Buffalo River Watershed

Restoration and Protection Strategy Report

August 2016

Minnesota Pollution Control Agency

BUFFALO-RED RIVER WATERSHED DISTRICT

CLEAN WATER LAND & LEGACY

wq-ws4-11a

Authors and contributors:

Timothy Erickson, P.E.
Mark R. Deutschman, Ph.D., P.E.
Jeremiah Jazdzewski
Houston Engineering, Inc.
6901 East Fish Lake Road, Suite 140
Maple Grove, Minnesota 55369

Timothy R. James
Minnesota Pollution Control Agency
714 Lake Avenue, Suite 220
Detroit Lakes, Minnesota 56501

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

Note Regarding Legislative Charge

The science, analysis, and strategy development described in this report began before accountability provisions were added to the Clean Water Legacy Act in 2013 (MS114D); thus, this report does not address all of those provisions. When this watershed is revisited (according to the 10-year cycle), the information will be updated according to the statutorily required elements of a Watershed Restoration and Protection Strategy Report.

Table of Contents

Key Terms

Assessment Unit Identifier (AUID): The unique water body identifier for each river reach comprised of the United States Geological Survey (USGS) eight-digit hydrologic unit code (HUC) plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus (TP), chlorophyll-*a*, or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Red River Basin is assigned a HUC-4 of 0902 and the Buffalo River Watershed is assigned a HUC-8 of 09020106.

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including: aquatic life, aquatic recreation, and aquatic consumption.

Index of biotic integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or Pollutant Source): This term is distinguished from ‘stressor’ to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or Biological Stressor): This is a broad term that includes both pollutant sources and non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation (WLA) for point sources, a load allocation (LA) for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety (MOS) as defined in the Code of Federal Regulations.

Executive Summary

The Buffalo River Watershed (BRW) is located in northwestern Minnesota and covers approximately 1,100 square miles within Clay, Becker, Wilkin, and Otter Tail counties. It is located in the Red River of the North Basin (i.e., Red River Basin) and spans three ecoregions: the Lake Agassiz Plain, the North Central Hardwood Forests, and the Northern Lakes and Forests. Land use within the BRW 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.

In general, water quality conditions in the BRW are poor and reflect the intensely cultivated land uses, altered watercourses, altered hydrology, intensive drainage, and a consistent lack of riparian cover (buffers) found around many of the lakes and streams in the watershed. Total suspended solids (TSS) and turbidity are elevated in most tributaries and main-stem river reaches. The sources of sediment and turbidity, in addition to the naturally occurring fine silts and clays, are overland runoff, field erosion, wind erosion, and stream bank scouring from hydrologic modifications in the watershed. Elevated bacteria levels were found in nearly all of the monitored streams. Aquatic use impairments were found in all areas except the Upper Buffalo River Subwatershed.

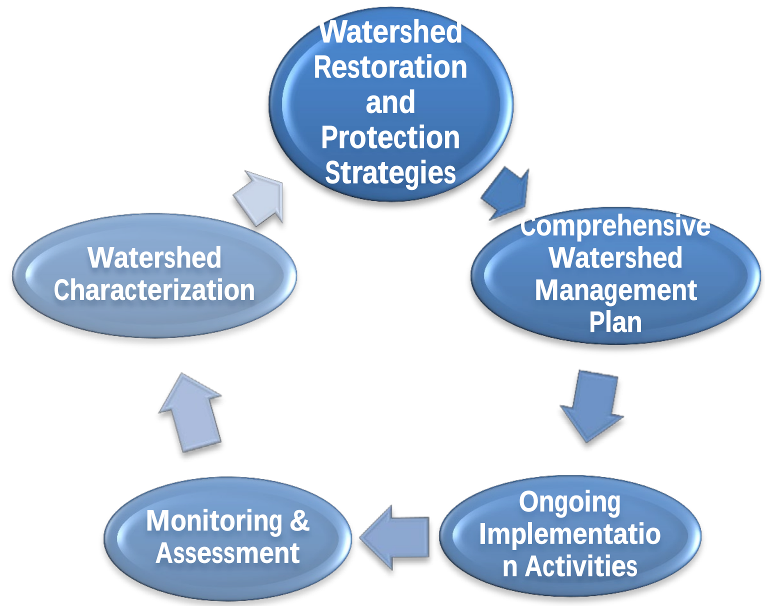
The BRW lakes were assessed against standards for deep and shallow lakes. Findings show that more than one-third of all monitored lakes exceed the excess nutrient (phosphorus) standards for their respective ecoregion and are impaired for aquatic recreation use; several more are very close to becoming impaired.

Pollutant reductions needed to correct impaired waters are large and will be challenging to accomplish. A coordinated, long term, sustained effort will be needed to both restore the impaired waters and to protect the others from being degraded down to an impaired condition. Reductions required for total phosphorus values range from 15% on the low end to as high as 94% for lakes that are impaired for excess nutrients. Sediment reductions for streams range from 47%-94% .

Common stressors that contribute to poor fish and aquatic insect populations include lack of fish passage (connectivity) and altered hydrology. Some examples of connectivity problems in the BRW include migration barriers that are both naturally occurring (beaver dams) and manmade (e.g. perched culverts, control structures, and sheet pile dams). Examples of the results of altered hydrology include increases in peak discharge and loss of base flow, as shown by a "flashy" hydrograph in many streams. This is a common occurrence in artificially-drained agricultural areas.

Increased use of best management practices will be required for all the working lands in the watershed and the management of the drainage systems. Examples for the landscape include, but are not limited to livestock management, nutrient management, field windbreaks, cover crops and perennial vegetation, residue management, riparian buffers, shoreline buffers, and ditch buffers. Examples for the waters themselves include engineered hydrologic controls, regional water retention, stream channel restoration, culvert resizing and replacement, and restoration of unconnected streams. In addition, maintenance and upgrades of individual on-site septic systems and compliance with NPDES permits for municipal storm water and waste water is required.

What is the WRAPS Report?



The state of Minnesota has adopted a "watershed approach" to address the state's 80 "major" watersheds (denoted by 8-digit hydrologic unit code or HUC). This watershed approach incorporates **water quality assessment, watershed analysis, civic engagement, planning**, **implementation**, and **measurement of results** into a 10-year cycle that addresses both restoration and protection.

As part of the watershed approach, waters not meeting state standards are still listed as impaired and Total Maximum Daily Load (TMDL) studies are performed, as they have been in the past, but in addition the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to help state agencies, local governments and other watershed stakeholders determine how to best proceed with restoring and protecting lakes and streams. This report summarizes past assessment and diagnostic work and outlines ways to prioritize actions and strategies for continued implementation.

Purpose

- Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning
- Summarize Watershed Approach work done to date including the following reports:
  - *Buffalo River Watershed Monitoring and Assessment*
  - *Buffalo River Watershed Biotic Stressor Identification*
  - *Buffalo River Watershed SWAT Modeling*
  - *Buffalo River Watershed Lakes Eutrophication Modeling*
  - *Buffalo River Watershed Total Maximum Daily Load*

Scope

- Impacts to aquatic recreation and impacts to aquatic life in streams
- Impacts to aquatic recreation in lakes

Audience

- Local working groups (local governments, SWCDs, watershed management groups, etc.)
- State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed Background & Description

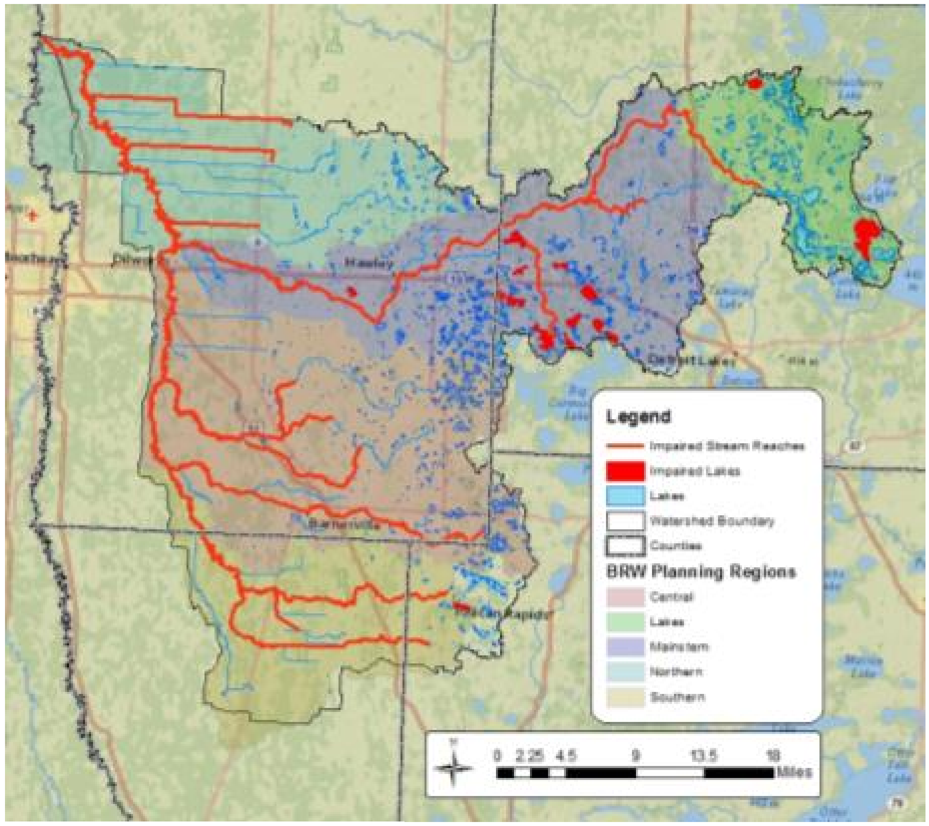


Figure 1. Buffalo River Watershed

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 BRW is located in the Red River of the North Basin (i.e., Red River Basin) and spans three ecoregions: the Lake Agassiz Plain, the North Central Hardwood Forests, and the Northern Lakes and Forests. Land use within the BRW 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.

Additional background information and description of the BRW can be found in the resources listed below.

