed to estimate internal loading rates (Nurnberg, 1984), given external loading rates (from HSPF), neither lake showed significant internal loading.

It should be noted, the 2008 TMDL report (MPCA, 2008) states in the Executive Summary:

"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."

The modeling effort could not confirm this and did not find a need for an explicit internal load rate for either North or South Heron lake. This doesn't mean internal loading doesn't exist in either lake. It means that any internal loading is accounted for in the calibration of the HSPF model. Thus, internal loading was assumed to be included in the nonpoint source loading and load allocation, if it exists.

The stochastic BATHUB modeling

The benefit of using stochastic modeling over the traditional BATHTUB modeling is the ability to capture the natural variation in the forcing data. Stochastic modeling is an approach where model input values (e.g. terms in hydrologic budget) and model parameters used in the equations to compute the in-lake mean concentration of TP and Chl-*a* and Secchi Disk depth, are allowed to vary according to their observed statistical distribution, and therefore their probability of occurrence. This allows the effect of parameter uncertainty and normal variability in the inputs (e.g., amount of surface runoff and nutrient load, which varies depending upon the amount of precipitation) to be quantified when computing the in-lake mean concentration of TP and Chl-*a,* as well as Secchi Disk depth.

Crystal Ball software was used to develop the model input statistical distributions based on the previously mentioned HSPF hydrologic and TP loading seasonal or yearly values for the period 1994-2014. Crystal Ball was used to fit the data to distributions and provide correlations between statistical distributions to simulate natural conditions of the forcing data.

Using Monte Carlo simulation through the Crystal Ball software allowed for multiple probabilistic model computations. Select inputs, primarily those components of the water budget or TP mass balance, were allowed to vary during the Monte Carlo simulation. The selected model inputs are precipitation, evaporation, atmospheric deposition, direct drainage inflows and loadings, and tributary inflows and loadings. Many trial values (10,000 trials in this modeling effort) were generated with each trial representing a different permutation of model input values within the bounds established by the statistical distributions. The many trials resulted in a computed distribution of expected in-lake water quality for each lake rather than a single, deterministic output that was based upon only one possible combination of model inputs.

Once the BATHTUB models were built and calibrated, load reduction scenarios were developed to estimate the required load reduction to meet the water quality standard. The load reduction needed to meet the numeric water quality standard was calculated from the median (50^{th} percentile) lake concentration. Only load reductions in tributary flows and overland (direct) drainage were made to reach the target load reduction. No reduction in atmospheric deposition were considered.

South Heron Lake (32-0057-07) Model Results

The following are results from the stochastic CNET modeling of South Heron Lake, including the water balance and phosphorus balances for the current condition and the TMDL condition and frequency and mean concentrations plots for phosphorus, chlorophyll-a, and Secchi disk depths.

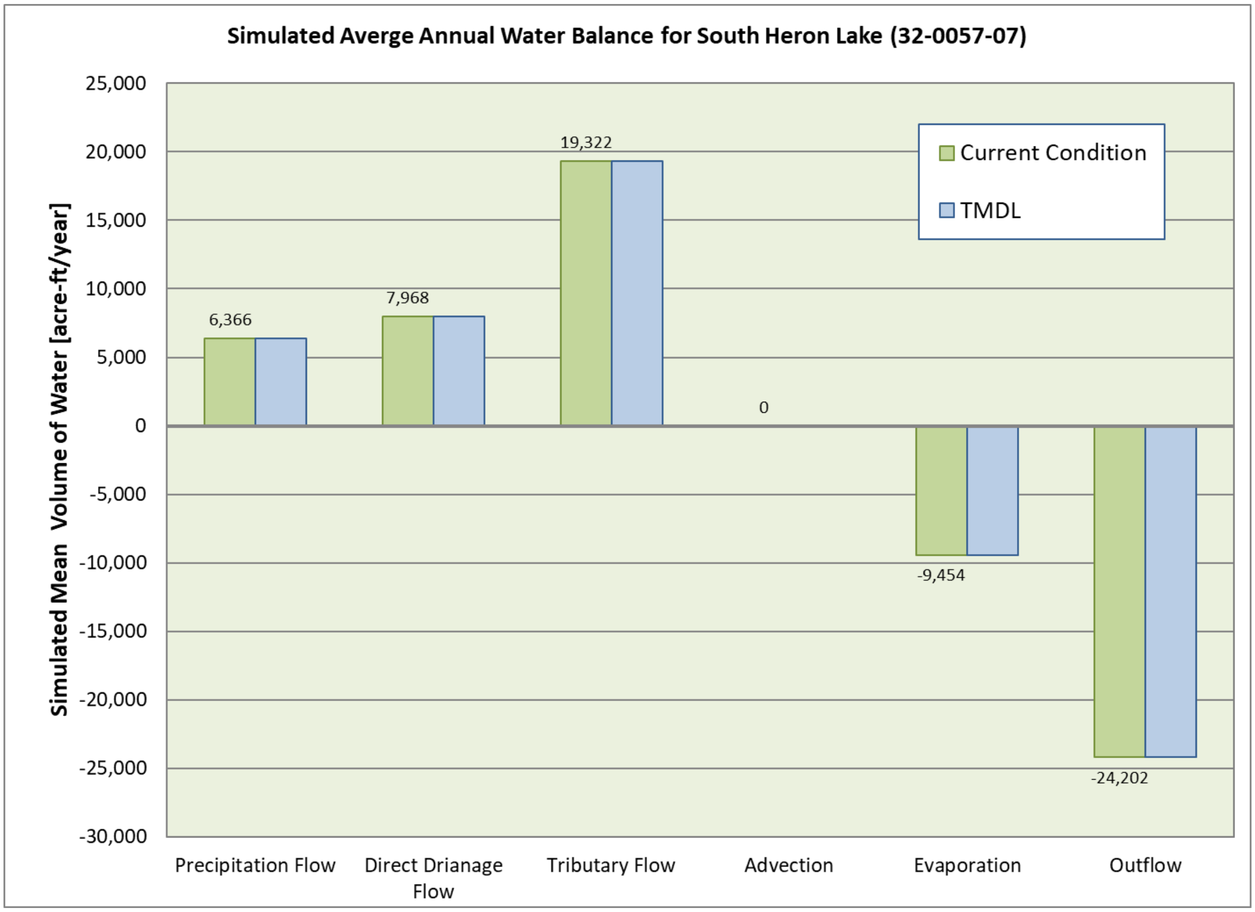

Figure 7C. Simulated average annual water balance for South Heron Lake (32-0057-07).

