Watershed

May 2019

Cedar River Watershed Total Suspended Solids, Lake Eutrophication, and Bacteria Total Maximum Daily Load

MINNESOTA POLLUTION CONTROL AGENCY

wq-iw7-46e

BARR

CLEAN WATER LAND & LEGACY AMENDMENT

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Cover picture: Lower Rose Creek, Tributary stream to the Cedar River

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Acronyms

AUID	Assessment Unit ID
BMP	best management practice
CAFO(s)	Concentrated Animal Feeding Operation(s)
cfu	colony-forming unit
Chl-*a*	Chlorophyll-*a*
DNR	Minnesota Department of Natural Resources
EPA	United States Environmental Protection Agency
FIS	Flood Insurance Study
HSPF	Hydrologic Simulation Program-Fortran
in/yr	inches per year
km^2	square kilometer
LA	load allocation
lb	pound
m	meter
mg/L	milligrams per liter
mL	milliliter
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NPDES	National Pollutant Discharge Elimination System
SRO	surface runoff
SONAR	Statement of Need and Reasonableness
SSTS	Subsurface Sewage Treatment Systems
SWPPP	Stormwater Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TP	Total phosphorus
WLA	wasteload allocation
WRAPS	Watershed Restoration and Protection Strategy

Executive Summary

The Clean Water Act, Section 303(d), requires states to publish a list of waters that do not meet water quality standards and do not support their designated uses. These waters are then considered "impaired". Once a waterbody is placed on the impaired waters list, a Total Maximum Daily Load (TMDL) must be developed. The TMDL provides a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. It is the sum of the individual wasteload allocations (WLAs) for point or permitted sources, load allocations (LAs) for nonpoint or non-permitted sources and natural background, plus a margin of safety (MOS). This is the TMDL report for the Minnesota portion of Cedar River Watershed (CRW) Hydrologic Unit Code (HUC) 07080201, which addresses 11 stream impairments caused by excessive sediment (total suspended solids (TSS)), 14 stream reaches impaired by bacteria, and the Geneva Lake impairment due to excess nutrients/ eutrophication. TMDLs describe the impairment in each waterbody and water quality targets, and include pollutant source assessments, supporting report components that document assumptions and methodologies, and a TMDL equation with completed LAs, WLAs, and MOS for each impairment.

This CRW TMDL Report is one of three "companion" documents that are involved in the watershed science component of Minnesota's watershed approach. The CRW Monitoring and Assessment Report (July 2012) covers the intensive watershed monitoring, which includes extensive data on stream biological, chemical, and physical conditions. The CRW Stressor Identification (SID) Report (June 2016), provides reach-by-reach details about what conditions and/or pollutants are negatively affecting the stream biota.

The findings from these reports, along with other watershed-specific information developed at the local level, is then compiled into the CRW Watershed Restoration and Protection Strategy (WRAPS). The purpose of the WRAPS report is to support local working groups and jointly develop scientifically supported restoration and protection strategies, to be used for subsequent implementation planning. The WRAPS provides additional discussion of pollutant sources, implementation strategies, and tools for prioritization. Following completion, the WRAPS and TMDL documents are publically available on the Minnesota Pollution Control Agency (MPCA) CRW Website:

https://www.pca.state.mn.us/water/watersheds/cedar-river.

The Minnesota portion of the CRW encompasses watershed districts for Turtle Creek (157 square miles) and the Cedar River (435 square miles). Each watershed has unique features and separate challenges, but all include TSS and bacteria impairments. The majority of the watershed is prime agricultural land, with many streams and drainage ditches flowing into the Cedar River. The city of Austin is downstream of several streams and rivers in the watershed, and the Cedar River flows directly through Austin. The mainstem Cedar River in Minnesota is 54 miles long, from the headwaters in Dodge County, to the Minnesota-Iowa border.

Over time, the entire watershed has gone through major hydrologic changes. "An analysis of seventy-seven annual flood peaks for the Cedar River near Austin (USGS 05457000) shows that 58% of the peaks were spring runoff events (February through May), but the seven highest peaks occurred outside the spring flow timeframe." (Reinartz 2017). High stream flows can produce significant pollutant loadings to the ditches, streams, and rivers.

This TMDL project used a variety of methods to evaluate the current loading and contributions from the various pollutant sources, as well as the allowable pollutant loading capacity of the impaired reaches. The load duration curve (LDC) approach was used for reaches impaired by TSS and bacteria. Each of the pollutant types are summarized below, with reach-by-reach data included in Section 4.2 (sediment) and Section 4.3 (bacteria). The TMDL information for Geneva Lake is in Section 4.4.

The TSS water quality standard is for the support of aquatic life in streams. For the Cedar River and its tributaries, the exceedances of the allowable TSS load occur most often at the highest flows, and are often 80% to 90% higher than the goal. Under high stream flow conditions, the TSS loads can be up to 20% higher than the goal.

Sediment sources include the streambanks and channels, gullies, sheet and rill erosion, urban stormwater runoff, riparian zones, and overgrazed pastures (relatively ranked in decreasing order of importance). Further details on the sediment conditions in the watershed are in Section 4.2.12.

For bacterial contamination and aquatic recreation use support, noncompliance with the TMDL occurs across all flow intervals for the tributary streams. For the Cedar River, noncompliance occurs across all flow intervals except the mid-range flows. For the nine tributary reaches included in this report, there are higher exceedances of the goal for the high and low flow intervals, than the other categories. For the three mainstem Cedar River sites, there appears to be fairly even distribution across the flow intervals with exceedances. Due to the rather small data sets for some sites, it is difficult to draw specific conclusions from the bacteria LDCs. Bacterial pollution can be better understood using the concentration-based water quality standards, either as a monthly geometric mean, or as a maximum concentration, as covered in Section 4.3.

The watershed sources of bacteria include wildlife, livestock facilities and pastures, fields with applied manure, improperly treated human sewage (failing septic systems and wastewater treatment plant (WWTP) bypasses), urban stormwater runoff, and natural growth. This project has used the basic indicator groups of bacteria, with the realization that bacterial contamination and risks to humans are broad regional issues facing nearly all Southern Minnesota watersheds. Further details on the bacteria conditions are in Section 4.3.15.

Geneva Lake is the one natural lake in the CRW, and is located near the headwaters of the Turtle Creek Subwatershed, northwest of Austin, Minnesota. It is designated as a wildlife lake by the Minnesota Department of Natural Resources (DNR), through Minnesota law. Similar to many shallow southern Minnesota lakes, Geneva Lake has both external and internal influences that degrade lake water quality. External factors include an 11,624-acre watershed dominated by row crop agricultural land use. To meet the southern Minnesota shallow lake water quality standards, a 13% reduction in total phosphorus (TP) loading is required. More information on the Geneva Lake TMDL is included in Section 4.4.

Ongoing monitoring of water and land resources will be an important ongoing aspect of work in the CRW. Utilizing Minnesota's watershed approach framework, this will involve the watershed pollutant load monitoring network, land use/land management assessments, specialized local monitoring, as well as focused monitoring to meet specific research needs. More details on these elements are found in Section 5.

A general strategy for implementation is included in Section 6, covering both point and nonpoint sources. More detailed strategies are provided in the CRW WRAPS, which has both watershed-wide and reach-specific strategies.

1. Project Overview

The Cedar River Basin in Minnesota includes parts of Mower, Freeborn, Steele, and Dodge Counties. The Minnesota portion of this basin is the headwaters of the larger system that includes 7,485 square miles of drainage area in Iowa. In the Minnesota headwaters, the main watersheds of the basin are the Cedar, Shell Rock, and Winnebago.

The CRW HUC 07080201 encompasses two watershed districts (MS 110D): the Turtle Creek Watershed District (157 square miles) and the CRW District (435 square miles). Figure 1 displays the entire Cedar River Basin in both Minnesota and Iowa.

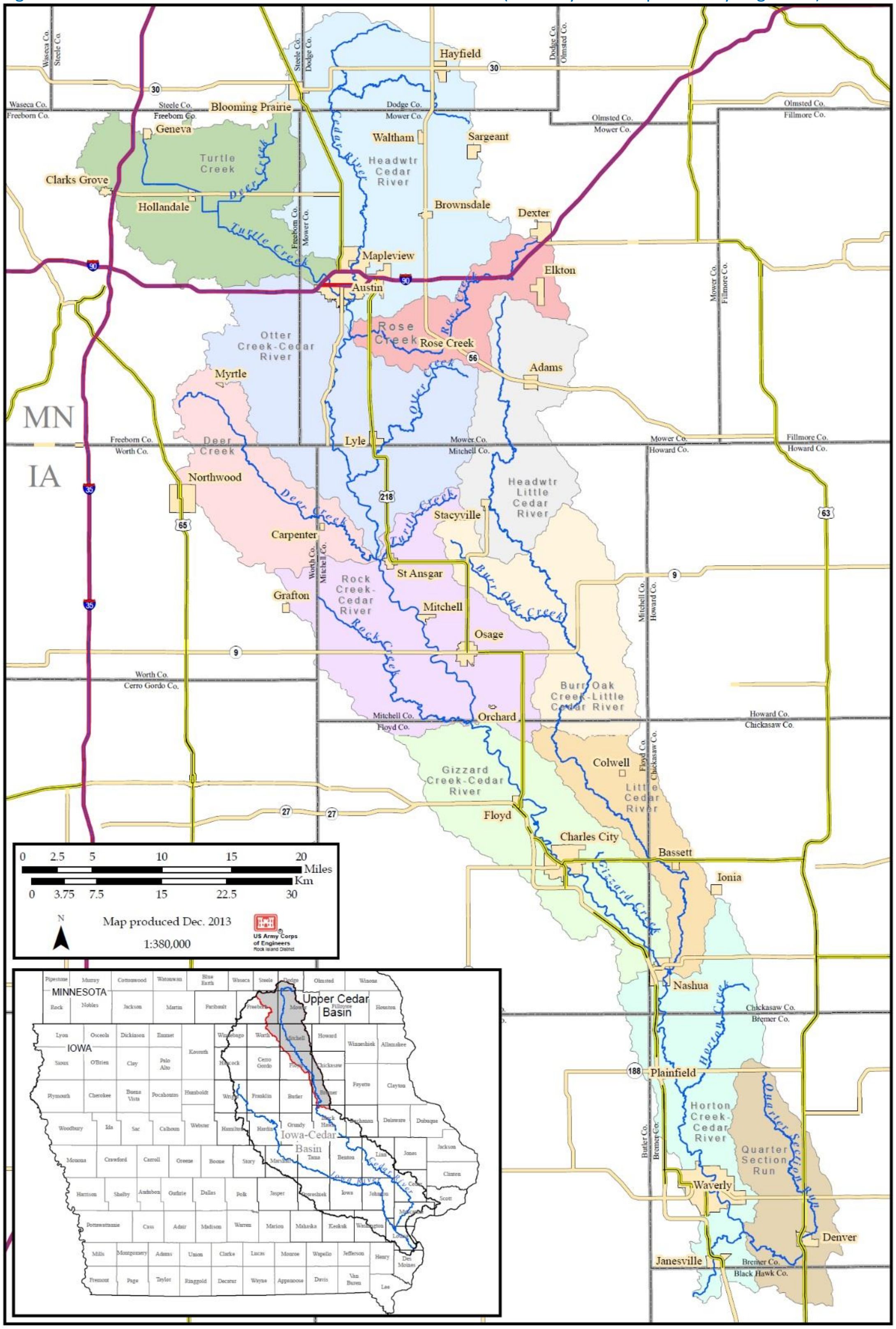
While each watershed in Minnesota has unique features and challenges, all include TSS/turbidity and fecal coliform impairments. The majority of the watershed is prime agricultural land with many streams and drainage ditches flowing into the Cedar River. The city of Austin is downstream of several streams and rivers in the watershed. Over time, the entire watershed has gone through major hydrologic changes. High stream flows produce significant pollutant loadings to the ditches, streams, rivers, and Geneva Lake – with significant economic implications in both rural and city locations.

A flood plain management study for the Cedar River Basin in Iowa provided some further analysis of this issue, in terms of the effects of non-structural actions on community flooding and the economy (Iowa Silver Jackets 2016). While this study focused on Iowa, and the city of Charles City, in particular, some analysis was done for the Cedar River near Austin. By using a hydraulic model, this assessment showed that for Austin, flows from a 10-year runoff event increased 38%, from 7,200 cfs to 9,900 cfs. Similar differences were noted for the 50-year, 100-year, and 500-year events. The timeframe used for a flood insurance study (FIS) was 1910 through 1983, and the FIS analysis method was Bulletin 17b.

Some flow conditions that exist in the summer season for the Cedar River near Austin include the 10th percentile flow (66 cfs), the median flow (180 cfs), and the 90th percentile flow of 833 cfs.

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

Figure 1: Entire Cedar River Basin in both Minnesota and Iowa (courtesy U.S. Corps of Army Engineers)



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

They are designed to implement applicable water quality criteria:

- include a total allowable load as well as individual WLAs;
- consider the impacts of background pollutant contributions;
- consider critical environmental conditions;
- consider seasonal environmental variations;
- include a MOS;
- provide opportunity for public participation; and
- have a reasonable assurance that the TMDL can be met.

In general, the TMDL is developed according to the following relationship: TMDL = WLA + LA + MOS

Where:

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

LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources of the relevant pollutant. The LA may also encompass "natural background" contributions, internal loading and atmospheric deposition;

MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The MOS can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity (EPA 1999).

1.1 Identification of Waterbodies

This TMDL report applies to 10 stream reaches in the CRW impaired by TSS. Three of the TSS reaches are the result of a conclusive TSS biology stressor being identified by the MPCA, using the SID process (MPCA 2016). There are 14 stream reaches in the CRW that are impaired by bacteria, of which three are mainstem Cedar River reaches and the rest are tributary streams. The final impairment addressed in this report is for Geneva Lake, for excess phosphorus and lake eutrophication. These impairments are currently on the 2010 and 2012 303(d) lists of impaired waters and are shown in Table 1 and Figure 2.

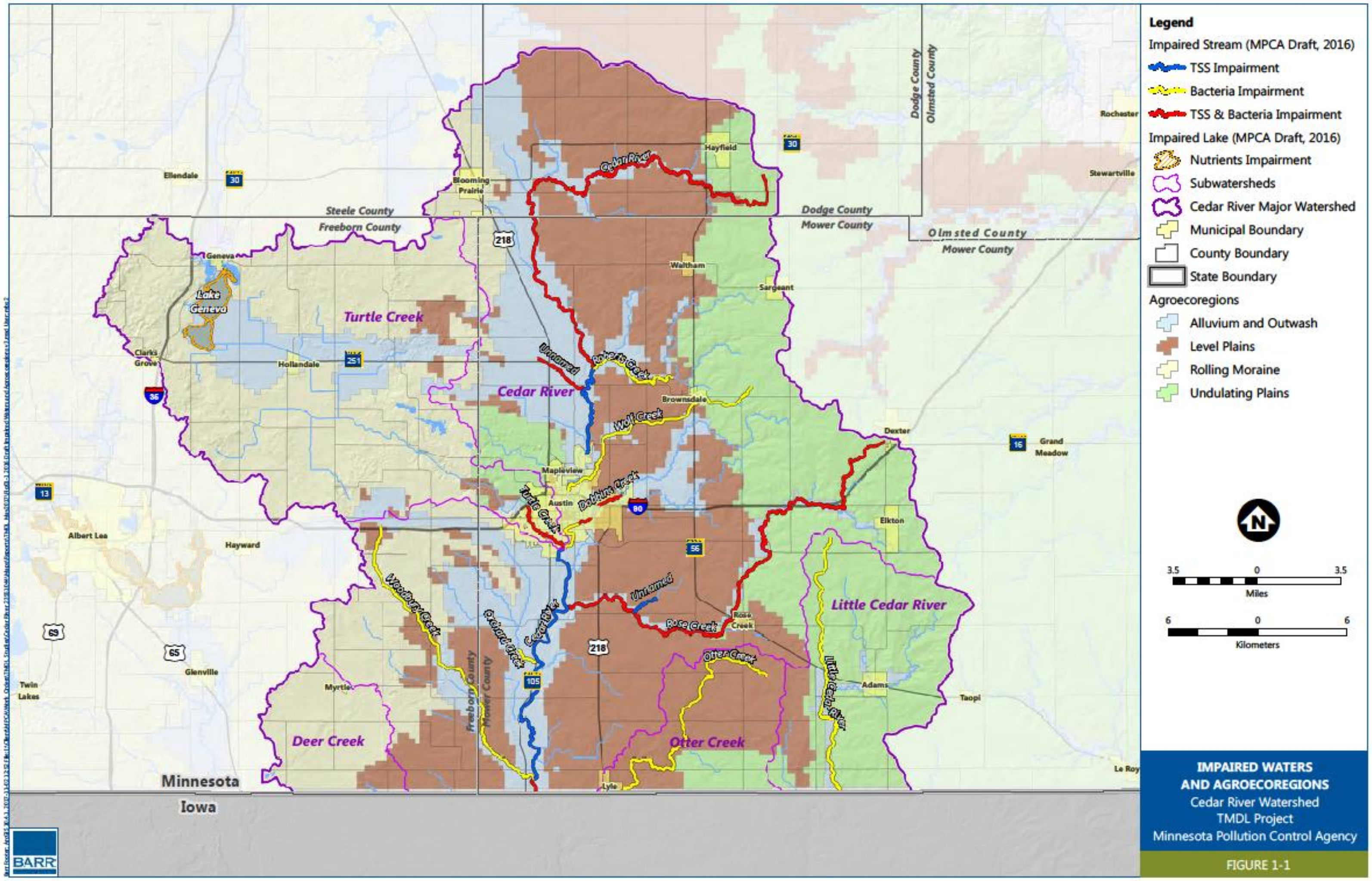
None of the drainage areas of impaired waterbodies addressed in this document contain tribal lands.

Table 1: Cedar River Watershed 303(d) impairments addressed in this report.

Waterbody	HUC12	AUID	Impairment(s)
Cedar River – Rose Cr to Woodbury Cr	JD No. 77 – Cedar River	07080201-501	TSS
Cedar River – Roberts Cr to Upper Austin Dam	Green Valley Ditch & City of Austin–Cedar	07080201-502	TSS
Cedar River – Turtle Cr to Rose Cr	City of Austin–Cedar River	07080201-515	TSS
Unnamed Creek – Unnamed Cr to Rose Cr	Lower Rose Creek	07080201-583	TSS*
Cedar River – Headwaters to Roberts Cr	Headwaters & Green Valley Ditch–Cedar	07080201-503	TSS*/Bact.-*E.coli* Bacteria/*E. coli*
Rose Creek – Headwaters to Cedar R	Upper & Lower Rose Creek	07080201-522	TSS/Bact.-*E.coli* Bacteria/*E. coli*
Unnamed Creek – Unnamed Cr to Cedar R	City of Austin–Cedar River	07080201-533	TSS*/Bact.-*E.coli* Bacteria/*E. coli*
Dobbins Creek – T103 R18W S36, east line to East	Dobbins Creek	07080201-535	TSS/Bact.-*E.coli* Bacteria/*E. coli*
Dobbins Creek – East Side Lk to Cedar R	Dobbins Creek	07080201-537	TSS/Bact.-*E.coli* Bacteria/*E. coli*
Turtle Creek – T102 R18W S4, north line to Cedar R	Turtle Creek	07080201-540	TSS/Bact.-*E.coli* Bacteria/*E. coli*
Orchard Creek – T101 R18W S5, north line to Cedar R	Orchard Creek	07080201-539	Bact.-*E. coli*
Woodbury Creek – Headwaters to Cedar R	Woodbury Creek	07080201-526	Bact.-*E. coli*
Otter Creek – Headwaters to MN/IA border	Otter Creek	07080201-517	Bact.-*E. coli*
Little Cedar River – Headwaters to MN/IA border	Village Of Meyer–Little Cedar River	07080201-518	Bact.-*E. coli*
Cedar River – Dobbins Cr to Turtle Cr	City of Austin–Cedar River	07080201-514	Bact.-*E. coli*
Cedar River – Woodbury Cr to MN/IA border	Town of Otranto–Cedar River	07080201-516	Bact.-*E.coli*
Wolf Creek – Headwaters to Cedar R	City of Austin–Cedar River	07080201-510	Bact.-*E. coli*
Roberts Creek – Unnamed Cr to Cedar R	Roberts Creek	07080201-504	Bact.-*E. coli*
Geneva Lake	Geneva Lake	24-0015-00	Excess Nutrients/ Eutrophication

*Denotes AUIDs with a conclusive TSS stressor to biota, all resulting in MIBI impairments.

Figure 2: Impaired Waters and Agroecoregions, Cedar River Watershed



There are 12 stream impairments that are not addressed by this TMDL, and these are tabulated in Appendix I. All of these reaches have macroinvertebrate index of biotic integrity (MIBI) impairment listings, with three also having fish index of biotic integrity (FIBI) impairments. The non-pollutant stressors that have been commonly identified include habitat/bedded sediment, and flow alteration.

Nitrate-nitrogen (NO3-N) is also a common stressor, but is a pollutant without a specific warm water stream WQS. The Middle Fork Cedar River (07080201-530) does have a dissolved oxygen stressor associated with it (MPCA 2016), but that has not been conclusively linked to a phosphorus load, and there are no TMDLs for other stressors. Roberts Creek (07080201-504) has an identified phosphorus stressor, but there is no definitive data set that uniquely links phosphorus to the MIBI impairment.

1.2 Priority Ranking

The MPCA's schedule for TMDL completions, as indicated on the 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. The MPCA has aligned our TMDL priorities with the watershed approach and our WRAPS cycle. 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 the EPA's national measure (WQ-27) under EPA's Long-Term Vision for Assessment, Restoration and Protection under the Clean Water Act 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 CRW waters addressed by this TMDL are part of that MPCA prioritization plan to meet the EPA's national measure.

2. Applicable Water Quality Standards and Numeric Water Quality Targets

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

All waters of Minnesota are assigned classes based on their suitability for the following beneficial uses:

- domestic consumption
- aquatic life and recreation
- industrial consumption
- agriculture and wildlife
- aesthetic enjoyment and navigation
- other uses
- limited resource value

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

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

Total Suspended Solids

The class 2B turbidity standard (Minn. R. ch. 7050.0222) that was in place at the time of the impairment assessment for some reaches in the project area was 25 nephelometric turbidity units (NTUs). Impairment listings occurred when greater than 10% of data points collected within the previous 10-year period exceeded the 25 NTU standard (or equivalent values for TSS or the transparency tube). If sufficient turbidity data did not exist, transparency tube data could be used to evaluate waters for turbidity impairments for the 2006 through 2014, 303(d) lists of impaired waters. A transparency tube measurement less than 20 centimeters (cm) indicated a violation of the 25 NTU turbidity standard. A stream was considered impaired if more than 10% of the transparency tube measurements were less than 20 cm.

Due to weaknesses in the turbidity standards, the MPCA developed numeric TSS criteria to replace them. These TSS criteria are regional in scope and based on a combination of biotic sensitivity to the TSS concentrations and reference streams/least impacted streams, as data allow. The results of the TSS criteria development were published by the MPCA in 2011. The new TSS standards were approved by EPA in January 2015. For the purpose of this TMDL report, the WQS of 65 mg/L standard for class 2B waters is used to address the turbidity impairment listings in the Minnesota River Basin project area.

The TSS WQS that applies to the streams in the CRW is:

- South Region TSS Standard
- 65 mg/l
- Exceeded no more than 10 % of the time.
- Standard applies from April 1 through September 30.

The organic portion of suspended sediment is estimated with a test for volatile suspended solids (VSS). The remainder of TSS (i.e. the non-organic component) is composed of mineral material, often dominated by silts, clays, and fine sand particles. Appendix B contains further information on suspended sediment concentration (SSC), and the reader is referred to Ellison et al. 2015 for more information. Future work in the CRW on suspended sediments can consider a more comprehensive effort, as noted by Ellison et al. 2016.

Current stream reaches listed with turbidity impairments will remain on the impaired waters list. There will not be a broad reassessment of all turbidity listings now that a TSS standard has been adopted. Thus, in general, assessment against the TSS standard will follow the monitoring and assessment cycle and will be one of multiple components considered in a weight-of-evidence process. It is possible that some turbidity listings will remain for several years before re-assessment occurs. In the CRW, the second cycle of intensive watershed monitoring will begin in 2019.

In most cases, the differences between TMDL allocations based on the turbidity standard versus those that would be based on the new TSS standard will not be significant. This is especially true in situations in which very high levels of TSS reduction from nonpoint sources are required. In these situations, implementation of practices to reduce sediment loading should continue unchanged at least until the next assessment cycle and subsequent TMDL computations.

For more information on the change from turbidity to TSS, and other background information on suspended sediment, see the MPCA's Aquatic Life Water Quality Standards Draft Technical Support Document for TSS (Turbidity) (MPCA 2011).

Bacteria

Escherichia coli

With the revisions of Minnesota's water quality rules in 2008, the State of Minnesota changed to an *E. coli* standard because it is a superior indicator of potential illness, and costs for lab analysis are less (MPCA 2007). The revised standards now state:

> "*E. coli* concentrations are not to exceed 126 colony forming units (cfu) per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar

month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 cfu/100 ml. The standard applies only between April 1 and October 31."

Fecal coliform

For some reaches, the fecal coliform data collected pre-2008 has been adjusted or transformed to *E. coli* equivalents. The details of this procedure are included in Appendix A, and the reach-specific LDC spreadsheets.

Impairment assessment is based on the procedures contained in the Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment (MPCA 2012).

The *E. coli* concentration standard of 126 cfu/100 ml was considered reasonably equivalent to the fecal coliform standard of 200 cfu/100 ml from a public health protection standpoint. The SONAR (Statement of Need and Reasonableness) section that supports this rationale uses a log plot to show the relationship between these two parameters. The relationship has an R2 value of 0.69. The following regression equation was deemed reasonable to convert fecal coliform data to *E. coli* equivalents:

E. coli concentration (equivalents) = 1.80 x (Fecal Coliform Concentration) 0.81

Although surface water quality standards are now based on *E. coli*, wastewater treatment facilities (WWTF) are permitted based on fecal coliform concentrations. Like *E. coli*, fecal coliform are an indicator of fecal contamination. The primary function of a bacterial effluent limit is to assure that the effluent is being adequately treated with a disinfectant to assure a complete of near-complete kill of fecal bacteria prior to discharge (MPCA 2007 SONAR Book III).

Excess nutrients

Excess nutrients from anthropogenic sources contribute to cultural eutrophication of lakes. Excessive nutrient loads, in particular TP, lead to increased algae blooms and reduced transparency – both of which may significantly impair or prohibit the designated use of aquatic recreation. The basis for assessing Minnesota lakes for impairment due to eutrophication includes the narrative water quality standards in Minn. R. chs. 7050.0150 and 7050.0222. The MPCA has completed extensive planning and research efforts to develop quantitative lake eutrophication standards for lakes in different ecoregions of Minnesota that would result in achievement of the goals described by the narrative water quality standards. To be listed as impaired by the MPCA, monitoring data must show that the standards for both TP (the causal factor) and either chlorophyll-a (Chl-*a*) or Secchi disc depth (the response factors) are not met (MPCA 2012). For more information regarding the basis of the lake WQS, see MPCA (2005).

Geneva Lake is listed and included in this TMDL based on the summer season (June 1 through September 30) eutrophication criteria for the Western Corn Belt Plains (WCBP) ecoregion (Table 2).

Table 2: The MPCA Lake Eutrophication Stands for Total Phosphorus, Chlorophyll a, and Secchi Disc Transparency in WCBP Ecoregion

Water Quality Parameter	MPCA Lake Eutrophication Standard (WCBP Ecoregion)
Total Phosphorus (µg/L)	90
Chlorophyll-a (µg/L)	30
Secchi Disc Transparency (m)	0.7

The narrative water quality standard that applies from Minnesota Rules is:

Minn. R. 7050.0150, DETERMINATION OF WATER QUALITY, BIOLOGICAL AND PHYSICAL CONDITIONS, AND COMPLIANCE WITH STANDARDS

Subp. 3. Narrative standards.

For all class 2 waters, 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 aquatic biota 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 aquatic biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters.

3. Watershed and Waterbody Characterization

3.1 Surface Water Quality Conditions

3.1.1 Lake

Geneva Lake (24-0015-00) is located in the northwestern region of the CRW, and is within the headwaters of Turtle Creek, an important tributary to the Cedar River (Figure 3). Figure 3 uses the name "Lake Geneva;" this is the same lake, and the more commonly used name is "Geneva Lake." Geneva Lake is a large and shallow lake, consisting of a north and south basin with a total surface area of 1,928 acres. A 125-acre subbasin along the east side of the lake's northern bay had been drained and farmed. In recent decades, it has been reconnected to the lake via a culvert under Freeborn County State Aid Highway 26 and water permanently restored. The outlet of Geneva Lake is through a dam to Turtle Creek, which is in the southeast portion of the lake. The predominately agricultural watershed of about 11,624 acres is entirely within Freeborn County, which includes some rolling topography that is part of a glacial moraine. The small town of Geneva (population 544 in 2015) lies directly north of the lake. The town's municipal wastewater discharges via a ditch to the north, and into the Cannon River Watershed. Table 3 provides some key morphometric and lake classification statistics for Geneva Lake.

The MPCA listed Geneva Lake for excessive nutrients/eutrophication in 2011. The June 1 through September 30, average TP concentration of data provided by the MPCA Environmental Data Access database and the DNR is 99 µg/L.
https://cf.pca.state.mn.us/water/watershedweb/wdip/details.cfm?wid=24-0015-00

Table 4 provides these TP data, as well as compiled data for Geneva Lake from 2002 through 2016, including chlorophyll a, secchi disc transparency, and alkalinity.

Figure 3: Geneva Lake and Immediate Watershed Areas

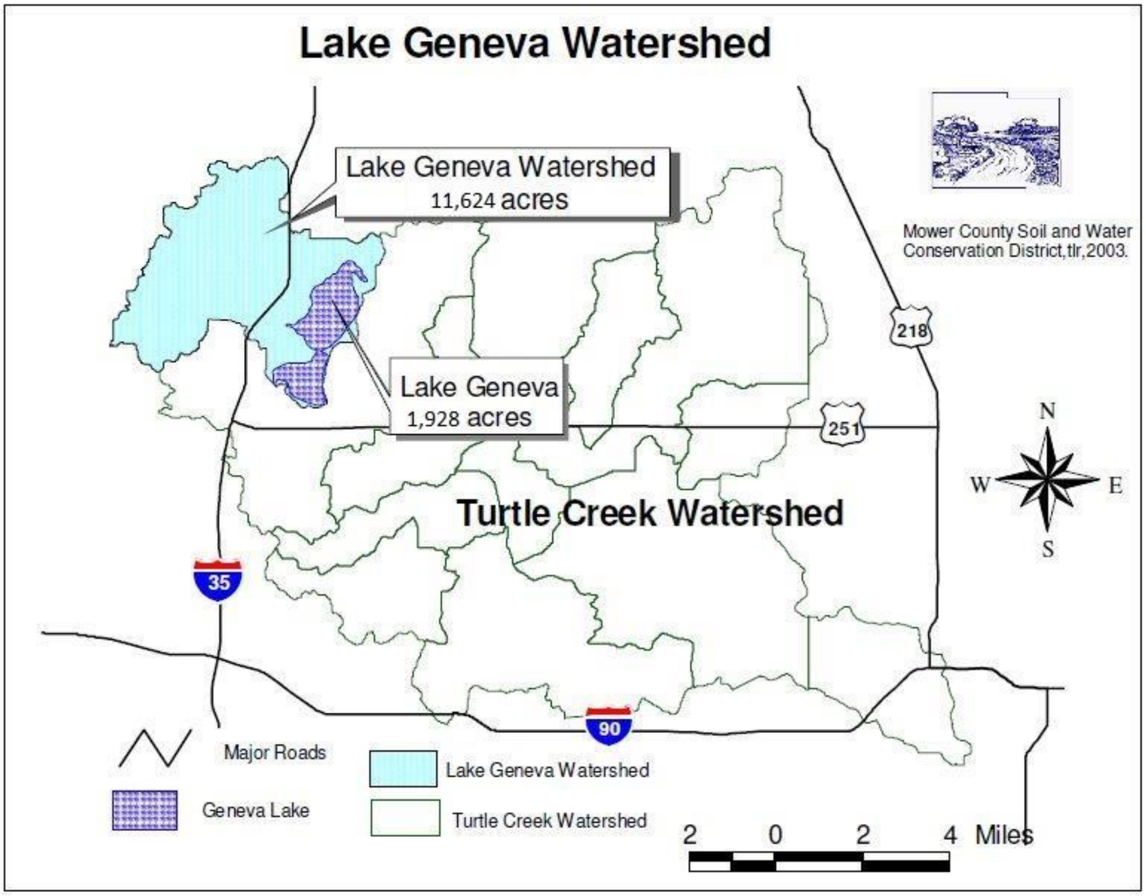


Table 3: Key Statistics about Geneva Lake

Lake ID	24-0015-00
7050 use Classification	2B, 3C
Total surface area	1,928 acres
Watershed area	11,624 acres
Watershed: Lake ratio	6.3:1
Mean depth	1.1 m
Maximum depth	2.4 m
Shoreline length	16.6 miles

Figure 4: In-lake Total Phosphorus for Geneva Lake, Minnesota (2002-2016)

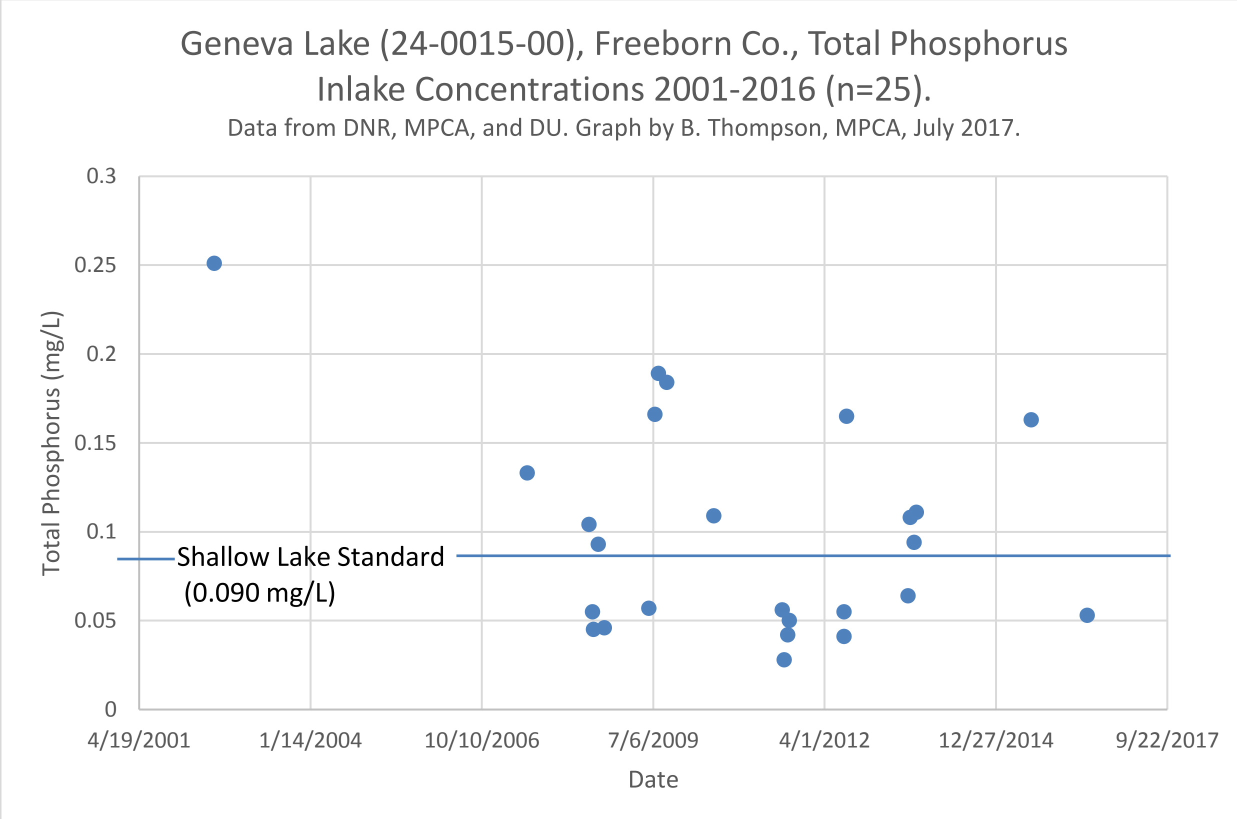


Table 4: Geneva Lake Summer Water Quality 2002-2016 (Compiled data from DNR, Ducks Unlimited, and MPCA)

Parameter	n	Minimum	Maximum	Average	Median	Water Quality Standard, June 1, Sept 30
Chlorophyll a (ug/L)	17	1.75	191	38	33	30
Secchi depth clarity (m)	23	0.12	1.3	0.6	0.5	0.7
Total Phosphorus (ug/L)	25	28	251	99	93	90
Alkalinity (mg/L)	11	91	233	143	130	no WQS

3.1.2 Streams

The TSS WQS is the basis for “sediment-related” impairments in this TMDL. Other data that have been utilized include turbidity (with several types of systems and units of measurement involved), transparency tube, and Secchi tube visual measurements. Detailed spreadsheets used to compute the TMDL were developed for this project, and are included in Appendix E.