Additional Buffalo River Watershed Resources
Buffalo River Watershed Conditions Report (HEI 2010a)
Buffalo River Watershed Conditions Report Addendum (HEI 2011c)
Buffalo River Watershed Lake Conditions Report (HEI 2011d) Buffalo-Red River Watershed District Revised Watershed Management Plan (HEI 2010b)
USDA Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Buffalo River Watershed: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022744.pdf
Department of Natural Resources (DNR) Buffalo River Watershed Assessment Map Book: http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/wsmb58.pdf

2. Watershed Conditions

The BRW consists of a forested, lake-dominated headwater region with rivers, streams and ditches passing through a predominantly agricultural central and western region, eventually meeting up with the Red River of the North.

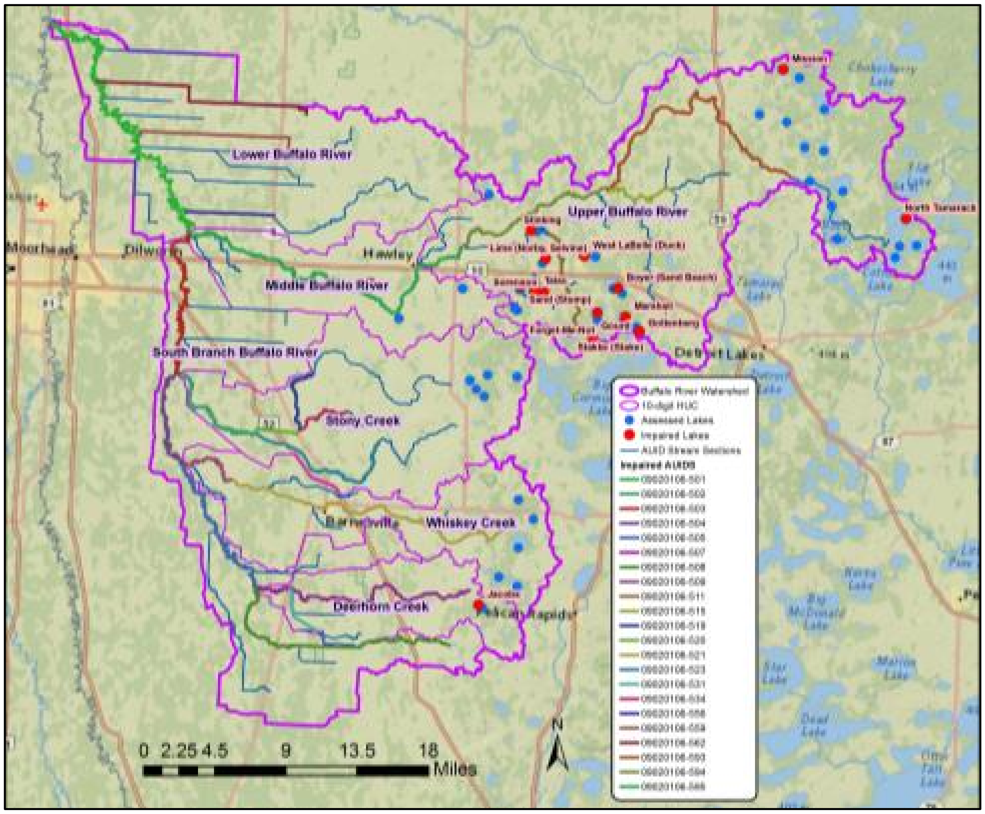


Figure 2. Buffalo River Watershed regulated and impaired waters.

There are 62 lakes and 84 streams in the BRW that are defined and regulated by the state of Minnesota (i.e., have an Assessment Unit ID – (AUID) – or DNR lake number). Of these, not all could be assessed for condition due to reasons including: insufficient data, limited resource waters, or predominantly channelized stream reaches. Of the 84 stream segments (AUIDs), 27 were assessed to some degree and 81% of those (22 streams) are not supporting aquatic life or recreation. Of the 62 lakes, 45 were assessed and 36% of those (16 lakes) are found to be not supporting aquatic recreation. The nature of the impairments leading to the lack of support for aquatic life and recreation are those commonly occurring in highly agricultural regions. These include excessive sediment, excessive bacteria, and reduced biological abundances.

There are 16 permitted point sources in the BRW; 8 WWTFs, one industrial wastewater discharger, and 7 Confined Animal Feeding Operations (CAFOs). Nonpoint sources and stressors in the watershed are typical of the agricultural setting of the Red River Basin.

A more detailed analysis of the quality of the waters within the BRW can be found in the Watershed Conditions Report (HEI 2010a) and its addendum (HEI 2011c), the Lake Conditions Report (HEI 2011d), the Monitoring and Assessment Report (MPCA 2012), and the Biotic Stressor Identification Report (MPCA 2013). The condition of these individual streams and lakes, including associated pollutant sources, are summarized in the following sections.

2.1 Condition Status

This section is used to identify the stream and lakes within the BRW that are both impaired and in need of protection. Impaired waters will be targets for restoration efforts while waters currently supporting aquatic life and recreation will be subject to protection efforts.

In general, water quality conditions in the BRW are poor and reflect the intensely cultivated land uses, altered watercourses and hydrology, and consistent lack of riparian cover found around many of the lakes and streams in the watershed. Total suspended solids (TSS) and turbidity are elevated in most tributaries and main-stem reaches. The sources of sediment and turbidity, in addition to the naturally occurring fine silts and clays, are overland runoff and stream bank scouring from hydrologic modifications in the watershed. Elevated bacteria levels were found in nearly all of the monitored streams and aquatic recreation use impairments were found in all but the Upper Buffalo River Subwatershed.

Measures of support for aquatic life described in this report include fish and macroinvertebrate indices of biotic integrity (IBI), dissolved oxygen (DO), and turbidity; measures of aquatic recreation include bacteria and lake nutrients. Two of the streams in the BRW are impaired due to low DO; however, DO impairment is not currently being addressed under the TMDL for the BRW and will be addressed at a later date. While this report identifies the DO impairments, their prioritization, restoration, and protection are not addressed. This is due in part to this project being a pilot for the WRAPS program. The maturation of Stressor Identification techniques and investigations into dissolved oxygen processes has advanced considerably since this project was initiated. Those techniques will be applied to DO impairments during the next round of the WRAPS cycle.

Streams

The BRW stream conditions were assessed using a range of parameters including fish and macroinvertebrate IBI, DO, suspended solids, and bacteria. Water quality measurements from streams were compared to the normal range for the ecoregion the steam is located in as well as state water quality standards. The aquatic life standards are based on the biological IBI scores as well as DO and suspended solids, while the aquatic recreation standard is based on bacteria.

Each of the BRW AUID segments is listed in Table 1; stream conditions are summarized for all assessed segments. Empty cells denote waters where no assessment data has been collected. The BRW contains a total of 90 stream AUIDs. Of these 90, 48 have been sampled for biological and/or chemical parameters; 27 have been assessed for one or more parameters. Of the 27 assessed waters, 18 do not support aquatic life and 22 do not support aquatic recreation. There are 15 waterbodies, all located in the Upper Buffalo River Subwatersheds, which have both a stream AUID and a lake ID. For consolidation purposes and to prevent redundancy, these waterbodies have not been included in both the streams and lakes section of this report. Nine of these are small creeks that connect the Sand-Axberg chain and have been listed as stream segments in Table 1. The remaining six are lakes and have been included in Table 2. Any assessment results for these 15 waterbodies are appropriately displayed in their respective tables. Information used to create this table was summarized using the Minnesota Pollution Control Agency's (MPCA) Watershed Monitoring and Assessment Report (MPCA 2012) as well as the MPCA's Watershed Biotic Stressor Identification Report (MPCA 2013).

Table 1. Assessment status of stream reaches in the BRW, presented (mostly) from east to west

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life				Aq Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Bacteria
Upper Buffalo River (0902010601)	511	Hay Creek	Headwaters to Stinking Lk	NA	NA	Sup	Sup	Imp
	513	Hay Creek	Stinking Lk to Buffalo R	Sup	NA	IF	Sup	
	514	Unnamed ditch	Headwaters to Spring Lk	NA	NA			
	515	Unnamed ditch	Unnamed ditch to Buffalo R	NA	NA	IF	Sup	Imp
	516	Unnamed ditch	T139 R42W S9, south line to Reep Lk	NA	NA			
	518	Unnamed stream	Reep Lk to Unnamed ditch	NA	NA			
	526	Unnamed ditch	Spring Lk to Unnamed ditch					
	527	Unnamed ditch	Unnamed ditch to T139 R42W S16, north line	NA	NA			
	539	Unnamed creek	Headwaters to Lee Lk (03-0625-00)					
	540	Unnamed creek	Unnamed lk (03-0626-00) to Sand Lk					
	549	Unnamed lake	Unnamed lk (06-0626-00)					
	567	Buffalo River	Headwaters to Momb Lk					
	569	Buffalo River	Momb Lk to Rock Lk					
	571	Buffalo River	Rock Lk to Rice Lk					
	573	Buffalo River	Rice Lk to Buffalo Lk					
	576	Unnamed creek	Unnamed cr to Hay Cr	NA	NA	IF	Sup	Sup
	577	Unnamed ditch	Unnamed cr to Unnamed ditch	NA	NA			
	578	Unnamed ditch	Unnamed cr to Unnamed cr	NA	NA			
	579	Unnamed ditch	Unnamed cr to Unnamed ditch					
	580	Unnamed creek	Unnamed cr to Buffalo Cr	NA	NA			
	581	County Ditch 16	Unnamed cr to Buffalo Cr	NA	NA			
	593	Buffalo River	Buffalo Lk to Unnamed ditch	Imp	Imp	IF	Imp	Imp
	594	Buffalo River	Unnamed ditch to Hay Cr	Sup	Sup	IF	Imp	Imp
	901	Unnamed ditch	Headwaters to Hay Cr					
	902	Unnamed creek	Headwaters to Lee Lk (03-0625-00)					
	904	Unnamed creek	to Unnamed lk (03-0617-00)					
	906	Unnamed creek	Sand Lk to Talac Lk (03-0619-00)					
	908	Unnamed creek	to Axberg Lk					
	909	Unnamed creek	Unidentified Waterbody to Unnamed lk (03-0626-00)					
	910	Unnamed creek	Wetland to Unnamed lk (03-0626-00)					
Middle Buffalo	532	Unnamed ditch	T139 R47W S12, east line to Buffalo R					