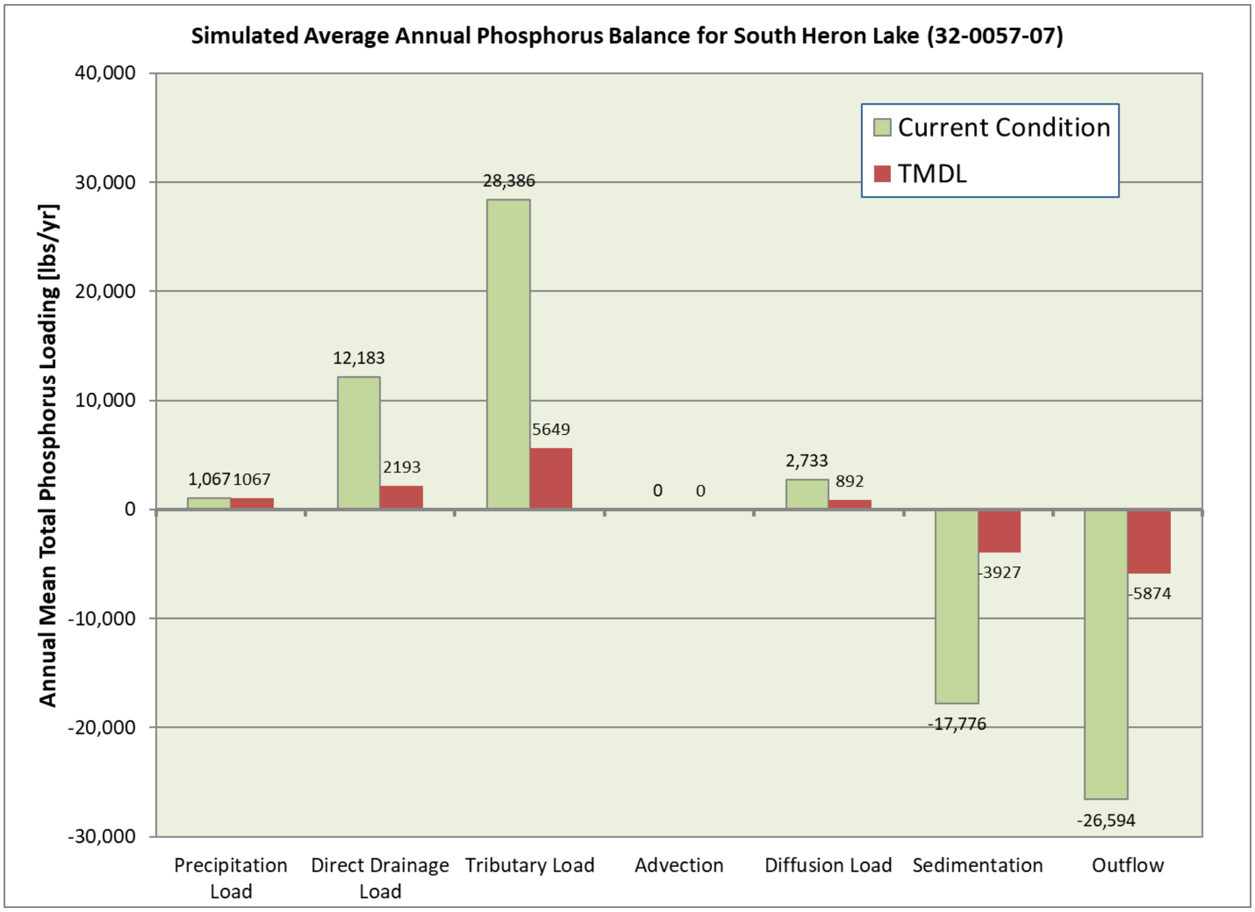

Figure 8C. Simulated average annual phosphorus balance for South Heron Lake (32-0057-07).

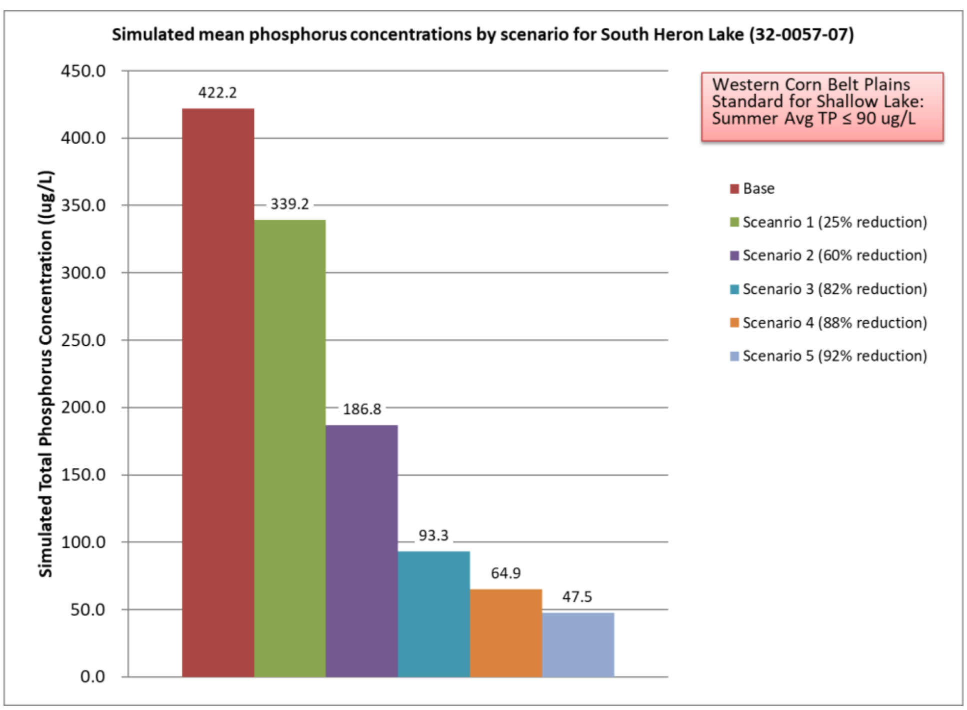

Figure 9C. Simulated mean phosphorus concentrations in South Heron Lake (32-0057-07) by load reduction scenario.

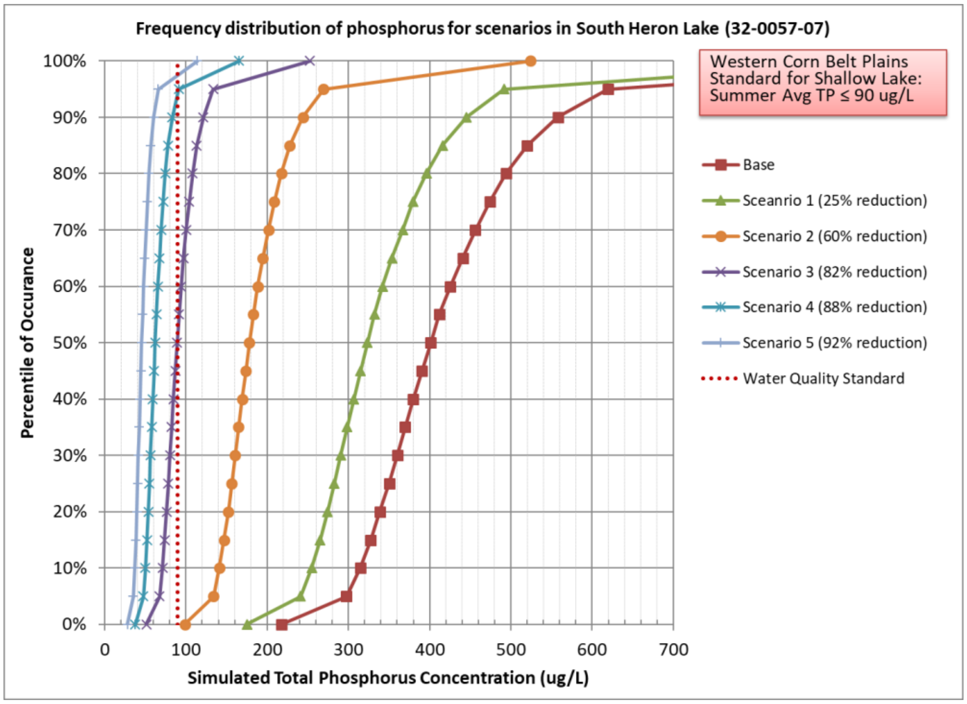

Figure 10C. Frequency distribution of phosphorus concentrations in South Heron Lake (32-0057-07) by load reduction scenario.

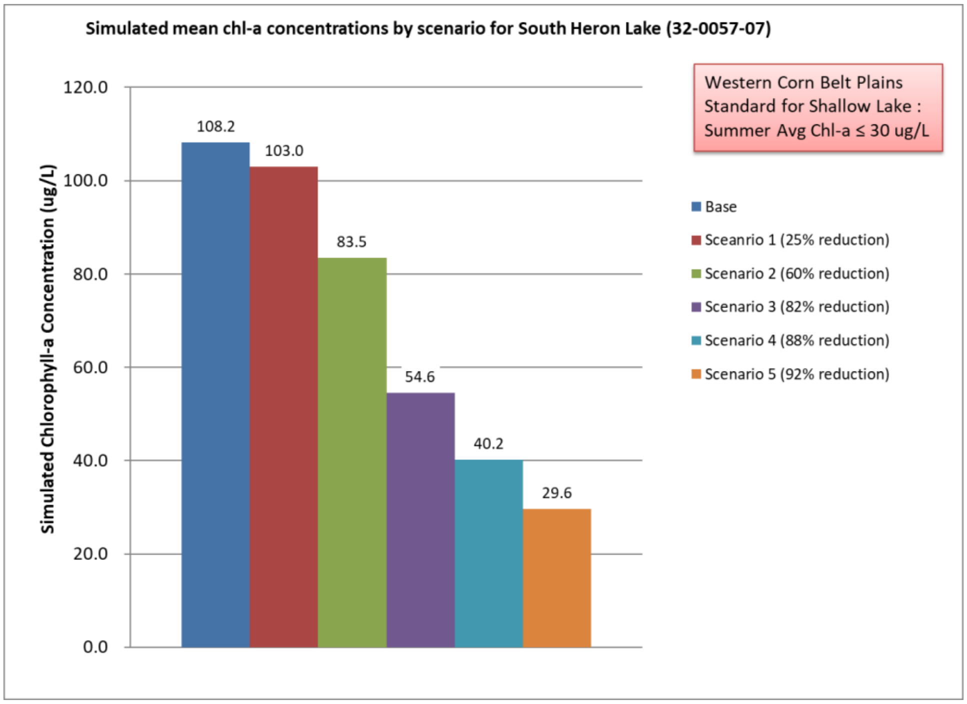

Figure 11C. Simulated mean chlorophyll-a concentrations in South Heron Lake (32-0057-07) by load reduction scenario.