At some stream monitoring sites, probes that collected continuous turbidity measurements were deployed. While this method can provide the most complete dataset for an impaired stream reach, the data needs to be transformed into TSS concentration values, in order to estimate sediment loads. It was also typical that water quality analysis involved a lab turbidity test, coincidental with the continuous turbidity measurements. This allowed for a better relationships, and tighter conversions.

Table A.2, in Appendix A, shows how turbidity readings collected from various methods are equated to TSS concentrations for these datasets, after applying the conversion factors described in Appendix A.

Reach-specific conversions and weighting of data are fully defined in Appendix A, and in each TSS LDC file (available from the MPCA).

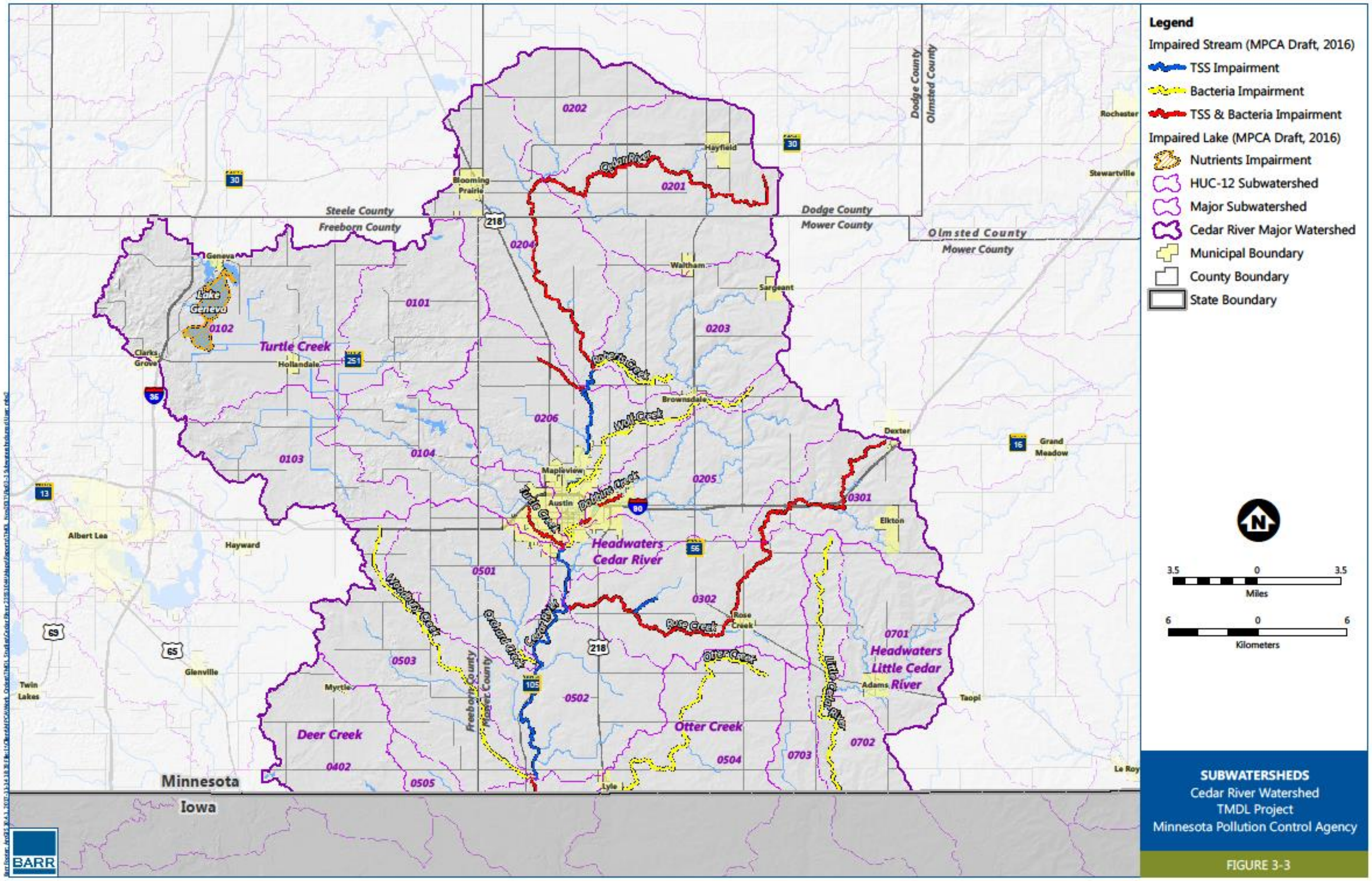
Table 5 provides a summary of TSS samples for the period 1996 through 2016 by Assessment Unit ID (AUID). In 5 of the 10 reaches, data from more than one monitoring site was used. This timeframe is different from assessment "window" that the MPCA used to determine the initial listings. To illustrate, Turtle Creek (AUID 540) was initially listed in 2006 for turbidity, and the 10-year assessment window was 1995 through 2005. The WQS in 2006 was a turbidity standard (25 NTU). The initial listing made use of turbidity data, as well as transparency tube/Secchi tube data (i.e. TSS surrogate data), which is not included in this table. These are factors to consider for reaches 501, 516, 533, and 537, which display percent exceedances less than 10% threshold for impairment. (The initial listing data can be obtained from the MPCA upon request). Stream reaches highlighted in yellow have an identified TSS stressor to aquatic life. These are not impairments to the TSS WQS. The Cedar River segment highlighted in turquoise will be corrected and removed from the impaired waters list (for TSS) by the MPCA. The remaining seven stream reaches that are not highlighted, are all impaired by TSS.

Table 5: Summary of TSS Monitoring Results in the Cedar River Watershed

Listed Waterbody Name	Reach (AUID)	WQ Station ID(s)	# TSS Samples Above 65 mg/L
Cedar River – Rose Cr to Woodbury Cr	07080201-501	S000-136, S000-222, S001-381	18 of 206
Cedar River – Roberts Cr to Upper Austin Dam	07080201-502	S000-137	14 of 136
Cedar River – Turtle Cr to Rose Cr	07080201-515	S000-001	42 of 395
Unnamed Creek – Unnamed Cr to Rose Cr	07080201-583	S005-094	4 of 35
Cedar River – Woodbury Cr to MN/IA border	07080201-516	S000-059	0 of 10
Cedar River – Headwaters to Roberts Cr	07080201-503	S000-060, S000-789, S000-803, S000-804, S006-105	18 of 186
Rose Creek – Headwaters to Cedar R	07080201-522	S000-229, S006-375, S007-806, S000-808, S006-858, S006-863	30 of 171
Unnamed Creek – Unnamed Cr to Cedar R	07080201-533	S003-077, S003-078	1 of 79
Dobbins Creek – T103 R18W S36, east line to East Side Lk	07080201-535	S003-065, S005-282, S008-963	20 of 128
Dobbins Creek – East Side Lk to Cedar R	07080201-537	S003-066	0 of 26
Turtle Creek – T102 R18W S4, north line to Cedar R	07080201-540	S004-430, S004-432, S006-860, S000-230, S000-809	51 of 322

Figure 5 is a watershed map with impairments and HUC 12 subwatersheds.

Figure 5: Subwatersheds, Cedar River Watershed.



The LDC methods described in Appendix A were also followed in developing the bacterial LDCs, except that the 126 cfu/100 ml *E. coli* standard was substituted for the 65 mg/L TSS standard in each case. This ensured that the same flow duration curve data were used for both standards.

Indicator bacteria levels above the WQS are commonplace in Southern Minnesota, and the Cedar River and its tributary streams are no exception.

Table 6 provides a summary of indicator bacteria data for the 14 bacteria-impaired AUIDs, with monthly geometric means aggregated over the years of 2000 through 2016, for the months of June, July and August. To indicate the total quantity of data available for a given river monitoring site, the number of samples is also provided, which varies from 5 to 20 samples for the designated month. In general, there were not enough data for the other months to assemble the minimum of five samples required to calculate the monthly geometric mean. The months of June, July, and August likely correlate with the season when more recreational river users are most active. All stream reaches in Table 6 are impaired by *E. coli*.

Figure 6 is a plot of this same data, which readily shows a significant portion of the bacteria concentrations are above the standard at almost all of the monitoring sites (except for the lower portion of Dobbins Creek); with greater exceedances of the WQS observed at the headwaters of the Cedar River, Roberts Creek, Rose Creek, Little Cedar River, Upper Dobbins Creek, and Woodbury Creek.

Figure 6: Monthly (June, July, and August) Geometric Means for *E. coli* bacteria in the Cedar River Watershed.

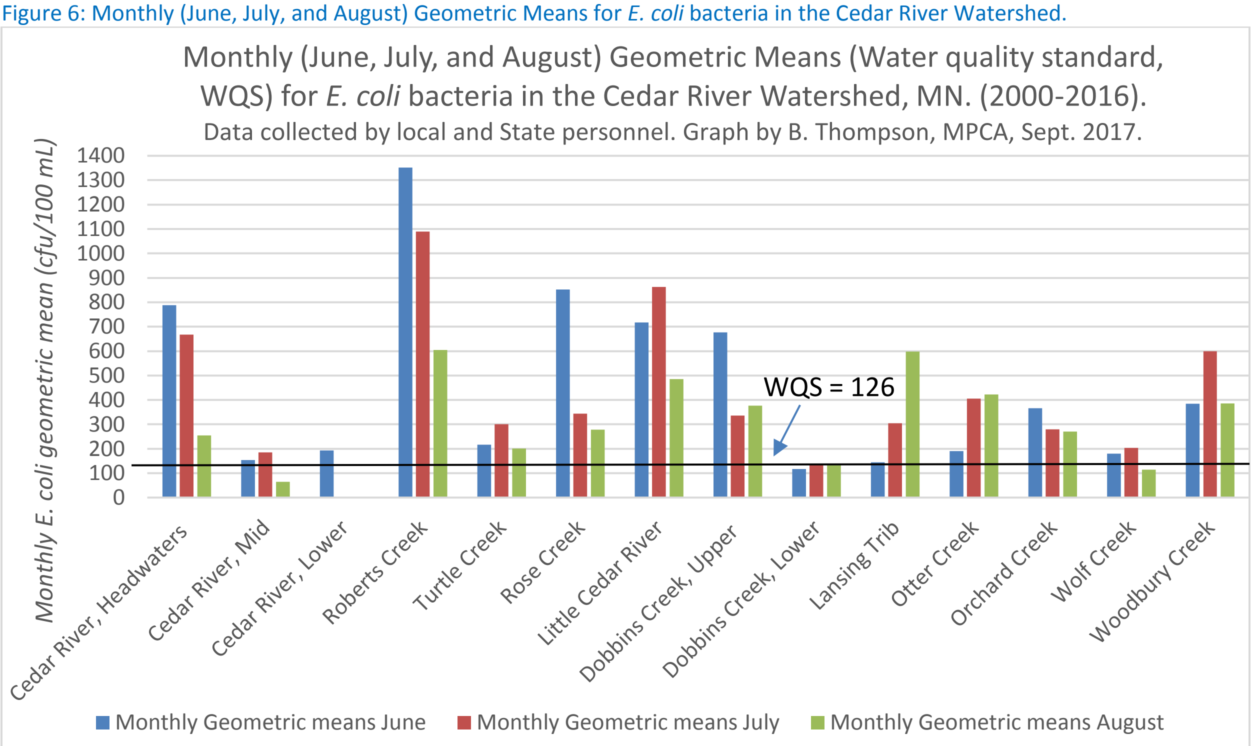


Table 6: Summary of Bacteria Monitoring Results in the Cedar River Watershed.

Reach Name	Main Monitoring site		*Escherichia coli* Maximum Standard		*E. coli* Monthly Geometric Mean			
					Standard org. per 100 ml	Geometric Mean (n), org/100 ml		
	EQuIS ID	AUID	Standard, org. per 100ml	Number of Standard Exceedances		June	July	August
Cedar River, Headwaters to Roberts Creek	S000-804	07080201–503	1260	2 of 21	126	788 (9)	667 (12)	255 (10)
Roberts Creek	S001-182	07080201–504	1260	3 of 21	126	1352 (10)	1089 (12)	605 (10)
Cedar River, Dobbins to Turtle Creek	S005-613	07080201–514	1260	1 of 15	126	154 (5)	185 (5)	65 (5)
Turtle Creek	S000-230	07080201–540	1260	1 of 14	126	216 (12)	300 (18)	201 (15)
Rose Creek	S000-229	07080201–522	1260	3 of 21	126	852 (14)	344 (20)	278 (14)
Cedar River, Woodbury Cr. To Iowa	S000-059	07080201–516	1260	0 of 13	126	193 (5)		
Little Cedar River	S005-614	07080201–518	1260	4 of 15	126	717 (5)	863 (5)	486 (5)
Dobbins Creek (Upper Reach)	S003-065	07080201–535	1260	12 of 41	126	677 (5)	336 (9)	377 (7)
Dobbins Creek (Below East Side Lake)	S003-066	07080201–537	1260	0 of 31	126	117 (7)	139 (12)	133 (10)
Unnamed Creek to Cedar River (aka Lansing Tributary)	S003-078	07080201–533	1260	1 of 31	126	145 (10)	304 (13)	598 (8)
Otter Creek	S003-068	07080201–517	1260	2 of 31	126	191 (7)	406 (12)	422 (10)
Orchard Creek	S003-067	07080201–539	1260	4 of 49	126	366 (10)	279 (17)	270 (14)
Wolf Creek	S003-064	07080201–510	1260	1 of 33	126	180 (7)	204 (14)	115 (12)
Woodbury Creek	S004-868	07080201–526	1260	7 of 45	126	385 (12)	599 (19)	386 (14)

Table notes: The monthly geometric means were calculated across years, and only for the months of June, July and August, when the number of samples collected allowed for a minimum of five. In some cases, fecal coliform data was used, and converted to *E. coli* equivalents.

3.2 Land Use and General Watershed Characteristics

The Cedar River Basin is located in southeastern Minnesota. The Cedar River is a tributary to the Iowa River, which flows into the Mississippi River. The Minnesota portion of the basin is 957 square miles in area and consists of five major subwatersheds: the Cedar River mainstem (435 square miles), Shell Rock River (246 square miles), Turtle Creek (154 square miles), Deer Creek (30 square miles), and Little Cedar River (92 square miles). The basin in Minnesota is a part of the WCBP ecoregion.

The Cedar River originates in Dodge County in the northeastern part of the basin. The river flows southward from the confluence of the East Fork Cedar River and Middle Fork Cedar River, through the important regional city of Austin (population 25,000) to the Minnesota/Iowa border. Turtle Creek flows into the Cedar River from the west at Austin, draining a large and productive agricultural area. In addition to the above major tributaries, numerous smaller tributary streams flow into the Cedar River, both upstream and downstream of Austin.

There are small cities in the CRW, and they are listed in Table 7 with human population, land area, and the nearest stream or river. The total land area in these small cities is about six square miles.

Table 7: Small Cities and Communities in the Cedar River Basin

City	Population*	Land Area (sq. miles)	Web/Comp. Plan Link:	Nearest stream/river
Adams	800	1.01	http://adamsmn.com/	Little Cedar River
Blooming Prairie	1996	1.41		Blooming Prairie Creek and Upper Cedar River
Brownsdale	678	0.47	https://www.brownsdalemn.com/	Roberts Creek
Elkton	144	1.30		Unnamed creek and Little Cedar River
Hollandale	294	0.44		Turtle Creek
Rose Creek	424	0.46		Rose Creek
Sargeant	61	0.83		Roberts Creek
Waltham	151	0.46		Roberts Creek
Totals	4548	6.38		

*2016 human population estimate
*https://www.bloomingprairie.com/vertical/sites/%7B544EA95D-EA95-4B17-8590-4217CC6E954B%7D/uploads/BP_Comp_Plan.pdf

The Cedar River and its tributaries have been modified by the construction of several dams. These include a mainstem dam upstream of Austin at the lower end of Ramsey Mill Pond, and a dam on Dobbins Creek, which creates a 45-acre reservoir called East Side Lake (also in Austin).

The dominant land use in the Cedar River Basin is row crop agriculture (approximately 78%, according to the 2008 through 2010 U.S. Department of Agriculture (USDA) Crop Data Layer (CDL) coverages), with water/wetlands and urbanized land uses each covering approximately 3% of the basin, and developed land and pasture covering the remainder. Land adjacent to the streams is utilized for pasture, cropland, urban development, and recreation.

Mower County covers about 68% of the CRW of Minnesota, and some agricultural production statistics (at the county-scale) illustrate the significance of agriculture, including:

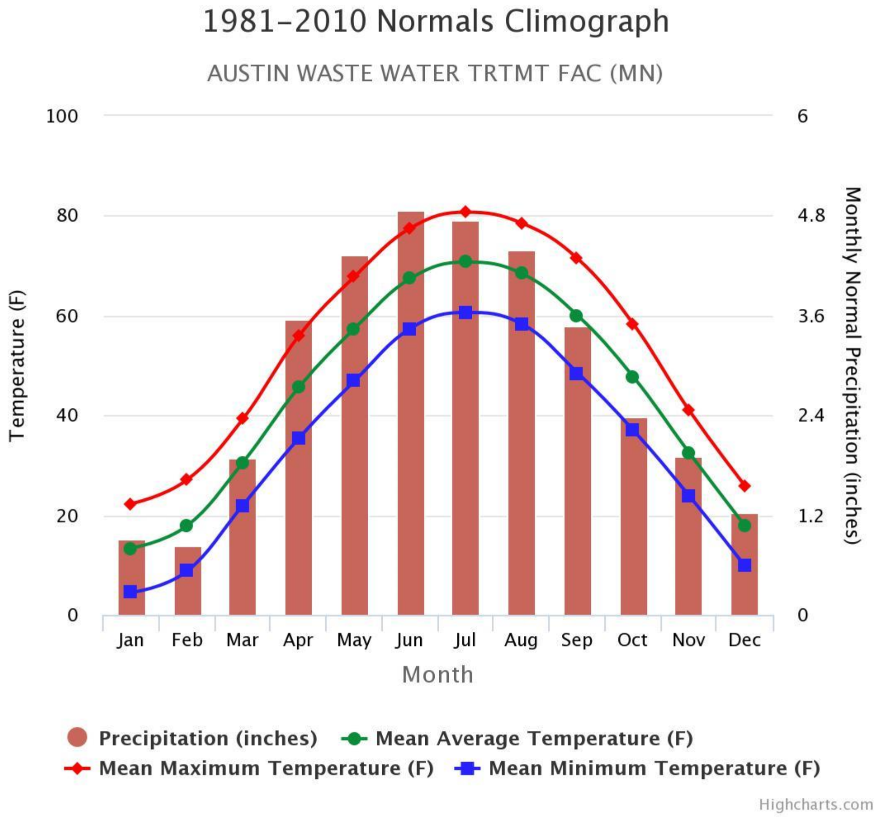
- 2016 acres harvested for grain: 206,500
- 2016 average corn grain yield: 193.7 bu/ac
- 2012 farm related income (total receipts): $24.1 million (USDA-NASS)

The water resources of the CRW in Minnesota was investigated by Farrell et al (1975), as part of a USGS and DNR hydrologic investigation. This work provided a series of atlas sheets that covered water supply quality and quantity, geology, soils, and rainfall-runoff. In the northeastern portion of the CRW, elevations reach 1,450 feet above mean sea level, and glacial drift is more than 200 feet thick. In the southern area of the CRW, near the Minnesota-Iowa border, the elevation is about 1,140 feet, with glacial drift less than 100 feet thick. The measured average annual precipitation is 30.3 inches (1940 to 1969), with 5.9 inches of runoff (average annual), and evapotranspiration of 24.4 inches.

The long-term average annual watershed precipitation throughout the basin ranges from 31 to 33 inches. During the 1995 through 2012 timeframe, annual precipitation at the Austin WWTP ranged from 22.2 to 42.5 inches, with a median of 33.9 inches (DNR 2017b). The closest long-term pan evaporation measurements are from the University of Minnesota's Waseca agricultural research station. The average pan evaporation is 38.9 inches (1964 through 2014), with the highest months being June, July, and August. http://www.dnr.state.mn.us/climate/historical/waseca_pan_evaporation.html

Air temperature and monthly precipitation data are displayed in Figure 7 for 20 years of data collected at the Austin WWTP.

Figure 7: 1981 – 2010 Normals Climograph for Austin, Minnesota including temperature and monthly normal precipitation. (National Weather Service).



The land draining to just the mainstem Cedar River at the Minnesota-Iowa border is 585 square miles. The mean basin slope, computed from a 10-meter digital elevation model (DEM) is 2.02%. The generalized mean annual runoff (1951 through 1985) is 7.43 inches (USGS Streamstats 2018).

Dr. David Mulla of the Department of Soil, Water, and Climate of the University of Minnesota has described the state's land area in terms of "agroecoregions", in which each agroecoregion is associated with a specific combination of soil types, landscape and climatic features, and land use (described in Hatch et al. 2001). The Cedar River Basin is predominantly made up of four agroecoregions: the Rolling Moraine in the western portion of the basin, the Level Plains mainly east of the Cedar River mainstem, the Undulating Plains in the eastern portion of the basin, and the Alluvium and Outwash adjacent to rivers and creeks throughout the basin (see Figure 2). These agroecoregions help describe the watershed, and also can provide some general BMP implementation information. Soils information is summarized below, for each of the four agroecoregions.

Rolling Moraine

This agroecoregion consists primarily of fine textured soils from the Lester, Clarion, Canisteo, and Cordova series. Steep to very steep well-drained soils account for roughly two-thirds of this agroecoregion. Flat, poorly drained soils constitute roughly one-third of this agroecoregion.

Level Plains

Soils in this agroecoregion are generally fine textured, and common soils include the Maxfield, Skyberg, Clyde, and Sargeant series. Slopes are generally flat or moderately steep. Two-thirds of the soils are poorly drained, while the other third are well drained.

Undulating Plains

Soils in this agroecoregion are fine textured, including the Racine, Tripoli, Maxfield, and Oran series. A very high density of intermittent streams exists. Soils are located primarily on moderately steep slopes, with one-fourth of the slopes being flat. Two-thirds of the soils are well drained, with one-third being poorly drained.

Alluvium and Outwash

This agroecoregion consists of either fine-textured alluvium or coarse-textured outwash. Soils are generally well drained, and are located on flat to moderately steep slopes. Soil series include Menahga, Hubbard, Mahtomedi, and Estherville.

3.3 Pollutant Sources Summary

Conclusions regarding pollutant sources and current loading are based largely on analysis/interpretation of the available data and information. Various sources of information are used in the analysis including water quality data and other information regarding watershed and receiving water characteristics, as well as soils, land use/land cover, topography and geomorphology (discussed in more detail in Appendix B).

This section of the TMDL provides summaries regarding 10 pollutant sources, with 7 tables and 4 figures that provide more detailed data and context. Some of the pollutant sources address both sediment and bacteria (ex. urban stormwater runoff), while others are more strongly affiliated with sediment (row crop agriculture) or bacteria (Subsurface Sewage Treatment Systems SSTS). Excess phosphorus in the CRW's aquatic systems is related to the land use/land management and point sources, as affected by precipitation and watershed hydrology. Because these sources vary in importance, based on time and geographic location/scale, the discussion in this section does not rank or further prioritize the sources of pollution.

This section is organized into the following three subsections: background information, point source/regulated stormwater, and nonpoint sources.

3.3.1 Background Information

Understanding the hydrology in the CRW is a foundational element for water quality restoration and protection. Hydrology is the study of inter-relationships and interactions between water and its environment in the hydrological cycle. Hydrology is one of the five components in Minnesota's watershed health assessment framework (DNR https://www.dnr.state.mn.us/whaf/about/5-component/index.html).

Long term streamflow (or stream discharge) records are critical in assessing hydrology. Stream flow records at the USGS monitoring gage below Austin (#05457000) have been collected since 1910. Figure 8 shows that the flow duration characteristics over the last 30 years are considerably higher throughout the entire flow regime (i.e. high flows to very low flows), in relation to an earlier period of record (prior seven decades).

Figure 9 displays runoff data for the Cedar River at Austin, with continuous data between 1942 and 2001. While the percent runoff is highly variable for this timeframe, ranging from less than 10% to 58%, a 20-year average percent runoff statistic shows an increase from near 20% to about 34%. The 20-year average precipitation at Austin displayed a similar rise, from 29 to 33 inches per year. The linear trend line in Figure 9 displayed is for the yearly annual percent runoff data.

Stream flows are a significant factor in stream sediment mobilization, stream channel erosion, sediment transport, and deposition. Figure 10 shows the sediment rating curve for the Cedar River at Austin. Sediment concentrations in the water column (suspended sediments) increase, as the flow increases. The regression lines and data points illustrated in Figure 10 show that the SSC is consistently higher than the TSS concentration for a given stream discharge (Appendix A, and MPCA 2004). This is because the SSC methodology allows for the collection and quantification of heavier suspended sediment particles. This results in TSS-based sediment loads that are significantly lower than what is actually present in the stream. The WQS for stream sediment is based on the TSS measurement. However, the heavier particles (often sand-sized), which can be collected and measured using the SSC protocols, can degrade habitats and affect stream biota.

Figure 8: Flow Duration Comparison, Cedar River at Austin

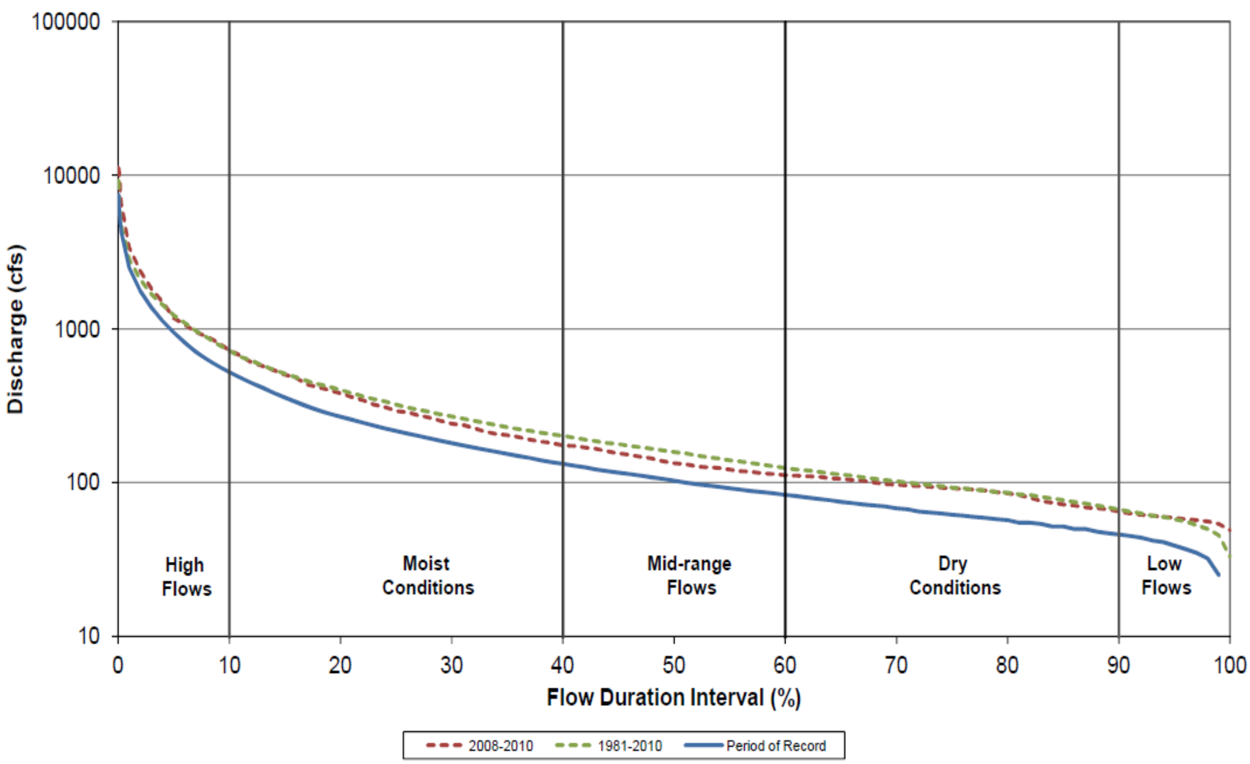


Figure 9: Watershed yield percentage, average precipitation and average runoff for Cedar River at Austin (1938-2001)

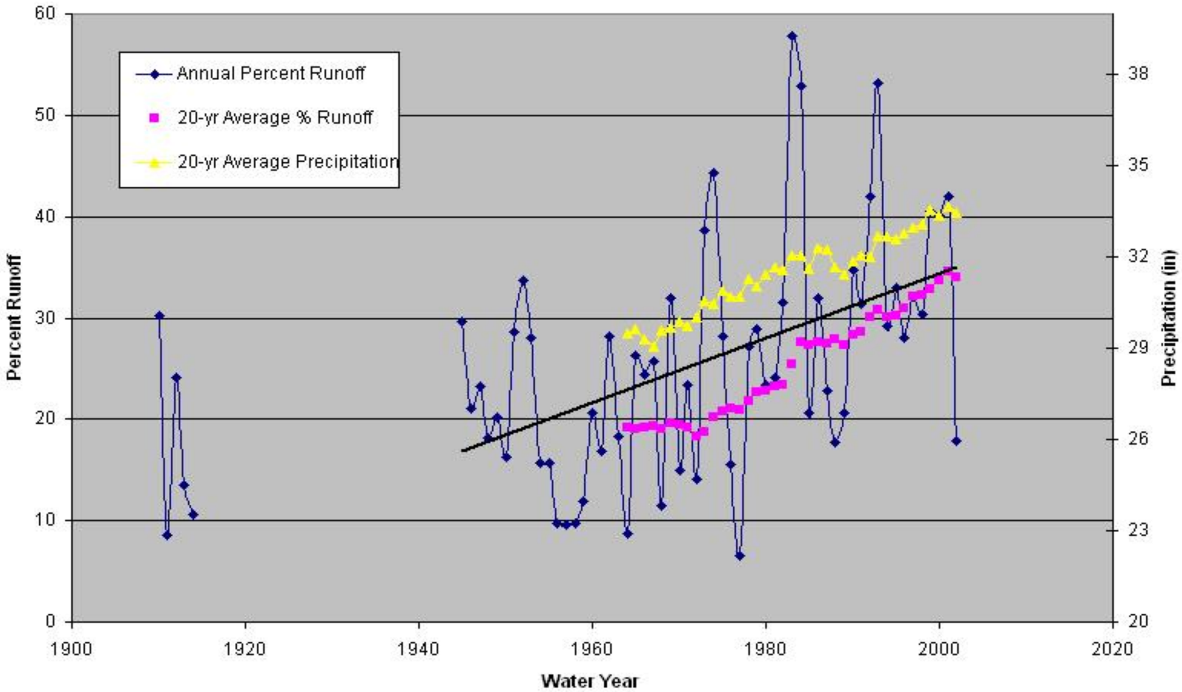


Figure 10: Sediment Rating Curves, Cedar River at Austin

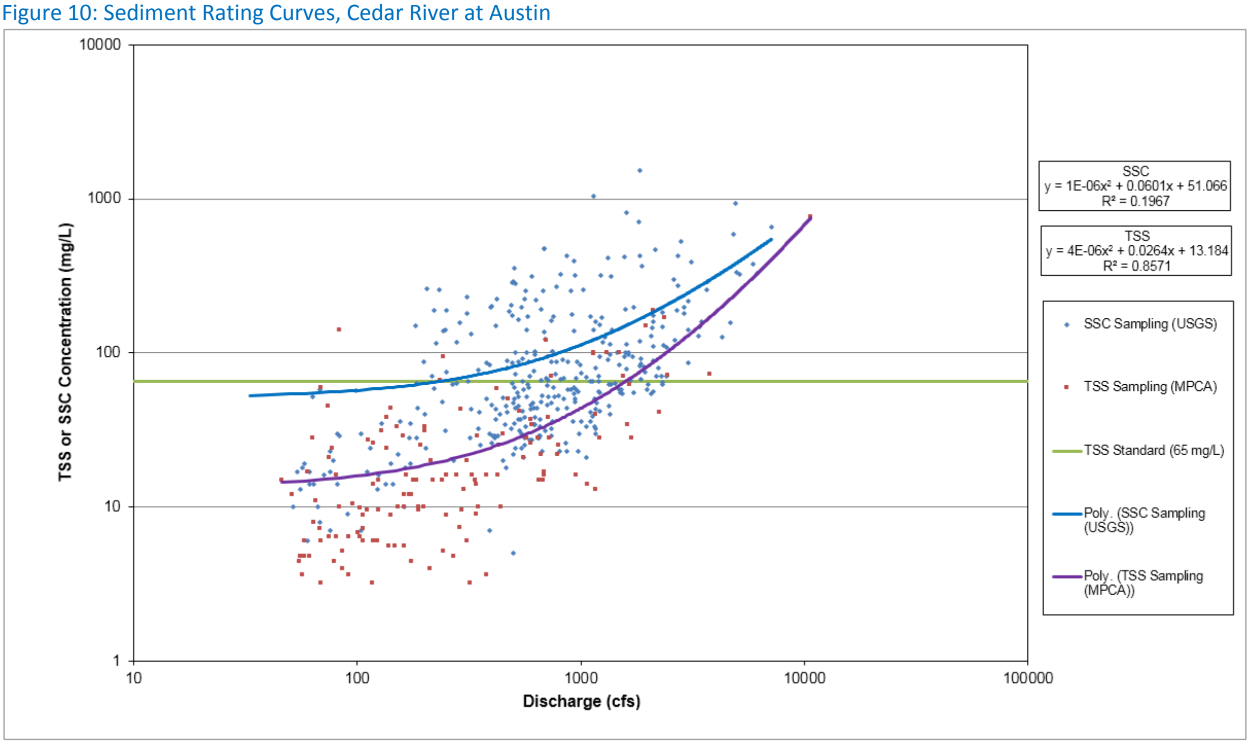
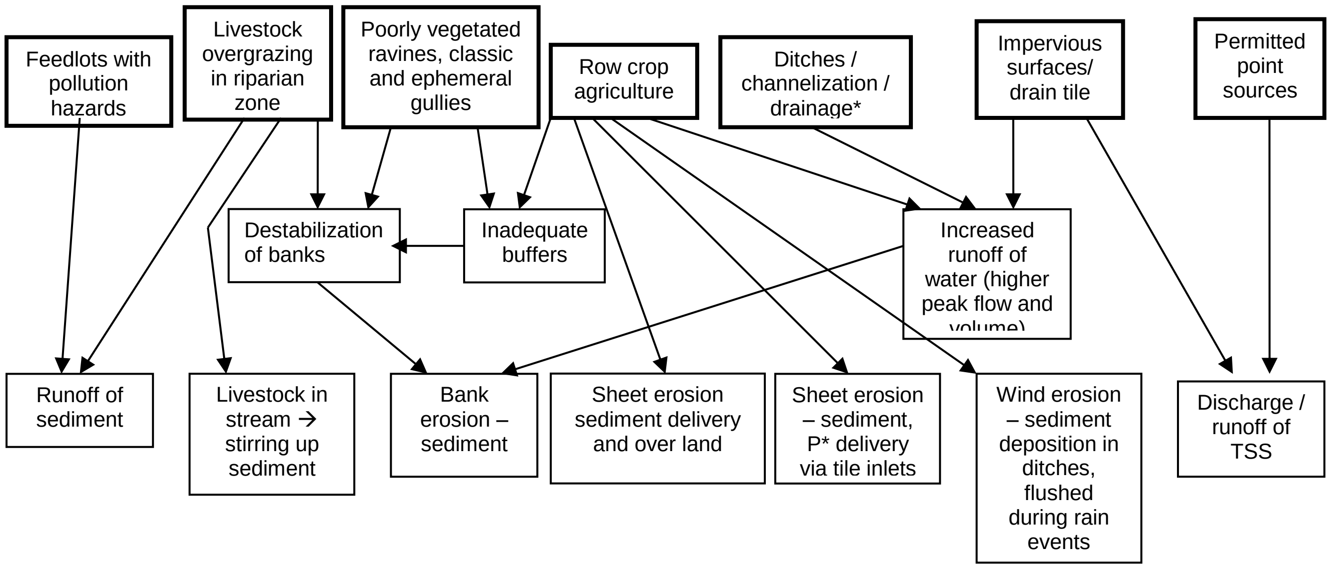


Figure 11: Simplified Conceptual Model for Sediment



* Ditches / channelization also can cause sediment delivery via:

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

With sediment a common pollutant in the CRW, a simplified conceptual model/diagram for sediment is presented in Figure 11, which shows several possible sources. This figure illustrates potential sediment sources, types of erosion, and pathways for sediment. Both "external" and "internal" sources of TSS are illustrated in this figure. Most point and nonpoint sources are typically considered external in that they are located in the watershed, but outside of the stream channel itself. TSS contribution from point sources is more easily quantified, while the nonpoint source sediment loads are harder to measure, model, and define. Internal sources typically encompass processes that occur within the channel (including the bed and banks) or the floodplain of a waterway, stream, or river. Such processes include channel and floodplain erosion or scour, stream bank erosion and bank slumping. These internal sediment sources are primarily due to changes in total runoff volumes, higher peak flows, and stream channel geomorphology.