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life				Aq Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Bacteria
River (0902010602)	582	Unnamed creek	Unnamed ditch to Buffalo Cr	NA	NA			
	595	Buffalo River	Hay Cr to S Br Buffalo R	Sup	Sup	IF	Imp	Imp
Lower Buffalo River (0902010607)	501	Buffalo River	S Br Buffalo R to Red R	Sup	Sup	Sup	Imp	Imp
	537	County Ditch 25/County Ditch 38	Headwaters to CD 26					
	538	County Ditch 25	CD 26 to Buffalo R	NA	NA			
	555	Unnamed creek	Headwaters to CD 2	Imp	Imp		Sup	
	556	County Ditch 2	Unnamed cr to Buffalo R	NA	NA	IF	Sup	Imp
	557	County Ditch 3	Headwaters to Buffalo R	NA	NA			
	558	County Ditch 26	Headwaters to CD 25					
	559	County Ditch 39	Headwaters to Buffalo R	NA	NA	IF	Imp	Imp
	560	County Ditch 59	Headwaters to Buffalo R	NA	NA			
	561	County Ditch 49	Headwaters to Buffalo R					
	562	County Ditch 10	Headwaters to Buffalo R	NA	NA	IF	Imp	Imp
	563	County Ditch 5 (County Ditch 8)	Headwaters to Buffalo R	NA	NA			
	564	County Ditch 35	Headwaters to Buffalo R					
Whiskey Creek (0902010604)	509	Whisky Creek	T137 R47W S13, east line to S Br Buffalo R	NA	NA	IF	Imp	Imp
	521	Whisky Creek	Headwaters to T137 R46W S18, west line	Sup	Sup	Sup	Imp	Imp
	533	Unnamed creek	Headwaters to Whisky Cr	NA	NA			
	575	Unnamed creek	Headwaters to Whisky Cr					
	585	Unnamed creek	Unnamed cr to Whisky Cr					
	586	Unnamed creek	Headwaters to Whisky Cr	Sup	IF			
Deerhorn Creek (0902010603)	507	Deerhorn Creek	Headwaters to S Br Buffalo R	Imp	Imp	Imp	Imp	Imp
	529	Unnamed creek (Lawndale Creek)	T135 R45W S5, east line to Unnamed ditch					
	530	Unnamed creek (Lawndale Creek)	Unnamed cr to Unnamed ditch	NA	NA			NA
	531	State Ditch 14	Unnamed ditch to Deerhorn Cr	NA	NA	IF	Sup	Imp
	548	Judicial Ditch 3-4	Unnamed cr to State Ditch 14					
	565	Unnamed ditch	T135 R45W S5, south line to Unnamed creek					
	566	Unnamed ditch	T135 R469W S1, north line to Unnamed creek					
	900	County Ditch 14	T135 R46W S2, west line to State Ditch 14					
Stony Creek (0902010605)	502	Stony Creek	Hay Cr to S Br Buffalo R	Sup	NA	Imp	Imp	Imp
	510	Stony Creek	Headwaters to T137 R45W S2, north line					
	519	Hay Creek	Unnamed cr to Spring Cr	NA	NA	IF	Sup	Imp

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life				Aq Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Bacteria
	520	Hay Creek	Spring Cr to Stony Cr	NA	NA	IF	Imp	Imp
	522	Stony Creek	T138 R45W S35, south line to T138 R45W S34, south line					
	523	Stony Creek	T137 R45W S3, north line to T137 R46W S5, north line	NA	NA	IF	Imp	Imp
	524	Stony Creek	T138 R46W S32, south line to Hay Cr					
	534	Spring Creek	Unnamed cr to Hay Cr	Imp	Imp	IF	Sup	Imp
	536	Unnamed creek	Unnamed ditch to Stony Cr					
	545	Unnamed creek	Unnamed cr to Unnamed ditch					
	547	Unnamed creek	Unnamed ditch to Spring Cr					
	589	Hay Creek	Headwaters (Softing Lk 14-0032-00) to Unnamed lk (14-0255-00)					
	590	Hay Creek (Unnamed lake)	Unnamed lk 14-0255-00					
	591	Hay Creek	Unnamed lk 14-0255-00 to Unnamed cr					
South Branch Buffalo River (0902010606)	503	Buffalo River, South Branch	Stony Cr to Buffalo R	Sup	Sup	Imp	Imp	Imp
	504	Buffalo River, South Branch	Whisky Cr to Stony Cr	NA	NA	IF	Imp	Imp
	505	Buffalo River, South Branch	Deerhorn Cr to Whisky Cr	Sup	Imp	Imp	Imp	Imp
	508	Buffalo River, South Branch	Headwaters to Deerhorn Cr	NA	NA	Imp	Imp	Imp
	535	State Ditch 15	Unnamed ditch to Unnamed cr	NA	NA	IF	IF	
	541	Unnamed creek	State Ditch 15 to Unnamed ditch					
	542	Unnamed creek	Unnamed ditch to Unnamed ditch					
	543	Unnamed creek	Unnamed ditch to Unnamed ditch					
	544	Unnamed creek	Unnamed ditch to S Br Buffalo R	NA	NA			
	550	County Ditch 12	Unnamed cr to S Br Buffalo R	NA	NA			
	551	County Ditch 21	Unnamed ditch to Unnamed cr	NA	NA			
	552	County Ditch 21	Headwaters to Unnamed ditch					
	553	Unnamed creek	CD 21 to S Br Buffalo R					
	554	Judicial Ditch 3-1	Unnamed ditch to S Br Buffalo R	NA	NA			
	587	Judicial Ditch 3-2	Unnamed cr to S Br Buffalo R	NA	NA			
	592	Unnamed creek	Unnamed cr to CD 21	NA	NA			

Imp = Impaired, Sup = Fully supporting, IF = Insufficient data to make an assessment, NA = Not assessed, [blank] = No data collected.

Lakes

The BRW lakes were assessed against Class 2B standards for deep and shallow lakes. Findings show that more than one-third of all monitored lakes exceed the eutrophication standards for their respective ecoregion and are impaired for aquatic recreation use; several more are very close to the standards.

Table 2 below presents a summary of the lakes in the BRW and identifies those which have been assessed, those that do or do not have sufficient information for assessment, and those that are impaired for or supporting aquatic recreation. Aquatic recreation impairment is based on eutrophication levels of lakes, which is typically caused by excess nutrients. Parameters used in eutrophication standards include phosphorus and chlorophyll-*a* concentrations as well as Secchi disc depths.

There are 56 lakes in the BRW that have ID numbers and have been sampled (not included stream/lake redundant naming discussed above). Of these, 36 were fully assessed, 8 have insufficient data, and 12 had no data collected. Of the 36 fully assessed lakes, 19 were found to fully support aquatic recreation. As discussed above, the seven lakes that also have AUIDs are listed in Table 2 along with their respective AUID numbers. Information used to create this table was summarized using the MPCA's Watershed Monitoring and Assessment Report (MPCA 2012) as well as the Watershed Biotic Stressor Identification Report (MPCA 2013).

Table 2. Assessment status of lakes in the BRW, presented by 10-digit HUC

HUC-10 Subwatershed	Lake ID	Lake	Aquatic Recreation
Upper Buffalo River (0902010601)	03-0647-00	Hay Creek (Stinking Lake), Stinking Lk (09020106-512)	Imp
	03-0685-00	Unnamed ditch (Spring Lake), Spring Lk (09020106-525)	
	03-0294-00	Buffalo River (Momb Lake), Momb Lk (09020106-568)	
	03-0350-00	Buffalo River (Buffalo Lake), Buffalo Lk (09020106-574)	Sup
	03-0291-00	Buffalo River (Rice Lake), Rice Lk (09020106-572)	Sup
	03-0513-00	Reep Lake, Reep Lk (09020106-517)	
	03-0293-00	Buffalo River (Rock Lake), Rock Lk (09020106-570)	Sup
	03-0200-00	Pine Lake	Sup
	03-0241-01	South Tamarac Lake	Sup
	03-0241-02	North Tamarac Lake	Imp
	03-0291-00	Rice Lake	Sup
	03-0293-00	Rock Lake	Sup
	03-0302-00	Little Round Lake	Sup
	03-0304-00	Big Sugar Bush Lake	Sup
	03-0313-00	Little Sugar Bush Lake	Sup
	03-0351-00	Island Lake	Sup
	03-0292-00	Balsam Lake	
	03-0352-00	Birch Lake	Sup
	03-0314-00	Fish Lake	
	03-0428-00	O-Me-Mee Lake	IF
	03-0430-00	St Clair Lake	Sup
	03-0471-00	Mission Lake	Imp
	03-0516-00	Canary (Felker) Lake	IF
	03-0526-00	Marshall Lake	Imp
	03-0528-00	Gottenberg Lake	Imp
	03-0579-00	Boyer (Sand Beach) Lake	Imp
	03-0618-00	Sand (Yort) Lake	IF
	03-0619-00	Talac Lake	Imp

HUC-10 Subwatershed	Lake ID	Lake	Aquatic
	03-0624-00	Forget-Me-Not Lake	Imp
	03-0625-00	Sorenson Lake	Imp
	03-0631-00	Stakke (Stake) Lake	Imp
	03-0635-00	Gourd Lake	Imp
	03-0645-00	West LaBelle (Duck) Lake	Imp
	03-0646-00	Lime (Norby, Selvine) Lake	Imp
	03-0648-00	East LaBelle Lake	IF
	03-0659-00	Sand (Stump) Lake	Imp
	03-0660-01	Axberg (Main Basin) Lake	
	03-0660-02	Axberg (West Basin) Lake	
	14-0078-00	Swede Grove Lake	Sup
Middle Buffalo River (0902010602)	14-0049-00	Lee Lake	Imp
	14-0089-00	Doran Lake	
	14-0099-00	Lake Maria (Marin)	Imp
	14-0100-00	Silver Lake	IF
Lower Buffalo River (0902010607)	14-0079-00	Meyer Lake	
Whiskey Creek (0902010604)	56-0934-00	Harrison (Helgeson) Lake	IF
	56-0941-00	Pete Lake	Sup
	56-0950-01	West Olaf Lake	Sup
	56-0950-02	East Olaf Lake	
	56-0952-00	Grove Lake	Sup
Deerhorn Creek (0902010603)	56-1039-00	Jacobs Lake	Imp
Stony Creek (0902010605)	03-0657-00	Turtle Lake	
	14-0019-00	Lake Three	
	14-0018-00	Lake Eleven	Sup
	14-0021-00	Lake Ten	IF
	14-0029-00	Unnamed Lake	IF
	14-0030-00	Lake Fifteen	Sup

Imp=impaired for impacts to aquatic recreation, Sup = fully supporting aquatic recreation, IF = insufficient data to make an assessment, [blank] = No data collected.