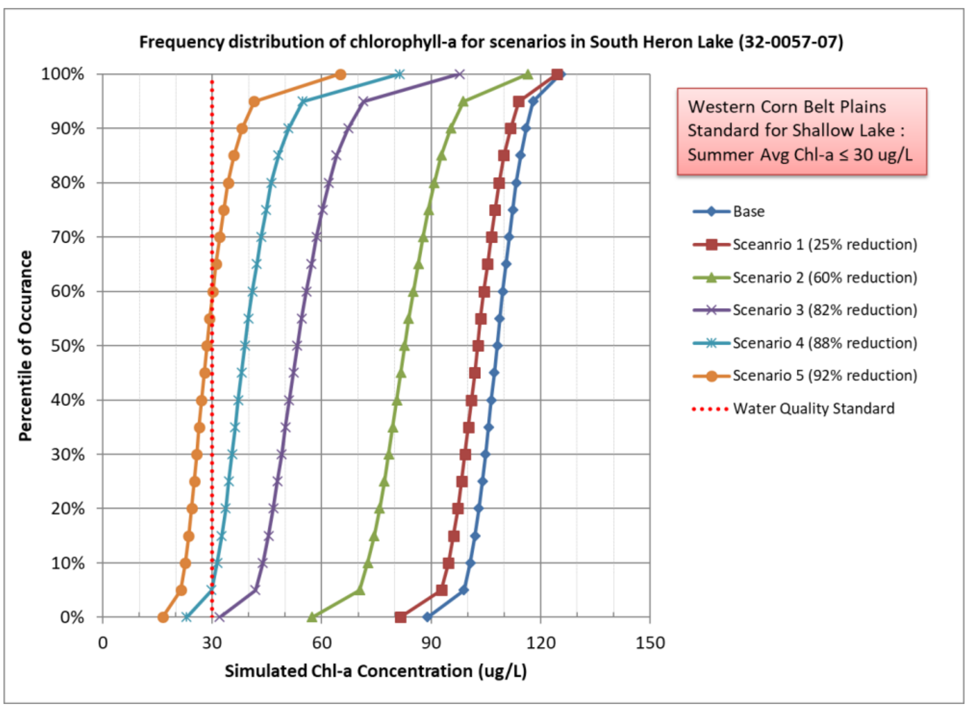

Figure 12C. Frequency distribution of chlorophyll-a concentrations in South Heron Lake (32-0057-07) by load reduction scenario.

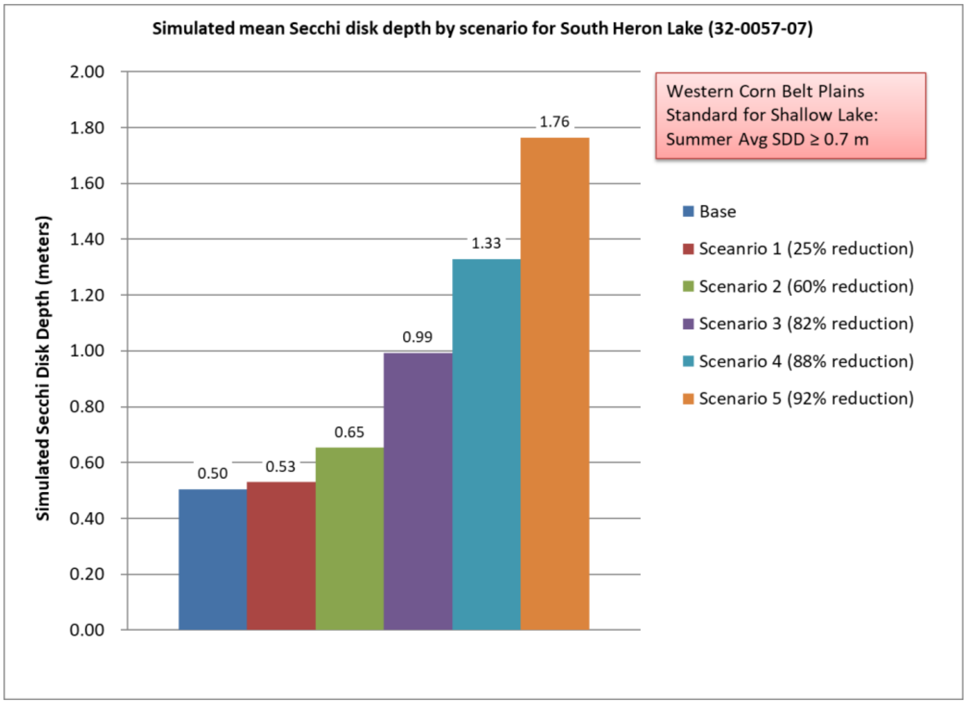

Figure 13C. Simulated mean Secchi disk depth in South Heron Lake (32-0057-07) by load reduction scenario.

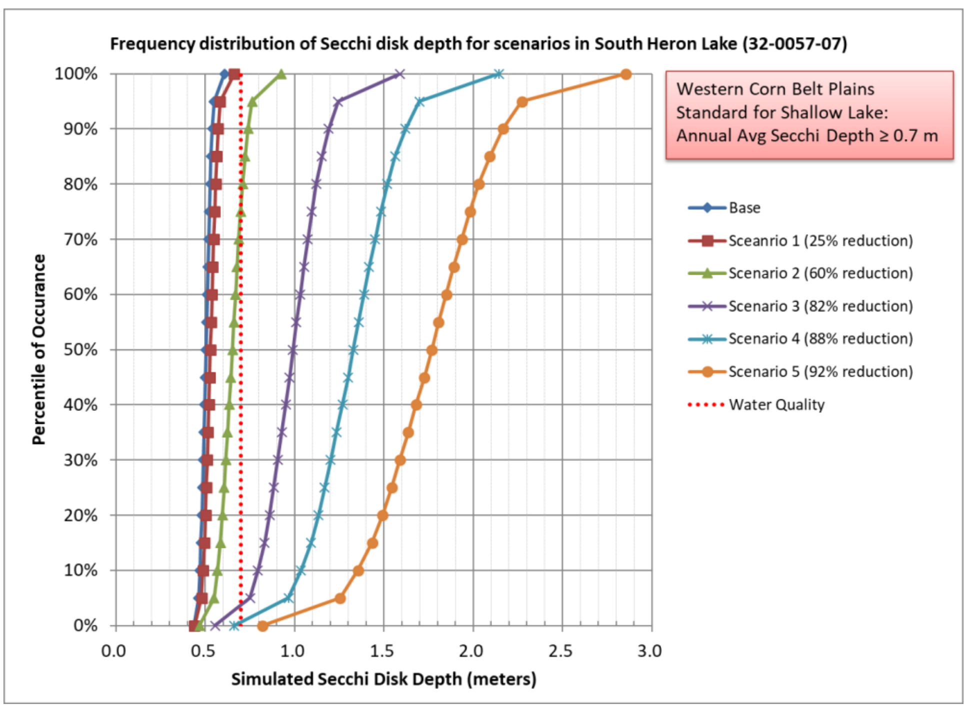

Figure 14C. Frequency distribution of Secchi disk depths in South Heron Lake (32-0057-07) by load reduction scenario.