Another internal process involves the growth and decay of algae, either floating in the water, or attached to rocks and channel substrates. Although somewhat limited in the CRW, phosphorus can contribute to TSS/turbidity through production of algae during lower flow periods or in low-gradient/low-velocity portions of the streams, or in lakes/ponds and reservoirs. Extra phosphorus transported to the river from the watershed promotes algal production. Primary production in Geneva Lake, with water discharge downstream via Turtle Creek, is a relevant case of this in the CRW.

While Figure 11 is focused on sediment, it does share some of the source categories with bacteria. Bacteria sources include municipal wastewater, livestock grazing, urban stormwater, and feedlots – all of which are depicted in the diagram. The consideration of three other sources including SSTS, field-applied manure, and wildlife rounds out the most common sources of bacteria (MPCA 2009). There was no bacterial source tracking or DNA analysis completed for this project.

Bacterial pollution in surface waters has a degree of complexity and variability beyond that of sediment. Using our current basic bacteria datasets, a more simplified process for consideration is put forward. Bacterial sources are considered with a general risk perspective that involves both prevalence of the source and the runoff/delivery pathways. Two examples of this approach can be illustrated on the "two ends" of the bacteria LDCs, which follow in Section 4.2. On the low-flow end (dry and low flow zones), municipal wastewater and SSTS sources are more critical. During higher flows (high and very high flow zones), the sources that correlate positively with runoff are the most critical – such as urban stormwater, pastures close to streams, feedlots with runoff pollution hazards, and manure applied to agricultural fields. During intermediate flows, a mix of sources are likely at play. Across the flow spectrum, the natural growth and reproduction of bacteria in sediments and soils can occur, and this can augment the bacterial community associated with runoff. Overall, with limited indicator group bacterial data sets at some stream sites in the CRW, this more simplified process is appropriate.

The following paragraphs, grouped for point and nonpoint sources, describe the source components from the conceptual model (Figure 11) for sediment, with application also for bacteria and excess nutrients.

3.3.2 Point Sources and Regulated Stormwater

Permitted - Point sources

Point sources, for the purpose of this TMDL, are those facilities/entities that discharge or potentially discharge solids and bacteria to surface water and require a National Pollutant Discharge Elimination System (NPDES) Permit from the MPCA. WWTFs are required to meet their assigned discharge limits for pollutants that include TSS and bacteria, and in some cases nutrients like phosphorus. In this watershed the potential point source categories are WWTFs (Table 8), the municipal separate storm sewer system (MS4) for Austin, and industrial and construction stormwater sources. NPDES permitted discharges for cooling water and industrial wastewater are considered under the WWTFs category. Concentrated Animal Feeding Operation (CAFO) are included in Table 10, and feedlots with pollution hazards, regardless of feedlot size in animal units, may also be considered here on a case-by-case basis.

The Construction Stormwater General Permit number is MNR1000001 and the Industrial Stormwater General Permit number is MNR0500000. Stormwater coming from these categories are only considered to be sources of TSS, and not sources of *E. coli* bacteria.

Table 8. Permitted wastewater treatment plants in the Cedar River Watershed

Facility	NPDES Number	Discharge
Adams WWTP	MN0021261	Continuous
Arkema Inc	MN0041521	Continuous
Austin WWTP	MN0022683	Continuous
Blooming Prairie WWTP	MN0021822	Continuous
Brownsdale WWTP	MN0022934	Controlled
Elkton WWTP	MNG580013	Controlled
Hollandale WWTP	MN0048992	Controlled
Hormel Foods Corp/Quality Pork Proc. SD003	MN0050911	Continuous
Hormel Foods Corp/Quality Pork Proc. SD004	MN0050911	Continuous
Lansing Township WWTP	MN0063461	Controlled
Lyle WWTP	MN0022101	Controlled
Oakland Sanitary District WWTP	MN0040631	Controlled
Rose Creek WWTP	MN0024651	Controlled
Sargeant WWTP	MNG580214	Controlled
Waltham WWTP	MN0025186	Controlled

Each of the WWTFs included in Table 8 in the watershed have TSS discharge limits of either 30 or 45 mg/L TSS, as well as average and maximum daily loading limits per calendar week and month. TSS limits are not normally imposed on water used for non-contact cooling, but an estimate of 5 mg/L TSS has been applied to such facilities that use ground water for cooling and discharging to surface waters.

Regulated Stormwater

Regarding runoff from construction sites, the MPCA issues construction permits for any construction activities disturbing: one acre or more of soil; less than one acre of soil if that activity is part of a “larger common plan of development or sale” that is greater than one acre; or less than one acre of soil if the MPCA determines that the activity poses a risk to water resources. Stormwater runoff at construction sites that do not have adequate runoff controls can be significant on a per acre basis (MPCA Stormwater web page 2006). The number of projects per year in the predominantly rural CRW is relatively small. Therefore, this source appears to be a very minor sediment source at river sites with larger drainage areas, but can be a biologically-significant factor at smaller sites where construction stormwater is not correctly managed.

Industrial Stormwater Discharge Permits are required for facilities with Standard Industrial Classification (SIC) codes in 10 categories of industrial activity with significant materials and activities exposed to stormwater. These include any material handled, used, processed, or generated that when exposed to stormwater may leak, leach, or decompose and be carried off-site. For industrial stormwater sources, water discharge permit holders in the watershed that are gravel pits do not appear to represent a TSS loading concern. (For the purpose of the TMDL, this source is lumped with construction stormwater into a categorical WLA.)

Impervious surfaces (roads, parking lots, roofs, etc.) can contribute excessive pollutants rapidly to surface waters in the CRW. The only MS4 in the CRW is approximately 12 square miles of the city of Austin (Permit #MS400251) and surrounding urbanizing area. Table 9 below provides the contributing MS4 areas for each AUID.

The main pollutants most frequently associated with runoff from an MS4 include sediment, bacteria, and nutrients. Stormwater runoff can also elevate water temperatures, and transport a variety of chemicals including metals and organic compounds.

Sediment is a common contaminant found in urban stormwater, and median TSS concentrations range from 52 to 75 mg/L (MPCA 2018).

Bacteria are living organisms that exist almost everywhere in the environment. Bacteria are capable of multiplying and persisting in both soil and water environments, and thus perfect indicators and thresholds are not currently available. In urban stormwater, bacteria sources include leaking sewer lines, sewer overflows, septic systems, pet waste, and landfills. The ultimate source is animal waste, including human, domestic pets, and wildlife, particularly birds (MPCA 2018). Bacteria are also hard to model with watershed modeling programs and tools, and consequently there are high levels of uncertainty.

Phosphorus is the main nutrient of concern associated with urban stormwater runoff. MPCA (2018) lists plant and leaf litter, soil particles, pet waste, road salt, fertilizer and atmospheric deposition as the main sources. Lawns and roads are contributing about 80% of the total and dissolved phosphorus loading, with roads being more important in commercial and industrial areas. While highly variable, median TP concentrations in urban stormwater runoff range from 0.13 to 0.26 mg/L.

Table 9: Contributing MS4 area for each AUID

AUID	Name	Reach Description	Contributing Area, sq. mi.	Austin MS4 Area, sq. mi.	Austin MS4 Area, %
07080201-501	Cedar River	Rose Cr to Woodbury Cr	543.00	12.0	2.2
07080201-502	Cedar River	Roberts Cr to Upper Austin Dam	182.72	0.1	0.1
07080201-503	Cedar River	Headwaters to Roberts Cr	119.01	0.0	0.0
07080201-504	Roberts Creek	Unnamed cr to Cedar R	39.12	0.0	0.0
07080201-510	Wolf Creek	Headwaters to Cedar R	11.81	0.9	7.7
07080201-514	Cedar River	Dobbins Cr to Turtle Cr	243.95	6.6	2.7
07080201-515	Cedar River	Turtle Cr to Rose Cr	405.92	11.3	2.8
07080201-516	Cedar River	Woodbury Cr to MN/IA border	585.61	12.0	2.1
07080201-517	Otter Creek	Headwaters to MN/IA border	37.94	0.0	0.0
07080201-518	Little Cedar River	Headwaters to MN/IA border	47.82	0.0	0.0
07080201-522	Rose Creek	Headwaters to Cedar R	67.87	0.0	0.0
07080201-526	Woodbury Creek	Headwaters to Cedar R	42.00	0.0	0.0
07080201-533	Unnamed creek	Unnamed cr to Cedar R	5.22	0.0	0.0
07080201-535	Dobbins Creek	T103 R18W S36, east line to East Side Lk	37.51	1.3	3.4
07080201-537	Dobbins Creek	East Side Lk to Cedar R	38.41	2.1	5.6
07080201-539	Orchard Creek	T101 R18W S5, north line to Cedar R	31.88	0.7	2.2
07080201-540	Turtle Creek	T102 R18W S4, north line to Cedar R	153.00	3.4	2.2
07080201-583	Unnamed creek	Unnamed cr to Rose Cr	9.36	0.0	0.0

Feedlots with pollution hazards

Feedlots near streams and watercourses can contribute to the pollution of water resources if not properly managed. The application of animal manure is an activity that can also degrade water quality through surface runoff (SRO) and/or subsurface transport of pollution, depending on timing, location, amount, and method of application. Table 10 provides data on CAFOs in the CRW, by HUC 11 subwatershed. There are a total of 36 CAFOs, with higher counts in the Upper Cedar River Subwatershed (07080201-030) with 8 CAFOS, and the Turtle Creek Subwatershed (07080201-040) with 9 CAFOs. Animal agriculture in the CRW is dominated by total confinement swine operations.

Table 10: Concentrated Animal Feeding Operation (CAFO) in the Cedar River Watershed, by HUC 11 subwatersheds.

Registration	Permit	Name	County	Township	T	R	S	AU	PS	C
07080201010 - Middle Fork Cedar River										
039-82079	MNG440956	Nick Masching Farm	Dodge	Westfield	105	18	12	1632	Swine	Y
039-112217	MNG441019	Jason Masching Farm	Dodge	Westfield	105	18	12	1440	Swine	Y
039-82084	MNG441024	Jim & Becky Masching Farm	Dodge	Westfield	105	18	15	1068	Swine	Y
039-125531	MNG441568	Jason & Kory Masching Farm	Dodge	Hayfield	105	17	33	990	Swine	Y
07080201020 - Roberts Creek										
099-83037	MNG441324	Todd M Hoebing Farm	Mower	Waltham	104	17	30	816	Swine	Y
07080201030 - Upper Cedar River										
099-60649	MN0069485	Bob Bartel Farm Sec 22	Mower	Udolpho	104	18	22	1920	Bovine	N
099-50007	MNG440065	Nielsen Farm Albert Lea	Mower	Lansing	103	18	20	1080	Swine	Y
147-50001	MNG440093	MJC Farms	Steele	Blooming Prairie	105	19	12	775	Swine	Y
047-96968	MNG441076	Johnson Finisher	Freeborn	Newry	104	19	29	900	Swine	Y
039-113809	MNG441149	Shane Masching Farm	Dodge	Westfield	105	18	7	1440	Swine	Y
099-100193	MNG441197	Dobbins Creek	Mower	Dexter	103	16	16	1333	Swine	Y
039-82082	MNG441462	Maple Lane Pork	Dodge	Westfield	105	18	15	840	Swine	Y
039-50003	MNG440322	Shane Masching Farm - Sec 8	Steele	Westfield	105	18	8	1080	Swine	Y
07080201040 - Turtle Creek										
047-96942	MN0070351	Scott Thompson Farm - Sec 2	Freeborn	Moscow	103	19	2	1165	Bovine	N
047-50005	MNG440205	Son D Max	Freeborn	Newry	104	19	21	1569	Swine	Y
047-50007	MNG440258	MHF of Freeborn County Inc - Farrowing	Freeborn	Newry	104	19	35	5539	Swine	Y
047-96991	MNG440258	MHF of Freeborn County Inc - Nursery	Freeborn	Newry	104	19	36	813	Swine	Y
047-96993	MNG440258	Dennis Magnuson Farm - Sec 35 NW	Freeborn	Newry	104	19	35	241	Swine	Y
047-50008	MNG440259	Dennis Magnuson Farm - Sec 23	Freeborn	Newry	104	19	23	2505	Swine	Y
047-68633	MNG440492	G & B Hog Farm	Freeborn	Moscow	103	19	1	1200	Swine	Y
047-111170	MNG440976	James O'Connor Feedlot	Freeborn	Newry	104	19	3	1440	Swine	Y
047-96951	MNG440740	Hanson Hog Farm	Freeborn	Bath	104	21	22	900	Swine	Y
07080201050 - Rose Creek										
099-50001	MNG440072	Geoff Stroup Hog Barns	Mower	Windom	102	17	15	1200	Swine	Y
099-83464	MNG440475	Yunker Farms	Mower	Marshall	102	16	20	1600	Swine	Y
099-93975	MNG440999	Justin Larson Farm - Sec 10	Mower	Marshall	102	16	10	840	Swine	Y
07080201065 - Lower Cedar River										
047-60153	MNG440206	Lukes Brothers Inc	Freeborn	London	101	19	12	2467	Swine	Y
099-83267	MNG440643	Hormel Foods Corporation - Austin Plant	Mower	Lansing	103	18	35	2625	Swine	Y
099-110100	MNG440941	The Santos Group - Kingston	Mower	Lyle	101	18	30	1996	Swine	Y
07080201075 - Otter Creek										
099-50002	MNG440069	David Reuter Farm	Mower	Nevada	101	17	22	1320	Swine	Y
099-50008	MNG440261	Steven Felten Farm	Mower	Nevada	101	17	11	1508	Swine	Y
099-83642	MNG441220	Jax Dairy Farm Inc	Mower	Nevada	101	17	25	1526	Bovine	N
099-83694	MNG441220	Jamie Jax Farm	Mower	Nevada	101	17	25	215	Bovine	N
07080201240 - Little Cedar River										
099-80380	MNG440450	John & Lori Smith Farm	Mower	Adams	101	16	20	1890	Swine	Y
099-100204	MNG440574	Gerald & Marlys Gerber Farm	Mower	Adams	101	16	13	1440	Swine	Y
099-115272	MNG441334	R & S Industries	Mower	Marshall	102	16	20	1440	Swine	Y
099-83048	MNG440466	James K Sathre Farm	Mower	Marshall	102	16	25	1200	Swine	Y
No CAFOs have been identified in: 07080201060 - West Beaver Creek, 07080201085 - Elk River, 07080201095 - Deer Creek										

Table 11 provides the number of sites, by primary stock type, while Table 12 displays the AUs by general and/or combined animal types. These numbers are based on data compiled by the MPCA, and include sites that are required to be registered or permitted, and did so between January 1, 2010, and January 1, 2018.

At the HUC 8 scale, there are about 350 site locations with domesticated livestock in the CRW.

The animal unit data shown in Table 10 indicates the dominance of hog operations. The total estimated animal units in the CRW based on 2017 data is nearly 130,000, with swine the primary livestock at 77% of the total animal units. Regarding the management of the site to reduce and mitigate runoff, approximately 11% of the sites with open lots have an open lot agreement. An open lot agreement sets a plan and schedule for improvement actions. It should be understood that the feedlot site and animal unit data are in constant flux, due to a variety of farm management decisions, the influence of market forces, and methods of data collection.

Table 11: Livestock Sites by Primary Stock Type in the Cedar River Watershed (2017 MPCA Data).

Animal Type (Primary Stock)*	Number of Sites in Watershed
Dairy	29
Beef	124
Swine	185
Horses/Donkeys/Mules	5
Sheep or Lambs	1
Turkey	3
Total	347

*Primary stock indicate the dominant stock type at a site, when two or more stock types are present (i.e. Larger swine and small cow-calf = swine site).

Table 12: Livestock animal units by general animal type in the Cedar River Watershed (2017 MPCA Data)

General Animal Type	Animal Units* (AU, in the HUC 8)
Bovine (Beef, Dairy)	25,046
Swine	103,134
Horses/Ponies/Donkey/Mule	340
Sheep/Goats	359
Birds (Turkey, Chicken, other birds)	560
Other	41
Total	129,445

*One 1000-lb. steer or stock cow = one animal unit.

Individual Sewage Treatment Systems

Individual Subsurface Sewage Treatment System (SSTS) data is readily available from the county environmental services offices in each county. These data are on the county scale, and not specific to the CRW. To provide a general background of this issue on a county-wide scale, there are about 3,900 SSTS in Mower and Freeborn counties, while Dodge County has about 2,900. On the total CRW scale, land apportionments by county is about 68% for Mower County (i.e. 68% of total CRW area is in Mower County), Freeborn (23%), and Dodge (9%). Because watershed-specific data is not available, percentages of total systems that are either in compliance, failing, or classified as imminent public health threats (IPHT) are noted in Table 13, and expressed as the median value for the 2008 through 2016.

Table 13: Median Percentages for SSTS Compliance Categories in the Cedar River Watersheds counties 2008-2016

County	% Failing	% IPHT	% In Compliance	% of County in CRW	Total SSTS*
Dodge	34	13	55	16	2,905
Mower	50	10	45	74	3,841
Freeborn	32	18	51	25	3,905

*median count for the entire county

Because these are median values (over a nine-year period) for each compliance category, the overall percentage does not add up exactly to 100%. It should also be noted that the sixth column of this table is a county-wide statistic and does not pertain to the CRW scale, as explained in the above text.

To put this into context, regarding the most serious threats to aquatic recreation and human health risks in the CRW surface waters, Mower County's IPHT percentage of about 10% county wide (362 total) would equate to about 284 individual IPHTs in the CRW of Mower County. Making the assumption of even distribution of systems within the land area for a county, for Mower County with a median value of 50% failing systems, where pollution of shallow ground water or seepage of wastewater from SSTS onto the ground surface could be occurring, this would mean a maximum of approximately 1424 systems could be classified as failing in Mower County's portion of the CRW. The respective estimates for Dodge County are 47 (IPHT estimate) and 158 (# failing) and Freeborn County are 176 (IPHT estimate) and 312 (# failing). Ongoing programs for all counties involve inspection and upgrading of SSTS, through local ordinance compliance and implementation, and this is covered in more detail in Section 7.

3.3.3 Nonpoint Sources

Row crop agriculture

Row cropland can contribute to excess sediment via sheet/rill erosion of soil either overland or through open surface tile intakes. Larger gullies can also form in cropland areas, and adjacent to fields, where water is flowing towards channels and streams. Other transport mechanisms for sediment include wind-eroded soil settling in ditches, destabilization and erosion of banks, and scouring of the stream channel. Drainage alterations and increased stream flows can change the hydrograph, and affect the rates of bank/bed erosion. The most recent crop survey statistics indicate corn and soybeans are grown on much of the harvested cropland in the watershed. Much of the poorly drained row cropland in the watershed has been tiled to improve drainage.

Ditches/channelization/artificial drainage

Open channel drainage ditches have been constructed in numerous locations across the CRW to lower the water table and provide for agricultural production, transportation and urbanization. The initial construction of many drainage ditches occurred from approximately 1900 to 1930. For further information on this process, see Minnesota Public Drainage Manual (BWSR 2016), Register (2016), and Taff (1998). There are 23 publically-administered (but privately-owned) drainage systems in the CRW, as listed below. There are numerous ditches in the CRW that are not publically administered by a county or a watershed district, and these are generally managed by a landowner, or a landowner group. Ditches in this second category are commonly known as "private ditches."

Both public administered agricultural drainage systems and private agricultural drainage systems are nonpoint sources as defined by the Clean Water Act, and as such are non-permitted sources. These are assigned to the LA for the TMDLs in this document.

Drainage ditches frequently are channelized natural stream channels. As such, they are shorter than the natural channel and steeper in gradient. Depending upon the landscape position, drainage ditches can exhibit higher velocities and higher peak flows than natural channel systems under similar conditions. Artificial drainage (surface ditches and subsurface tile lines) can exacerbate downstream hydrology conditions by increasing the volume and peak rate of runoff (Blann et al. 2009; Schottler et al. 2013). At other times, artificial drainage of fields may dampen the peak flows for a given rainfall/runoff event, but increase the overall volume discharged. Variation in hydrologic response is a function of numerous variables, including precipitation duration and intensity, cropping factors/conditions, soils, and management. The University of Minnesota (2015) lists six potential effects of agricultural drainage systems on the water cycle, and these are: reduce the time that water is being stored in the soil; change the pathway of water over land; reduce overland flow; decrease evaporation; increase annual transpiration; increase the total amount of water that reaches streams; and reduce, delay, and extend the peak flow in a stream. This report also notes that whether these effects occur depend on six main factors, which are: 1) type of drainage; 2) the scale ; 3) precipitation patterns; 4) field conditions; 5) conditions in the rest of the watershed; and 6) system design and landscape details.

Deeper ditch channels by design limit water's access to the floodplain, and thus stream energy is more frequently confined to such channels. Straightened channels also exhibit a continuous tendency to revert to a meandering condition, and can develop a low-flow channel within the over-widened ditch cross section. Soil types and the constructed ditch geometry are also important factors playing into the stability of a given ditch. Temporary release of sediments also occurs during ditch clean outs and repairs. Drainage ditch systems, both publically and privately administered, are an important management unit at the intermediate scale. The following lists the public ditch systems (i.e. administration is by MS 103E, and owned by the landowners), with associated township locations in the CRW:

- CD 5 Lansing
- CD 26 Lansing
- CD 4 Austin
- CD 17 Austin
- CD 77 Lyle
- CD 79 Lyle
- CD 8 Bath
- JD 7 Bath
- CD 61 Bath
- JD 67 Bath
- CD 57 Bath
- CD 81 Bath
- CD 30 Bancroft and Riceland
- CD 31 Moscow
- CD 36 Riceland
- JD 12 Riceland
- JD 18 Riceland
- JD 24 Riceland, Geneva, Newry & Moscow
- JD 27 Newry
- JD 28 Geneva
- JD 29 Riceland
- JD 30 Newry
- JD 22 Hayward and Riceland

A full assessment of the influence of ditches/channelization/artificial drainage in terms of hydrology and sediment transport involves a multi-faceted and complex set of factors. The best data currently available in the CRW indicates that about 40% of the sediment is from near-channel sources (see Appendix B).

It is helpful to better understand what has been learned by other efforts, which have applied more time and resources to this important issue. Blann et al. (2009) completed a review of literature addressing the effects of agricultural drainage on peak flows. Field-scale surface drainage typically increases peak flows by reducing surface storage, while the effects of subsurface drainage on peak flows are more variable at the field scale, depending on local soil properties and antecedent moisture condition. Subsurface drainage reduces both peak outflows and the frequency of SRO events at sites characterized by high water tables or surface saturation in the undrained condition. Sites with more permeable soils result in increased peak flows because subsurface drainage may not substantially affect infiltration, whereas the rate of subsurface flow through the soil profile may increase over that prior to installation of artificial drainage (Blann et al. 2009). At larger scales and event magnitudes, the effects of subsurface drainage on peak flows tend to be dominated by precipitation variables and the design and layout of surface and subsurface drainage networks, and the capacity and conveyance of the surface drainage network (Blann et al. 2009).

There is also the foundational work by Lane (1955), on defining how alluvial channels become unstable and adjust to changes in order to re-establish equilibrium and offset the effects of the imposed changes. The general expression, presented by Lane (1955), shows that the product of the bed material sediment load and median grain size (also referred to as erosional resistance) should balance the product of the water discharge and channel slope (referred to as stream power) for channels that are in equilibrium. If any of these four variables are altered, it indicates that proportional changes in one or more of the other variables must take place to re-establish equilibrium in the stream. For example, increases in water discharge (or slope) will result in increased sediment loadings until changes to grain size distribution or slope allow a channel to re-establish a new equilibrium. Simon (1994) indicates that stream systems may take up to 100 or more years to reach equilibrium following significant disturbances that alter any of the four aforementioned variables in the Lane (1955) expression. A channel evolution model developed by Simon and Hupp (1986) indicates that channel erosion and mass wasting associated with bank failures would be expected to follow these types of channel disturbances.

Barr Engineering completed a technical memorandum regarding the hydrologic trends, sources of additional runoff and implications for streambank erosion for each of the Minnesota basins (including the CRW), as a follow-up to the Detailed Phosphorus Assessment (Barr Engineering Company 2004). Figure 9 shows the trend analysis done for the hydrologic data collected for the CRW water yield at Austin. The upward trend in annual watershed yield is statistically significant over the period of record. As part of the analysis, stepwise multiple regressions were used to show that 50% of the trend can be attributed to climatic factors, while the remaining contribution is due to non-climatic factors or changes within the watershed (such as drainage, urbanization and shifts in cropping). As a result, additional runoff associated with these anthropogenic changes, would account for an additional 15,000 tons of sediment per year due to increased streambank erosion within the Cedar River Basin during high flow conditions. As a result, additional runoff associated with non-climatic factors during high-flow conditions would account for an additional 59,600 kg of phosphorus per year, on average, due to increased streambank erosion within the Cedar River Basin. This study did not directly address the runoff ratio, which is the proportionality between flow and precipitation (i.e. water yield divided by precipitation). However, Schottler et al. (2013) assessed changes to the runoff ratio in the CRW above Austin, and found a significant difference ($p < 0.1$) in median values for both May and June, and September and October month groupings. This analysis used median values for two 35-year periods (1940 to 1974 versus 1975 to 2009) time periods. These authors also report that annual changes followed a similar pattern. The change in runoff ratio for the Cedar River was + 0.13 and a change in water yield of + 26 mm, for the May and June months, an important focal period for assessing changes to the evapotranspiration component of the water balance (Schottler et al. 2013). While Figure 9 displays a 20-year average precipitation statistic trending upward until year 2000, Schottler et al. (2013) did not find statistically significant changes in precipitation for the spring and fall monthly groupings noted above, when testing for the two time 35-year periods.

Moore et al. (2013) analyzed cropping shifts in 21 Minnesota watersheds, including the CRW in Minnesota, for two 35-year time periods (1940 through 1974, and 1975 through 2009). The results shown in Table 14 show a doubling of acres in soybeans, and a reduction in acres planted to alfalfa and small grains.

Table 14: Cropping Shifts in the Cedar River Watershed (Moore et al. 2013)

Time Period	% Agricultural	% Soybeans	% Corn	% Hay, Small Grains
1940-1974	66	14	27	25
1975-2009	77	31	38	8

Schottler et al. (2013) found a mean change in water yield for the Cedar River (at USGS gauge near Austin, 399 square miles drainage) of 10 cm, when comparing the same two time periods (1940 through 1974, and 1975 through 2009). The annual precipitation had a mean change of +7.4 cm. These researchers then conducted an exercise to apportion the water yield change to three factors, and for the CRW, hypothesized that about 3.5 cm is the result of a wetter climate, 6.3 cm for artificial drainage, and about 0.3 cm for crop conversion.

Poorly vegetated ravines and gullies

It is evident from field observation and aerial photos that poorly vegetated ravines and ephemeral gullies are adjacent to intermittent and permanent waterways, and classic gully erosion is occurring in these and other poorly vegetated areas of the watershed that receive concentrated flow. Runoff from these sources may enter streams directly and is not slowed to allow sediments to filter out. In some situations, these sources of sediment result from livestock overgrazing.

Riparian zone vegetation and buffers

The stream side areas known as riparian zones are an important interface between the land and the water environments. The term “buffer” is a common term used to describe part of this interface zone.

Buffer implementation and improvement is occurring in the counties and within the CRW. Implementation of the buffer law (Minn. Stat. 103F.48 https://www.revisor.mn.gov/statutes/?id=103F.48) applies to public waters and open channel drainage ditch systems managed under the Drainage Code (Minn. Stat. 103E). The implementation date for the requirement for 50 foot buffers on public waters was November 2017. The deadline for establishment of buffers on 103E ditches (publically-administered) is November 2018. Over the past several years, there have been many actions by landowners, with technical assistance from local conservation staff, and direction/guidance from BWSR and DNR. Preliminary buffer compliance rates for the counties in the CRW are all above 80% (BWSR. https://mn.gov/portal/buffer-law/map/compliance-map.jsp). The new buffer law requires perennial vegetation be present, and this can include alternative practices that provide comparable water quality protection.

There are areas in the CRW with poorly functioning riparian zones, where runoff may enter streams directly and is not slowed to allow sediments to filter out. In general, this is a function of both rainfall and land use/land management.

Livestock in riparian zone

Livestock overgrazing in riparian areas can contribute to polluted runoff directly from unvegetated areas, resuspending of sediments by direct access to the channel, deposition of their manure in the riparian area or directly into the water, and by destabilizing the banks leading to increased bank erosion or slumping. The Minnesota Conservation Corps (MCC) completed an inventory of the Cedar River and several of its tributaries in October 2007 (Hanson 2008). Pasture was found to be 23% of the adjacent land use along one of the tributaries. While overgrazing in riparian pastures in the Cedar River Basin has not been thoroughly investigated, this source can contribute significant loadings per unit area and should be further identified and addressed.

The method of pasture management was found to be a key factor in a study of southeastern Minnesota streams by Sovell et al. (2000). In continuously grazed sites, where cattle had access to the stream and riparian zone, higher levels of both sediment and bacteria were found, when compared to pastures with rotational grazing with reduced cattle exposure to the stream corridor.

As part of the Generic EIS on animal agriculture (EQB 2002), Mull et al (2001) reviewed data and literature sources on pathogens from manured and grazed lands. Manure runoff on snow or frozen soils showed significantly higher fecal bacteria counts, when compared to runoff quality from a spring or fall event.

Wildlife sources of bacteria

The major categories of wildlife related to indicator group bacteria in surface waters includes mammals such as deer, beaver, and raccoon, and birds. While seasonal factors such as bird migrations are pertinent, wildlife sources are part of the background conditions in the CRW. The DNR Wildlife staff estimate the pre-fawn deer population in the majority of the CRW to be about four to seven deer per square mile. These density estimates are based on land-base (non-water). Deer are not evenly distributed across the landscape. In winter, they are associated with timber and larger grassland /marshland complexes. In summer, they utilize more of the land, although most deer will still be associated with permanent habitats, which encompasses about 20% of the landscape. Therefore, the actual populations in good habitats are much higher, leaving a sizable percentage of the watershed with few to no deer, especially in winter. In the CRW, a good deal of permanent deer habitat is largely associated with watercourses, although the direct deposition of fecal material to water would be minor. Most deposition of urine and feces will be scattered in permanent natural habitats where runoff rates are low and the ability of the environment to assimilate the deposition is greatest. Deer have fawns in the spring and there is a fairly dramatic population reduction in fall associated with hunting. At this time we believe the births and deaths are roughly the same and the population is stable to slightly increasing

(Vorland 2018). Using the average weight of an adult deer of 175 pounds (0.175 animal unit), the estimated deer population in the CRW is from 2,368 – 4,144 (414 to 725 animal units).

Migratory birds find habitats on ponds, lakes, and streams. There are population estimates by the DNR and U.S. FWS using both ground and aerial survey methods (Cordts 2007). For example, an estimate of 68,000 ducks and 43,000 geese was derived in one sampling strata with a low density of lakes (2-10 lake basins/township). This strata includes the western portion of the CRW. These estimates are for a large portion of southcentral, southwestern, and west central Minnesota, and are not specific to the CRW or the counties in the CRW. The distribution of these waterfowl populations is not estimated, and varies with habitats and seasons. Further data and information on migratory birds is available at https://www.fws.gov/birds/surveys-and-data.php.

Natural growth/reproduction of bacteria

For a better understanding of the potential sources of bacteria, it is important to also consider the results of current scientific research studies. In the last 15 years, researchers have found the persistence of *E. coli* in soil, beach sand, and sediments throughout the year in the north central United States, without the continuous presence of sewage or wildlife sources. An Alaskan study [Adhikari et al. 2007] found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions. A study of cold water streams in southeastern Minnesota completed by the MPCA staff found the resuspension of *E. coli* in the stream water column due to stream sediment disturbance. A study near Duluth, Minnesota [Ishii et al. 2010] found that *E. coli* were able to grow in agricultural field soil. Survival and growth of fecal coliform has been documented in storm sewer sediment in Michigan [Marino and Gannon 1991].

E. coli bacteria may have the ability to reproduce naturally in water and sediment. Two Minnesota studies describe the presence and growth of “naturalized” or “indigenous” strains of *E. coli* in watershed soils (Ishii et al. 2006) and ditch sediment and water (Chandrasekaran et al. 2015). The latter study was conducted in the agriculturally-dominated Seven Mile Creek Watershed located in south-central Minnesota, with sampling sites on both open channel ditches and the creek. Within the ditch and stream system, these researchers found there was mixing of bacteria between the water column and channel bottom sediments. They further state that naturalized *E. coli* from sediments can be re-suspended into the water column, and this can lead to observed increases in *E. coli* levels. Since the study at Seven Mile Creek is not definitive as to the ultimate origins of these bacteria, it would not be appropriate to consider it as “natural” background (MPCA 2012c).

Non-regulated urban stormwater runoff

There are nine smaller cities and communities in the CRW that generate urban stormwater runoff, but are unregulated. These cities include Hayfield, Blooming Prairie, Brownsdale, Hollandale, Elkton, Rose Creek, Sargeant, Waltham, and Adams. Stormwater runoff from these non-permitted developed areas has the same source types and mechanisms of delivery as stormwater runoff from permitted MS4 communities, discussed under permitted sources. The developed areas in the impairment watersheds that are not regulated through an MS4 permit can also be a source of sediment, *E. coli* bacteria, and nutrients loads to surface waters.

Nonpoint source phosphorus

While this report provides for only one TP TMDL, which is for Geneva Lake, the issue of phosphorus effects in the aquatic system are of a broader concern in the CRW. There are four tributary streams with a conclusive phosphorus stressor to aquatic life, as well as three mainstem Cedar River reaches (MPCA 2016). A recent report on the transport of nitrogen and phosphorus in the Cedar River (USGS 2018) found that for the Cedar River in Minnesota (drainage area is 399 square miles, and includes the upper watershed areas, as well as stormwater and wastewater from the city of Austin), the average annual phosphorus load from 2007 through 2015 was 124 tons/year. On a yield basis, that equates to 0.981 lbs/acre for TP in the CRW above Austin. Orthophosphate is an estimate of the dissolved phosphorus fraction of the TP load, and this averages about 59%, for the Cedar River in Minnesota. The importance of the orthophosphate is that this is the form more readily available for algal uptake. MPCA (2016) have recorded significant variation in daily stream DO concentrations in the Cedar River, which indicates high algal production of DO during the daylight hours, followed by low DO during the night, when algal respiration occurs.

Using a modeling approach, the MPCA (2014) estimates the phosphorus load in the Cedar River (in Minnesota) to be 169.3 MT/year (years 2000 to 2002, with updated wastewater point source loading to 2009). These data are included in Minnesota's nutrient reduction strategy, which includes a cropland load reduction target of 12.7 MT/year (for new BMPs), as part of an overall reduction target of 20.3 MT/year.

Some nearby work in 12 Iowa Rivers by Schilling et al. (2017), found that TP is delivered to streams by two distinct delivery mechanisms. The first mechanism is phosphorus transport dominated by episodic SRO events. The second mechanism involves the more continuous delivery of soluble OP, in well-drained areas and areas underlain by tile drainage. The ratio of total loads (OP/TP) varied across the 12 rivers, from 12% to 68%. This work has relevance in the CRW of Minnesota as well, because the prevalence of delivery mechanism will be an important factor for determining the source of conservation practices that are needed (King et al. 2015).

