Buffalo River Watershed Total Maximum Daily Load

Minnesota Pollution Control Agency

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Authors and contributors:

Timothy Erickson, P.E.
Mark R. Deutschman, Ph.D., P.E.
Jeremiah Jazdzewski
Timothy R. James

Prepared for:

Minnesota Pollution Control Agency

520 Lafayette Road North
St. Paul, Minnesota 55155

Buffalo-Red River Watershed District

1303 Fourth Avenue Northeast
P.O. Box 341
Barnesville, Minnesota 56514
Telephone: 218-354-7710
Fax: 218-354-2503
http://www.brrwd.org/

Prepared by:

Houston Engineering Inc.

6901 East Fish Lake Road
Suite 140
Maple Grove, Minnesota 55369
Telephone: 763-493-5572
http://www.houstoneng.com

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Acronyms

AU	Animal Units
AUID	Assessment Unit Identifier
BMP	Best Management Practices
BRW	Buffalo River Watershed
BRRWD	Buffalo-Red River Watershed District
BWSR	Board of Water and Soil Resources
CAFO	Confined Animal Feedlot Operations
Chl-*a*	Chlorophyll-*a*
CWLA	Clean Water Legacy Act
DNR	Department of Natural Resources
DO	Dissolved Oxygen
E. coli	Escherichia coli
EDA	Environmental Data Access
EPA	Environmental Protection Agency
EQuIS	Environmental Quality Information System
FDC	Flow duration curve
HEI	Houston Engineering Inc.
HUC	Hydrologic Unit Code
IWM	Intensive Watershed Monitoring
LA	Load Allocation
LAP	Lake Agassiz Plain
LDC	Load Duration Curve
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
NCHF	North Central Hardwood Forest
NGP	Northern Glaciated Plains
NLF	Northern Lakes and Forests
NPDES	National Pollution Discharge Elimination System
RC	Reserve Capacity

SWAT	Soil and Water Assessment Tool
SWCD	Soil and Water Conservation District
SSTS	Subsurface Sewage Treatment Systems
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
USACE	U.S. Army Corps of Engineers
WCP	Western Cornbelt Plains
WLA	Wasteload Allocation
WWTF	Wastewater Treatment Facility

TMDL SUMMARY TABLE

EPA/MPCA Required Elements	Summary	TMDL Page #
Location	The Buffalo River Watershed is in northwest Minnesota. The watershed contains portions of Becker, Clay, Wilkin and Ottertail County. There are 37 stream segments and lakes addressed in this report.	8
303(d) Listing Information	There are 61 listings for the BRW on the draft 2014 303(d) list: *E. coli* (22), DO (2), mercury in fish (1) turbidity (13), excess nutrients (15), aquatic invertebrate bioassessment (4), and fishes bioassessment (3). See Table 1.3	4
Applicable Water Quality Standards/Numeric Targets	See Section 1.1	2
Loading Capacity (expressed as daily load)	Loading capacities for stream impairments are provided in Section 4.2 and lake impairments in Section 5.2	58, 74
Wasteload Allocation	WLAs for stream impairments are provided in Section 4.2 and lake impairments in Section 5.2	58, 74
Load Allocation	LAs for stream impairments are provided in Section 4.2 and lake impairments in Section 5.2	58, 74
Margin of Safety	Explicit 10% MOS used for TSS and *E. coli*. Stochastic modeling and 5% MOS used for excess nutrients in lakes; See Section 3.5	52
Seasonal Variation	Seasonal variation is accounted for in the methods used to compute the loading capacities: load duration curves for the stream impairments and stochastic modeling for the lake impairments.	69, 78
Reasonable Assurance	This TMDL project was sponsored and led by local agencies, with financial support from state agencies. The findings and goals are supported by local watershed plans, various state and local programs, and state and federal regulations. The suggested source reduction strategies are currently being implemented in the watershed and have been shown to improve water quality. Numerous funding sources are available for continuing these strategies.	83

Monitoring	The BRRWD continues to sponsor long-term stream water quality monitoring at 20 locations within the watershed. No ongoing lake water quality monitoring is occurring. Intensive watershed monitoring (which includes lakes) will occur on a ten-year cycle, returning to the BRW in 2019. In addition, the MPCA continues to monitor long-term water quality in the BRW at the watershed outlet.	79
Implementation	A summary of potential management activities along with associated costs are included in this TMDL.	80
Public Participation	Civic engagement for this TMDL effort has been underway since the project began in 2009. The public comment period for this TMDL was open from March 30, 2015 to April 29, 2015. There were three comment letters received and responded to as a result.	84

1 Introduction

The Buffalo River Watershed (BRW) is located in northwest Minnesota and comprises approximately 1,100 square miles within Clay, Becker, Wilkin, and Otter Tail counties. The watershed is located in the Red River of the North Basin and spans three ecoregions: The Lake Agassiz Plain (LAP), the North Central Hardwood Forests (NCHF), and the Northern Lakes and Forests (NLF). Land use within the watershed is predominantly agricultural, occurring in the west and central portions; the eastern portion of the watershed is mostly forested. Municipalities located within the BRW include Glyndon, Hawley, Lake Park, Audubon, Callaway, Georgetown, and Barnesville.

The Minnesota Pollution Control Agency (MPCA) has listed 38 waterbodies in the BRW as impaired for water quality (i.e., not meeting the standards that have been set for them) and needing a Total Maximum Daily Load (TMDL). The draft 2014 303(d) list contains a total of 61 impairment listings for the BRW's waterbodies: 22 for *E. coli*, 13 for turbidity, 16 for excess nutrients, 4 for aquatic macroinvertebrate bioassessment, 3 for fish bioassessment, 2 for dissolved oxygen (DO), and 1 for mercury. Of the 61 listings on the 303(d) list, 53 are addressed in this TMDL, i.e. a TMDL calculation is performed. They include the 22 *E. coli*, 13 turbidities, 15 excess nutrients, and 3 biologic impairments. In January of 2015, the Environmental Protection Agency (EPA) issued an approval of the adopted amendments to the State Water Quality Standards, replacing the historically used turbidity standard with Total Suspended Solids (TSS) standards. All turbidity impairments on the 2014-303(d) list will be considered as TSS impairments and address as TSS TMDLs. The remaining eight listings are not addressed because either they already have an approved TMDL (one mercury impairment), are the result of non-conventional stressors like altered hydrology (four biological impairments), are wholly located within a National Wildlife Refuge (one excess nutrient impairment – North Tamarack Lake), or will be completed in the future because of a lack of necessary data (two DO impairments).

In 2006, Minnesota passed the Clean Water Legacy Act (CWLA) (in part) to protect, restore, and preserve the quality of Minnesota's surface waters. As a result, the MPCA established a watershed approach to restore and protect Minnesota's waters. One component of that work is to complete TMDLs for the impaired waterbodies within each watershed and develop a watershed-wide TMDL report. This is that report for the BRW.

The findings from this TMDL study will be used to aid the selection of implementation activities as part of the Buffalo River Watershed Restoration and Protection Strategy (WRAPS) process. 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. Following completion, the WRAPS report will be publically available on the MPCA BRW website:

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/buffalo-river.html

Multiple reports and memorandum were used to inform this TMDL. **Appendix A** provides a supporting materials quick reference table that summarizes each supporting report and memorandum, as well as a quick reference guide to locations in each report/memorandum of relevant topics.

1.1 Applicable Water Quality Standards

Water quality standards are the fundamental benchmarks by which the quality of surface waters are measured and used to determine impairment. Use attainment status describes whether a waterbody is supporting its designated use as evaluated by the comparison of monitoring data to criteria specified in the *Minnesota Water Quality Standards* (Minn. R. ch. 7050, 2008[1]). These standards can be numeric or narrative in nature and define the concentrations or conditions of surface waters that allow them to meet their designated beneficial uses, such as for fishing (aquatic life), swimming (aquatic recreation), or human consumption (aquatic consumption). All impaired waters addressed in this TMDL are classified as Class 2B or 2C waters.

> ***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. This class of surface water is not protected as a source of drinking water (Minn. R. 7050.0222, subp. 4).

> ***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 (Minn. R. 7050.0222, subp. 5).

Applicable water quality standards for the BRW stream impairments in this report are shown in Table 1-1; applicable lake water quality standards are shown in **Table 1-2**.

Table 1-1: Surface water quality standards for BRW stream reaches addressed in this report.

Parameter	Water Quality Standard	Units	Criteria	Period of Time Standard Applies
Escherichia coli (*E. coli*)	Not to exceed 126	org/100 mL	Monthly geometric mean	April 1-October 31
	Not to exceed 1,260	org/100 mL	Upper 10th percentile	
Total suspended solids (TSS)[1]	Not to exceed 65	mg/L	Upper 10th percentile	April 1 – September 30

[1] As on January 2015, replaces turbidity standard.

The MPCA previously used fecal coliform as the standard to indicate the presence of waterborne pathogens. Both fecal coliform and *E. coli* are fecal bacteria and indicators of waterborne pathogens having the potential to cause human illness. *E. coli* is the indicator preferred by the EPA. Although water quality standards are presently based in *E coli*, wastewater treatment facilities (WWTF) are permitted based on fecal coliform, not *E. coli*. The previous fecal coliform standard is a geometric mean of 200 org/100 mL and less than 10% of the samples exceeding 2000 org/100 mL. Based on the previous fecal standard and the current *E. coli* standard (**Table 1-1**), a ratio of 200:126 (0.63) is used to convert fecal coliform to *E. coli* when computing the wasteload allocations (WLAs) of WWTF (see **Section 3.3**).

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[1] https://www.revisor.leg.state.mn.us/rules/?id=7050

In January of 2015, the EPA issued an approval of the adopted amendments to the State Water Quality Standards, replacing the historically used turbidity standard with TSS standards. Therefore, this TMDL will address all of the turbidity impairments as TSS impairments. TSS is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water (MPCA 2015). The TSS standard is based on nutrient regions (south, central, and north) in the state. The dynamics that contribute to excess nutrients in river systems can be similar to those that contribute to excess turbidity. Therefore, the same regions are used for the river nutrient standards and the TSS standard. The river nutrient regions are mainly based on ecoregions with some area-specific changes (MPCA 2011c; page 13). All of the turbidity-impaired streams in the BRW are located in the South River Nutrient Region, which has a TSS standard of 65 mg/L.

Lake eutrophication standards are written to protect lakes as a function of their protected use. The lakes of the BRW are considered Class 2B waters, which are protected for aquatic recreation. The MPCA considers a lake impaired when total phosphorus (TP) and a least one of the response variables (chlorophyll-*a* (Chl-*a*) or Secchi disk depth) do not meet the applicable standards (MPCA 2013b; page 40).

Minnesota's lake water quality standards were developed by depth classification and ecoregion and are listed in **Table 1-2**. Ecoregions in the BRW include the NLF, NCHF, and LAP. Currently the MPCA does not have specific numeric water quality standard for the LAP ecoregion but rather lakes within this area are assessed on a case-by-case basis. In practice, when assessing a lake in the LAP ecoregion, the MPCA considers the land use within the lake's total contributing lakeshed and compares that land use to typical values seen in the other ecoregions (as summarized in Heiskary and Wilson 2005). The numeric criteria of whichever ecoregion's land use characteristics most closely match those of the lake in question are then applied for determining impairment. In the lakes of the BRW, this analysis has resulted in the Northern Glaciated Plains (NGP) ecoregion criteria being used for assessment purposes. The water quality standards for the NGP are included in **Table 1-2**.

Table 1-2: Lake water quality standards for BRW lakes addressed in this report.

Ecoregion	Total Phosphorus (ug/L)	Chl-*a* (ug/L)	Secchi Disk Depth (m) [2]	Period of Time Standard Applies
Northern Lakes and Forest	30	9	2	June 1-Sept. 30
North Central Hardwood Forest[1]				
- Deep lakes and reservoirs	40	14	1.4	June 1-Sept. 30
- Shallow Lakes	60	20	1	June 1-Sept. 30
Northern Glaciated Plains[1]				
- Deep lakes and reservoirs	65	22	0.9	June 1-Sept. 30
- Shallow Lakes	90	30	0.7	June 1-Sept. 30
[1]: Deep lakes are classified as having a maximum depth greater than 15 feet whereas shallow lakes have a maximum depth less than 15 feet or greater than 80% of the lake is part of the littoral zone. [2]: Standard for Secchi disk depth is the minimum transparency value (i.e., values must be greater than the standard)				

1.2 Impaired Waters

According to the draft 2014, 303(d) impaired waters list[2], there are 61 listings in the BRW for 22 stream segments and 16 lakes. Of the 61 listings, 4 are listed for aquatic marcoinvertebrate bioassessments, 22 for *E. coli*, 3 for fishes bioassessments, 1 for mercury in fish tissue, 16 for nutrient/eutrophication biological indicators, 2 for DO, and 13 turbidity impairments. The draft 2014 303(d) listings in the BRW are provided in **Table 1-3** and the impaired waterbodies are shown in **Figure 1-1**.

Of the 61 303(d) listings, TMDLs were calculated for 53 listings for 37 waterbodies in this TMDL document, including 22 *E. coli* impairments, 13 turbidity impairments, 3 biological impairments, and 15 lakes with excess nutrient impairments. Four of the seven biological impairments in the watershed are not explicitly addressed in this report since their identified stressors (MPCA 2013a; page 98) do not include conventional pollutants for which TMDLs can be written. For the remaining biological impairments (those in AUIDs 09020106-505 and -507), turbidity/sediment was identified as a stressor. The turbidity/sediment aspects of the biological impairments are addressed through the TSS TMDLs for these reaches. The remaining stressors of the biological impairments (i.e. connectivity, altered hydrology, and habitat) are not conventional pollutants and are not addressed in this TMDL. The mercury impairment (09020106-501) is addressed in the approved Minnesota statewide Mercury TMDL. The two DO impairments are not addressed in this TMDL due to a lack of data for model calibration and validation. A nutrient TMDL for North Tamarac Lake (03-0241-02) was not calculated because it is being considered for de-listing and the drainage area is wholly located with the Tamarac Lake National Wildlife Refuge. North Tamarac Lake just exceeds the TP standard and it has been determined the excess nutrients are due to background sources.

Table 1-3: 2014 draft 303(d) listings for the BRW.

AUID	Name/Description	Year added to List	Affected designated use	Pollutant or stressor	Part of this TMDL
09020106-501	Buffalo River-S Branch Buffalo River to Red River	2012	Aquatic recreation	*Escherichia coli*	Yes
		2012	Aquatic consumption	Mercury in fish tissue	No[a]
		1996	Aquatic life	Turbidity	Yes
09020106-502	Stony Creek-Hay Creek to S Branch Buffalo River	2012	Aquatic recreation	*Escherichia coli*	Yes
		2010	Aquatic Life	Oxygen, Dissolved	No
		1996	Aquatic life	Turbidity[e]	Yes
09020106-503	Buffalo River, S Branch-Stony Creek to Buffalo River	2012	Aquatic recreation	*Escherichia coli*	Yes
		2012	Aquatic life	Turbidity[e]	Yes

[2] https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list

AUID	Name/Description	Year added to List	Affected designated use	Pollutant or stressor	Part of this TMDL
09020106-504	Buffalo River, S Branch-Whisky Creek to Stony Creek	2012	Aquatic recreation	*Escherichia coli*	Yes
		2012	Aquatic life	Turbidity[e]	Yes
09020106-505	Buffalo River, S Branch-Deerhorn Creek to Whisky Creek	2012	Aquatic Life	Aquatic Macroinvertebrate Bioassessments	Yes[b]
		2012	Aquatic recreation	*Escherichia coli*	Yes
		2010	Aquatic life	Turbidity[e]	Yes
09020106-507	Deerhorn Creek-Headwaters to S Branch Buffalo River	2012	Aquatic Life	Aquatic Macroinvertebrate Bioassessments	Yes[b]
		2012	Aquatic recreation	*Escherichia coli*	Yes
		2012	Aquatic life	Fishes Bioassessments	Yes[b]
		2010	Aquatic life	Turbidity[e]	Yes
09020106-508	Buffalo River, S Branch-Headwaters to Deerhorn Creek	2012	Aquatic recreation	*Escherichia coli*	Yes
		2012	Aquatic Life	Oxygen, Dissolved	No
		2010	Aquatic life	Turbidity[e]	Yes
09020106-509	Whisky Creek-T137 R47W S13, east line to S Branch Buffalo River	2012	Aquatic recreation	*Escherichia coli*	Yes
		2012	Aquatic life	Turbidity[e]	Yes
09020106-511	Hay Creek-Headwaters to Stinking Lake	2012	Aquatic recreation	*Escherichia coli*	Yes
09020106-515	Becker County Ditch 15-Unnamed ditch to Buffalo River	2012	Aquatic recreation	*Escherichia coli*	Yes
09020106-519	Hay Creek-Unnamed Creek to Spring Creek	2012	Aquatic recreation	*Escherichia coli*	Yes
09020106-520	Hay Creek-Spring Creek to Stony Creek	2012	Aquatic recreation	*Escherichia coli*	Yes
09020106-521	Whisky Creek-Headwaters to T137 R46W S18, west line	2012	Aquatic recreation	*Escherichia coli*	Yes
		2010	Aquatic life	Turbidity[e]	Yes
09020106-523	Stony Creek-T137 R45W S3, north line to T 137	2012	Aquatic recreation	*Escherichia coli*	Yes

AUID	Name/Description	Year added to List	Affected designated use	Pollutant or stressor	Part of this TMDL
	R46W S5, north line	2010	Aquatic life	Turbidity[e]	Yes
09020106-531	State Ditch 14-Wilkin County Ditch 40 to Deerhorn Creek	2012	Aquatic recreation	*Escherichia coli*	Yes
09020106-534	Spring Creek-Unnamed Creek to Hay Creek	2012	Aquatic Life	Aquatic Macroinvertebrate Bioassessments	No[c]
		2012	Aquatic Recreation	*Escherichia coli*	Yes
		2012	Aquatic life	Fishes Bioassessments	No[c]
09020106-556	County Ditch 2-Unnamed Creek to Buffalo River	2012	Aquatic recreation	*Escherichia coli*	Yes
09020106-559	County Ditch 39-Headwaters to Buffalo River	2012	Aquatic recreation	*Escherichia coli*	Yes
09020106-562	County Ditch 10-Headwaters to Buffalo River	2012	Aquatic recreation	*Escherichia coli*	Yes
09020106-593	Buffalo River-Buffalo Lake to Becker County Ditch 15	2012	Aquatic Life	Aquatic Macroinvertebrate Bioassessments	No[c]
		2010	Aquatic Recreation	*Escherichia coli*	Yes
		2012	Aquatic life	Fishes Bioassessments	No[c]
		2010	Aquatic life	Turbidity[e]	Yes
09020106-594	Buffalo River-Becker County Ditch 15 to Hay Creek	2010	Aquatic Recreation	*Escherichia coli*	Yes
		2010	Aquatic life	Turbidity[e]	Yes
09020106-595	Buffalo River-Hay Creek to S Branch Buffalo River	2010	Aquatic Recreation	*Escherichia coli*	Yes
		2010	Aquatic life	Turbidity[e]	Yes
03-0579-00	Boyer	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0624-00	Forget-Me-Not	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0528-00	Gottenberg	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0635-00	Gourd	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes

AUID	Name/Description	Year added to List	Affected designated use	Pollutant or stressor	Part of this TMDL
56-1039-00	Jacobs	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0646-00	Lime	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
14-0099-00	Maria	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0526-00	Marshall	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0471-00	Mission	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0241-02	North Tamarack	2010	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	No[d]
03-0659-00	Sand	2008	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0625-00	Sorenson	2010	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0631-00	Stakke	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0647-00	Stinking	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0619-00	Talac	2002	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes
03-0645-00	West LaBelle	2012	Aquatic recreation	Nutrient/Eutrophication Biological Indicators	Yes

[a]Addressed in Minnesota state-wide mercury TMDL.
[b]Turbidity identified as stressor, partially address through TSS TMDLs
[c]No conventional pollutant identified as a stressor.
[d]Considered for delisting because of high natural background concentrations.
[e]In January 2015, Minnesota replaced turbidity standard with a TSS standard. All impairments are still listed on 303(d) list as turbidity but will be addressed through TSS TMDLs.

1.3 Priority Ranking

The MPCA's projected schedule for TMDL completions, as indicated on the draft 2014 303(d) impaired waters list[3], implicitly reflects Minnesota's priority ranking of this TMDL. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

The MPCA's projected schedule for completion of these TMDLs, as indicated on Minnesota's 303(d) impaired waters list, is 2014, with this TMDL document. Schedules are estimated and indicate when a TMDL may be completed, not when a waterbody will meet its water quality standard.

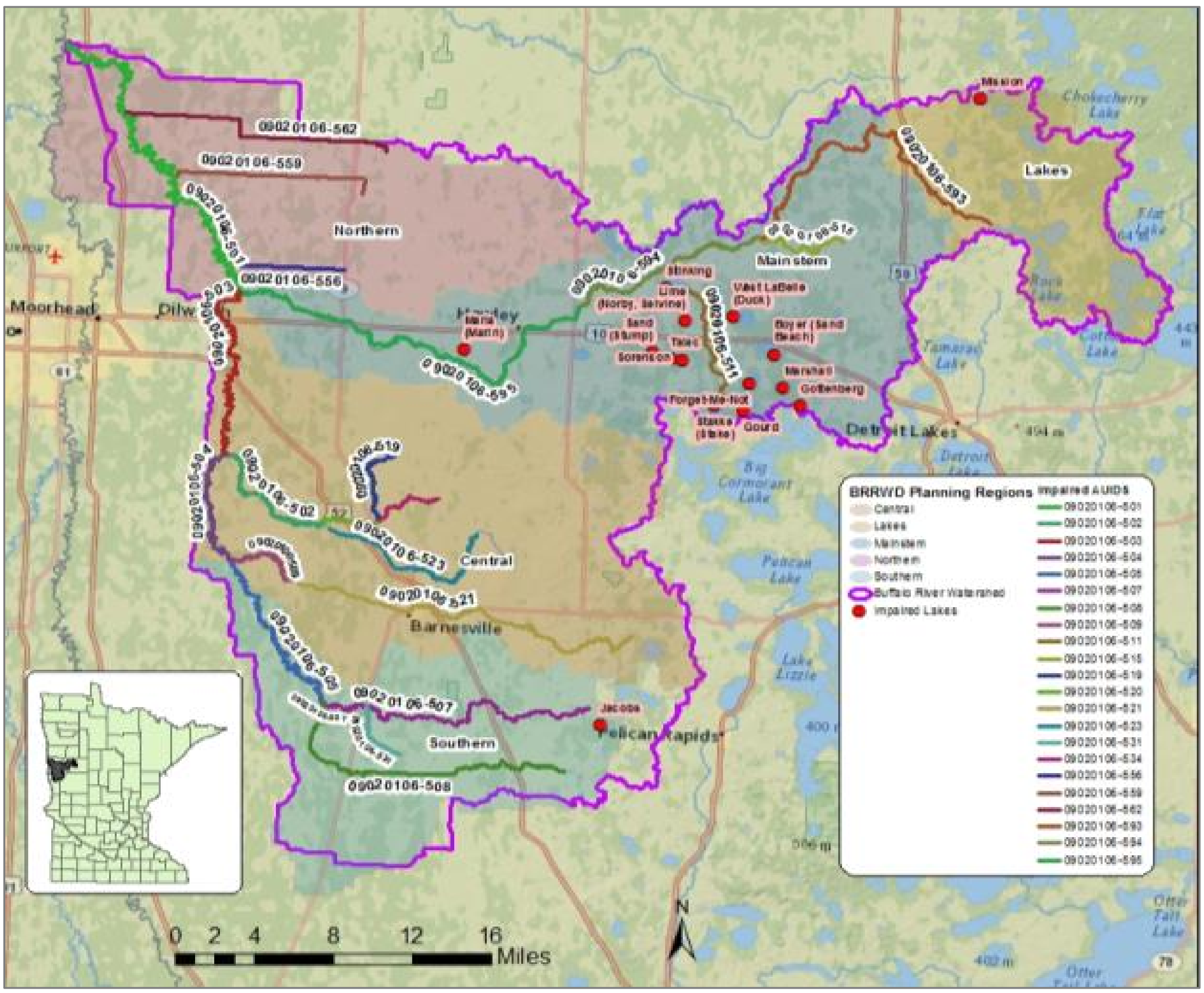

Figure 1-1: Map of BRW, BRRWD Planning Regions, and impaired waterbodies.

[3] http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/impaired-waters-list.html

2 Physical Characteristics

2.1 Buffalo River Watershed

The BRW (Hydrologic Unit Code (HUC) 09020106), located in northwest Minnesota, comprises over 1,100 square miles in portions of Clay, Becker, Wilkin, and Otter Tail Counties. Flow in the BRW is generally south-to-north and east-to-west. Flow enters the Red River of the North and proceeds north to the U.S. – Canada border. Land-use in the watershed is primarily agricultural (over 70%), with forested areas, lakes, and wetlands present in the eastern portion (see **Figure 2-1**)

The BRW contains one main river system, the Buffalo River, which terminates at the Red River of the North. The South Branch of the Buffalo River is a main tributary to the Buffalo River, draining approximately 454 square miles of the watershed[4]. Numerous additional streams contribute to the Buffalo River and Buffalo River, South Branch.

Some areas in the BRW include tribal lands, specifically the White Earth Band of Minnesota Chippewa (WEBMC). Efforts were made to consult with the WEBMC on this TMDL, regarding areas affecting the WEBMC. On April 15, 2014, the MPCA Project Manager contacted Monica Hedstrom, the Environmental Manager with the White Earth Nation by phone, to introduce himself and update her on the BRW TMDL and WRAP project. They discussed the comments that the EPA had generated in their preliminary review of the Buffalo River TMDL. On April 18, 2014, the MPCA Project Manager sent an e-mail to her with attachments of EPA's comments regarding tribal relationships along with the draft TMDL for her department's review. Subsequent e-mails and phone messages have gone unanswered. Her contact information for the White Earth Nation has been included on the project mailing list for all upcoming correspondence and meeting invites.

The Buffalo-Red River Watershed District (BRRWD) manages waters within the BRW and is the lead local agency on this TMDL effort. For management purposes, the BRRWD has divided the BRW into five Planning Regions. These regions are shown on the map in **Figure 1-1** and are used to organize components of this TMDL throughout the document. **Figure 2-1** shows the spatial distribution of the 2006 NLCD land uses in the BRW. **Table 2-1** contains a summary of land use in the BRW both as a whole as well as by drainage area to each of the impaired waters in the watershed.

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[4] USGS: http://waterdata.usgs.gov/nwis/nwisman/?site_no=05061500&agency_cd=USGS (Accessed 2011).

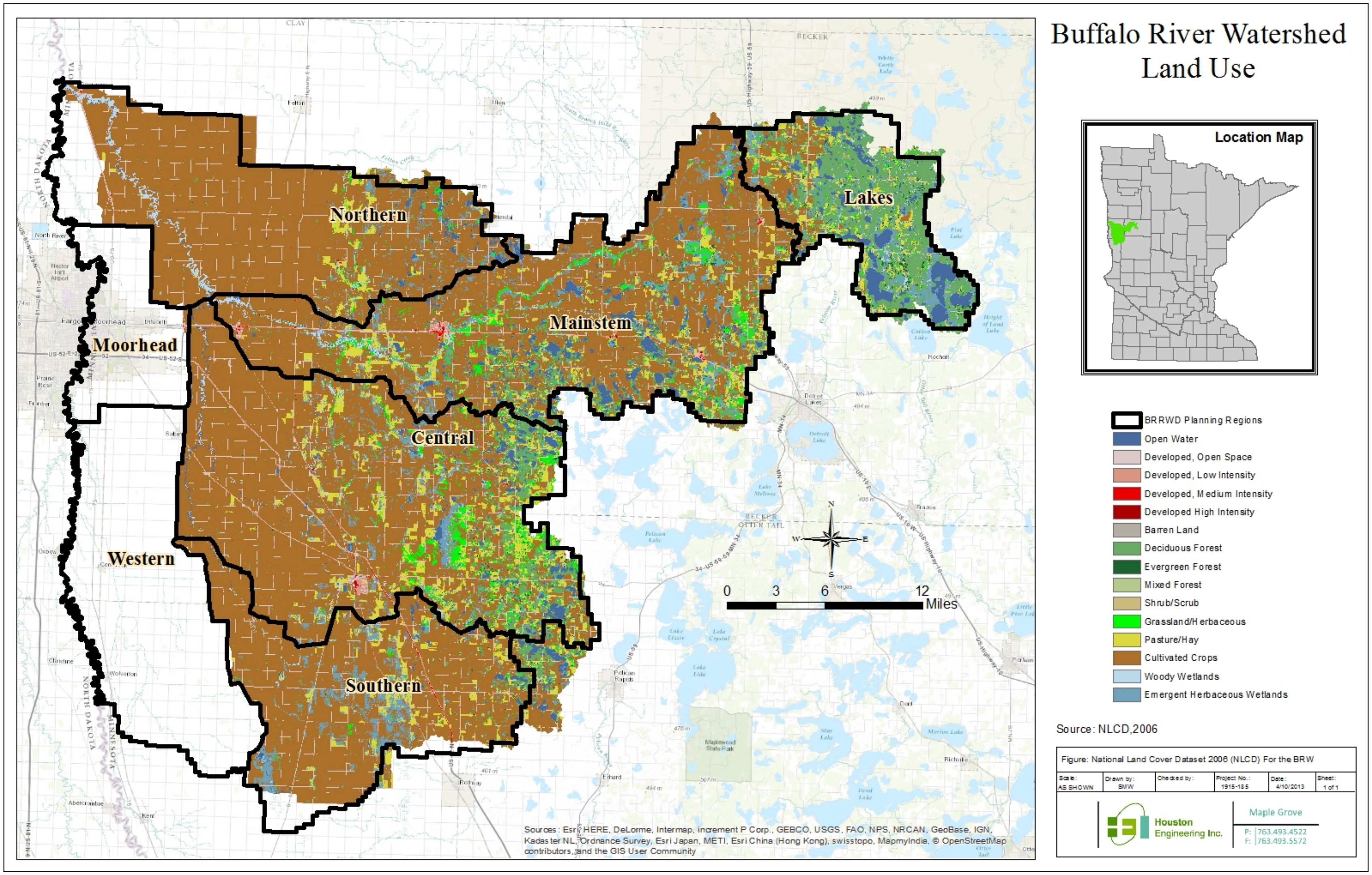

Figure 2-1. 2006 NLCD land classification in the BRW.

Table 2-1: Land use percentages in the BRW and AUID immediate drainage areas by planning region in the BRW. Land use statistics are based on National Land Cover Database (NLCD) 2006.

Watershed/ Immediate Drainage Area	Open Water	Urban	Barren	Forest/ Shrub	Pasture/ Hay/ Grassland	Cropland	Wetland
Whole	3.9	4.8	0.03	9.5	9.0	65.9	6.9
Lakes Planning Region							
09020106-593	3.9	3.7	0.06	18.7	10.5	53.9	9.3
Mission Lake	28.8	2.5	0.0	44.0	6.5	15.9	2.4
Mainstem Planning Region							
09020106-593	3.9	3.7	0.06	18.7	10.5	53.9	9.3
09020106-594	2.2	4.6	0.01	1.6	6.6	76.9	8.1
09020106-595	1.6	7.3	0.08	2.7	9.4	69.0	10.0
09020106-515	3.5	3.6	0.0	2.8	6.7	71.5	12.0
09020106-511	7.2	5.8	0.0	3.4	2.9	76.2	4.5
Maria Lake	8.9	6.7	0.0	1.6	8.0	73.4	1.5
Stinking Lake	7.2	5.8	0.0	3.4	2.9	76.2	4.5
Lime Lake	12.3	6.9	0.0	10.8	6.9	56.6	6.6
Sand Lake	19.8	3.3	0.65	28.9	8.5	36.6	2.2
Talac Lake	12.5	3.1	0.0	19.3	14.6	47.1	3.4
Stakke Lake	21.9	2.7	0.0	25.3	12.2	35.8	2.1
Sorenson Lake	12.5	3.1	0.0	19.3	14.6	47.1	3.4
Gourd Lake	32.5	4.3	0.0	21.7	7.5	34.0	0.0
West Labelle Lake	28.8	10.1	0.0	8.0	1.7	47.4	3.9
Boyer Lake	24.1	3.6	0.0	22.8	7.6	40.1	1.9
Forget-Me-Not Lake	13.5	3.9	0.0	14.5	6.8	58.7	2.6
Marshall Lake	33.6	3.4	0.0	19.0	5.6	38.5	0.0
Gottenberg Lake	21.5	3.4	0.0	31.3	14.4	28.9	0.4
Northern Planning Region							
09020106-501	1.6	7.1	0.0	0.3	0.6	81.2	9.2
09020106-556	0.1	3.0	0.0	0.2	1.4	94.6	0.7
09020106-559	3.2	4.4	0.03	1.9	6.7	77.1	6.6
09020106-562	0.1	3.5	0.0	0.5	2.9	92.1	0.8
Central Planning Region							
09020106-521	2.5	7.8	0.06	11.7	20.5	50.0	7.4
09020106-509	0.3	4.5	0.0	0.5	2.6	90.0	2.1
09020106-504	1.7	5.9	0.0	0.5	1.0	89.8	1.0
09020106-523	0.7	5.6	0.0	1.4	12.2	74.5	5.7
09020106-534	0.6	3.9	0.05	1.3	12.3	75.6	6.2
09020106-519	0.3	3.9	0.07	1.7	11.1	74.2	8.6
09020106-520	0.3	3.9	0.07	1.7	11.1	74.2	8.6
09020106-502	1.1	6.8	0.01	0.7	0.7	89.5	1.2
09020106-503	3.0	6.1	0.14	0.5	0.0	87.6	2.6
Southern Planning Region							
09020106-508	0.3	4.2	0.03	2.3	6.3	77.5	9.5
09020106-531	0.1	5.6	0.0	1.1	8.7	64.7	19.7
09020106-507	2.0	5.0	0.0	3.8	8.9	74.1	6.3
09020106-505	0.3	3.6	0.0	0.6	0.1	93.4	2.0
Jacobs Lake	12.7	5.5	0.0	29.1	12.1	38.9	1.7

Figure 2-2 shows the EPA's level 3 eco-regions in the BRW. The northeastern portion of the BRW contains a small portion of the NLF ecoregion. The land area makes up only 16 square miles and is characterized by lakes and forests. From east to west, the NLF ecoregion transitions into the NCHF ecoregion and then transitions into the LAP eco-region. The NCHF ecoregion is characterized by a shift from forest to a combination of forest and grassland (prairie), some of which has been converted to pasture or crop production. In addition, the coniferous forest of the NLF ecoregion shifts to a hardwood forest of oak, ash, maple, and basswood as one travels east to west into this ecoregion. The NCHF is often referred to the transition zone between the heavily forested northeast portion of Minnesota and the open farmland (once prairie) of western and southern Minnesota. The NCHF makes up 319 square miles of the BRW. The western boundary of the NCHF is characterized by the loss of the forests and lakes that transitions to prairie and wetland in the LAP ecoregion. This ecoregion has largely been tilled for agricultural production. Seventy percent or 797 square miles of the BRW is comprised of the LAP. The fertile lake bed soils are rich and highly productive for agriculture. These fine lake bed soils of silt and clay are easily suspended and stream flow is often high in turbidity, especially during times of runoff and high rates of stream discharge (MPCA 2013; page 11).

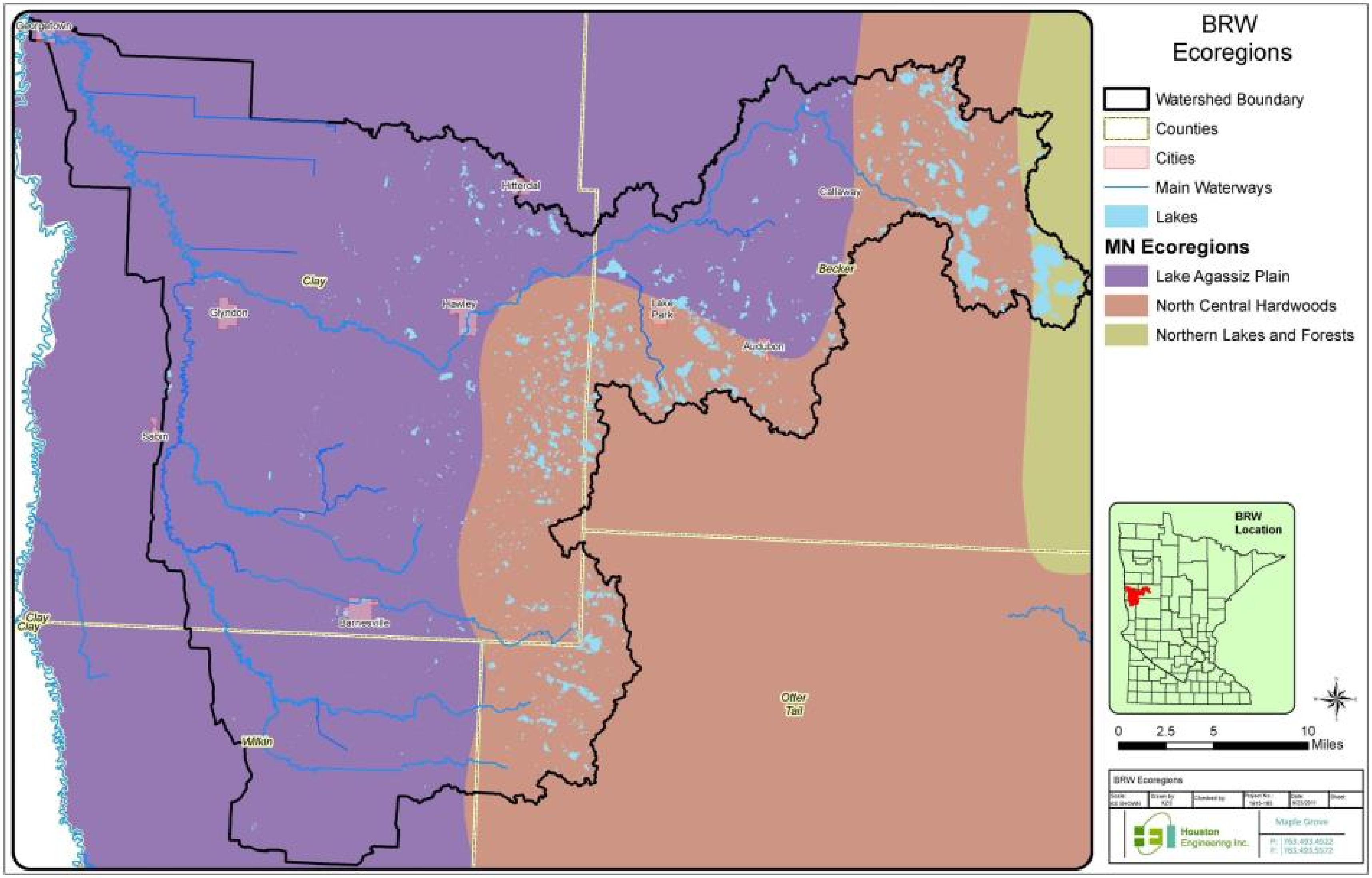

Figure 2-2. EPA Level 3 Eco-regions in the BRW

Following the EPA ecoregions, the BRW consists of three distinct geographic landforms (**Figure 2-3**) impact the quality and quantity of flow to its waters. These landforms, oriented from east to west, include the Glacial Moraines, the Agassiz Beach Ridges, and the Lake Plain. Changes in land use, soil type, and topography (stream gradient) from each zone have a significant impact on watershed hydrology and water quality. The following is a description of the three landforms as described in the Buffalo River Watershed Biotic Stressor Identification Report (MPCA 2013a; page 13):

> *"Making up a small component (in the eastern portion) of the watershed, the Glacial Moraines are characterized by forested and mixed forest/agricultural land use with numerous lakes and wetlands. Drainage is accomplished in the form of surface drainage of shallow lakes and wetlands, the channelization/ditching of tributary streams, and subsurface drainage accomplished with tile. The extensive network of drainage systems is proficient at moving water off the land in a highly accelerated fashion. Flooding is prevalent during spring melt and during large summer storms as a result of this intensive agricultural drainage network that in some cases has inadequate outlets. The drainage results in a more "flashy" hydrograph that has significant impacts to the system ecology with higher peak flows and the associated flooding and stream channel instability problems and a reduction in flow rates during critical low flow periods often typical of late summer and fall.*
>
> *The Agassiz Beach Ridges are relatively narrow zones that run north to south, beginning just west of Detroit Lakes and extend west several miles west of Hawley, and are characterized by sand and gravel deposits and significant change in elevation. The Agassiz Beach Ridges were formed when Lake Agassiz retreated over 10,000 years ago. This area of relatively poor fertility and well drained soils is of less importance to agriculture as demonstrated by the large percentage of land that is enrolled in set-aside programs (CRP), restored to grassland, or is used for haying or grazing.*
>
> *The Lake Plain is the remnant floor of Lake Agassiz and is characterized by deep, rich silt and clay sediments that support intensive, productive agriculture. This low gradient landscape (often less than 1 foot of elevation change per mile) has an extensive network of drainage to facilitate agricultural production. This zone is vulnerable to flooding as the stream discharge rates and slope from the Beach Ridge are reduced when the streams enter the Lake Plain region. Water quality becomes degraded as the tributaries work through this zone to the Red River. The phosphorus-rich clay and silt sediments tend to be easily suspended and transported within the stream system. The fine soils and their propensity to stay in suspension even at relatively low-flow conditions, combined with the extensive drainage network and stream channel instability, results in high turbidity and the degraded condition of these streams."*

For more information on the physical characteristics of the BRW, refer to the Buffalo River Watershed Biotic Stressor Identification (MPCA2013a) report, the Buffalo River Watershed Monitoring and Assessment Report (MPCA 2012a), and/or the Watershed Conditions Report Addendum (HEI 2012a).