North Heron Lake (32-0057-05) Model Results

The following are results from the stochastic CNET modeling of North Heron Lake, including the water balance and phosphorus balances for the current condition and the TMDL condition and frequency and mean concentrations plots for phosphorus, chlorophyll-a, and Secchi disk depths.

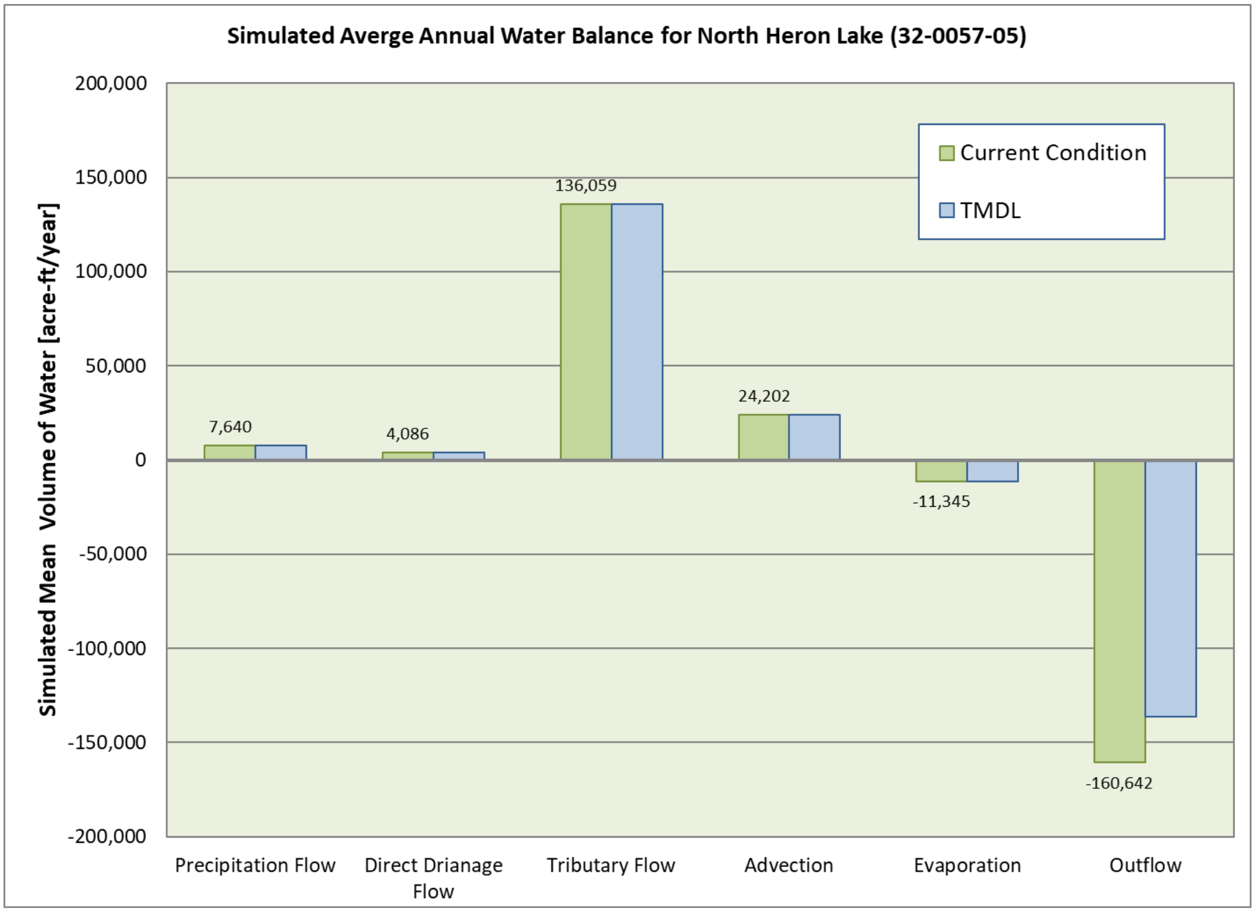

Figure 15C. Simulated average annual water balance for North Heron Lake (32-0057-05).

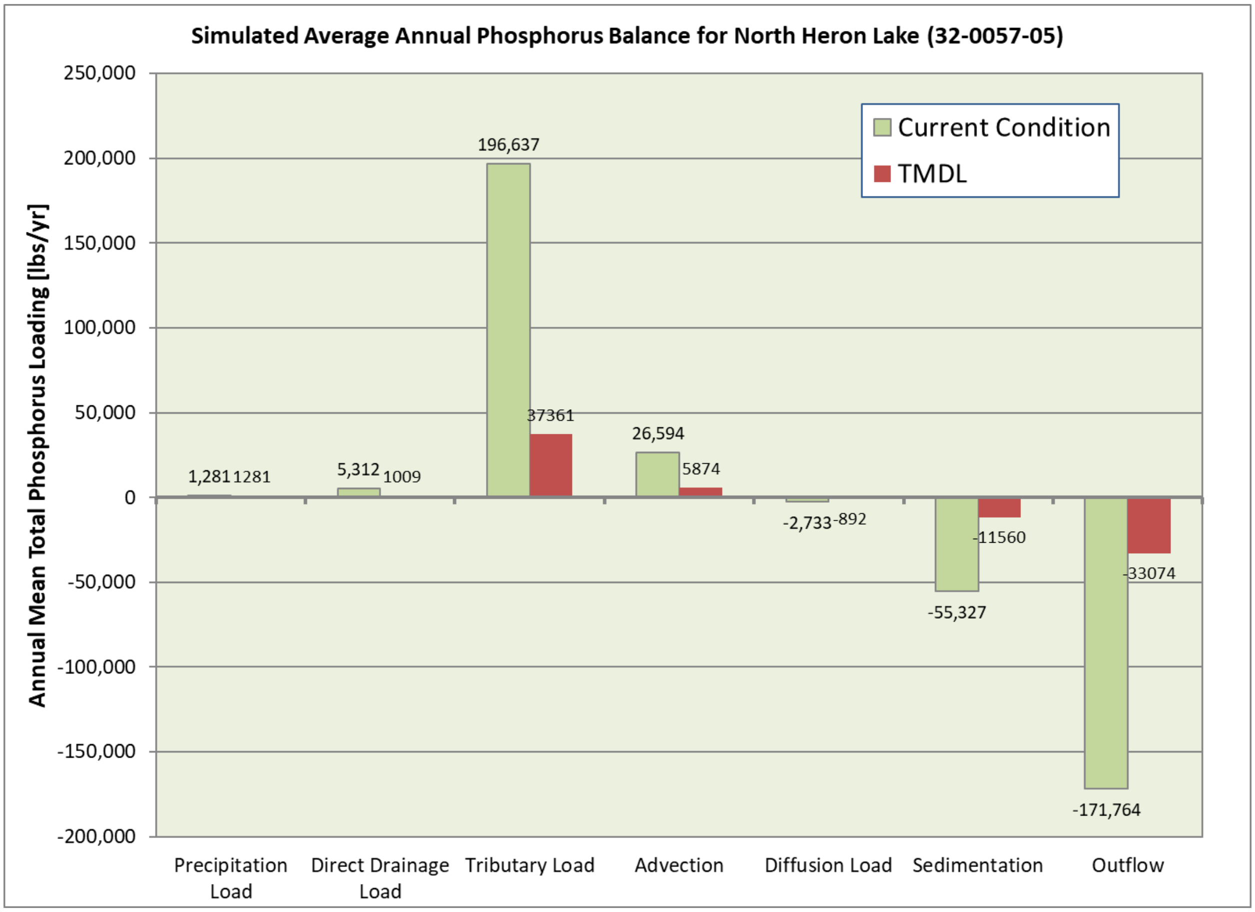

Figure 16C. Simulated average annual phosphorus balance for North Heron Lake (32-0057-05).