4. TMDL Development

4.1 Methodology for Load Allocations, Wasteload Allocations and Margins of Safety, Seasonal Variation and Critical Conditions

The TMDLs developed for the stream reaches in this report consist of three main components: WLA, LA, and MOS as defined in Section 1.0. The WLA includes three sub-categories: permitted wastewater facilities with TSS limits, the MS4 permitted stormwater source category, and a construction plus industrial permitted stormwater category. The LA, reported as a single category, includes the nonpoint sources described in the previous section. The third component, MOS, is the part of the allocation that accounts for uncertainty that the allocations will result in attainment of water quality standards.

The three components (WLA, LA, and MOS) were calculated as total daily load of each pollutant. The methodology to derive and express the pollutant load components is the duration curve approach, further described in Appendix A. For each impaired reach and flow condition, the total loading capacity or "TMDL" was divided into its component WLA, LA, and MOS. It should be noted that this method implicitly assumes that observed stream flows and flow regimes must remain constant over time.

The LDC method is based on an analysis that encompasses the cumulative frequency of historic 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 report (shown in Sections 4.2 and 4.3) only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is what is ultimately approved by the EPA.

The baseline year or conditions from which pollutant load reductions should be evaluated is 2010. The process for computing each component of the TMDL is described below.

The TMDL for Geneva Lake was developed using both lake water quality monitoring data, and a predictive lake water quality model. There was no direct effort to collect data on tributary pollutant inputs and flows. Modeled TP loads were developed from the HSPF watershed simulation model, which covered the timeframe of 1996 through 2012. The Geneva Lake TP allocation does not include any WLA or MS4 elements. A 10% MOS was used to address variation in modeling and internal/external loading uncertainty. Section 4.4 includes details on lake history and management, HSPF and MINLEAP modeling parameters and predictions, and the TP allocation.

4.1.1 Wasteload Allocation

Watershed scale pollutant load modeling was conducted and LDCs have been developed to establish these TMDLs at levels necessary to attain and maintain applicable water quality standards. Federal regulation 40 CFR 130.3 states that TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. All Municipal and Industrial NPDES Wastewater Permits in the watersheds of the sediment impaired reaches contain effluent TSS and/or fecal coliform concentration limits that are at least as restrictive as the applicable water quality standards. Thus, according to the nature of the NPDES permits written for the various sub-categories of point source dischargers, appropriate measures for achieving compliance with the WLA are described as follows.

Industrial and Municipal Wastewater Treatment Facilities: Individual WLAs

All WWTFs in the Cedar River Basin are permitted to discharge TSS at a concentration (30 to 45 mg/l) that is below the 65 mg/l standard used in computing TMDLs for the impaired reaches, and therefore do not cause or contribute to violations of the water quality standard. In the case of bacteria, the facilities are permitted to discharge fecal coliform at the 200 cfu/100 ml concentration, considered to be equivalent to the *E. coli* standard of 126 cfu/100 ml.

Construction Stormwater: Categorical WLA

Given the transient nature of construction work, these loads are difficult to quantify. Construction stormwater activities are therefore considered to be in compliance with their TMDL WLA, or will meet their WLA, if they obtain a Construction General Permit under the NPDES program and comply with that permit. *E. coli* WLAs do not apply to construction stormwater since *E. coli* is not a typical pollutant from construction sites.

Industrial Stormwater: Categorical WLA

Given the lack of design flows and concentration limits, these loads are difficult to quantify. Industrial stormwater activities are therefore considered to be in compliance with their TMDL WLA, or will meet their WLA, if they obtain an Industrial Stormwater General Permit or General Sand and Gravel General Permit (MNG49) under the NPDES program and comply with that permit. 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 & 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. It should be noted that all local stormwater management requirements must also be met, and *E. coli* WLAs do not apply to industrial stormwater. Industrial stormwater receives a WLA only if the pollutant is part of benchmark monitoring for an industrial site in the watershed of an impaired water body. There are no bacteria benchmarks associated with any of the Industrial Stormwater Permits in the watershed, therefore no industrial stormwater *E. coli* WLAs were assigned.

Municipal Separate Storm Sewer Systems (MS4s): Individual WLA

MS4s are apart from the preceding three categories of point source dischargers in that they have the potential to encompass large land areas, and thus can generate significant runoff to surface waters during high flow conditions; thus they have the potential to change over time the flow duration characteristics of a given stream reach.

The MS4 systems are designed to convey stormwater into a receiving waterbody and are permitted under the NPDES Permit. The city of Austin is the only MS4 (MS4 Permit #00251) in the CRW.

MS4 allocations for the Austin MS4 were calculated using the following equations:

$$\textbf{S4 Allocation} = \%\textbf{MS4 Area} * (\textbf{TLC} - \textbf{MOS} - \textbf{Permitted WW Facility})$$

Where:

%MS4 Area: the ratio of the total MS4 area to the total drainage area for the given AUID. Areas were obtained using ArcMap.

Wastewater

Permitted WW Facilities: the total WLA for all permitted Industrial and Municipal WWTFs that discharge into the AUID's drainage area.

The methodology for developing the WLAs was as follows:

The permitted wastewater facility and cooling water WLAs were determined based on their permitted discharge design flow rates, or maximum permitted discharge rate for pond systems, and their permitted TSS/bacteria concentration limits or their permitted daily loading rates, whichever were higher. A series of tables in Sections 4.2 and 4.3 detail the permitted wastewater discharges in the drainage area for each impaired reach, including permitted concentrations or loading rates for the permitted wastewater facilities in each impaired reach of the CRW.

Construction and Industrial Stormwater:

Construction stormwater and industrial stormwater are lumped together into a categorical WLA based on an approximation of the land area covered by those activities. To account for industrial stormwater, which the MPCA does have readily accessible acreage data (but is likely much smaller than construction), as well as reserve capacity (to allow for the potential of higher rates of construction and additional industrial facilities), this TMDL assumes 0.05% of the land area for a combined construction and industrial stormwater category for the TSS allocations. The allocation to this category is made after the WLA for water and WWTFs and the MOS are subtracted from the total loading capacity. That remaining capacity is divided up between construction and industrial stormwater, permitted MS4s and all of the nonpoint sources (the LA) based on the percent land area covered.

As indicated above the allocation for communities subject to MS4 NPDES Stormwater Permit requirements is made after the WLA for WWTFs and the MOS are subtracted from the total loading capacity. The allocation for the MS4 is based on the percentage of the jurisdictional land area in the impaired reach watershed that the MS4 Permit covers. For this TMDL the permitted MS4 area (12 square miles) includes the city of Austin (Permit Number MS400251) and does not include non-regulated MS4 stormwater (i.e., runoff from cities with populations below 5,000).

4.1.2 Load Allocation

After allocations have been made to the WLA categories for the permitted stormwater components and WWTFs, and the MOS are subtracted from the total loading capacity, the remaining loading capacity is distributed to all of the nonpoint sources as the LA.

The LA is the portion of the total loading capacity assigned to nonpoint and natural background sources of nutrient loading. These sources include the atmospheric loading and nearly all of the loading from watershed runoff, or in this case tributary inflow. The only portion of the watershed runoff not included in the LA is the small loading set aside for regulated stormwater runoff from construction and industrial sites. The LA includes nonpoint sources that are not subject to NPDES permit requirements, as well as "natural background" sources.

The new TSS criteria are stratified by geographic region and stream class, due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The assessment period for these samples is April through September; any TSS data collected outside of this period was not considered for assessment purposes. The TSS standard for class 2B streams in the South River Nutrient Region is 65 mg/L. For assessment, this concentration is not to be exceeded in more than 10% of samples within a 10-year period. The TSS results are available for the watershed from state-certified laboratories, and the existing data covers a large spatial and temporal scale in the watershed. The TSS LDCs and TMDLs were developed for all stream TSS impairments, (Heiskary et al. 2013).

Natural background as defined in Minn. R. 7050.0150, subp. 4, refers to 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. Anthropogenic sources of stress are not a component of natural background as it has been defined by Minnesota rule.

Natural background conditions refer to pollutant inputs that would be expected under natural, undisturbed conditions. Natural background sources can include natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion (Section 3.3) of this study. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, urban stormwater, WWTFs, failing SSTSs and other anthropogenic sources. Separate LAs were not determined for natural background sources in this report due to the factors outlined above, as well as a lack of research or data that would be required to differentiate between nonpoint and natural background sources of the pollutants.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest natural background sources are a major driver of any of the impairments and/or affect their ability to meet state water quality standards. For all impairments addressed in this study, 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.

4.1.3 Margin of Safety

The purpose of the MOS is to account for uncertainty that the allocations will result in attainment of water quality standards, given the uncertainty about the pollutant loadings and water body response. For the TMDLs in this report an explicit 10% MOS is applied to each impairment. This approach for the CRW sets a more conservative level than the applicable WQS and as such is a safety factor to the pollutant load estimates. In the CRW there are reaches with lower sample sizes as well as variation regarding the timing of sample collection (higher runoff vs. lower base flows) to be considered. These factors support an explicit MOS. Therefore, based on best professional judgment of the overall TMDL development, this provides a reasonable and achievable LA and WLA. This is expected to provide an adequate accounting of uncertainty, especially given that WWTFs have generally demonstrated consistent meeting of pollutant discharge limits, and in the case of wastewater facilities with pond systems discharge only during spring and fall windows (i.e., before June 15 and after September 15). The WLA allocated to pond treatment systems is calculated as the design flow multiplied by the TSS limit and represents a worst-case scenario with all ponds discharging at the maximum allowable rate at the same time (see WLA section above). When these ponds are not discharging in summer and winter their portion of the WLA functions as a MOS. Also, the mechanisms for soil loss from agricultural sources and the factors that affect this have been extensively studied over the decades and are well understood. Agricultural BMPs have been targeted for soil loss prevention (see Section 6.2). Follow-up effectiveness monitoring will provide a means to evaluate installed BMPs in terms of compliance with WLAs and LAs, and progress or achievement of the TMDL. The MOS cannot be used as reserve capacity.

4.1.4 Seasonal Variation and Critical Conditions

The TSS water quality standard applies for the period April through September, and the *E. coli* standard applies from April through October, which generally correspond to the open water recreational season when aquatic organisms are most active and when higher stream pollutant concentrations generally occur. Pollutant loading varies with the flow regime and season. To generalize, spring is associated with large flows from snowmelt, the summer is associated with the growing season as well as periodic storm events and receding streamflows, and the fall has variable precipitation and rapidly changing agricultural landscapes.

Critical conditions and seasonal variation are addressed in this TMDL through several mechanisms. The TSS and bacteria standards apply during the open water months, and data was collected throughout this period. The water quality analysis conducted on these data evaluated variability in flow through the use of five flow regimes, from high flows, such as flood events, to low flows, such as baseflow. Through the use of LDCs, TSS and bacteria loading was evaluated at actual flow conditions at the time of sampling.

For sediment impairments, the critical conditions exist when excessive sediment transport results in the deposition of sediment particles into the stream channel substrates required to support aquatic life, above established thresholds. The bedded sediment conditions that were frequently identified as important for the MIBI are a critical condition effect, and identified as conclusive stressors in the CRW. The working hypothesis is that fine sand particles are more effective at causing these conditions, and such sediments require higher stream flows and velocities to be eroded, transported, and eventually to deposit into the critical stream habitats. This critical time is further identified when an important life stage of the biota is in a more vulnerable condition.

For bacterial impairments, the critical conditions exist when bacterial levels exceed the water quality standards (monthly geometric mean and maximum), during periods when aquatic recreation by the public is taking place. These conditions can exist across various flow regimes, and most likely in the spring, summer and fall seasons.

The TP water quality standard for Geneva Lake applies June 1 through September 30. Due to natural variability of important factors such as precipitation, runoff, and temperatures, critical lake conditions may occur anytime within this four-month window. High TP concentrations combined with higher air and water temperatures may lead to both high dissolved oxygen variation in the lake water, and a higher frequency of severe algal blooms. The frequency and severity of algal blooms affected by the interaction of these factors can then lead to elevated chlorophyll and decreased water transparency.

4.2 TMDL Summaries - Allocations for TSS Impaired Reaches

In the sections below, TMDL allocations are provided for the individual TSS-impaired reaches (indicated in Figure 2). Calculations for the TMDL, LA, WLA and MOS consider the total drainage area represented by the end of the listed reach. The flows and loads were scaled to the representative site tributary area. The impaired reach watershed area and the watershed area of the flow gauge used to develop the duration curve are given in Table 15.

Table 15: AUID watershed area and associated flow gauge watershed area

AUID	AUID Watershed Area, sq. mi.	Flow Gauged Watershed ID	Flow Gauge Watershed Area, sq. mi.
07080201-501	399	07080201-501	399
07080201-502	160	S000-137	160
07080201-503	119	S000-137	160
07080201-504	39	07080201-535	37
07080201-510	12	07080201-535	37
07080201-514	244	07080201-501	399
07080201-515	406	07080201-501	399
07080201-516	586	07080201-501	399
07080201-517	38	07080201-535	37
07080201-518	48	07080201-535	37
07080201-522	68	07080201-535	37
07080201-526	42	07080201-535	37
07080201-533	5.2	07080201-535	37
07080201-535	37	07080201-535	37
07080201-537	38	07080201-535	37
07080201-539	32	07080201-535	37
07080201-540	153	07080201-538	144
07080201-583	9	07080201-535	37

Water quality LDCs integrate flow and the measured TSS/turbidity to illustrate the loading capacity across the flow record, as well as comparisons to the loading capacity using collected water quality data and the 65 mg/L TSS standard are also included in each section.

4.2.1 Cedar River: Rose Cr to Woodbury Cr (AUID: 07080201-501)

Table 16 shows the WWTFs and other permitted discharges within the land area that drains to this listed reach. There is also a 12 square mile area of the city of Austin, which is subject to stormwater MS4 NPDES Permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 17 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 16: Wastewater treatment facilities and associated WLAs (AUID: 07080201-501)

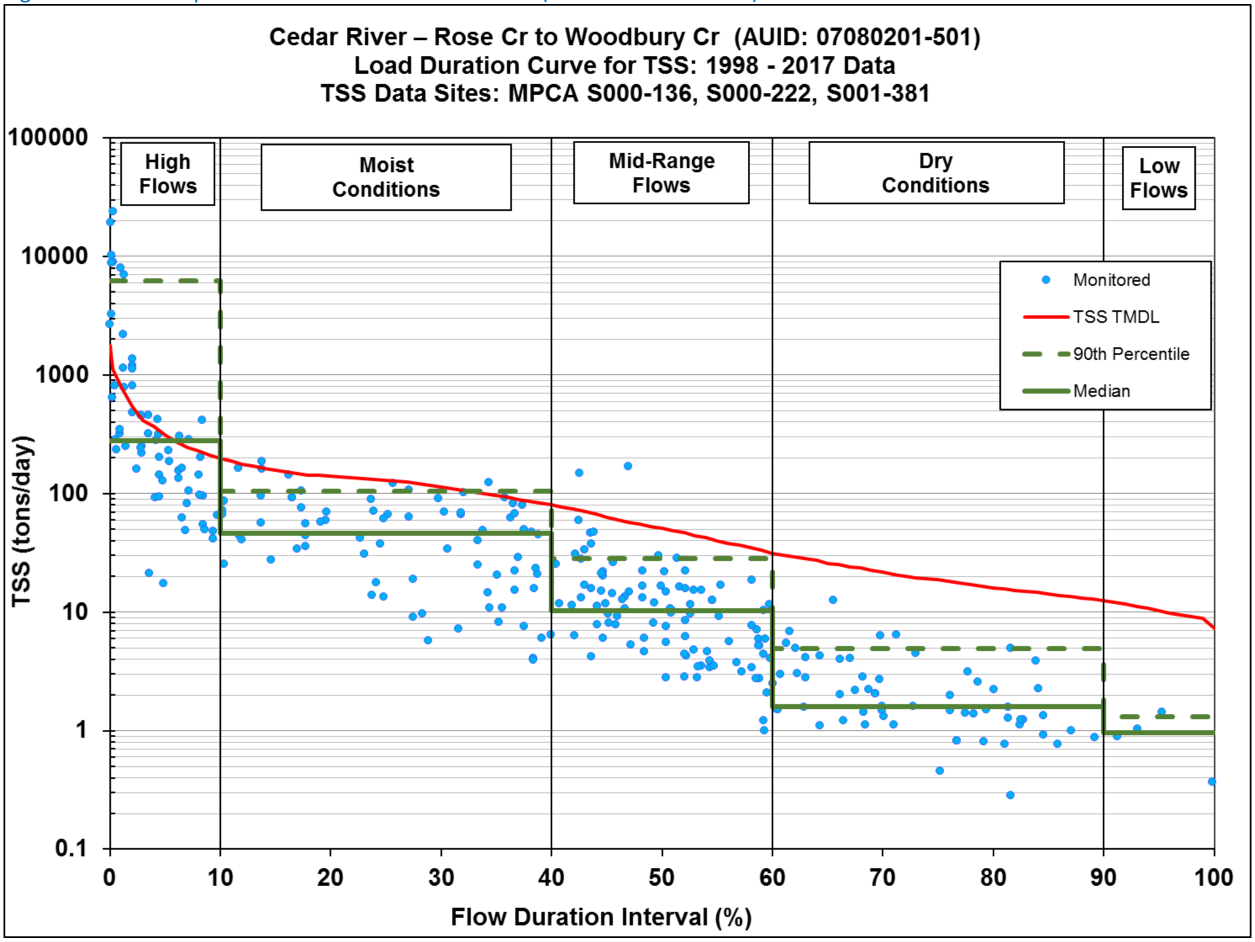
Facility	NPDES Permit #	Discharge, mgd	TSS WLA, kg/day	TSS WLA, tons/day
Austin WWTP	MN0022683	8.475	962.4	1.06
Blooming Prairie WWTP	MN0021822	0.899	102.1	0.113
Brownsdale WWTP	MN0022934	1.377	234.5	0.259
Elkton WWTP	MNG580013	0.163	27.8	0.0306
Hollandale WWTP	MN0048992	0.386	65.8	0.0725
Hormel Foods	MN0050911	1.448	164.4	0.181
Rose Creek WWTP	MN0024651	0.401	68.3	0.0753
Lansing TWP WWTP	MN0063461	0.204	34.7	0.0382
Oakland SD WWTP	MN0040631	0.088	15.0	0.0165
Sargeant WWTP	MNG580214	0.081	13.9	0.0153
Arkema Inc.	MN0041521	0.063	7.15	0.00789
Waltham WWTP	MN0025186	0.139	23.6	0.0260

Table 17: Total Suspended solids loading capacities and allocations (AUID: 07080201-501)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	311.98	128.56	50.80	18.65	10.26
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	1.89	1.89	1.89	1.89	1.89
Austin City MS4	6.18	2.52	0.97	0.33	0.16
Construction and Industrial Stormwater	0.14	0.057	0.022	0.0074	0.0037
Load Allocation	272.57	111.23	42.84	14.56	7.17
Margin of Safety	31.20	12.86	5.08	1.87	1.03
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	1%	1%	4%	10%	19%
Austin City MS4	2.0%	2.0%	1.9%	1.8%	1.6%
Construction and Industrial Stormwater	0.04%	0.04%	0.04%	0.04%	0.04%
Load Allocation	87%	87%	84%	78%	70%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 12) for the available dataset shows that 18 of the samples exceeded the target load. The exceedances occurred under medium, moist and high flow zones, with the most under the high flow category. Under high flows, near-channel sources are an important component, as discussed in Section 3, and the watershed modeling summaries (Appendices D and G).

Figure 12: Total Suspended Solids Load Duration Curve (AUID: 07080201-501)



4.2.2 Cedar River: Roberts Cr to Upper Austin Dam (AUID: 07080201-502)

Table 18 shows the WWTFs and other permitted discharges within the land area that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach.

Table 19 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 18: Wastewater treatment facilities and associated WLAs (AUID: 07080201-502)

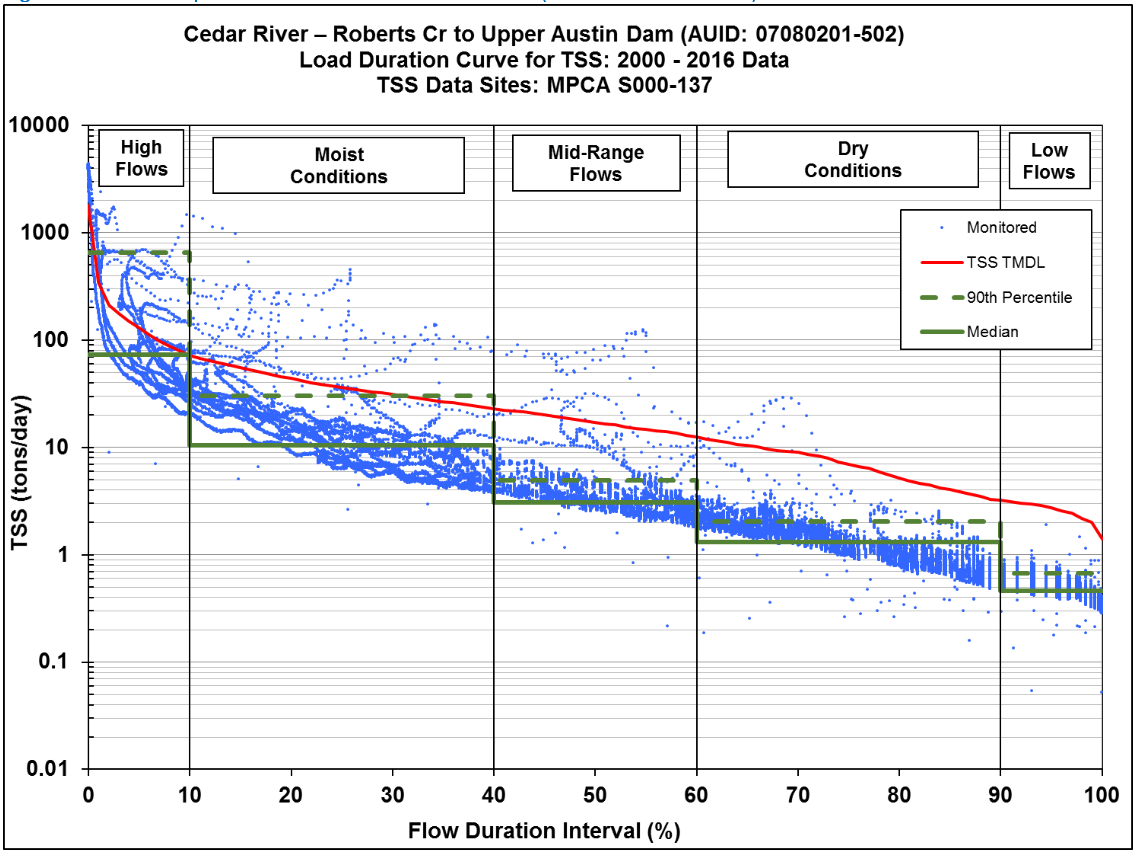
Facility	NPDES Permit #	Discharge, mgd	TSS WLA, kg/day	TSS WLA, tons/day
Blooming Prairie WWTP	MN0021822	0.899	102.1	0.113
Brownsdale WWTP	MN0022934	1.377	234.5	0.259
Lansing TWP WWTP	MN0063461	0.204	34.7	0.0382
Sargeant WWTP	MNG580214	0.081	13.9	0.0153
Arkema Inc.	MN0041521	0.063	7.15	0.00789
Waltham WWTP	MN0025186	0.139	23.6	0.0260

Table 19: Total suspended solids loading capacities and allocations (AUID: 07080201-502)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	129.79	36.17	17.15	7.00	2.72
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.46	0.46	0.46	0.46	0.46
Austin City MS4	0.10	0.03	0.01	0.005	0.002
Construction and Industrial Stormwater	0.06	0.016	0.007	0.0029	0.0010
Load Allocation	116.20	32.05	14.95	5.83	1.99
Margin of Safety	12.98	3.62	1.71	0.70	0.27
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	1%	3%	7%	17%
Austin City MS4	0.1%	0.1%	0.1%	0.1%	0.1%
Construction and Industrial Stormwater	0.04%	0.04%	0.04%	0.04%	0.04%
Load Allocation	90%	89%	87%	83%	73%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 13) for the available dataset indicates exceedances of the target under all flow regimes except low flows.

Figure 13: Total Suspended Solids Flow Duration Curve (AUID: 07080201-502)



4.2.3 Cedar River: Turtle Cr to Rose Cr (AUID: 07080201-515)

Table 20 shows the WWTFs and other permitted discharges within the land area that drains to this listed reach. There is also a 12 square mile area of the city of Austin, which is subject to stormwater MS4 NPDES Permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for the wastewater treatment as the respective WLAs.

Table 21 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 20: Wastewater treatment facilities and associated WLAs (AUID: 07080201-515)

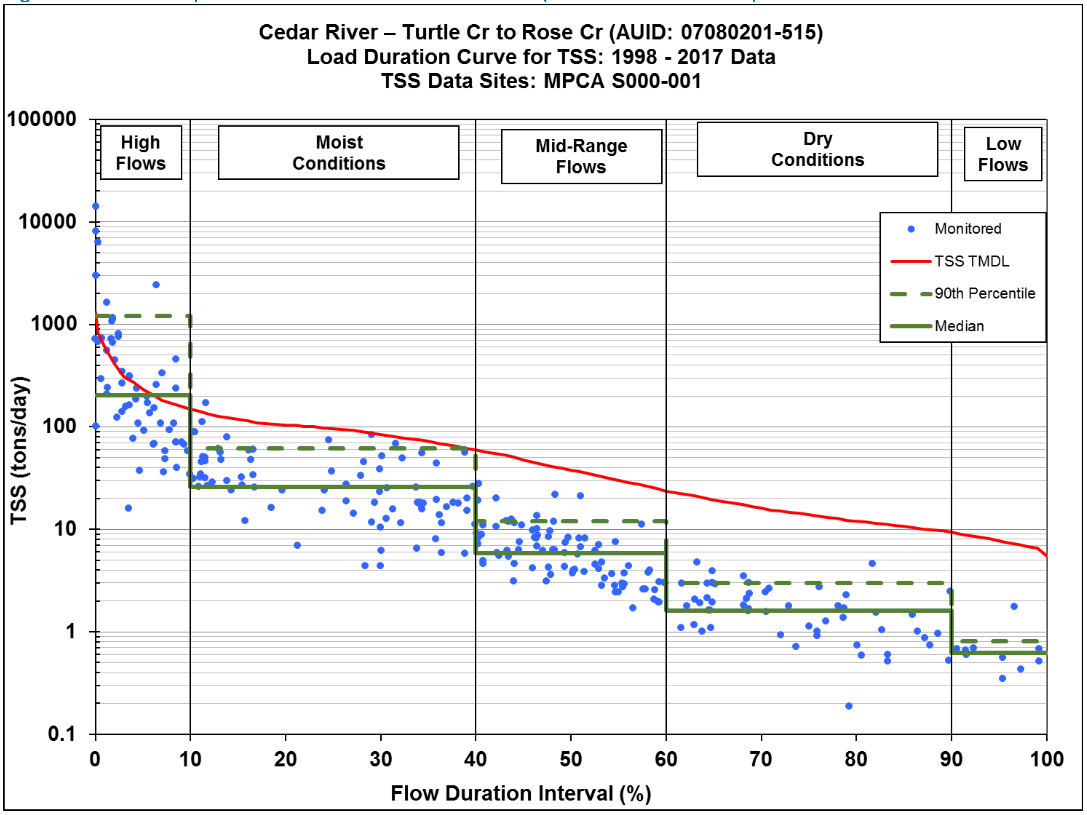
Facility	NPDES Permit #	Discharge, mgd	TSS WLA, kg/day	TSS WLA, tons/day
Austin WWTP	MN0022683	8.475	962.4	1.06
Blooming Prairie WWTP	MN0021822	0.899	102.1	0.113
Brownsdale WWTP	MN0022934	1.377	234.5	0.259
Hollandale WWTP	MN0048992	0.386	65.8	0.0725
Hormel Foods	MN0050911	1.448	164.4	0.181
Lansing TWP WWTP	MN0063461	0.204	34.7	0.0382
Oakland SD WWTP	MN0040631	0.088	15.0	0.0165
Sargeant WWTP	MNG580214	0.081	13.9	0.0153
Arkema Inc.	MN0041521	0.063	7.15	0.00789
Waltham WWTP	MN0025186	0.139	23.6	0.0260

Table 21: Total suspended solids loading capacities and allocations (AUID: 07080201-515).

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	233.22	96.11	37.98	13.94	7.67
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	1.79	1.79	1.79	1.79	1.79
Austin City MS4	5.81	2.37	0.90	0.30	0.14
Construction and Industrial Stormwater	0.10	0.042	0.016	0.0054	0.0026
Load Allocation	202.20	82.30	31.47	10.46	4.97
Margin of Safety	23.32	9.61	3.80	1.39	0.77
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	1%	2%	5%	13%	23%
Austin City MS4	2.5%	2.5%	2.4%	2.2%	1.9%
Construction and Industrial Stormwater	0.04%	0.04%	0.04%	0.04%	0.03%
Load Allocation	87%	86%	83%	75%	65%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 14) for the available dataset indicates exceedance of the target only under the high flows that have been recorded.

Figure 14: Total Suspended Solids Load Duration Curve (AUID: 07080201-515)



4.2.4 Unnamed Creek: Unnamed Creek to Rose Cr (AUID: 07080201-583)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach.

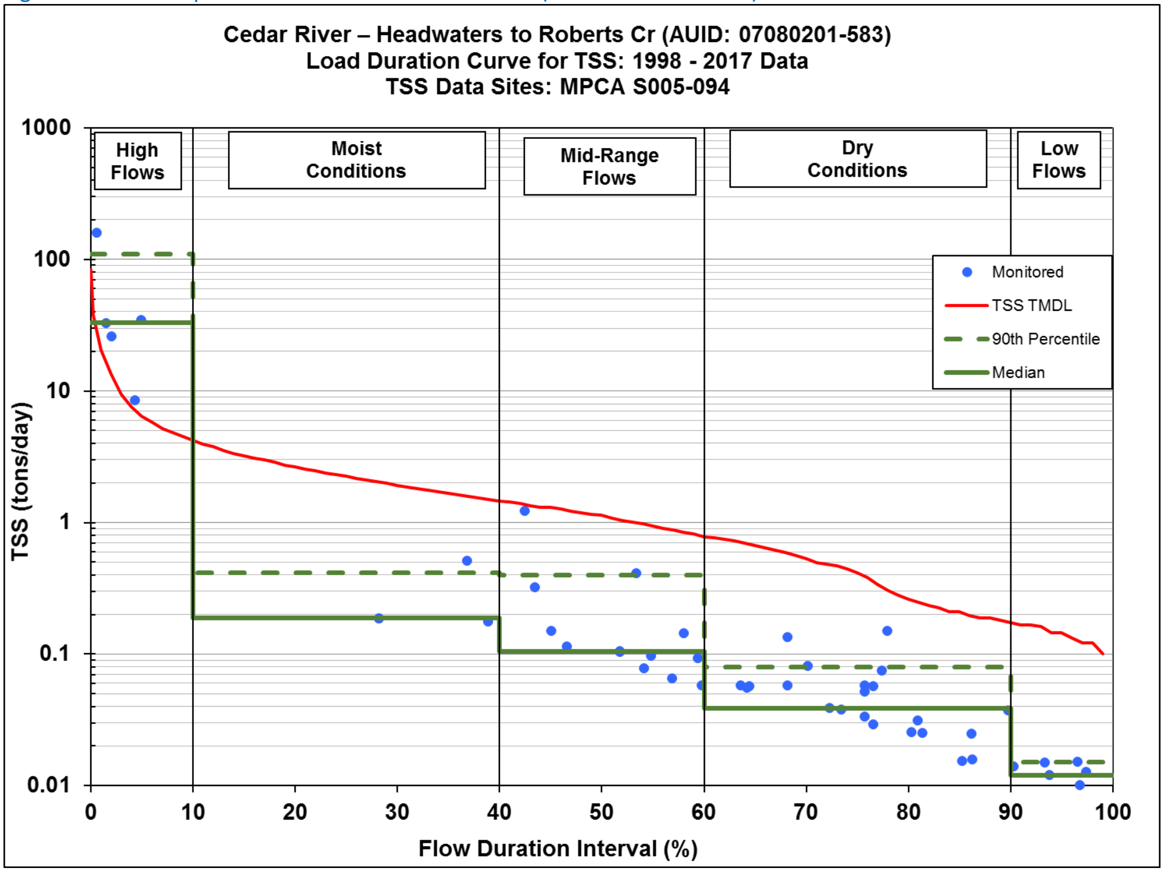
Table 22 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 22: Total suspended solids loading capacities and allocations (AUID: 07080201-583)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	6.43	2.25	1.13	0.41	0.14
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Austin City MS4	0.00	0.00	0.00	0.00	0.00
Construction and Industrial Stormwater	0.003	0.001	0.001	0.0002	0.0001
Load Allocation	5.79	2.03	1.02	0.37	0.13
Margin of Safety	0.64	0.23	0.11	0.04	0.01
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Austin City MS4	0.0%	0.0%	0.0%	0.0%	0.0%
Construction and Industrial Stormwater	0.05%	0.05%	0.05%	0.05%	0.05%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 15) for the available dataset indicates exceedance of the target under only high flows.

Figure 15: Total Suspended Solids Load Duration Curve (AUID: 07080201-583)



4.2.5 Cedar River: Headwaters to Roberts Cr (AUID: 07080201-503)

Table 23 shows the WWTFs and other permitted discharges within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLA's.

Table 24 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS.

Table 23: Wastewater treatment facilities and associated WLAs (AUID: 07080201-503)

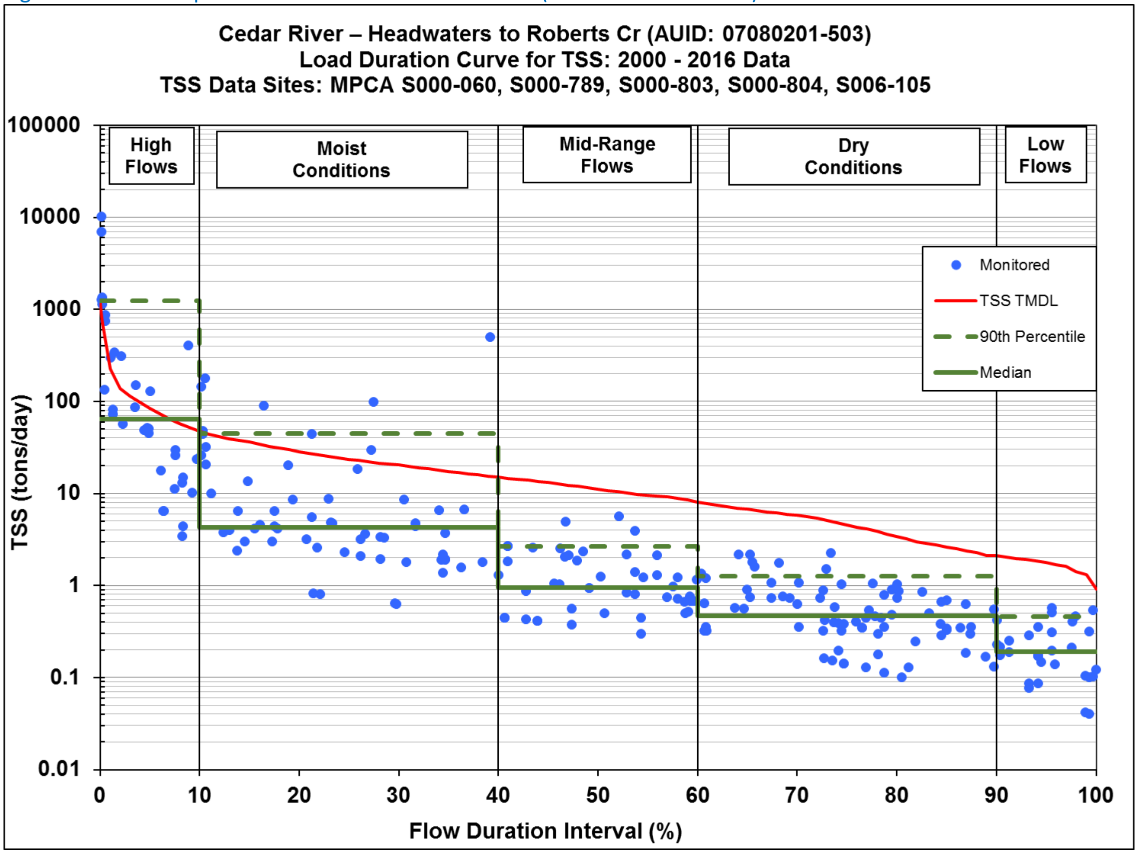
Facility	NPDES Permit #	Discharge, mgd	TSS WLA, kg/day	TSS WLA, tons/day
Blooming Prairie WWTP	MN0021822	0.899	102.1	0.113
Arkema Inc.	MN0041521	0.063	7.15	0.00789
Waltham WWTP	MN0025186	0.139	23.6	0.0260

Table 24: Total suspended solids loading capacities and allocations (AUID: 07080201-503)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	84.53	23.56	11.17	4.56	1.77
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.15	0.15	0.15	0.15	0.15
Austin City MS4	0.00	0.00	0.00	0.00	0.00
Construction and Industrial Stormwater	0.04	0.011	0.005	0.0020	0.0007
Load Allocation	75.89	21.05	9.90	3.95	1.45
Margin of Safety	8.45	2.36	1.12	0.46	0.18
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	1%	1%	3%	8%
Austin City MS4	0.0%	0.0%	0.0%	0.0%	0.0%
Construction and Industrial Stormwater	0.04%	0.04%	0.04%	0.04%	0.04%
Load Allocation	90%	89%	89%	87%	82%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 16) for the available dataset indicates exceedance of the target under moderately high to high flows.