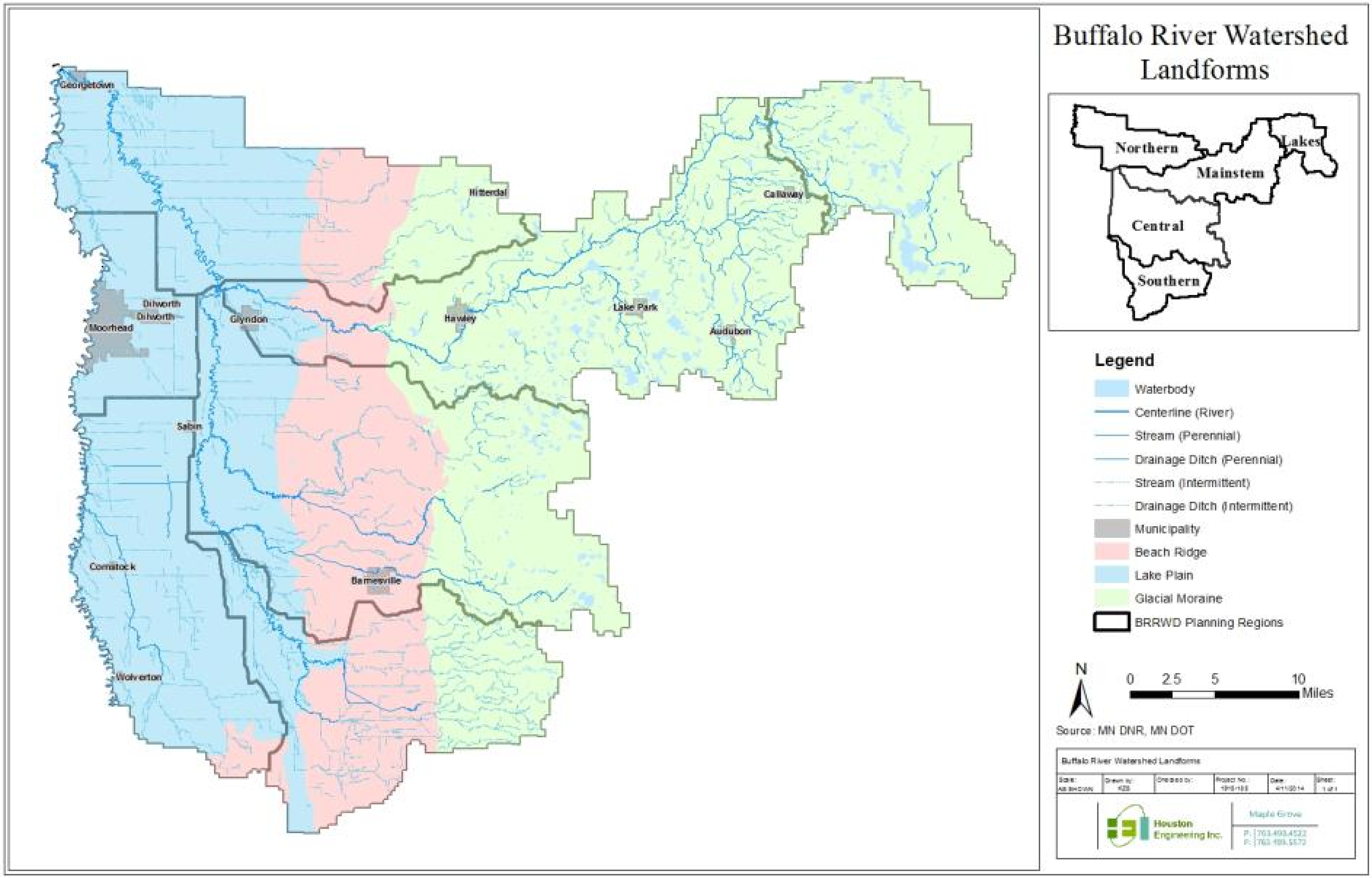

Figure 2-3: Geological Landforms in the BRW.

2.2 Planning Regions and Sub-watersheds

The BRRWD has broken the BRW into five planning regions for the purposes of managing the water resources in its jurisdiction. To best align the goals of the TMDL with the management of these resources, this TMDL is also subdivided by BRRWD planning region. Characteristics of each planning region and its impaired subwatersheds are discussed below. Characteristics of the catchments of the impaired lakes were taken from the MPCA's Assessment Report of Selected Lakes within the Buffalo River Watershed-Red River of the North Basin (MPCA 2012b).

The summary of each planning region contains a summary table of relevant information for each impaired waterbody in that region (**Tables 2-2 – 2-6**). The relevant information includes immediate drainage area, total drainage area, percent of cropland, number of point sources; number of National Pollution Discharge Elimination System (NPDES) permitted Confined Animal Feedlot Operations (CAFOs), and total number of feedlots. The immediate drainage area is defined as all the land that drains to the specified Assessment Unit Identifier (AUID) that does not drain through any other AUID or lake. The total drainage area (in **Tables 2-2 – 2-6**) is the total area of land upstream of the AUID. The percent cropland (in **Tables 2-2 – 2-6**) is the percentage of cropland in the immediate drainage area. The number of point sources, NPDES-permitted CAFOs, and total feedlots (in **Tables 2-2 – 2-6**) are the numbers in the planning region or the specified AUID's immediate drainage area. The feedlots are a potential source of bacteria (*E. coli*) and nutrients. See **Section 4.1.2** for the impact livestock and feedlots, as well as other sources, have on the stream reaches in the BRW.

2.2.1 Lakes Planning Region

The Lakes Planning Region is the headwaters of the Buffalo River, originating in Tamarac Lake. It is located in the far northeast portion of the BRW and comprised of both NLF and NCHF ecoregions. Forests and lakes dominate the planning region. The region contains two impaired waterbodies in need of a TMDL, the main channel through the planning region, i.e. Buffalo River-Buffalo Lake to Becker County Ditch 15 (AUID 09020106-593), and Mission Lake.

The Lakes Planning Region contains 10 registered feedlots, none of which require NPDES permits, and no wastewater discharges. The NPDES Permits are only required for federal defined CAFOS and CAFOs having 1,000 or more animal units (AUs). **Table 2-2** provides relevant information on each drainage area for reaches and lakes in need of a TMDL. It should be noted, AUID 09020106-593 extends beyond the boundary of the Lakes Planning Region, hence the 12 feedlots listed in **Table 2-2** versus the 10 feedlots in the Lakes Planning Region, as stated above.

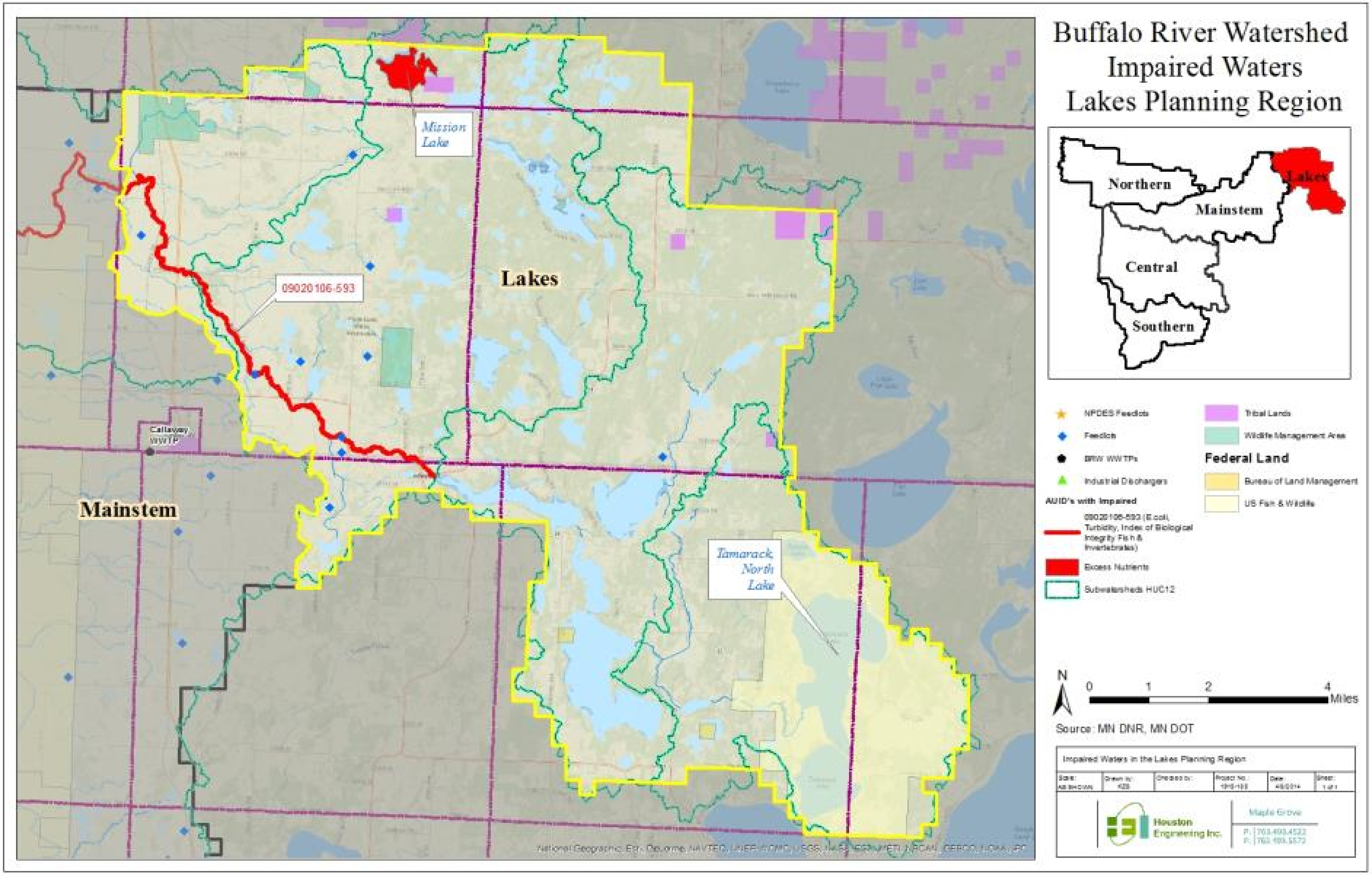

Figure 2-4: Lakes Planning Region Impaired Waterbodies.

Table 2-2: Attributes of the drainage areas for impaired waters in the Lakes Planning Region.

AUID	Immediate Drainage Area (acres)	Total Drainage Area (acres)	% Cropland[1]	# of Point Sources[1]	# of NPDES CAFOs[1]	# of Feedlots[1]
09020106-593	37,567	81,917	53.9	0	0	12
03-0471-00 (Mission Lake)	886	886	15.9	0	0	0

[1]Values for immediate drainage areas

Mission Lake is a shallow, 245 acre lake with a maximum depth of 7.8 feet located southeast of White Earth, Minnesota. The lake has an 886 acre watershed (3.6:1 watershed to lake ratio) dominated by forested and water/wetland land uses. The lake is not heavily developed; a residence is on the southwest shore and a gravel operation is on the northern shore; the land to the west of the lake is cultivated (MPCA 2012b; page 12).

2.2.2 Mainstem Planning Region

The Mainstem Planning Region is located west and downstream, along the mainstem of the Buffalo River, of the Lakes Planning Region (**Figure 2-5**). The Mainstem Planning Region is located in the NCHF ecoregion in the east and the LAP ecoregion in the west. Much of the planning region is agricultural lands (see **Table 2-1** and **Table 2-3**). The Buffalo River's mainstem travels east-to-west from the glacial moraines through the Agassiz beach ridges and into the lake plain, connecting with the South Branch of the Buffalo River at the western end of the planning region.

The entire length of the Buffalo River in the Mainstem Planning Region is impaired for turbidity and *E. coli* and in need of TMDLs. These reaches include AUIDs 09020106-593, 09020106-594, 09020106-595. In addition, two tributaries to the Buffalo River are impaired for *E. coli*, Hay Creek (AUID 09020106-511), and Becker County Ditch 15 (AUID 09020106-515). Bank erosion from livestock access, riparian vegetation change, and excessive high flows caused from ditching, wetland loss and altered hydrology are causing excess sediment to be delivered to the streams. Buffers of inadequate width to protect stream bank integrity and aquatic habitat have been observed throughout the upper reaches of the Buffalo River. Some of this sediment input is deposited, filling pools, causing excessive bar formation and smothering riffles, resulting in the loss of important fish and macroinvertebrate habitat (MPCA 2013a; page 36).

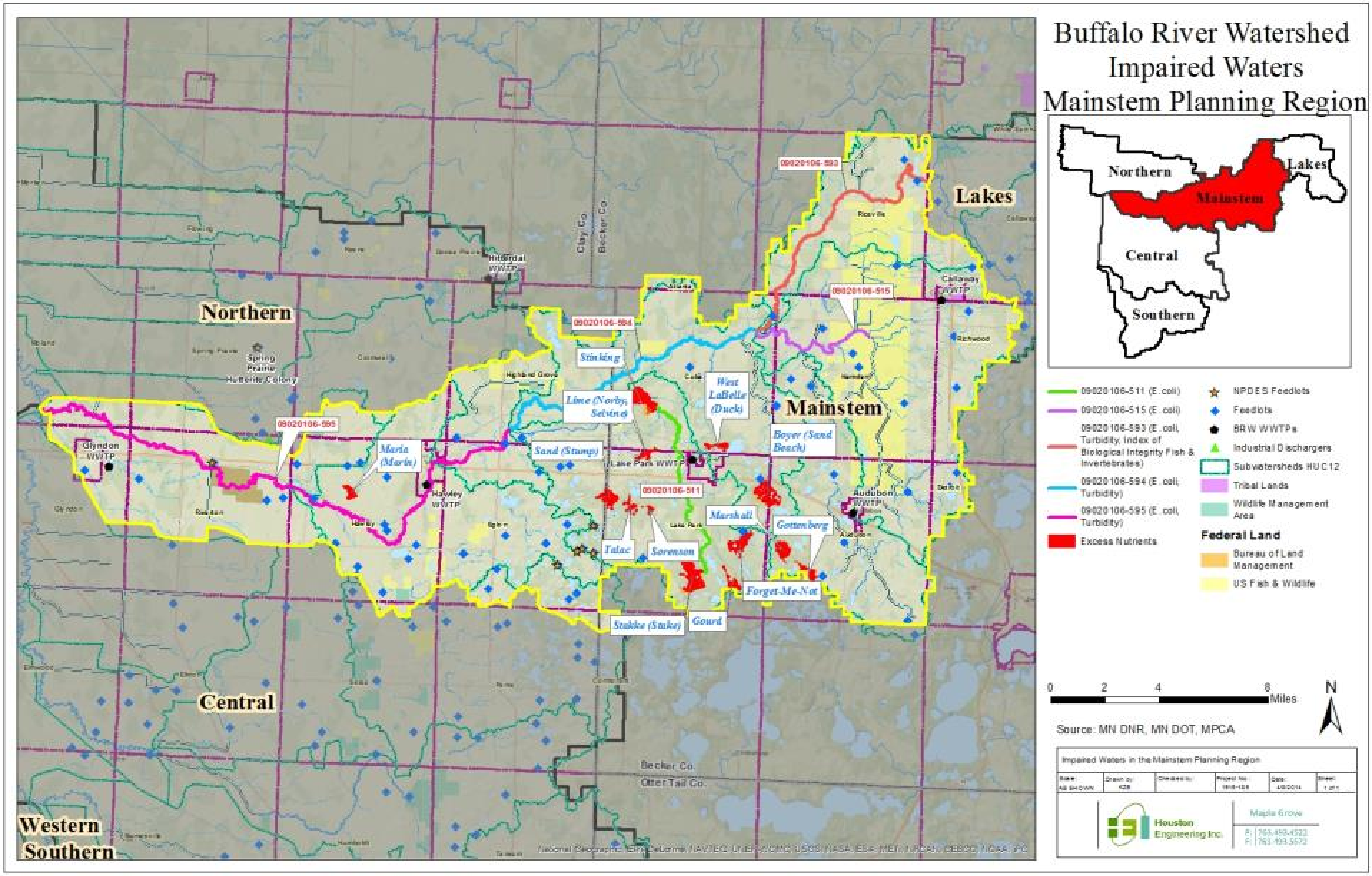

Figure 2-5: Mainstem Planning Region Impaired Waterbodies.

The Mainstem Planning Region contains 65 registered feedlots (35 located in impaired AUID drainage areas), six of which have NPDES Permits. Five of the NPDES-permitted CAFOs are located around the Sand-Axberg Chain-of-Lakes and the remaining NPDES permitted CAFO is located near the AUID 09020106-595.

There are also five permitted municipal WWTFs in the Region. **Table 2-3** provides relevant information on each drainage area for reaches and lakes in need of a TMDL. Of the five WWTFs in the planning region, only Hawley and Lake Park WWTPs discharge directly into impaired reaches. The Hawley WWTF discharges into the upper end of AUID 09020106-595 and Lake Park WWTF discharges into Stinking Lake via the middle of AUID 09020106-551. All other WWTF (Audubon, Callaway, and Glyndon WWTFs) discharge into either unassessed or non-impaired reaches.

Table 2-3: Attributes of the drainage areas for impaired waters in the Mainstem Planning Region.

AUID	Immediate Drainage Area (acres)	Total Drainage Area (acres)	% Cropland[1]	# of Point Sources[1]	# of NPDES CAFOs[1]	# of Feedlots
09020106-593	37,567	81,917	53.9	0	0	12
09020106-594	15,895	164,801	76.9	0	0	2
09020106-595	46,653	260,181	69	1	1	14
09020106-515	6,490	56,027	71.5	0	0	0
09020106-511	8,059	15,477	76.2	1	0	0
14-0099-00 (Lake Maria)	1,340	1,340	73.4	0	0	1
03-0647-00 (Stinking Lake)	8,059	15,477	76.2	1	0	0
03-0646-00 (Lime Lake)	1,171	6,882	56.6	0	0	0
03-0659-00 (Sand (Stump) Lake)	3,664	3,664	36.6	0	4	4
03-0619-00 (Talac (Lee) Lake)	603	5,421	47.1	0	0	0
03-0631-00 (Stakke Lake)	3,039	3,039	35.8	0	0	1
03-0625-00 (Sorenson Lake)	929	929	47.1	0	0	0
03-0635-00 (Gourd Lake)	362	362	34	0	0	0
03-0645-00 (West LaBelle Lake)	410	1,928	47.4	0	0	0
03-0579-00 (Boyer Lake)	2,084	2,084	40.1	0	0	0
03-0624-00 (Forget-Me-Not Lake)	2,123	2,123	58.7	0	0	1
03-0526-00 (Marshall Lake)	531	531	38.5	0	0	0
03-0528-00 (Gottenberg Lake)	709	1,240	28.9	0	0	0

[1]Values for immediate drainage areas

The planning region contains numerous lakes, many of which are impaired and in need of TMDLs. These lakes include Lake Maria, Stinking Lake, Lime Lake, Sand Lake, Talac Lake, Stakke Lake, Sorenson Lake, Gourd Lake, West Labelle Lake, Boyer Lake, Forget-Me-Not Lake, Marshall Lake, and Gottenberg Lake.

Lake Maria is a shallow, 109 acre lake with a maximum depth of 8 feet, located southwest of Hawley, Minnesota. The lake has a 1,340 acre watershed (12.3:1 watershed to lake ratio) dominated by cultivated land uses. The lake has one residence and is surrounded by cultivated land with little riparian fringe. Land use in the watershed is consistent with the NGP ecoregion (MPCA 2012b; page 40).

Stinking Lake is a shallow, 378 acre lake with a maximum depth of 8 feet located northwest of Lake Park, Minnesota. The lake has a 15,476 acre watershed dominated by cultivated land use. The lakeshore is bordered by cultivated land with little to no forested riparian fringe. Land use in the watershed is dominated by cultivated agriculture and, while transitional between NCHF and NGP ecoregions, it was determined the lake should be held to the NGP shallow lake eutrophication standard (MPCA 2012b; page 33).

Stinking Lake historically and currently receives the wastewater effluent from the city of Lake Park. Wastewater effluent from Lake Park's pond system discharges to Hay Creek, which flows northwest of the city for about three miles before discharging into Stinking Lake. The Stinking Lake outlet has a control structure constructed so that it can be used for flood storage. When in operation, the water level of the lake can bounce several feet in order to impound flood water. Both of these situations can have an impact of the water quality of the lake (MPCA 2012b; page 33).

Lime Lake is a shallow, 106 acre lake with a maximum depth of 8 feet located west of Lake Park, Minnesota. The lake has a 6,882 acre watershed dominated by cultivated and water/ wetland land uses. The lakeshore has a few residences, but primarily is bordered by cultivated land with little to no forested riparian fringe (MPCA 2012b; page 32).

Stakke Lake is a shallow, 482 acre lake with a maximum depth of 15 feet located south of Lake Park, Minnesota. The lake has a 3,039 acre watershed dominated by cultivated and forested land uses. The fringe of the lake is narrow and forested; much of the western shore is being developed into residential lots (MPCA 2012b; page 29).

Gourd Lake is a shallow, 121 acre lake with a maximum depth of 6 feet located south of Lake Park, Minnesota. The lake has a 361 acre watershed dominated by cultivated and water/wetland land uses. There are a couple of residences on the lake; the majority of the shoreline is a narrow forested riparian area that abuts agricultural land (MPCA 2012b; page 30).

West LaBelle Lake is a shallow, 101 acre lake with a maximum depth of 19 feet located in Lake Park, Minnesota. The lake has a 1927 acre watershed dominated by cultivated and water/wetland land uses. The southern shore of the lake has residential development; the northern shore is cultivated up to the shoreline and the eastern shore abuts County Highway 9. With 100% of the lake considered littoral, the lake was assessed as a shallow lake (MPCA 2012b; page 31).

Boyer Lake is a deep, 321 acre lake with a maximum depth of 26 feet located east of Lake Park, Minnesota. The lake has a 2,084 acre watershed (6.5:1 watershed to lake ratio) dominated by cultivated and water/wetland land uses. The lake is lightly developed and predominantly surrounded by cultivated land, typically with a narrow forested riparian area. The lake increased in water level during the high precipitation in the late 1990s. This rise in water levels resulted in significant shoreline erosion in areas of steep shoreline, most notably on the east side of the lake. An artificial outlet was installed under U.S. Highway 10 in 2011 to reduce and stabilize the rising water levels. The outlet lowered the lake level roughly 4 feet in order to return the lake to the relatively stable lake level that existed prior to the recent 18-year period of greater than normal precipitation (MPCA 2012b; page 16).

Forget-Me-Not Lake is a shallow, 235 acre lake with a maximum depth of 7 feet located near Lake Park, Minnesota. The lake has a 2,123 acre watershed (9:1 watershed to lake ratio) dominated by cultivated land uses. The lake has two residences and is predominantly surrounded by cultivated land, typically with a narrow forested riparian area (MPCA 2012b; page 16).

Marshall Lake is a 185 acre lake with a maximum depth of 19.7 feet located near Audubon, Minnesota. The lake has a 531 acre watershed (2.8:1 watershed to lake ratio) dominated by cultivated and water/wetland land uses. The lake has few residences, but is surrounded by cultivated land typically with a narrow forested riparian area (MPCA 2012b; page 14).

The Mainstem Planning Region also includes the Sand-Axberg Chain-of-Lakes, which includes three impaired waterbodies: Sand, Talac, and Sorenson. Yort (a.k.a. Sand) and Axberg Lakes are also in the chain, but not listed as impaired. The chain-of-lakes has been locally controversial since the early 1990's. Concern about high phosphorus concentrations flowing from Axberg Lake into Sand Lake were first brought to the attention of the MPCA in the fall of 1993. The northwest bay of Axberg Lake was diked off from the remainder of the lake in the early to mid-1960 and used as a chicken manure lagoon for an egg production facility. Discharge from Axberg Lake had been channeled through this lagoon and then north through several wetlands and ponds and into the southeast corner of Sand Lake. After assessing the situation, the MPCA hired a contractor in 1997, to install a 24 inch corrugated metal pipe to bypass the flow of Axberg Lake around the chicken manure pond. This effort resulted in significant reductions of phosphorus loading from Axberg Lake to the downstream receiving lakes (MPCA 2012b; page 24).

The increase in precipitation and runoff that affected lake levels within this watershed resulted in significant phosphorus loading to the lake system. In addition, a previously isolated portion of the watershed west of Clay County Road 118 began discharging into a pond (Chicken Drop Marsh) located immediately west of Axberg Lake. This pond was piped into the West Bay of Axberg Lake (location of spill) and this excess flow and phosphorus was discharged downstream into Sand, Talac, and Yort Lakes. In addition, the rise in lake levels in Sand and Talac Lakes has resulted in significant shoreline erosion.

Sand (Stump) Lake is a deep, 200 acre lake with a maximum depth of 36 feet located southwest of Lake Park, Minnesota. This lake underwent a large change in water elevation in the floods of the late 1990s; originally, a 28 feet deep lake that drained Axberg, Talac, and Sorenson Lakes, now it receives water only from Axberg and drains to Talac, reducing the watershed to 3,665 acres from an original drainage area of 5,419 acres. The lake has a 1,517 acre watershed dominated by cultivated and forested land uses. The lakeshore is very lightly developed, with the majority being a forested riparian area surrounded by cultivated land (MPCA 2012b; page 26).

Talac (Lee) Lake is a shallow, 99 acre lake with a maximum depth of 20 feet located southwest of Lake Park, Minnesota. The lake had a 1,757 acre watershed prior to rise in water level in 1997. The current watershed area, which drains Sand, Sorenson, and Axberg Lakes, is 5,419 acres (54.7:1 watershed to lake ratio) dominated by cultivated and forested land uses. Originally, the lake was 13 feet deep; during the rise in water levels in 1997s, the maximum depth rose to 20 feet. Talac Lake is still considered shallow in terms of assessment (MPCA 2012b, page 27).

Sorenson Lake is a shallow, 42 acre lake with a maximum depth of 10 feet located southwest of Lake Park, Minnesota. The lake has a 944 acre watershed dominated by cultivated and forested land uses. Originally, the lake was 7.8 feet deep; during the elevated water levels in the 1990s, the maximum depth rose to 9.8 feet. The lake is still considered shallow in terms of assessment (MPCA 2012b; page 29).

Gottenberg Lake is a shallow, 116 acre lake with a maximum depth of 11 feet located southwest of Lake Park, Minnesota. The lake has a 1240 acre watershed dominated by cultivated and forested land uses. The lake is surrounded by cultivated land, typically with a narrow forested riparian area (MPCA 2012b; page 15).

2.2.3 Northern Planning Region

The Northern Planning Region is located in the northwest corner of the BRW and is the most downstream portion (**Figure 2-6**). The Northern Planning Region is primarily in the LAP ecoregion and has extensive agricultural lands. The region starts where the South Branch and mainstem of the Buffalo River merge and ends where the Buffalo River flows into the Red River of the North. The region contains four impaired stream reaches in need of TMDLs. The four stream reaches include the Buffalo River-S Branch Buffalo River to Red River (AUID 09020106-501), County Ditch 2-Unnamed Creek to Buffalo River (AUID 09020106-556), County Ditch 39-Headwaters to Buffalo River (AUID 09020106-559), and County Ditch 10-Headwaters to Buffalo River (AUID 09020106-562).

The planning region contains 15 registered feedlots (nine are located in impaired AUIDs), with none requiring an NPDES Permit, and one WWTF (Spring Prairie Hutterite Colony WWTF). The WWTF is located in the upper drainage basin of AUID 09020106-556. A breakdown of relevant information by impaired AUID is provided in Table 2-4.

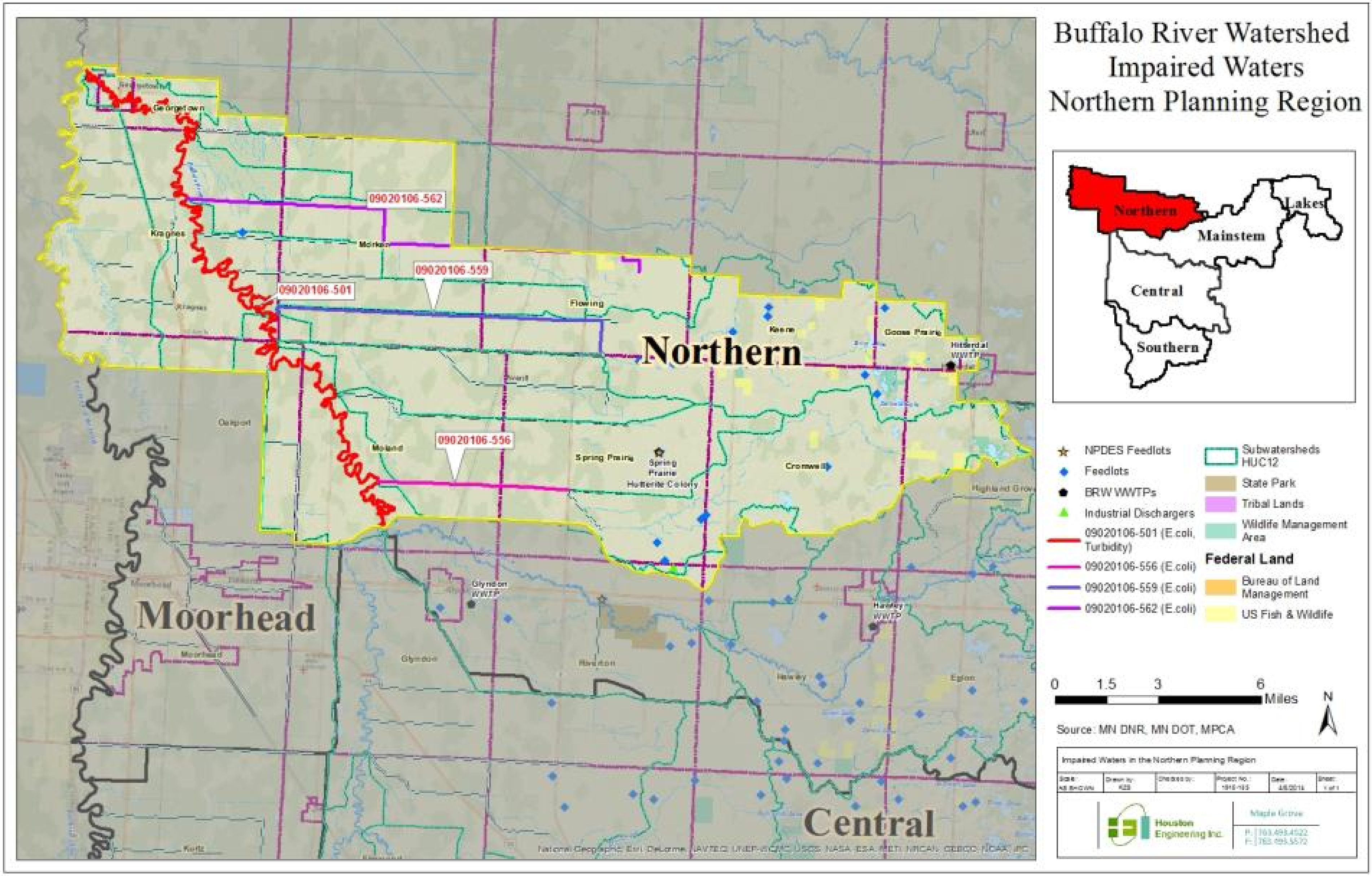

Figure 2-6: Northern Planning Region Impaired Waterbodies.

Table 2-4: Attributes of the drainage areas for impaired waters in the Northern Planning Region.

AUID	Immediate Drainage Area (acres)	Total Drainage Area (acres)	% Cropland[1]	# of Point Sources[1]	# of NPDES CAFOs[1]	# of Feedlots
09020106-501	22,582	724,098	81.2	0	0	0
09020106-556	3,781	22,954	94.6	1	0	0
09020106-559	28,427	28,427	77.1	0	0	9
09020106-562	12,835	12,835	92.1	0	0	0

[1]Values for immediate drainage areas

2.2.4 Central Planning Region

The Central Planning Region is located in the center of the BRW, with the Southern Planning Region to the south and the Mainstem Planning Region to the north (**Figure 2-7**). The Central Planning Region is located in the NCHF ecoregion in the east and the LAP ecoregion in the west. The planning region contains a section of the South Branch of the Buffalo River and three main tributaries (Whiskey Creek, Stoney Creek, and Spring Creek). The planning region transitions from lakes and forest in the east to extensive agricultural lands in the west.

The region contains nine impaired stream reaches in need of TMDLs: Whisky Creek-Headwaters to Township 137 Range 46 West South 18, West line (AUID 09020106-521), Whisky Creek-Township 137 Range 47 West South 13, east line to South Branch Buffalo River (AUID 09020106-509), Buffalo River, South Branch-Whisky Creek to Stony Creek (AUID 09020106-504), Stony Creek-Township 137 Range 45 West South 3, north line to Township 137 Range 46 West South 5, north line (AUID 09020106-523), Spring Creek-Unnamed Creek to Hay Creek (AUID 09020106-534), Hay Creek-Unnamed Creek to Spring Creek (AUID 09020106-519), Hay Creek-Spring Creek to Stony Creek (AUID 09020106-520), Stony Creek-Hay Creek to South Branch Buffalo River (AUID 09020106-502), and Buffalo River, South Branch-Stony Creek to Buffalo River (AUID 09020106-503).

The Central Planning Region contains 73 registered feedlots (40 of which are in the drainage areas of impaired AUIDs) with none requiring an NPDES Permit. The Barnsville WWTF is the only point source in the planning region and discharges into AUID 09020106-521, near the middle of the reach. A breakdown of relevant information by impaired AUID is provided in **Table 2-5.**

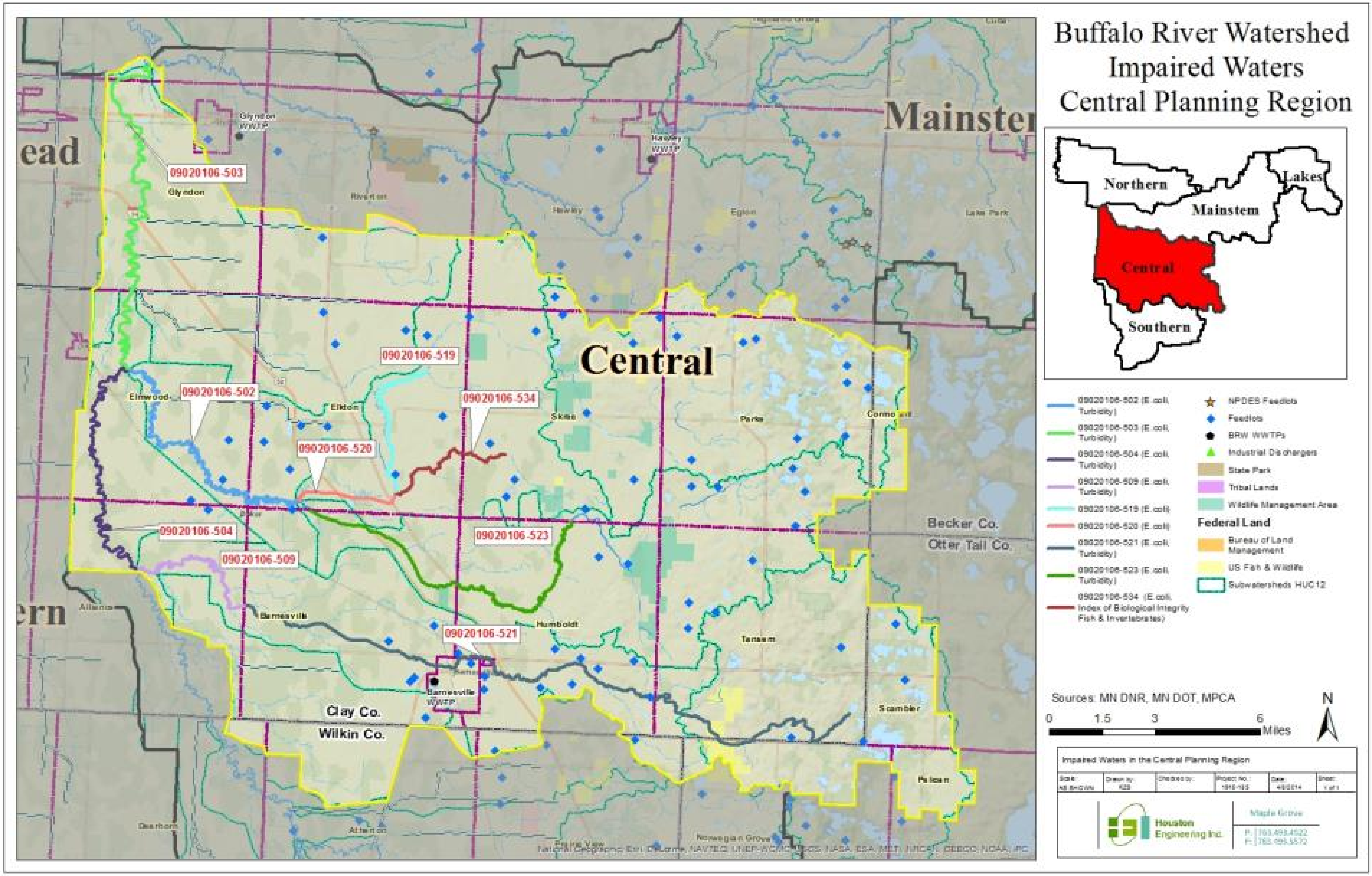

Figure 2-7: Central Planning Region Impaired Waterbodies.

Table 2-5: Attributes of the drainage areas for impaired waters in the Central Planning Region.

AUID	Immediate Drainage Area (acres)	Total Drainage Area (acres)	% Cropland[1]	# of Point Sources[1]	# of NPDES CAFOs[1]	# of Feedlots
09020106-521	22,295	45,596	50	1	0	12
09020106-509	10,165	72,938	90	0	0	2
09020106-504	11,074	295,163	89.8	0	0	2
09020106-523	14,586	30,660	74.5	0	0	2
09020106-534	6,203	6,203	75.6	0	0	4
09020106-519	18,424	58,439	74.2	0	0	5
09020106-520	18,424	58,439	74.2	0	0	5
09020106-502	12,186	101,285	89.5	0	0	8
09020106-503	13,778	330,062	87.6	0	0	0

[1]Values for immediate drainage areas

2.2.5 Southern Planning Region

The Southern Planning Region is located at the southernmost end of the BRW, with the Central Planning Region to the north (**Figure 2-8**). The Southern Planning Region is located in the NCHF ecoregion in the east and the LAP ecoregion in the west. The region contains four impaired stream reaches and one lake in need of TMDLs. The four stream reaches include headwaters of the South Branch-Buffalo River (AUID 09020106-508 and 09020106-505), and Deerhorn Creek (AUID 09020106-531 and 09020106-507). The only impaired lake is Jacobs Lake, located near the eastern edge of the planning region.

Field reconnaissance surveys found that field sediment sources were a significant cause of excess turbidity and TSS in the headwater streams of this area, including Deerhorn Creek and the Upper South Branch Buffalo River. Stream Power Index ground-truthing in these watersheds found numerous instances where gully erosion sent hundreds of cubic yards of soil into the receiving stream. These gullies were typically located where first or second order streams were being farmed through. These farmed-through headwater streams are prone to severe erosion, as any storm event with the proper combination of intensity and duration will send a flush of water through the location of the prior stream bed and carve out a new channel in the cultivated soil.

The planning region contains 23 registered feedlots, with none requiring an NPDES Permit. There are no point sources in the planning region. A breakdown of relevant information by impaired AUID is provided in Table 2-6**.** It should be noted, some of the AUIDs' drainage areas overlap due to tributaries connecting before the end of the connecting AUID. This is important in the sum of number of feedlots (31) listed in **Table 2-6** exceeding the total number of feedlots (23) provided above.

Table 2-6: Attributes of the drainage areas for impaired waters in the Southern Planning Region.

AUID	Immediate Drainage Area (acres)	Total Drainage Area (acres)	% Cropland[1]	# of Point Sources[1]	# of NPDES CAFOs[1]	# of Feedlots
09020106-508	24,873	24,873	77.5	0	0	10
09020106-531	12,510	12,510	64.7	0	0	1
09020106-507	16,974	22,768	74.1	0	0	8
09020106-505	11,518	109,866	93.4	0	0	10
56-1039-00 (Jacobs Lake)	3,099	5,794	38.9	0	0	2

[1]Values for immediate drainage areas

Jacobs Lake is a shallow, 121 acre lake with a maximum depth of 17 feet located west of Pelican Rapids, Minnesota. The lake has a 5,795 acre watershed (48:1 watershed to lake ratio) dominated by cultivated and forested land uses. The lake has a few residences and is surrounded by a forested fringe and cultivated land (MPCA 2012b; page 43).

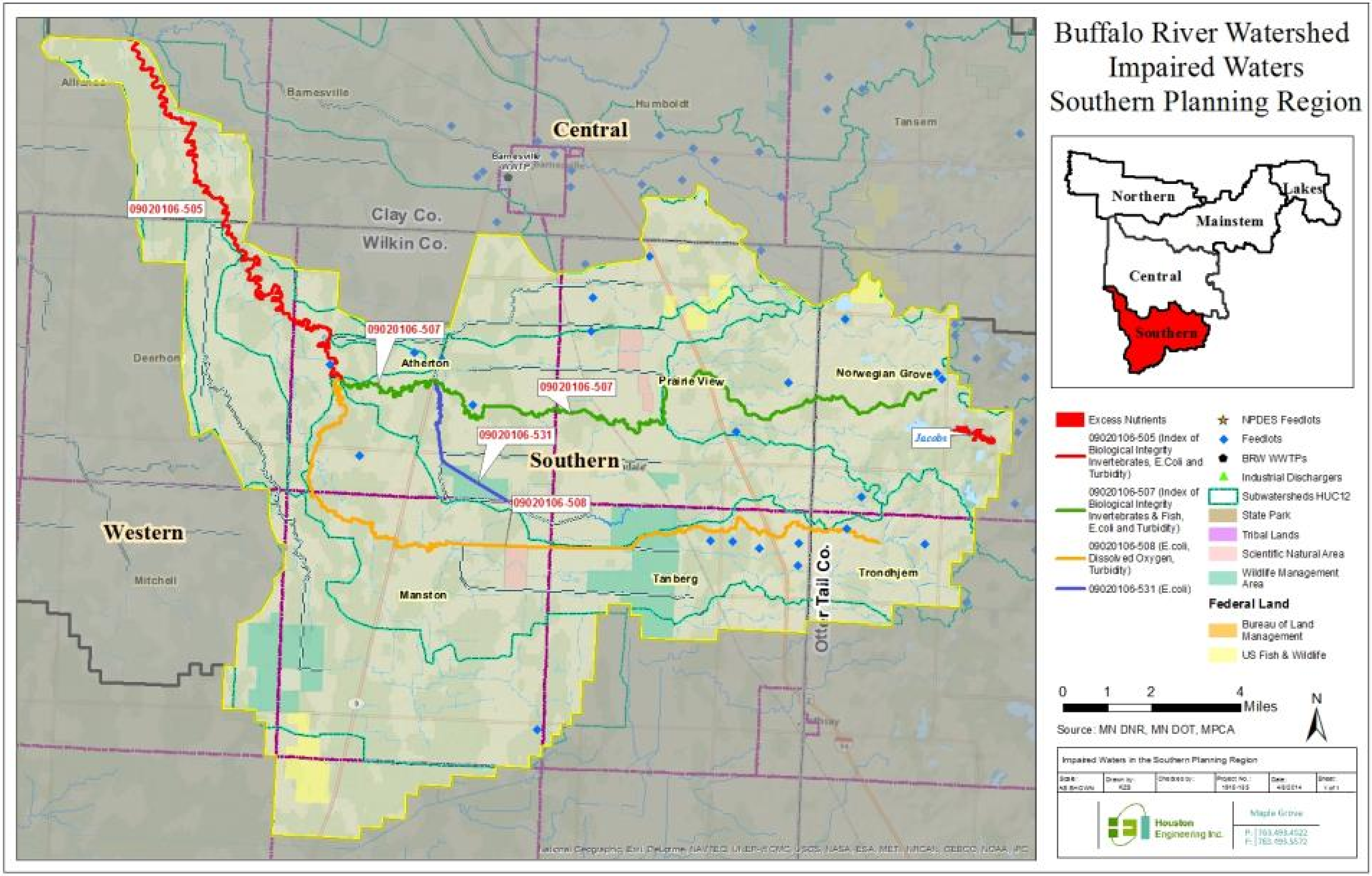

Figure 2-8: Southern Planning Region Impaired Waterbodies.