2.2 Water Quality Trends

There is currently no long-term stream water quality trend data available for the BRW.

2.3 Stressors and Sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated. Biological stressor identification is done for streams with either fish or macroinvertebrate biota impairments and encompasses both evaluation of pollutants and non-pollutant-related factors as potential stressors (e.g. altered hydrology, fish passage, and habitat). Pollutant source assessments are done where a biological stressor ID process identifies a pollutant as a stressor as well as for the typical pollutant impairment listings. Section 3 provides further detail on stressors and pollutant sources.

Stressors of Biologically-Impaired Stream Reaches

The primary stressors for biological impairments in the BRW are listed in Table 3. Common stressors across each of the impairments include both fish passage (connectivity) and altered hydrology. Some examples of connectivity problems in the BRW include migration barriers that are both naturally occurring (beaver dams) and manmade (e.g. perched culverts, control structures, and sheet pile dams). Examples of altered hydrology include increases in peak discharge and loss of base flow (shown by a flashy hydrograph). This is a common occurrence in artificially-drained agricultural areas. Altered hydrology can lead to secondary impacts including habitat loss attributed to bank erosion and scour. Not surprisingly, turbidity is listed as a primary stressor in the South Branch and Deerhorn reaches. Habitat and DO also appear as stressors in the South Branch Buffalo River Subwatershed. Habitat was evaluated using the MPCA Stream Habitat Assessment (MSHA), which evaluates factors such as surrounding land use, riparian zone, in-stream zone, and channel morphology. The South Branch Buffalo River Subwatershed sites scored 'poor' in all of the measured categories.

Further detailed stressor identification information can be found in the MPCA's Watershed Biotic Stressor Identification Report (MPCA 2013).

Table 3: Primary stressors to aquatic life in biologically-impaired reaches in the BRW

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Biological Impairment	Primary Stressor				
					Dissolved Oxygen	Turbidity/Sediment	Connectivity	Altered Hydrology	Habitat
Upper Buffalo River (0902010601)	593	Buffalo River	Buffalo Lake to unnamed ditch	Fish & Macroinvert.			●		
South Branch Buffalo River (0902010606)	505	South Branch Buffalo River	Deerhorn Creek to Whisky Creek	Macroinvert.	●	●	●	●	●
Deerhorn Creek (0902010603)	507	Deerhorn Creek	Headwaters to S Br Buffalo R	Fish & Macroinvert.		●	●	●	
Stony Creek (0902010605)	534	Spring Creek	Unnamed cr to Hay Cr	Fish & Macroinvert.			●	●	

Pollutant sources

Point and nonpoint sources of pollutants are identified in Table 4 and Table 5, respectively. More specific information regarding the nonpoint sources' geographic location and prioritization is detailed in Section 3 where various methods of targeting and evaluating geographic areas are described.

There are 16 permitted point sources in the BRW; 8 WWTFs, one industrial wastewater discharger, and 7 Confined Animal Feeding Operations (CAFOs). These sources are listed in Table 4.

Table 5 includes a general summary of potential nonpoint sources and their magnitudes. Only impaired waterbodies are included in Table 5.

Table 4: Point Sources in the BRW

HUC-10 Subwatershed	Point Source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
Upper Buffalo River (0902010601)	Audubon WWTF	MNG580148	Municipal Wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Callaway WWTF	MNT022985	Municipal Wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Lake Park WWTF	MNG580157	Municipal Wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L, fecal coliform limit of 200 organisms/100 mL, and TP limit of 1 mg/L
	Baers Poultry Co – Old Barn Site	MNG441163	CAFO	No	Zero discharge permit; therefore, no WLA given
	Jona Baer Inc.	MNG441148	CAFO	No	Zero discharge permit; therefore, no WLA given
Middle Buffalo River (0902010602)	Glyndon WWTF	MN0020630	Municipal Wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Hawley WWTF	MN0020338	Municipal Wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Aggregate Industries – Pit 21	MN0069515	Industrial Wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Baers Poultry Co – New Barn Site	MNG441162	CAFO	No	Zero discharge permit; therefore, no WLA given
	Highlevel Egg	MNG441114	CAFO	No	Zero discharge permit; therefore, no WLA given
	J & A Farms LLC	MNG441159	CAFO	No	Zero discharge permit; therefore, no WLA given
	Taves Turkey Farm Inc.	MNG441136	CAFO	No	Zero discharge permit; therefore, no WLA given
Whiskey Creek (0902010604)	Barnesville WWTF	MN0022501	Municipal Wastewater	Yes	WLAs based on new permitted TSS limit of 32 mg/L and fecal coliform limit of 200 organisms/100 mL
Lower Buffalo River (0902010607)	Hitterdahl WWTF	MNG580178	Municipal Wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Spring Prairie Hutterite Colony WWTF	MN0070467	Municipal Wastewater	No	WLAs based on current permitted TSS limit of 45 mg/L and fecal coliform limit of 200 organisms/100 mL
	Spring Prairie Colony - Hawley	MNG440000	CAFO	No	Zero discharge permit; therefore, no WLA given

Table 5: Nonpoint Sources in the BRW. Relative magnitudes of contributing sources are indicated

HUC-10 Subwatershed	Stream/Reach (AUID) or Lake (ID)	Pollutant	Pollutant Sources											
			Fertilizer & manure run-off	Livestock overgrazing in riparian	Failing septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank erosion/excessive peak flows	Channelization	Upstream influences	Farmed-through headwater streams	Poor shoreline buffer	Internal sources
Upper Buffalo River (0902010601)	Hay Creek (511)	Bacteria	›	™	™	™								
	Hay Creek (Stinking Lake) (512, 03-0647-00)	Nutrients	›		™	™		›			˜		˜	›
	Unnamed ditch (515)	Bacteria	›	™	™	™								
	Buffalo River (593)	Sediment					˜	›	˜	˜				
		Bacteria	›	›	™	™	□							
	Buffalo River (594)	Sediment					˜	›	˜	˜	˜			
		Bacteria	›	™	™	™					˜			
	North Tamarac Lake (03-0241-02)[2]	Nutrients												›
	Mission Lake (03-0471-00)	Nutrients	›		™	™		›					˜	›
	Marshall Lake (03-0526-00)	Nutrients	›		™	™		›					˜	›
	Boyer (Sand Beach) Lake (03-0579-00)	Nutrients	›		™	™		›					˜	›
	Talac Lake (03-0619-00)	Nutrients	›		™	™		˜			˜		˜	˜
	Sorenson Lake (03-0625-00)	Nutrients	›		™	™		˜			˜		˜	˜
	Stakke (Stake) Lake (03-0631-00)	Nutrients	›		™	™		›					˜	›
	Gourd Lake (03-0635-00)	Nutrients	›		™	™		›					˜	›
	West LaBelle (Duck) Lake (03-0645-00)	Nutrients	›		™	™		™					˜	›
	Lime (Norby, Selvine) Lake (03-0646-00)	Nutrients	›		™	™		˜					˜	›
	Sand (Stump) Lake (03-0659-00)	Nutrients	›		™	™		˜			˜		˜	˜
Middle Buffalo River (0902010602)	Buffalo River (595)	Sediment					˜	™	˜	˜	˜			
		Bacteria	›	›	™	™					˜			
	Lee Lake (14-0049-00)	Nutrients	›		™	™		˜					˜	›
	Lake Maria (Marin) (14-0099-00)	Nutrients	›		™	™		™					˜	›
Lower Buffalo River (0902010607)	Buffalo River (501)	Sediment					˜	™	˜	˜	˜			
		Bacteria	›	™	™	™					˜			
	County Ditch 2 (556)	Bacteria	›	™	™	™								
	County Ditch 39 (559)	Sediment					˜	™	˜	˜				
		Bacteria	›	™	™	™								

HUC-10 Subwatershed	Stream/Reach (AUID) or Lake (ID)	Pollutant	Pollutant Sources											
			Fertilizer & manure run-off	Livestock overgrazing in riparian	Failing septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank erosion/excessive peak flows	Channelization	Upstream influences	Farmed-through headwater streams	Poor shoreline buffer	Internal sources
	County Ditch 10 (562)	Sediment					˜	™	˜	˜				
		Bacteria	›	™	™	™								
Whiskey Creek (0902010604)	Whisky Creek (509)	Sediment					˜	™	˜	˜	˜			
		Bacteria	›	™	™	™					˜			
	Whisky Creek (521)	Sediment					˜	™	˜	˜				
		Bacteria	›	›	™	™								
Deerhorn Creek (0902010603)	Deerhorn Creek (507)[1]	Sediment					˜	™	˜	˜		˜		
		Bacteria	›	™	™	™						˜		
	State Ditch 14 (531)	Bacteria	›	™	™	™						˜		
	Jacobs Lake (56-1039-00)	Nutrients	›		™	™		›				˜	˜	›
Stony Creek (0902010605)	Stony Creek (502)[1]	Sediment				™	˜	™	˜	˜	˜			
		Bacteria	›	™	™	™					˜			
	Hay Creek (519)	Bacteria	›	™	™	™								
	Hay Creek (520)	Sediment					˜	™	˜	˜				
		Bacteria	›	™	™	™					˜			
	Stony Creek (523)	Sediment					˜	™	˜	˜				
		Bacteria	›	™	™	™								
	Spring Creek (534)	Bacteria	›	™	™	™								
South Branch Buffalo River (0902010606)	Buffalo River, South Branch (503)[1]	Sediment					˜	™	˜	˜	˜	˜		
		Bacteria	›	™	™	™					˜	˜		
	Buffalo River, South Branch (504)[1]	Sediment					˜	™	˜	˜	˜	˜		
		Bacteria	›	™	™	™					˜	˜		
	Buffalo River, South Branch (505)[1]	Sediment					˜	™	˜	˜	˜	˜		
		Bacteria	›	™	™	™					˜	˜		
	Buffalo River, South Branch (508)[1]	Sediment					˜	™	˜	˜		˜		
		Bacteria	›	›	™	™						˜		

Key: ˜ = High; › = Moderate; ™ = Low

[1] Also impaired for dissolved oxygen, not covered under this TMDL

[2] Lakes are considered impaired but not needing TMDLs

2.4 TMDL Summary

This section summarizes the results of the BRW TMDLs. Due to the large number of AUIDs, lakes, and impairments within the BRW, this section is a general summary of those streams and lakes denoted as impaired. The section gives a brief overview of how each allocation, current loading, and required reduction was developed. Additional detailed information about the tools used to develop this information is discussed in Section 3 of this report.