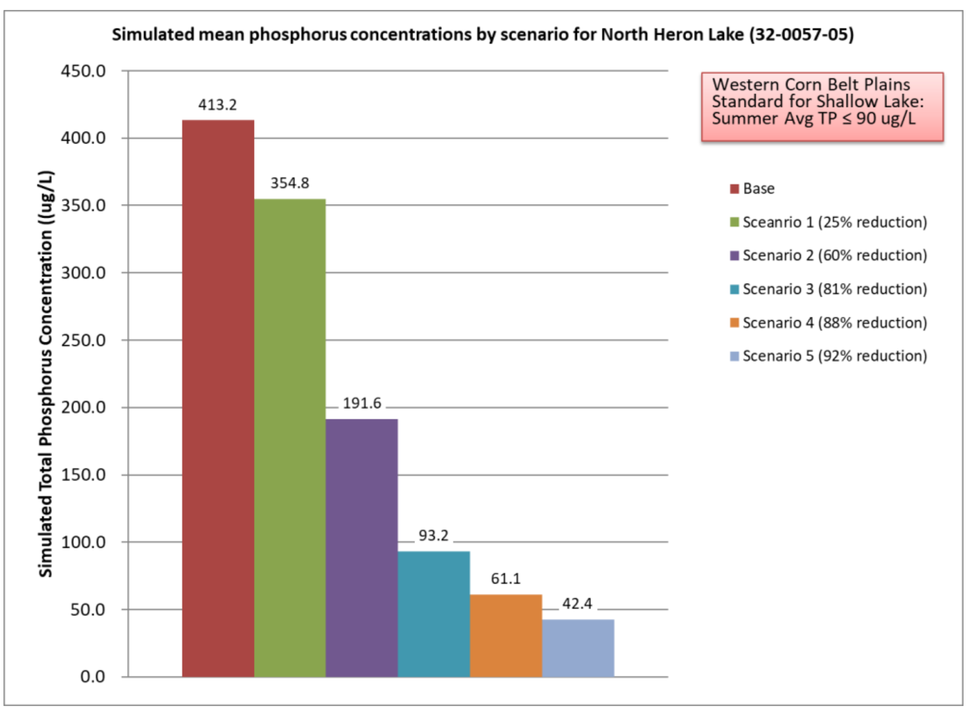

Figure 17C. Simulated mean phosphorus concentrations in North Heron Lake (32-0057-05) by load reduction scenario.

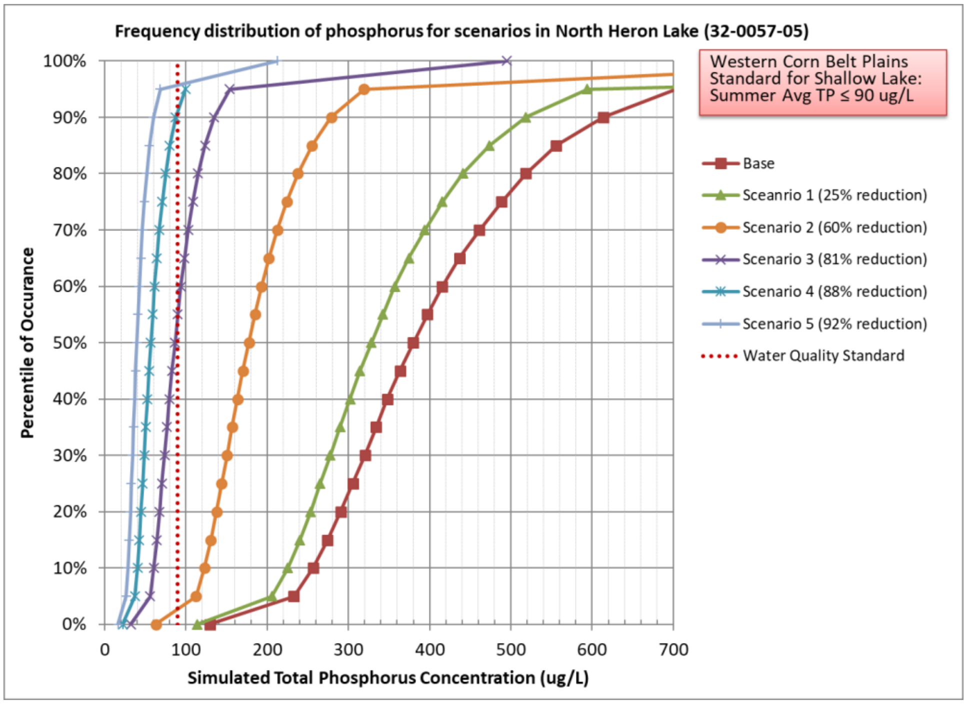

Figure 18C. Frequency distribution of phosphorus concentrations in North Heron Lake (32-0057-05) by load reduction scenario.

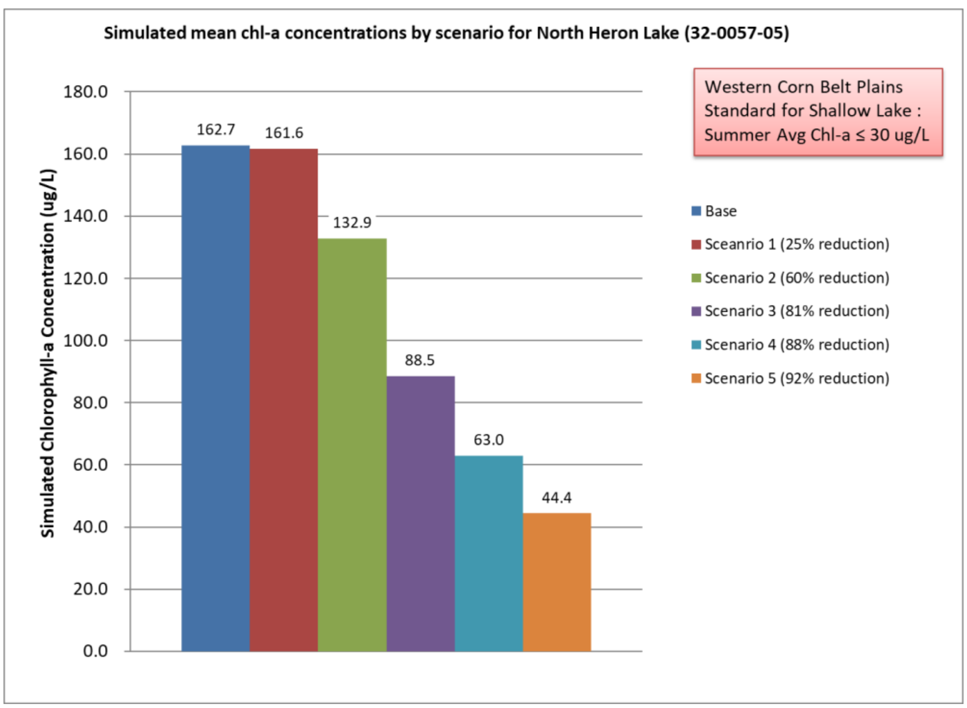

Figure 19C. Simulated mean chlorophyll-a concentrations in North Heron Lake (32-0057-05) by load reduction scenario.

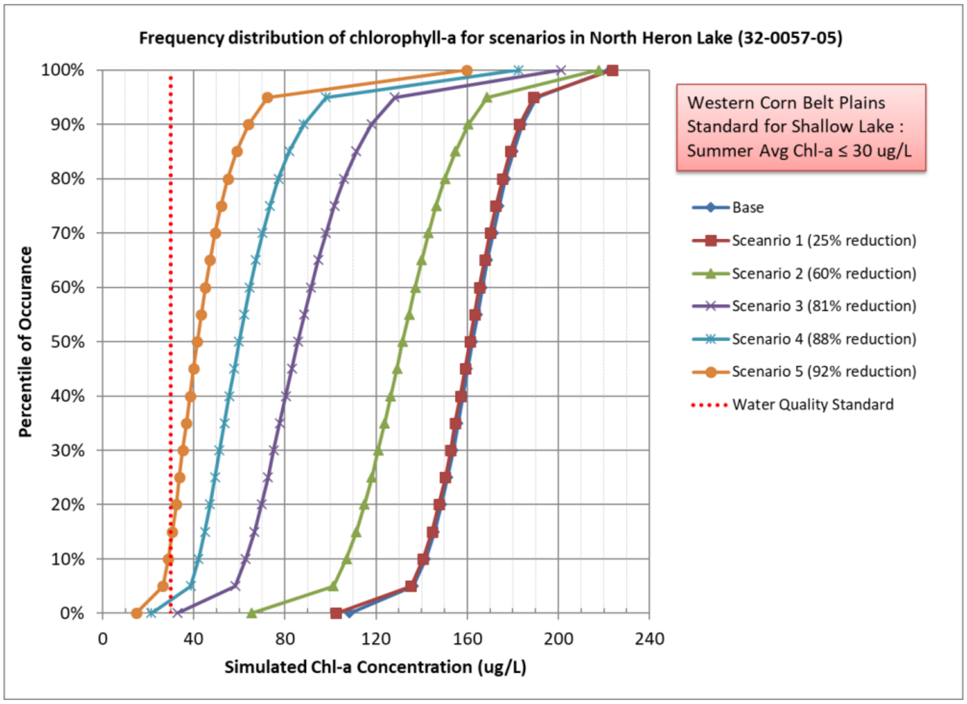

Figure 20C. Frequency distribution of chlorophyll-a concentrations in North Heron Lake (32-0057-05) by load reduction scenario.