2.3 Registered and Permitted Facilities

The MPCA requires that animal feeding operations with less than 1,000, but more than 50, AUs (and outside of shoreland areas) be registered with the MPCA. Facilities with more than 10 AUs and inside shoreland areas are also required to register under this program. These facilities are subject to state feedlot rules, which include provisions for registration, inspection, permitting, and upgrading. Shoreland is defined in Minn. Stat. § 103F.205, to include: land within 1,000 feet of the normal high-watermark of lakes, ponds, or flowages; land within 300 feet of a river or stream; and designated floodplains (MPCA 2009). The BRW has 205 registered feedlot operations.

Of the 205 registered feedlots in the BRW, seven also require an NPDES Permit. The MPCA also regulates the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation wastes from these facilities (MPCA 2011). The NPDES CAFO Permits require zero discharge, meaning no pollutants should escape the facility's site.

The NPDES program is a nation-wide federal regulatory program stemming from the Clean Water Act. Under NPDES, all facilities that discharge pollutants from any point source into waters of the United States are required to obtain a permit. Point source discharges include stormwater and related pollution from municipal, commercial, industrial, and agricultural sources. Effluent limits, which control the discharge of pollutants to receiving waters, are either technology-based or water quality-based (EPA 2002). In Minnesota, this program is implemented by the MPCA. In addition to the seven CAFOs with NPDES Permits, the BRW also has eight WWTFs and one industrial wastewater discharger that require NPDES Permits. Details on these permitted facilities are contained in **Section 3.3**.

According to the MPCA's data, there are 2,141,831 agricultural animals (in registered and permitted facilities) in the BRW. The majority of these animals are birds (2,092,190), followed by bovine (26,847) and all other animals (22,794). **Table 2-7** contains a summary of this data, by county. **Figure 2-9** shows the location of the facilities. Currently, seven livestock facilities in the BRW operate under NPDES Permits. These facilities contain 1,478,336, or 69% of the agricultural birds in the watershed. Per their permit requirements, these facilities must be designed to totally contain all surface water runoff and have manure management plans.

Table 2-7: Livestock population estimates for BRW, by county

	Becker	Clay	Otter Tail	Wilkin	Watershed Total
MPCA-Registered Facilities[1]					
Bovine					
Beef	3,413	11,810	643	2,140	**18,006**
Dairy	2,934	3,060	1,744	373	**8,111**
Birds					
Broilers	60	100	25	75	**260**
Layers	20	305,552	0	20	**305,592**
Turkey	48,000	0	140,002	120,000	**308,002**
Goats/Sheep	80	415	0	0	**495**
Horses	51	155	13	7	**226**
Pigs	25	15,856	12	0	**15,893**
NPDES-Permitted Facilities[2]					
Bovine					
Dairy		730			**730**
Birds					
Broilers		2,000			**2,000**
Layers		1,339,000			**1,339,000**
Turkey		137,336			**137,336**
Pigs		6,180			**6,180**

[1] Facilities outside shoreland with >50 and <1,000 AUs or within shoreland and having >10 AUs;

[2] Facilities with >1,000 AUs

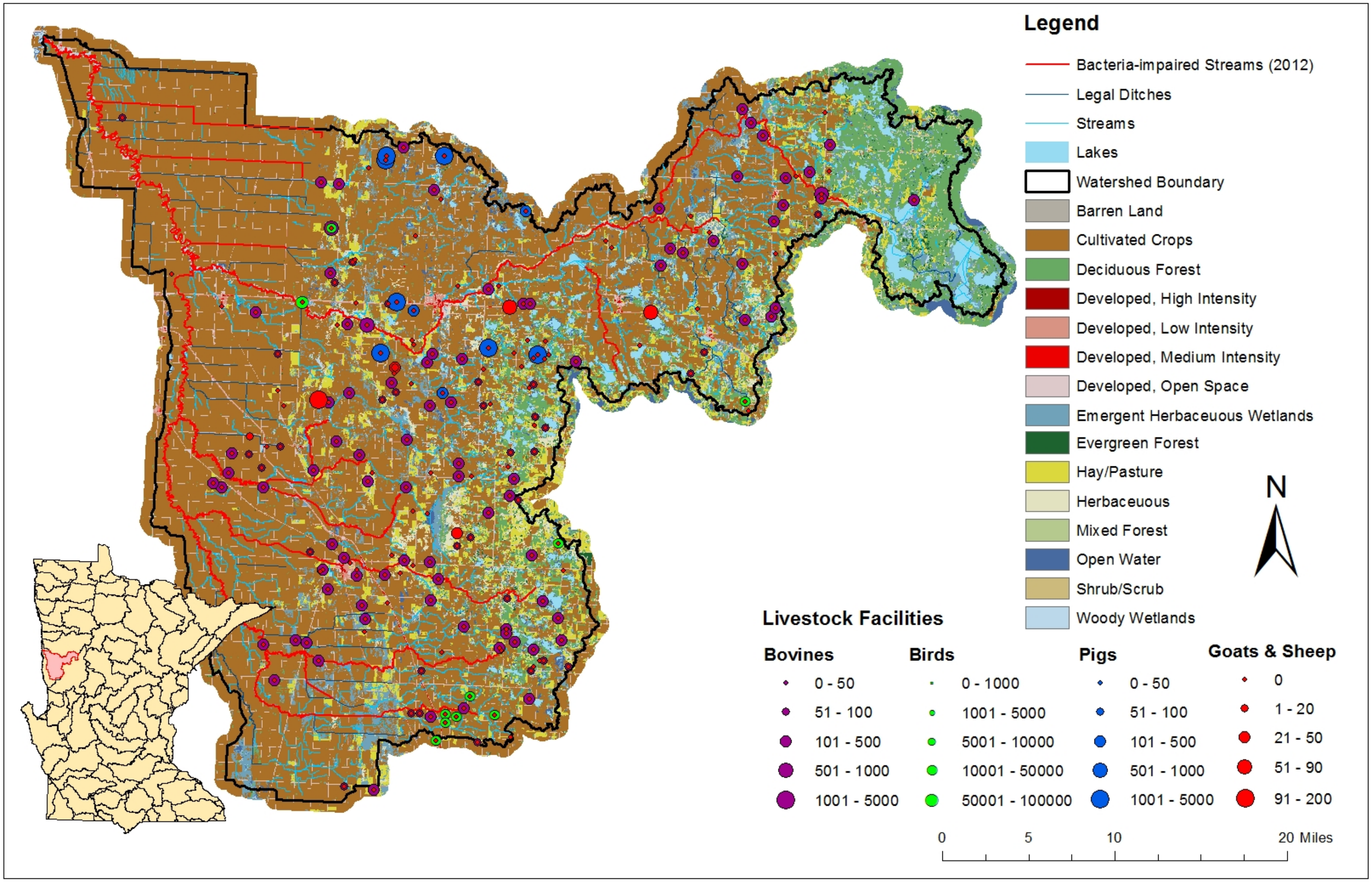

Figure 2-9: BRW NPDES-permitted and MPCA-register livestock facilities.

2.4 Future Growth

The primary economic force in the BRW is agriculture. Farms in the western portions of the watershed tend to be large, cash crop farms, where smaller, livestock farms tend to be more common in the east. The watershed is primarily agricultural little change in land use is expected in the future. Like much of the Red River Valley, land use in the BRW has changed very little in recent years. Analysis of the 2001 and 2006 NLCD dataset show about 1% change in land uses in the BRW between the years. Most of this small changes occurred in increases in cropland and wetland areas and decreases in forest and urban areas.

Small changes are occurring in the demographics of the watershed. Rural areas have been experiencing a general decline in population since the 1960s, due to changes in farm practices and the difficulty in finding employment in small towns. Other areas in the BRW have seen increases in growth, typically around the eastern portions of the watershed, most likely due to the increasing popularity of the lakes and vacation homes. Based on information from the Minnesota State Demographic Center, areas that are more urban and more recreationally sought (lakes) are increasing in population and the more rural areas are decreasing (HEI 2010; page 2-3).

3 Methodology for Estimating TMDL Components

TMDLs are developed based on the following equation:

$$\textbf{TMDL = LC = ∑WLA + ∑LA + MOS + RC}$$

Where:

LC = loading capacity, or the greatest amount of a pollutant a waterbody can receive and still meet water quality standards (see **Section 3.1**);

WLA = Wasteload allocation, or the portion of the loading capacity allocated to existing or future permitted point sources (see **Section 3.2**);

LA = load allocation, or the portion of the loading capacity allocated for existing or future nonpoint sources (see **Section 3.3**);

MOS = margin of safety, or accounting for any uncertainty associated with attaining the water quality standard. The margin of safety (MOS) may be explicitly stated as an added, separate quantity in the TMDL calculation or maybe implicit, as in a conservative assumption (EPA 2007) (see **Section 3.4**);

RC = reserve capacity, or the portion of the TMDL that accommodates for future loads;

The following sections discuss each component of the BRW TMDLs in detail. Summaries of the actual TMDL allocations for *E. coli* are found in **Section 4.2**, for TSS are found in **Section 4.3**, and TP are found in **Section 5.2**.

3.1 Data Sources

Multiple data sources were used in developing the BRW TMDLs. Empirical and simulated values were used to compute both current and allowable loads in the impaired waterbodies. Uncertainty associated with these data was then used to develop MOSs and RCs.

3.1.1 EQuIS

The empirical water quality data used in this work was obtained through the MPCA's Environmental Quality Information System (EQuIS). EQuIS stores water quality data from more than 17,000 sampling locations across the state, containing information from Minnesota streams and lakes dating back to 1926. EQuIS stores data collected by the MPCA, partner agencies, grantees, and citizen volunteers. All water quality sampling data utilized for assessments, modeling, and data analysis for this report, and reference reports, are stored in this database and are accessible through the MPCA's EDA (Environmental Data Access) website[5].

[5] http://www.pca.state.mn.us/index.php/data/environmental-data-access.html.

The MPCA conducts intensive watershed monitoring (IMW) for two years in all 81 watersheds in Minnesota on a 10-year cycle, i.e. every major watershed is sample for 2 years, once every 10-years. The BRW IMW occurred in 2009 and 2010. To supplement between intensive monitoring years, the MPCA coordinates two programs aimed at encouraging citizen surface water monitoring; i.e., the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Sustained citizen monitoring can provide the long-term picture needed to help evaluate current water quality status and trends. The advance identification of lake and stream sites that will be sampled by agency staff provides an opportunity to actively recruit volunteers to monitor those sites, so that water quality data collected by volunteers are available for the years before and after the intensive monitoring effort by the MPCA staff (MPCA 2012a; page 14).

Data from the current 10-year assessment period (2002 through 2011) for the time period consistent with the water standard were used for development of this TMDL. For *E. coli*, data only collected during the months April through October were used while for the TSS standard, only data collected from April through September were used. Lake nutrient data is collected from May through September, but only June through September data were used for assessment and in development of the nutrient TMDLs to correspond to the period of the standard.

According to EQuIS and the MPCA spatial datasets[6], there are 72 biological sites, 104 lake sites, 97 stream water quality sites, 43 discharge sites, and 6 USGS gauging stations located in the BRW (**Figure 3-1**). Not all sites were used in the development of the BRW's TMDLs. Sites were excluded for various reasons: 1) their records were outside of the assessment period (2002 through 2011); 2) the sites were not located in impaired stream reaches or lakes; or 3) a site did not have relevant observed data. Table 3-1 **Table 3-1** lists the water quality stations and time periods of available data used to develop the LDCs by AUID. Only sites located within the 15 impaired lakes (**Table 1-3**) were used for the development of the lakes TMDLs. Three of the six USGS stations (05061000, 05061500, and 05062000) provided in the MPCA's spatial information had enough continuous data to be used for the model and LDC development. **Figure 3-1** shows the locations of all sites in EQuIS and the locations of the sites used in development of this TMDL. Additional discussion on the data used to develop the LDCs, lake models, and LAs is provided in **Sections 4.1 and 5.1**).

[6] http://www.pca.state.mn.us/index.php/data/spatial-data.html

Table 3-1: Water quality sites used to develop load duration curves by AUID

AUID (09020106-XXX)	Water Quality Monitoring Locations	*E. coli* Data	TSS Data
501	S000-174, S002-125, S002-708, S003-693	2008-2009	2001, 2003-2009
502	S002-711, S003-694	2009	2005-2007, 2009
503	S004-148, S002-709	2009-2010	2006-2009
504	S004-147, S005-608	2009-2010	2006-2009
505	S003-145	2008-2009	2002-2009
507	S003-151	2008-2009	2002-2009
508	S003-148	2009	2002-2009
509	S005-607	2009-2010	2009
511	S005-133	2008-2009	---
515	S005-135	2008-2010	---
519	S003-313	2009	---
520	S003-316	2008-2010	---
521	S002-112, S002-111,S005-611	2006, 2008-2009	2002-2009
523	S003-312	2008-2009	2003-2009
531	S005-060	2008-2010	---
534	S003-315	2009-2010	---
556	S005-609	2009-2010	---
559	S005-605	2009-2010	---
562	S005-610	2009-2010	---
593	S004-105	2008-2009	2008-2009
594	S003-155, S004-145	2008-2009	2002-2009
595	S002-700, S003-152	2008-2009	2002-2009

"---" = Not impaired for turbidity/TSS

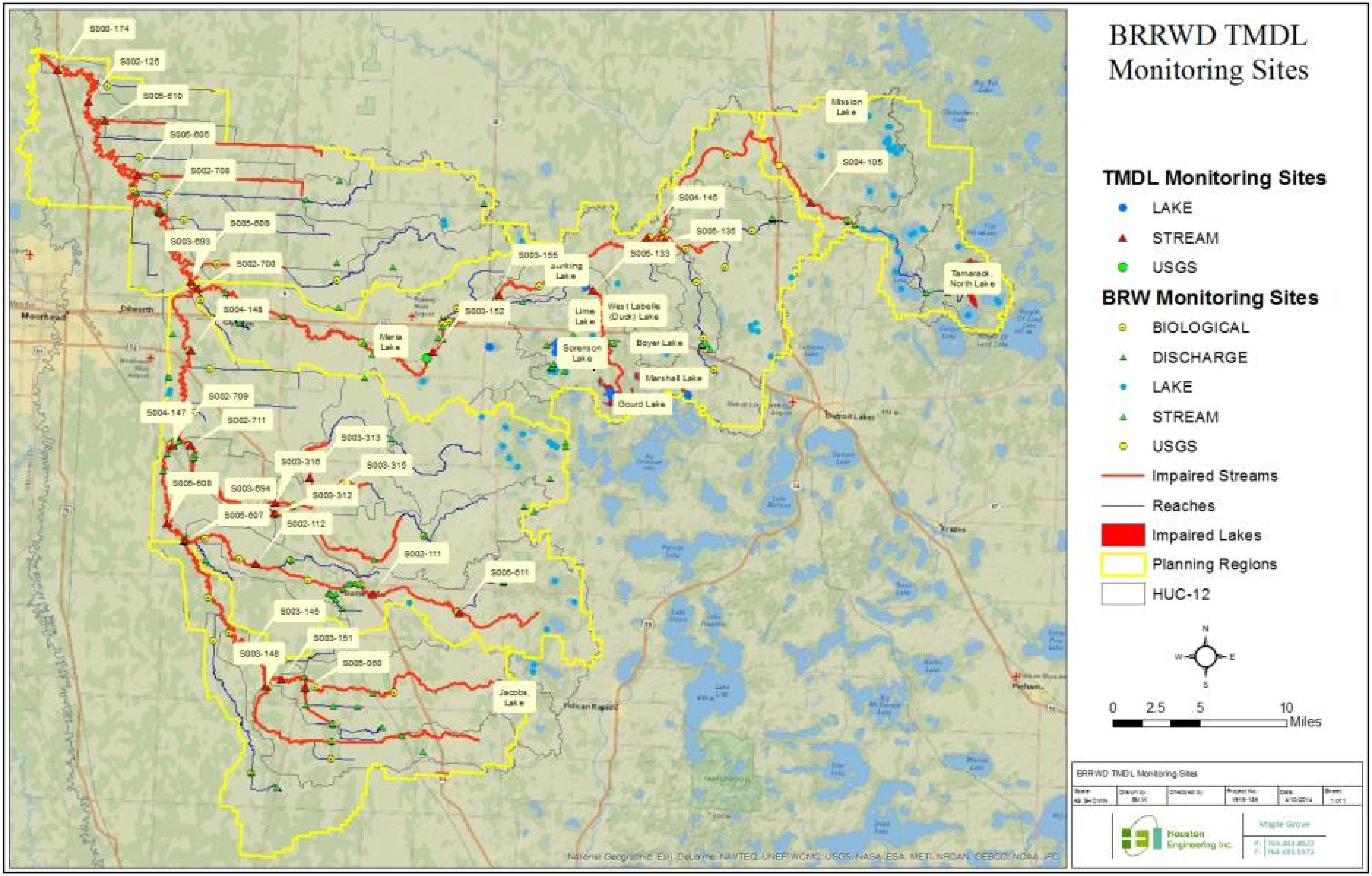

Figure 3-1: Monitoring location in the BRW.

3.1.2 Soil and Water Assessment Tool (SWAT)

Soil and Water Assessment Tool (SWAT) is a watershed scale model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time (Neitsch et al., 2011). The 2009 version of the SWAT model was used to develop two separate models for the South Branch and Upper Mainstem of the Buffalo River. The Upper Mainstem SWAT model covered the mainstem of the Buffalo River from the headwaters to the confluence with the south branch and included the Lakes and Mainstem Planning Regions. The South Branch SWAT model included all other areas, i.e. all of the South Branch of the Buffalo River, through the confluence with the mainstem, and to the outlet into the Red River of the North. The South Branch Model included the Southern, Central, and Northern Planning Regions.

The primary sources of climate data for the BRW SWAT models were from the EPA's Better Assessment Science Integrating point and Non-point Sources[7] (BASINS) program. At the time of development, the BASIN's climate data extended through 2006. To extend the SWAT model through 2009, additional weather data were appended to those data from the BASINS. Precipitation and temperature records at the various stations were extended using data downloaded through a tool maintained by the Minnesota Climatology Working Group[8]. Wind speed and relative humidity data were downloaded from the National Climate Data Center[9] for various. Solar radiation data was filled by inputting no data values (-999) into the SWAT model and allowing the Weather Generator to substitute values.

The basic operational unit in the SWAT model is a polygon comprised of a unique combination of land use, slope, and soil type; these polygons are referred to as hydrologic response units, or HRUs. Land cover data for the BRW were derived from the 2006 National Land Cover Dataset[10]. Soils data were derived from county-level soil survey map units (SSURGO) downloaded from the web soil survey[11]. Overland slopes within the BRW were determined from a 10m digital elevation model obtained from the national seamless data server[12]. Spatial data (land use, SSURGO map units, and slope classes) that comprised less than 5% of a subbasin were excluded from final HRU delineation. For crop management practices, fertilizer application rates were based on typical practices for various Minnesota locations summarized in the Minnesota Department of Agriculture FANMAP Surveys[13]. Manure application rates were based on the estimated production of AUs reported for the BRW.

The SWAT models were developed to simulate hydrology, sediment, and TP for the period 1995 through 2009. The models were calibrated using data from 2001 through 2006 and validated with data from

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[7] http://water.epa.gov/scitech/datait/models/basins/
[8] http://climate.umn.edu/hidradius/radius.asp
[9] http://www.ncdc.noaa.gov/cdo-web/search
[10] Available from the United States Geological Survey (USGS) seamless data warehouse: http://seamless.usgs.gov/
[11] http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm
[12] http://seamless.usgs.gov/
[13] Farm Nutrient Management Assessment Program; http://www.mda.state.mn.us/protecting/soilprotection/fanmap.aspx

1996 through 2000, with 1995 being a model warm-up period to initialize the system. The hydrologic calibration was performed at the three locations corresponding to USGS gauging stations: USGS #05061000 at Hawley, Minnesota in the Mainstem model, USGS# 05061500 at Sabin, Minnesota in the South Branch model, and USGS #05062000 near Dilworth, Minnesota in the South Branch model. Five water quality sites were used to calibrate sediment and TP: S002-111, S003-145, S003-316, S002-125, and S003-152. Additional information on the model development of the BRW SWAT models can be found in SWAT models' final report (HEI 2013b, pages 2-8).

The SWAT models were used for two primary purposes when developing the TMDLs. Flows at the downstream end of the AUIDs extracted from SWAT were used to develop the LDCs. Model daily discharges were paired to concentrations occurring on the same day for use in LDC development. Runoff volumes and loadings were extracted and used to develop the hydrologic budgets and nutrient mass balances as input to the lake models (CNET models), The runoff volumes extracted from the SWAT model were extracted for location near/at the end of AUIDs and used, in conjunction with observed sediment and bacteria concentration data, to develop the LDCs. Climate information, surface water hydrology and nutrient loading results from the SWAT model were used as inputs in the CNET lake modeling. Additional information on the model development of the BRW SWAT models and its data sources can be found in the final report (HEI 2013b).

3.1.3 CNET

Individual lake models were developed for each impaired lake in the BRW using the in-lake water quality model CNET. CNET is a modified, spreadsheet, version of the U.S. Army Corps of Engineers (USACE's) BATHTUB model. The CNET modeling implements a Monte Carlo approach, resulting in stochastic simulations. The Monte Carlo approach allowed selected modeling inputs to vary, based upon known or assumed statistical distributions, and result in distributions of in-lake eutrophication conditions based on the distributions of the input parameters. The stochastic modeling approach reflects the variability in model parameters inherent in natural systems (e.g., climate) and allows for a more realistic prediction of long-term water quality condition. Crystal Ball[14] was used to perform the Monte Carlo simulations. The lake models were used to estimate the TP load reductions necessary to meet current water quality lake eutrophication standards in each lake.

CNET requires lake morphometric characteristics (mean depth, surface area) drainage area, climate/hydrologic information (precipitation, evaporation, runoff, and atmospheric deposition), and nutrient (TP) loadings (surface runoff loads, tributary loads, and any point sources). The primary data sources used for lake morphometric characteristics (surface area, mean depth) and drainage area, total drainage area) were the Minnesota Department of Natural Resources (DNR) LakeFinder website[15] and the DNR Geographic Information Systems (GIS) online data deli [16].

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[14] A proprietary software developed by Oracle;http://www.oracle.com/technetwork/middleware/crystalball/overview/index.html
[15] http://www.dnr.state.mn.us/lakefind/index.html
[16] http://deli.dnr.state.mn.us

Annual precipitation depths, evaporation depths, surface runoff flows and loadings, and tributary flows and loadings were extracted from the BRW SWAT models for subwatersheds containing the drainage basins of the lakes in the BRW. The data extracted was for the period 1996 through 2009. The depths, flows, and loadings were extracts in unit form (i.e. inches per year, cubic meters per hectare per year, kilograms per hectare per year). Total flows and loads were calculated by taking the drainage areas times the unit flows and loads.

The CNET lakes models were calibrated to the average TP, chl-*a*, and Secchi disk depths of the observed data (from the EQuIS database) in the most recent assessment period (2002 through 2011). Most lakes only had two years of monthly observations during the summer months. A complete in-depth discussion on the data sources and observed water quality data used in the lake modeling (CNET) can be found in the *Buffalo River Watershed Lakes Eutrophication Modeling Report* (HEI 2013d, pages 8-16).

3.1.4 Load Duration Curves

The load duration curve (LDC) approach was used to compute load capacities and needed load reductions for *E. coli* and TSS. To adequately capture different types of flow events and pollutant loading during these events five flow regimes were identified per EPA guidance (EPA 2007; page 2): High flow (0% to 10%), Moist Conditions (10% to 40%), Mid-range Flows (40% to 60%), Dry Conditions (60% to 90%), and Low Flow (90% to 100%). More discussion on LDCs is provided in **Section 3.2**.

The LDC approach is useful when computing TMDLs because it provides a visual link between streamflow and loading capacity, accounts for the effect in loading by changes in streamflow patterns, and provides a link between water quality and key watershed processes. Under the LDC approach, the loading capacity of a stream reach is essentially the curve itself. The loading capacity on any given day is determined by the flow and its frequency of exceedance. The summary flow regimes, described above, provide a simplified summary through the discrete loading capacity points by zone (EPA 2007; page 11).

LDC analysis is similar to flow duration curve analysis (FDC). FDC analysis looks at the cumulative frequency of historic flows and plots flows over the exceedance probability scale. The probability of exceedance scale ranges from 0% to 100% with high flows near 0% and low flows being near 100% exceedance (e.g. the maximum flow during the time period will be near 0% exceedance). LDC analysis is the same but applies the water standard to the flows to obtain a load for a given flow frequency.

Benefits of LDC analysis include: (1) the loading capacities are calculated for multiple flow regimes, not just a single point; (2) use of the method helps identify specific flow regimes and hydrologic processes/patterns where loading maybe a concern; and (3) ensuring that the applicable water quality standards are protective across all flow regimes. Some limitations with the LDC approach exist: (1) the approach is limited in the ability to track individual loadings or relative source contributions; (2) is appropriate when a correlation between flow and water quality exists and flow is the driving force behind pollutant delivery mechanics; and (3) issues may arise under low flow conditions, loading capacity, and WLAs (see **Section 3.3.1.1**).

For the BRW, the following data sources were used to develop the LDC. Observed daily flow data are limited in the BRW. Therefore, simulated daily mean flows from the BRW SWAT model (HEI 2013b) were used to create the LDCs. The flows form the SWAT model for any given AUID was taken at downstream end of the AUID. In order to best capture the flow regimes of each AUID, this entire record of the SWAT model (1996 through 2009) was used in development of the LDCs. The water quality data used was obtained from the MPCA through their EQuIS database (as described above). All water quality sites within an AUID were used in the LDC analysis. For the purposes of creating of the LDCs, only water quality data from the most recent completed assessment period (2002 through 2011) were used. While data exists for bacteria and TSS spanning from 2002 through 2010, the SWAT model only estimates flows for 1995 through 2009; therefore, the LDCs are based on bacteria and TSS data from the overlapping time period of 2002 through 2009.

3.2 Loading Capacity

For this TMDL, load capacities for the stream reaches where estimated using the LDC approach. For lake nutrient loading capacity, the CNET lake model was utilized. The following sections discuss methods used to develop the loading capacities in the BRW's impaired waterbodies. Load capacities for TSS and *E. coli* were estimated using the LDC approach. **Appendix C** provides a memorandum on the development of the LDCs, as well as the LDCs for impaired AUIDs in the BRW.

3.2.1 TSS

The LDC approach was used to compute needed TSS load reductions in the BRW. To adequately capture different types of flow events and pollutant loading during these events five flow regimes were identified per EPA guidance: High flow (0% to 10%), Moist Conditions (10% to 40%), Mid-range Flows (40% to 60%), Dry Conditions (60% to 90%), and Low Flow (90% to 100%). In the case of County Ditch 10 (an ephemeral ditch; AUID 09020106-562), these flow regimes were adjusted to better reflect flow patterns in the reach. The reach experiences zero flow a considerable amount of the year and, therefore, required that the flow regimes to be redefined to account for the zero flow (i.e. high flows (0% to 10%), moist condition (10% to 30%), mid-range (30% to 50%), dry conditions (50% to 70%), and low flows (70% to 100%).

The LDC approach was used to compute the necessary load reductions under the TSS standard. Conversion factors are shown in **Table 3-2**. The TSS standard LDCs were created for the Southern Region TSS standard of 65 mg/L. The TSS standard LDCs were calculated using combined TSS and equivalent turbidity data (see **Section 3.2.1.1**) collected during the assessment period. The standard only applies during the months of April through September. Therefore, the TSS standard LDCs were created using TSS/turbidity data and flow data from this period. As with the other LDCs, a 10% MOS was applied.

Table 3-2: Converting flow and TSS concentration to TSS load.

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

3.2.1.1 Expanding TSS dataset with turbidity

Turbidity is a measure of water clarity, determined by the amount of light that is scattered by suspended particles. Suspended materials including soil particles, algae, plankton, microbes, and other substances all affect turbidity. Turbidity is not a direct measurement of the amount of suspended particles present in the water; however, there is typically a strong correlation relationship between turbidity and TSS. A common practice in developing TSS TMDLs with limited data is to expand the dataset with converted turbidity values. Turbidity data was used only for days when TSS was not measured. That is the approach used in this TMDL.

Using all available paired turbidity and TSS data in the BRW, a linear turbidity-TSS relationship was developed (**Figure 3-2**). The resultant equation was then used to convert turbidity values to equivalent TSS values. **Equation 1** shows the result of this analysis. The R^2 value for this equation is 0.8756.

Equation 1. Estimated TSS based on turbidity/TSS relationship (mg/L)

$$\text{TSS [mg/L]} = 0.9536 * \text{turbidity [NTU or NTRU]} + 8.1967 \qquad [1]$$

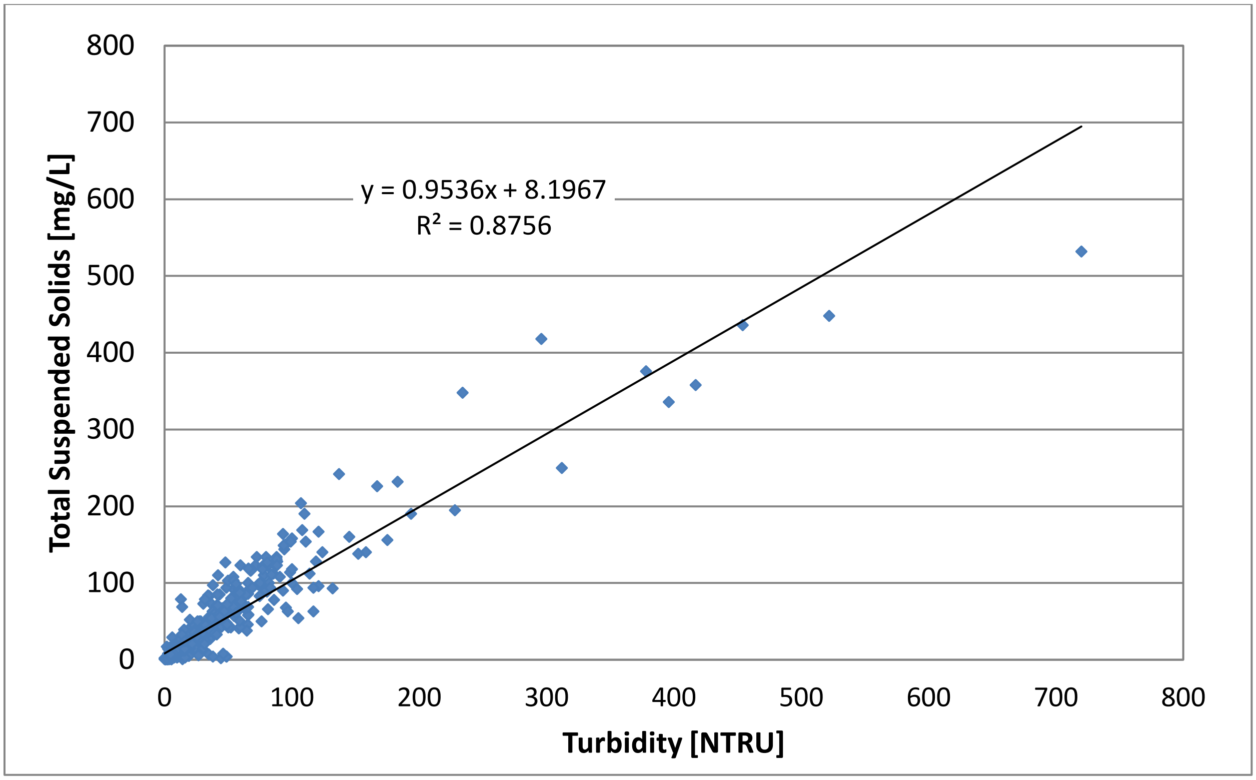

Figure 3-2: Relationship between turbidity and TSS for the BRW.

3.2.2 *E. coli*

The LDC approach was also used to compute the needed bacteria load reductions in the BRW. In this case, the loading capacity was calculated using both the instantaneous standard of 1260 organisms/100 mL and the geometric mean (i.e., geomean) standard of 126 organisms/100 mL. Given that all bacteria impairments in the BRW occur under the geomean standard (see **Table 4-39**), the load reductions computed under the geomean scenario were used to set the TMDLs. Conversions for computing bacterial loads are shown in **Table 3-3**.

Table 3-3: Converting flow and concentration into bacterial load.

Load (org/day) = Concentration (organisms/100mL) * Flow (cfs) * Factor			
Multiply by **28.316** to convert	ft^3 per second	→	L/sec
Multiply by **1000** to convert	Liters per second	→	mL/sec
Divide by **100** to convert	Milliliters per second	→	organisms/sec
Multiply by **86,400** to convert	organisms per second	→	organisms/day

To match the time period when the water quality standard is applicable, the *E. coli* LDCs were created using flow and *E. coli* water quality data from April through October only. Individual loading estimates were calculated by combining the observed *E. coli* concentration and simulated mean daily flow value on each sampling date. The load estimates were separated by month and by station, mainly for purposes of display on the curve (see **Appendix C**). "Allowable" loading curves were created for both the instantaneous (1260 organisms/100mL) and monthly geometric mean, i.e., geomean, (126 organisms/100mL) criteria by multiplying each "allowable" concentration by the simulated mean daily flow values and ranking the flows. A 10% MOS was applied to each of the "allowable" loading curves.

3.2.3 Lakes, Excess Nutrients

Lake loading capacities were computed using the CNET modeling program. CNET is a spreadsheet version of the BATHTUB model currently available as a "beta" version from Dr. William W. Walker[17]. Like BATHTUB, CNET is a steady-state model that simulates eutrophication-related water quality conditions in lakes and reservoirs. The primary modification to the CNET model during this effort was to implement a Monte Carlo approach, resulting in stochastic simulations. The Monte Carlo approach allowed selected modeling inputs to vary, based upon known or assumed statistical distributions, and result in distributions of in-lake eutrophication conditions based on the distributions of the input parameters. The stochastic modeling approach reflects the variability in model parameters inherent in natural systems (e.g., climate) and allows for a more realistic prediction of long-term water quality condition. Crystal Ball[18] was used to perform the Monte Carlo simulations.

The CNET models were calibrated to the assumed average condition in each lake using the average observed in-lake water quality conditions and watershed inputs (flow and TP loading) from 13 years (1997 through 2009) simulated in the BRW SWAT model. After the models were calibrated, the lake's loading capacity was found by systematically reducing the loading until the water quality standards (including the 5% MOS) were meet. The resulting loading capacity for impaired lakes in the BRW is provided in **Table 3-4**.

Table 3-4: Observed and modeled lake conditions as well as loading estimates for observed conditions and loading capacities to meet the phosphorus standards.

Lake	Observed Mean TP (ug/L)	Predicted TP (ug/L)	Estimated Annual Phosphorus Load (lbs)	Predicted TP (ug/L) Calibrated to Standard	Annual Phosphorus Load Capacity (lbs)	Percent Phosphorus Load Reduction to Achieve Standard (%)
Boyer	54.4	54.5	97.0	40	58.2	40%
Forget-Me-Not	82.4	82.6	1,907	60	1,107	42%
Gottenberg	68	67.3	516	60	439	15%
Gourd	113.3	113.2	192	60	61.7	68%
Jacobs	86.8	87.1	218	40	48.5	78%
Lime	137.7	137.7	18,768	60	3,754	80%
Lake Maria	199.2	200	5,747	90	1,609	72%

[17] URL: http://www.wwwalker.net/bathtub/help/bathtubWebMain.html

[18] A proprietary software developed by Oracle;http://www.oracle.com/technetwork/middleware/crystalball/overview/index.html

Lake	Observed Mean TP (ug/L)	Predicted TP (ug/L)	Estimated Annual Phosphorus Load (lbs)	Predicted TP (ug/L) Calibrated to Standard	Annual Phosphorus Load Capacity (lbs)	Percent Phosphorus Load Reduction to Achieve Standard (%)
Marshall	41.8	41.6	278	40	278	0%
Mission	120.3	119.7	256	60	101	60%
Sand (Stump)	188.1	34.2	9,409	40	659	93%
Sorenson	217.7	188.5	697	60	187	73%
Stakke	64.8	218.2	2,326	60	2,255	3%
Stinking	308.6	64.2	30,483	90	4,877	84%
Lee (Talac)	125.8	125.6	1,986	60	955	52%
West LaBelle	89.3	89.2	137	60	75.0	45%

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. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson 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.

3.3 Wasteload Allocation

There are 16 NPDES-permitted point sources in the BRW; 8 WWTFs, 1 industrial wastewater discharger, and 7 permitted CAFOs. Explicit WLAs were computed for each of these facilities, based on their permitted limits. Other activities requiring a WLA in the watershed are associated with construction and industrial stormwater, "straight pipe septic systems", and municipal separate storm sewer systems (MS4s).

This TMDL assumes that 0.1% of the BRW's land area contributes construction or industrial stormwater at any given time. Although it is assumed that provisions of the general permits associated with these activities provide reasonable assurance that they will not cause or contribute TSS and nutrients (TP) above the applicable water quality standards, a portion of the WLA is explicitly reserved for these activities. Details on this TMDL's WLAs and appropriate measures for achieving compliance follow.

3.3.1 Wastewater Treatment Facilities

3.3.1.1 Current Wastewater Treatment Facilities

The BRW contains eight "minor" (as defined by the MPCA) WWTFs. Locations of these WWTFs are shown in **Figures 2-3** to **2-7.** These facilities are all pond-type plants with primary and secondary treatment lagoons. Per their permits, these facilities are allowed to discharge only during certain time periods during the year: March 1 through June 30 and September 1 through December 31. They are listed in **Table 3-5.**

Table 3-5: Relevant WWTF permits in the TMDL.

Facility	Permit Number	12-Digit HUC	City / Township	System Type	Secondary Pond size (acres)
Audubon WWTF	MNG580148	Marshall Lake-County Ditch No. 15	Audubon	Pond	8.76 & 3.0
Callaway WWTF	MNT022985	County Ditch No. 15	Callaway	Pond	3.44
Lake Park WWTF	MNG580157	Hay Creek	Lake Park	Pond	8.05
Barnesville WWTF	MN0022501	Lower Whiskey Creek	Barnesville	Pond	8, 10.9, & 24
Glyndon WWTF	MN0020630	City of Glyndon-Buffalo River	Glyndon	Pond	10.2
Hawley WWTF	MN0020338	City of Hawley-Buffalo River	Hawley	Pond	13.2
Hitterdahl WWTF	MNG580178	County Ditch No. 39	Hitterdahl	Pond	3.0
Spring Prairie Hutterite Colony WWTF	MN0070467	County Ditch No. 3	Spring Prairie	Pond	1.3

The Barnesville WWTF is authorized to discharge from each of three secondary treatment lagoons. The facility is limited to discharging either from the 8-acre and 10.9-acre ponds simultaneously, or from the 24-acre pond. All other plants are limited to discharging from a single surface secondary treatment cell. All WWTFs are permitted to discharge only during specified discharge windows in the spring and fall. The discharge windows are March 1 through June 30 and September 1 through December 31 with no discharge to ice covered waters.

Maximum daily permitted WLAs were calculated for each WWTF based on a maximum discharge of six inches of pond depth per day, per the MPCA guidance (Oakes 2013). WLAs were computed for TSS and bacteria based on the maximum permitted daily flow rate from each facility. TP WLAs were computed only for the Lake Park WWTF, since none of the other facilities discharge to TP-impaired waters. TP WLAs are calculated as annual loads based on the facility's average wet weather design flow and permitted TP concentration of 1 mg/L. This approach (using average wet weather design flows) for TP WLAs is typical in other nutrient TMDLs in the state of Minnesota.

The maximum daily permitted TSS and bacteria WLAs were converted to maximum annual loads by reviewing Discharge Monitoring Reports to determine the average number of days that each WWTF discharged each year (over the past 10 years) and multiplying that value by the allowable daily loads. The Spring Prairie Hutterite Colony WWTF is new in 2013 so the number of days that it will discharge during the year is unknown. For estimating a maximum annual WLA for that facility, it was assumed that it would discharge an average of 20 days per year (which is comparable to other small WWTFs in the watershed). Maximum permitted daily and annual TSS and bacteria WLAs for the BRW WWTFs are shown in **Table 3-6** and **Table 3-7** respectively.

Table 3-6: Annual and daily TSS wasteload allocations for BRW WWTFs.

	A	B	C	D	E	F	G	H	I	J
Facility	Secondary Pond Size (acres)	Permitted Max Daily Discharge (gpd)[1] (A*0.163*10^6)	Liters per Gallon	Permitted Max Daily Discharge (liters/day)[1] (B*C)	Average # of Days Discharging per Year	Permitted TSS Conc. (mg/L)	WLA-TSS (kg/day) (D*F/10^6)	Kg per Ton	WLA-TSS (tons/ day) (G/H)	WLA-TSS (tons/yr) (E*I)
Barnesville	24	3,912,000	3.785	14,808,531	23	32[2]	474	907.2	0.52	12.0
Glyndon	10.2	1,662,600	3.785	6,293,626	25	45	283	907.2	0.31	7.8
Hawley	13.2	2,151,600	3.785	8,144,692	27	45	367	907.2	0.40	11.1
Hitterdahl	3	489,000	3.785	1,851,066	19	45	83	907.2	0.09	1.7
Callaway	3.44	560,720	3.785	2,122,556	25	45	96	907.2	0.11	2.6
Lake Park	8.05	1,312,150	3.785	4,967,028	37	45	224	907.2	0.25	9.1
Audubon	8.76	1,427,880	3.785	5,405,114	47	45	243	907.2	0.27	12.5
Spring Prairie	1.3	211,900	3.785	802,129	20	45	36	907.2	0.04	0.8

[1] Computed based on the average surface area of the secondary treatment pond size and an assumed maximum daily discharge of six inches per day.
[2] The Barnesville WWTF's TSS WLA was computed based on a TSS permit limit of 32 mg/L; their current limit is 45 mg/L.