Figure 16: Total Suspended Solids Load Duration Curve (AUID: 07080201-503)



4.2.6 Rose Creek: Headwaters to Cedar River (AUID: 07080201-522)

Table 25 shows the WWTFs within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 26 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS.

Table 25: Wastewater treatment facilities and associated WLAs (AUID: 07080201-522)

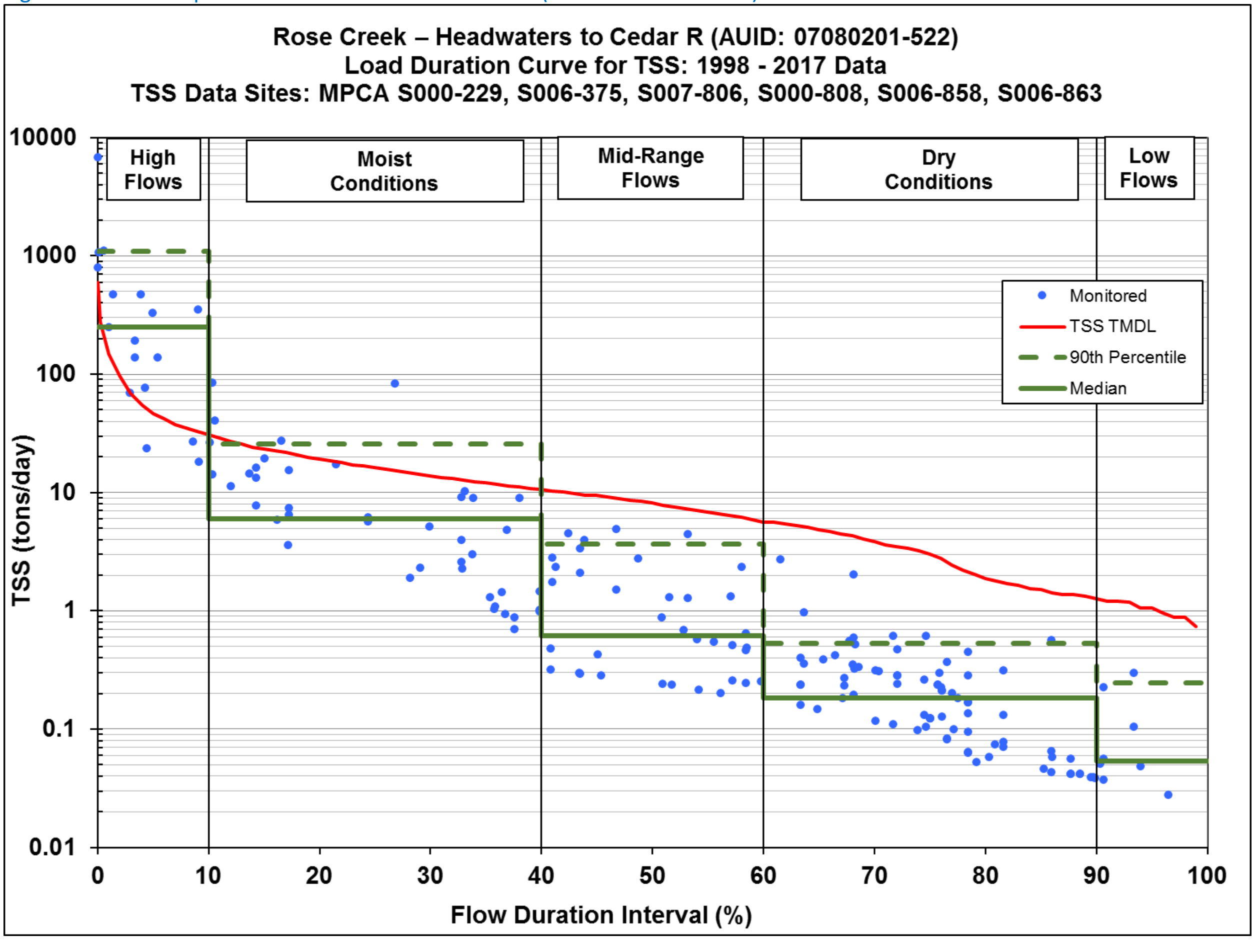
Facility	NPDES Permit #	Discharge, mgd	TSS WLA, kg/day	TSS WLA, tons/day
Elkton WWTP	MNG580013	0.163	27.8	0.0306
Rose Creek WWTP	MN0024651	0.401	68.3	0.0753

Table 26: Total suspended solids loading capacities and allocations (AUID: 07080201-522)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	46.64	16.34	8.20	3.00	1.05
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.11	0.11	0.11	0.11	0.11
Austin City MS4	0.00	0.00	0.00	0.00	0.00
Construction and Industrial Stormwater	0.02	0.007	0.004	0.0013	0.0004
Load Allocation	41.85	14.59	7.27	2.59	0.84
Margin of Safety	4.66	1.63	0.82	0.30	0.11
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	1%	1%	4%	10%
Austin City MS4	0.0%	0.0%	0.0%	0.0%	0.0%
Construction and Industrial Stormwater	0.04%	0.04%	0.04%	0.04%	0.04%
Load Allocation	90%	89%	89%	86%	80%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 17) for the available dataset indicates exceedance of the target under moderately high to high flows.

Figure 17: Total Suspended Solids Load Duration Curve (AUID: 07080201-522)



4.2.7 Unnamed Creek: Unnamed Cr to Cedar River (AUID: 07080201-533)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach.

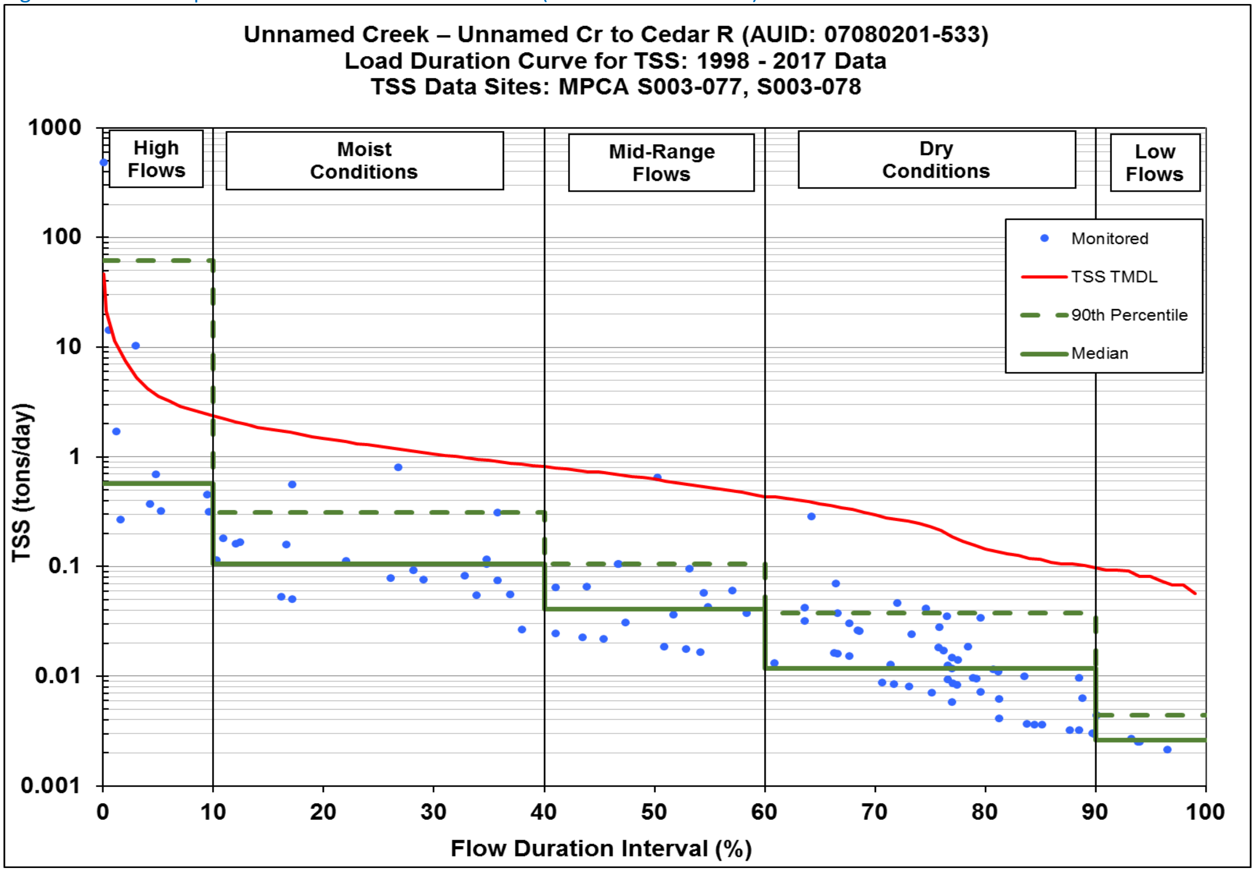
Table 27 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 27: Total suspended solids loading capacities and allocations (AUID: 07080201-533)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	3.59	1.26	0.63	0.23	0.08
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Austin City MS4	0.00	0.00	0.00	0.00	0.00
Construction and Industrial Stormwater	0.002	0.001	0.0003	0.0001	0.00004
Load Allocation	3.23	1.13	0.57	0.21	0.07
Margin of Safety	0.36	0.13	0.06	0.02	0.01
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Austin City MS4	0.0%	0.0%	0.0%	0.0%	0.0%
Construction and Industrial Stormwater	0.05%	0.05%	0.05%	0.05%	0.05%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 18) for the available dataset indicates exceedance of the target under high flows.

Figure 18: Total Suspended Solids Load Duration Curve (AUID: 07080201-533)



4.2.8 Dobbins Creek: T103 R18W S36, east line to East Side Lk (AUID: 07080201-535)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There is a 1.3 square mile area of the city of Austin, which is subject to stormwater MS4 NPDES Permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for this permit as the WLA.

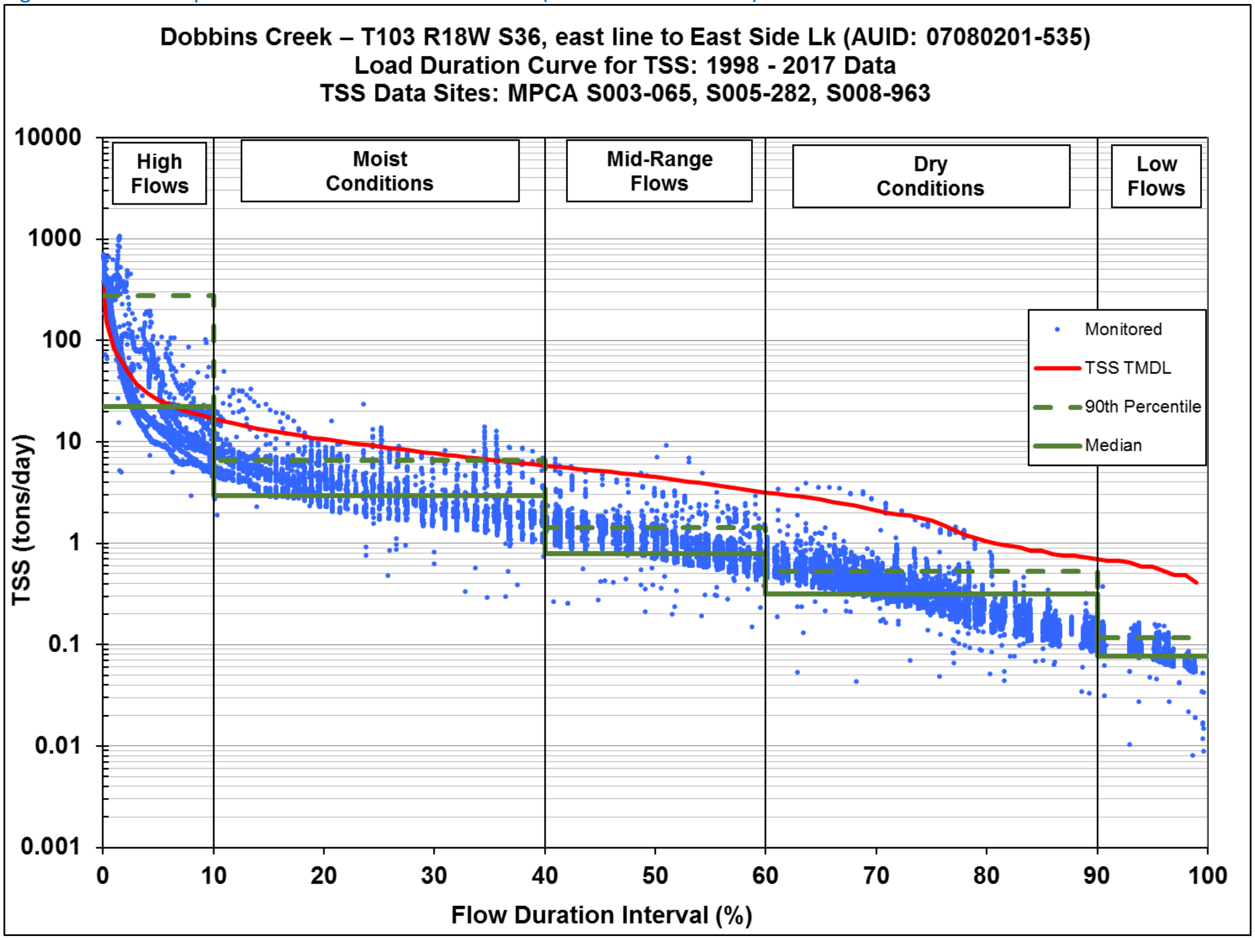
Table 28 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 28: Total suspended solids loading capacities and allocations (AUID: 07080201-535)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	25.78	9.03	4.53	1.66	0.58
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Austin City MS4	0.79	0.28	0.14	0.05	0.02
Construction and Industrial Stormwater	0.01	0.004	0.002	0.0007	0.0003
Load Allocation	22.40	7.85	3.94	1.44	0.50
Margin of Safety	2.58	0.90	0.45	0.17	0.06
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Austin City MS4	3.1%	3.1%	3.1%	3.1%	3.1%
Construction and Industrial Stormwater	0.05%	0.05%	0.05%	0.05%	0.05%
Load Allocation	87%	87%	87%	87%	87%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 19) for the available dataset indicates exceedance of the target under all flow regimes, except low flows. The large data set shows the greatest propensity of exceedances under high flows.

Figure 19: Total Suspended Solids Load Duration Curve (AUID: 07080201-535)



4.2.9 Dobbins Creek: East Side Lk to Cedar River (AUID: 07080201-537)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There are 2.1 square miles in the city of Austin, which is subject to Stormwater MS4 NPDES Permit requirements, draining to this listed reach. This TMDL utilizes the permitted daily loading rates for this permit as the WLA.

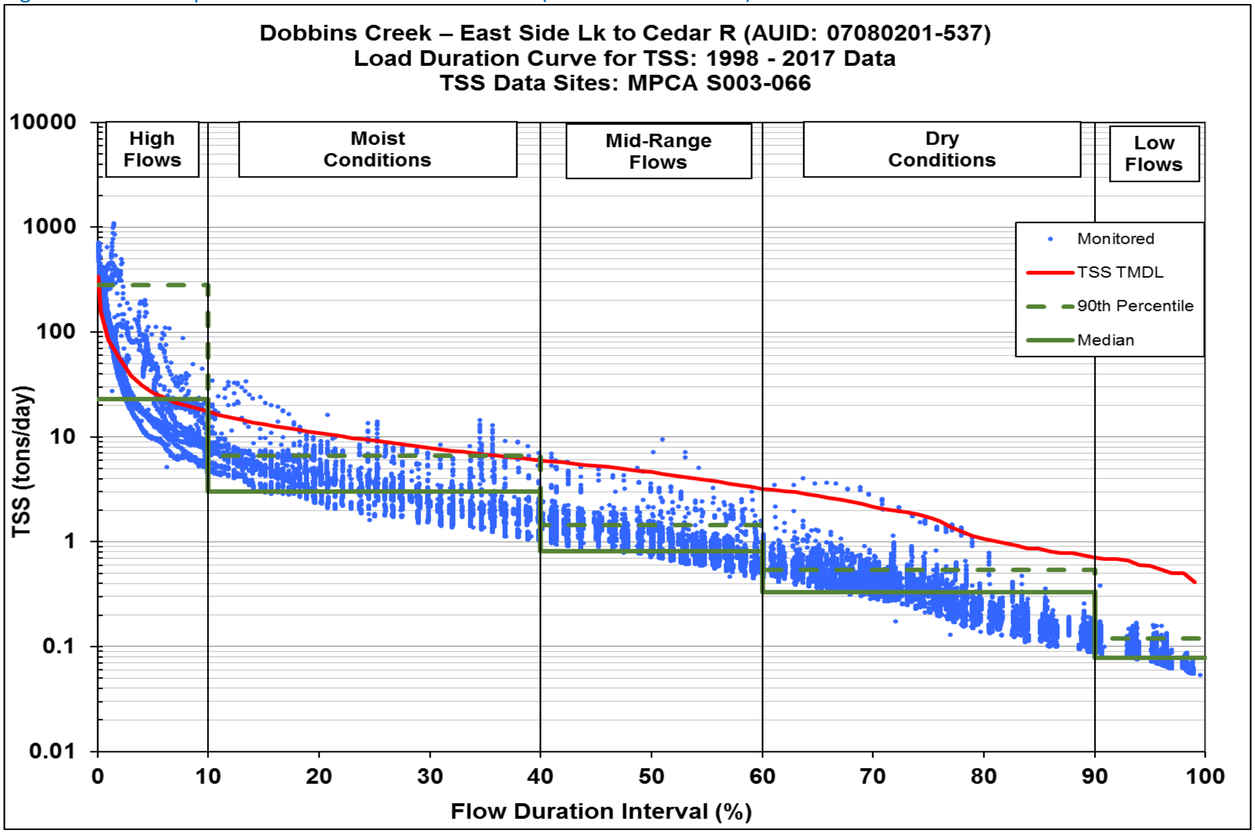
Table 29 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 29: Total suspended solids loading capacities and allocations (AUID: 07080201-537)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	26.40	9.25	4.64	1.70	0.59
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Austin City MS4	1.33	0.47	0.23	0.09	0.03
Construction and Industrial Stormwater	0.01	0.004	0.002	0.0008	0.0003
Load Allocation	22.42	7.86	3.94	1.44	0.50
Margin of Safety	2.64	0.92	0.46	0.17	0.06
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Austin City MS4	5.0%	5.0%	5.0%	5.0%	5.0%
Construction and Industrial Stormwater	0.05%	0.05%	0.05%	0.05%	0.05%
Load Allocation	85%	85%	85%	85%	85%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 20) for the available dataset indicates exceedance of the target under all flow regimes except low flows. The large dataset shows the greatest propensity of exceedances under high flows.

Figure 20: Total Suspended Solids Flow Duration Curve (AUID 07080201-537)



4.2.10 Turtle Creek: T102 R18W S4, north line to Cedar R (AUID: 07080201-540)

Table 30 shows the WWTFs that drain to this listed reach. There are 3.4 square miles of the city of Austin, which is subject to stormwater MS4 NPDES Permit requirements, draining to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 31 provides the average TSS loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 30: Wastewater treatment facilities and associated WLAs (AUID: 07080201-540)

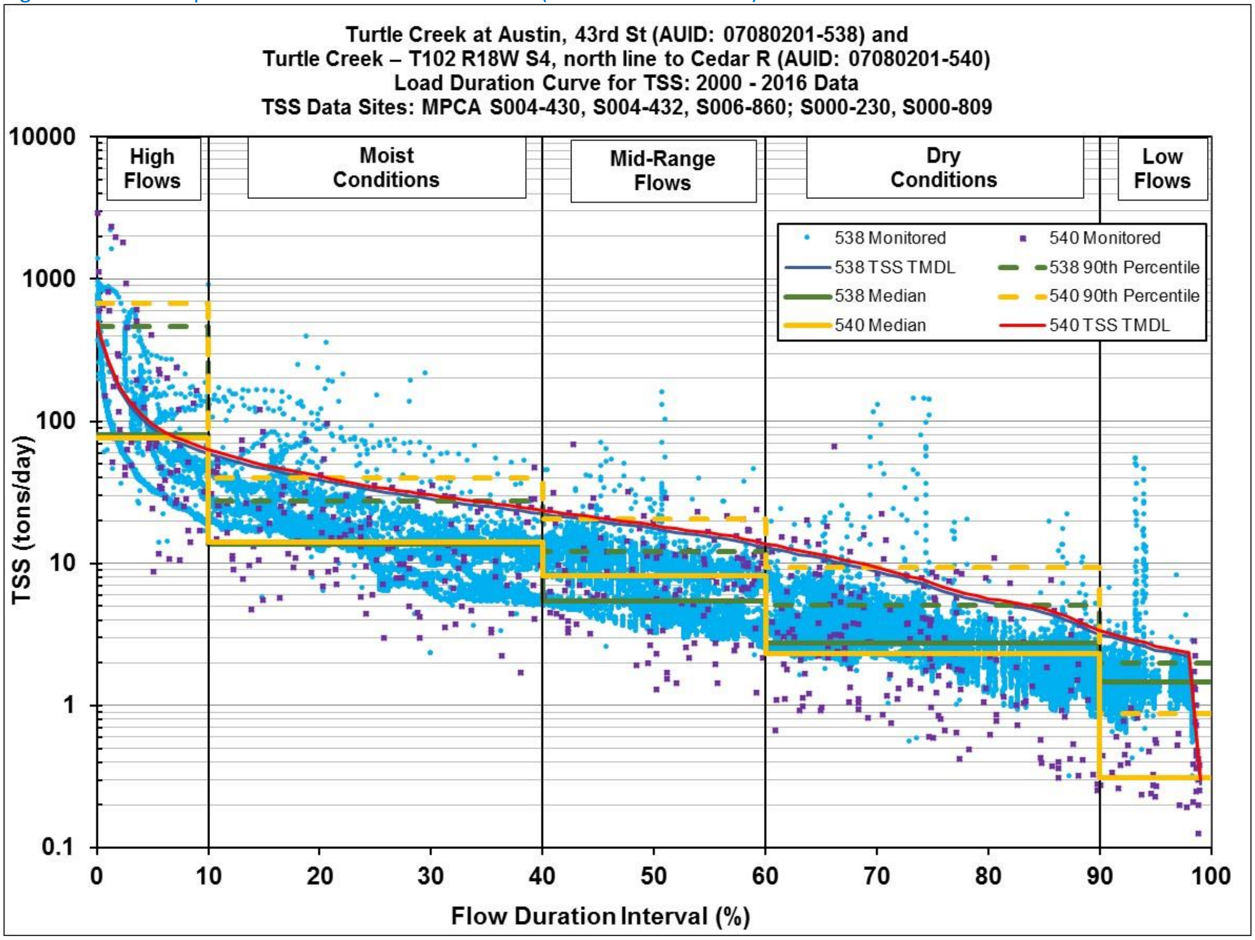
Facility	NPDES Permit #	Discharge, mgd	TSS WLA, kg/day	TSS WLA, tons/day
Hollandale WWTP	MN0048992	0.386	65.8	0.0725
Oakland SD WWTP	MN0040631	0.088	15.0	0.0165

Table 31: Total suspended solids loading capacities and allocations (AUID: 07080201-540)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	94.36	34.45	18.64	7.26	2.60
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.09	0.09	0.09	0.09	0.09
Austin City MS4	1.89	0.69	0.37	0.14	0.05
Construction and Industrial Stormwater	0.04	0.015	0.008	0.0032	0.0011
Load Allocation	82.90	30.21	16.30	6.30	2.20
Margin of Safety	9.44	3.45	1.86	0.73	0.26
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	1%	3%
Austin City MS4	2.0%	2.0%	2.0%	2.0%	1.9%
Construction and Industrial Stormwater	0.04%	0.04%	0.04%	0.04%	0.04%
Load Allocation	88%	88%	87%	87%	85%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 21) for the available dataset indicates exceedance of the target under all flow regimes. Data from AUID 07080201-538 are included in Figure 21 and this analysis, as it is the reach immediately upstream of AUID 07080201-540 and contains the primary source of continuous flow (and supplemental continuous turbidity) data that represents more than 94% of the total drainage area to the AUID 07080201-540 reach. This combination plot allows for a comparison of data between the two reaches, which are both based on surrogate turbidity data. All median TSS values are similar across the flow categories, except for low flows when the upstream reach is notably higher than the downstream reach. However, the 90th percentile TSS loads are consistently higher in the downstream reach, at all flows except the low flow zone.

Figure 21: Total Suspended Solids Flow Duration Curve (AUID: 07080201-540)



4.2.11 Overall Conclusions from Sediment-Related Monitoring and TMDL Allocations

Some of the conclusions to be drawn from this project's monitoring experience, including data and assessments discussed in the previous subsections, are as follows:

- TSS impairments in the watershed are significant. While some site differences do exist, a significant portion of data from the wet-weather and higher runoff periods are above the standard at all of the monitoring sites.
- Four TSS-listed reaches on the mainstem Cedar River cover 46 miles of stream, out of a total stream length in Minnesota of 54 miles.
- For stream sites with large datasets (which utilize continuous turbidity measurements), exceedances occur under all flow regimes except low flow, and in some cases under low flow as well. Reaches with moderate size datasets, which utilize transparency and Secchi tube sampling, show exceedances predominately in the moderately high to high flow zones.
- Primary sources contributing TSS within this watershed are streambank/bed erosion, sheet and rill erosion from row cropland, ravine and gully erosion, channelization of streams, urban stormwater runoff, concentrated flow in riparian zones and buffers near streams and waterways, and overgrazed pasture in close proximity to surface waters. Depending on the flow

conditions and landscape of the various subwatershed areas, each one of these primary sources may be contributing significant amounts of TSS at localized scales. There may also be seasonally significant contributions from algae to the TSS conditions downstream of reservoirs or impoundments (such as Ramsey Mill Pond and East Side Lake) and Geneva Lake, in localized areas of the watershed.

- Biological monitoring of creeks, streams and rivers in the CRW has shown that habitats are degraded, and that bedded sediments are frequently the critical factor affecting that condition (MPCA 2016). Seventeen of the eighteen sites listed in the SID report include a confirmed stressor for "habitat/bedded sediment." TSS was a confirmed biological stressor in 27% of the stream reaches, and was an inconclusive stressor in the remainder of the stream reaches studied. The 10 stream reaches with TSS TMDLs in this report have load reductions to meet the TSS WQS. Future efforts in Cycle 2 (IWM) could consider sediment load reductions tied more directly to actual watershed processes, and biocriteria thresholds.

4.3 TMDL Summaries – Allocations for Bacteria Impaired Reaches

In the sections below, TMDL allocations are provided for the individual bacteria-impaired reaches (indicated in Figure 1). Calculations for the TMDL, LA, WLA, and MOS consider the total drainage area represented by the end of the listed reach. Water quality duration curves, which integrate flow and the measured bacteria concentrations to illustrate the loading capacity across the flow record, as well as comparisons to the loading capacity using collected water quality data and the 126 cfu/100 ml *E. coli* standard, are also included in each section.

4.3.1 Cedar River: Woodbury Cr to MN/IA Border (AUID: 07080201-516)

Table 32 shows the WWTFs and other permitted discharges within the land area that drains to this listed reach. There is also a 12 square mile area of the city of Austin, which is subject to stormwater MS4 NPDES Permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 33 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS.

Table 32: Wastewater treatment facilities and associated bacteria WLAs (AUID: 07080201-516)

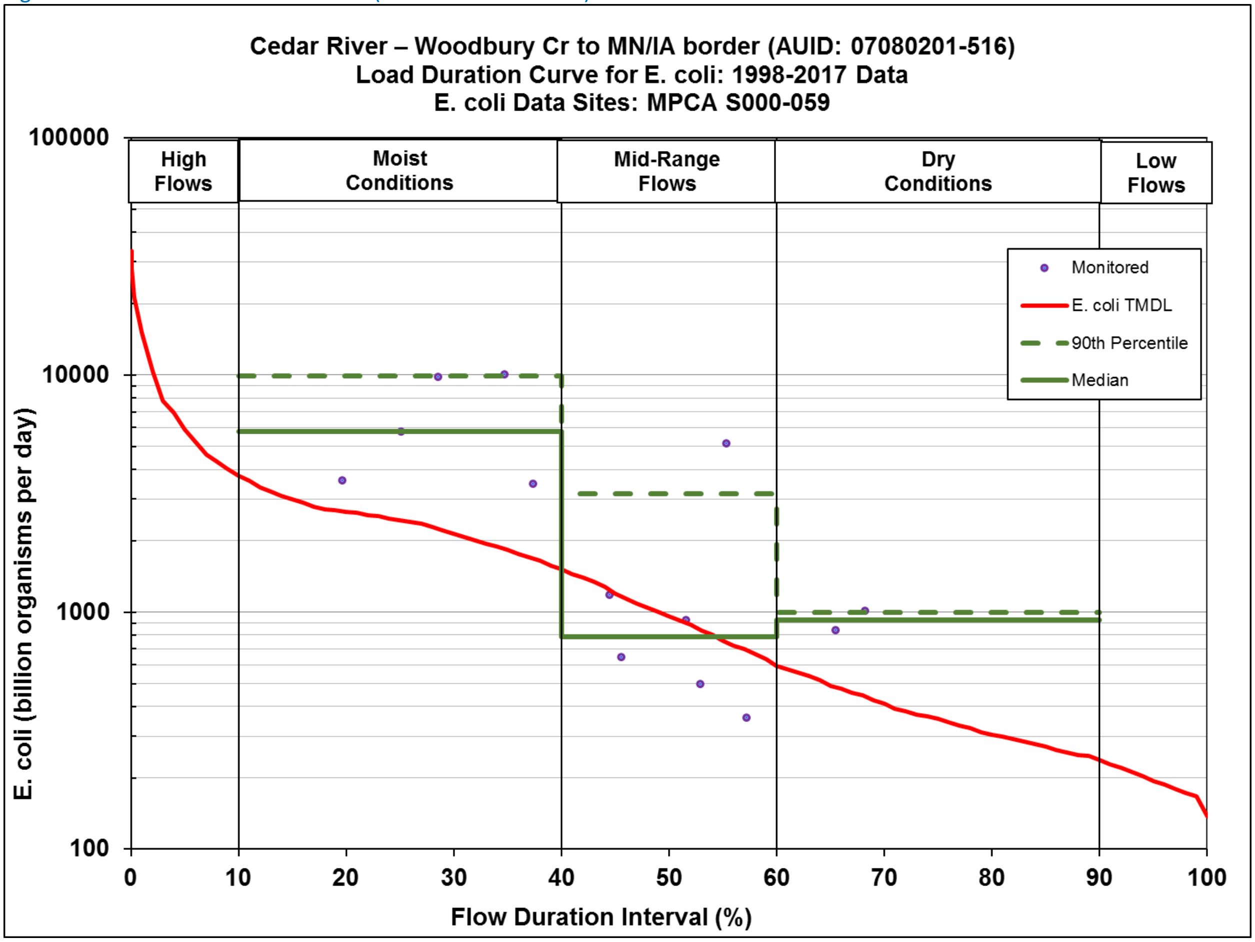
Facility	NPDES Permit #	Discharge, mgd	WLA (Billion organisms/day)
Austin WWTP	MN0022683	8.475	40.42
Blooming Prairie WWTP	MN0021822	0.899	4.29
Brownsdale WWTP	MN0022934	1.374	6.55
Elkton WWTP	MNG580013	0.163	0.78
Hollandale WWTP	MN0048992	0.387	1.85
Rose Creek WWTP	MN0024651	0.400	1.91
Lansing Township WWTP	MN0063461	0.205	0.98
Oakland Sanitary District WWTP	MN0040631	0.088	0.42
Sargeant WWTP	MNG580214	0.082	0.39
Waltham WWTP	MN0025186	0.139	0.66

Table 33: Bacteria loading capacities and allocations (AUID: 07080201-516)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	5916.93	2438.25	963.54	353.75	194.52
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	58.25	58.25	58.25	58.25	58.25
Communities Subject to MS4 NPDES Requirements	108.29	43.92	16.63	5.35	2.40
Load Allocation	5158.70	2092.26	792.30	254.78	114.42
Margin of Safety	591.69	243.82	96.35	35.37	19.45
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	1%	2%	6%	16%	30%
Communities Subject to MS4 NPDES Requirements	1.8%	1.8%	1.7%	1.5%	1.2%
Load Allocation	87%	86%	82%	72%	59%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 22) for the available dataset indicates exceedance of the target for all flow conditions except under high and low flows, where no data was available.

Figure 22: *E. coli* Load Duration Curve (AUID: 07080201-516)



4.3.2 Cedar River: Headwaters to Roberts Cr (AUID: 07080201-503)

Table 34 shows the WWTFs and other permitted discharges within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 35 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 34: Wastewater treatment facilities and associated bacteria WLAs (AUID: 07080201-503)

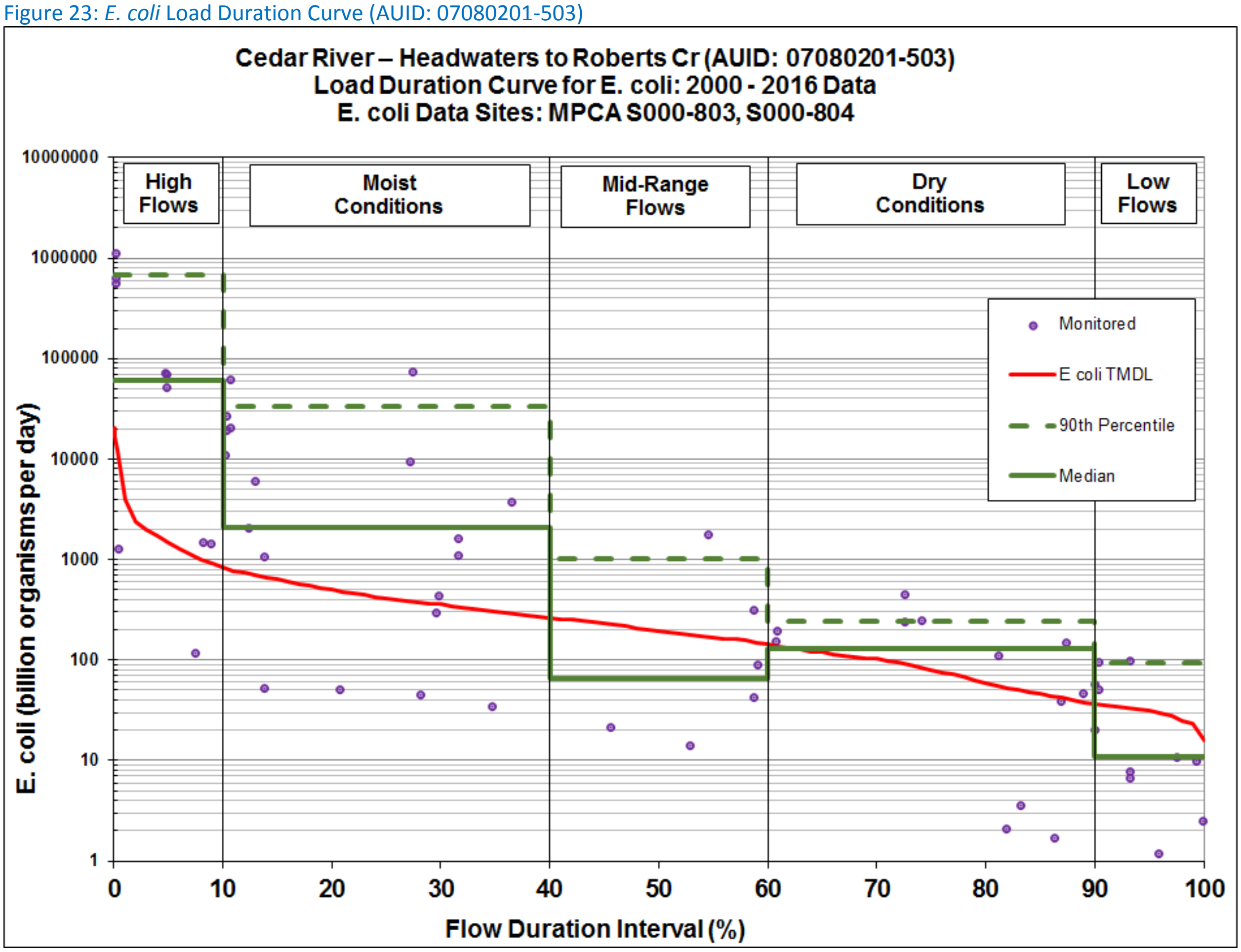
Facility	NPDES Permit #	Discharge, mgd	WLA (Billion organisms/day)
Blooming Prairie WWTP	MN0021822	0.899	4.29
Waltham WWTP	MN0025186	0.139	0.66

Table 35: Bacteria loading capacities and allocations (AUID: 07080201-503

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	1486.53	414.27	196.40	80.18	31.17
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	4.95	4.95	4.95	4.95	4.95
Communities Subject to MS4 NPDES Requirements	0.00	0.00	0.00	0.00	0.00
Load Allocation	1332.93	367.90	171.81	67.21	23.11
Margin of Safety	148.65	41.43	19.64	8.02	3.12
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.3%	1.2%	2.5%	6.2%	15.9%
Communities Subject to MS4 NPDES Requirements	0.0%	0.0%	0.0%	0.0%	0.0%
Load Allocation	89.7%	88.8%	87.5%	83.8%	74.1%
Margin of Safety	10.0%	10.0%	10.0%	10.0%	10.0%

The LDC (Figure 23) for the available dataset indicates exceedance of the target throughout all flow conditions except under high and low flows, where no data was available.