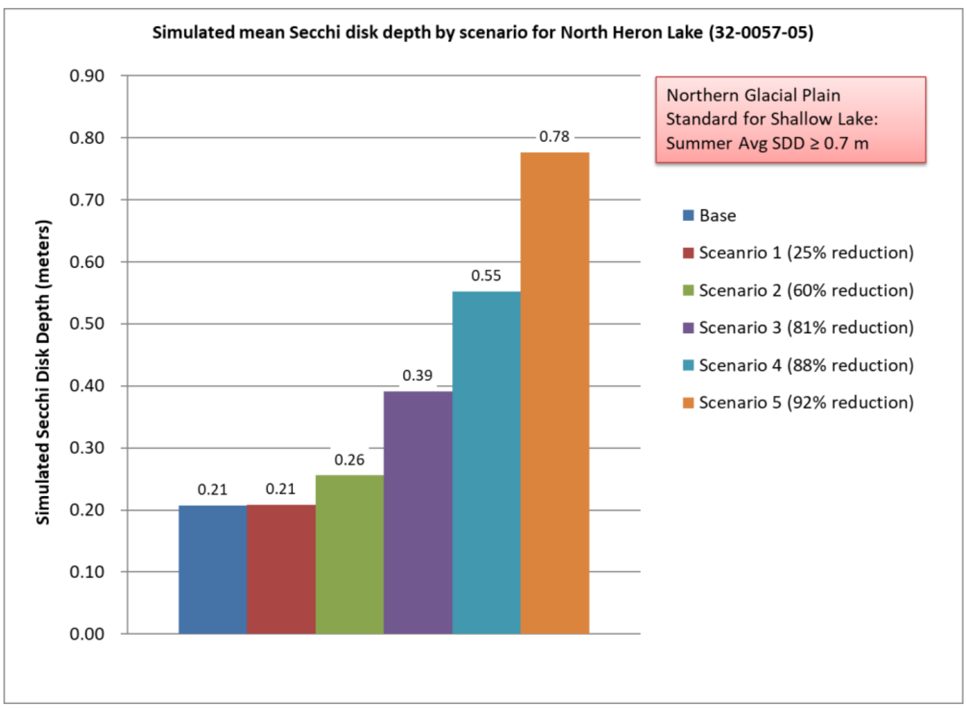

Figure 21C. Simulated mean Secchi disk depth in North Heron Lake (32-0057-05) by load reduction scenario.

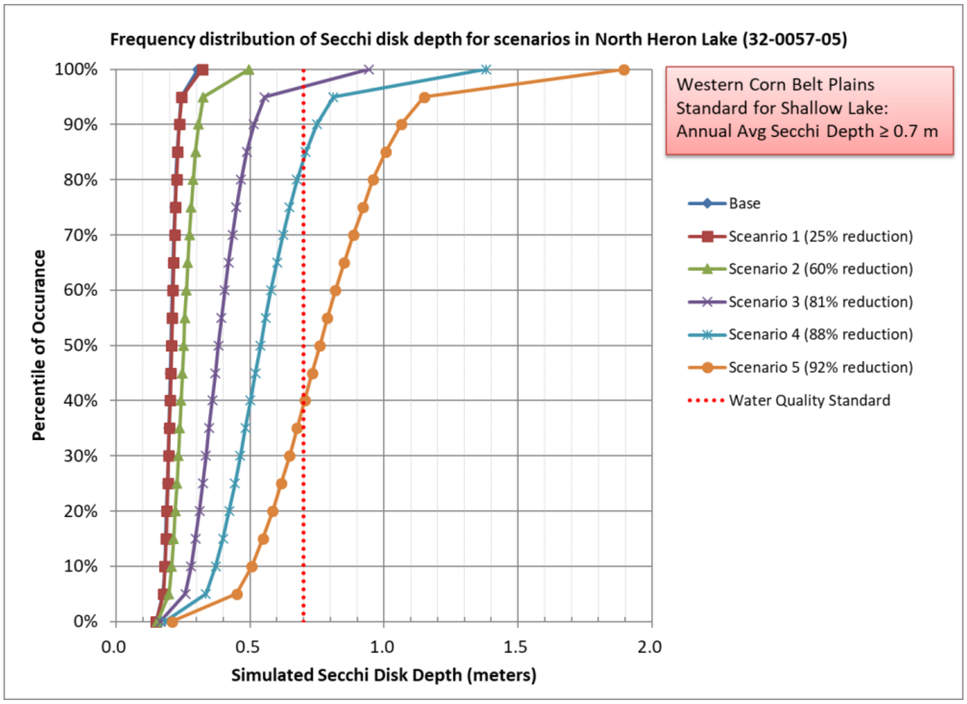

Figure 22C. Frequency distribution of Secchi disk depths in North Heron Lake (32-0057-05) by load reduction scenario.

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Appendix D: CAFO List and Watershed Summary

Watershed	Name	Reg Num	County	AUID
Des Moines River - Headwaters	507 Feeders LLC	101-126302	Murray	524, 527, 652
	Adam Miller Farm	101-77147	Murray	524, 17-0060-00
	Andy Henning Farm - Sec 9	105-125986	Nobles	524, 527, 652
	Birch Lawn Farms Inc	101-106920	Murray	524, 17-0060-00
	Brake Feedyards LP	105-50003	Nobles	524, 527, 652
	Brewster Finisher	063-60201	Jackson	512, 524, 527
	Brian & Mark Soleta Farm	063-87740	Jackson	524, 527
	Brian & Mark Soleta Farm - Sec 16	063-94446	Jackson	524, 527
	Buldhaupt Farms	101-50001	Murray	524, 17-0060-00
	Chad Swenson Swine Facility	101-105300	Murray	524, 17-0060-00
	Christensen Farms Site - F132	033-112870	Cottonwood	524
	Christensen Farms Site C013	033-50009	Cottonwood	524, 527
	Christensen Farms Site F077	033-98008	Cottonwood	524
	Darin Henning Feedlot	101-108194	Murray	524, 527, 564
	Doug & Jerry Brake	101-107958	Murray	524, 527, 652
	Faccendiere - Tutt Site	101-50008	Murray	524, 17-0060-00, 51-0046-00
	Faccendiere-Gilbertson	101-121129	Murray	524, 17-0060-00
	G & K Kramer Inc	101-101400	Murray	524, 527, 652
	G & K Kramer Inc - Sec 21	101-107831	Murray	524, 17-0060-00, 51-0024-00
	Gervais Brothers II	101-62021	Murray	524, 17-0060-00
	Grant Prins - Sec 35	101-107959	Murray	524, 527, 652
	Hurd Hog Farm Inc	101-108127	Murray	1-524, 17-0060-00
	Keith Doeden Farm	101-105740	Murray	524, 17-0060-00
	Kramer Swine Finishing	101-62124	Murray	524, 17-0060-00
	Lake Shore Pork	063-60485	Jackson	524, 527
	Mike Haupert Farm	101-105360	Murray	524, 17-0060-00
	Multi-Site - Double K Inc	105-50006	Nobles	524, 527
	Multi-Site - Double K Inc	105-50007	Nobles	524, 527
	MW Gervais Farms LLC	101-101240	Murray	524, 17-0060-00, 51-0046-00
	Nick Henning Farm - Sundberg Site	105-125987	Nobles	524, 527, 564
	Oscar Carlson Farm	101-119165	Murray	524, 17-0060-00, 51-0046-00, 51-0063-00
	Paradise Pork	105-50009	Nobles	524, 527
	Phil Gervais Farm	101-88993	Murray	524, 17-0060-00
	PJ4 Operation LLC - Paul Henning	063-87981	Jackson	524, 527
	Randy Hein Farm	105-92833	Nobles	524, 527, 564, 53-0020-00, 53-0021-00
	Robert Ford Farm - Dennis Site	101-108143	Murray	524, 17-0060-00
	Russ Penning Farm - Sec 4	105-103955	Nobles	524, 527
	Salentiny Brothers Farm	063-87769	Jackson	524
	Schultz Hog Farms Inc	101-50007	Murray	524, 17-0060-00, 51-0046-00
	Schwartz Farms Inc - Brewster	063-94443	Jackson	524, 527
	Southwest Prairie Pork - Wilmont 13	105-63161	Nobles	524, 527
	Todd Miller Farm	101-88964	Murray	524, 17-0060-00
	Triple X Swine LLP	033-50012	Cottonwood	524
	VanderPoel Hog Properties	101-50003	Murray	524, 17-0060-00
	Wilmont Finishers	105-123679	Nobles	524, 527