Table 3-7: Annual and daily *E. coli* wasteload allocations for BRW WWTFs.

	A	B	C	D	E	F	G
Facility	Permitted Max Daily Discharge (liters/day)[1]	Average # of Days Discharging per Year	Permitted Fecal Coliform Conc. (org/100 mL)	WLA-Fecal Coliform (10^9org/day) (A*C/10^6/100)	*E. coli* Colonies per Fecal Coliform Colony[2]	WLA- *E. coli* (10^9org/day) (D*E)	WLA- *E. coli* (10^9/yr) (B*F)
Barnesville	14,808,531	23	200	30	0.63	19	429
Glyndon	6,293,626	25	200	13	0.63	8	198
Hawley	8,144,692	27	200	16	0.63	10	282
Hitterdahl	1,851,066	19	200	4	0.63	2	44
Callaway	2,122,556	25	200	4	0.63	3	67
Lake Park	4,967,028	37	200	10	0.63	6	231
Audubon	5,405,114	47	200	11	0.63	7	318
Spring Prairie	802,129	20	200	2	0.63	1	32

[1] Computed based on the average surface area of the secondary treatment pond size and an assumed maximum daily discharge of six inches per day.
[2] Based on the MPCA recommended *E. coli* to fecal coliform ratio of 126:200

In some stream reaches, the total daily loading capacities in the lower flow zones are very small due to the occurrence of very low flows in the long-term flow records. Consequently, in four of the impaired reaches downstream of the Barnesville WWTF (AUIDs 09020106-521, -509, -504, and -501), the permitted WWTF flows exceed the stream flow in these flow zones. In reality, WWTFs flow cannot exceed stream flow, as it is a component of stream flow. To account for these unique situations, the WLAs and LAs are expressed as an equation rather than an absolute number.

Allocation = (flow contribution from given source) x (permitted concentration)

Since the permitted concentration is equal to the water quality standard, in these cases, the loading capacity of the stream under these scenarios will not be exceeded. The WLAs for straight pipe septic systems and NPDES-permitted livestock operations remain at zero.

Table 3-8 shows the TP WLA for the Lake Park WWTF. The maximum daily WLA was computed using the same approach used for maximum daily TSS and bacteria WLAs (i.e., assuming a maximum discharge of six inches per day). In this case, however, the maximum annual WLA was computed using the permitted concentration and the permitted average wet weather design flow value of 151,700 gallons per day (gpd).

For the daily WLA, it is not appropriate to be expressed as 1/365th of the annual WLA. The daily WLA and current permit limit allow for a discharge of 5 kg/day based on the 1 mg/L effluent limit and the maximum permitted discharge volume. The annual WLA is calculated from the 1 mg/L permit limit and the facility's average wet weather design flow (0.1517 mgd) over 365.25 days. The facility only discharges 37 days per year (see **Table 3-6**) so the daily 10.95 lb/day WLA is consistent with the annual 462.4 lbs/year WLA

Table 3-8: Annual and daily TP wasteload allocations for impacted BRW WWTFs.

	A	B	C	D	E	F	G
Facility	Permitted Max Daily Discharge (liters/day)[1]	Permitted TP Conc. (mg/L)	WLA-TP (lb/day) (A*B/1000* 2.205)	Avg Wet Weather Design flow (gpd)	Liters per Gallon	Avg Wet Weather Design flow (liters/day)[1] (D*E)	Annual WLA-TP (lb/yr) (B*F/10^6*365 .25*2.205)
Lake Park	4,967,028	1	11	151,700	3.785	574,247	462

[1] Computed based on the average surface area of the secondary treatment pond size and an assumed maximum daily discharge of six inches per day.

3.3.1.2 Future and Expanding Discharges

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 2012c). 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.

Current discharges can be expanded and new NPDES discharges can be added while maintaining water quality standards provided the permitted NPDES [Permits Program] effluent concentrations remain below the in-stream targets. Given this circumstance, a streamlined process for updating TMDL WLAs to incorporate new or expanding discharges will be employed. This process will apply to the non-stormwater facilities identified in **Table 3-5** (in the case of expansion) and any new wastewater or cooling water discharge in the watershed:

1. A new or expanding discharger will file with the MPCA permit program a permit modification request or an application for a permit reissuance. The permit application information will include documentation of the current and proposed future flow volumes and regulated water quality loads (e.g. TP and TSS loads (TP/TSS)).
2. The MPCA permit program will notify the MPCA TMDL program upon receipt of the request/application, and provide the appropriate information, including the proposed discharge volumes and the TP/TSS loads.
3. The TMDL Program staff will provide the permit writer with information on the TMDL WLA to be published with the permit's public notice.
4. The supporting documentation (fact sheet, statement of basis, effluent limits summary sheet) for the proposed permit will include information about the TP/TSS discharge requirements, noting that for TP/TSS, the effluent limit is below the in-stream TSS target and the increased discharge will maintain the nutrient/TSS water quality standard. The public will have the opportunity to provide comments on the new proposed permit, including the TP/TSS discharge and its relationship to the TMDL.
5. The MPCA TMDL program will notify the EPA TMDL program of the proposed action at the start of the public comment period. The MPCA permit program will provide the permit language with attached fact sheet (or other appropriate supporting documentation) and new TP/TSS information to the MPCA TMDL program and the EPA TMDL program.
6. The EPA will transmit any comments to the MPCA Permits and TMDL programs during the public comment period, typically via e-mail. The MPCA will consider any comments provided by the EPA and by the public on the proposed permit action and WLA and respond accordingly, conferring with EPA if necessary.
7. If, following the review of comments, the MPCA determines that the new or expanded TP/TSS discharge, with a concentration below the in-stream target, is consistent with applicable water quality standards and the above analysis, the MPCA will issue the permit with these conditions and send a copy of the final TP/TSS information to the EPA TMDL program. The MPCA's final permit action, which has been through a public notice period, will constitute an update of the WLA only.
8. The EPA will document the update to the WLA in the administrative record for the TMDL. Through this process, the EPA will maintain an up-to-date record of the applicable WLA for permitted facilities in the watershed.

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

3.3.2 Industrial process wastewater

There is currently one industrial discharger permitted for the TSS in the BRW, Aggregate Industries – Pit 21 (MN0069515). This facility is permitted to discharge a maximum flow of 1.7 mgd and has a maximum monthly average TSS concentration of 30 mg/L. For the purposes of computing a WLA for this facility, it was assumed that the maximum daily value equates to the maximum monthly average. The annual loading was computed assuming that the facility discharges 365 days per year. Table 3-9 details this WLA calculation.

Table 3-9: Annual and daily TSS wasteload allocations for permitted industrial dischargers.

	A	B	C	D	E	F	G	H	I
Facility	Permitted Max Daily Discharge (gpd)	Liters per Gallon	Permitted Max Daily Discharge (liters/day) (A*B)	Days Discharging per Year	Permitted TSS Conc. (mg/L)	WLA-TSS (kg/day) (C*E/10^6)	Kg per Ton	WLA-TSS (tons/ day) (F/G)	WLA-TSS (tons/yr) (D*H)
Aggregate Industries – Pit 21	1,700,000	3.785	6,435,200	365	30	193	907.2	0.21	77.7

3.3.3 Confined Animal Feeding Operations

There are seven CAFOs in the BRW that are large enough to require a NPDES Permit. Per their Permit requirements, these facilities must be designed to totally contain all surface water runoff (i.e., have zero discharge) and have manure management plans. Given the zero discharge effluent limitation, WLAs for these facilities are set to zero. The permitted facilities include: Baers Poultry Co – Old Barn Site (MNG441163), Jona Baer Inc. (MNG441148), Baers Poultry Co – New Barn Site (MNG441162), Highlevel Egg (MNG441114), J & A Farms LLC (MNG441159), Taves Turkey Farm Inc. (MNG441136), and Spring Prairie Colony – Hawley (MNG440000).

3.3.4 Construction and Industrial Stormwater

The WLAs for construction and industrial stormwater discharges in the BRW are combined and addressed through a categorical allocation. This TMDL assumes that 0.1% of the BRW's land use contributes construction and/or industrial stormwater runoff at any given time. Historic permits and land use in the watershed support this assumption.

Stormwater runoff from construction sites that disturb ≥ 1 acre of soil are regulated under the state's NPDES/State Disposal System (SDS) General Stormwater Permits for Construction Activity (MNR1000001). This permit requires and identifies BMPs to be implemented to protect water resources from mobilized sediment and other pollutants of concern. If the owner/operators of impacted construction sites within the BRW obtain and abide by the NPDES/SDS General Construction Stormwater Permit, the stormwater discharges associated with those sites are expected to meet the WLAs set in this TMDL.

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

3.3.5 Straight Pipe Septic Systems

Straight pipe septic systems are illegal; therefore, their WLA is zero. According to Minn. Stat. 115.55, subd. 1, a straight pipe-system means a sewage disposal system that transports raw or partially treated sewage directly to a lake, a stream, a drainage system, or ground surface.

3.3.6 Municipal Separate Storm Sewer Systems (MS4s)

There are no municipalities subject to MS4 permits within the BRW. Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries:

- 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.
- One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
- 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 LAs.
- 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.
- 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 **[Specify method, if needed. E.g., “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.

3.4 Load Allocation

Once WLAs, reserve capacities, and MOSs were determined, the remaining loading capacity was considered to be LAs. LAs are associated with loads that are not regulated by NPDES Permits, including nonpoint sources of pollutants and “natural background” contributions. “Natural background” can be described as physical, chemical, or biological conditions that would exist in a waterbody that are not a result of human activity. Nonpoint sources of pollution in the BRW were discussed previously and include overland erosion, channel degradation, wildlife, and other sources.

3.5 Margin of Safety

The purpose of the MOS is to account for any uncertainty with attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% MOS was applied to each flow regime for all LDCs developed for this TMDL. An explicit 10% MOS is typically applied for TMDLs of these types and was deemed appropriate due to the robust water quality dataset available to construct the LDCs and TMDL components, the assumptions and methods used to develop the LDCs and TMDL components, the low percent error (-6.0% and 3.4%) in hydrologic simulation during the validation period of the SWAT used to derive flows in ungagged stream reaches, and the conservative assumptions made during the development of the watershed model (SWAT).

For some low flow conditions, the explicit MOS is not applicable because the WLA exceeds the loading capacity. This is primarily due to the very low flows occurring in this flow regime. Since the WLA's are associated with an outflow and that outflow is a component of streamflow, the LA and 10% MOS is implicit and dependent on the outflow from the point source (see **Section 3.3**). This will technically never occur, since discharge from the point source will raise the streamflow to a higher flow condition, since discharge from the point source (WWTFs) is typically higher than flows in the low flow condition.

Lake TMDLs include an explicit 5% MOS. Due to the natural of the stochastic simulation, on average, the difference between the mean stochastically simulated and observed values in the lake models was 4.1%. To account for this difference in computing TMDLs, incorporate the stochastic natural of simulations, and estimated load reductions for the impaired lakes, the 5% MOS was applied. The lower lake MOS was deemed appropriate due to the stochastic modeling approach used to compute loading capacities; 5% is based on a measure of model uncertainty (HEI 2013d; page 32).

3.6 Reserve Capacity

No RC was included for the point sources in the BRW, given the nature of assumptions used to create the WLAs. Similarly, no RC was included for nonpoint sources in the watershed (LAs), given that the land use in the BRW is dominated by agriculture and is unlikely to substantially change in the future.

4 Buffalo River Watershed: Stream and River Impairments

4.1 Sources and Current Contributions

The BRW is a complex system with great diversity in land use, topography, soils, and drainage intensity. This diversity results in a variety of conditions that support a broad spectrum of fish and other aquatic life. Several stressors in the BRW play an important role in degrading water quality in the system and limiting the health of these biological communities.

A summary of sources and current conditions for the pollutants causing impairments in the streams and rivers of the BRW is provided in the following sections. A more in-depth discussion of the biological stressors, pollutant sources, and causal pathways, excluding *E. coli*, can be found in the Buffalo River Watershed Biotic Stressor Identification report (MPCA 2013). More discussion on the current conditions in the watershed can be found in the Buffalo River Watershed Monitoring and Assessment Report (MPCA 2012a). The following discussion highlights the findings of those reports.

4.1.1 TSS Sources and Current Conditions

The Buffalo River Watershed Biotic Stressor Identification Report (MPCA 2013) describes the sources and causal pathways for elevated turbidity and high TSS. That report states that high turbidity/TSS occurs when heavy rains fall on unprotected soils, dislodging the soil particles, which are transported by surface runoff into the rivers and streams (MPCA 2013). The soil may be unprotected for a variety of reasons, such as row crop agriculture, ditch maintenance/repair, construction, mining, insufficiently vegetated pastures, or livestock access to stream banks. Since 78% of the BRW is comprised of row crop agriculture and the soils are often insufficiently protected (without a crop canopy for eight to nine months), this is the leading source of soil into rivers and streams. Another significant source of soil loss and high stream turbidity/TSS levels is eroding stream channels (often referred to as stream channel instability or streambank erosion) where sediment/soil is eroded from the stream banks and stream bed. This destabilization is often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, increases in impervious surfaces, and livestock access to the stream channel. However, the leading cause of stream channel instability is increases in stream flow due to agricultural drainage (ditching, tiling, and wetland drainage or filling).

Elevated turbidity and high TSS is somewhat inherent to the lake plain portions of the BRW due to the very fine sediment size of clays and silts. Turbidity levels in the glacial moraine and beach ridge zones are in a large part tied to two factors. First, farming through the first and second order stream beds causes excessive erosion during each precipitation event that is significant enough to provide flow to the old stream bed. Soil erosion from this concentrated flow moves downstream into the next receiving stream and contributes sediment/turbidity to the system.

Field reconnaissance surveys found that field sediment sources were a significant cause of turbidity and TSS in the headwater streams including Deerhorn Creek and the Upper South Branch Buffalo River. Stream Power Index ground-truthing in these watersheds found numerous instances where gully erosion sent hundreds of cubic yards of soil into the receiving stream. These gullies were typically located where first or second order streams were being farmed through. These farmed-through headwater streams are prone to severe erosion as any storm event with the proper combination of intensity and duration will send a flush of water through the location of the prior stream bed and carve out a new channel in the cultivated soil. These findings tie in well to the results of the longitudinal survey turbidity results that found over a ten-fold increase in turbidity levels in some locations during storm events vs. base flow conditions (MPCA 2013).

The current conditions for TSS in impaired reaches are shown in **Table 4-1**. TSS observations ranged from 1 mg/L to 660 mg/L in the BRW. The percentage of exceedances of the TSS Southern Nutrient Region standard of 65 mg/L in impaired reaches ranged from 0% at AUID 9020106-593 to 59% at AUID 9020106-501.

Table 4-1: Current conditions of stream reaches in the BRW with TSS impairments.

AUID	Water Quality Monitoring Site	Years of Observations	# of Samples	Range	% of Exceed.
09020106-501	S000-174, S002-125, S002-708, S003-693	2001, 2003-2009	223	4 - 660 mg/L	59%
09020106-502	S002-711, S003-694	2005-2007, 2009	47	5 - 112 mg/L	28%
09020106-503	S004-148, S002-709	2006-2009	35	6 - 100 mg/L	9%
09020106-504	S004-147, S005-608	2006-2009	17	6.9 - 74 mg/L	6%
09020106-505	S004-145	2002-2009	47	2 - 250 mg/L	15%
09020106-507	S003-151	2002-2009	51	4 - 232 mg/L	4%
09020106-508	S003-148	2002-2009	49	1 - 116 mg/L	2%
09020106-509	S005-607	2009	10	11 - 94 mg/L	10%
09020106-521	S002-112, S002-111,S005-611	2002-2009	166	4 - 242 mg/L	10%
09020106-523	S003-312	2003-2009	41	15 - 126 mg/L	27%
09020106-593	S004-105	2008-2009	15	10 - 52 mg/L	0%
09020106-594	S003-155, S004-145	2002-2009	55	1 - 532 mg/L	18%
09020106-595	S002-700, S003-152	2002-2009	53	2 - 436 mg/L	21%

4.1.2 *E. coli* Sources and Current Conditions

The relationship between bacterial sources and bacterial concentrations found in streams is complex, involving precipitation and flow, temperature, livestock management practices, wildlife activities, survival rates, land use practices, and other environmental factors. Despite the complexity of the relationship between sources and in-stream bacterial concentrations, the following can be considered major sources in rural areas: livestock facilities, livestock manure, wildlife, malfunctioning subsurface sewage treatment systems (SSTSs), and WWTFs. A more detailed discussion on sources and current conditions of *E. coli* in the BRW can be found in the BRW Bacteria Source Assessment and Quantification memorandum (HEI 2013a). The following is a brief summary by potential source followed by a summary of current conditions by AUID.

Livestock - Livestock contribute bacteria to the watershed through runoff from; manure applied to row crops, poorly managed feedlots, pasture land, and direct defecation into streams and lakes by livestock if allowed access to these waterbodies. According to the MPCA's data, there are a total of 2,141,831 agricultural animals (in registered and permitted facilities) in the BRW. The majority of these animals are chickens (1,646,852) and turkeys (445,302), followed by bovine (26,847), and all other animals (22,794) including pigs, goats, and horses (HEI 2013a; page 5). Currently, seven livestock facilities in the BRW operate under NPDES Permits. These facilities contain 1,478,336 - or 69%- of the agricultural birds (chickens and turkeys) in the watershed. Per their permit requirements, these facilities must be designed to totally contain all surface water runoff and have manure management plans.

The majority of the MPCA-registered cattle operations are relatively small (<500 animals), with open feedlots, presenting the potential for polluted runoff much of the year. In addition, the MPCA estimates nearly 100% of both the registered and non-registered facilities in the BRW land apply their manure. Manure application typically occurs in the fall months, September through November, with the highest volume of manure application in October (Brands 2012). Manure from these facilities has a high likelihood of transport into the surface waters of the BRW.

Wildlife/Natural Sources - Wildlife, especially waterfowl, contributes bacteria to the watershed by directly defecating into waterbodies and through runoff from wetlands and fields adjacent to waterbodies, which are used as feeding grounds. In the BRW, land cover that could potentially attract wildlife includes herbaceous wetlands and row crops adjacent to streams and lakes, wildlife management areas (WMA), and open water.

Two Minnesota studies described the potential for the presence of "naturalized" or "indigenous" *E. coli* in watershed soils (Ishii et al. 2006) and ditch sediment and water (Sadowsky et al. 2010). Sadowsky et al. (2010) conducted DNA fingerprinting of *E. coli* in sediment and water samples from Seven Mile Creek, located in south-central Minnesota. They concluded that roughly 63.5% were represented by a single isolate, suggesting new or transient sources of *E. coli*. The remaining 36.5% of strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. The authors suggested that 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period but results might not be transferable to other locations without further study. Although the result may not be transferable to other locations, they do suggest the presence of natural background *E. coli* and a fraction of *E. coli* may be present regardless of the control measures taken by traditional implementation strategies.

Subsurface Sewage Treatment Systems - Malfunctioning SSTSs can be an important source of fecal contamination to surface waters, especially during dry periods when these sources continue to discharge and surface water runoff is minimal. According to the MPCA (MPCA 2011b; Page 6), these malfunctioning SSTSs fall into two categories: Imminent Public Health Threat (IPHT) or failing to protect groundwater (i.e., failing). IPHT indicates the system has a sewage discharge to surface water; sewage discharge to ground surface; sewage backup; or any other situation with the potential to immediately and adversely affect or threaten public health or safety. Failing to protect groundwater indicates the bottom of the systems does not have the required three-foot separation to groundwater or bedrock and there is not sufficient amount of unsaturated soil between where the sewage is discharged and the groundwater.

Of the rural population in the BRW, an estimated 1,252 households, or 38% have inadequate treatment of their household wastewater. This includes individual residences and un-sewered communities (e.g. Kragnes, Richwood, Rollag, Baker, and Averill). An MPCA document (MPCA 2011) reports numbers from

2000 through 2009 on the total number of SSTSs by county, along with the average estimated percent of SSTSs that are failing versus the percent that are considered IPHTs. Although estimates of the number of SSTSs per county were provided in the report, Becker County had no data reported for this parameter, so U.S. Census-based estimates of SSTS numbers were used for this work. The total numbers of SSTSs per county were multiplied by the estimated percent IPHT and percent failing within each area (MPCA 2011) to compute the number of potential IPHTs and potentially failing SSTSs per county and in the BRW overall. **Table 4-2** summarizes the results.

Table 4-2: SSTS compliance status in the BRW, by county.

	Becker	Clay	Otter Tail	Wilkin	Watershed Total
Identified # of SSTSs	842	2,141	114	190	3,287
Estimated % IPHT	0%	12%	13%	16%	---
Estimated % Failing	28%	27%	40%	48%	---
# of potential IPHTs	0	257	15	30	302
# of potentially failing SSTSs	236	578	46	91	951

Wastewater Treatment Facilities – There are eight WWTFs in the BRW. Information on the location, permitted flow and concentrations, and monitored flow and concentrations for each of these facilities were provided by the MPCA. All permitted WWTFs in the state of Minnesota are required to monitor their effluent to ensure that concentrations of specific pollutants remain within levels specified in their discharge permit. Although water quality standards in Minnesota for fecal bacteria are now based in *E coli*, WWTF are permitted based on fecal coliform, not *E. coli*. Effluent limits require that fecal coliform concentrations remain below 200 organisms/100 mL (MPCA 2002; page 2). Based on the previous fecal standard and the current *E. coli* standard (**Table 1-1**), a ratio of 200:126 (0.63) is used to convert fecal coliform to *E. coli*. Therefore, the effluent limit for *E. coli* concentrations remains below 126 organisms/100 mL.

The WWTFs in the BRW are all pond-type treatment plants with primary and secondary treatment lagoons. The general operation of these facilities is to discharge their treated waste into the surface water system in the spring/early summer and again in the late fall of each year. The most typical windows for releases are in April through June and then again in September through November.

The current conditions for *E. coli* in impaired reaches are provided in **Table 4-3**. Shaded areas in **Table 4-3** indicate *E. coli* standard exceedances.

Table 4-3: Current conditions of stream reaches in the BRW with *E. coli* impairments.

AUID (09020106-XXX)	Sampled Years	Range	Geometric Mean [org/100 mL]	Number of Observations[1]					Geometric Mean[1] [org/100 mL]				
				May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep
501	2008, 2009	23 - 579	143	0	9	13	12	12	---	65	196	146	178
502	2009	5 - 2,500	383	0	6	6	6	6	---	235	861	384	277
503	2009	81 - 1,553	255	0	6	6	6	6	---	175	209	336	344
504	2009	19 - 1,733	226	0	4	8	6	6	---	64	363	242	261
505	2008, 2009	6 - 548	153	1	3	3	5	5	31	109	306	222	118
507	2008, 2009	6 - 816	114	1	3	3	4	5	17	149	320	140	65
508	2009	27 - 980	165	0	3	3	3	2	---	109	89	109	869
509	2009	74 - 1,553	310	0	2	4	3	3	---	135	368	321	414
511	2008, 2009	99 - 2,420	416	0	3	5	5	3	---	265	452	751	212
515	2008, 2009	19 - 2,500	169	0	4	5	5	5	---	118	100	159	406
519	2009	138 - 2,500	613	0	2	0	0	2	---	200	---	---	1880
520	2008, 2009	2 - 2,500	620	1	3	3	4	5	261	529	1638	809	366
521	2006, 2008, 2009	10 - 2,500	316	1	11	13	11	15	100	330	586	380	162
523	2008, 2009	7 - 2,420	321	1	3	3	4	5	10	168	881	435	203
531	2008, 2009	30 - 1,203	212	0	1	5	4	5	---	55	309	327	179
534	2009	79 - 1,733	269	0	3	3	3	3	---	141	956	131	297
556	2009	23 - 727	243	0	3	3	3	0	---	95	306	497	---
559	2009	118 - 1,046	347	0	3	3	3	0	---	267	284	550	---
562	2009	22 - 1,414	231	0	3	3	3	0	---	145	358	237	---
593	2008, 2009	12 - 2,500	353	0	4	5	5	5	---	78	201	592	1,246
594	2008, 2009	16 - 2,500	196	1	6	8	9	10	16	258	223	246	157
595	2008, 2009	29 - 866	178	1	5	7	7	8	29	109	213	285	171

= Exceeds monthly geometric mean standard.

[1]No observations were made in April or October

4.2 TMDL Allocations for *E. Coli*

Table 4-254 through **Table 4-25** show the computed loading capacities and allocations for the *E. coli* impairments in the BRW. The various components of these allocations were developed as described in **Section 3**. The LDC used to develop the loading capacities and allocations are provided in **Appendix A**.

A few tables show "*" in the WLA and LA for dry conditions and/or low flow conditions. The "*" is due to the WLA and WWTF outflows being higher than the loading capacity and representative flow. In reality, WWTF flow cannot exceed stream flow as it is a component of stream flow. To account for these unique situations, the WLAs and LAs are expressed as an equation rather than an absolute number.

Allocation = (flow contribution from given source) x (permitted concentration)

Since the permitted concentration is equal to the water quality standard, in these cases, the loading capacity of the stream under these scenarios will not be exceeded. This is discussed in greater detail in **Section 3.3**.

Table 4-4: *E. coli* loading capacities and allocations for AUID 09020106-593 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	370.8	152.8	104.7	48.0	16.8
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	333.7	137.6	94.3	43.2	15.1
Margin of Safety	37.1	15.3	10.5	4.8	1.7

[1] There are no WWTFs in this watershed.

Table 4-5: *E. coli* loading capacities and allocations for AUID 09020106-594 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	1,031.1	338.4	201.6	117.9	56.4
Wasteload Allocation					
Callaway WWTF	2.7	2.7	2.7	2.7	2.7
Lake Park WWTF	6.3	6.3	6.3	6.3	6.3
Audobon WWTF	6.8	6.8	6.8	6.8	6.8
Baers Poultry Co - Old Barn Site	0.0	0.0	0.0	0.0	0.0
Jona Baer Inc.	0.0	0.0	0.0	0.0	0.0
Load Allocation	912.2	288.9	165.7	90.4	35.0
Margin of Safety	103.1	33.8	20.2	11.8	5.6

Table 4-6: *E. coli* loading capacities and allocations for AUID 09020106-595 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	1,718.9	586.5	382.2	243.4	114.0
Wasteload Allocation					
Callaway WWTF	2.7	2.7	2.7	2.7	2.7
Hawley WWTF	10.3	10.3	10.3	10.3	10.3
Glyndon WWTF	7.9	7.9	7.9	7.9	7.9
Lake Park WWTF	6.3	6.3	6.3	6.3	6.3
Audobon WWTF	6.8	6.8	6.8	6.8	6.8
Livestock facilities requiring NPDES permit	0.0	0.0	0.0	0.0	0.0
Load Allocation	1,513.1	494.0	310.1	185.1	68.6
Margin of Safety	171.9	58.7	38.2	24.3	11.4

Table 4-7: *E. coli* loading capacities and allocations for AUID 09020106-511 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	210.8	35.3	18.2	12.4	7.1
Wasteload Allocation					
Lake Park WWTF	6.3	6.3	6.3	6.3	6.3
Load Allocation	183.4	25.6	10.1	4.9	0.2
Margin of Safety	21.1	3.5	1.8	1.2	0.7

Table 4-8: *E. coli* loading capacities and allocations for AUID 09020106-501 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	4,834.0	840.4	397.6	204.5	97.9
Wasteload Allocation					
Callaway WWTF	2.7	2.7	2.7	2.7	2.7
Hawley WWTF	10.3	10.3	10.3	10.3	10.3
Lake Park WWTF	6.3	6.3	6.3	6.3	6.3
Audobon WWTF	6.8	6.8	6.8	6.8	6.8
Hitterdahl WWTF	2.3	2.3	2.3	2.3	2.3
Spring Prairie Hutterite Colony WWTF	1.0	1.0	1.0	1.0	1.0
Barnesville WWTF	18.7	18.7	18.7	18.7	18.7
Livestock facilities requiring NPDES permit	0.0	0.0	0.0	0.0	0.0
Load Allocation	4,302.5	708.3	309.7	135.9	40.0
Margin of Safety	483.4	84.0	39.8	20.5	9.8

Table 4-9: *E. coli* loading capacities and allocations for AUID 09020106-556 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	355.4	49.5	13.9	4.9	0.2
Wasteload Allocation					
Spring Prairie Hutterite Colony WWTF	1.0	1.0	1.0	1.0	*
Livestock facilities requiring NPDES permit	0.0	0.0	0.0	0.0	0.0
Load Allocation	318.9	43.6	11.5	3.4	0.2
Margin of Safety	35.5	4.9	1.4	0.5	0.0

* The outflows from WWTFs will be greater than the median flows under these flow conditions. Since outflow is a portion of the streamflow, load under these conditions is unlikely to occur. If outflows from WWTF during these flow conditions, the WLA will be the permitted outflow concentration times to flow rate. See Section 3.3 for further detail.

Table 4-10: *E. coli* loading capacities and allocations for AUID 09020106-559 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	146.9	22.2	6.2	1.9	0.2
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	132.18	19.96	5.54	1.69	0.16
Margin of Safety	14.7	2.2	0.6	0.2	0.0

[1] There are no WWTFs in this watershed.

Table 4-11: *E. coli* loading capacities and allocations for AUID 09020106-562 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	78.6	10.2	1.4	0.1	0.0
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	70.74	9.18	1.26	0.11	0.00
Margin of Safety	7.9	1.0	0.1	0.0	0.0

[1] There are no WWTFs in this watershed.

Table 4-12: ***E. coli*** **loading capacities and allocations for AUID 09020106-521 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	176.6	56.0	27.4	15.1	5.8
Wasteload Allocation					
Barnesville WWTF	18.7	18.7	18.7	*	*
Load Allocation	140.3	31.8	6.0	13.6	5.2
Margin of Safety	17.7	5.6	2.7	1.5	0.6

* The outflows from WWTFs will be greater than the median flows under these flow conditions. Since outflow is a portion of the streamflow, load under these conditions is unlikely to occur. If outflows from WWTF during these flow conditions, the WLA will be the permitted outflow concentration times to flow rate. See Section 3.3 for further detail.

Table 4-13: ***E. coli*** **loading capacities and allocations for AUID 09020106-509 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	208.0	63.6	30.1	15.1	5.8
Wasteload Allocation					
Barnesville WWTF	18.7	18.7	18.7	*	*
Load Allocation	168.6	38.6	8.5	13.6	5.2
Margin of Safety	20.8	6.4	3.0	1.5	0.6

* The outflows from WWTFs will be greater than the median flows under these flow conditions. Since outflow is a portion of the streamflow, load under these conditions is unlikely to occur. If outflows from WWTF during these flow conditions, the WLA will be the permitted outflow concentration times to flow rate. See Section 3.3 for further detail.

Table 4-14: ***E. coli*** **loading capacities and allocations for AUID 09020106-504 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	1,327.6	291.9	95.8	36.0	9.7
Wasteload Allocation					
Barnesville WWTF	18.7	18.7	18.7	18.7	*
Load Allocation	1176.1	244.0	67.5	13.8	8.7
Margin of Safety	132.8	29.2	9.6	3.6	1.0

* The outflows from WWTFs will be greater than the median flows under these flow conditions. Since outflow is a portion of the streamflow, load under these conditions is unlikely to occur. If outflows from WWTF during these flow conditions, the WLA will be the permitted outflow concentration times to flow rate. See Section 3.3 for further detail.

Table 4-15: ***E. coli*** **loading capacities and allocations for AUID 09020106-523 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	101.2	33.6	9.9	2.6	0.4
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	91.1	30.2	8.9	2.3	0.3
Margin of Safety	10.1	3.4	1.0	0.3	0.0

[1] There are no WWTFs in this watershed.

Table 4-16: ***E. coli*** **loading capacities and allocations for AUID 09020106-534 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	47.4	4.9	1.3	0.3	0.005
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	42.6	4.4	1.2	0.23	0.004
Margin of Safety	4.7	0.5	0.1	0.003	0.001

[1] There are no WWTFs in this watershed.

Table 4-17: ***E. coli*** **loading capacities and allocations for AUID 09020106-519 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	127.5	41.4	22.1	10.6	3.1
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	114.7	37.2	19.9	9.6	2.756
Margin of Safety	12.7	4.1	2.2	1.1	0.306

[1] There are no WWTFs in this watershed.

Table 4-18: ***E. coli*** **loading capacities and allocations for AUID 09020106-520 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	126.2	55.4	34.5	19.2	7.4
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	113.60	49.88	31.02	17.32	6.68
Margin of Safety	12.6	5.5	3.4	1.9	0.7

[1] There are no WWTFs in this watershed.

Table 4-19: *E. coli* loading capacities and allocations for AUID 09020106-502 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	259.3	108.6	49.0	25.3	8.2
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	233.4	97.8	44.1	22.7	7.4
Margin of Safety	25.9	10.9	4.9	2.5	0.8

[1] There are no WWTFs in this watershed.

Table 4-20: *E. coli* loading capacities and allocations for AUID 09020106-503 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	70,967.0	14,739.3	6,731.5	2,914.4	982.4
Wasteload Allocation					
Barnesville WWTF	18.7	18.7	18.7	18.7	18.7
Load Allocation	63,851.6	13,246.7	6,039.7	2,604.3	865.5
Margin of Safety	7096.7	1473.9	673.1	291.4	98.2

Table 4-21: *E. coli* loading capacities and allocations for AUID 09020106-508 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	123.2	21.0	3.9	0.7	0.1
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	110.9	18.9	3.5	0.7	0.1
Margin of Safety	12.3	2.1	0.4	0.1	0.0

[1] There are no WWTFs in this watershed.

Table 4-22: *E. coli* loading capacities and allocations for AUID 09020106-531 using geometric mean criteria.

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	52.5	8.5	2.4	0.95	0.474
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	47.3	7.7	2.2	0.85	0.426
Margin of Safety	5.3	0.85	0.2	0.1	0.047

[1] There are no WWTFs in this watershed.

Table 4-23: ***E. coli*** **loading capacities and allocations for AUID 09020106-507 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	150.5	28.2	8.6	3.0	0.9
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	135.5	25.4	7.8	2.7	0.8
Margin of Safety	15.1	2.8	0.9	0.3	0.1

[1] There are no WWTFs in this watershed.

Table 4-24: ***E. coli*** **loading capacities and allocations for AUID 09020106-505 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	493.0	102.9	30.1	8.8	1.5
Wasteload Allocation [1]	0.0	0.0	0.0	0.0	0.0
Load Allocation	443.7	92.6	27.1	7.9	1.4
Margin of Safety	49.3	10.3	3.0	0.9	0.2

[1] There are no WWTFs in this watershed.

Table 4-25: ***E. coli*** **loading capacities and allocations for AUID 09020106-515 using geometric mean criteria.**

E. coli	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Billion organisms per day				
Loading Capacity	434.3	102.5	70.4	45.2	23.9
Wasteload Allocation					
Audobon WWTF	6.8	6.8	6.8	6.8	6.8
Callaway WWTF	2.7	2.7	2.7	2.7	2.7
Load Allocation	381.4	82.7	53.9	31.2	12.0
Margin of Safety	43.4	10.2	7.0	4.5	2.4

4.3 TMDL Allocations for TSS

Table 4-26 through **Table 4-38** show the computed loading capacities and allocations for the BRW streams that are currently impaired of the TSS standard. The various components of these allocations were developed as described in **Section 3**. The Barnesville WWTF WLAs in **Table 4-29**, **Table 4-30**, **Table 4-31**, **Table 4-32**Table 4-32, and **Table 4-35** were computed assuming a permit limit of 45 mg/L TSS. The LDC used to develop the loading capacities and allocations are provided in **Appendix C**. It should be noted that the sum of some of the TMDL calculations might not equal the loading capacity of the AUID; this is due to round errors.

For stream reaches with biological impairments where elevated turbidity was identified as a primary stressor, it is believed that if the TSS in the stream reach is addressed, the elevated turbidity stressor of the biological impairment will be addressed. This does not mean the biological impairment will be completely addressed, as other factors and stressors may contribute to the biological impairment.

Table 4-26: TSS loading capacities and allocations for AUID 09020106-593.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	20.99	8.96	5.94	2.61	0.90
Wasteload Allocation [1]					
Construction/Industrial Stormwater	0.019	0.008	0.005	0.002	0.001
Load Allocation	18.88	8.06	5.34	2.35	0.81
Margin of Safety	2.10	0.90	0.59	0.26	0.09

[1] There are no WWTFs in this watershed.

Table 4-27: TSS loading capacities and allocations for AUID 09020106-594.

Total Suspended Solids	Flow Zone				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	57.95	19.83	11.47	6.33	3.05
Wasteload Allocation					
Callaway WWTF	0.11	0.11	0.11	0.11	0.11
Lake Park WWTF	0.25	0.25	0.25	0.25	0.25
Audobon WWTF	0.27	0.27	0.27	0.27	0.27
Construction/Industrial Stormwater	0.05	0.02	0.01	0.005	0.002
Load Allocation	51.48	17.21	9.69	5.08	2.13
Margin of Safety	5.79	1.98	1.15	0.63	0.31

Table 4-28: TSS loading capacities and allocations for AUID 09020106-595.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	96.48	34.50	22.41	14.13	6.27
Wasteload Allocation					
Callaway WWTF	0.11	0.11	0.11	0.11	0.11
Hawley WWTF	0.40	0.40	0.40	0.40	0.40
Glyndon WWTF	0.31	0.31	0.31	0.31	0.31
Lake Park WWTF	0.25	0.25	0.25	0.25	0.25
Audobon WWTF	0.27	0.27	0.27	0.27	0.27
Aggregate Industries - Pit 21	0.21	0.21	0.21	0.21	0.21
Construction/Industrial Stormwater	0.09	0.03	0.02	0.01	0.004
Load Allocation	85.20	29.47	18.60	11.15	4.09
Margin of Safety	9.65	3.45	2.24	1.41	0.63

Table 4-29: PTSS loading capacities and allocations for AUID 09020106-501.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	462.71	78.35	37.55	18.73	9.59
Wasteload Allocation					
Callaway WWTF	0.11	0.11	0.11	0.11	0.11
Hawley WWTF	0.40	0.40	0.40	0.40	0.40
Lake Park WWTF	0.25	0.25	0.25	0.25	0.25
Audobon WWTF	0.27	0.27	0.27	0.27	0.27
Hitterdahl WWTF	0.09	0.09	0.09	0.09	0.09
Spring Prairie Hutterite Colony WWTF	0.04	0.04	0.04	0.04	0.04
Barnesville WWTF	0.73	0.73	0.73	0.73	0.73
Aggregate Industries - Pit 21	0.21	0.21	0.21	0.21	0.21
Construction/Industrial Stormwater	0.41	0.07	0.03	0.01	0.007
Load Allocation	413.93	68.34	31.66	14.75	6.52
Margin of Safety	46.27	7.84	3.76	1.87	0.96

Table 4-30: TSS loading capacities and allocations for AUID 09020106-521.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	10.69	3.32	1.61	0.88	0.33
Wasteload Allocation					
Barnesville WWTF	0.73	0.73	0.73	*	*
Construction/Industrial Stormwater	0.009	0.002	0.001	*	0.001
Load Allocation	8.88	2.25	0.71	*	0.30
Margin of Safety	1.07	0.33	0.16	*	0.03

* The outflows from WWTFs will be greater than the median flows under these flow conditions. Since outflow is a portion of the streamflow, loading under these conditions is unlikely to occur. If outflows from WWTFs occur during these flow conditions, the WLA will be the permitted outflow concentration times the flow rate. See Section 3.3 for further detail.

Table 4-31: TSS loading capacities and allocations for AUID 09020106-509.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	13.04	3.76	1.79	0.88	0.33
Wasteload Allocation					
Barnesville WWTF	0.73	0.73	0.73	*	*
Construction/Industrial Stormwater	0.011	0.003	0.001	*	0.001
Load Allocation	10.99	2.65	0.87	*	0.30
Margin of Safety	1.30	0.38	0.18	*	0.03

* The outflows from WWTFs will be greater than the median flows under these flow conditions. Since outflow is a portion of the streamflow, loading under this condition is unlikely to occur. If outflows from WWTFs occur during these flow conditions, the WLA will be the permitted outflow concentration times the flow rate. See Section 3.3 for further detail.

Table 4-32: TSS loading capacities and allocations for AUID 09020106-504.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	82.24	17.18	6.02	2.31	0.55
Wasteload Allocation					
Barnesville WWTF	0.73	0.73	0.73	0.73	*
Construction/Industrial Stormwater	0.073	0.015	0.005	0.001	0.001
Load Allocation	73.21	14.71	4.68	1.34	0.49
Margin of Safety	8.22	1.72	0.60	0.23	0.06

* The outflows from WWTFs will be greater than the median flows under these flow conditions. Since outflow is a portion of the streamflow, loading under these conditions is unlikely to occur. If outflows from WWTFs occur during these flow conditions, the WLA will be the permitted outflow concentration times the flow rate. See Section 3.3 for further detail.

Table 4-33: TSS loading capacities and allocations for AUID 09020106-523.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	9.51	3.10	0.92	0.24	0.03
Wasteload Allocation [1]					
Construction/Industrial Stormwater	0.009	0.003	0.0008	0.0002	0.00003
Load Allocation	8.55	2.79	0.83	0.21	0.03
Margin of Safety	0.95	0.31	0.09	0.02	0.00

[1] There are no WWTFs in this watershed.

Table 4-34: TSS loading capacities and allocations for AUID 09020106-502.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	25.19	10.18	4.69	2.39	0.79
Wasteload Allocation [1]					
Construction/Industrial Stormwater	0.023	0.009	0.004	0.002	0.0007
Load Allocation	22.65	9.15	4.21	2.15	0.71
Margin of Safety	2.52	1.02	0.47	0.24	0.08

[1] There are no WWTFs in this watershed.

Table 4-35: TSS loading capacities and allocations for AUID 09020106-503.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	127.37	24.57	11.63	4.95	1.79
Wasteload Allocation					
Barnesville WWTF	0.73	0.73	0.73	0.73	0.73
Construction/Industrial Stormwater	0.114	0.021	0.010	0.004	0.001
Load Allocation	113.78	21.36	9.72	3.71	0.87
Margin of Safety	12.74	2.46	1.16	0.49	0.18

Table 4-36: TSS loading capacities and allocations for AUID 09020106-508.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	12.02	2.02	0.39	0.07	0.01
Wasteload Allocation [1]					
Construction/Industrial Stormwater	0.011	0.0018	0.0004	0.0001	0.00001
Load Allocation	10.81	1.81	0.35	0.06	0.01
Margin of Safety	1.20	0.20	0.04	0.01	0.00

[1] There are no WWTFs in this watershed.

Table 4-37: TSS loading capacities and allocations for AUID 09020106-507.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	14.06	2.69	0.84	0.28	0.08
Wasteload Allocation [1]					
Construction/Industrial Stormwater	0.013	0.002	0.0008	0.0003	0.0001
Load Allocation	12.64	2.42	0.75	0.25	0.08
Margin of Safety	1.41	0.27	0.08	0.03	0.01

[1] There are no WWTFs in this watershed.