A majority of the stream impairments in the BRW are related to either turbidity or bacteria. In order to determine the necessary bacteria and sediment load reductions in the BRW, a Soil and Water Assessment Tool (SWAT) model was created for the watershed. Additional information regarding the SWAT model development can be found in Section 3 of this report and in the SWAT model development report (HEI 2013b). Flows simulated in the SWAT model were combined with empirical sediment and bacteria data from each impaired AUID and load duration curves (including a 10% Margin of Safety (MOS)) were created. Results were used to identify the critical flow regime under which standard exceedances occurred as well as computing the required loading reductions. Results are summarized by indicating the maximum required percent load reduction for each load duration curve and the flow regime and the water quality criteria under which this maximum reduction occurred (i.e., the critical flow regime and criteria). The results of this analysis are summarized in Table 6. A detailed accounting of this process can be found in the BRW load duration curve memo (HEI 2013d). The complete sediment and bacteria TMDL and allocation tables for each of the AUIDs can be found in Appendix A.

Table 6. Maximum required bacteria and sediment load reductions for impaired streams in the BRW

HUC-10 Subwatershed	AUID (09020106-XXX)	Bacterial			Sediment	
		Max. % Load Reduction	Critical Flow Regime	Critical Standard	Max. % Load Reduction	Critical Flow Regime
Upper Buffalo River (0902010601)	511	75%	Moist	Geomean	---	---
	515	71%	Average	Geomean	---	---
	593	88%	Average	Geomean	41%	High
	594	62%	Average	Geomean	91%	High
Middle Buffalo River (0902010602)	595	57%	Dry	Geomean	93%	High
Lower Buffalo River (0902010607)	501	55%	High	Geomean	94%	High/Average
	556	67%	High	Geomean	---	---
	559	72%	Dry	Geomean	---	---
	562	64%	Dry	Geomean	---	---
Whiskey Creek (0902010604)	509	62%	Average	Geomean	59%	Moist
	521	83%	Dry	Geomean	69%	High
Deerhorn Creek (0902010603)	507	77%	High	Geomean	64%	High
	531	90%	High	Geomean	---	---
Stony Creek (0902010605)	502	69%	High	Geomean	71%	Average
	519	94%	Average	Geomean	---	---
	520	93%	High	Geomean	---	---
	523	90%	High	Geomean	71%	Moist
	534	79%	High	Geomean	---	---
South Branch Buffalo River (0902010606)	503	57%	High	Geomean	65%	High
	504	47%	Average	Geomean	44%	Moist
	505	64%	High	Geomean	84%	Dry
	508	61%	Average	Geomean	49%	Moist

--- Not impaired by turbidity

The loading capacities (including a 5% MOS) of the impaired lakes in the BRW were determined using in-lake water quality modeling via a modified BATHTUB model (CNET). Model inputs for flow and total phosphorus (TP) were taken from the established SWAT model, and each lake model was calibrated to in-lake water quality data. Stochastic simulations of the lake models were used to represent naturally-occurring variability in the systems and load reduction scenarios were determined from the results. The necessary TP load reductions (as a "percent load reduction" of the existing load and the actual "load reduction" in kilograms per year) for the impaired lakes of the BRW are given in Table 7. Additional information on the BRW lake modeling can be found in the lake eutrophication modeling report (HEI 2013c). The complete TMDL and allocation tables for each of the impaired lakes can be found in Appendix B.

Table 7. Required TP load reductions for impaired lakes in the BRW

HUC-10 Subwatershed	Lake Name	Lake ID	TP Standard - 5% MOS	Percent Load Reduction	Load Reduction	TMDL
			(ug/L)	(%)	(kg/yr)	(kg/yr)
Upper Buffalo River (0902010601)	Boyer (Sand Beach) Lake	03-0579-00	38	52%	23	21
	Forget-Me-Not Lake	03-0624-00	57	47%	407	458
	Gottenberg Lake	03-0528-00	57	22%	51	183
	Gourd Lake	03-0635-00	57	72%	63	24
	Lime (Norby, Selvine) Lake	03-0646-00	57	82%	6,981	1,532
	Marshall Lake	03-0526-00	38	1%	1.3	125
	Mission Lake	03-0471-00	57	63%	73	43
	North Tamarac Lake	03-0241-02	29	35%	48	90
	Sand (Stump) Lake	03-0659-00	38	94%	4,012	256
	Sorenson Lake	03-0625-00	57	74%	234	82
	Stakke (Stake) Lake	03-0631-00	57	8%	84	971
	Stinking Lake	03-0647-00	86	85%	11,753	2,074
	Talac Lake	03-0619-00	57	55%	496	406
	West LaBelle (Duck) Lake	03-0645-00	57	49%	30	32
Middle Buffalo River (0902010602)	Lake Maria (Marin)	14-0099-00	86	74%	1,929	678
Deerhorn Creek (0902010603)	Jacobs Lake	56-1039-00	38	82%	81	18

2.5 Protection Considerations

All streams and lakes currently supporting aquatic life and aquatic recreation in the BRW are candidates for protection. Over time, if these waters are not subject to protection strategies, it is likely that they will become impaired similar to currently non-supporting waters in the BRW. Strategies for addressing protection of these waters are discussed in more detail in Section 3 of this report.

3. Prioritizing and Implementing Restoration and Protection

The Clean Water Legacy Act (CWLA) requires that Watershed Restoration and Protection Strategy (WRAPS) Reports summarize priority areas for targeting actions to improve water quality, identify point sources and identify nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires including an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources.

This section of the report provides the results of such prioritization and strategy development. In particular, it discusses the methodologies that have been used to determine various non-point source focus areas within the BRW. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users and residents of the watershed, it is imperative to create social capital (trust, networks and positive relationships) with those who will be needed to voluntarily implement best management practices (BMP). Thus, effective ongoing civic engagement is fully a part of the overall plan for moving forward.

The successful implementation of restoration and protection strategies requires a combined effort from multiple entities within the BRW. By bringing these groups together in the decision making process, it will increase the transparency and eventual success of implementation efforts. Collaboration and compromise will also ensure that identified priorities and strategies are incorporated into local plans, future budgeting, and grant development.

The BRW WRAPS effort has been led by the Buffalo-Red River Watershed District (BRRWD). The BRRWD has a long history of collaborating with local and state partners (i.e., soil and water conservation districts (SWCDs), MPCA, the Department of Natural Resources (DNR), and the Board of Water and Soil Resources (BWSR) to prioritize, implement, and fund restoration and protection activities within its jurisdiction. Future restoration and protection work in the area will benefit from these relationships, building on previous successes.

3.1 Targeting of Geographic Areas

Several watershed modeling tools were used for the purpose of simulating and evaluating hydrology and water quality (sediment, nutrients, and bacteria) within the BRW. The watershed based results developed under this WRAPS effort utilized:

- SWAT model
- Hydrological Simulation Program – FORTRAN (HSPF) model
- In-lake (CNET) models
- Load duration curves
- Light Detection and Ranging (LiDAR) terrain analysis

This section gives an overview of the development of these tools, their results, and an outline of how the tools can be used in identifying restoration and protection target areas in the watershed.

SWAT Model

The SWAT is a river, basin, or watershed 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.

The 2009 version of the SWAT model was used to develop two separate models for the South Branch and Upper Main-Stem of the Buffalo River. The models were developed, calibrated, and validated using data ranging from 1995 through 2009. The SWAT models were found to simulate hydrology well in both watersheds. Likewise, the models did a good to excellent job predicting sediment and phosphorus loading. Fecal coliform concentrations simulated with the SWAT models did not compare well against observed data, therefore attempts to simulate bacteria in the BRW were considered unsuccessful with the SWAT model. Flow data extracted from the SWAT model was used along with empirical sediment and bacteria data for development of load duration curves. Results of this are described in Section 2.4. Additional information on the development of the BRW SWAT model can be found in the final reporting (HEI 2013b). The results of the BRW SWAT modeling for sediment and TP yield are shown in Figure 3 and Figure 4, respectively. The color ramp is used to easily identify subwatersheds with high sediment and TP yields for use in prioritizing implementation areas.

One of the major benefits of the SWAT model is that it has the ability to simulate the use of agricultural BMPs and other future management scenarios in the watershed. Results of the modeling under these various scenarios provide insight on the effectiveness and overall impact that the various management strategies may produce. The SWAT modeling report provides detailed results of four BMP/management scenarios. These four scenarios were determined using input from local managers (i.e. the BRRWD, local SWCDs, and BWSR). Of the four management scenarios evaluated, filter strips and side inlets/sediment control basins were shown to be most effective at reducing sediment and TP loads throughout the watershed. Reduced tillage was shown to have minimal, if any, water quality impact, while the targeted retention project scenario showed some water quality benefit. These results are useful in prioritizing management strategies in the watershed. More detailed results of the scenarios can be found in the SWAT modeling report (HEI 2013b).

In addition to the uses mentioned above, future use of the SWAT model in restoration and protection efforts may include the simulation of additional agricultural BMPs and scenarios to determine impacts to waters both currently impaired and those under protection.