Watershed	Name	Reg Num	County	AUID
East Fork Des Moines River	Art Benda Farms - Sec 23	063-95339	Jackson	503, 515, 527, 46-0051-00
	Brad & Meg Freking Farm - NFP 197 Truesdel	091-109580	Martin	527, 525, 510, 46-0051-00
	Christensen Farms Site F053	091-106020	Martin	527, 503, 46-0051-00
	Clair Schmidt Jr Farm	091-50011	Martin	46-0051-00
	Don Schley Finisher	091-95735	Martin	527, 525, 46-0051-00
	Earl Tusa & Sons Inc	063-61883	Jackson	510, 525, 527, 46-0051-00
	Farm 10 - Benda	063-88039	Jackson	525, 527, 46-0051-00
	Farm 133 - Simmons	063-100786	Jackson	527, 525, 46-0051-00
	Farm 152 - Theilhorn	063-100701	Jackson	525, 527, 46-0051-00
	Farm 163 - Floyd	091-105580	Martin	527, 525, 46-0051-00
	Farm 199 - Stephan	091-109560	Martin	527, 503, 515, 46-0051-00
	Farm 209 - Finke	091-111720	Martin	527, 503, 515, 46-0051-00
	Farm 288 - Zebedee	091-126729	Martin	46-0051-00
	Gerhardt East	091-50018	Martin	527, 46-0051-00
	Gerhardt North	091-50017	Martin	46-0051-00, 46-0052-00
	Gerhardt West	091-50016	Martin	527, 46-0051-00
	Hawkeye Two LLP	091-50006	Martin	46-0051-00
	Jacob Brolsma Farm - Sec 35	091-96151	Martin	527, 46-0051-00
	Kevin Schmidt Farm	091-50004	Martin	46-0051-00
	Kyle Gustafson Farm - Sec 23	091-125498	Martin	46-0051-00, 46-0052-00
	Manyaska	091-96243	Martin	503, 527, 46-0051-00
	Miller Pork	091-96016	Martin	527, 46-0051-00
	Pro Pork Inc	091-95760	Martin	525, 527, 46-0051-00
	Terry Wagenman Finishers	091-95637	Martin	527, 525, 46-0051-00
	Truesdell Finisher	091-50027	Martin	503, 527, 46-0051-00
	Truesdell Finisher	091-111018	Martin	503, 527, 46-0051-00
	Whitehead Finishing Site	091-95622	Martin	525, 527, 46-0051-00
	Windmill Farms West	091-95894	Martin	527, 46-0051-00

Feedlot summary for the Des Moines River Basin by HUC08[1].

Description		Des Moines River Headwaters (07100001)	Lower Des Moines River (07100002)	East Fork Des Moines River (07100003)
General				
	Total Feedlots	518	31	98
	Total Permitted CAFOs[3]	49	4	31
	Total AUs	215,493	13,102	66,564
	Primary Animal Type[2]	Swine 58%	Swine 74%	Swine 88%
		Cattle 40%	Cattle 25%	Cattle 12%
Sensitive Areas				
	Open Lot Feedlots	337	19	23
	Feedlots in Shoreland	45	3	4
	Open Lot Feedlots in Shoreland	39	3	3

[1]Data from "Feedlots in Minnesota" data layer. Downloaded 1/29/19 from https://gisdata.mn.gov/dataset/env-feedlots
[2]Percentages based on animal units. Top 2 provided as primary animal type.
[3]Permitted Large CAFOs identified in the feedlots GIS layer ("Feedlots in Minnesota").

Appendix E: TMDL Accounting

HUC08	Waterbody Name (ID)	Use Class	Year Listed	Proposed Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in this Report
Des Moines River - Headwaters (07100001)	Des Moines River, Windom Dam to Jackson Dam (501)	2Bg, 3C	1994	5	Ammonia, un-ionized		No - More data needed to confirm impairment
			2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			1994	5	Dissolved oxygen		No - More data needed to confirm impairment
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2016	5	Nutrients	Phosphorus	No - Being completed in RES TMDL
			1998	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
			2004	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
	County Ditch 20, Headwaters to Beaver Cr (504)	2Bg, 3C	2002	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Lower Lake Sarah Outlet, First Unnamed cr on Lk Sarah outlet str to Lk Shetek inlet (508)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2002	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Okabena Creek, Unnamed cr to T102 R38W S6, north line (512)	7	2010	5	Escherichia coli (E.coli)	E. coli	Yes
	Upper Lake Sarah Outlet, Lk Sarah to Unnamed cr (513)	2Bg, 3C	2002	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
	Jack Creek, N Br Jack Cr to JD 26 (514)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to Unnamed cr (517)	2Bg, 3C	2002	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
	Unnamed creek, Unnamed cr to JD 3 (518)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to Unnamed cr (519)	2Bg, 3C	2002	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
	Judicial Ditch 26, Unnamed cr to Jack Lk (523)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
	Des Moines River, Heron Lk outlet to Windom Dam (524)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data

HUC08	Waterbody Name (ID)	Use Class	Year Listed	Proposed Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in this Report
Des Moines River - Headwaters (07100001)			2018	5	Escherichia coli (E.coli)	E. coli	Yes
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2006	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Heron Lake Outlet, Heron Lk (32-0057-01) to Des Moines R (527)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Escherichia coli (E.coli)	E. coli	Yes
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2016	5	Nutrients	Phosphorus	No - Being completed in RES TMDL
			2006	4A	pH	Phosphorus	No - TMDL completed in 2008 (PRJ04160-001)
			2006	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Division Creek, Okabena Cr to Heron Lk (32-0057-06) (529)	2Bg, 3C	2006	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Des Moines River, Lime Cr to Heron Lk outlet (533)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2004	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2004	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Lime Creek, Lime Lk to Des Moines R (353)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2004	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2004	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Des Moines River, Jackson Dam to JD 66 (541)	2Bg, 3C	2002	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Perkins Creek, Warren Lk to Des Moines R (544)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
	Des Moines River, Lk Shetek to Beaver Cr (545)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2006	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Des Moines River, Beaver Cr to Lime Cr (546)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data

HUC08	Waterbody Name (ID)	Use Class	Year Listed	Proposed Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in this Report
Des Moines River - Headwaters (07100001)			2004	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2004	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Jack Creek, T104 R40W S31, west line to N Br Jack Cr (549)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, String Lk to Des Moines R (551)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2008	5	Turbidity	TSS	Yes
	County Ditch 43 (Scheldorf Creek), Unnamed cr to Des Moines R (552)	1B, 2Ag, 3B	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Harder Lk to Unnamed cr (563)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed ditch to Jack Cr (564)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Escherichia coli (E.coli)	E. coli	Yes
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Okabena Creek, Elk Cr to Division Cr (602)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Chloride	Chloride	Yes
			2006	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 part of reach 506 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2006	4A	Turbidity	TSS	No - TMDL completed in 2008 part of reach 506 (PRJ04160-001)
	Unnamed creek, Unnamed cr to Des Moines R (613)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to JD 84 (614)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to Unnamed lk (618)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data