Figure 23: *E. coli* Load Duration Curve (AUID: 07080201-503)



4.3.3 Rose Creek: Headwaters to Cedar R (AUID: 07080201-522)

Table 36 shows the WWTFs within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 37 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 36: Wastewater treatment facilities and associated bacteria WLAs (AUID: 07080201-522)

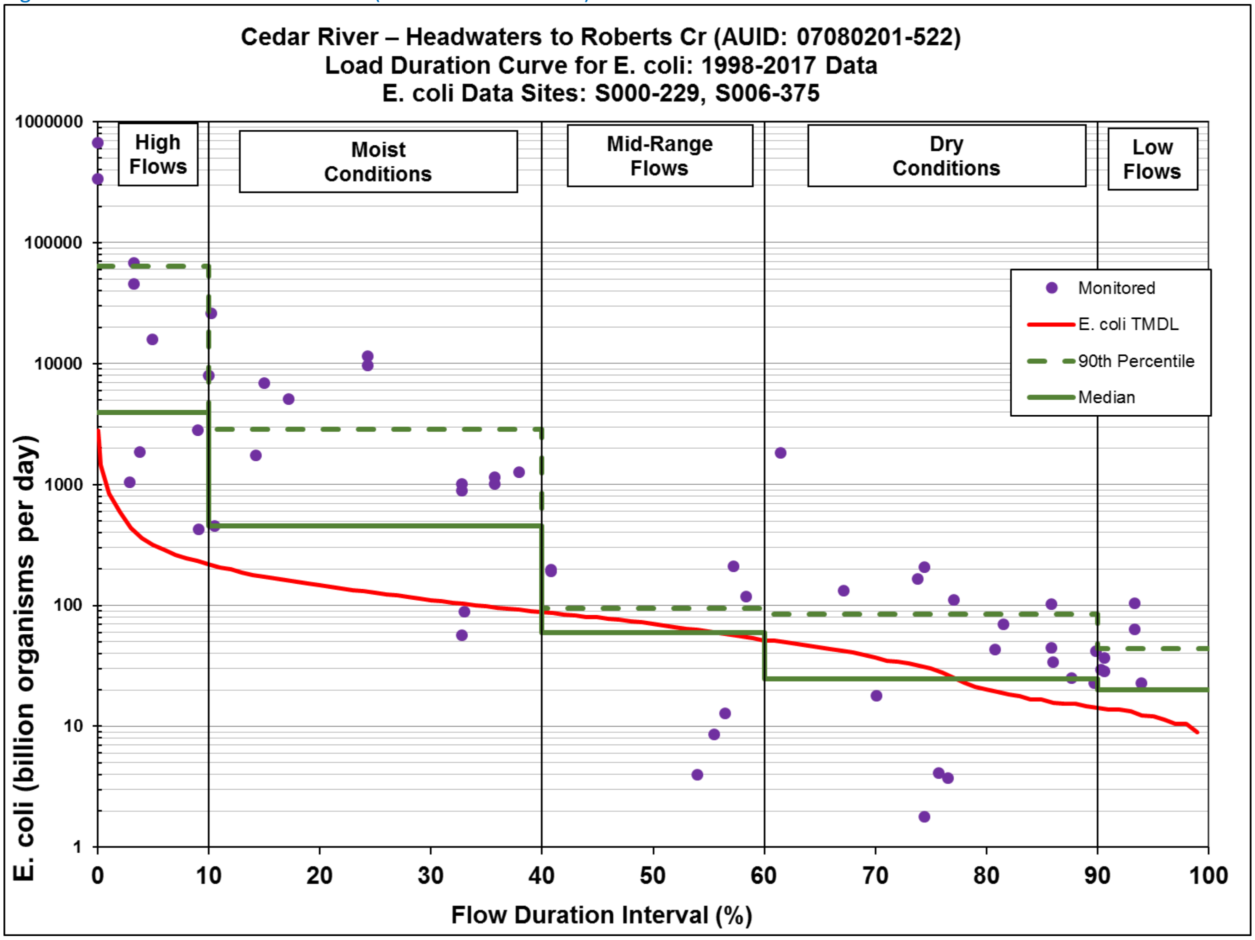
Facility	NPDES Permit #	Discharge, mgd	WLA (Billion organisms/day)
Elkton WWTP	MNG580013	0.163	0.78
Rose Creek WWTP	MN0024651	0.400	1.91

Table 37: Bacteria loading capacities and allocations (AUID: 07080201-522)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	820.10	287.37	144.26	52.78	18.47
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	2.69	2.69	2.69	2.69	2.69
Communities Subject to MS4 NPDES Requirements	0.00	0.00	0.00	0.00	0.00
Load Allocation	735.41	255.95	127.15	44.81	13.94
Margin of Safety	82.01	28.74	14.43	5.28	1.85
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	1%	2%	5%	15%
Communities Subject to MS4 NPDES Requirements	0.0%	0.0%	0.0%	0.0%	0.0%
Load Allocation	90%	89%	88%	85%	75%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 24) for the available dataset indicates exceedance of the target throughout all flow conditions that have been recorded.

Figure 24: *E. coli* Load Duration Curve (AUID: 07080201-522)



4.3.4 Unnamed Creek: Unnamed Cr to Cedar R (AUID: 07080201-533)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach.

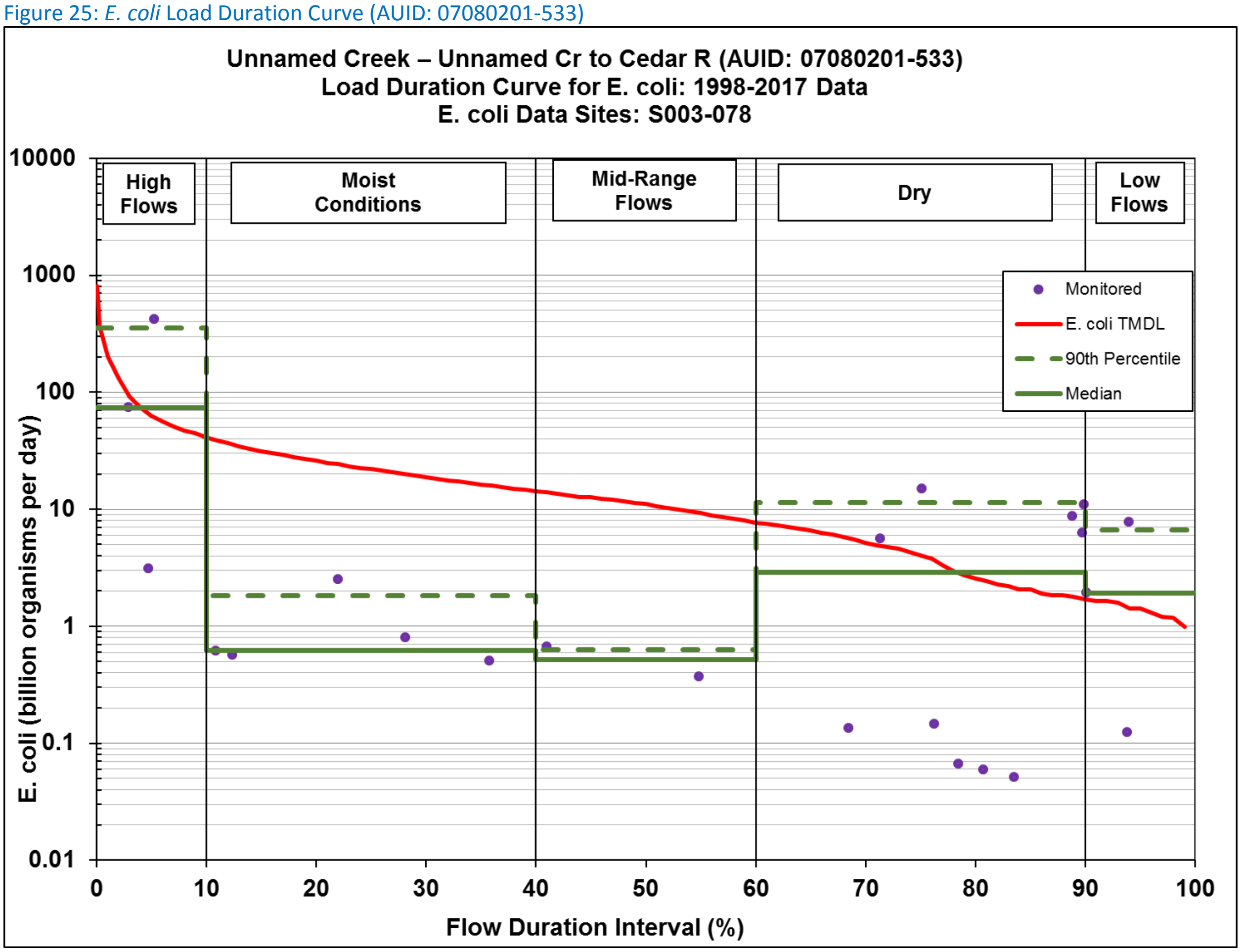
Table 38 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 38: Bacteria loading capacities and allocations (AUID: 07080201-533)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	63.13	22.12	11.10	4.06	1.42
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Communities Subject to MS4 NPDES Requirements	0.00	0.00	0.00	0.00	0.00
Load Allocation	56.81	19.91	9.99	3.66	1.28
Margin of Safety	6.31	2.21	1.11	0.41	0.14
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Communities Subject to MS4 NPDES Requirements	0.0%	0.0%	0.0%	0.0%	0.0%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 25) for the available dataset indicates exceedance of the target under low flow and dry conditions and high flows that have been recorded.

Figure 25: *E. coli* Load Duration Curve (AUID: 07080201-533)



4.3.5 Dobbins Creek: T103 R18W S36, east line to East Side Lk (AUID: 07080201-535)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There is a 1.3 square mile area of the city of Austin, which is subject to stormwater MS4 NPDES Permit requirements, that drains to this listed reach. This TMDL utilizes the permitted daily loading rates for this permit as the WLA.

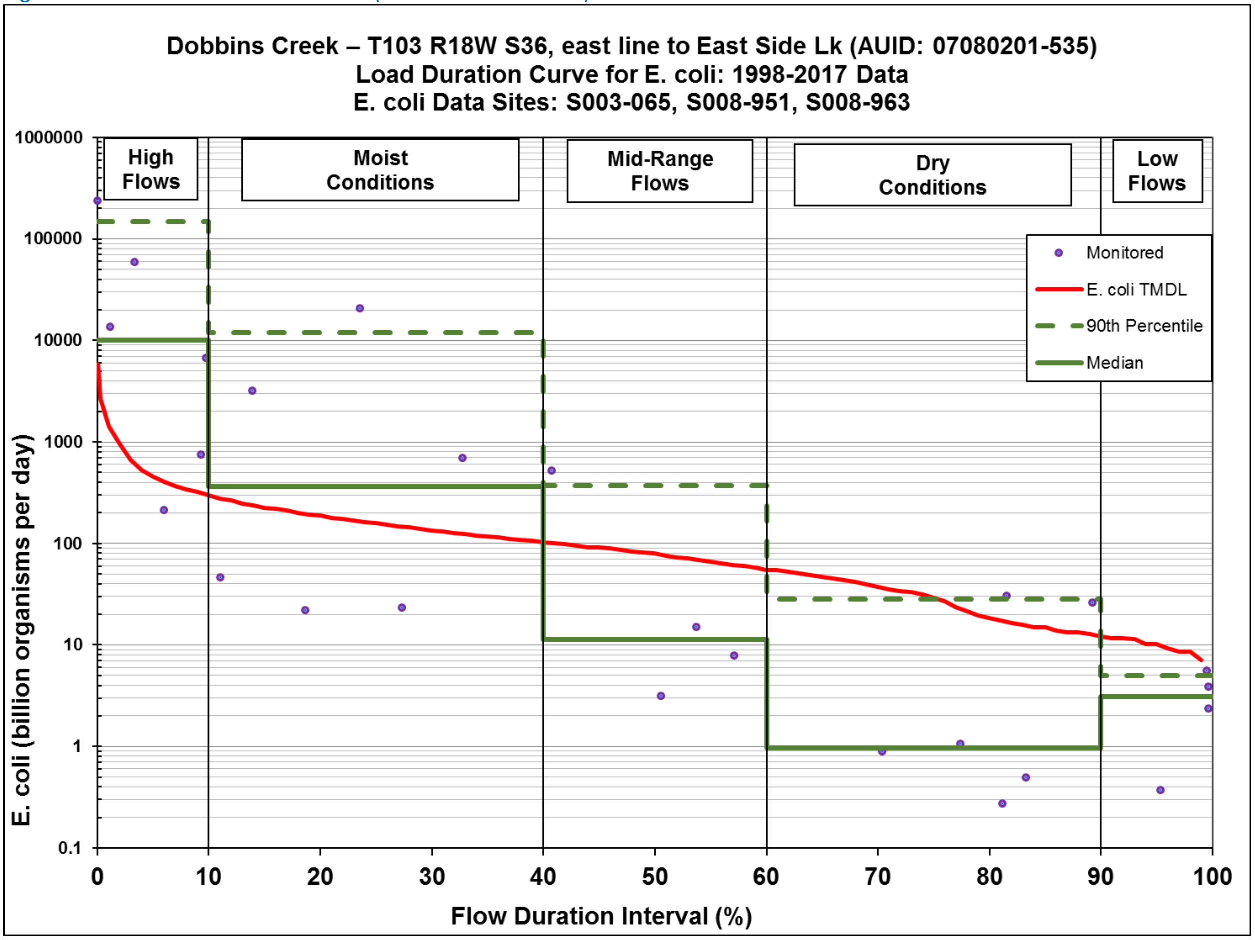
Table 39 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS.

Table 39: Bacteria loading capacities and allocations (AUID: 07080201-535)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	453.31	158.84	79.74	29.17	10.21
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Communities Subject to MS4 NPDES Requirements	13.88	4.86	2.44	0.89	0.31
Load Allocation	394.10	138.09	69.32	25.36	8.87
Margin of Safety	45.33	15.88	7.97	2.92	1.02
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Communities Subject to MS4 NPDES Requirements	3.1%	3.1%	3.1%	3.1%	3.1%
Load Allocation	87%	87%	87%	87%	87%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 26) for the available dataset indicates exceedance of the target under mid-range flow and high flows that have been recorded.

Figure 26: *E. coli* Load Duration Curve (AUID: 07080201-535)



4.3.6 Dobbins Creek: East Side Lk to Cedar R (AUID: 07080201-537

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There are 2.1 square miles in the city of Austin, which is subject to Stormwater MS4 NPDES Permit requirements, draining to this listed reach. This TMDL utilizes the permitted daily loading rates for this permit as the WLA.

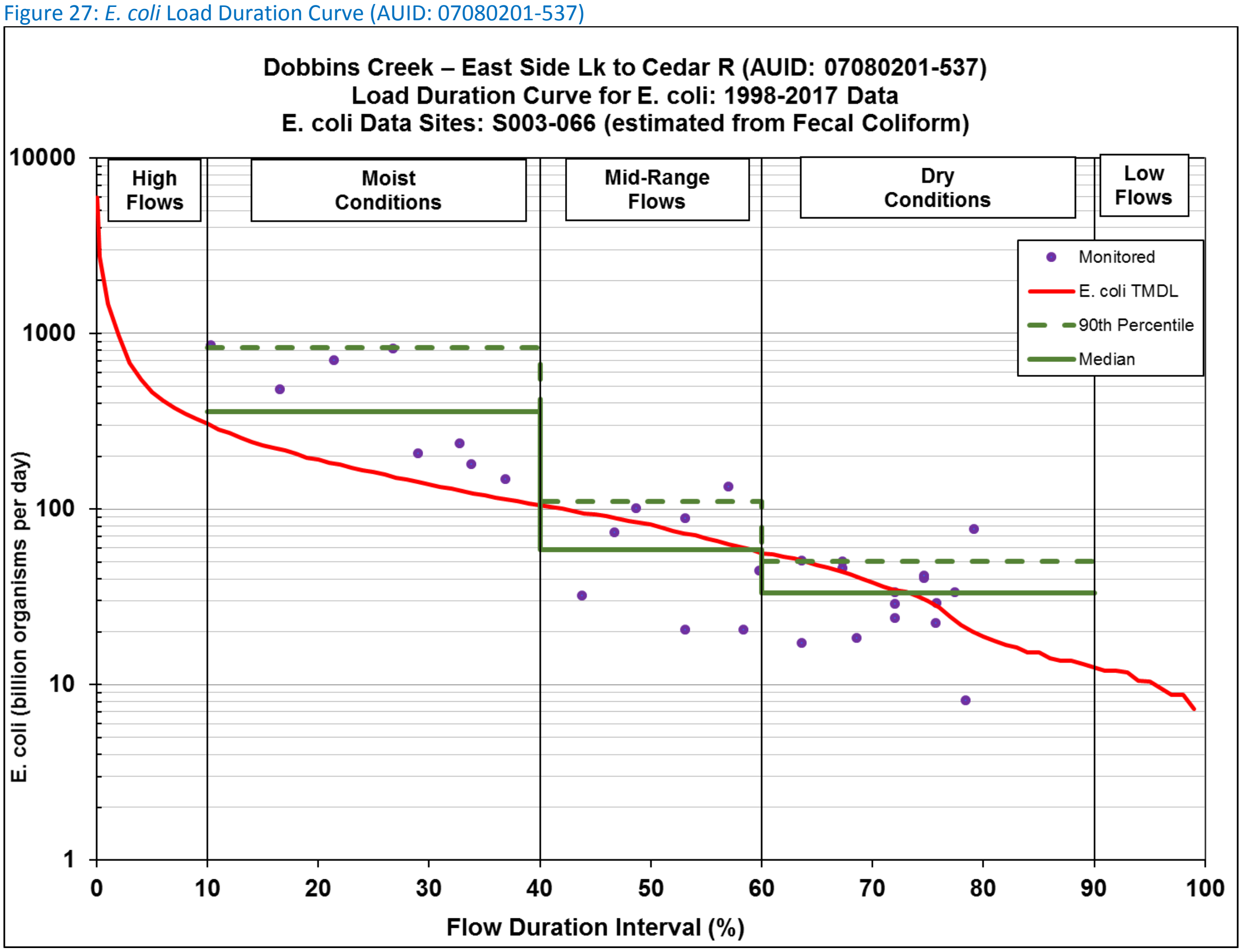
Table 40 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 40: Bacteria loading capacities and allocations (AUID: 07080201-537)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	464.19	162.65	81.65	29.87	10.45
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Communities Subject to MS4 NPDES Requirements	23.34	8.18	4.11	1.50	0.53
Load Allocation	394.43	138.21	69.38	25.38	8.88
Margin of Safety	46.42	16.27	8.17	2.99	1.05
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Communities Subject to MS4 NPDES Requirements	5.0%	5.0%	5.0%	5.0%	5.0%
Load Allocation	85%	85%	85%	85%	85%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 27) for the available dataset indicates exceedance of the target under all flow conditions except low and high flow regimes, where no data was collected.

Figure 27: *E. coli* Load Duration Curve (AUID: 07080201-537)



4.3.7 Turtle Creek: T102 R18W S4, north line to Cedar R (AUID: 07080201-540)

Table 41 shows the WWTFs that drain to this listed reach. There are 3.4 square miles of the city of Austin, which is subject to stormwater MS4 NPDES Permit requirements, draining to this listed reach. This TMDL utilizes the permitted daily loading rates for this permit as the respective WLAs.

Table 41: Wastewater treatment facilities and associated bacteria WLAs (AUID: 07080201-540).

Facility	NPDES Permit #	Discharge, mgd	WLA (Billion organisms/day)
Hollandale WWTP	MN0048992	0.387	1.85
Oakland Sanitary District WWTP	MN0040631	0.088	0.42

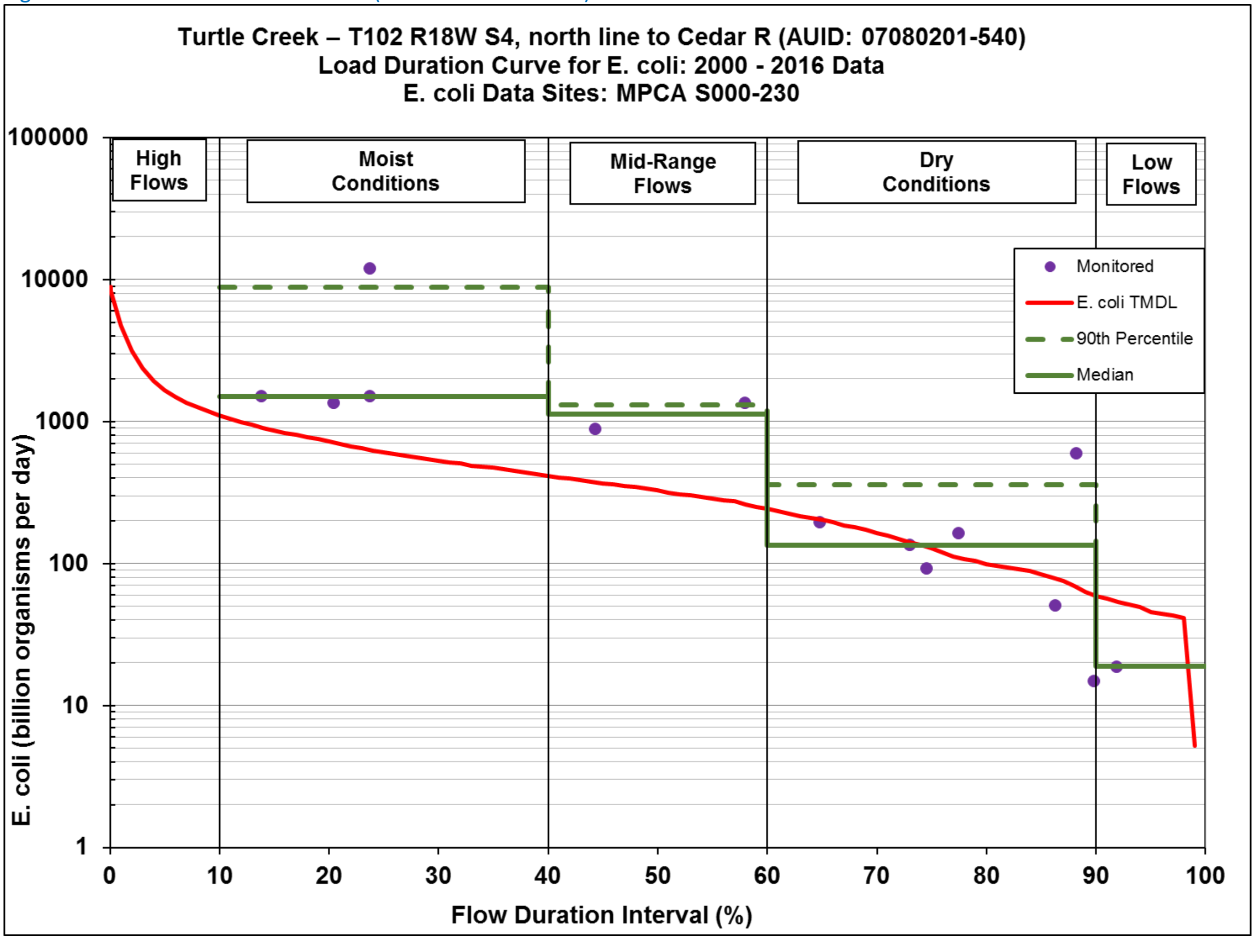
Table 42 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS.

Table 42: Bacteria loading capacities and allocations (AUID: 07080201-540)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	1659.32	605.88	327.73	127.72	45.72
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	2.27	2.27	2.27	2.27	2.27
Communities Subject to MS4 NPDES Requirements	33.20	12.09	6.52	2.51	0.87
Load Allocation	1457.92	530.93	286.17	110.17	38.01
Margin of Safety	165.93	60.59	32.77	12.77	4.57
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	1%	2%	5%
Communities Subject to MS4 NPDES Requirements	2.0%	2.0%	2.0%	2.0%	1.9%
Load Allocation	88%	88%	87%	86%	83%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 28) for the available dataset indicates exceedance of the target under all flow conditions except low and high flows. No data was collected under high flow conditions.

Figure 28: *E. coli* Load Duration Curve (AUID: 07080201-540)



4.3.8 Orchard Creek: T101 R18W S5, north line to Cedar R (AUID: 07080201-539)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There are 0.7 square miles in the city of Austin, which is subject to Stormwater MS4 NPDES Permit requirements, draining to this listed reach. This TMDL utilizes the permitted daily loading rates for this permit as the WLA.

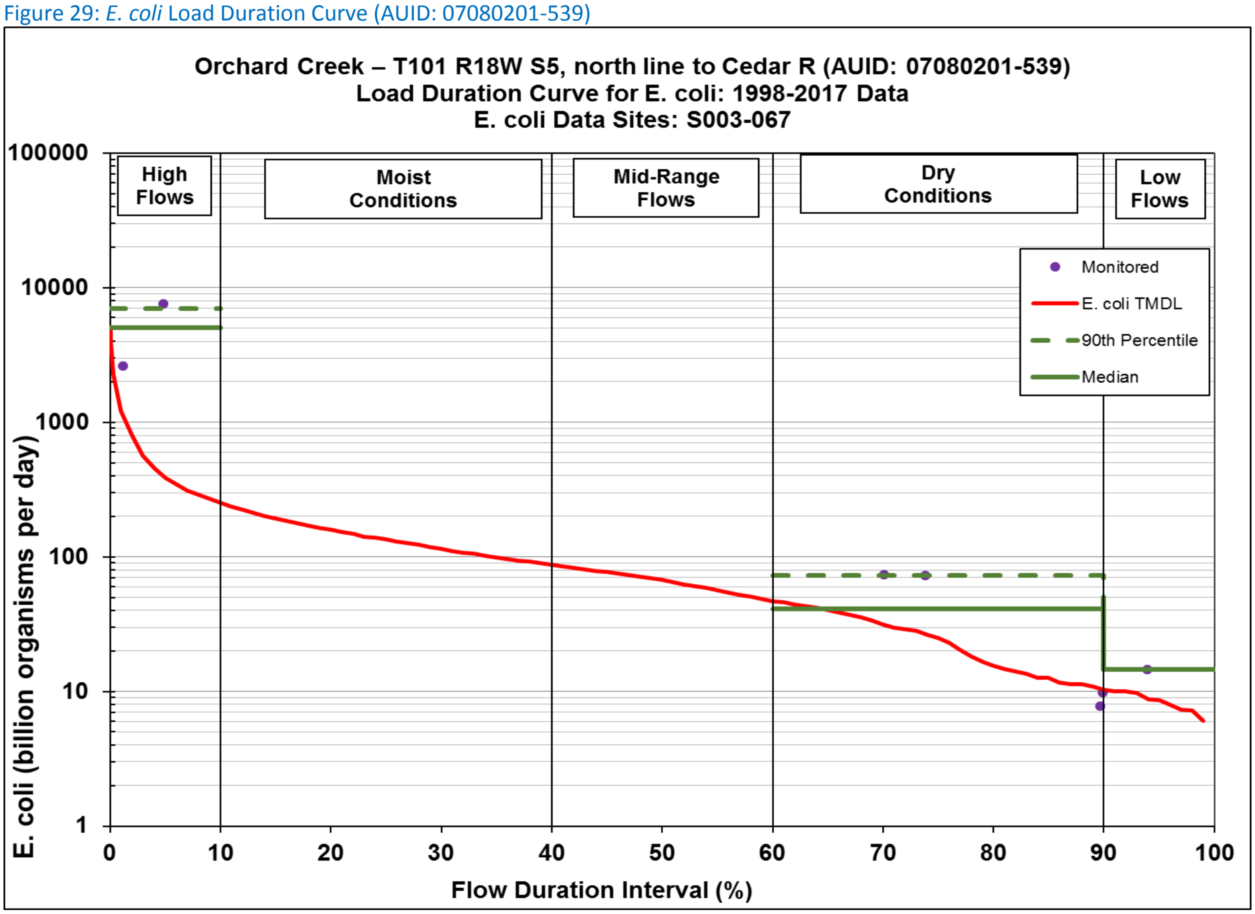
Table 43 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 43: Bacteria loading capacities and allocations (AUID: 07080201-539)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	385.22	134.98	67.76	24.79	8.67
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Communities Subject to MS4 NPDES Requirements	7.63	2.67	1.34	0.49	0.17
Load Allocation	339.07	118.81	59.64	21.82	7.64
Margin of Safety	38.52	13.50	6.78	2.48	0.87
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Communities Subject to MS4 NPDES Requirements	2.0%	2.0%	2.0%	2.0%	2.0%
Load Allocation	88%	88%	88%	88%	88%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 29) for the available dataset indicates exceedance of the target under low and high flow conditions. Only seven samples were collected, none of which were between the 70% flow exceedance and the 5% flow exceedance.

Figure 29: *E. coli* Load Duration Curve (AUID: 07080201-539)



4.3.9 Woodbury Creek: Headwaters to Cedar R (AUID: 07080201-526)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach.

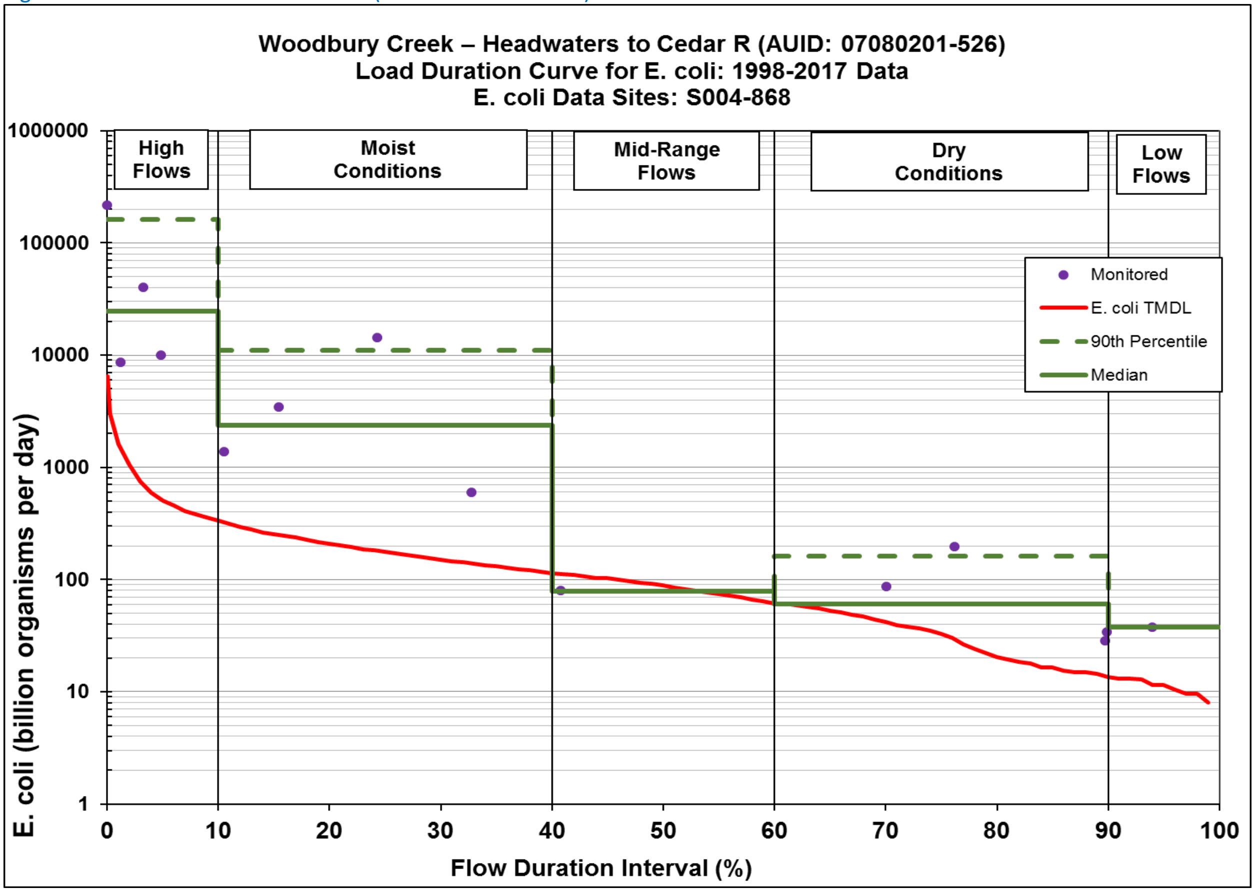
Table 44 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 44: Bacteria loading capacities and allocations (AUID: 07080201-526)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	507.57	177.85	89.28	32.66	11.43
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Communities Subject to MS4 NPDES Requirements	0.00	0.00	0.00	0.00	0.00
Load Allocation	456.81	160.07	80.35	29.40	10.29
Margin of Safety	50.76	17.79	8.93	3.27	1.14
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Communities Subject to MS4 NPDES Requirements	0.0%	0.0%	0.0%	0.0%	0.0%
Load Allocation	90%	90%	90%	90%	90%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 30) for the available dataset indicates exceedance of the target throughout all flow conditions except mid-range flows, where only one sample was collected.

Figure 30: *E. coli* Load Duration Curve (AUID: 07080201-526)



4.3.10 Otter Creek: Headwaters to MN/IA Border (AUID: 07080201-517)

Table 45 shows the WWTF within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach. This TMDL utilizes the permitted daily loading rates for this facility as the WLA.