Figure 3. The BRW SWAT model average annual (1995-2009) sediment yields (tons/acre/year) (HEI 2013a)

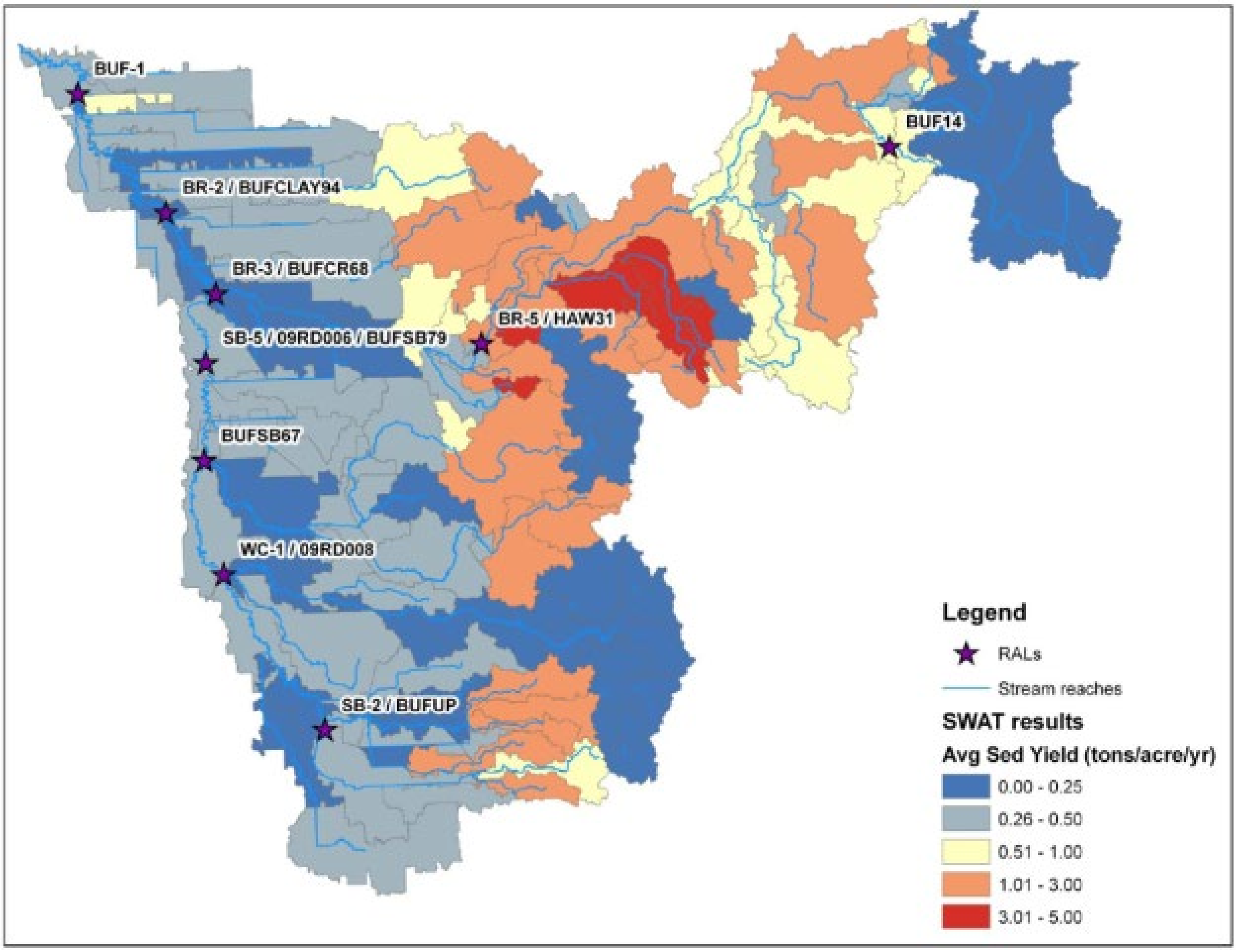
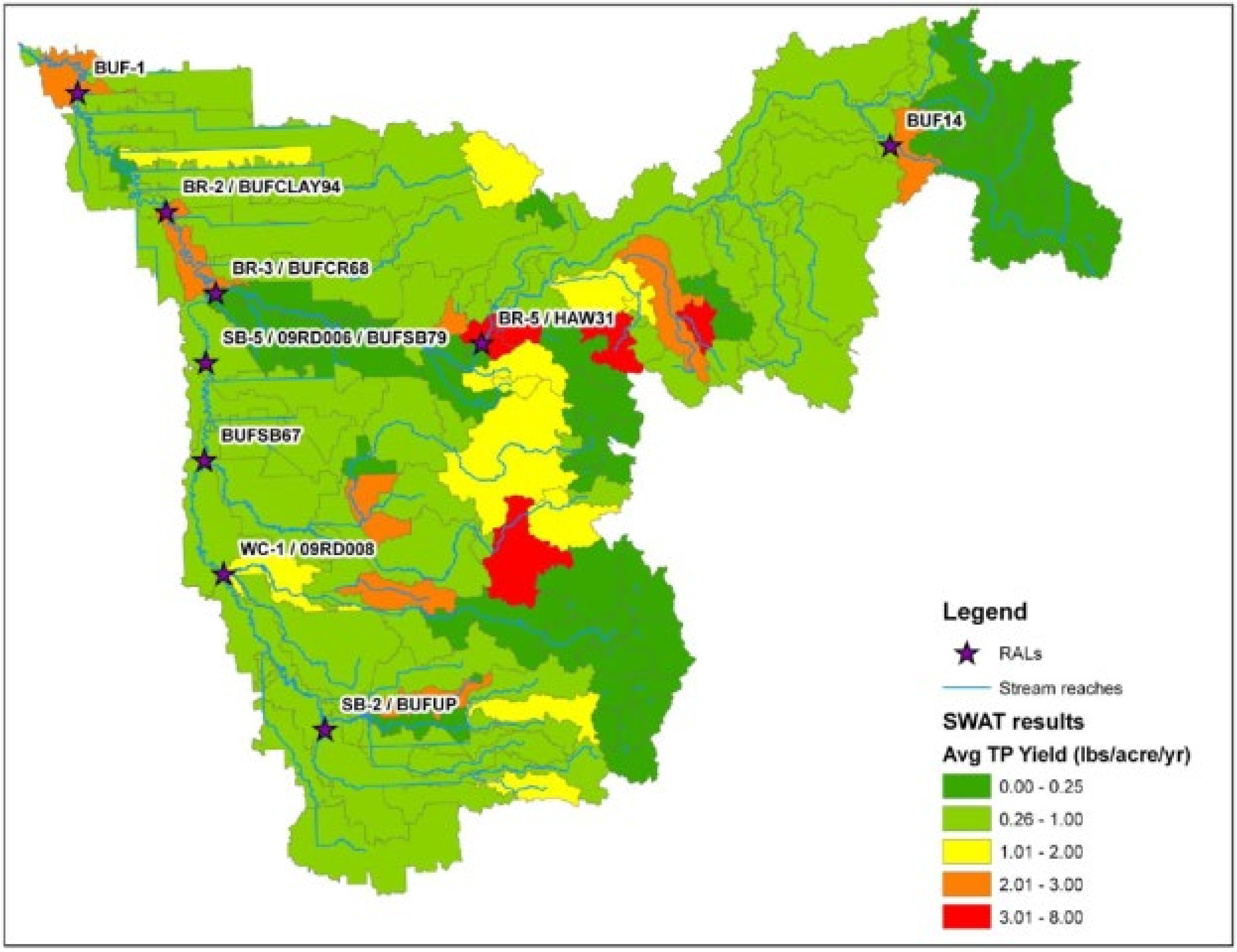


Figure 4. The BRW SWAT model average annual (1995-2009) TP yields (pounds/acre/year) (HEI 2013a)



HSPF Model

In an effort to expedite the completion of WRAPS, the MPCA is constructing watershed models that have the potential to support simultaneous development of restoration and protection strategies for all waters within a given watershed. The Hydrologic Simulation Program-FORTRAN (HSPF) model was chosen for use in the BRW.

A series of reports and memoranda were written and previously submitted to the MPCA that describe various components of the BRW HSPF model, including: model segmentation and development, the availability and selection of flow data for hydrologic calibration/validation, the simulation of point sources and atmospheric deposition within the model, hydrologic calibration and validation, and sediment sourcing and calibration.

The overall goal is to successfully develop, calibrate, and validate a HSPF model for the BRW. The fully functioning HSPF model successfully simulates the following at a 12-didgit HUC (or similar scale) level:

- Hydrology
- Sediment
- Water temperature
- DO
- Biologic oxygen demand (BOD)

- Phosphorus (P)
- Nitrogen (N)
- Chlorophyll-a (Chl-a)

The HSPF model was constructed between 2011 and 2013. Three work orders covering three phases were issued to build the BRW HSPF model and calibrate/validate its simulation of hydrology, sediment, and water quality. The objectives of these work orders were:

1. Compile both the geographic and time-series data required to construct the model framework.
2. Develop representation of the watershed area and drainage network.
3. Develop and implement a strategy for the representation of point sources within the HSPF model domain.
4. Formulate a time-series from observed flow and water quality monitoring data to be used for modeling calibration and validation.
5. Perform the hydrologic calibration and validation and show the model accurately simulates the water balance.
6. Define the sources of sediment within the watershed and conduct sediment calibration and validation.
7. Conduct water quality calibration, validation, and model evaluation.
8. Create GenScn project containing output from the BRW. . Generation and analysis of model simulation SCeNarios (GenScn) provides an interactive framework for analysis built around an established and adaptable watershed model. Here it is used in conjunction with the Hydrological Simulation Program--Fortran (HSPF) model.

The memoranda, reports, GenScn project, HSPF model files, and Geographic Information Systems (GIS) data were provide separately in deliverable packages throughout the project timeframe (2011 through 2013).

Memoranda and reports include detailed discussion of the approaches used to develop and implement the BRW HSPF model, the calibration and validation results, and any shortcomings/uncertainty in the models.