Table 4-38: TSS loading capacities and allocations for AUID 09020106-505.

Total Suspended Solids	Flow Condition				
	High Flows	Moist Conditions	Mid-range Flows	Dry Conditions	Low Flows
	Tons per day				
Loading Capacity	49.39	9.59	3.04	0.87	0.14
Wasteload Allocation [1]					
Construction/Industrial Stormwater	0.044	0.009	0.003	0.0008	0.0001
Load Allocation	44.40	8.62	2.73	0.78	0.12
Margin of Safety	4.94	0.96	0.30	0.09	0.01

[1] There are no WWTFs in this watershed.

4.4 Critical Conditions and Seasonal Variation

A summary of the bacteria and TSS load reduction results can be found in Table 4-39. Results are summarized by indicating the maximum required percent load reduction for each curve and the flow regime and water quality criteria under which this maximum reduction occurred (i.e., the critical flow regime and criteria). The critical criterion for each of the bacterial LDCs is consistently the geomean criterion, indicating a chronic bacterial water quality problem in the watershed. The critical flow regime for bacteria and TSS loading is most often under high flow conditions. It should be noted that three AUIDs (09020106-504, 09020106-508, and 09020106-593) currently listed as impaired for turbidity do not require reductions under the current TSS standard.

Results of this analysis showed maximum required bacterial load reductions ranging from 47% to 94%, all based on the geomean *E. coli* criterion, and typically occurring during high flow conditions. AUIDs -519, -520, -521, -523, -531, and -593 require at least 80% reductions, mostly in the high flow regime. Only AUID -593 is not in the primarily agricultural region in the southern half of the BRW (Southern and Central Planning Regions).

Maximum TSS standard load reductions range from 13% to 85%, based on the Southern Region TSS criterion of 65 mg/L, also most often found during high flow conditions. For more information on the LDCs, see **Appendix C**.

Table 4-39. Maximum required bacterial and TSS load reductions for the BRW.

AUID	Bacteria			Total Suspended Solids	
	Max. % Load Reduction	Critical Flow Regime	Critical Criterion	Max. % Load Reduction	Critical Flow Regime
09020106-501	55%	High	Geomean	52%	High
09020106-502	69%	High / Moist	Geomean	36%	Average
09020106-503	57%	High	Geomean	13%	Moist
09020106-504	47%	Average	Geomean	NR	NA
09020106-505	64%	High	Geomean	72%	High
09020106-507	77%	High	Geomean	60%	High
09020106-508	61%	Average	Geomean	NR	NA
09020106-509	62%	Average	Geomean	34%	Average
09020106-511	75%	Dry	Geomean	---	---
09020106-515	71%	Average	Geomean	---	---
09020106-519	94%	Average	Geomean	---	---
09020106-520	93%	High	Geomean	---	---
09020106-521	83%	Dry	Geomean	43%	High
09020106-523	90%	High	Geomean	43%	Moist
09020106-531	90%	High	Geomean	---	---
09020106-534	79%	High	Geomean	---	---
09020106-556	67%	High	Geomean	---	---
09020106-559	72%	Dry	Geomean	---	---
09020106-562	64%	Dry	Geomean	---	---
09020106-593	88%	Average	Geomean	NR	NA
09020106-594	62%	Average	Geomean	61%	High
09020106-595	57%	Dry	Geomean	85%	High

NA Not applicable
NR No required reduction required.
--- Not impaired for turbidity (TSS)

5 Buffalo River Watershed: Lake Excess Nutrients

A summary of sources and current conditions is provided in this section for the pollutants causing impairments in the lakes of the BRW. A more in-depth discussion of these topics can be found in the Buffalo River Watershed Monitoring and Assessment Report (MPCA 2012a). Detailed description of the lake modeling effort can be found in the Buffalo River Watershed Lakes Eutrophication Modeling Report (HEI 2013d).

5.1 Phosphorus Sources and Current Contributions

Phosphorus is delivered to streams by agriculture, WWTFs, urban stormwater, and direct discharges of sewage. With 78% of the BRW in agricultural production, it comprises a major pollutant source in the area, according to model results (HEI 2013b). A further breakout of agricultural sources includes erosion and drainage from row crop production, feedlots, pastures, winter application of manure, and watercourse (stream and ditch) bank and bed erosion from drainage.

Lake eutrophication from excess phosphorus is a significant problem in the BRW. With few exceptions, when sufficient data is collected to allow for assessment, sampled lakes are found to be impaired. More than one-third of all monitored lakes (16 of 43) in the watershed exceed the eutrophication standard and are impaired for aquatic recreation use, and several more are very close to the standard. Impairments are found across the watershed, with the exception of the two eastern subwatersheds that are headwaters in nature, with more intact (forested) watersheds than the rest of the agriculturally-dominated landscape.

The following is a list of potential nonpoint sources of phosphorus in the BRW:

Forest/Shrub Land – Forest and shrub land accounts for 1.6% – 44.0% of the land use in the BRW lake catchment areas. Runoff from forested land can include decomposing vegetation and organic soils.

Cropland – Cropland (land that is under annual cultivation) accounts for 15.9% – 76.2% of the land use in the lake catchment areas. Runoff from agricultural lands can include land-applied livestock manure, fertilizers, soil particles, and organic material from agronomic crops.

Pasture/Hay/Grassland – This category combines several land uses including pasture, hay land, idle grasslands, Conservation Reserve Program (CRP) and any other state or federal program lands managed as grasslands. Between 1.7% - 14.6% of land use in these catchments is included in this category. Surface runoff can deliver phosphorus from manure deposited by livestock and wildlife.

Developed Land– Between 2.5% – 10.1% of the land use in these catchments falls under this category. Runoff from residences and impervious surfaces can include fertilizer, leaf and grass litter, pet waste, and numerous other sources of phosphorus.

Wetlands/Open Water – Wetlands and open water comprise 7.2% – 40.2% of the land use in these catchments. Wetlands and open water can export phosphorus through suspended solids as well as organic debris that flow through waterways.

Atmospheric Load – Direct atmospheric deposition to the surface of the lakes was based on regional values. Sources of particulate phosphorus in the atmosphere may include pollen, soil erosion, oil and coal combustion, and fertilizers. The atmospheric export coefficient used in the model was 0.3 kg/ha-yr.

Internal Load – Internal loading of phosphorus can come from a wide variety of sources including re-suspension of sediments due to wave action, rough fish, wildlife activity, boating and bio-chemical processes that release phosphorus. The nutrient retention models within the BATHTUB/CNET framework already account for nutrient recycling, so it is generally not advisable to add internal load without independent estimates or measurements (Walker, 1999). No information on internal loading rates in the BRW is available at this time, therefore internal loading was assumed to be included in the calibration factors when modeling responses nutrient loadings (i.e., implicitly accounted for as part of the calibration factor in the CNET modeling which determines net sedimentation of TP).

Livestock –Livestock can contribute phosphorus to the watershed through runoff at feeding, holding and manure storage areas as well as direct loading if allowed access to streams or lakes. Additional runoff can occur through manure applications. The phosphorus loading from livestock/manure was not explicitly included but was implicitly account for in the calibration of the SWAT model.

Inadequate SSTS –Without individual inspections, it is difficult to know the rate of compliance for septic systems in the lake catchment areas. Individual county estimates range from 28% - 42% compliance (see **Table 4-2**). Increasing septic compliance should be a focus of the lake restoration strategy, especially in shoreland areas. The phosphorus loading from failing SSTSs was not explicitly included but was implicitly account for in the calibration of the SWAT model.

Estimated annual phosphorus loading rates into the lakes of the BRW were taken from the BRW SWAT model (HEI 2013b); including surface water runoff unit loadings and tributary TP loads. The SWAT model accounts (both explicitly and implicitly) for all of the above listed potential sources of phosphorus and transports them overland and, eventually, into the nearest waterbody, in this case, the nearest lake.

Table 5-1 shows the average annual phosphorus balance, as calculated using the CNET model, for the lakes in the BRW using climate, flows and loadings from the SWAT model. The loadings are grouped into gains and losses. The gains add TP to the lake and include atmospheric deposition or direct TP loading from the atmosphere; direct drainage loading coming from overland runoff from the immediate drainage area; and tributary loads from any tributaries and non-immediate drainage areas flowing into lake. The losses include outflow loads leaving the lake through the outlet and in-lake processes/sedimentation, representing the TP remaining in the lake and taken as the total TP gains minus the outflow load.

Table 5-1: Average Annual Phosphorus Budget estimated by CNET using SWAT loads for Lakes in the BRW.

Lake Name	Gains (lbs/yr)[1]			Losses (lbs/yr)[1]	
	Atmospheric Deposition	Direct Drainage Load	Tributary Load	In-lake Processes/ Sedimentation	Outflow Load
Boyer	88	90	0	178	0
Forget-me-not	59	1,839	0	1,608	293
Gottenberg	31	220	260	414	97
Gourd	33	176	0	163	44
Jacobs	35	35	200	235	33
Lime	29	1,938	15,827	16,122	1,672
Maria	29	3,940	1,547	4,640	878
Marshall	48	264	0	295	20
Mission	66	244	0	310	0
Sand (Stump)	53	8,855	660	8,428	1,142
Sorenson (Lee)	20	706	0	334	392
Stakke	130	2,246	0	2,053	323
Stinking	101	17,626	11,757	20,922	8,565
Talac	37	458	1,533	904	1,122
West Labelle (Duck)	31	13	114	125	33

[1]Some balances might not equal zero due to rounding errors.

The current condition in the lakes of the BRW can be seen in the observed eutrophication data (**Table 5-2**).

Table 5-2 shows that all impaired lakes in the BRW exceed the water quality standard for phosphorus and at least one response variable (either Chl-*a* or Secchi Disk).

Table 5-3 shows the annual average observed TP concentrations, simulated TP concentrations, existing estimated TP loading, the estimated TP loading capacity, and required reduction to meet the nutrient standards for each impaired lake in the BRW.

Table 5-3 shows that the required reductions in TP loading ranges from near 0% to 93%.

Table 5-2: Observed Eutrophication Conditions for Lake in the BRW.

Lake Name	Observation Period	TP		Chl-*a*		Secchi Disk Depth	
		# of Obs	Mean (ug/L)	# of Obs	Mean (ug/L)	# of Obs	Mean (m)
Boyer	2008-2009	11	54.4	11	23.7	11	2.37
Forget-me-not	2009-2010	12	82.4	12	27.4	12	0.94
Gottenberg	2009-2010	12	68.0	12	33.8	12	0.81
Gourd	2009-2010	12	113.3	12	53.9	12	0.58
Jacobs	2009-2010	12	86.8	12	37.5	11	1.93
Lime	2009-2010	12	137.7	12	63.4	12	0.85
Maria	2009-2010	12	199.2	12	55.5	12	1.05
Marshall	2008-2009	12	41.8	12	20.5	11	1.85
Mission	2009-2010	12	120.3	12	75.6	12	0.58
Sand (Stump)	2002-2008	29	168.5	29	24.8	29	2.2
Sorenson (Lee)	2002-2006, 2008	27	218	27	46.9	27	1.36
Stakke	2008-2009	10	64.8	9	29.8	9	1.48
Stinking	2009-2010	12	308.6	12	95.8	12	0.66
Talac	2002-2006, 2008	29	118.4	29	34.4	29	2.06
West Labelle (Duck)	2009-2010	12	89.3	12	41.1	12	1.29

Table 5-3: TP Simulation Results and Required Reduction for Lakes in the BRW.

Lake	Observed Mean TP (ug/L)	Predicted TP (ug/L)	Estimated Annual Phosphorus Load (lbs)	Predicted TP (ug/L) Calibrated to Standard	Annual Phosphorus Load Capacity (lbs)	Percent Phosphorus Load Reduction to Achieve Standard (%)
Boyer	54.4	54.5	97	40	58.2	40%
Forget-Me-Not	82.4	78.8	1,907	60	1,107	42%
Gottenberg	68	66.2	516	60	439	15%
Gourd	113.3	106.3	192	60	61.7	68%
Jacobs	86.8	76.9	218	40	48.5	78%
Lime	137.7	133.4	18,768	60	3,754	80%
Lake Maria	199.2	190.7	5,747	90	1,609	72%
Marshall	41.8	39.4	278	40	278	0%
Mission	120.3	117	256	60	101	60%
Sand (Stump)	188.1	177.4	9,409	40	659	93%
Sorenson	217.7	215.9	697	60	187	73%
Stakke	64.8	61.5	2,326	60	2,255	3%
Stinking	308.6	302.1	30,483	90	4,877	84%
Lee (Talac)	125.8	122.9	1,986	60	955	52%
West LaBelle	89.3	83.9	137	60	75	45%

5.2 TMDL Allocations

Table 5-4 through **Table 5-18** show the computed loading capacities and allocations for the BRW's impaired lakes. The various components of these allocations were developed as described in **Section 3**. It should be noted, the sum of some TMDL calculations does not add up to the load capacity of the lake; this is primarily due to rounding errors.

Table 5-4: Loading capacities and allocations for Boyer Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.16	58.2
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.0001	0.05
Load Allocation	0.13	46.3
Margin of Safety	0.03	11.9

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-5: Loading capacities and allocations for Forget-Me-Not Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	3.03	1,106.7
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.003	1.0
Load Allocation	2.76	1,008.7
Margin of Safety	0.27	97.0

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-6: Loading capacities and allocations for Gottenberg Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	1.20	438.7
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.001	0.4
Load Allocation	1.10	403.0
Margin of Safety	0.10	35.3

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-7: Loading capacities and allocations for Gourd Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.17	61.7
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.0001	0.06
Load Allocation	0.14	52.9
Margin of Safety	0.03	8.8

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-8: Loading capacities and allocations for Jacobs Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.13	48.5
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.0001	0.04
Load Allocation	0.11	39.6
Margin of Safety	0.02	8.9

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-9: Loading capacities and allocations for Lime Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	10.29	3,754.5
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.01	3.4
Load Allocation	9.24	3,374.1
Margin of Safety	1.04	377.0

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-10: Loading capacities and allocations for Lake Maria.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	4.41	1,609.4
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.004	1.5
Load Allocation	4.09	1,493.2
Margin of Safety	0.32	114.7

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-11: Loading capacities and allocations for Marshall Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.76	277.8
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.0008	0.3
Load Allocation	0.75	275.3
Margin of Safety	0.01	2.2

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-12: Loading capacities and allocations for Mission Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.28	101.4
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.0003	0.1
Load Allocation	0.26	94.7
Margin of Safety	0.02	6.6

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-13: Loading capacities and allocations for Sand (Stump) Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	1.81	659.2
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.002	0.6
Load Allocation	1.54	563.8
Margin of Safety	0.27	94.8

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-14: Loading capacities and allocations for Sorenson Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.51	187.4
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.0005	0.2
Load Allocation	0.49	180.6
Margin of Safety	0.02	6.6

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-15: Loading capacities and allocations for Stakke Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	6.18	2,255.3
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.006	2.1
Load Allocation	5.86	2,138.5
Margin of Safety	0.31	114.7

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-16: Loading capacities and allocations for Stinking Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	13.36	4,876.6
Wasteload Allocation [1]		0.0
Lake Park WWTF [2]	1.27[3]	462.4
Construction/Industrial Stormwater	0.01	4.1
Load Allocation	11.25	4,106
Margin of Safety	0.83	304.2

[1] Other than the Lake Park WWTF, there are no facilities requiring NPDES permits in the watershed

[2] See Section 3.3 for discussion of daily and annual WLAs for the Lake Park WWTF.

[3] Daily WLA for Lake Park WWTF shown is for 365 day discharge. However, the permitted discharge is limited to 37 days not 365 days. Therefore the actual permitted daily load is 10.95 lb/day.

Table 5-17: Loading capacities and allocations for Talac (Lee) Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	2.62	954.6
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.003	0.9
Load Allocation	2.45	894.2
Margin of Safety	0.17	59.5

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

Table 5-18: Loading capacities and allocations for West LaBelle Lake.

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.21	75.0
Wasteload Allocation [1]		
Construction/Industrial Stormwater	0.0002	0.1
Load Allocation	0.19	70.5
Margin of Safety	0.02	4.4

[1] There are no facilities (including WTTFs) requiring NPDES permits in the watershed

5.3 Critical Conditions and Seasonal Variation

Water quality monitoring for the BRW suggests the in-lake TP concentrations vary over the course of the growing season (June through September), generally peaking in mid to late summer. The MPCA eutrophication water quality guideline for assessing TP is defined as the June through September mean concentration. TP loadings were calculated to meet the water quality standards during the summer growing season, the most critical period of the year. Calibration to this critical period will provide adequate protection during other times of the year with reduced loading.

In addition, the lake modeling performed for this study was completed using stochastic simulations in the CNET models. Use of the stochastic approach allows for the representation of naturally occurring variability in the systems due to changing hydrology, weather patterns, and other considerations. Basing the load reduction scenarios on these results explicitly incorporates seasonal variation and critical conditions into the analysis.

6 Monitoring

Continued stream monitoring within the BRW will continue primarily through the efforts of the BRRWD. As outlined in the **Section 4.2** of the BRRWD WMP (HEI 2010), the BRRWD has established regional assessment locations (RALs) in streams throughout the BRW and are currently employing a water quality monitoring program that consists of financial support to the River Watch Program and International Water Institute. Samples are collected on (at least) a monthly basis from April through September. The samples are analyzed for turbidity, temperature, pH, DO, connectivity, chloride, nutrients, TSS, and *E. coli*. In addition to the stream monitoring sponsored by the BRRWD, the MPCA also has ongoing monitoring in the watershed. Their major watershed outlet monitoring will continue to provide a long-term ongoing record of water quality at the BRW outlet.

The lakes of the BRW are not being routinely monitored at this time. The MPCA will return to the watershed and monitor lakes under their IMW program in 2019 and 2020.

7 Implementation

Water quality restoration and implementation strategies within the BRW were identified through collaboration with state and local partners. Due to the homogeneous nature of the watershed, most of the suggested strategies are applicable throughout the watershed. Exceptions include residue management, which is not practical for implementation in the Lake Plain region. Similarly, side inlet controls are effective in the Lake Plain, but water and sediment control basins are more appropriate in the central and eastern portions of the watershed.

The identified implementation strategies and priorities are discussed in the BRW WRAPS Report (HEI 2013e) and the Buffalo River Watershed Biotic Stressor Identification Report (MPCA 2013). Below is a summary of the suggested strategies needed to achieve restoration goals in the watershed.

- Increase septic system compliance;
- Improve livestock management;
- Restore and protect riparian and/or ditch system buffers;
- Restore unstable channels;
- Install engineered hydrologic control structures;
- Increase shoreline buffers;
- Improve nutrient management;
- Construct regional retention projects;
- Install field wind breaks;
- Increase cover crops / perennial vegetation;
- Ensure NPDES permit compliance;
- Ensure compliance with MPCA's feedlot regulations;
- Restore upstream waters (when applicable);
- Replace perched culverts;
- Remove and/or rehab dams that are blocking fish migration; and
- Manage beaver dams.

The BRW WRAPS Report (HEI 2013e) includes a process to prioritize subwatersheds for implementation using the SWAT model results. Those subwatersheds with the greatest yields for a stressor causing an impairment (e.g., TSS) are prioritized preferentially for implementation. The BRW WRAPS Report includes a summary table of the proposed implementation practices, prioritized by the watershed district. This table is included in **Appendix B**. Funding used to implement practices is expected to come largely from the Clean Water Fund of the 2008 Clean Water, Land and Legacy Act Amendment.

7.1 Construction and Industrial Stormwater Discharges

The WLA for stormwater discharges from sites where there are construction activities reflects the number of construction sites one or more acres expected to be active in the watershed at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General

Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

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 facility specific Individual Wastewater Permit (MN00XXXXX) 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.

7.2 Cost of Implementation

The CWLA requires that a TMDL include an overall approximation of implementation costs (Minn. Stat. 2007, § 114D.25). Based on cost estimates from similar work done in the BRW, a reasonable estimate for reducing turbidity and TSS in the impaired reaches addressed in this study would be $40 to $50 million dollars over 10 years. These dollars would be spent primarily on practices such as regional retention projects, riparian vegetative buffers, sediment BMPs (water and sediment control basins and side inlets), pasture management, conservation tillage, vegetative practices, wetland restorations, rain gardens, urban BMPs, and structural practices.

Phosphorus and bacteria reductions will also be needed to meet the targets of this TMDL. Residential practices would include those that reduce runoff from lakeshore homes and residences within the watershed. These practices could include shoreland buffers, rain gardens, lawn fertilizer reductions, vegetation management, and permeable pavement. Continued residential development of shoreland through construction and increased runoff, has the potential to add phosphorus to the system. Low impact practices and shoreland BMPs should be utilized for any new development. Practices on the homeowner scale often vary widely in cost (i.e. $500 for a small rain garden to $5,000 for permeable pavement).

Non-compliant septic systems can be a significant source of phosphorus and bacteria, especially during low flow periods. Upgrading non-compliant septic systems should be a priority within the BRW. Compliance levels can be improved by increasing the rate at which systems are inspected and repaired. Another option would be to tie lakeshore waste into a local municipal WWTF. Although this is not a current option, it might be incorporated in the future. Assuming the 70% of septic systems are compliant (see **Table 4-2**), approximately 951 septic systems are in need of upgrading in the BRW. Based on an average system cost of $10,000, the cost to upgrade homes could be as much as $9,510,000. In addition to septic system upgrades and residential practices, many of the BMPs associated with reducing TSS and turbidity would be effective at reducing the phosphorus load to the impaired waters. Therefore, the $40 - $50 million dollar estimate to address the TSS impairment serves as a reasonable estimate for the cost of phosphorus load reduction.

7.3 Adaptive Management

Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities. It is an ongoing process of evaluating and adjusting the strategies and activities that will be developed to implement the TMDL. The implementation of practicable controls should take place even while additional data collection and analysis are conducted to guide future implementation actions. Adaptive management does not include changes to water quality standards or loading capacity. Any changes to water quality standards or loading capacity must be preceded by appropriate administrative processes; including public notice and an opportunity for public review and comment.

A detailed implementation plan will be prepared from the management strategies and activities listed in Section 7 (and HEI 2013e), following EPA's approval of this TMDL assessment report. The implementation plan focuses on adaptive management (**Figure 7-1**) to evaluate project progress as well as to determine if the implementation plan should be amended. Implementation of TMDL related activities can take many years, and water quality benefits associated with these activities can take many years. As the pollutant source dynamics within the watershed are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reaches. The follow up water monitoring program outlined in **Section 6** will be integral to the adaptive management approach, providing assurance that implementation measures are succeeding in attaining water quality standards.

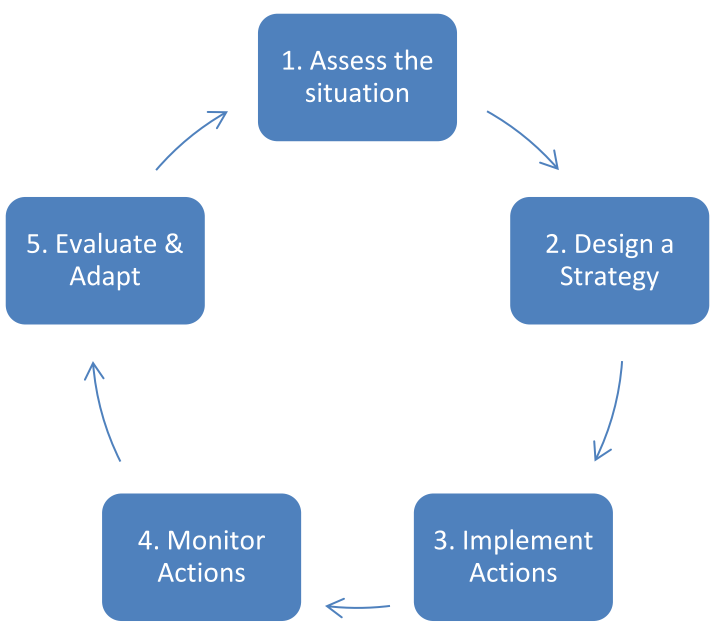

Figure 7-1: Adaptive management cycle.

8 Reasonable Assurance

Reasonable assurance of the load reductions and strategies developed under this TMDL comes from multiple sources. WLAs are assured through the issuance and regulation of NPDES Permits. LAs and their associated nonpoint source implementation strategies are reasonably assured by historic and ongoing collaborations in the watershed. Several agencies and local governmental units have been and continue to work toward the goal of reducing pollutant loads in the BRW. Strong partnerships between the BRRWD, counties, and soil and water conservation districts (SWCDs) have led to the implementation of conservation practices in the past and will continue to do so into the future. Upon approval of the TMDL by the EPA, the BRRWD will incorporate the various implementation activities described by this TMDL into their WMP. The BRRWD is committed to taking a lead role during the implementation of this TMDL and has the ability to generate revenue and receive grants to finance the implementation items.

In addition to commitment from local agencies, the state of Minnesota has also made a commitment to protect and restore the quality of its waters. In 2008, Minnesota voters approved the Clean Water, Land, and Legacy Amendment to increase the state sales tax to fund water quality improvements. The interagency Minnesota Water Quality Framework (**Figure 8-1**) illustrates the cycle of assessment, watershed planning, and implementation to which the state is committed. Funding to support implementation activities under this framework is made available through Minnesota's Board of Water and Soil Resources (BWSR), an agency that the BRRWD has received grants from in the past.

The Buffalo Red River Watershed has the ability to provide funding for projects consistent with those identified within the Watershed Management Plan. The Watershed Management Plan is required to be updated following a 10-year cycle and future revisions will include projects and methods to make progress toward implementing the TMDLs.

Figure 8-1: Minnesota Water Quality Framework

9 Public Participation

Public participation (i.e., civic engagement) during this TMDL process was led by the BRRWD. A TMDL stakeholder group was identified early in the TMDL process and kept up to date of actions as the project proceeded. Members of the group included area landowners, representatives from the area SWCDs, counties and townships, representatives from state agencies (MPCA, DNR, BWSR), and board members of the BRRWD. TMDL updates were regularly presented through open houses and public meetings in the watershed. In addition, the BRRWD developed a project webpage where updates and select reports were posted. The MPCA also developed a project webpage to keep the public informed of progress.

A public comment period was open from March 30, 2015, through April 29, 2015. There were three comment letters received as a result.

Since water quality is among the ongoing priorities of the BRRWD's management activities, future civic engagement will continue to go through the District. The BRRWD will update, educate, and engage stakeholders on water quality issues through the normal District communications, including plan update events and on their website. As one of most trusted authorities on water issues in the area (U of MN WRC 2012), the BRRWD is uniquely suited to provide information and leadership on this topic.

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Appendix A: Support Material Quick Reference Table

Report/Memorandum Title	Reference	Summary/Topic	Starting Page
Buffalo-Red River Watershed District Revised Watershed Management Plan	HEI, 2010	The management plan is the BRRWD's master plan to allocate district resources and guide the district's future planning. This plan is required by Minn. Stat. 103D.405 and contains the following: watershed description, assessment of existing and emerging resource management issues, guidance of future activities, planning regions and regional assessment locations, watershed district administration, and a summary of previous district data collection and modeling.	Summary
Watershed Condition Report Addendum	HEI, 2011a	The BRW Water Quality Improvement Project was initiated to identify sources of water quality impairments associated with turbidity and low fish diversity. In support of this project, current conditions within the Buffalo River Watershed were assessed with respect to water quality. This addendum extends the water quality analysis through the intensive watershed monitoring (2009-2010).	Summary
Lake Conditions Report-Buffalo River Watershed	HEI, 2011b	This report discusses the watershed conditions and current water quality conditions of lakes in the BRW. This report parallels the Watershed Conditions Report and Ammendum, focusing on the watershed's lakes.	Summary
Lake Classification Report-Buffalo River Watershed	HEI, 2011c	This report addresses the classification / grouping of lakes in the BRW as described in Task 9 of the MPCA contract #B55092: Buffalo River Watershed Approach Plan Phase 2. Creating models for each of the over 300 lakes in the BRW is not a realistic goal. An approach is therefore, needed to develop more generalized models that are reflective of water quality processes in the lakes of the BRW, in general, and to use those models to inform management of the individual lakes of the area.	Summary
Lake Water and Nutrient Budgets Report-Buffalo River Watershed	HEI, 2012a	This report addresses the water and TP budgets created for lakes in the BRW as described in Task 10 of the MPCA contract #B55092: Buffalo River Watershed Approach Plan Phase 2. Results of these budgets will be used to inform modeling to be completed during the next steps of the BRW Approach project. Budgets were created for the five lakes in the Sand-Axberg Chain of Lakes in the north-central portion of the BRW. In addition, water and TP budgets were created for each of the five "example" lakes developed under Task 9 of this project (HEI 2011a).	Summary

Report/Memorandum Title	Reference	Summary/Topic	Starting Page
BRW Bacteria Source Assessment and Quantification	HEI, 2013a	The following memorandum is intended to summarize rural bacteria sources in the BRW (HUC 09020106) for purposes of source identification and quantification. The findings will be used to inform the on-going watershed restoration and protection efforts in the area, including the creation of watershed loading models (SWAT). Findings of this work were informed by numerous state and local datasets, in addition to discussions amongst stakeholders and resource managers within the BRW	Summary
		Description of livestock facilities in the BRW	3
		Livestock population estimates for BRW	5
		Bacteria source-livestock manure	6
		Bacteria source-wildlife	7
		Bacteria source-SSTSs	9
		Bacteria source-WWTFs	10
		Watershed-wide waste creation and fecal coliform production	11
Buffalo River Watershed SWAT Modeling	HEI, 2013b	This report summarizes the development, calibration, and use of the BRW SWAT model.	
		Model Description	1
		Description of data sources used for model set-up (i.e. land-uses, soils, precipitation and climate data, etc.)	2
		Hydrologic Calibration	8
		Water Quality Calibration	14
		Water Quality Management Scenarios Descriptions	28
		Existing Conditions	30
		Future Conditions	35
		Model Conclusions	38
Buffalo River Watershed Load Duration Curves	HEI, 2013c	This memorandum summarizes the methods used and results for creating load duration curves (LDCs) for 22 impaired stream segments (delineated by assessment unit identification (AUID) numbers) in the BRW. Each of the 22 segments is impaired for aquatic recreation due to elevated *E. coli* levels. Some of the reaches are also impaired relative to aquatic life due to high turbidity and/or do not meet criterion for the current TSS standards.	Summary
		Water quality sites used to develop LDCs	2
		LDC methodology	4
		Description of source data	4
		Bacteria LDCs development	5
		Turbidity LDCs development	6

Report/Memorandum Title	Reference	Summary/Topic	Starting Page
		TSS LDCs development	6
		LDC results	6
		Load reductions	9
		Critical conditions	10
		LDCs by AUID	Appendix A
Buffalo River Watershed Lakes Eutrophication Modeling	HEI, 2013d	This report summarizes the in-lake water quality modeling efforts for lakes in the BRW as described in Tasks 10 and 11 of the MPCA contract #B55092: Buffalo River Watershed Approach Plan (WRAP) Phase II.	Summary
		Description of Lakes	5
		Lake Morphology	8
		Observed Water Quality in Lakes	9
		Water Budgets	11
		TP Budgets	13
		Description of the SWAT data used as inputs into the CNET Models	16
		Description of the CNET model and Monte Carlo approach, using Crystal Ball, used to simulate water quality in BRW lakes	20
		Description of the stochastic simulations and distributions	23
		Load reduction scenarios and eutrophication responses	26
		Recommended load reductions	32
		Individual lake results	Appendix A
Buffalo River Watershed-Watershed Restoration and Protection Strategy Report	HEI, 2013e	This report provides an overview of activities related the BRW WRAPS and summarizes past assessment and diagnostic work and outlines ways to prioritize actions and strategies for continued implementation.	Summary

Report/Memorandum Title	Reference	Summary/Topic	Starting Page
Buffalo River Watershed Monitoring and Assessment Report	MPCA, 2012a	In 2009, the MPCA undertook an intensive watershed monitoring effort of the Buffalo River Watershed's surface waters. Of the 41 AUIDs in the watershed, 25 had data available to assess aquatic recreation and 18 stream segments had sufficient information to assess aquatic life (not all lake and stream AUIDs were able to be assessed due to insufficient data, modified channel condition or their status as limited resources waters) (Appendix 5). Overall, 71 sites were sampled for biology at the outlets of variable sized sub-watersheds within the Buffalo River watershed (Appendices 6 and 7). Of the biological sites sampled, data from 13 sites that were sampled in either 2005 or 2007 and two sites sampled in 2010 were also included in the assessments. As part of this effort, the MPCA also joined with local partners to complete stream water chemistry sampling at the outlets of the Buffalo River's nine major subwatersheds (11-digit HUC). In addition to the biology and water chemistry sampling in streams, 41 lakes were also assessed in this effort to determine the suitability of lakes in the watershed to support aquatic recreation.	Summary
		The watershed monitoring approach	11
		Assessment methodology	15
		Watershed overview	20
		Watershed -wide data collection methodology	25
		Upper Buffalo River Watershed Unit (HUC 09020106010)	30
		County Ditch #15 Watershed Unit (HUC 09020106020)	36
		Middle Buffalo River Watershed Unit (HUC 09020106040)	48
		Deerhorn-Buffalo Watershed Unit (HUC 09020106050)	54
		South of Hawley-South Buffalo Watershed Unit (HUC 09020106060)	61
		Olaf Groves Lakes Watershed Unit (HUC 09020106070)	68
		County Ditch #2 Watershed Unit (HUC 09020106080)	73
		Lower Buffalo River Watershed Unit (HUC 09020106090)	77
		Watershed-wide results-TSS	83
		Watershed-wide results-TP	84
		Stressor ID	90
Assessment Report of Selected Lakes within the Buffalo River Watershed Red River of the North Basin	MPCA, 2012b	This report details the assessment of selected lakes within the Buffalo River Hydrologic Unit Code (HUC)-8 watershed. The Buffalo River Watershed is made up of nine HUC-11 intensively monitored watersheds. A general description at the eight-digit HUC level is provided, followed by discussions for each 11-digit HUC that has lakes identified as impaired. A full list of the assessed lakes within the Buffalo River Watershed, including their morphometric characteristics, is located in Appendix A.	Summary
		Assessment-Boyer Lake	16

Report/Memorandum Title	Reference	Summary/Topic	Starting Page
		Assessment-Forget-me-not Lake	16
		Assessment-Gottenberg Lake	15
		Assessment-Gourd Lake	30
		Assessment-Jacobs Lake	43
		Assessment-Lime Lake	32
		Assessment-Lake Maria	40
		Assessment-Marshall Lake	14
		Assessment-Mission Lake	12
		Assessment-Sand (Stump) Lake	22
		Assessment-Sorenson (Lee) Lake	29
		Assessment-Stakke Lake	29
		Assessment-Stinking Lake	33
		Assessment-Talac Lake	27
		Assessment-West Labelle (Duck) Lake	31
Buffalo River Watershed Biotic Stressor Indentification	MPCA, 2013	The Buffalo River Watershed was assessed in 2009 for aquatic recreation, aquatic consumption, and aquatic life beneficial uses. Based on this investigation, it was determined that four stream reaches were determined to be impaired for fish and/or invertebrates, as part of the aquatic life use designation. One of the impaired reaches is the Upper Buffalo River beginning at the outlet of Buffalo Lake and continuing to the confluence with an unnamed ditch located about 4.5 miles NE of Lake Park. The other three impaired reaches are tributaries to the Buffalo River: Deerhorn Creek, the South Branch Buffalo River, and Spring Creek. This report connects the biological community to the stressor(s) causing the impairments.	Summary
		Organization framework of stressor identification	4
		Biological monitoring stations and locations	5
		Summary of biological impairments	8
		Ecoregions of the BRW	11
		Hydrologic features and landforms in the BRW	13
		Candidate Causes of the Biological Impairments	20
		Candidate Cause: Turbidity	35
		Impaired Reach Stressor Assessment-Upper Buffalo River	63
		Impaired Reach Stressor Assessment-Buffalo River, South Branch	71
		Impaired Reach Stressor Assessment-Deerhorn Creek	83
		Impaired Reach Stressor Assessment-Spring Creek	95
		Summary of primary Stressors of the biological community	98

Appendix B: Implementation Strategy Table

HUC-10 Subwatershed	Waterbody (ID)	Location & Upstream Counties	Parameter	Current Conditions [2]	Goals / Targets	Strategies & Governmental Units with Primary Responsibility [3]																		Estimated Scale of Adoption Needed	Interim 10-Year Milestones	Notes
						Septic system compliance	Livestock management	Riparian and/or ditch system buffers	Engineered hydrologic control structures [4]	Regional retention project(s) [6]	Field wind breaks	Increase cover crops / perennial vegetation	Residue Management [5]	Channel restoration	Fish passage(s) around dam(s)	Shoreline Buffer	Nutrient Management	Regional Storage Site	NPDES permit compliance	Restore upstream waters	Culvert replacements	Manage beaver dams	Other [6]			
All	Unimpaired streams [1]	All	TSS	Varies	90% of samples ≤ 65 mg/L TSS			A, B	A,B, E					A, E					D	A,B, D,E				Watershed-wide	No waters that currently meet standards become impaired	Maintain current riparian and/or ditch system buffers; protect existing wetlands; protect stable, self-maintaining ditches; protect upstream waters
			Biological habitat	Varies	Varies			A, B						A, E						A,B, D,E				Watershed-wide	No waters that currently meet standards become impaired	Maintain current riparian and/or ditch system buffers; protect stable, self-maintaining ditches; protect upstream waters
			E. coli	Varies	Geometric mean ≤ 126 org/100mL	C													D	A,B, D,E				Watershed-wide	No waters that currently meet standards become impaired	Continued septic system compliance; protect upstream waters
	Unimpaired lakes [1]		Nutrients	Varies	Varies		B									B	B		D	A,B, D,E				Watershed-wide	No waters that currently meet standards become impaired	Promote Nutrient Management, especially around lakes; maintain existing shoreline buffers; protect upstream waters
Deerhorn Creek (0902010603)	State Ditch 14, Unnamed ditch to Deerhorn Cr (09020106-531)	Wilkin	*E. coli*	High = 1096 org/100mL Moist = 814 org/100mL Avg = 285 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributin g drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
	Deerhorn Creek, Headwaters to S Br Buffalo R (09020106-507)	Wilkin, Otter Tail	*E. coli*	High = 488.4 org/100mL Moist = 147.5 org/100mL Avg = 30.7 org/100mL Dry =16.9 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D					Contributin g drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 84 mg/L Moist = 35 mg/L Avg = 23 mg/L Dry = 27 mg/L Low = 44 mg/L	90% of samples ≤ 65 mg/L TSS			A, B	A,B	A	B	B	B						D				A, B	Contributin g drainage area	2 regional retention projects built in the BRW; 50% of farmed upstream waters buffered and/or addressed through stream restoration	Restore farmed-through waterways; Deerhorn Creek Site 2A regional retention project
			Biological - invertebrate s	IBI Score = 9.04-24.32	IBI Score > 38.3				A,B	A								A						Contributin g drainage area	Meet milestones for turbidity impairments; remove connectivity barriers	Deerhorn Creek Site 2A regional retention project

HUC-10 Subwatershed	Waterbody (ID)	Location & Upstream Counties	Parameter	Current Conditions [2]	Goals / Targets	Strategies & Governmental Units with Primary Responsibility [3]																		Estimated Scale of Adoption Needed	Interim 10-Year Milestones	Notes
						Septic system compliance	Livestock management	Riparian and/or ditch system buffers	Engineered hydrologic control structures [4]	Regional retention project(s) [6]	Field wind breaks	Increase cover crops / perennial vegetation	Residue Management [5]	Channel restoration	Fish passage(s) around dam(s)	Shoreline Buffer	Nutrient Management	Regional Storage Site	NPDES permit compliance	Restore upstream waters	Culvert replacements	Manage beaver dams	Other [6]			
			Biological - fish	IBI Score = 0 - 2	IBI Score > 40				A,B						A, E									Contributing drainage area	Meet milestones for turbidity impairments; remove connectivity barriers	
	Jacobs Lake (56-1039-00)	Otter Tail	Nutrients	Mean TP = 86.8 ug/L	Mean TP ≤ 40 ug/L				A,B							B	B							Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
Lower Buffalo River (0902010607)	County Ditch 2, Unnamed cr to Buffalo R (09020106-556)	Clay	*E. coli*	High = 345 org/100mL Moist = 193 org/100mL Avg = 217 org/100mL Dry = 284 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D					Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
	Buffalo River, S Br Buffalo R to Red R (09020106-501)	Clay, Becker, Wilkin, Otter Tail	*E. coli*	High = 250 org/100mL Moist = 98 org/100mL Avg = 162 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 171 mg/L Moist = 138 mg/L Avg = 170 mg/L Dry = 100 mg/L Low = 452 mg/L	90% of samples ≤ 65 mg/L TSS			A, B	A,B	A	B	B							D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	Spring Prairie Regional Retention Project
	County Ditch 39, Headwaters to Buffalo R (09020106-559)	Clay	*E. coli*	High = 344 org/100mL Moist = 306 org/100mL Avg = 365 org/100mL Dry = 403 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D					Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
	County Ditch 10, Headwaters to Buffalo R (09020106-562)	Clay	*E. coli*	High = NA Moist = NA Avg = 97 org/100mL Dry = 319 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D					Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
Middle Buffalo River (0902010602)	Buffalo River, Hay Cr to S Br Buffalo R (09020106-595)	Clay, Becker	*E. coli*	High = 99 org/100mL Moist = 147 org/100mL Avg = 231 org/100mL Dry = 264 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	