Table 46 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 45: Wastewater treatment facilities and associated bacteria WLAs (AUID: 07080201-517)

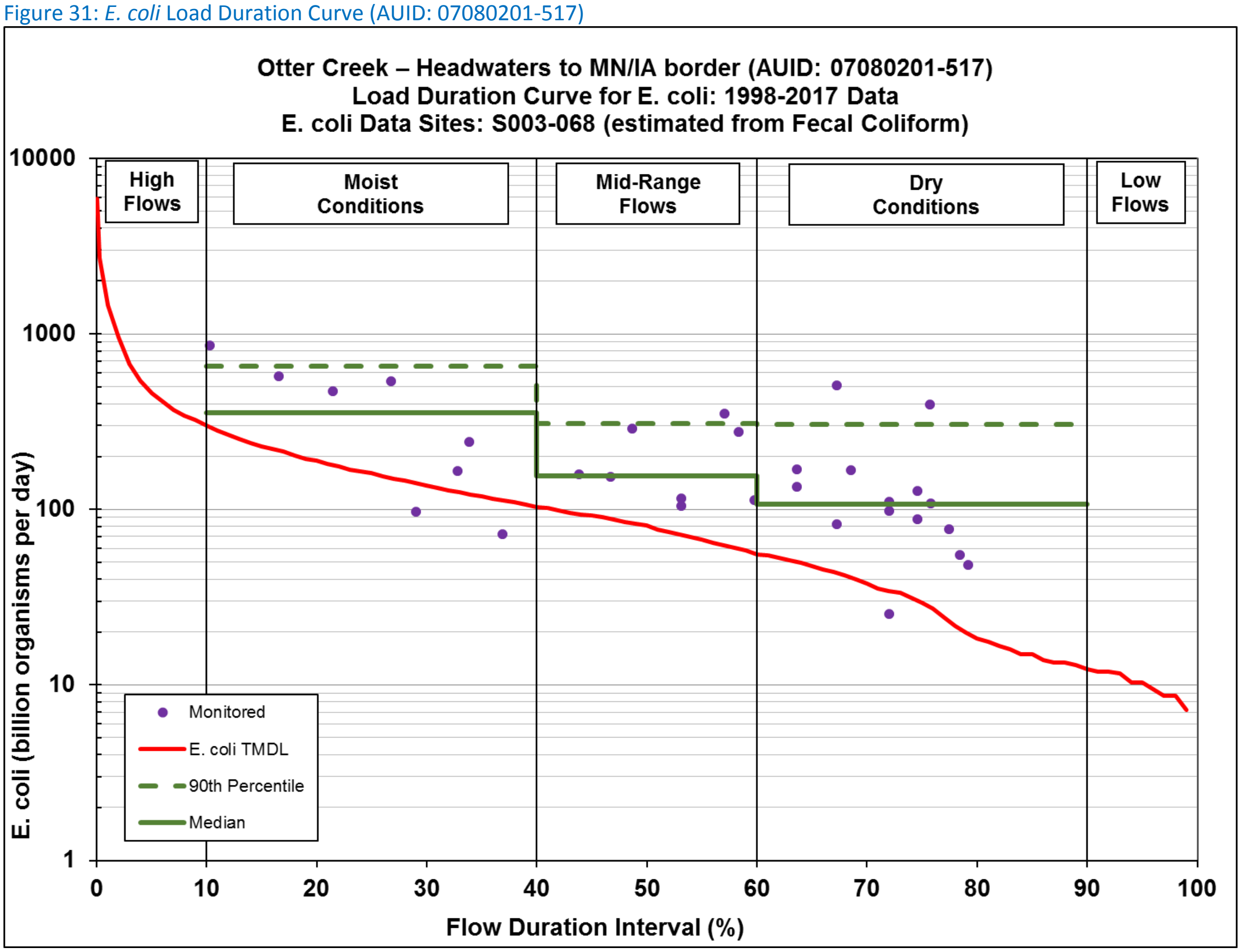
Facility	NPDES Permit #	Discharge, mgd	WLA (Billion organisms/day)
Lyle WWTP	MN0022101	1.579	7.53

Table 46: Bacteria loading capacities and allocations (AUID: 07080201-517)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	458.44	160.64	80.64	29.50	10.32
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	7.53	7.53	7.53	7.53	7.53
Communities Subject to MS4 NPDES Requirements	0.00	0.00	0.00	0.00	0.00
Load Allocation	405.07	137.04	65.04	19.02	1.76
Margin of Safety	45.84	16.06	8.06	2.95	1.03
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	2%	5%	9%	26%	73%
Communities Subject to MS4 NPDES Requirements	0.0%	0.0%	0.0%	0.0%	0.0%
Load Allocation	88%	85%	81%	64%	17%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 31) for the available dataset indicates exceedance of the target throughout all flow conditions except high and low flows, where no data was collected.

Figure 31: *E. coli* Load Duration Curve (AUID: 07080201-517)



4.3.11 Little Cedar River: Headwaters to MN/IA Border (AUID: 07080201-518)

Table 47 shows the WWTF within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach. This TMDL utilizes the permitted daily loading rates for this facility as the WLA.

Table 48 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs and MOS.

Table 47: Wastewater treatment facilities and associated bacteria WLAs (AUID: 07080201-518)

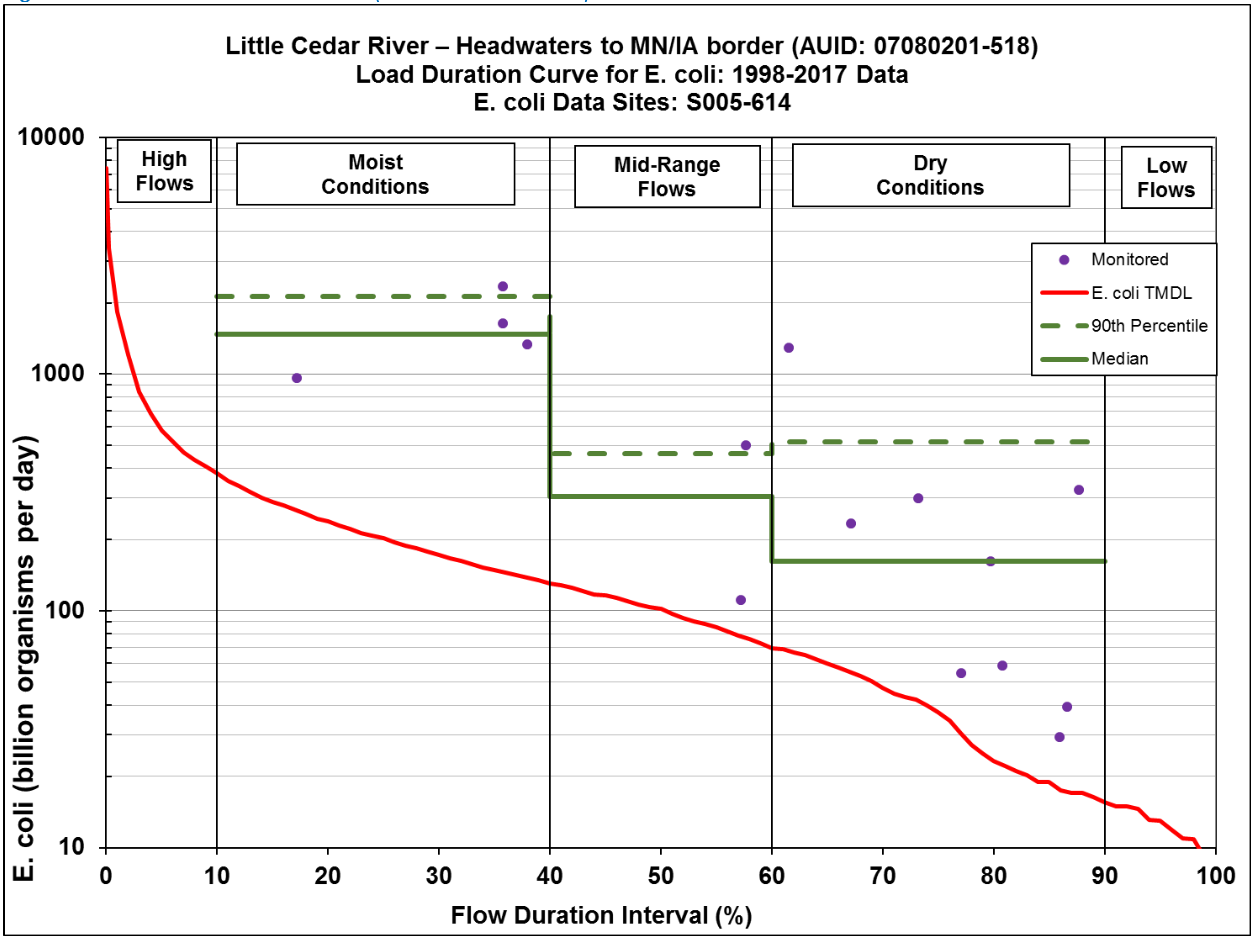
Facility	NPDES Permit #	Discharge, mgd	WLA (Billion organisms/day)
Adams WWTP	MN0021261	0.278	1.33

Table 48: Bacteria loading capacities and allocations (AUID: 07080201-518)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	577.84	202.48	101.64	37.19	13.01
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	1.33	1.33	1.33	1.33	1.33
Communities Subject to MS4 NPDES Requirements	0.00	0.00	0.00	0.00	0.00
Load Allocation	518.73	180.90	90.15	32.14	10.38
Margin of Safety	57.78	20.25	10.16	3.72	1.30
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	1%	1%	4%	10%
Communities Subject to MS4 NPDES Requirements	0.0%	0.0%	0.0%	0.0%	0.0%
Load Allocation	90%	89%	89%	86%	80%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 32) for the available dataset indicates exceedance of the target throughout all flow conditions except high and low flows, where no data was collected. All 15 samples exceeded the water quality target.

Figure 32: *E. coli* Load Duration Curve (AUID: 07080201-518)



4.3.12 Cedar River: Dobbins Cr to Turtle Cr (AUID: 07080201-514)

Table 49 shows the WWTFs and other dischargers that drain to this listed reach. There are 6.6 square miles of the city of Austin, which is subject to stormwater MS4 NPDES Permit requirements, draining to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the respective WLAs.

Table 49: Wastewater treatment facilities and associated bacteria WLAs (AUID: 07080201-514)

Facility	NPDES Permit #	Discharge, mgd	WLA (Billion organisms/day)
Austin WWTP	MN0022683	8.475	40.42
Blooming Prairie WWTP	MN0021822	0.899	4.29
Brownsdale WWTP	MN0022934	1.374	6.55
Lansing Township WWTP	MN0063461	0.205	0.98
Sargeant WWTP	MNG580214	0.082	0.39
Waltham WWTP	MN0025186	0.139	0.66

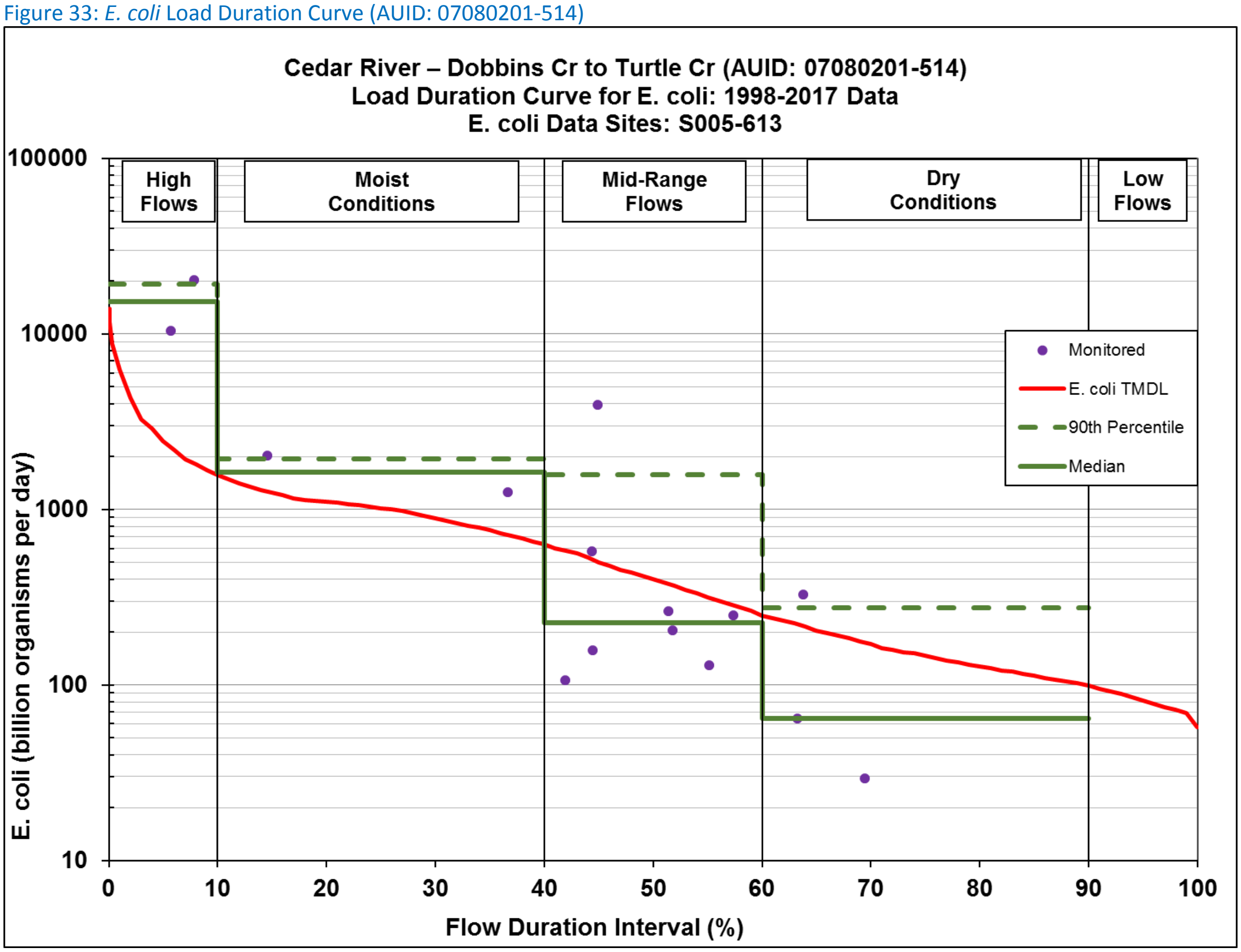
Table 50 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 50: Bacteria loading capacities and allocations (AUID: 07080201-514)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	2464.80	1015.69	401.38	147.36	81.03
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	53.29	53.29	53.29	53.29	53.29
Communities Subject to MS4 NPDES Requirements	58.47	23.25	8.32	2.14	0.53
Load Allocation	2106.55	837.58	299.63	77.19	19.10
Margin of Safety	246.48	101.57	40.14	14.74	8.10
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	2.2%	5.2%	13.3%	36.2%	65.8%
Communities Subject to MS4 NPDES Requirements	2.4%	2.3%	2.1%	1.5%	0.7%
Load Allocation	85.5%	82.5%	74.7%	52.4%	23.6%
Margin of Safety	10.0%	10.0%	10.0%	10.0%	10.0%

The LDC (Figure 33) for the available dataset indicates exceedance of the target under all flow conditions, except low flow, where no samples have been collected.

Figure 33: *E. coli* Load Duration Curve (AUID: 07080201-514)



4.3.13 Wolf Creek: Headwaters to Cedar R (AUID: 07080201-510)

There are no WWTFs or permitted discharges within the land area that drains to this listed reach. There are 0.9 square miles in the city of Austin, which is subject to Stormwater MS4 NPDES Permit requirements, draining to this listed reach. This TMDL utilizes the permitted daily loading rates for this permit as the WLA.

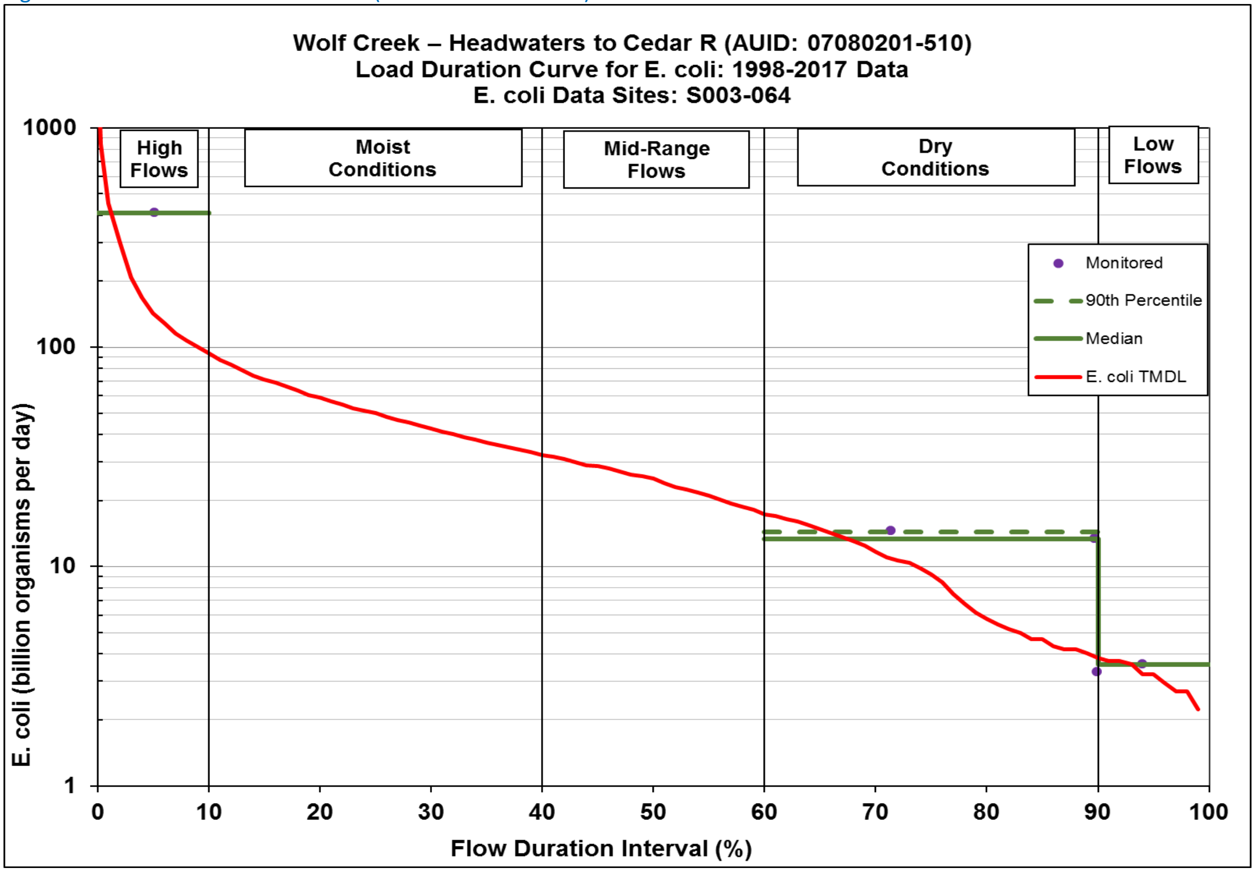
Table 51 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 51: Bacteria loading capacities and allocations (AUID: 07080201-510)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	142.75	50.02	25.11	9.19	3.21
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Communities Subject to MS4 NPDES Requirements	9.84	3.45	1.73	0.63	0.22
Load Allocation	118.64	41.57	20.87	7.63	2.67
Margin of Safety	14.27	5.00	2.51	0.92	0.32
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	0%	0%	0%	0%	0%
Communities Subject to MS4 NPDES Requirements	6.9%	6.9%	6.9%	6.9%	6.9%
Load Allocation	83%	83%	83%	83%	83%
Margin of Safety	10%	10%	10%	10%	10%

As shown in the LDC (Figure 34) for Wolf Creek, only five bacteria samples were collected in this reach. No samples were collected between the 70% flow exceedance and the 5% flow exceedance. Sample bacteria loads were higher than the target in the flow regimes monitored.

Figure 34: *E. coli* Load Duration Curve (AUID: 07080201-510)



4.3.14 Roberts Creek: Unnamed Cr to Cedar R (AUID: 07080201-504)

Table 52 shows the WWTFs within the land area that drains to this listed reach. There are no areas subject to Stormwater MS4 NPDES Permit requirements that drain to this listed reach. This TMDL utilizes the permitted daily loading rates for these facilities as the WLA.

Table 53 provides the average *E. coli* loading capacities for this reach to meet the water quality standard, as well as the component WLAs, LAs, and MOS.

Table 52: Wastewater treatment facilities and associated bacteria WLAs (AUID: 07080201-504)

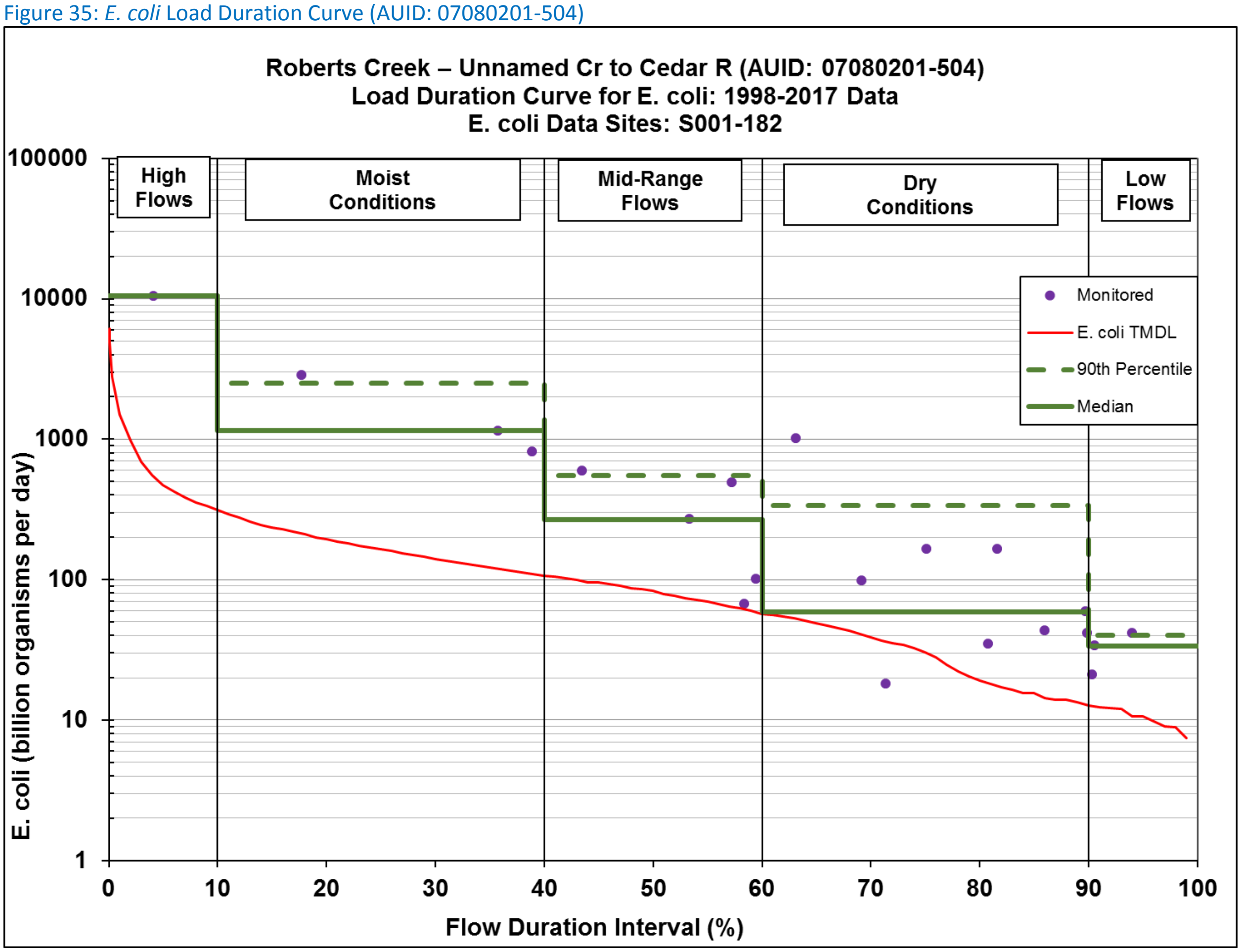
Facility	NPDES Permit #	Discharge, mgd	WLA (Billion organisms/day)
Brownsdale WWTP	MN0022934	1.374	6.55
Sargeant WWTP	MNG580214	0.082	0.39

Table 53: Bacteria loading capacities and allocations (AUID: 07080201-504)

	Flow Zone				
	Very High	High	Mid	Low	Very Low
	Billion Organisms/day				
TOTAL DAILY LOADING CAPACITY	472.74	165.65	83.16	30.42	10.65
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	6.94	6.94	6.94	6.94	6.94
Communities Subject to MS4 NPDES Requirements	0.00	0.00	0.00	0.00	0.00
Load Allocation	418.52	142.14	67.90	20.44	2.64
Margin of Safety	47.27	16.56	8.32	3.04	1.06
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	1%	4%	8%	23%	65%
Communities Subject to MS4 NPDES Requirements	0.0%	0.0%	0.0%	0.0%	0.0%
Load Allocation	89%	86%	82%	67%	25%
Margin of Safety	10%	10%	10%	10%	10%

The LDC (Figure 35) for the available dataset indicates exceedance of the target throughout all flow conditions.

Figure 35: *E. coli* Load Duration Curve (AUID: 07080201-504)



4.3.15 Overall Conclusions from Bacteria-Related Monitoring and TMDL Allocations

Some of the conclusions that can be drawn from the project monitoring experience, data and assessments discussed in the previous subsections are as follows:

- The 14 bacteria impairments in the watershed are significant when assessed across the various flow conditions. A significant portion of the wet-weather and dry-weather concentrations are above the standard at almost all of the monitoring sites; however, some site differences do exist where mid-range flows are meeting the criteria.
- Where sufficient data is available, it appears that the existing bacteria load exceeds the target under all flow conditions.
- Eighty-six percent, or 46 river miles, of the Cedar River in Minnesota are impaired by bacteria. This includes the three stream reaches included in this report, and the two included in the 2006 Regional TMDL Evaluation of fecal coliform bacteria impairments in the Lower Mississippi River Basin Report.
- The stream reaches that show bacteria exceedances across all flow zones include the upper Cedar River, Roberts Creek, and Woodbury Creek.
- There are an additional six stream segments, which also show exceedances to the monthly geometric mean WQS, for the summer months of June, July and August, when recreational usage is higher. These streams are Turtle Creek, Rose Creek, the Little Cedar River, Upper Dobbins Creek, Otter Creek, and Orchard Creek.
- The three mainstem Cedar River reaches have median bacterial loads above the TMDL bacterial load standard under very high, high and low flow zones. There are no medians exceeding the TMDL bacterial load standard under mid flows and very low flows. This suggests either a runoff-associated source, or re-introduction of bacteria into the water column when stream flows increase and water velocities create more turbulence in the channel
- Under moderate flows, the minimum LA percentage is 75%. As stream flows increase in the Cedar River, this increases to 85% or more.
- Except for the very low flow zone in the Cedar River’s 1.9 mile reach in the south district of Austin (AUID 514, which includes the city’s WWTP discharge), the nonpoint bacterial load is always 50% or more, for the entire Cedar River in Minnesota.
- The highest WLA in the Cedar River is 66% of the loading capacity in AUID-514 under very low stream flows, and this is the result of Austin’s WWTP permitted discharge.
- The 11 tributary stream reaches have median bacterial loads above the TMDL bacterial load standard under all flow regimes, with a higher tendency at low flows. Of all the tributaries, Roberts Creek and Woodbury Creek display higher median values, across more flow zones, than the other nine tributary streams.
- Primary sources contributing bacteria within this watershed can include animal agriculture sources such as feedlots and runoff from manure applications, or overgrazed pasture in close

proximity to surface waters. Other sources include stormwater runoff, failing septic systems, and the persistence and reproduction of bacteria in streams and in algal mats. Depending on the flow conditions and land use/land management conditions present in the various subwatershed areas, each one of these primary sources may be contributing significant amounts of bacteria at localized scales.

4.4 TMDL Summary - Allocations for Geneva Lake

Geneva Lake is near the headwaters of the Turtle Creek Subwatershed in the northwest corner of the CRW. Geneva Lake has an upgradient catchment of over 7,000 acres, which is drained by Freeborn County Ditch Number 8. There is also a local watershed catchment of 4,500 acres, which is principally drained by two intermittent streams which discharge to the west side of the upper bay of the lake, and an intermittent stream/ditch which discharges to a reclaimed pond on the northeast corner of the upper bay of the lake. The pond is separated from Geneva Lake by the roadbed of Freeborn County State Aid Highway 26. A culvert near the north end of the pond provides a hydraulic connection to the lake. The reclaimed pond does not completely mix with the lake, which violates an assumption of the Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) model. Therefore, the area of the pond is not included as part of the modeled lake surface area. Table 4 provides other basic lake water quality parameters and statistics for Geneva Lake from 2002 through 2016. The southern Minnesota shallow lakes water quality standard for TP is 90 ug/L.

Nutrient-enriched shallow lakes tend to exist in one of two alternate ecological states, turbid or clear water (Scheffer 2004). In the turbid, algae dominated state submersed macrophytes, wildlife uses and diversity are limited, and the fish community is dominated by a few species of tolerant omnivores and benthivores. The alternative state is characterized by much greater Secchi transparencies, submersed macrophytes are common throughout the littoral zone, and fish biomass is either low or more evenly distributed across trophic levels. In a clear water state Geneva Lake is used by a much greater abundance and diversity of wildlife species. Excess nutrients and rough fishes, especially common carp, act to push Geneva Lake toward a turbid condition with low Secchi transparencies.

Geneva Lake is the only surviving natural lake in the CRW, and has unique rare and natural features of high biological significance. There are native plant communities that help support waterfowl, other waterbirds, and other wildlife including rare species and species of greatest conservation need (DNR 2017). There is a public water access on the southwest side of the main basin, which is operated by the DNR’s Parks and Trails Division. Freeborn County owns the dam at the outlet of the lake. This dam allows for water level manipulations for lake management. The normal runout is 1,210.5 feet and ordinary high water elevation is at 1,211.1 feet, and pool elevations fluctuate several feet above and below that elevation (Figure 36).

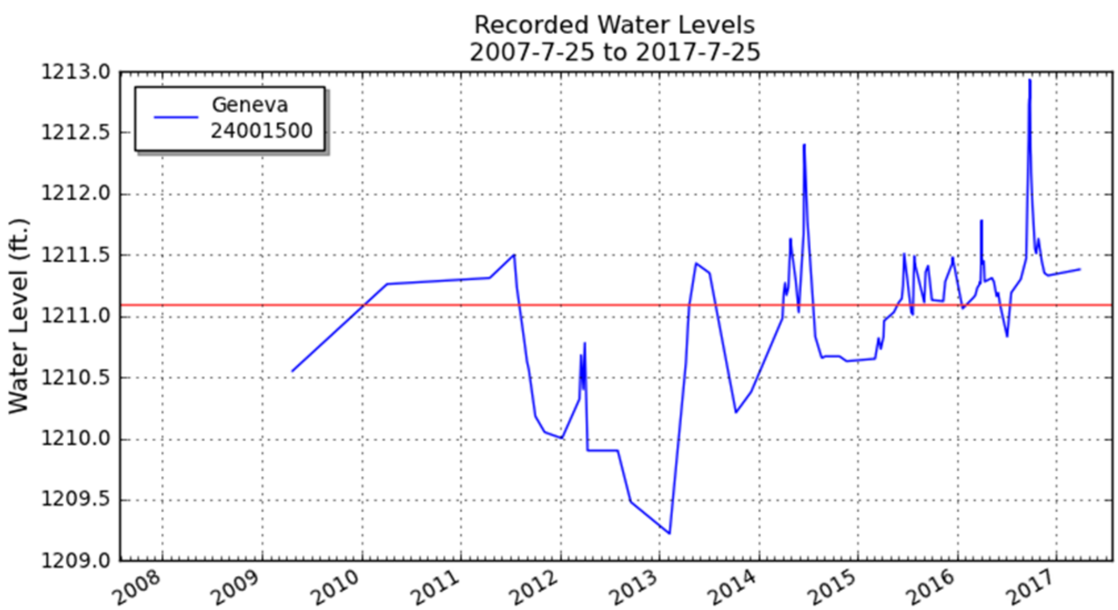
The lake has been formally designated by the DNR for its primary wildlife use and benefit under the authority of Minn. Stat. 97A.101, subd. 2. Once so designated, the DNR Wildlife Division may be permitted to temporarily lower lake levels periodically to improve wildlife habitat. The Geneva dam has stop logs that can be removed to manipulate water levels as provided by the lake’s management plan (Idstrom and Vorland 2002), agreement with Freeborn County and the operating permit. Historically, the lake has been dominated by common carp and/or black bullhead and other tolerant species. More recently, there have been stockings of northern pike and yellow perch in 2007, 2008, 2009, and 2014, to increase the populations of piscivorous fishes following biomanipulations and/or winterkills that severely reduced rough fish populations. The DNR uses temporary water level drawdowns to limit rough fish abundance and provide better growing conditions for aquatic vegetation. After a kill event, rough fish biomass is expected to increase and have noticeable deleterious effects in the lake over about three to five year period.

In 2006 and 2007, the lake was subjected to a major artificial draw down to replace the dam, to regenerate aquatic vegetation and to reduce rough fish abundance. In early July of 2007, the lake level was 2.8 feet below the normal runout. A fish toxicant (rotenone) was applied under ice in early 2008 to kill more rough fishes. Water levels were fully restored by precipitation and snowmelt that spring. In 2014, a minor winter drawdown was conducted to encourage winter hypoxia to reduce rough fishes (DNR 2017).

Aquatic plants are a critical part of the overall Geneva Lake water quality condition, and will need to be more fully incorporated into the standard lake water quality criteria and standards, in the coming years.

The upper subwatersheds that drain to Geneva Lake are critical zones for reducing runoff and phosphorus export. Cooperative conservation implementation projects in the JD-8 public drainage system was making progress to address these needs. This project is led by the Freeborn Soil and Water Conservation District (SWCD) and involvement from the Freeborn County drainage authority, and the Turtle Creek Watershed District. Numerous other voluntary conservation efforts are implemented on farmlands including reduced tillage, cover crops, permanently vegetated buffers, wetland restorations with some additional shoreland protections.

Figure 36: Geneva Lake Recorded Water Levels (DNR)



In July of 2012, both the south and north basins of Geneva Lake were sampled and monitored as part of the statewide wild rice project, and to address issues with the sulfate water quality standard. There was historical information that Geneva Lake did have wild rice, but that it did not persist. The 2012 survey results confirmed that no wild rice is currently present. This research-level work collected data on water, pore water and sediment parameters. Significantly high levels of sulfide were found in the pore water from both basins, as sulfide converts from sulfate when conditions include high organic matter and low iron levels. Further information and data can be obtained from the MPCA.

A Hydrologic Simulation Program-Fortran (HSPF) watershed simulation model was developed for the entire CRW, including two subwatersheds that drain to Geneva Lake (RESPEC 2014). HSPF Reach 351 is drained by Freeborn County Ditch 8, which discharges to the west side of the upper bay of the lake. HSPF Reach 352 includes the immediate watershed surrounding Geneva Lake. Modeled data on the annual average water, sediment, and nutrient loads and yields for the period of 1996 through 2012 are displayed in Table 54.

Table 54: HSPF Modeled Outputs for Reaches Which Discharge to Geneva Lake

HSPF Output	Reach 351	Reach 352
Area (acres)	7,043	4,581
Precipitation (inches)	33.1	33.1
Runoff (inches/yr)	10.6	10.2
Runoff (acre-feet/yr)	6,209	3,881
Total Phosphorus Load (lbs/yr)	1,764	1,127
Total Phosphorus Yield (lbs/ac./yr)	0.25	0.25
Total suspended solids Load (tons/yr)	783	497
Total suspended solids Yield, (tons/ac./yr)	0.11	0.11
Total Nitrogen Load (lbs/yr)	161,287	100,622
Total Nitrogen Yield (lbs/ac./yr)	23	22

To determine the loading capacity of Geneva Lake for TP, the MINLEAP model was used (Wilson and Walker 1989). This model is set up on the ecoregion scale, and provides reasonable estimates for water and nutrient budgets, and phosphorus loadings. It employs the Canfield and Bachman (1981) sedimentation model, and uses data from a set of ecoregion reference lakes. It is noted that the polymictic conditions present in many shallow southern Minnesota lakes are difficult to model, and the MINLEAP procedure does not explicitly account for internal loading from the sediments and from rough fish populations.

The input and calibration data used for Geneva Lake MINLEAP model are given in Table 55.

Table 55: MINLEAP Modeling for Geneva Lake—Input and Calibration Factors

Parameter	Value	Source
Upland Runoff TP concentration, µg/L	112	HSPF upland load to reach from Subwatersheds 351 and 352
Upland watershed area, acres	11,624	HSPF output
Geneva Lake area, acres	1,928	GIS area of subwatersheds 351 & 352 minus HSPF upland area
Runoff, mean annual, m/yr	0.27	HSPF, area–weighted of subs 351 & 352
Precipitation, mean annual, m/yr	0.88	Minnesota State Climatological Office
Lake Evaporation, m	0.81	Based upon calculations in Dadaser–Celik & Stephan 2008; Hydrology Guide for Minnesota
Mean Depth, m	1.1	Monitored average
In–Lake TP Concentration, µg/L	99	Monitored average
Secchi Disk Transparency Depth, m	0.6	Monitored average
Alkalinity, mg/L	143	Monitored average
Atmospheric TP Load, $kg/km^2/yr$	46.9	P Study 2007 update [Twaroski et al 2007]
Chlorophyll a, µg/L	38	Monitored average

The upland HSPF–predicted TP loads to Lake Geneva resulted in a predicted in–lake TP concentration of 61 µg TP/L, which is well below the monitored seasonal average TP concentration of 99 µg/L. Therefore, the Calibration module in MINLEAP was used to determine an inflow TP concentration that corresponds to the monitored seasonal average in–lake TP concentration of 99 µg/L. The resulting load was used as the existing conditions for calculation of the seasonal TP required reduction.