Due to the nature of the Buffalo WRAPS being a pilot project, not all products were developed sequentially. The fully constructed model was not available for usage for writing TMDLs and for protection strategy development, as it was not available until the end of December 2013. The TMDLs, restoration and protection strategies were completed using other models; SWAT, which is described in the previous section of this report, and CNET, which is described in the following section on In-Lake Models.

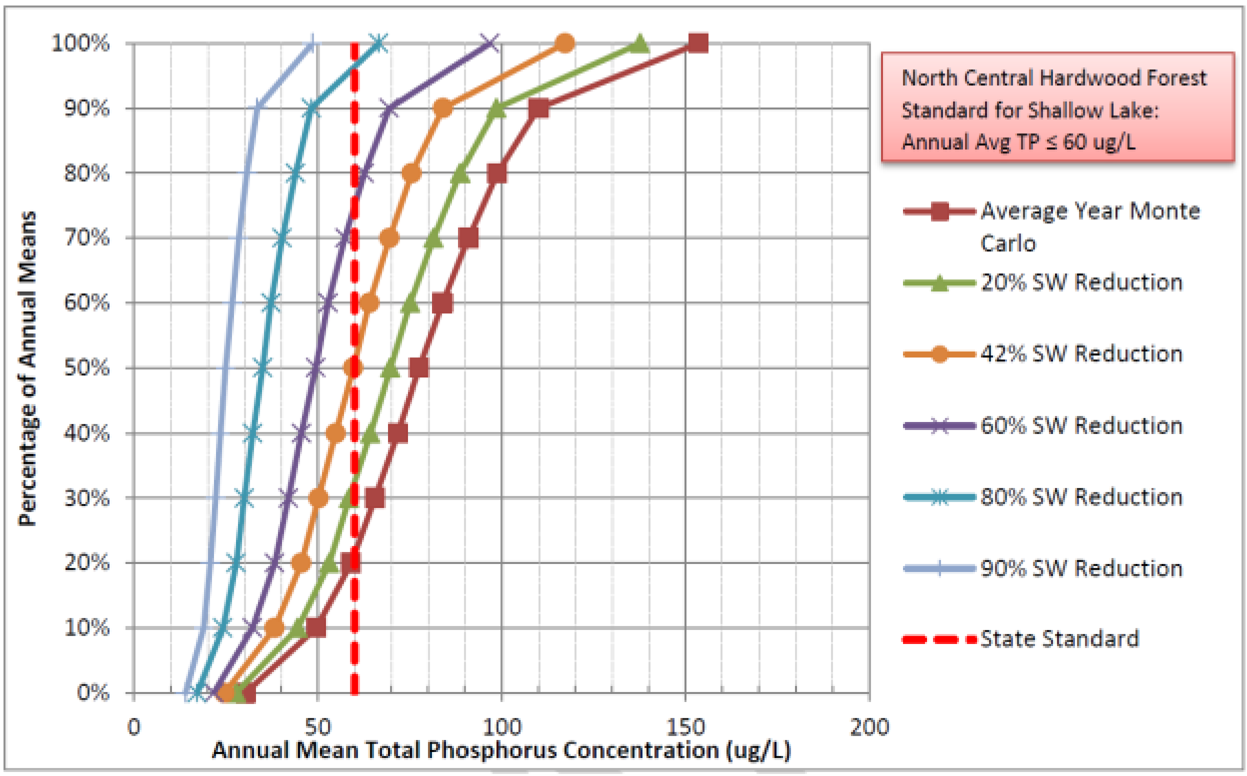
The HSPF model is complete and therefore available to be used by the BRRWD for any of their planning and pollution reduction scenarios and is also available for the second round of the WRAPs process (2017 through 2027).

In-Lake Models

As discussed in Section 2.4, multiple CNET models were created for the impaired lakes in the BRW. These models produce results that include an in-lake response to nutrient loading on an annual timescale. The models are developed in such a way so that stochastic Monte Carlo simulations can be utilized to compute the likelihood of water quality outcomes. This allows for looking at lake impairments from a probabilistic standpoint, rather than as a single event.

The CNET models can be used for future lake planning by analyzing load reduction scenarios. In some cases this may include the use of other tools that provide input to the CNET models. For example, as outputs from the BRW SWAT model change for various future scenarios, they can be used with the accompanying CNET models to predict in-lake response to the changes in loading. Figure 5 is an example of the results that the BRW CNET models provide; highlighting the necessary reduction to meet the state water quality standard. Additional information on the models created for the BRW can be found in the lakes modeling report (HEI 2013c).

Figure 5. Example of frequency distribution of mean annual TP concentrations resulting from select load reduction scenarios in Forget-Me-Not Lake (HEI 2013c)



LiDAR Terrain Analysis

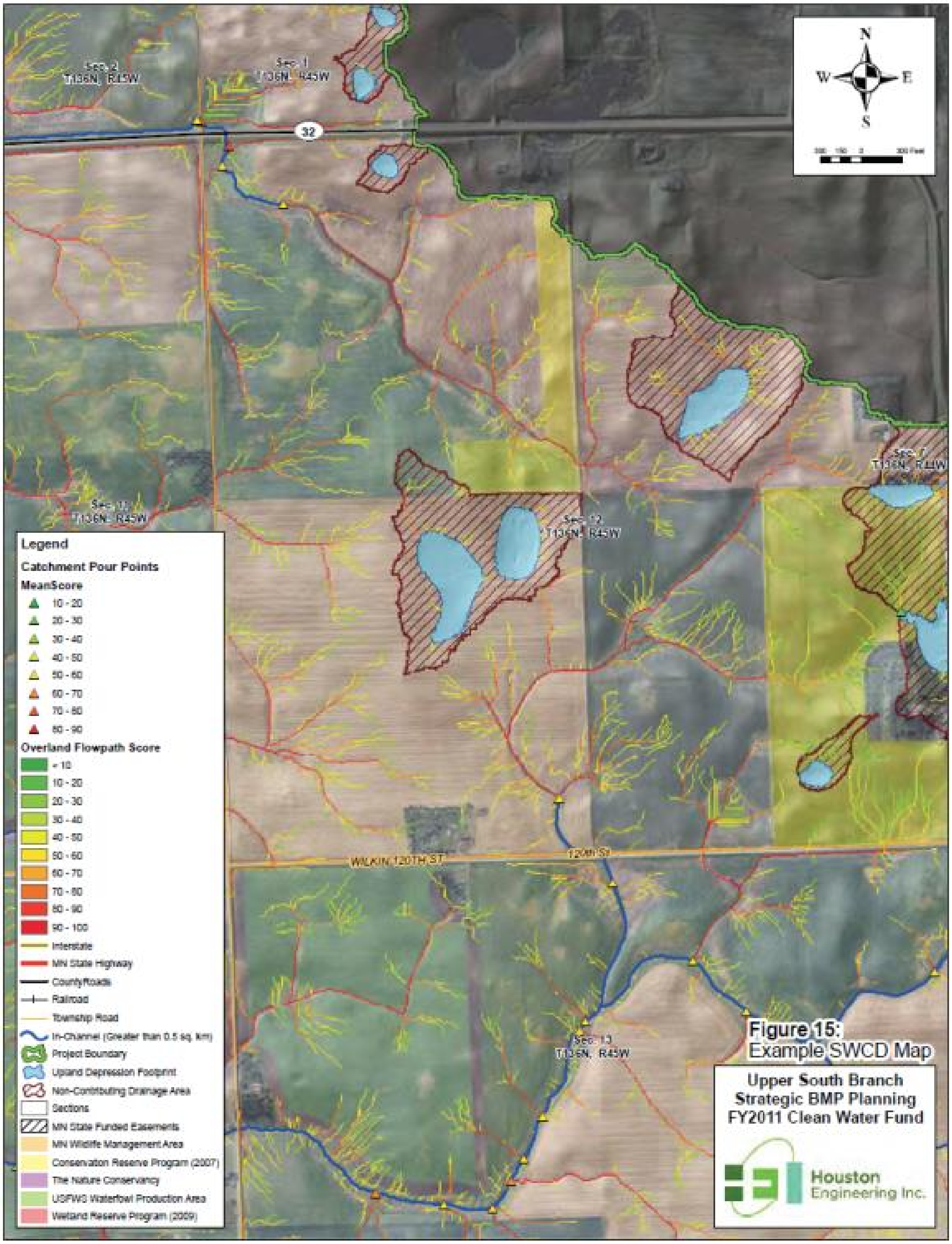
Light Detection and Radar (LiDAR) is a remote sensing technology that uses laser light to detect and measure surface features on the earth. The resulting data can be converted into elevation data and used to create a digital elevation model (DEM) for GIS analysis. The general mapping and analysis of elevation/terrain has been used for erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.

Excessive sediment loading in BRW streams is responsible for many of the turbidity impairments throughout the watershed. As part of local planning in the watershed, advanced GIS techniques utilizing LiDAR topography and soils and land cover data have been used to rank and classify highly erosive portions of the watershed. This methodology ranks basins within the watershed by analyzing and scoring the results of the Stream Power Index (SPI) and a spatial application of the Revised Universal Soil

Loss Equation (RUSLE). This methodology can be used to identify critical management areas to prioritize the implementation of BMPs. The application results in a detailed mapping of SPI values for the BRW. This mapping provides a relative indication of the erosive power of the overland, concentrated, surface water runoff at locations across the landscape. Additionally, this methodology results in a mapping of potential soil yields from overland flow areas, computed using the RUSLE. Priority management areas in the BRW are identified by analyzing and combing the SPI and RUSLE results to locate those areas where the most potentially erosive flows and highest predicted sediment yields combine. An example of the types of products produced, for the Upper South Branch Buffalo River, is shown in Figure 6. Lastly, these identified areas undergo field verification by the local land managers. The main benefit of this work is the field-scale accuracy of the results.

Future use of the LiDAR terrain analysis in restoration and protection efforts will include the identification of field-scale priority management areas within the BRW.

Figure 6. Example LiDAR Terrain Analysis mapping for the Upper South Branch Buffalo River (HEI 2011e).