HUC-10 Subwatershed	Waterbody (ID)	Location & Upstream Counties	Parameter	Current Conditions [2]	Goals / Targets	Strategies & Governmental Units with Primary Responsibility [3]																		Estimated Scale of Adoption Needed	Interim 10-Year Milestones	Notes
						Septic system compliance	Livestock management	Riparian and/or ditch system buffers	Engineered hydrologic control structures [4]	Regional retention project(s) [6]	Field wind breaks	Increase cover crops / perennial vegetation	Residue Management [5]	Channel restoration	Fish passage(s) around dam(s)	Shoreline Buffer	Nutrient Management	Regional Storage Site	NPDES permit compliance	Restore upstream waters	Culvert replacements	Manage beaver dams	Other [6]			
			TSS	High = 401 mg/L Moist = 77 mg/L Avg = 28 mg/L Dry = 41 mg/L Low = NA	90% of samples ≤ 65 mg/L TSS			A, B	A,B		B	B	B						D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	
	Lake Maria (Marin) (14-0099-00)	Clay	Nutrients	Mean TP = 199.2 ug/L	Mean TP ≤ 90 ug/L				A,B							B								Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
South Branch Buffalo River (0902010606)	Buffalo River, South Branch, Deerhorn Cr to Whisky Cr (09020106-505)	Clay, Wilkin, Otter Tail	*E. coli*	High = 316 org/100mL Moist = 193 org/100mL Avg = 79 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 185 mg/L Moist = 51 mg/L Avg = 27 mg/L Dry = 64 mg/L Low = 83 mg/L	90% of samples ≤ 65 mg/L TSS			A, B	A,B	A	B	B							D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	Deerhorn Township Off-Channel regional retention project
			Biological - invertebrates	IBI Scores = 21.0-40.5	IBI Score > 38.3				A,B					A, E										Contributing drainage area	Meet milestones for turbidity impairments; remove connectivity barriers	
	Buffalo River, South Branch, Whisky Cr to Stony Cr (09020106-504)	Clay, Wilkin, Otter Tail	*E. coli*	High = NA Moist = 219 org/100mL Avg = 236 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 38 mg/L Moist = 51 mg/L Avg = NA Dry = 23 mg/L Low = NA	90% of samples ≤ 65 mg/L TSS			A, B	A,B		B	B							D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	
	Buffalo River, South Branch, Stony Cr to Buffalo R (09020106-503)	Clay, Wilkin, Otter Tail	*E. coli*	High = 291 org/100mL Moist = 250 org/100mL Avg = 255 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	

HUC-10 Subwatershed	Waterbody (ID)	Location & Upstream Counties	Parameter	Current Conditions [2]	Goals / Targets	Strategies & Governmental Units with Primary Responsibility [3]																		Estimated Scale of Adoption Needed	Interim 10-Year Milestones	Notes
						Septic system compliance	Livestock management	Riparian and/or ditch system buffers	Engineered hydrologic control structures [4]	Regional retention project(s) [6]	Field wind breaks	Increase cover crops / perennial vegetation	Residue Management [5]	Channel restoration	Fish passage(s) around dam(s)	Shoreline Buffer	Nutrient Management	Regional Storage Site	NPDES permit compliance	Restore upstream waters	Culvert replacements	Manage beaver dams	Other [6]			
			TSS	High = 82 mg/L Moist = 62 mg/L Avg = 51 mg/L Dry = 23 mg/L Low = 7 mg/L	90% of samples ≤ 65 mg/L TSS			A, B	A,B		B	B							D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	
	Buffalo River, South Branch, Headwaters to Deerhorn Cr (09020106-508)	Wilkin, Otter Tail	*E. coli*	High = 186 org/100mL Moist = 93.7 org/100mL Avg = 290.3 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D					Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 43 mg/L Moist = 54 mg/L Avg = 30 mg/L Dry = 32 mg/L Low = 11 mg/L	90% of samples ≤ 65 mg/L TSS			A, B	A,B	A	B	B	B	A, E					D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	Manston Township regional retention project
Stony Creek (0902010605)	Hay Creek, Unnamed cr to Spring Cr (09020106-519)	Clay	*E. coli*	High = NA Moist = 200 org/100mL Avg = 1880 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
	Spring Creek, Unnamed cr to Hay Cr (09020106-534)	Clay	*E. coli*	High = 533 org/100mL Moist = 227 org/100mL Avg = 237 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			Biological - invertebrates	IBI Score = 30.92	IBI Score > 38.3				A,B															Contributing drainage area	Remove connectivity barriers	
			Biological - fish	IBI Score = 43	IBI Score > 51				A,B						A, E									Contributing drainage area	Remove connectivity barriers	
	Stony Creek, Hay Cr to S Br Buffalo R (09020106-502)	Clay	*E. coli*	High = 361 org/100mL Moist = 362 org/100mL Avg = NA Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 59 mg/L Moist = 92 mg/L Avg = 99 mg/L Dry = 40 mg/L Low = NA	90% of samples ≤ 65 mg/L TSS			A, B	A,B		B	B	B						D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	

HUC-10 Subwatershed	Waterbody (ID)	Location & Upstream Counties	Parameter	Current Conditions [2]	Goals / Targets	Strategies & Governmental Units with Primary Responsibility [3]																		Estimated Scale of Adoption Needed	Interim 10-Year Milestones	Notes
						Septic system compliance	Livestock management	Riparian and/or ditch system buffers	Engineered hydrologic control structures [4]	Regional retention project(s) [6]	Field wind breaks	Increase cover crops / perennial vegetation	Residue Management [5]	Channel restoration	Fish passage(s) around dam(s)	Shoreline Buffer	Nutrient Management	Regional Storage Site	NPDES permit compliance	Restore upstream waters	Culvert replacements	Manage beaver dams	Other [6]			
	Stony Creek, T137 R45W S3, north line to T137 R46W S5, north line (09020106-523)	Clay	*E. coli*	High = 1152 org/100mL Moist = 209 org/100mL Avg = 327 org/100mL Dry = 10 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 87 mg/L Moist = 100 mg/L Avg = 78 mg/L Dry = 63 mg/L Low = 62 mg/L	90% of samples ≤ 65 mg/L TSS			A, B	A,B	A	B	B	B	A, E					D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	Stony Creek Off-Channel regional retention project
	Hay Creek, Spring Cr to Stony Cr (09020106-520)	Clay	*E. coli*	High =1655 org/100mL Moist = 412 org/100mL Avg = 1062 org/100mL Dry = 261 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
Upper Buffalo River (0902010601)	Hay Creek, Headwaters to Stinking Lk (09020106-511)	Becker	*E. coli*	High = NA Moist = 407 org/100mL Avg = 236 org/100mL Dry = 462 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D					Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
	Hay Creek (Stinking Lake), Stinking Lk (03-0647-00) (09020106-512)	Becker	Nutrients	Mean TP = 308.6 ug/L	Mean TP ≤ 90 ug/L			A, B	A,B							B			D	A,D				Contributing drainage area	75% sediment control within watershed through buffers and sediment BMPs	
	Buffalo River, Unnamed ditch to Hay Cr (09020106-594)	Clay, Becker	*E. coli*	High = 75 org/100mL Moist = 181 org/100mL Avg = 298 org/100mL Dry = 250.2 org/100mL Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 324 mg/L Moist = 97 mg/L Avg = 27 mg/L Dry = 50 mg/L Low = 99 mg/L	90% of samples ≤ 65 mg/L TSS			A, B	A,B		B	B	B						D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	
	Unnamed ditch, Unnamed ditch to Buffalo R (09020106-515)	Becker	*E. coli*	High = 19 org/100mL Moist = 143 org/100mL Avg = 389 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B											A(2x)	D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	Pierce Lake regional storage site, Reep Lake regional storage site

HUC-10 Subwatershed	Waterbody (ID)	Location & Upstream Counties	Parameter	Current Conditions [2]	Goals / Targets	Strategies & Governmental Units with Primary Responsibility [3]																		Estimated Scale of Adoption Needed	Interim 10-Year Milestones	Notes
						Septic system compliance	Livestock management	Riparian and/or ditch system buffers	Engineered hydrologic control structures [4]	Regional retention project(s) [6]	Field wind breaks	Increase cover crops / perennial vegetation	Residue Management [5]	Channel restoration	Fish passage(s) around dam(s)	Shoreline Buffer	Nutrient Management	Regional Storage Site	NPDES permit compliance	Restore upstream waters	Culvert replacements	Manage beaver dams	Other [6]			
	Buffalo River, Buffalo Lk to Unnamed ditch (09020106-593)	Becker	*E. coli*	High = NA Moist = 335 org/100mL Avg = 922 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D					Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 49 mg/L Moist = 33 mg/L Avg = 25 mg/L Dry = 22 mg/L Low = NA	90% of samples ≤ 65 mg/L TSS			A, B	A,B		B	B	B						D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	
			Biological - invertebrates	IBI Score = 25.70-48.28	IBI Scores > 38.3-46.8			A, B	A,B			B												Contributing drainage area	Remove connectivity barriers	
			Biological - fish	IBI Score = 27-51	IBI Score > 50																E		E	Numerous locations downstream of reach	Remove connectivity barriers	
	Mission Lake (03-0471-00)	Becker	Nutrients	Mean TP = 120.3 ug/L	Mean TP ≤ 60 ug/L				A,B							B	B							Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Marshall Lake (03-0526-00)	Becker	Nutrients	Mean TP = 41.8 ug/L	Mean TP ≤ 40 ug/L				A,B							B	B							Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Gottenberg Lake (03-0528-00)	Becker	Nutrients	Mean TP = 68.0 ug/L	Mean TP ≤ 60 ug/L				A,B							B	B							Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Boyer (Sand Beach) Lake (03-0579-00)	Becker	Nutrients	Mean TP = 54.4 ug/L	Mean TP ≤ 40 ug/L				A,B							B	B							Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Talac Lake (03-0619-00)	Becker	Nutrients	Mean TP = 118.4 ug/L	Mean TP ≤ 60 ug/L			A, B	A,B							B	B			A,B, D				Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Forget-Me-Not Lake (03-0624-00)	Becker	Nutrients	Mean TP = 82.4 ug/L	Mean TP ≤ 60 ug/L				A,B							B								Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Sorenson Lake (03-0625-00)	Becker	Nutrients	Mean TP = 218 ug/L	Mean TP ≤ 60 ug/L				A,B							B				A,D				Surrounding lake	Install 20% of sediment controls on contributing	

HUC-10 Subwatershed	Waterbody (ID)	Location & Upstream Counties	Parameter	Current Conditions [2]	Goals / Targets	Strategies & Governmental Units with Primary Responsibility [3]																		Estimated Scale of Adoption Needed	Interim 10-Year Milestones	Notes
						Septic system compliance	Livestock management	Riparian and/or ditch system buffers	Engineered hydrologic control structures [4]	Regional retention project(s) [6]	Field wind breaks	Increase cover crops / perennial vegetation	Residue Management [5]	Channel restoration	Fish passage(s) around dam(s)	Shoreline Buffer	Nutrient Management	Regional Storage Site	NPDES permit compliance	Restore upstream waters	Culvert replacements	Manage beaver dams	Other [6]			
																									waterways; install 50% of buffer around lake	
	Stakke (Stake) Lake (03-0631-00)	Becker	Nutrients	Mean TP = 64.8 ug/L	Mean TP ≤ 60 ug/L				A,B							B								Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Gourd Lake (03-0635-00)	Becker	Nutrients	Mean TP = 113.3 ug/L	Mean TP ≤ 60 ug/L				A,B							B								Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	West LaBelle (Duck) Lake (03-0645-00)	Becker	Nutrients	Mean TP = 89.3 ug/L	Mean TP ≤ 60 ug/L				A,B							B				A,D				Surrounding lake, especially on west and north sides	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Lime (Norby, Selvine) Lake (03-0646-00)	Becker	Nutrients	Mean TP = 137.7 ug/L	Mean TP ≤ 60 ug/L				A,B							B								Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Sand (Stump) Lake (03-0659-00)	Clay	Nutrients	Mean TP = 168.5 ug/L	Mean TP ≤ 40 ug/L				A,B							B				A,D				Surrounding lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	
	Axberg (Main Basin) Lake (03-0660-01)	Clay	Nutrients	Mean TP = 230.2 ug/L	Mean TP ≤ 60 ug/L											B	B						D	Surrounding and within lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	Cap, remove or segregate legacy pollutants
	Axberg (West Basin) Lake (03-0660-02)	Clay	Nutrients	Unknown	Mean TP ≤ 60 ug/L											B	B						D	Surrounding and within lake	Install 20% of sediment controls on contributing waterways; install 50% of buffer around lake	Cap, remove or segregate legacy pollutants
Whiskey Creek (0902010604)	Whisky Creek, Headwaters to T137 R46W S18, west line (09020106-521)	Clay, Otter Tail	*E. coli*	High = 550 org/100mL Moist = 275 org/100mL Avg = 156 org/100mL Dry = 685 org/100mL Low = 406 org/100mL	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 93 mg/L Moist = 54 mg/L Avg = 40 mg/L Dry = 50 mg/L Low = 28 mg/L	90% of samples ≤ 65 mg/L TSS			A, B	A,B		B	B	B						D					Downstream of S005-611	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	

HUC-10 Subwatershed	Waterbody (ID)	Location & Upstream Counties	Parameter	Current Conditions [2]	Goals / Targets	Strategies & Governmental Units with Primary Responsibility [3]																		Estimated Scale of Adoption Needed	Interim 10-Year Milestones	Notes
						Septic system compliance	Livestock management	Riparian and/or ditch system buffers	Engineered hydrologic control structures [4]	Regional retention project(s) [6]	Field wind breaks	Increase cover crops / perennial vegetation	Residue Management [5]	Channel restoration	Fish passage(s) around dam(s)	Shoreline Buffer	Nutrient Management	Regional Storage Site	NPDES permit compliance	Restore upstream waters	Culvert replacements	Manage beaver dams	Other [6]			
	Whisky Creek, T137 R47W S13, east line to S Br Buffalo R (09020106-509)	Clay, Otter Tail	*E. coli*	High = NA Moist = 295 org/100mL Avg = 332 org/100mL Dry = NA Low = NA	Geometric mean ≤ 126 org/100mL	C	B												D	A,D				Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 56 mg/L Moist = 70 mg/L Avg = NA Dry = NA Low = NA	90% of samples ≤ 65 mg/L TSS			A, B	A,B	A	B	B	B	A, E					D					Contributing drainage area	2 regional retention projects built in the BRW; install sediment controls and buffers on 20% of un-buffered streams	Barnesville Township regional retention project

Key: Unimpaired waters; Impaired waters

[1] More specifics on protection strategies are provided in "Notes" column

[2] Current Condition for *E. coli* and sediment provide by flow class; NA = "Not Available"

[3] Governmental Units with Primary Responsibility: A=BRRWD; B=SWCD; C=County; D=MPCA; E=DNR

[4] Engineered hydrologic control structures = on-field or regional structures to control hydrology, including side inlets, water/sediment control basins, wetland restoration and regional retention projects

[5] Residue management/reduced tillage may be an option outside of the lake plain

[6] See notes column for more information on "Other" strategies and identification of proposed regional retention projects

Appendix C: Load Duration Curves Memorandum

MEMO

(External Correspondence)

To: Bruce Albright, BRRWD
Tim James, MPCA

Date: August 21, 2013

File: 1915-185

From: Stephanie Johnson, PhD, PE

Subject: Buffalo River Watershed Load Duration Curves

INTRODUCTION

This memorandum summarizes the methods used for and results of creating load duration curves (LDCs) for twenty-two impaired stream segments (delineated by assessment unit identification (AUID) numbers) in the Buffalo River Watershed (BRW). Each of the 22 segments is impaired for aquatic recreation due to elevated *E. coli* levels; some of the reaches are also impaired aquatic life due to high turbidity. Results of the LDCs include computing necessary load reductions within each flow regime of the curve, which will be used to inform the development of total maximum daily loads (TMDLs) for these reaches. This effort was performed under Task 3 of the Buffalo River Watershed Restoration and Protection (WRAP) project.

A list of the 22 AUIDs addressed in this memorandum is included in **Table 1**. Also included is an indication of the impairments that LDCs will be used to address, a list of water quality monitoring stations located within each AUID and the associated SWAT (Soil and Water Assessment Tool) model subbasin which was used to represent flows for creating the curves. The AUIDs, monitoring locations and SWAT subbasins are also shown in **Figure 1**.

Document number wq-iw5-06r

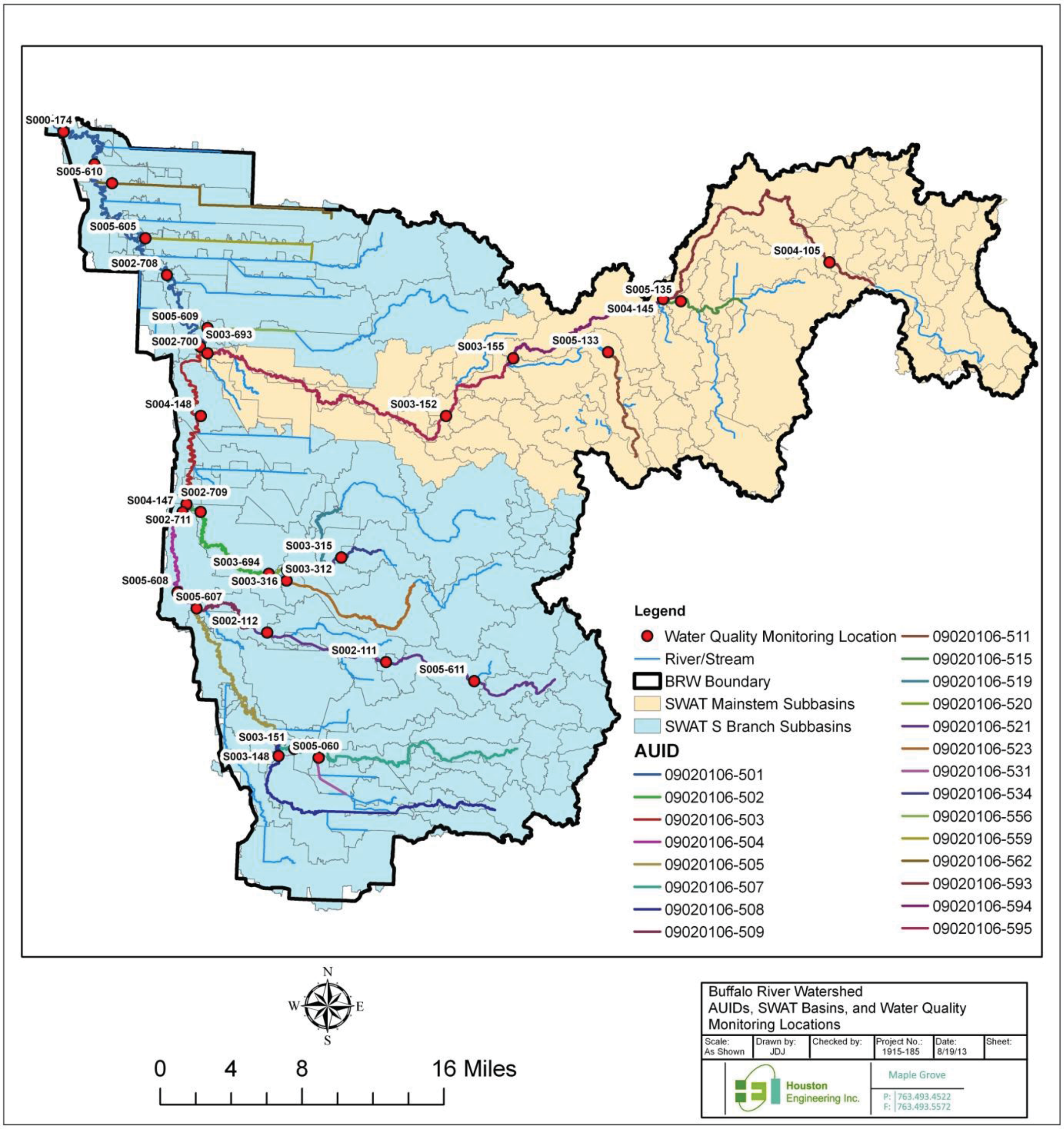


Figure 1. AUIDs, water quality monitoring locations and SWAT model subbasins used for LDCs in the BRW.

Table 1. LDC AUIDs, impairments and data used.

AUID (09020106-XXX)	Impairments	Water Quality Stations	SWAT Subbasin	SWAT Model
501	*E. coli*, Turbidity	S000-174, S002-125, S002-708, S003-693	1	S. Branch
502	*E. coli*, Turbidity	S002-711, S003-694	40	S. Branch
503	*E. coli*, Turbidity	S004-148, S002-709	28	S. Branch
504	*E. coli*, Turbidity	S004-147, S005-608	31	S. Branch
505	*E. coli*, Turbidity	S003-145	32	S. Branch
507	*E. coli*, Turbidity	S003-151	81	S. Branch
508	*E. coli*, Turbidity	S003-148	92	S. Branch
509	*E. coli*, Turbidity	S005-607	61	S. Branch
511	*E. coli*	S005-133	31	Mainstem
515	*E. coli*	S005-135	43	Mainstem
519	*E. coli*	S003-313	42	S. Branch
520	*E. coli*	S003-316	41	S. Branch
521	*E. coli*, Turbidity	S002-112, S002-111,S005-611	62	S. Branch
523	*E. coli*, Turbidity	S003-312	56	S. Branch
531	*E. coli*	S005-060	88	S. Branch
534	*E. coli*	S003-315	55	S. Branch
556	*E. coli*	S005-609	24	S. Branch
559	*E. coli*	S005-605	13	S. Branch
562	*E. coli*	S005-610	7	S. Branch
593	*E. coli*, Turbidity	S004-105	44	Mainstem
594	*E. coli*, Turbidity	S003-155, S004-145	20	Mainstem
595	*E. coli*, Turbidity	S002-700, S003-152	1	Mainstem

METHODOLOGY

LDCs were developed for each of the 22 AUIDs listed in **Table 1**. Each LDC was developed by combining the (simulated) river/stream flow at the downstream end of the AUID with the numeric water quality data available within the segment. Methods detailed in the US Environmental Protection Agency (USEPA) document *An Approach for Using Load Duration Curves in the Development of TMDLs* were used in creating the curves (USEPA, 2007). A summary of this methodology, as applied in the BRW, is provided below; full details on LDC methods can be found in the USEPA guidance (USEPA, 2007).

Data

Observed daily flow data is limited within the BRW; therefore simulated daily mean flows from the BRW SWAT model (HEI, 2013) were used to create the curves. The SWAT model simulates flows from 1995-2009; in order to best capture the flow regimes of each AUID, this entire record was used in development of the LDCs.

The water quality data used in this work was obtained from the Minnesota Pollution Control Agency (MPCA) through their EQuIS (Environmental Quality Information System) database. For the purposes of creating of the curves (which will inform TMDL development), only water quality data from the most recent completed assessment period (2002-2011) was used. While data exists for bacteria and sediment, spanning from 2002-2010, the SWAT model only estimates flows for 1995-2009; therefore the LDCs are based on bacteria and sediment data from the overlapping time period of 2002-2009. **Table 2** summarizes the water quality data used in the bacteria and sediment LDCs for each AUID in the BRW.

Table 2. Water quality data used for each LDC.

AUID (09020106-XXX)	Water Quality Monitoring Locations	*E. coli* Data	Turbidity/TSS Data
501	S000-174, S002-125, S002-708, S003-693	2008-2009	2001, 2003-2009
502	S002-711, S003-694	2009	2005-2007, 2009
503	S004-148, S002-709	2009-2010	2006-2009
504	S004-147, S005-608	2009-2010	2006-2009
505	S003-145	2008-2009	2002-2009
507	S003-151	2008-2009	2002-2009
508	S003-148	2009	2002-2009
509	S005-607	2009-2010	2009
511	S005-133	2008-2009	---
515	S005-135	2008-2010	---
519	S003-313	2009	---
520	S003-316	2008-2010	---
521	S002-112, S002-111,S005-611	2006, 2008-2009	2002-2009
523	S003-312	2008-2009	2003-2009
531	S005-060	2008-2010	---
534	S003-315	2009-2010	---
556	S005-609	2009-2010	---
559	S005-605	2009-2010	---

AUID (09020106-XXX)	Water Quality Monitoring Locations	*E. coli* Data	Turbidity/TSS Data
562	S005-610	2009-2010	---
593	S004-105	2008-2009	2008-2009
594	S003-155, S004-145	2008-2009	2002-2009
595	S002-700, S003-152	2008-2009	2002-2009

--- Not impaired for turbidity/TSS

Bacterial LDCs

To match the time period when the water quality standard is applicable, the bacterial LDCs were created using flow and *E. coli* water quality data from April through October only. Individual loading estimates were calculated by combining the observed *E. coli* concentration and simulated mean daily flow value on each sampling date. The load estimates were separated by month and by station, mainly for purposes of display on the curve. "Allowable" loading curves were created for both the instantaneous (1260 organisms/100mL) and geometric mean, i.e., geomean, (126 organisms/100mL) criteria by multiplying each "allowable" concentration by the simulated mean daily flow values and ranking the flows. A 10% margin of safety (MOS) was applied to each of the "allowable" loading curves.

Sediment (Turbidity) LDCs

Following common practice, sediment LDCs were used as a surrogate to represent and address turbidity impairments in the turbidity-impaired BRW AUIDs. Sediment LDCs were calculated using a combination of total suspended solids (TSS) and turbidity data. When available, TSS was used as the preferred value for calculating sediment loading. However, since turbidity data are more prevalent in the BRW, turbidity was used to estimate TSS values at sites where insufficient TSS data was available. This is consistent with MPCA guidance (MPCA, 2012). TSS and turbidity data was paired for the BRW and a linear regression was applied to test the relationship. The resulting linear regression equation for converting turbidity values (in NTU) in the BRW to TSS (in mg/L) during the 2002-2011 time period is:

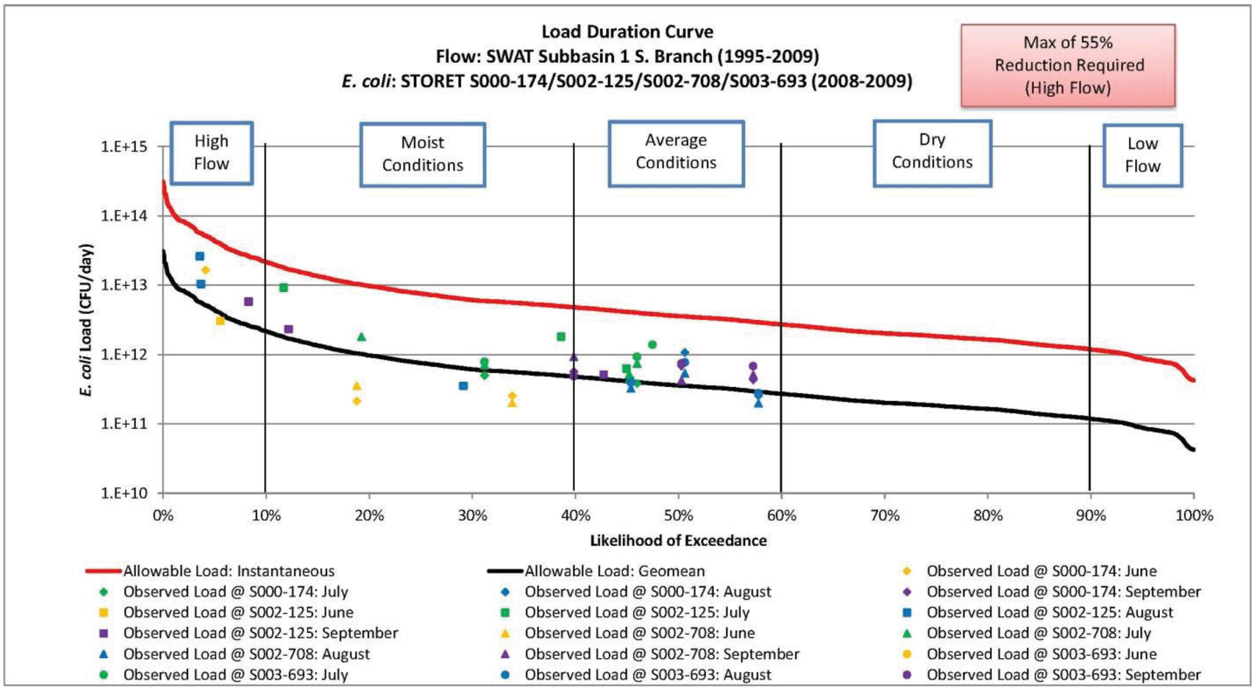
$$TSS = 0.9536 * Turbidity + 8.1967$$

Application of this regression equation to Minnesota's Class 2B stream turbidity water quality standard of 25 NTU (Nephelometric Turbidity Units) yields an "allowable" TSS value of 32 mg/L. As such, it is expected that a stream in the BRW with TSS concentrations of less than or equal to 32 mg/L would meet the turbidity water quality standard. The North Central Hardwood Forest (NCHF) surrogate TSS standard, by comparison, is 100 mg/L (a portion of the BRW lies in the NCHF so this surrogate standard could also be considered applicable). Both of these values were used in creating “allowable” loading curves and computing necessary sediment load reductions. Again, a 10% MOS was applied.

RESULTS

A system’s water quality often varies based on flow regime, with elevated pollutant loadings happening more frequency under one regime or another. Loading dynamics during certain flow conditions can be indicative of the type of pollutant loading causing an exceedance (e.g., point sources contributing more loading under low flow conditions). The LDC approach identifies these flow regimes and presents the observed and “allowable” loading with each, to compute necessary load reductions. To represent different types of flow events, and pollutant loading during these events, five flow regimes were identified in the BRW LDCs based on percent exceedance: High Flow (0%-10%), Moist Conditions (10%-40%), Average Conditions (40%-60%), Dry Conditions (60%-90%), and Low Flow (90%-100%). An example *E. coli* LDC is shown in **Figure 2**. The five flow regimes have been identified in the figure. There was one exception made to the defined flow regimes, for AUID 09020106-562. This stream reach experiences zero flow a considerable amount of the year and, therefore, required the low flow condition to be re-defined; its LDC is included in **Appendix A**.

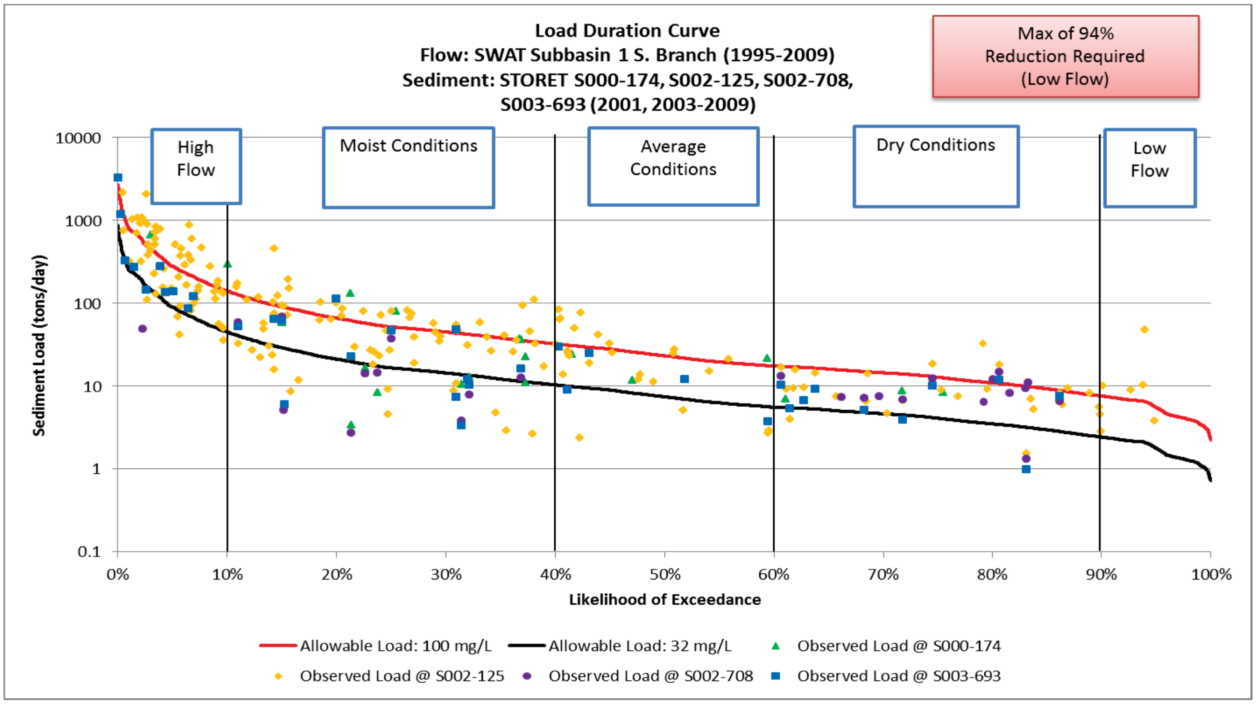
Figure 2. Example bacterial LDC (AUID 09020106-501)



The example bacterial LDC in **Figure 2** was created with flow and water quality data from April through October. The percent likelihood of flow exceedance is shown on the x-axis, while the computed bacterial loading is shown on the y-axis. "Allowable" loadings under each flow condition, based on the instantaneous and geomean standards, are shown with the red and black lines, respectively. Observed loads are also shown, indicated by points on the plot. Observed loads are broken out by station as well as month, allowing for a detailed examination of when and where loading exceedances have occurred. The bacterial LDCs for all of the AUIDs indicating bacterial impairment in **Table 1**a re included in **Appendix A**.

The BRW sediment LDCs were created using similar methods to the bacterial curves, however, the entire annual flow record was used and the empirical loading data was not broken out by month. These modifications are due to the nature by which turbidity impairment are assessed. An example sediment LDC is shown in **Figure 3**.

Figure 3. Example sediment LDC (AUID 09020106-501)



The red line in the sediment LDC represents the "allowable" load based on the NCHF TSS standard of 100 mg/L and the bottom curve represents the "allowable" load based on the BRW turbidity/TSS relationship of 25 NTU to 32 mg/L. The sediment LDCs for all of the AUIDs indicating turbidity impairment in **Table 1** are included in **Appendix B**.

LOAD REDUCTIONS

Bacteria

Total required bacterial load reductions (in organisms/day) and percent load reductions were calculated for each curve, using both the geomean and instantaneous criteria. Methods outlined in the USEPA guidance document (USEPA, 2007) were followed, computing observed and "allowable" loads for each flow regime by combining the median flow in each regime with the applicable water quality criteria and/or representative observed *E. coli* concentration. An example of this process is shown in **Table 3**. The reduction for each criterion (in each flow regime) is determined using the difference between the observed and "allowable" values.

Table 3. Example bacterial load reduction table (AUID 09020106-501)

Flow Regimes	Median Observed Flow (cfs)	Geomean Standard						Instantaneous Standard				
		Observed *E. coli* Geomean (#/100 mL)	Observed *E. coli* Geomean Loading (#/day)	Allowable Load (#/day)	Allowable Load w/ 10% MOS (#/day)	Required Load Reduction (#/day)	% Load Reduction	*E. coli* Value that 90% are less than (#/100 mL)	Allowable Load (#/day)	Allowable Load w/ 10% MOS (#/day)	Required Load Reduction (#/day)	Required % Load Reduction
0-10%	1568	250	$9.6x10^{12}$	$4.8x10^{12}$	$4.4x10^{12}$	$5.2x10^{12}$	55%	517	$4.8x10^{13}$	$4.4x10^{13}$	$-2.4x10^{12}$	NR
10-40%	273	98	$6.6x10^{11}$	$8.4x10^{11}$	$7.6x10^{11}$	$-1.0x10^{11}$	NR	411	$8.4x10^{12}$	$7.6x10^{12}$	$-4.8x10^{12}$	NR
40-60%	129	162	$5.1x10^{11}$	$4.0x10^{11}$	$3.6x10^{11}$	$1.6x10^{11}$	30%	261	$4.0x10^{12}$	$3.6x10^{12}$	$-2.8x10^{12}$	NR
60-90%	66	---	---	$2.1x10^{11}$	$1.8x10^{11}$	---	---	---	$2.1x10^{12}$	$1.8x10^{12}$	---	---
90-100%	32	---	---	$9.8x10^{10}$	$8.8x10^{10}$	---	---	---	$9.8x10^{11}$	$8.8x10^{11}$	---	---

--- insufficient data

NR – no reduction required

Table 4. Example sediment load reduction table (AUID 09020106-501)

Flow Regime	Observed Data			NCHF TSS Guidance (100 mg/L)				Turbidity/TSS Conversion (32 mg/L)			
	Median Observed Flow (cfs)	90th % Observed TSS (mg/L)	Average Observed TSS Loading (tons/day)	Allowable TSS Load (tons/day)	Allowable Load w/ 10% MOS (tons/day)	Required Load Reduction (tons/day)	% Load Reduction	Allowable TSS Load (tons/day)	Allowable Load w/ 10% MOS (tons/day)	Required Load Reduction (tons/day)	% Load Reduction
0-10%	1160	175	547	312.8	281.5	265.9	49%	100.1	90.1	457.3	84%
10-40%	214	136	78	57.6	51.8	26.5	34%	18.4	16.6	61.7	79%
40-60%	96	182	47	25.9	23.3	23.9	51%	8.3	7.5	39.8	84%
60-90%	53	100	14	14.3	12.8	1.4	10%	4.6	4.1	10.2	71%
90-100%	23	120	8	6.3	5.6	1.9	25%	2.0	1.8	5.7	76%

Sediment

Similar methods were used to compute the total required sediment load reductions (tons/day) and percent reductions for the NCHF TSS and BRW turbidity/TSS conversion criterion at the median of each of the five flow regimes. An example of this process is shown in **Table 4**. Again, the reduction for each criterion is determined using the difference between the observed and "allowable" loads.

Critical Condition

A summary of the bacterial and sediment load reduction results can be found in **Table 5**. Results are summarized by indicating the maximum required percent load reduction for each curve and the flow regime and water quality criteria under which this maximum reduction occurred (i.e., the critical flow regime and criteria). The critical criterion for each of the bacterial LDCs is consistently the geomean criterion, indicating a chronic bacterial water quality problem in the watershed. The critical condition for turbidity impairments is always under the turbidity/TSS conversion criterion. The critical flow regime for both bacteria and sediment loading is most often under high flow conditions.

Table 5. Maximum required bacterial and sediment load reductions for the BRW.

	Bacterial			Sediment		
AUID (09020106-XXX)	**Max. % Load Reduction**	**Critical Flow Regime**	**Critical Criterion**	**Max. % Load Reduction**	**Critical Flow Regime**	**Critical Criterion**
501	55%	High	Geomean	94%	Low	32 mg/L
502	69%	High / Moist	Geomean	71%	Average	32 mg/L
503	57%	High	Geomean	65%	High	32 mg/L
504	47%	Average	Geomean	44%	Moist	32 mg/L
505	64%	High	Geomean	84%	High	32 mg/L
507	77%	High	Geomean	66%	High	32 mg/L
508	61%	Average	Geomean	46%	Moist	32 mg/L
509	62%	Average	Geomean	59%	Moist	32 mg/L
511	75%	Dry	Geomean	---	---	---
515	71%	Average	Geomean	---	---	---
519	94%	Average	Geomean	---	---	---
520	93%	High	Geomean	---	---	---
521	83%	Dry	Geomean	69%	High	32 mg/L
523	90%	High	Geomean	71%	Moist	32 mg/L
531	90%	High	Geomean	---	---	---
534	79%	High	Geomean	---	---	---
556	67%	High	Geomean	---	---	---
559	72%	Dry	Geomean	---	---	---
562	64%	Dry	Geomean	---	---	---
593	88%	Average	Geomean	41%	High	32 mg/L
594	62%	Average	Geomean	91%	High	32 mg/L
595	57%	Dry	Geomean	93%	High	32 mg/L

--- Not impaired for turbidity

CONCLUSION

Sediment and/or bacteria LDCs were developed for 22 AUIDs in the BRW based on impairment status. The curves were developed following the methods in the USEPA guidance document, *An Approach for Using Load Duration Curves in the Development of TMDLs* (USEPA, 2007). Results of this analysis showed maximum required bacterial load reductions ranging from 47-94%, all based on the geomean *E. coli* criterion, and typically occurring during high flow conditions. Maximum sediment load reductions range from 41-93%, all based on the turbidity/TSS conversion criterion of

32 mg/L, and also most often found during high flow conditions. Results of the LDC analysis will be used to compute TMDLs for these stream segments under future tasks of the BRW WRAP project.

REFERENCES

Houston Engineering, Inc. (HEI). 2013. Buffalo River Watershed SWAT Modeling Final Report. August 13, 2013.

MPCA (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. Minnesota Pollution Control Agency. St. Paul, MN

United States Environmental Protection Agency (USEPA). 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006. August 2007.