In turn, the model was used to determine the TP TMDL by using the Calibration tool to determine the seasonal inflow TP concentration that results in a predicted in–lake TP concentration of 90 µg/L – the target concentration.

The MINLEAP modeling output results are presented in Table 56. The TMDL scenario provides compliance with the southern Minnesota shallow lake TP water quality standard of 90 ug/L. In addition to meeting phosphorus limits, Chl-*a* and Secchi transparency standards must be met. 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 phosphorus target in each lake, the Chl-*a* and Secchi standards will likewise be met.

Table 56: MINLEAP Output for Current Conditions and TMDL Scenario.

	Existing Conditions	TMDL
Calibrated Inflow TP, µg/L	245	210
Predicted In–Lake TP, ug/L	99	90
Residence Time, yr	0.6	0.6
Predicted TP Load, kg/yr	8,594	7,495
Predicted TP Inflow, µg/L	263	229

The TP TMDL allocations for Geneva Lake are presented in Table 57. Based upon the MINLEAP predicted TP load to achieve the water quality standard of 90 µg/L, the TMDL for Geneva Lake is 20.5 kg TP/day, or 45.2 lbs TP/day. The required reduction in TP load to the lake (internal lake sediment load and watershed load) is 3.01 kg TP/day, or 6.63 lbs TP/day – a 12.8 % reduction.

Table 57: Geneva Lake Total Phosphorus Loading Capacity and Allocations

Allocation	Seasonal TP, lbs/day
TMDL	45.2
Margin of Safety	4.52
Atmospheric Load	2.30
Construction and Industrial Stormwater	0.0192
Loading Allocation (internal and external)	38.4

4.5 Future Growth and Wastewater Reserve Capacity

4.5.1 Non-Stormwater Wasteload Allocations for TSS and Bacteria

As a result of population changes and contributions from industrial wastewater discharges, flows at some WWTFs are likely to increase over time. This is not likely to have a negative impact on any of the impaired reaches because permits authorizing the vast majority of wastewater flow in the watershed contain calendar month average TSS effluent limits at concentrations that are below the water quality criterion set for each of the impaired reaches. Therefore, increased flows from most WWTFs add to the overall loading capacity by increasing river flows.

As demonstrated by the environmental consultant Tetratech (Cleland 2011), discharges from these facilities provide assimilative capacity beyond that which is required to offset their respective TSS loads. Although facilities are discharging below the in-stream targets, they are still discharging the pollutant of concern, and therefore individual WLAs are required.

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

Individual WLAs for permits that contain calendar month average TSS effluent limits in excess of the water quality criterion include 50% more than the authorized discharge load to accommodate future growth.

4.5.2 New or Expanding Wastewater

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 2012). 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.

4.6 Permitted Stormwater Sources

4.6.1 Construction Stormwater

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

4.6.2 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 & 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. All local stormwater management requirements must also be met.

4.6.3 MS4

The MPCA oversees all regulated MS4 entities in stormwater management accounting activities. The city of Austin MS4 falls under the category of Phase II. The MS4 NPDES/SDS Permits require regulated municipalities to implement BMPs to reduce pollutants in stormwater runoff to the maximum extent practicable.

All owners or operators of regulated MS4s (also referred to as "permittees") are required to satisfy the requirements of the MS4 General Permit. The MS4 General Permit requires the permittee to develop a Stormwater Pollution Prevention Program (SWPPP) that addresses all permit requirements, including the following six minimum control measures:

- Public education and outreach
- Public participation
- Illicit Discharge Detection and Elimination (IDDE) Program
- Construction-site runoff controls
- Post-construction runoff controls
- Pollution prevention and municipal good housekeeping measures

A SWPPP is a management plan that describes the MS4 permittee's activities for managing stormwater within their jurisdiction or regulated area. In the event a TMDL study has been completed, approved by the EPA prior to the effective date of the general permit, and assigns a WLA to an MS4 permittee, that permittee must document the WLA in their future NPDES/SDS permit application, and provide an outline of the BMPs to be implemented in the current permit term to address any needed reduction in loading from the MS4.

The MPCA requires applicants submit their application materials and SWPPP document to the MPCA for review. Prior to extension of coverage under the general permit, all application materials are placed on 30-day public notice by the MPCA, to ensure adequate opportunity for the public to comment on each permittee's stormwater management program. Upon extension of coverage by the MPCA, the permittees are to implement the activities described within their SWPPP, and submit annual reports to the MPCA by June 30 of each year. These reports document the implementation activities, which have been completed within the previous year, analyze implementation activities already installed, and outline any changes within the SWPPP from the previous year. For information on all requirements for SWPPPs and annual reporting, see the Minnesota Stormwater Manual.

4.6.4 New or Expanding Permitted MS4 WLA Transfer Process

Future transfer of watershed runoff loads in this TMDL 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 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 (i.e., loads will be transferred on a simple land-area basis). 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. Monitoring

Watershed Approach Framework

Future monitoring in the CRW will be according to the Watershed Approach Framework. The IWM strategy utilizes a nested watershed design allowing the aggregation of watersheds from coarse to fine scale. The foundation of this comprehensive approach is the 80 major watersheds within Minnesota. Streams are segmented by HUC. Sampling occurs in each major watershed once every 10 years (MPCA 2012). The goals of follow-up monitoring are generally to both evaluate progress toward the water quality targets provided in the TMDL and to inform and guide implementation activities. More specific monitoring plan(s) will be developed as part of the Cycle 2, IWM, and specific implementation efforts. Monitoring of both streams and Geneva Lake will be accomplished. Monitoring will be repeated on some of the assessment units noted in this document (see Table 1); this will provide trend information at intervals. The impaired waterbodies will remain listed until criteria for de-listing are met.

Watershed Pollutant Load Monitoring Network

In addition to the Watershed Approach based monitoring, the MPCA and its partners will also conduct sampling through their Watershed Pollutant Load Monitoring Program (WPLMN). The WPLMN is designed to obtain spatial and temporal pollutant load information from Minnesota's rivers and streams and track water quality trends. In the CRW, the sites included are Turtle Creek (AUID 07080201-540; water chemistry site S004-432, and flow monitoring site 48027001) and the Cedar River (AUID 07080201-515; water chemistry site S000-001, and flow monitoring site 05457000). More detail is available on the WPLMN.

Specialized/Local Monitoring

Ongoing stream monitoring conducted by the Mower SWCD/Cedar River WD includes eight sites on the upper and lower reaches of the Cedar River, Dobbins Creek, Rose Creek, and tributaries at Lansing and near Blooming Prairie. Monitoring will primarily be conducted by local staff (Mower SWCD, Cedar River WD, city of Austin), and State of Minnesota personnel. Funding will likely come from both state and local sources. The Dobbins Creek Targeted Watershed Project in conjunction with the Effectiveness of Targeted Dobbins Creek BMP Project will provide a smaller scaled effort for conservation implementation and water monitoring.

There are also two long-term biological monitoring sites in the CRW, Roberts Creek (09CD013) and Woodbury Creek (09CD028). Both of these sites have more frequent biological monitoring by the MPCA staff, which over time can help assess variability and trends.

Focused Monitoring and Research Needs

In addition to monitoring for both assessment and effectiveness purposes, there are research needs to better understand pollutant loads and dynamics in the CRW. Streamflow monitoring, groundwater level monitoring, and/or aquifer tests in certain areas may further form the basis for protection strategies for higher priority surface waters, as well as help inform wellhead protection efforts.

Specific to bacterial/aquatic recreation impairments, the *Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota*

(MPCA 2006) includes a monitoring section that describes activities and responsibilities pertaining to the greater regional examination of pathogens in surface water. Cedar River AUIDs – 502 and -501, which are a 5-mile reach above Austin, and a 10-mile reach below Austin, respectively, are included in that earlier TMDL, and are still covered by that document. Important research needs related to pathogens, from the 2006 TMDL, and which remain relevant to the 14 new impairments covered in this TMDL, are:

- Study of sources of pathogens in cities and urban areas;
- Better understanding of load reduction capabilities for applicable structural and non-structural BMPs;
- Models to evaluate loading sources and track load reductions;
- Methods to evaluate pollutant migration pathways and delivery mechanisms from pathogen sources to surface waters, both in general, as well as in landscapes with karst. This also involves DNA "fingerprinting" to identify pathogen sources.

These needs should be evaluated and tailored to the CRW.

Sediment pollution is significant in the CRW. Seventeen of the eighteen reaches evaluated in the SID document have a conclusive stressor for "habitat and bedded sediment" (some of these reaches are included in this study, while the rest are listed in Appendix I). Since bedded sediment conditions are driven by the coarser particles (i.e. the SSC sand fractions), it is recommended that some SSC monitoring should be integrated with future TSS monitoring and evaluation. In addition, monitoring and research should evaluate the sources of these heavier particles, as well as transport factors, links to stream geomorphology, watershed modeling and GIS terrain analysis. Stream channel stabilization is more fully addressed in the CRW WRAPS. Selected sites should be monitored to determine the rate of erosion. This can be accomplished by establishing benchmarks and performing high-definition laser scanning of the erosion sites, or by using traditional survey methods (see Appendix B). Surveys should be repeated at some appropriate frequency, and following severe runoff events. Monitoring the sites over a period of years will provide a better picture of which erosion sites are most active. A more detailed investigation of local runoff to gullies and ravines should be performed to determine if upland BMPs could be implemented to reduce the rate of runoff and likelihood of erosion in the ravines.

Three stream reaches in the Cedar River Watershed (CRW) had conclusive low DO and elevated TP stressors. These reaches are the Upper Cedar River (AUID – 503), the Lower Cedar River (AUID – 515) and the Lower Turtle Creek (AUID – 540). River eutrophication assessments were conducted on these reaches. Further monitoring and assessment of these reaches is recommended, including measured or predicted nutrient loading changes from point and non-point sources. Of these three reaches, several factors point toward the Lower Cedar River (AUID – 515) as an important priority, including the convergence of important tributaries, the ongoing monitoring site (flow, chemistry), and the effects of the city of Austin's WWTP discharge.

Land Use/Land Management Assessments

Monitoring will also include the compilation and assessment of available land use and land management statistics for the counties, cities, and watersheds. Some of these statistics are available from the USDA, and the State of Minnesota (Minnesota Department of Agriculture (MDA) and Board of Soil and Water Resources). For example, new data on crop residues will be available soon, and the extent of cover cropping and BMP installation can be utilized. Stormwater management activities by the city of Austin will also be assessed. Finally, it is expected that there will be an ongoing need for monitoring at various scales following BMP implementation or other changes to land management that can be used to calibrate/validate watershed and/or specific stream water quality models.

6. Implementation Strategy Summary

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

Permitted Point Sources

WWTF will be addressed through NPDES Permit programs within the MPCA. Section 4.6 covers construction stormwater, industrial stormwater and MS4 areas. In the city of Austin MS4 the city manages a stormwater utility, with fees being applied to management practices to reduce flows and pollutant loads, detention basin projects, public information and education. More information on stormwater and erosion control actions in the Austin MS4 are at http://www.ci.austin.mn.us/public-works/storm-water.

Section 4.6 covers NPDES point sources including municipal and industrial discharges.

6.1 Nonpoint Sources

Topographic, hydrologic, and agronomic factors are critical to understanding nonpoint source pollution. As a result, identifying these features and targeting the areas of highest priority for treatment of nonpoint source pollution that are more detrimental than others is important. The prioritized, targeted and measured (PTM) aspect of Minnesota's Watershed Approach is used to address this (BWSR 2016). The companion report to this TMDL, the CRW WRAPS, provides direction and guidance for targeting and prioritizing at the HUC 11 scale.

The response of the lakes and streams will be evaluated as management practices are implemented. The management approach to achieving the goals should be adapted as new information is collected and evaluated. This list of implementation elements and the more detailed WRAPS report that is being prepared concurrently with this TMDL report focuses on adaptive management (continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL). Management activities will be changed or refined over time to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water bodies.

Streambank, ravine and gully erosion are important contributing sources to the sediment problem. It is not clear to what extent gully and bank restoration will be pursued in this watershed. Due to potential high cost, any gully and bank restoration projects should be prioritized based on magnitude of apparent contribution. Appendices C and D provide more detailed information for identifying problem and potential problem areas, and for prioritizing the potential for implementing management practices.

A reference for potential agricultural BMP implementation options is available in a matrix format and was developed by faculty of the Department of Soil, Water, and Climate of the University of Minnesota (Hatch et al. 2001). It was designed to provide options on an agroecoregion basis and is focused on phosphorus impairments, though it appears to have applicability to other runoff-driven pollutants. The Cedar River Basin is predominantly in the Level Plains, Rolling Moraine, and Undulating Plains agroecoregions (see Figure 2). The following narratives discuss these agroecoregions and provide summaries of appropriate BMPs for the range of agricultural-related water quality impacts that occur there.

Alluvium and Outwash

BMPs for phosphorus in this agroecoregion should focus primarily on nutrient management practices associated with animal agriculture, especially in ground water recharge areas and in areas close to streams and lakes. Poultry manure could be composted before being applied to land. Riparian forest and grass buffer strips are encouraged along streams and lake shorelines.

Level Plains

Practices to control soil erosion by water and sediment delivery to streams are important. These include conservation tillage, and grassed filter strips along streams. Tile intakes at the base of steep slopes should be replaced with French drains or blind inlets. Phosphorus fertilizer management is also important through P soil tests, applying fertilizer at rates recommended by the University of Minnesota, and banding or incorporation of phosphorus fertilizer.

Rolling Moraine

Control of sediment and phosphorus entering streams and lakes is a high priority. Conservation practices that leave crop residue are encouraged. Surface tile intakes at the bottom of steep slopes should be replaced with blind inlets or French drains. Direct runoff to streams and lakes should be filtered using grass or forest buffer strips. Highly erodible land should be placed in permanent grass easements. Proper management of animals and crop nutrients is important. Runoff from feedlots should be minimized, and overflow or seepage from liquid waste basins should be minimized. Livestock should be excluded from streams. Manure should be injected or incorporated, and rates of land application should be carefully controlled if soil test phosphorus (P) levels exceed 21 ppm. Phosphorus fertilizer recommendations should be based on soil test P levels and the University of Minnesota guidelines. Phosphorus fertilizer should be incorporated or banded.

Undulating Plains

Erosion control practices through conservation tillage are recommended. Steep lands can be further protected by permanent grass easements or riparian forest and grass buffer strips. Proper animal and manure management practices are important, including livestock exclusion from streams, improved pasture management, and injection of liquid manure. Application of manure to frozen soils should be limited. Phosphorus fertilizer recommendations should be based on a soil P test and University of Minnesota guidelines. Use of the Manure Application Planner is recommended.

Pasture Management

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

Implementation Summary Conclusions

The CRW WRAPS Report has further details for implementation at various scales.

The use and adaptation of agronomic, hydrologic, engineering, and ecological tools and methods will be required over the longterm, to meet and achieve water quality goals.

The consideration and management of the watershed as a whole system (Meadows et al. 2008) is a path forward.

Section 7 (Reasonable Assurance) also includes a summary of nonpoint source activities, of which many are focused on implementation. Appendix F also describes in more detail work that began in 2012 and 2013 to support watershed implementation of conservation and pollution reduction BMPs.

An increase in impervious areas in the form of roads, parking lots, buildings, and landscape changes due to a growing population could contribute additional runoff and pollutant loading to aquatic systems. The allocations for nonpoint sources are for all current *and* future sources. This means that any expansion of nonpoint sources will need to comply with the LA provided in this report. Additional nonpoint sources (e.g., shifting grassland to row cropland or urban land uses) could very well make meeting the TMDL more difficult over time. Therefore, continued efforts over time to prevent pollutant delivery to the stream systems will be critical.

Cost approximation to implement TMDL

The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL [Minn. Stat. § 2007114D.25]. The initial estimate for implementing the Cedar River Basin TMDL ranges from approximately $67 million to $112 million, over a 10-year period. To develop this estimate, data from the counties, watershed districts, SWCDs, and the city of Austin were used. Detailed information from the Cedar River Watershed Districts (CRWDs) CIP was scaled-up for the entire watershed. A similar method of "up-scaling" was used for detailed implementation data from the Targeted Watershed Demonstration project in the Dobbins Creek Subwatershed, which addresses nonpoint sources and hydrology, in a comprehensive fashion. For SSTS, 2008 through 2016 data from the counties were used, and upgrades for all IPHT and 90% of systems classified as "failing" in the watershed were estimated. Other cost estimates included the city of Austin's stormwater efforts for the TMDL, health of agricultural soils, and public engagement. All together, these estimates will be refined by future water planning initiatives and through planning and implementation by private sector entities, and local units of government.

7. Reasonable Assurance

TMDLs that have both a WLA and a LA must include reasonable assurance that the nonpoint source implementation measures will achieve the necessary load reductions. The NPDES permitted point sources may not cause or contribute to any downstream WQS violations [40 CFR 122.4(d)]. If there is limited assurance on the nonpoint source side, point sources could face more stringent effluent limits. This same federal regulation states that point source effluent limits in permits are to be consistent with the assumptions and requirements of any available WLA in an approved TMDL. The following conditions or factors are reasonable assurance that implementation will occur and result in sediment, phosphorus, and bacterial reductions in the listed waters. The broad objective is to move these waters toward meeting their designated uses via attainment of the WQS.

- The CRW WRAPS is a companion document to this TMDL and provides nonpoint source implementation strategies for each impaired water, and is organized on a HUC 11 subwatershed scale.
- Local governments are currently developing a CRW plan. This is known as a “One Watershed, One Plan” effort, and represents a significant coordination of water-related plans from the counties, the watershed districts, the SWCDs, and the city of Austin. This effort will streamline and prioritize efforts to improve land management and water quality in the entire CRW. Both the TMDL and the WRAPS are supporting documents in this process.
- Cooperative and complimentary work to reduce nonpoint source (NPS) pollution has been taking place in the CRW for a decade. This is illustrated by the combined efforts of the CRWD and the Mower SWCD, since the establishment of the CRWD 10 years ago. The combination of jurisdictional (Minn. Stat. 103D) watershed district capacity (funding, engineering assistance, etc.) and SWCD planning and delivery of conservation practices on private lands is functional and effective.
- Funding for NPS implementation is available via the State’s Clean Water Fund, and from USDA programs administered by Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA). Special project funds can also be obtained via various State of Minnesota Departments (MDA, DNR, Board of Water and Soil Resources (BWSR), MPCA), as well as from private sector sources and local units of government. For example, a solid effort is underway with direct assistance from the Hormel Foundation ($90,000) to support and promote soil health and applied cover crop research. The National Wildlife Federation has also provided a cover crop champion grant ($8,740) to Mower SWCD, to increase awareness of cover crops, through farmer-to-farmer communications.
- The most significant aspect of work on hydrology and water quality in the CRW is the CRWD’s capital improvement project (CIP). Twenty-five projects in the rural watershed areas have been identified, planned, and scheduled for implementation. On an individual site basis, the objective is to reduce peak flows from 40% to 70%. The overall objective for the Lower Cedar River, at the USGS gage, is a reduction of 8%, with a long-term target of 20% at Austin. The total cost of the two-phased CIP is estimated at $8.4 million.

- The CRWD continues to work on a targeted watershed grant (2014 through 2018) from BWSR that provides 1.5 million dollars for hydrology and erosion control BMP implementation. Another grant from the BWSR is a Clean Water Assistance grant for various basin projects, and this includes $133,250 through 2019.
- Streamside vegetative buffers are being installed and maintained in the CRW. Minnesota's 2016 buffer law required permanent vegetation on public water courses in 2017, and buffers on public drainage ditches by 2018. This is a landowner requirement, and compliance rates in both categories are high. Compliance and enforcement measures can be taken, if buffers are not installed and maintained, as required by the law.
- Funding for SSTS compliance includes both local and State of Minnesota components. For the three main counties in the CRW (Dodge, Freeborn, and Mower), all have used the base grant of $18,600 per year per county, to buy SSTS equipment, train and pay staff, review designs and conduct inspections. The base grant total for 2013 to 2018 is $335,823 (at the county scale). A second grant provided from the State to the counties is for conducting inspections on property transfer, as well as work on plans to improve compliance, conduct compliance inspections, and work on unsewered areas. For these counties, that amounted to $73,218, over the same time frame. The third grant from the State to the counties is for low-income SSTS upgrades. Dodge and Freeborn counties have chosen to receive these funds, which total $215,000 over the last five years. About 18 SSTS systems have been completed with the fix-up grants, with residents qualifying by having a low income, a homesteaded property, and a failing SSTS identified by an inspection.
- The 25,000-acre Dobbins Creek Subwatershed has been a priority project area for the Mower SWCD, the city of Austin, and the CRWD, for several decades (Dobbins Creek is a tributary to the Cedar River, where it enters the main river at Austin, Minnesota). A high level of monitoring and assessment, conservation planning, hydrology and erosion control BMP implementation, and watershed modeling has been focused on this watershed. An EPA-funded CWA Section 319 grant titled "Effectiveness of Targeted Dobbins Creek BMPs" has been completed. The total project cost includes $300,000 from Section 319, and a Local/State match of $400,000, for a total project cost of $700,000 (2015 through 2018 project dates). Dobbins Creek was also included as a National Water Quality Initiative (NWQI) project area by USDA (in 2017), which allowed for additional EQIP funds to be utilized for implementation. Information and procedures learned at this smaller scale will be used to expand nonpoint source and hydrology activities to other areas in the larger CRW. The project was also recently selected to receive Section 319 Focus Watershed funding over the next decade.
- Monitoring of water and land management will be conducted to track progress and provide data and information for adjustments in the implementation approach (see Section 5). This will support an adaptive management approach.
- The Minnesota agricultural water quality certification program began in 2012, and is well-established and gaining momentum. This is a partnership program involves the state of Minnesota and the USDA-NRCS and EPA, as well as private sector groups and farmers. This program certifies farmers for management of their land in ways that protection water quality. It

involves an online tool, technical assistance from the SWCDs, and a certification of compliance with existing laws and rules. https://www.mda.state.mn.us/awqcp

- NPDES Permits for WWTFs in the Cedar River Basin will contain calendar month average and calendar week maximum mass and concentration effluent limits for TSS and monthly geometric mean Fecal Coliform bacteria concentration effluent limits. Other ongoing regulatory activities including CSW, ISW, and MS4 work by the city of Austin will continue as defined by the program requirements with implementation by the entities with permits.
- Animal feedlot and manure application efforts are a joint responsibility between the landowner/operator, the county, and the MPCA. Both Mower and Freeborn counties have delegated authority from the MPCA, with a dedicated CFO working in cooperation with the MPCA feedlot unit staff. The MPCA has feedlot regulatory responsibility in Dodge County. Work plans for the CFOs and the MPCA feedlot staff consider information from the impaired waters list and priorities from the TMDL and WRAPS.
- Statewide strategies also play an important role in reducing nonpoint source pollution, and lend assurance that the CRW TMDL and WRAPS can achieve results in the midterm timeframes (5 to 20 years). Minnesota's Nutrient Reduction Strategy (NRS) has set basin-wide goals for the Mississippi River at a 45% reduction in TP from the average conditions of 1980 through 1996, by the year 2025 (MPCA 2014). Since TP transport often involves a significant component associated with SRO, implementation actions to reduce TP will often also help reduce suspended sediments. The NRS includes specific numbers for the CRW in Minnesota, including the current modeled load of 169 Metric Tons per year (MT/year) of TP, and a reduction of 20 MT/year required. The portion of that reduction that needs to come from cropland is 12.7 MT/year, or about 63% of the total needed TP reduction. This effort has also produced a nutrient planning portal web page, for the CRW (http://mrbdc.mnsu.edu/mnnutrients/watersheds/cedar-river-watershed).
- The EPA (1991) guidance addresses waters impaired by both point and nonpoint sources where the WLAs are predicated on nonpoint source loading reductions because the TMDL assumes that a larger share of load reductions will come from nonpoint sources. This is the case for all of the impaired stream reaches. For the Geneva Lake TMDL, balancing the lake TMDL equation in this report was predicated on practicable reductions in internal load, consistent with the control of rough fish and establishment of macrophytes in shallow lake systems, which are intended to greatly minimize sediment resuspension. There is also an external phosphorus reduction from the upper watershed, which will be critical to achieve and sustain in-lake management actions.

8. Public Participation

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

- July 10, 2008, Hollandale, Cedar River Basin TMDL development meeting
- February 19, 2008, Hollandale, Turtle Creek Watershed District meeting for TMDL Project
- December 15, 2011, Austin, Mower County water planning meeting
- March 19, 2012, City of Austin, City Council work session
- March 21, 2012, CRWD board meeting.
- March 20, 2012, Turtle Creek Watershed District Meeting in Hollandale for TMDL Project/Report Update
- Nov. 14, 2012, Mower SWCD Board Meeting in Austin for TMDL Project
- March 7, 2016, Austin, JC Hormel Nature Center, Izsak Walton League meeting
- Additional public participation and civic engagement activities are included in Appendix F.
- Public participation will continue in the current on-going 1W1P effort.

The draft CRW TMDL and the CRW WRAPS reports were placed on public notice for a 30-day review and comment period.

Public Notice

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from March 4, 2019 through April 3, 2019. There was one comment letter received and responded to as a result of the public comment period.

9. References

Adhikari, Hrishikesh, David L. Barnes, Silke Schiewer, and Daniel M. White. “Total Coliform Survival Characteristics in Frozen Soils.” Journal of Environmental Engineering, Vol. 133, No. 12, pp: 1098–1105, December 2007.

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

Blann, K.L., J.L. Anderson, G.R. Sands, and B. Vondracek. 2009. Effects of Agricultural Drainage on Aquatic Ecosystems: A Review. Critical Reviews in Environmental Science and Technology. 39: 909-1001.

Board of Water and Soil Resources. 2016. 2016 Nonpoint Priority Funding Plan (July 2016 – June 2018). http://www.bwsr.state.mn.us/planning/npfp/2016_NPFP_Final.pdf

Chandrasekaran, Ramyavardhanee, Matthew J. Hamilton, Ping Wanga, Christopher Staley, Scott Matteson, Adam Birr, and Michael J. Sadowsky. “Geographic Isolation of Escherichia coli Genotypes in Sediments and Water of the Seven Mile Creek — A Constructed Riverine Watershed.” Science of the Total Environment 538:78–85, 2015.

http://www.sciencedirect.com/science/article/pii/S0048969715305179

Cleland, B.R. March 3, 2011. Zumbro River Watershed TMDL WLA Linkage Analysis. Working Notes.

Cordts, S. 2007. Migratory Bird Populations. Wetland Wildlife Populations and Research, Minnesota Department of Natural Resources. https://files.dnr.state.mn.us/publications/wildlife/populationstatus2007/ch5_07.pdf

Dadaser-Celik, Filiz, and Heinz G. Stefan. “Stream Flow Response to Climate in Minnesota.” Project Report No. 510. St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, April, 2009.

Ellison, C.A., Savage, B.E., and Johnson, G.D. 2015. Suspended-sediment concentrations, yields, total suspended solids, turbidity, and particle size for selected rivers in Minnesota, 2007 through 2011. Conference proceeding at the 5th Federal Interagency Hydrologic Modeling conference and the 10th Federal Interagency Sedimentation conference, April 2015, Reno NV. https://pubs.er.usgs.gov/publication/70155207

Ellison, C.A., Groten, J.T., Lorenz, D.L., and Koller, K.S. 2016. Application of dimensionless sediment rating curves to predict suspended sediment concentrations, bedload, and annual sediment loads for rivers in Minnesota. Scientific Investigations Report 2016-5146, U.S. Geological Survey, Minnesota Water Science Center. https://pubs.er.usgs.gov/publication/sir20165146

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

Hanson, J. 2008. Cedar River Watershed Stream Survey Report. Cedar River Watershed District.

Hatch, L.K., A.P. Mallawatantri, D. Wheeler, A. Gleason, D.J. Mulla, J.A. Perry, K.W. Easter, P. Brezonik, R. Smith, and L. Gerlach. 2001. Land Management at the major watershed – agroecoregion intersection. J. Soil Water Conservation. 56:44-51.

Huser, B.J., Przemyslaw, G., Bajer, G., Chizinski, C.J., and Sorensen, P.W. 2016. Effects of common carp (Cyprinus carpio) on sediment mixing depth and mobile phosphorus mass in the active sediment layer of a shallow lake. Hydrobiologia (2016) 763:23-33.

Idstrom, J. & Vorland, J. (DNR), 2002. Management Plan for Geneva Lake. Minnesota Department of Natural Resources, 12 p.

Iowa Silver Jackets. 2016. Non-structural landuse change impacts on structure losses in Cedar River Communities. An Iowa Silver Jackets non-structural flood risk management study, submitted to the U.S. ACE National Flood Risk Management Program. Final Report, January 2016. (this was produced by a U.S. ACE study team, and the project manager was Jason T. Smith, Rock Island District office).

Ishii, S., Yan, T., Vu, H., Hansen, D. L., Hicks, R. E., & Sadowsky, M. J. (2010). Factors controlling long-term survival and growth of naturalized Escherichia coli populations in temperate field soils. *Microbes and Environments*, *25*(1), 8-14. DOI: 10.1264/jsme2.ME09172

Iowa Department of Natural Resources (DNR). 2006. Total Maximum Daily Load for Nitrate, Cedar River, Linn County, Iowa. Watershed Improvement Section.

King, K.W., Williams, M.R., Macrac, M.L., Fausey, N.R., Frankenberger, D.R., and Smith D.R. (2015) Phosphorus transport in agricultural subsurface drainage: A review. JEQ:44:467-485.

Lane, E.W. 1955. The importance of fluvial morphology in hydraulic engineering. ASCE

Proceedings. 81(745):1-17.

Marino, Robert P, and John J. Gannon. "Survival of Fecal Coliforms and Fecal Streptococci in Storm Drain Sediments." Water Research, Vol. 25 No. 9, pp. 1089–1098, 1991.

Meadows, D., and Wright D. 2008. Thinking in systems: a primer. Chelsea Green Publishing, 240 pages.

DNR, 2017a. Survey reports, and spreadsheets, and personal communication with Jeanine Vorland, Wildlife manager, DNR.

DNR, 2017b. State Climatology Office.

http://www.dnr.state.mn.us/climate/historical/acis_stn_data_monthly_table.html?sid=210355&sname=AUSTIN WASTE WATER TREATMENT

Minnesota Environmental Quality Board 2002. Final Animal Agriculture Generic Environmental Impact Statement. https://www.eqb.state.mn.us/sites/default/files/geis/GEIS-AnimalAgFinal.pdf

MPCA 2005. Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria, 3rd Edition (http://www.pca.state.mn.us/index.php/view-document.html?gid=6503) September 2005.

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

MPCA, 2007/ Statement of need and reasonableness (SONAR Book III), proposed revisions to Minnesota Rules Chapter 7050, relating to the classification and standards for Waters of the State. https://www.pca.state.mn.us/sites/default/files/sonar-book3.pdf

MPCA, 2011. Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity), https://www.pca.state.mn.us/sites/default/files/wq-s6-11.pdf

Minnesota Pollution Control Agency. 2012. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. 2012 Assessment Cycle. https://www.pca.state.mn.us/sites/default/files/wq-iw1-04g.pdf

MPCA, 2014. The Minnesota Nutrient Reduction Strategy. https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf

MPCA, 2018. Stormwater manual. Stormwater pollutants chapter. https://stormwater.pca.state.mn.us/index.php?title=Stormwater_pollutants

Moore, Richard. 2013. Evaluation of Artificial Drainage in Altering Hydrology. SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM, FINAL REPORT, Minnesota State University Mankato. (available from MSUM Water Resources Center or MPCA).

Mulla, D.J., and A.S. Birr, G. Randall, J. Moncrief, M. Schmidt, A. Sekely, and E. Kerre. 2001. Technical Work Paper: Impacts of Animal Agriculture on Water Quality. Department of Soil, Water, and Climate, University of Minnesota. Prepared for the Minnesota Environmental Quality Board and Citizen Advisory Committee, April 3, 2001.

Register, Cherri. 2016. The Big Marsh – The Story of a Lost Landscape. Minnesota Historical Society Press, St. Paul, Minnesota.

Radomski, P. and Perleberg, D. 2012. Application of a versatile aquatic macrophyte integrity index for Minnesota Lakes. Ecological Indicators 20 (2012) 252 – 268.

Radomski, P. and Perleberg, D. 2016. Lake plant eutrophication IBI for Minnesota Lakes in MPCA's watershed assessment process for aquatic life use. (7 page memo/report from these DNR personnel)

RESPEC, 2014. Cedar River Watershed HSPF Modeling Development and Calibration Reports. (available from MPCA).

Scheffer, M., 2004. Ecology of Shallow Lakes. Kluwer Academic Publishers, Dordrecht, The Netherlands, 357 p.

Schilling, K.E., Kim, S-E., Jones, C.S., and Wolter, C.F. 2017. Orthophosphorus contnributions to total phosphorus concentrations and loads in Iowa agricultural watersheds. JEQ:46:828-835.

Schottler, S.P., Ulrich, J., Belmont, P., Moore, R., Lauer, J. W., Engstrom, D.R., Almendinger, J.E. 2013. Twentieth century agricultural drainage creates more erosive rivers. Hydrol. Processes DOI: 10.1002/hyp.

Simon, A. 1994. Gradation Processes and Channel Evolution in Modified West Tennessee Streams: Process, Response, and Form. U.S. Geological Survey Professional Paper 1470.

Simon, A., and C.R. Hupp. 1986. Channel evolution in modified Tennessee channels. Fourth Federal Interagency Sedimentation Conference. Las Vegas, Nevada. March 24-27, 1986. Vol.2, pp. 5-71 to 5-82.

Sovell, Laurie, *et al*., 2000 "Impacts of Rotational Grazing and Riparian Buffers on Physicochemical and Biological Characteristics of Southeastern Minnesota, USA, Streams" Environmental Management, 26(6) 629 – 641.

Taff, Steve 1998. Managing Minnesota's Drainage System. Minnesota Agricultural Economist, No. 692, Spring 1998. University of Minnesota Extension Service and Department of Applied Economics.

Twaroski, Cliff, Nadine Czoschke, and Tim Anderson. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds – Atmospheric Deposition: 2007 Update. Technical Memorandum to MPCA, Barr Engineering, Minneapolis, MN, June 29th, 2007.

University of Minnesota, Water Resources Center. 2015. Field to Streams – Managing Water in Rural Landscapes, Part One, Water Shaping the Landscape. http://www.extension.umn.edu/environment/water/publications/docs/fields-to-streams1.pdf

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

USDA-NASS (National Ag Statistics Service). 2016. Minnesota Ag News. 2016 Corn County Estimates. https://www.nass.usda.gov/Statistics_by_State/Minnesota/index.php

USDA–Soil Conservation Service. Hydrology Guide for Minnesota. Saint Paul, Minnesota.

USGS Streamstats. 2018. U.S. Geological Survey. https://streamstats.usgs.gov/ss/

USGS. 2018. Transport of nitrogen and phosphorus in the Cedar River Basin, Iowa and Minnesota, 2000-2015. Scientific Investigations Report 2018-5090. Stephen J. Kalkhoff (main author), and prepared in cooperation with the City of Cedar Rapids, Iowa.

Vorland, J. 2018. Personal communication. (Minnesota Department of Natural Resources – Division of Wildlife. Area and Regional Wildlife Manger).

Wilson, B. and Walker W. Jr. 1989. Development of lake assessment methods based on aquatic ecoregion concept. Lake and Reservoir Management 5(2): 11-22.

Appendices

See separate document.

Appendix A. Methodology for TMDL Equations and Load Duration Curves

Appendix B. Stream Channel Survey Summary and Analysis

Appendix C. Terrain Analysis

Appendix D. Soil and Water Assessment Tool (SWAT) Watershed Modeling

Appendix E. Geneva Lake Water Quality and Lake Levels

Appendix F. Cedar River Watershed Strategy and Implementation Plan – Phase 1. Final Project Report, August 2013.

Appendix G. Cedar River Watershed Modeling Summary, MPCA.

Appendix H. Crop residue data, Cedar River Watershed.

Appendix I. Table of impaired waters, Cedar River Watershed, with no required TMDL