HUC08	Waterbody Name (ID)	Use Class	Year Listed	Proposed Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in this Report
Des Moines River - Headwaters (07100001)	Unnamed creek, Unnamed cr to JD 20 (619)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed lk to Des Moines R (621)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
	Unnamed creek, Headwaters to Unnamed creek (624)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to unnamed cr (625)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to Unnamed cr (626)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to Unnamed cr (628)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to Lk Maria (632)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, Unnamed cr to Lk Shetek inlet (637)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
	Lake Shetek Inlet, -95.9137 44.1640 to -95.8869 44.2032 (641)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Lake Shetek Inlet, -95.8869 44.2032 to -95.8495 44.2061 (642)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
	Lake Shetek Inlet, -95.8495 44.2061 to -95.7553 44.1793 (643)	2Bg, 3C	2002	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 as part of reach 502 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Lake Shetek Inlet, -95.7553 44.1793 to Lk Shetek (644)	2Bg, 3C	2002	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 as part of reach 502 (PRJ04160-001)
	Beaver Creek, 121st Ave to Des Moines R (646)	2Bg, 3C	2018	5	Chlorpyrifos		No
			2002	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 as part of reach 503 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data

HUC08	Waterbody Name (ID)	Use Class	Year Listed	Proposed Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in this Report
Des Moines River - Headwaters (07100001)			2004	4A	Turbidity	TSS	No - TMDL completed in 2008 as part of reach 503 (PRJ04160-001)
	Jack Creek, North Branch, T-148 to 1st St (649)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
	Jack Creek, North Branch, 31st St to JD 12 (651)	2Bg, 3C	2006	4A	Turbidity	TSS	No - TMDL completed in 2008 as part of reach 505 (PRJ04160-001)
	Jack Creek, North Branch, JD 12 to Jack Cr (652)	2Bg, 3C	2018	5	Escherichia coli (E.coli)	E. coli	Yes
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2006	4A	Turbidity	TSS	No - TMDL completed in 2008 as part of reach 505 (PRJ04160-001)
	Elk Creek, -95.4791 43.6750 to Okabena Cr (656)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2006	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 as part of reach 507 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2006	4A	Turbidity	TSS	No - TMDL completed in 2008 as part of reach 507 (PRJ04160-001)
	Jack Creek, MN Hwy 60 to -93.3062 43.7685 (658)	2Bg, 3C	2018	5	Chlorpyrifos		No
			2006	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 as part of reach 509 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2006	4A	Turbidity	TSS	No - TMDL completed in 2008 as part of reach 509 (PRJ04160-001)
	Jack Creek, -93.3062 43.7685 to Heron Lk (659)	2Bg, 3C	2006	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 as part of reach 509 (PRJ04160-001)
			2006	4A	Turbidity	TSS	No - TMDL completed in 2008 as part of reach 509 (PRJ04160-001)
	Unnamed creek, -95.5572 43.8293 to West Graham Lk (661)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Beaver Creek, 131st St to JD 14 (663)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Beaver Creek, JD 14 to CD 20 (664)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
	Judicial Ditch 12, CSAH 18 to N Br Jack Cr (666)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data

HUC08	Waterbody Name (ID)	Use Class	Year Listed	Proposed Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in this Report
Des Moines River - Headwaters (07100001)	Devils Run Creek, Unnamed cr to Des Moines R (668)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed creek, 490th Ave to Warren Lk (670)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
	Unnamed creek, 21st St to Talcot Lk (672)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Cottonwood (17-0022-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
	North Oaks (17-0044-00)	2B, 3C	2018	5	Nutrients	Phosphorus	Yes
	Talcot (17-0060-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2010	5	Nutrients	Phosphorus	Yes
	Boot (32-0015-00)	2B, 3C	2018	5	Nutrients	Phosphorus	Yes
	Flahtery (32-0045-00)	2B, 3C	2010	5	Nutrients	Phosphorus	Yes
	Teal (32-0053-00)	2B, 3C	2018	5	Nutrients	Phosphorus	Yes
	Heron (Duck) (32-0057-02)	2B, 3C	2002	5	Nutrients	Phosphorus	Yes
	Heron (North Heron) (32-0057-05)	2B, 3C	2002	4A	Nutrients	Phosphorus	Yes - Redoing TMDL (PRJ04160-001)
	Heron (South Heron) (32-0057-07)	2B, 3C	2002	4A	Nutrients	Phosphorus	Yes - Redoing TMDL (PRJ04160-001)
	Timber (32-0058-00)	2B, 3C	2018	5	Nutrients	Phosphorus	Yes
	Yankton (42-0047-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2010	5	Nutrients	Phosphorus	Yes
	Lime (51-0024-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2010	5	Nutrients	Phosphorus	Yes
	Bloody (51-0040-00)	2B, 3C	2010	5	Nutrients	Phosphorus	Yes
	Fox (51-0043-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2018	5	Nutrients	Phosphorus	Yes
	Shetek (51-0046-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2006	5	Nutrients	Phosphorus	Yes
	Corabelle (51-0054-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2018	5	Nutrients	Phosphorus	Yes

HUC08	Waterbody Name (ID)	Use Class	Year Listed	Proposed Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in this Report
Des Moines River - Headwaters (07100001)	Sarah (51-0063-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2006	5	Nutrients	Phosphorus	Yes
	Currant (51-0082-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2008	5	Nutrients	Phosphorus	Yes
	East Graham (53-0020-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2008	5	Nutrients	Phosphorus	Yes
	West Graham (53-0021-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2008	5	Nutrients	Phosphorus	Yes
Lower Des Moines River (07100002)	Des Moines River, JD 66 to MN/IA border (501)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2004	4A	Fecal coliform	Fecal coliform	No - TMDL completed in 2008 (PRJ04160-001)
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2002	4A	Turbidity	TSS	No - TMDL completed in 2008 (PRJ04160-001)
	Brown Creek (Judicial Ditch 10), Headwaters to MN/IA border (502)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
	Unnamed creek, JD 11 to Des Moines R (504)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Judicial Ditch 56, Unnamed cr to Des Moines R (505)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2008	5	Turbidity	TSS	Yes
	Story Brook, JD 56 to Des Moines R (507)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Unnamed ditch, Unnamed ditch to Unnamed ditch (510)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
East Fork Des Moines River (07100003)	County Ditch 11, Headwaters to E Fk Des Moines R (503)	7	2018	5	Escherichia coli (E.coli)	E. coli	Yes
	County Ditch 53, Unnamed cr to MN/IA border (506)	2Bg, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data

HUC08	Waterbody Name (ID)	Use Class	Year Listed	Proposed Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in this Report
East Fork Des Moines River (07100003)	Fourmile Creek, JD 105 to Des Moines R (510)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Escherichia coli (E.coli)	E. coli	Yes
			2018	5	Fish bioassessments		No - deferred to collect additional data
	County Ditch 1/Judicial Ditch 50, Unnamed cr to CD 11 (515)	2Bg, 3C	2018	5	Escherichia coli (E.coli)	E. coli	Yes
	Des Moines River, East Branch, Unnamed cr to CD 11 (525)	2Bg, 3C	2018	5	Escherichia coli (E.coli)	E. coli	Yes
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Des Moines River, East Branch, -94.6258 43.5659 to Okamanpeedan Lk (527)	2Bg, 3C	2006	5	Dissolved oxygen		No - More data needed to confirm impairment
			2018	5	Escherichia coli (E.coli)	E. coli	Yes
			2018	5	Fish bioassessments		No - deferred to collect additional data
			2002	5	Turbidity		No - More data needed to confirm impairment
	Unnamed creek, -94.8641 43.6264 to Des Moines R (529)	2Bg, 3C	2018	5	Benthic macroinvertebrates bioassessments		No - deferred to collect additional data
			2018	5	Fish bioassessments		No - deferred to collect additional data
	Okamanpeedan (46-0051-00)	2B, 3C	2010	5	Nutrients	Phosphorus	Yes
	Bright (46-0052-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2018	5	Nutrients	Phosphorus	Yes
	Pierce (46-0076-00)	2B, 3C	2018	5	Nutrients	Phosphorus	Yes
	Temperance (46-0103-00)	2B, 3C	2018	5	Fish bioassessments		No - deferred to collect additional data
			2018	5	Nutrients	Phosphorus	Yes