APPENDIX A. BACTERIAL LOAD DURATION CURVES

Figure A1. AUID 09020106-501 bacterial LDC

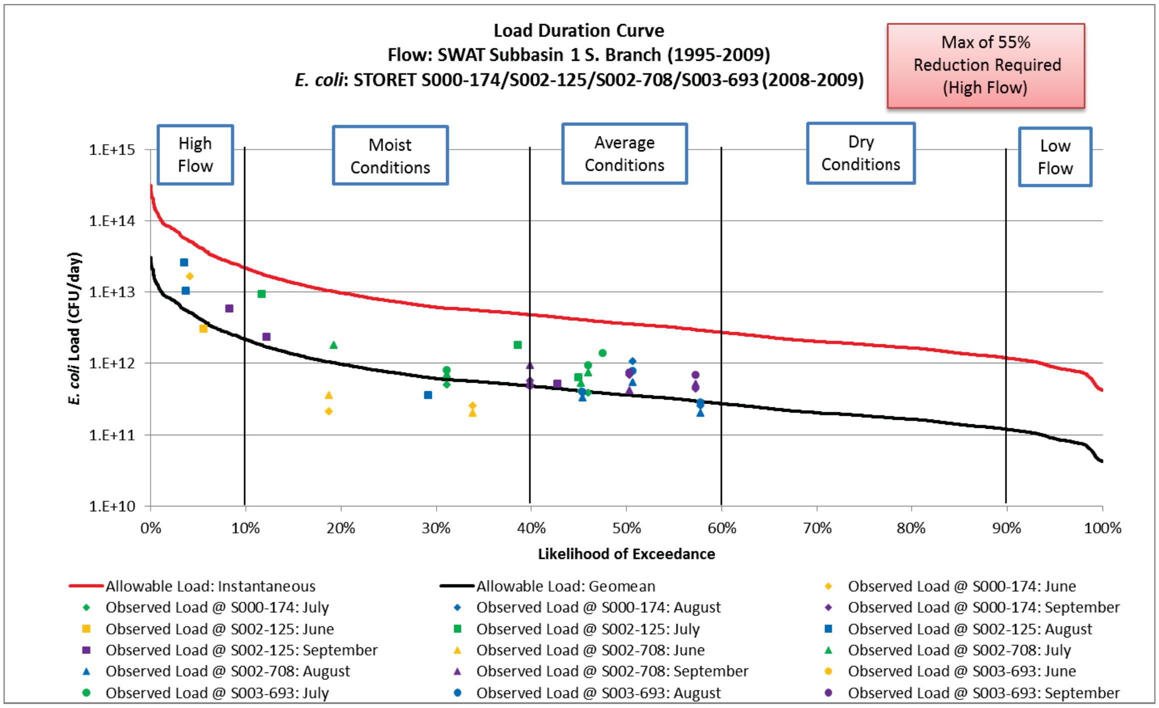


Figure A2. AUID 09020106-502 bacterial LDC

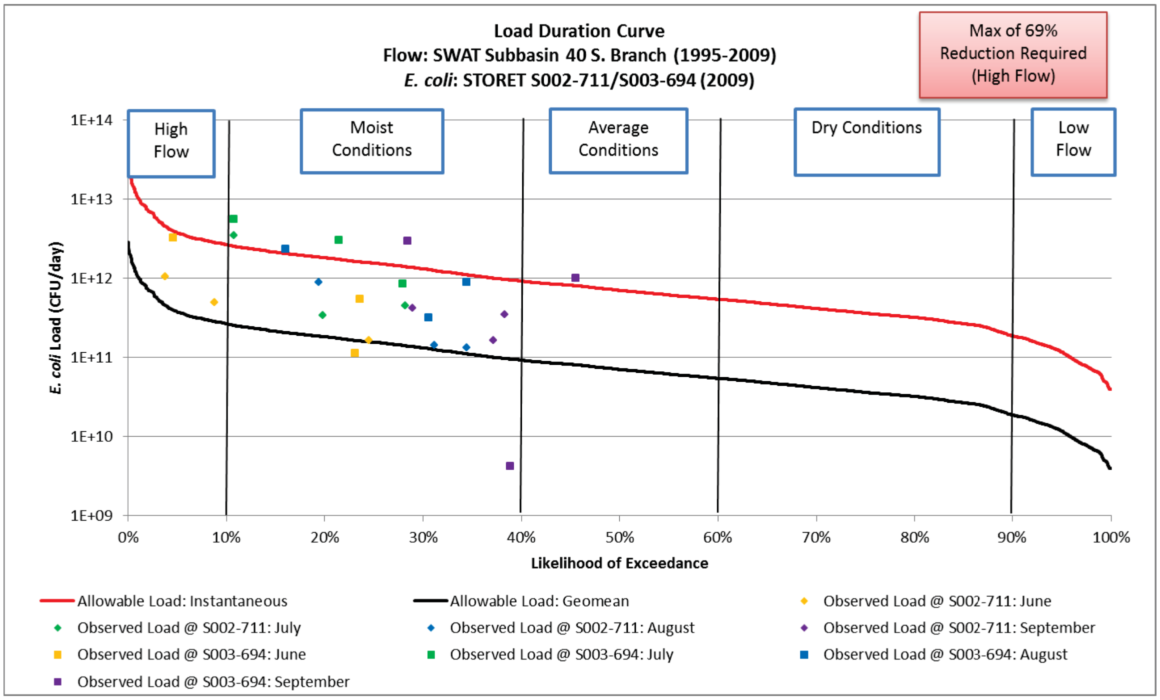


Figure A3. AUID 09020106-503 bacterial LDC

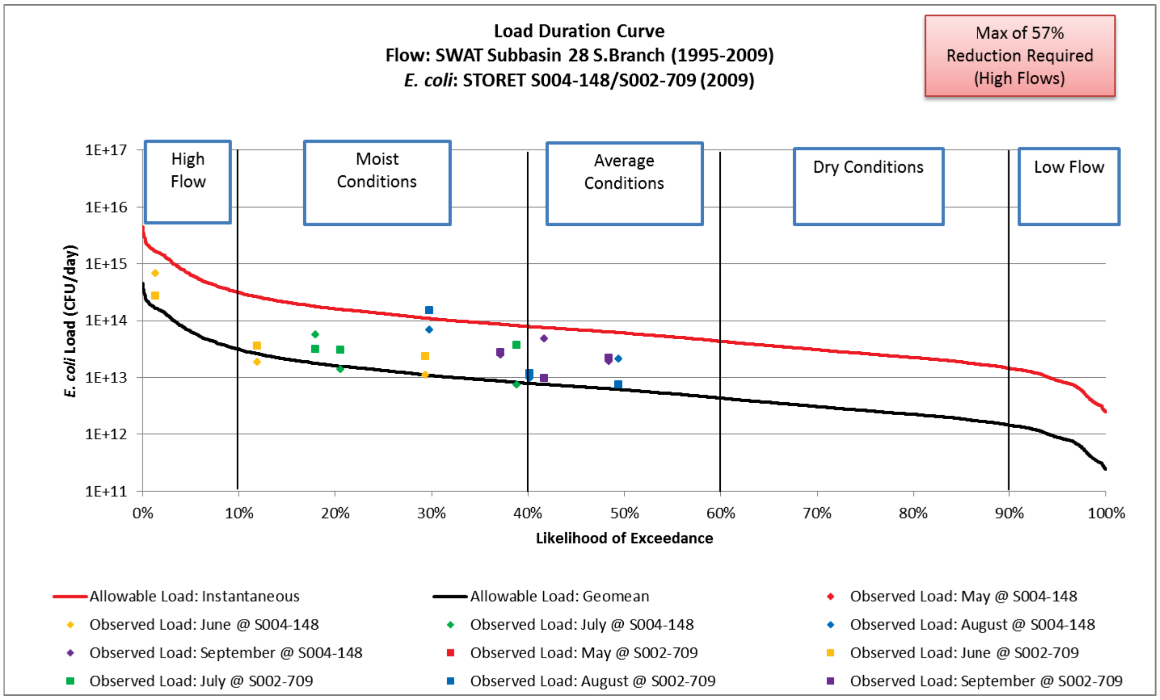


Figure A4. AUID 09020106-504 bacterial LDC

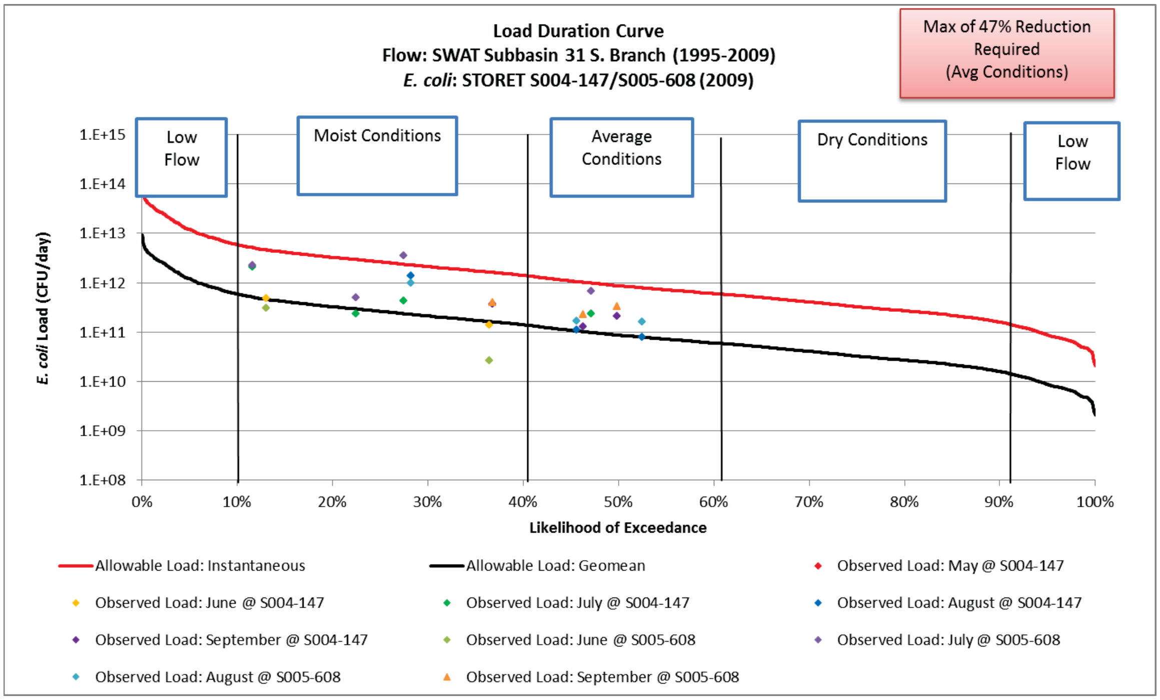


Figure A5. AUID 09020106-505 bacterial LDC

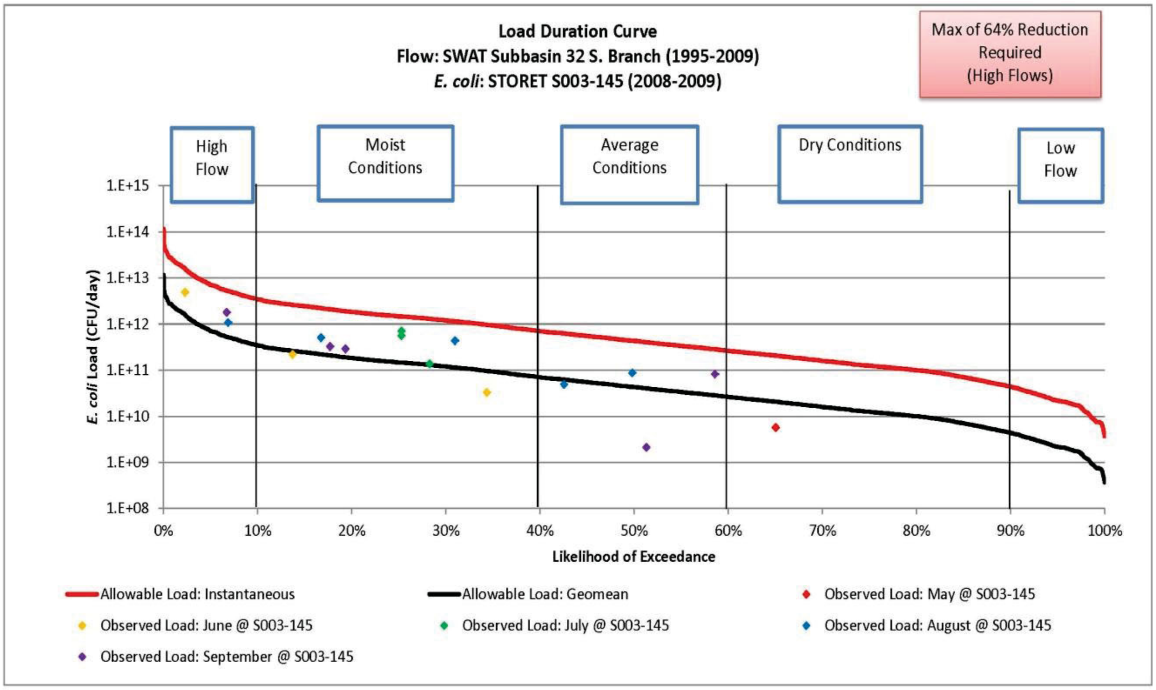


Figure A6. AUID 09020106-507 bacterial LDC

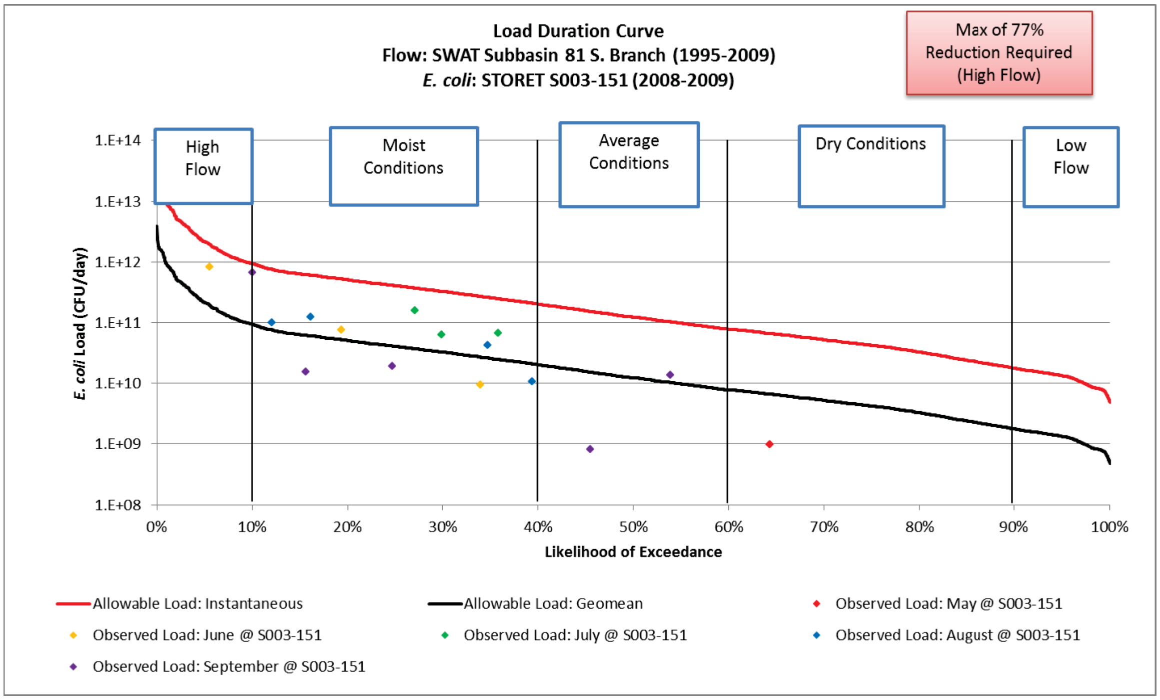


Figure A7. AUID 09020106-508 bacterial LDC

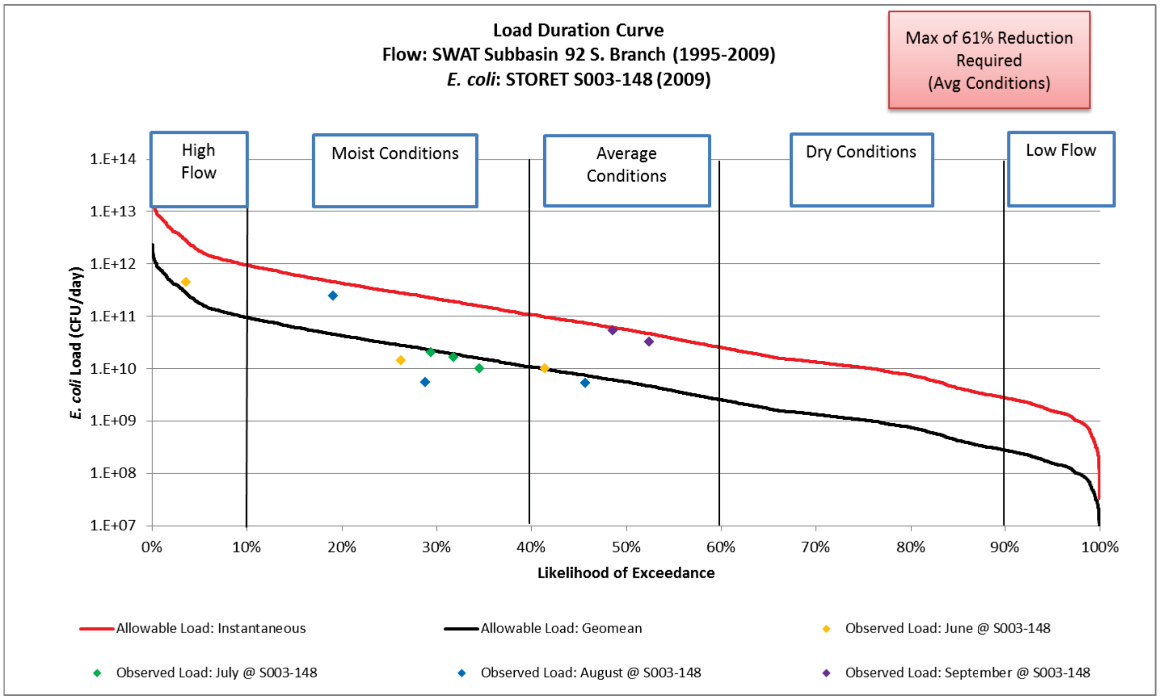


Figure A8. AUID 09020106-509 bacterial LDC

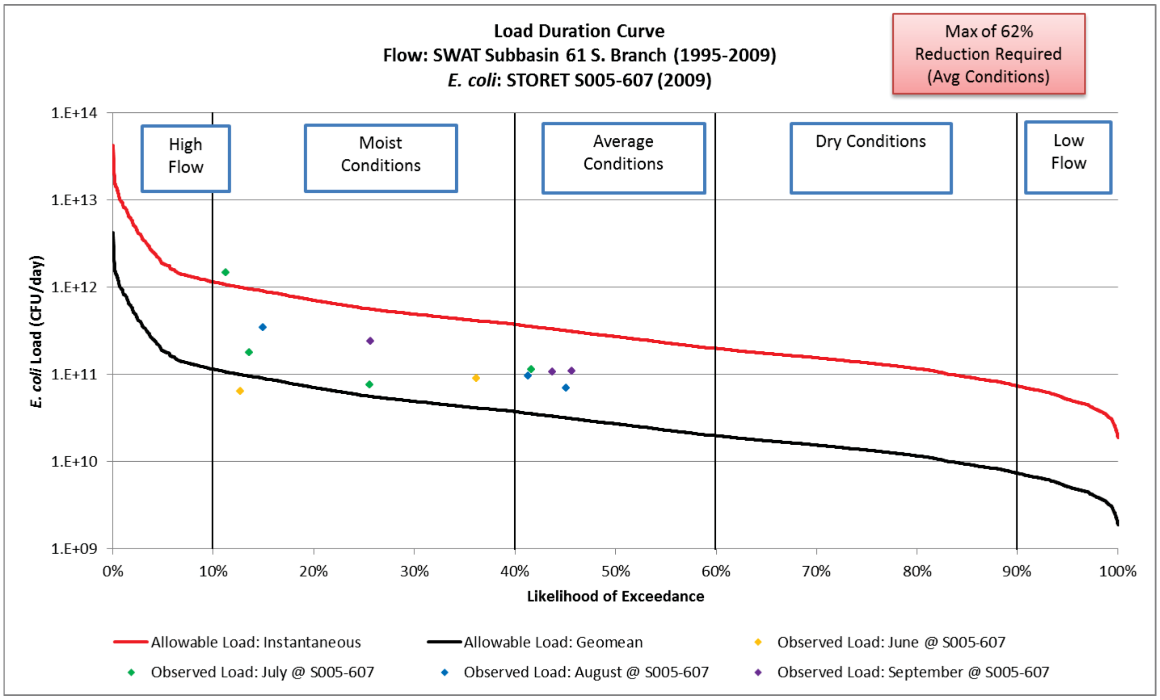


Figure A9. AUID 09020106-511 bacterial LDC

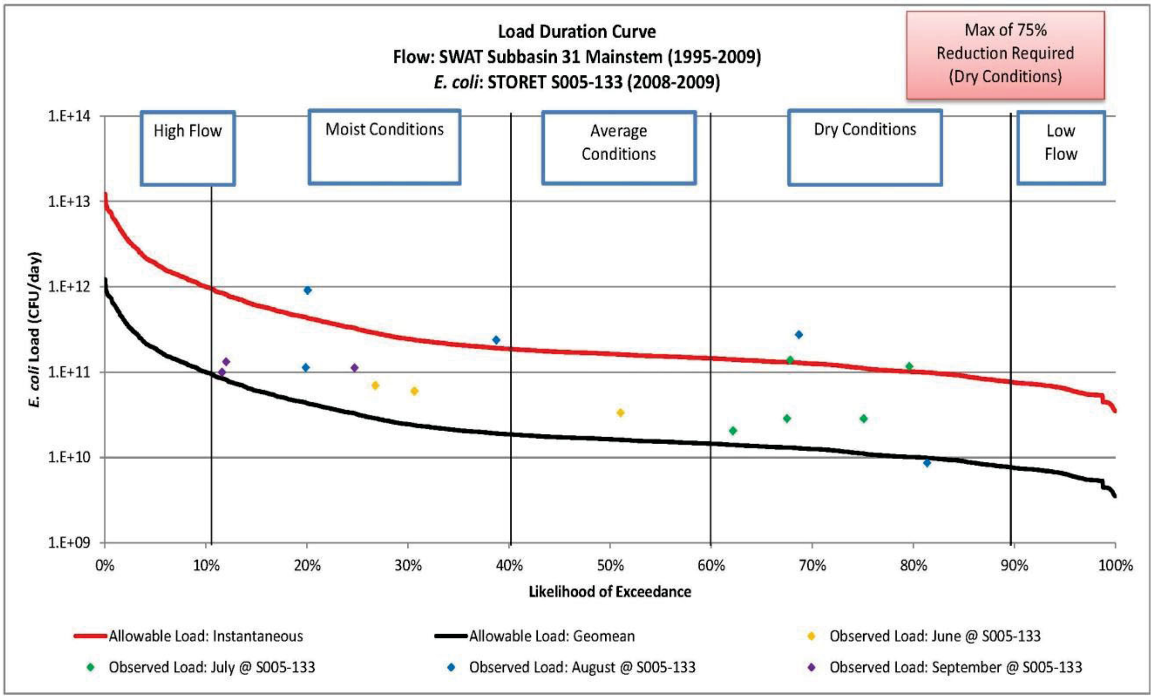


Figure A10. AUID 09020106-515 bacterial LDC

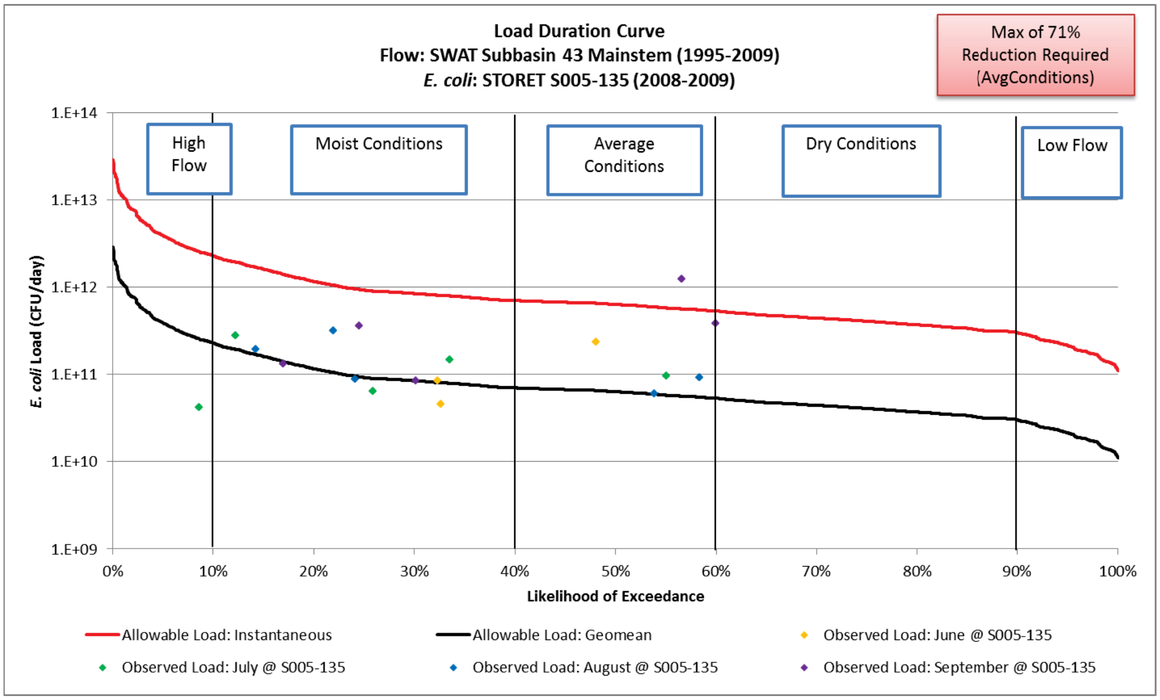


Figure A11. AUID 09020106-519 bacterial LDC

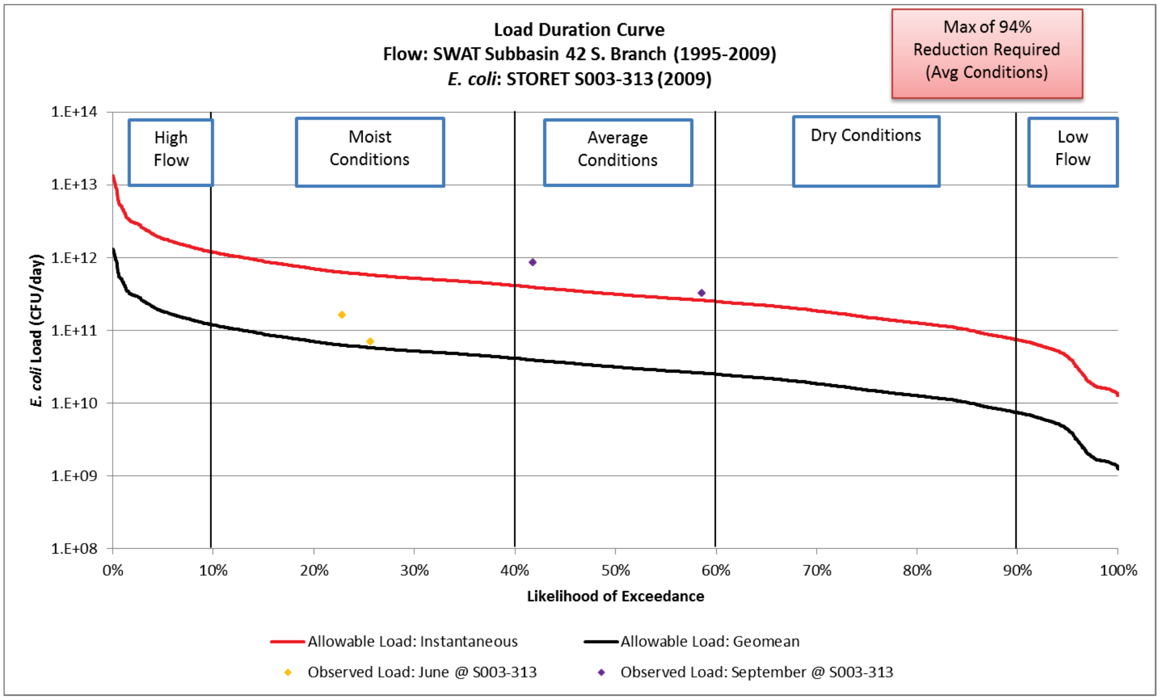


Figure A12. AUID 09020106-520 bacterial LDC

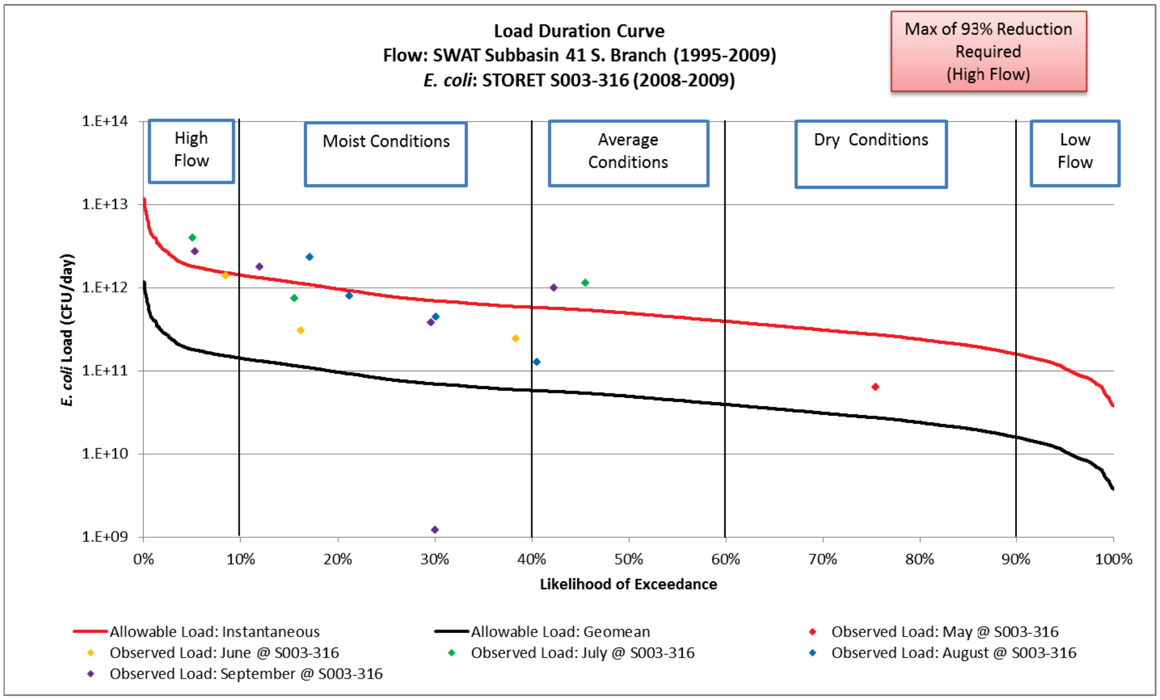


Figure A13. AUID 09020106-521 bacterial LDC

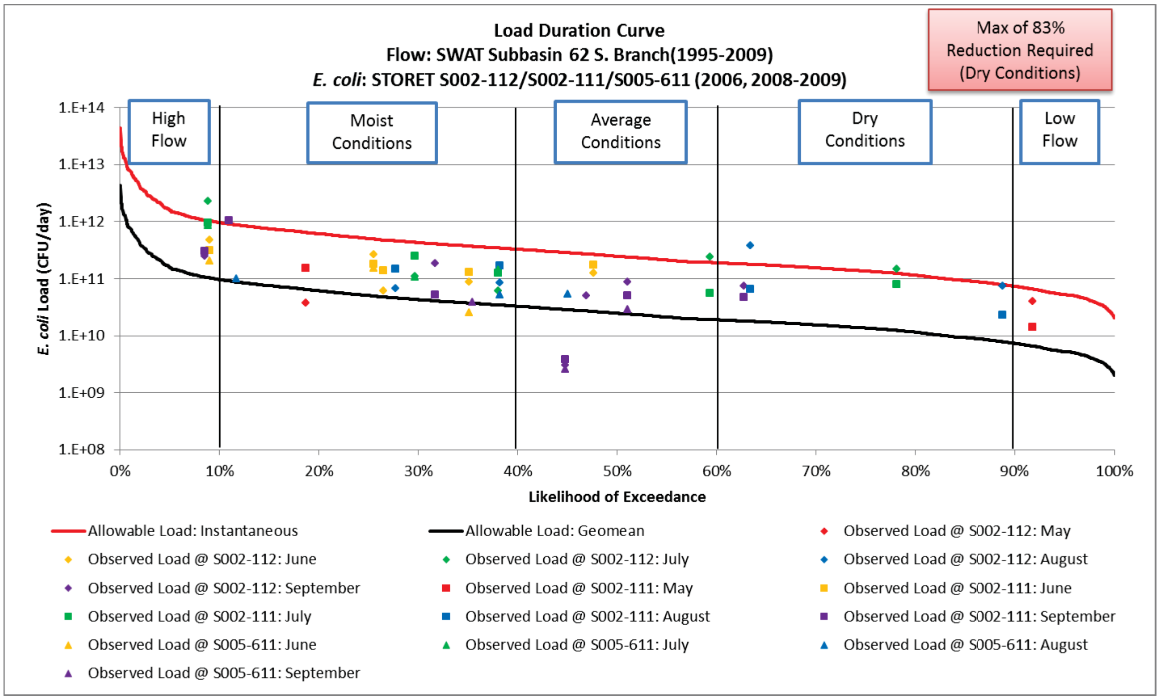


Figure A14. AUID 09020106-523 bacterial LDC

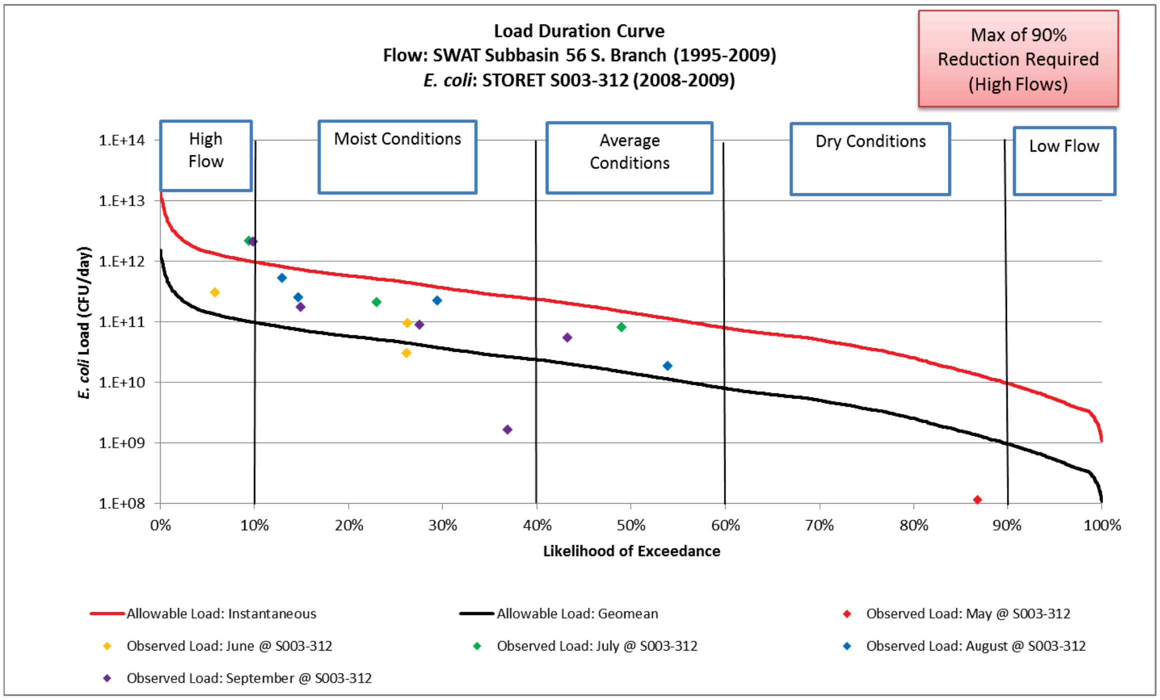


Figure A15. AUID 09020106-531 bacterial LDC

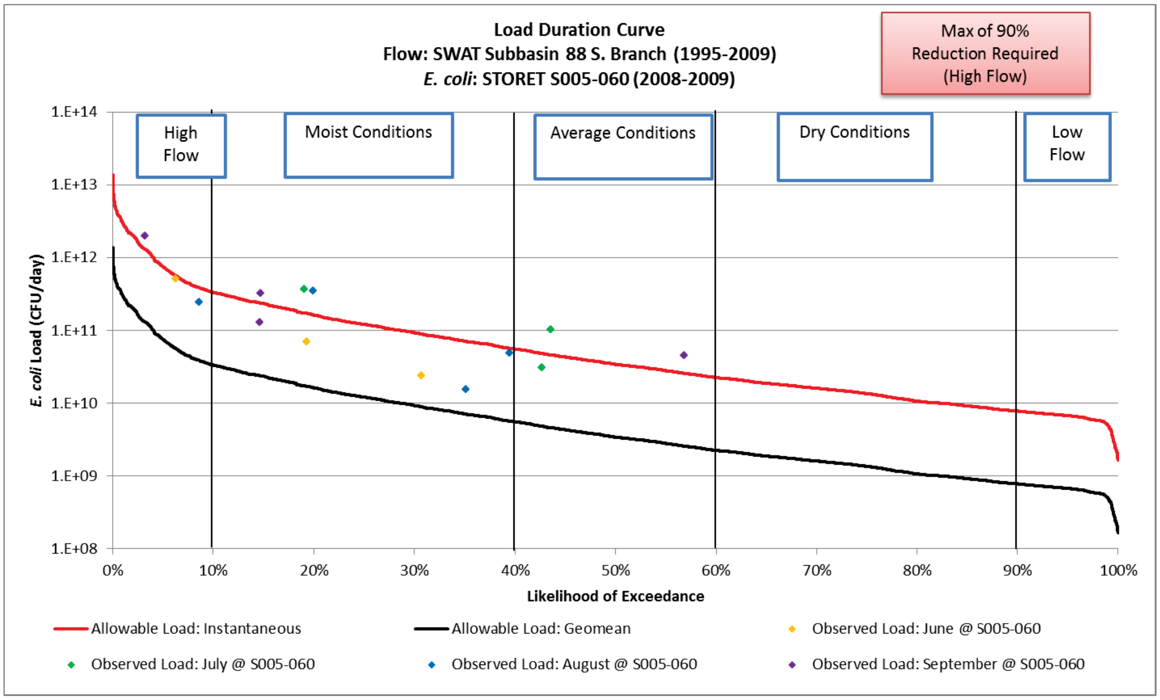


Figure A16. AUID 09020106-534 bacterial LDC

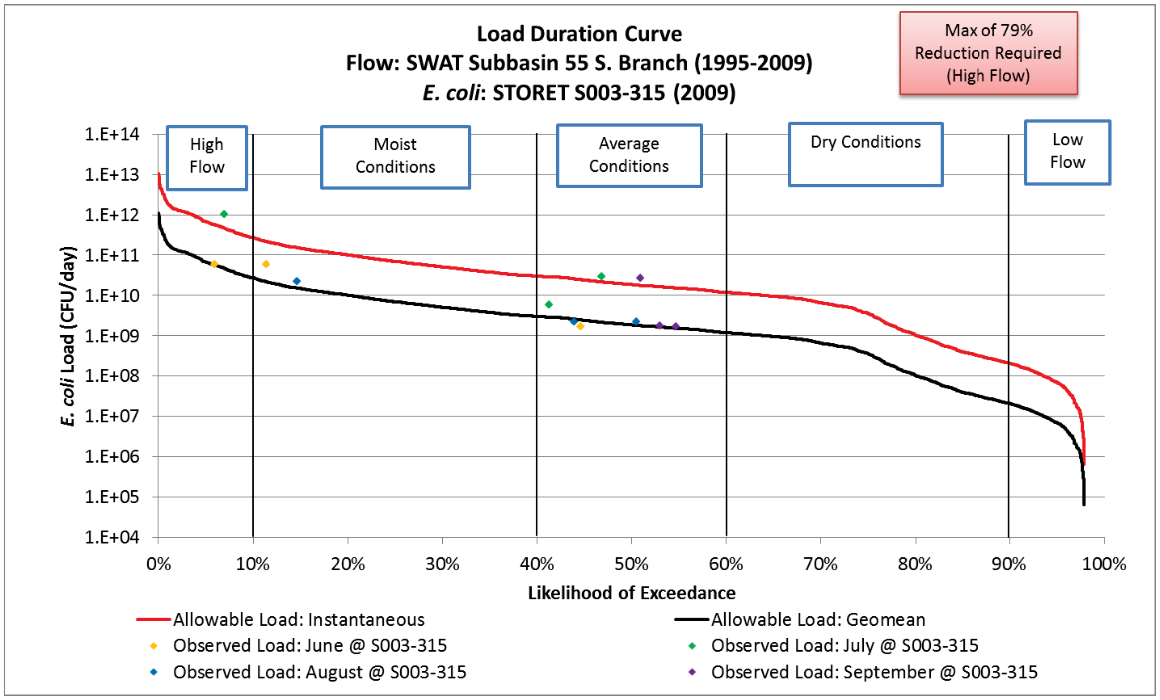


Figure A17. AUID 09020106-556 bacterial LDC

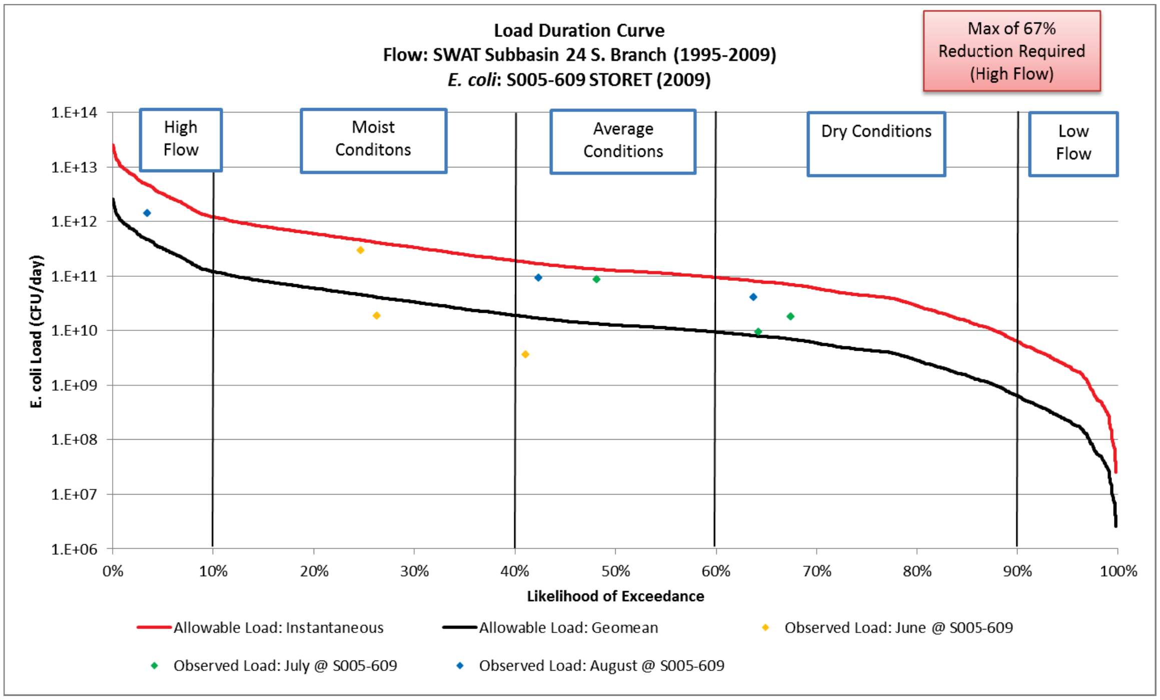


Figure A18. AUID 09020106-559 bacterial LDC

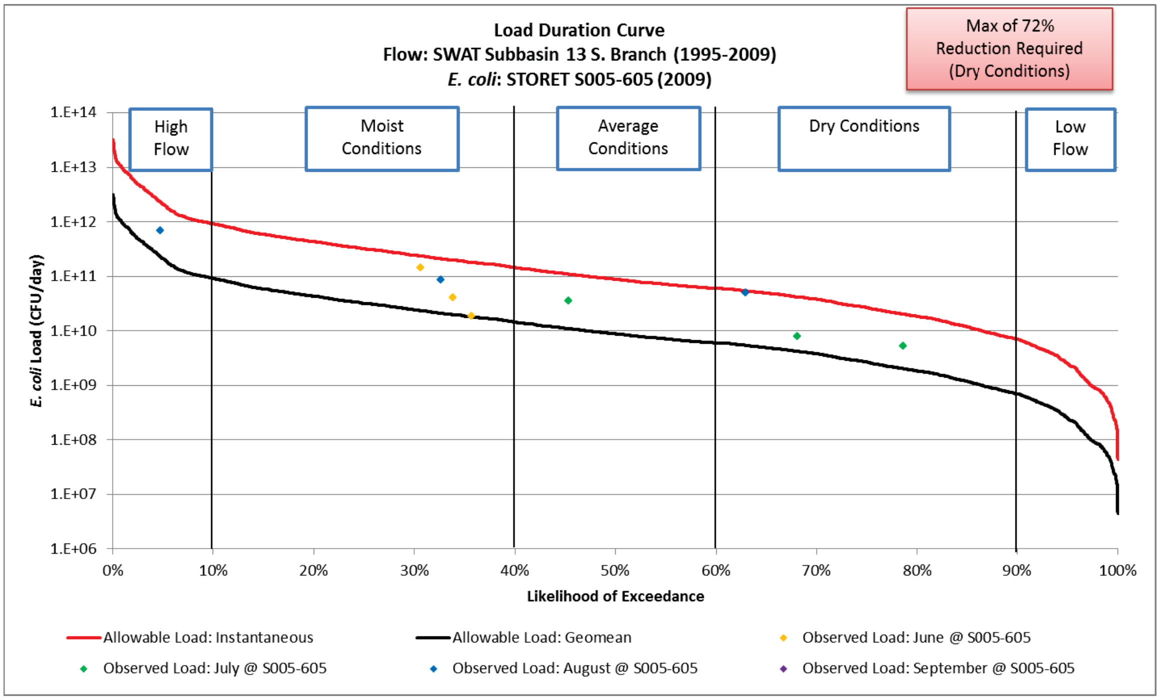


Figure A19. AUID 09020106-562 bacterial LDC

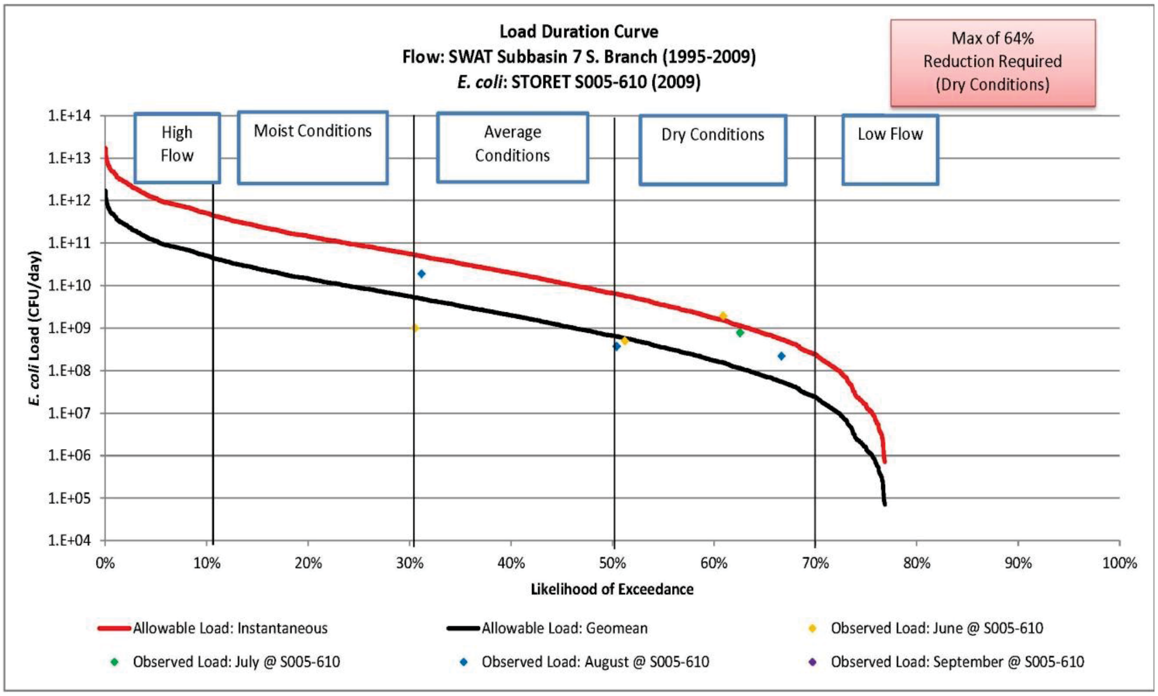


Figure A20. AUID 09020106-593 bacterial LDC

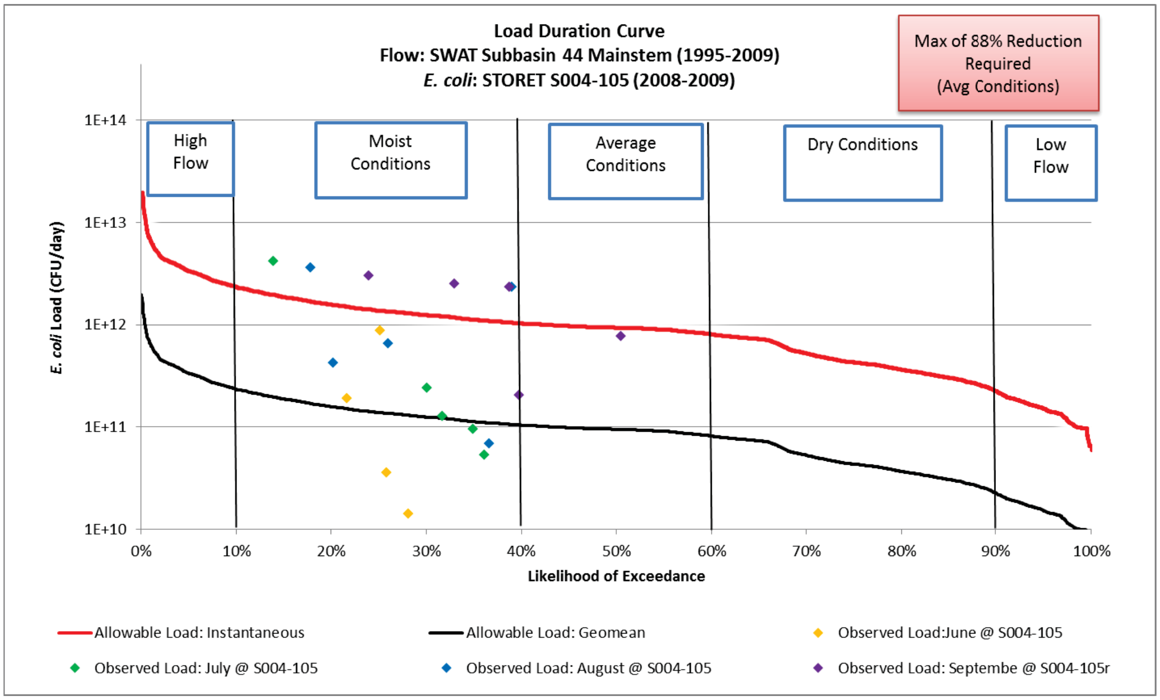


Figure A21. AUID 09020106-594 bacterial LDC

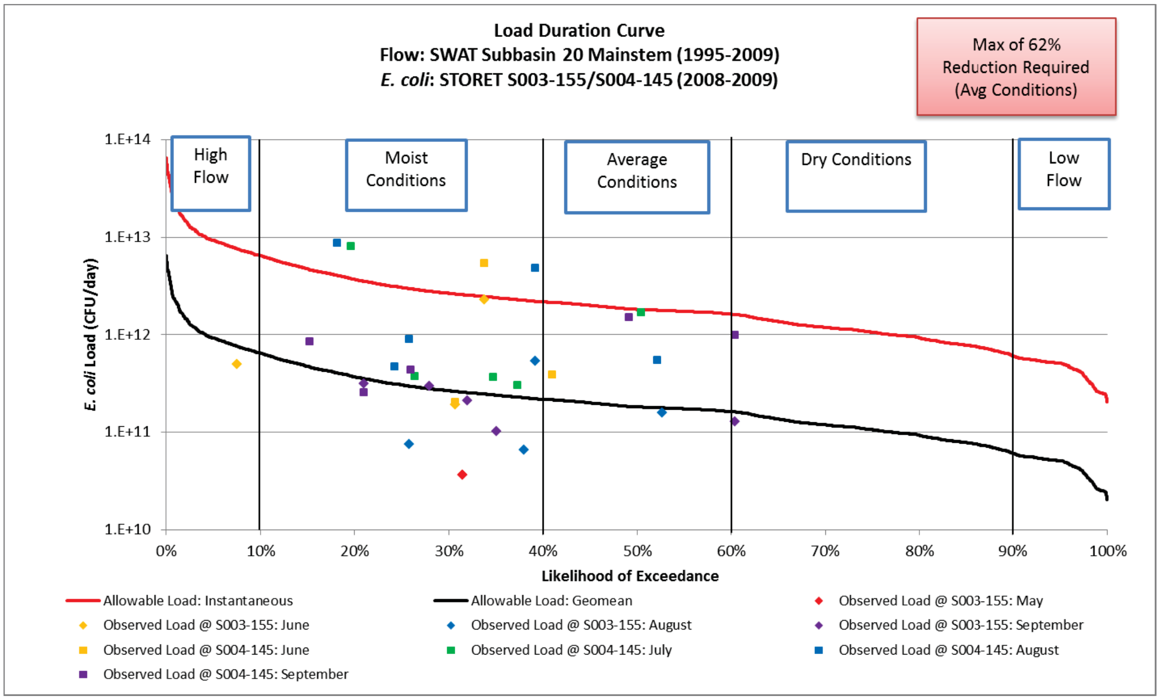
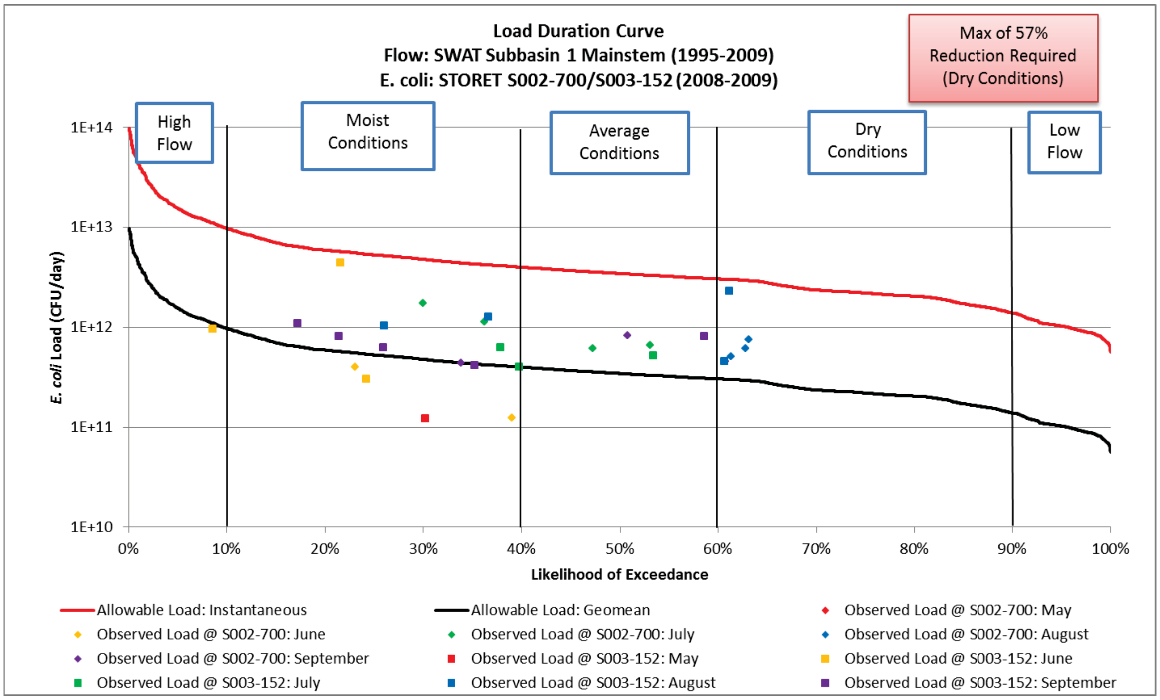


Figure A22. AUID 09020106-595 bacterial LDC



APPENDIX B. SEDIMENT LOAD DURATION CURVES

Figure B1. AUID 09020106-501 sediment LDC

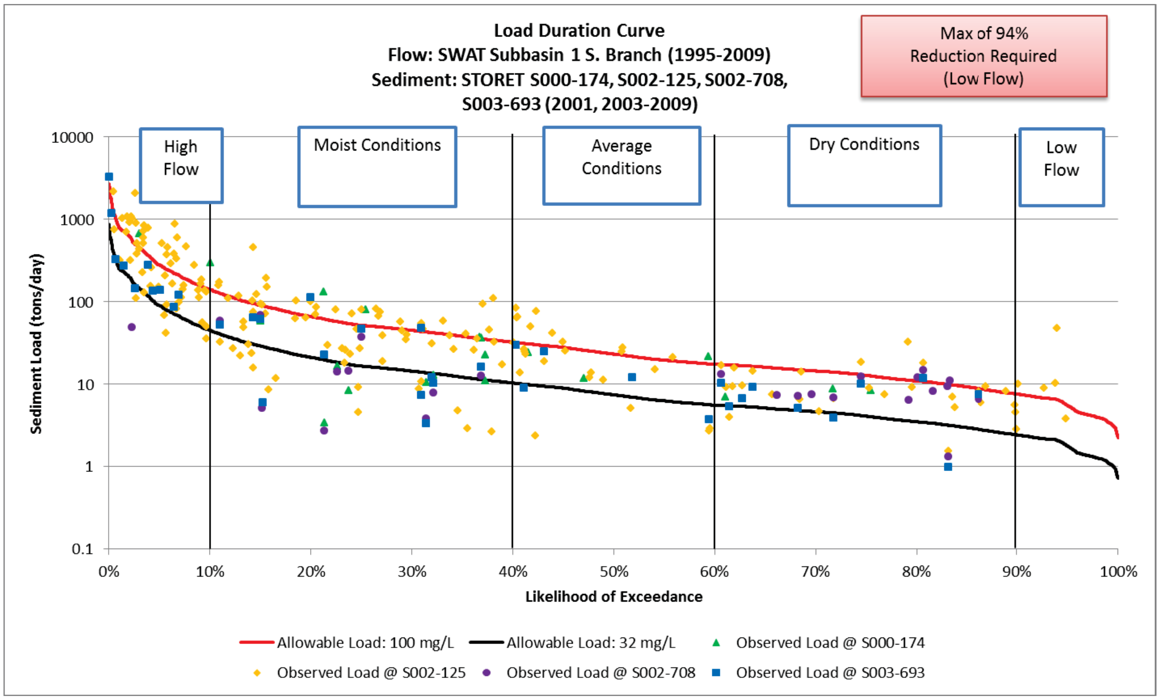


Figure B2. AUID 09020106-502 sediment LDC

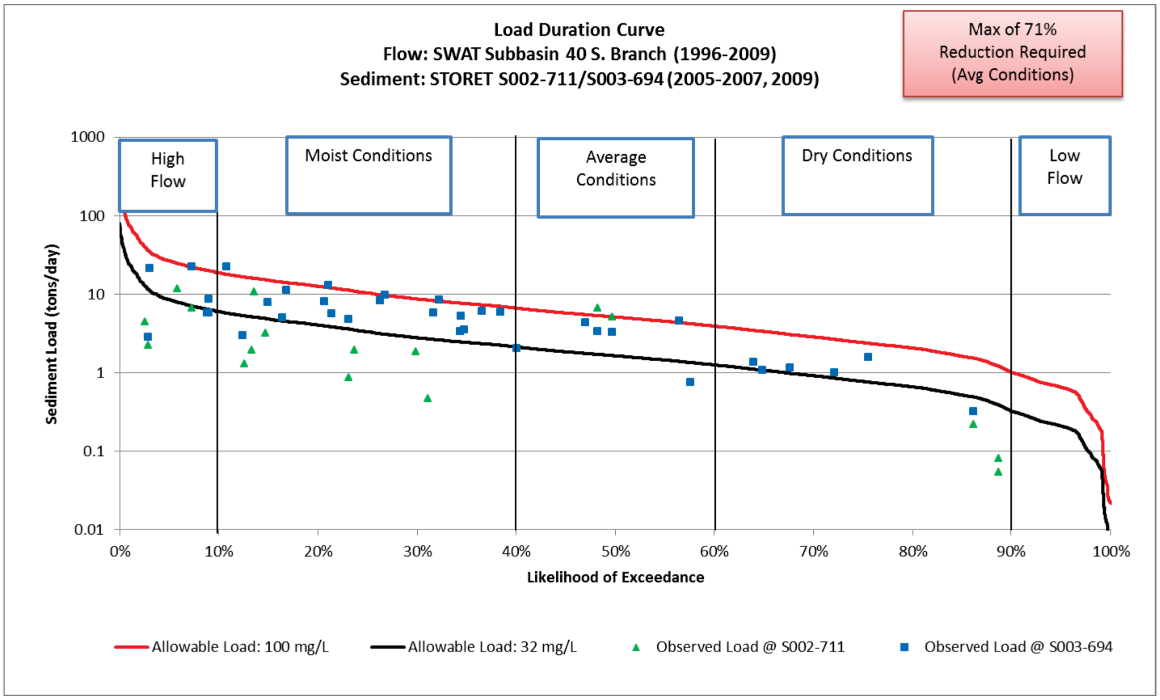


Figure B3. AUID 09020106-503 sediment LDC

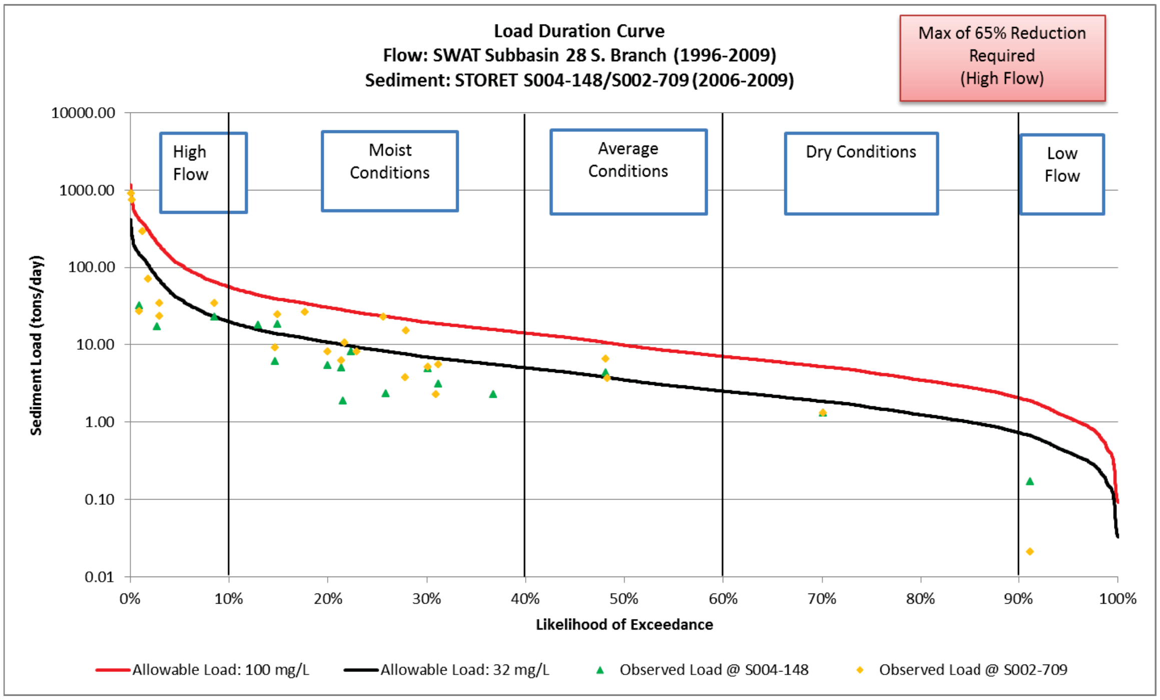


Figure B4. AUID 09020106-504 sediment LDC

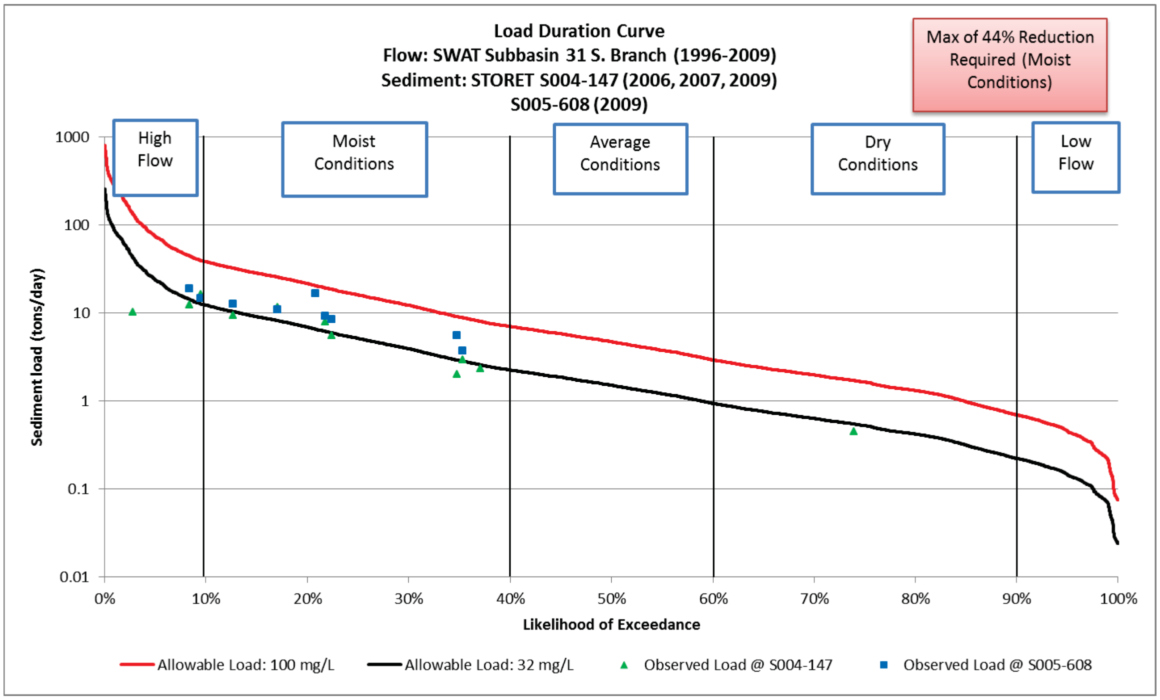


Figure B5. AUID 09020106-505 sediment LDC

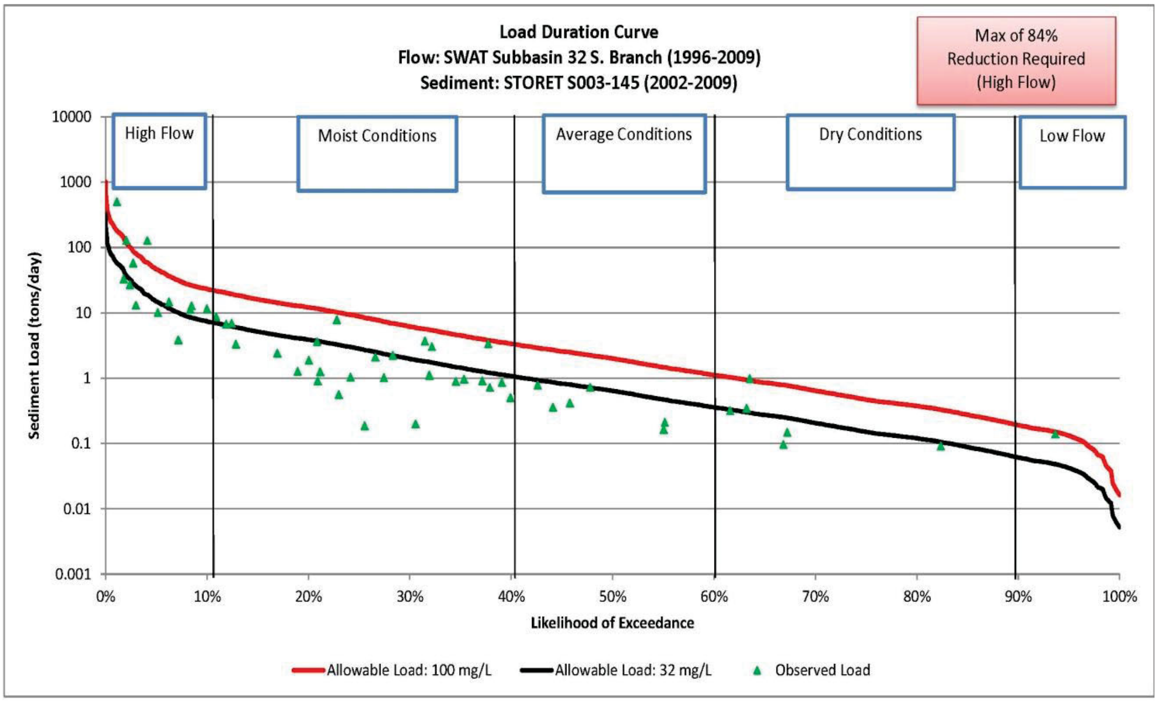


Figure B6. AUID 09020106-507 sediment LDC

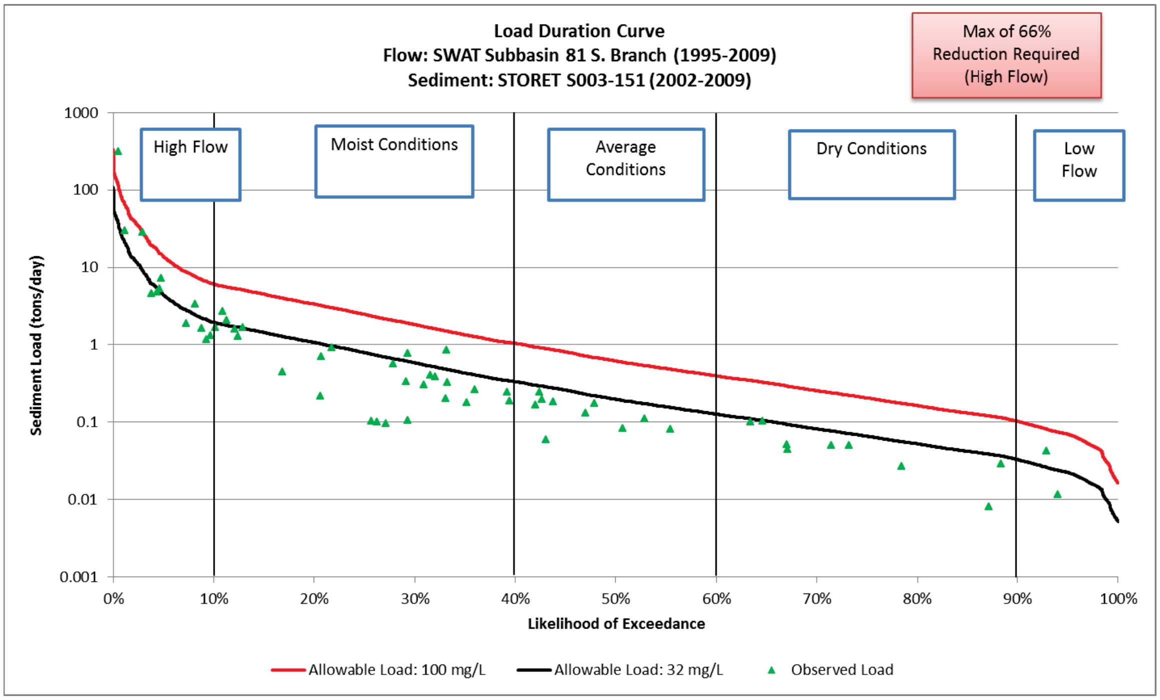


Figure B7. AUID 09020106-508 sediment LDC

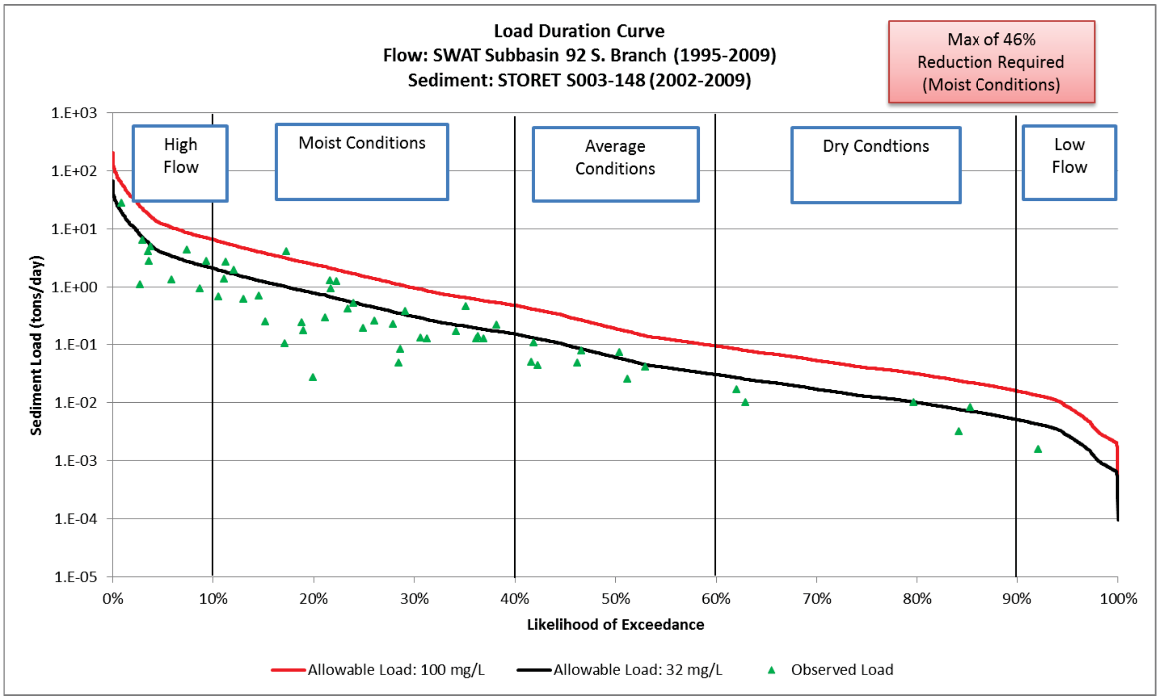


Figure B8. AUID 09020106-509 sediment LDC

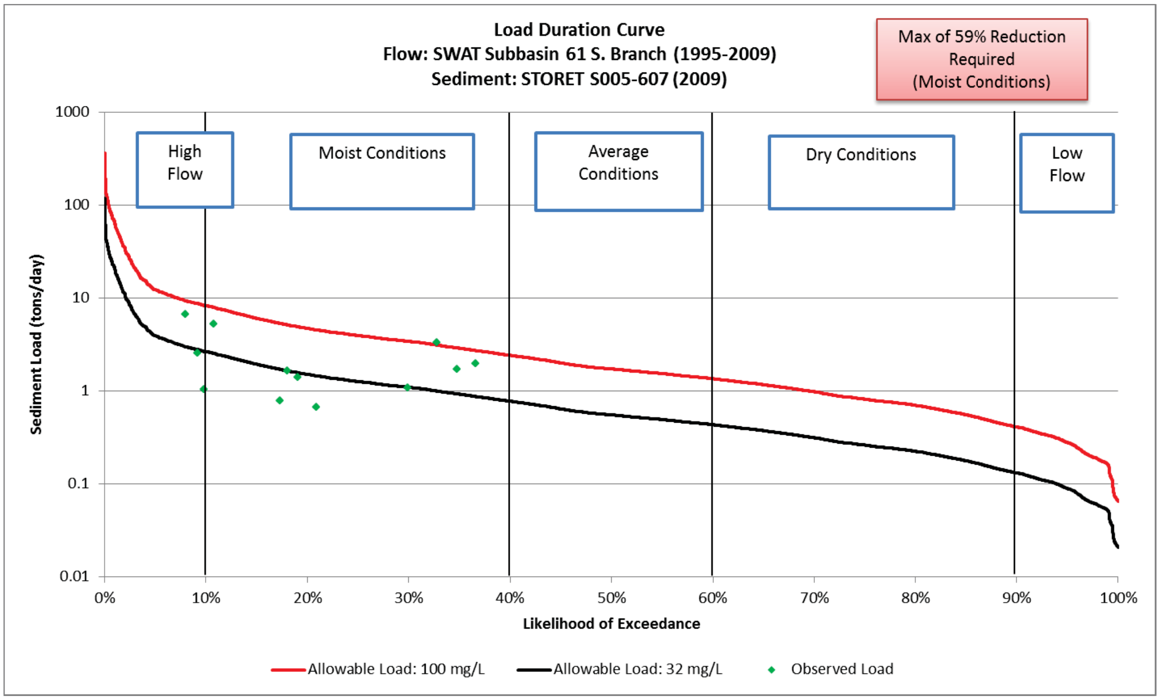


Figure B9. AUID 09020106-521 sediment LDC

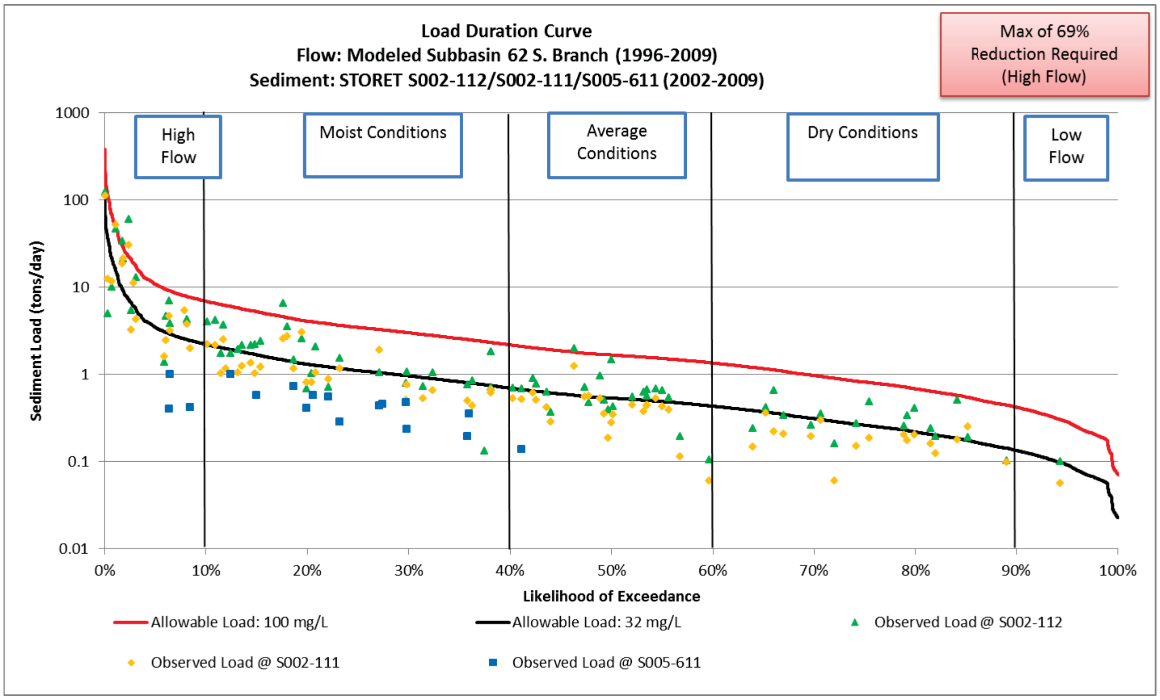


Figure B10. AUID 09020106-523 sediment LDC

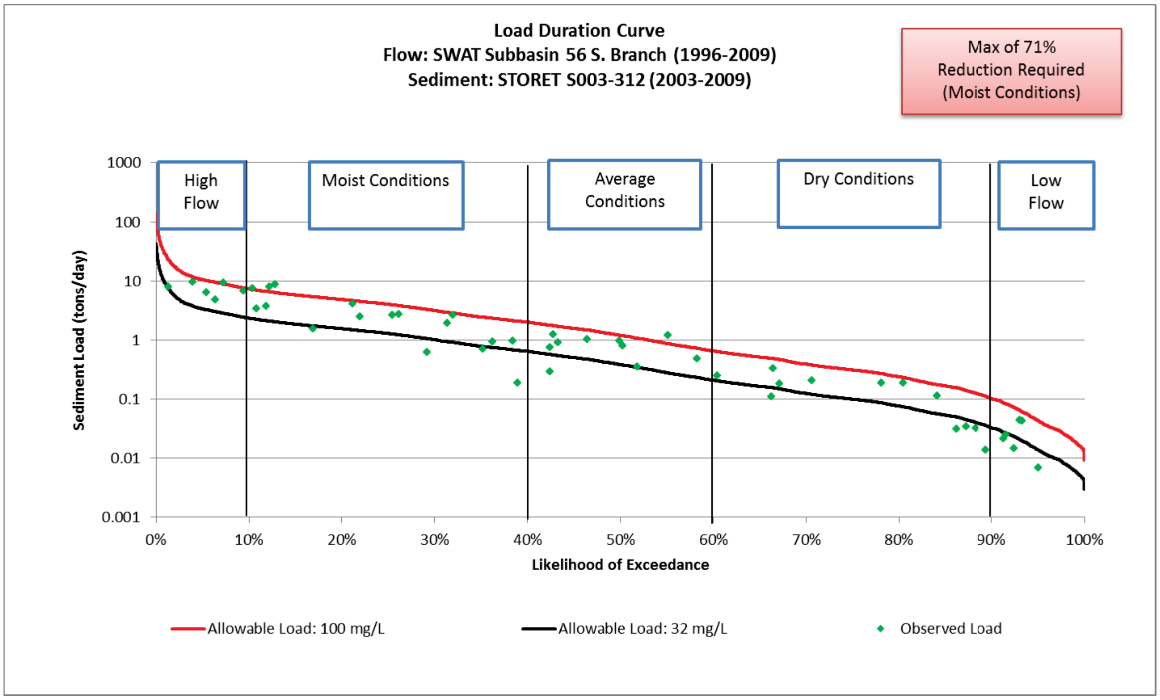


Figure B11. AUID 09020106-593 sediment LDC

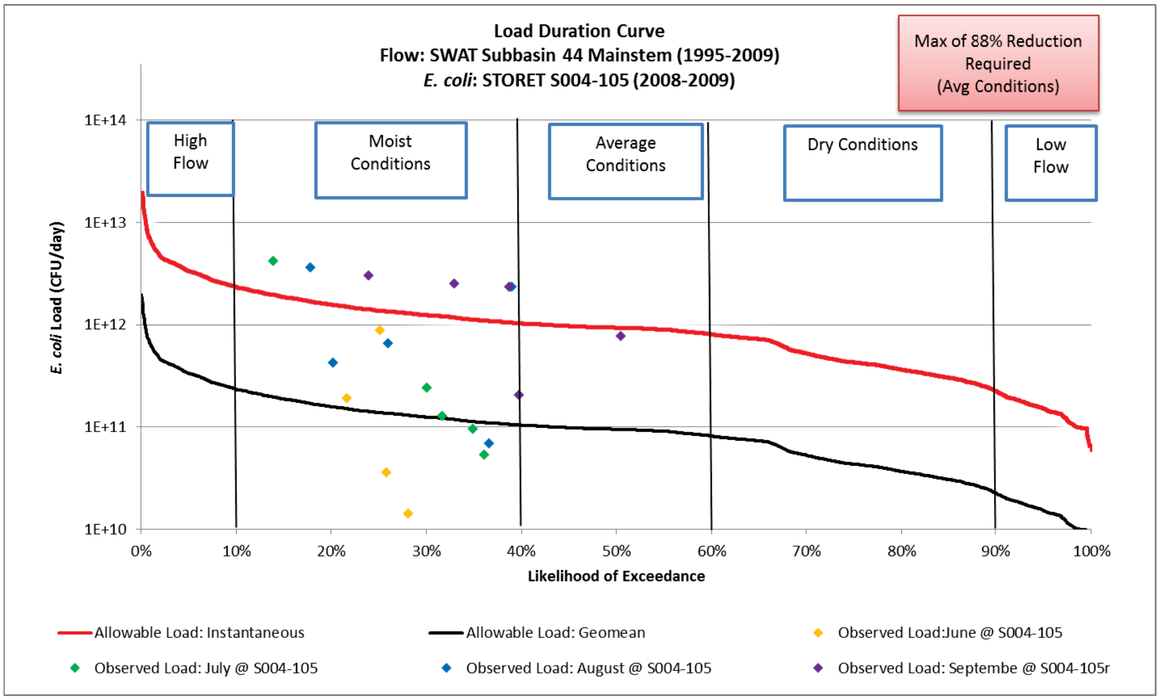


Figure B12. AUID 09020106-594 sediment LDC

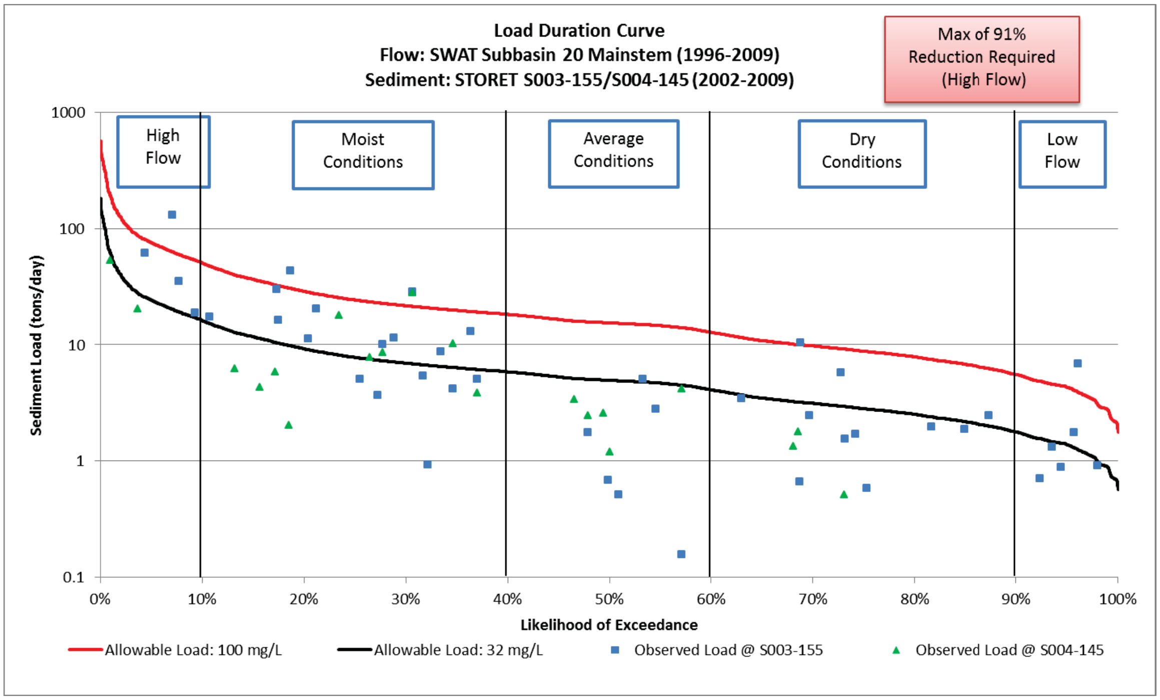


Figure B13. AUID 09020106-595 sediment LDC