Buffalo River Watershed Management Plan

Pursuant to Minnesota statute, the BRRWD is required to prepare a Watershed Management Plan (WMP) and to continually update and revise the plan every 10 years. The WMP is an important tool for identifying problems and issues, goals, and long and short-term strategies to address these issues and attain the goals. The WMP also inventories resources, assesses resource quality, and establishes regulatory controls, programs, or infrastructure improvements needed to manage the resources within the watershed. The WMP provides guidance for the BRRWD to manage the water and natural resources within the watershed boundary.

The BRRWD WMP was most recently updated in June of 2010. In the updated plan, great efforts have been made to quantify the goals and suggest implementation strategies of the BRRWD for managing water quantity and quality, as well as natural resource enhancement. The BRRWD WMP is scheduled for its next update to be completed in 2016. Results of the WRAPS will be directly incorporated into the updated Plan.

Future use of the BRRWD WMP in water quality restoration and protection efforts will include integrating the principles, goals, and policies of the BRRWD into the work and providing a management framework under which it can occur.

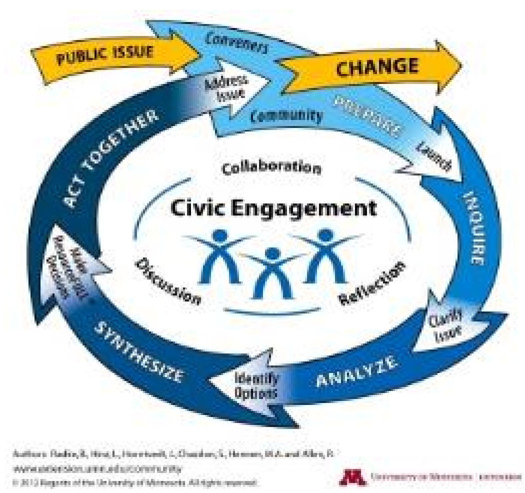
Additional Tools

A number of additional tools are available for use in restoration and protection of impaired waters in the BRW. A non-exhaustive list of some of these tools, their description, and how they may be utilized is listed in Table 8.

Table 8. Additional tools for restoration and protection in the BRW

Tool	Description	How can the tool be used?
Ecological Ranking Tool (Environmental Benefit Index - EBI)	Three GIS layers containing: soil erosion risk, water quality risk, and habitat quality. Locations on each layer are assigned a score from 0-100. The sum of all three layer scores (max of 300) is the EBI score. This higher the score, the higher the value in applying restoration or protection.	Any one of the three layers can be used separately or the sum of the layers (EBI) can be used to identify areas that are in line with local priorities. Raster calculator allows a user to make their own sum of the layers to better reflect local values.
Zonation	A framework and software for large-scale spatial conservation prioritization; it is a decision support tool for conservation planning. This values-based model can be used to identify areas important for protection and restoration.	Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells).
Restorable Depressional Wetland Inventory	A GIS layer representing drained, potentially restorable wetlands in agricultural landscapes. Created primarily through photo-interpretation of 1:40,000 scale color infrared photographs acquired in April and May, 1991 and 1992.	Identify restorable wetland areas with an emphasis on: wildlife habitat, surface and ground water quality, reducing flood damage risk. To see a comprehensive map of restorable wetlands, must display this dataset in conjunction with the USGS National Wetlands Inventory (NWI) polygons that have a 'd' modifier in their NWI classification code
National Hydrography Dataset (NHD) & Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. These data has been used for: fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of the data set is to identify buffers around riparian areas.

3.2 Civic Engagement



A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement. This is distinguished from the broader term ‘public participation’ in that civic engagement encompasses a higher, more interactive level of involvement. Specifically, the University of Minnesota Extension’s definition of civic engagement is “Making ‘resourceFULL’ decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration.” A resourceFULL decision is one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on civic engagement is available at: http://www1.extension.umn.edu/community/civic-engagement/

Accomplishments and Future Plans

The civic engagement efforts related to the BRW WRAPS have been overseen and carried out by the BRRWD. Numerous public meetings and open house events were held at key points in the WRAPS process to update stakeholders on the WRAPS efforts as well as receive input and guidance on water quality values and concerns in the area. In addition, the BRRWD posted project updates on their website (http://www.brrwd.org/) and a core team, including the BRRWD board members and local/state agency partners, was established and kept abreast of technical components of the work.

Since water quality is among the priorities of the BRRWD's management activities, future civic engagement will continue to be coordinated by 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 (University of Minnesota WRC 2012), the BRRWD is uniquely suited to provide information and leadership on this topic.

3.3 Restoration & Protection Strategies

Water quality restoration and protection 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.

Table 9 contains a list of the impaired waters of the BRW, along with goals for restoration and suggested implementation strategies to achieve those goals. All other waters in the watershed are assumed to be unimpaired and, therefore, subject to protection strategies. Given the homogeneity of the watershed, protection strategies are identified on a watershed-wide basis and generalized for all unimpaired streams and lakes.

The timeline for achieving the goals/targets identified, in Table 9, for the impaired waters is at least 50 years. Interim 10-year milestones are identified for each impaired subwatershed so incremental progress is achieved. On-going water quality monitoring data will be used in future components of the WRAPS process to judge the effectiveness of the proposed strategies and inform adaptive implementation toward meeting the identified long-term goals. The timeline for the identified protection strategies is on-going.

Two waterbodies in the BRW have unique considerations: Axberg Lake and North Tamarac Lake. Available water quality data show an excessive amount of TP in Axberg Lake; however, insufficient data prevents it from being listed as impaired. Given local concerns over the Sand-Axberg Chain of Lakes, however, Axberg Lake is included in Table 9 and restoration strategies are presented for its management. North Tamarac Lake is impaired for excess nutrients based on available data. On April 25, 2011, North Tamarac Lake was evaluated by the MPCA staff for a determination of nutrient impairment in lakes due to natural background conditions. Evaluation of the existing watershed and the historical land use provided by the US Fish and Wildlife Service led the group to recommend a change to the

303(d) List to move North Tamarack 03-0241-02 from category 5 to category 4D (Impaired or threatened but does not require a TMDL because impairment is solely a result of natural sources).Based on the headwaters nature of the watershed and limited development in the watershed (none on shoreline) the elevated phosphorus is not caused by anthropogenic sources. Sedimentation would have naturally occurred in this basin, considering the shallow nature of the lake. The majority of the land in the watershed is part of the National Wildlife Refuge; possibility of further development is small. In this situation, presenting restoration strategies for North Tamarac Lake does not make sense. Therefore, it is not included in Table 9.

Table 9. Strategies and actions proposed for the BWR

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				Contributing 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					Contributing drainage area	100% compliance of existing septic systems; develop grazing management plans for riparian zones	
			TSS	High = 146 mg/L Moist = 36 mg/L Avg = 30 mg/L Dry = 27 mg/L Low = 42 mg/L	90% of samples ≤ 65mg/L TSS			A, B	A,B	A	B	B	B						D				A, B	Contributing 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 - invertebrates	IBI Score = 9.04-24.32	IBI Score > 38.3				A,B	A								A						Contributing drainage area	Meet milestones for turbidity impairments; remove connectivity	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]			
																									barriers	
			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 = 188 mg/L Moist = 149 mg/L Avg = 144 mg/L Dry = 100 mg/L Low = 137 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 = 399 mg/L Moist = 87 mg/L Avg = 57 mg/L Dry = 43 mg/L Low = 71 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	
	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 = 212 mg/L Moist = 39 mg/L Avg = 57 mg/L Dry = 52 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 = 7 mg/L Moist = 43 mg/L Avg = 48 mg/L Dry = NA 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 = 46 mg/L Moist = 67 mg/L Avg = 26 mg/L Dry = 48 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, 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 = 35 mg/L Moist = 53 mg/L Avg = 36 mg/L Dry = 33 mg/L Low = 32 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 = 50 mg/L Moist = 91 mg/L Avg = 92 mg/L Dry = 80 mg/L Low = 18 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	

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 = 103 mg/L Avg = 89 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 = 150 mg/L Moist = 120 mg/L Avg = 33 mg/L Dry = 52 mg/L Low = 110 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 = 52 mg/L Moist = 38 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	

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]			
	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 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	

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 = 98 mg/L Moist = 55 mg/L Avg = 48 mg/L Dry = 39 mg/L Low = 53 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	
	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 = NA Moist = 61 mg/L Avg = 88 mg/L 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

4. Monitoring Plan

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 2010b), 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 on-going monitoring in the watershed. Their major watershed outlet monitoring will continue to provide a long-term on-going 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 Intensive Watershed Monitoring program in 2019 and 2020.

5. References and Further Information

Houston Engineering, Inc. (HEI). 2010a. Watershed Conditions Report. Buffalo-Red River Watershed District. May 10, 2010.

Houston Engineering, Inc. (HEI). 2010b. Buffalo-Red River Watershed District Revised Watershed Management Plan. June 23, 2010.

Houston Engineering, Inc. (HEI). 2011a. Memo: Summary of Work under the Buffalo River Watershed HSPF Model Framework Development Work Plan (MPCA Work Plan #B55117). June 27, 2011.

Houston Engineering, Inc. (HEI). 2011b. Lake Classification Approach. Buffalo River Watershed. December 20, 2011.

Houston Engineering, Inc. (HEI). 2011c. Watershed Conditions Report Addendum. Buffalo River Watershed. December 22, 2011.

Houston Engineering, Inc. (HEI). 2011d. Lake Conditions Report. Buffalo River Watershed. December 22, 2011.

Houston Engineering, Inc. (HEI). 2011e. Upper South Branch BMP Strategic Plan. October 4, 2011.

Houston Engineering, Inc. (HEI). 2012. Lake Water and Nutrient Budgets Report. January 25, 2012.

Houston Engineering, Inc. (HEI). 2013a. Memo: Buffalo River Watershed Bacteria Source Assessment and Quantification. January 21, 2013.

Houston Engineering, Inc. (HEI). 2013b. Buffalo River Watershed SWAT Modeling. Draft Report. Buffalo Red River Watershed District. August 13, 2013.

Houston Engineering, Inc. (HEI). 2013c. Buffalo River Watershed Lakes Eutrophication Modeling. Draft Report. Buffalo Red River Watershed District. August 21, 2013.

Houston Engineering, Inc. (HEI). 2013d. Memo: Buffalo River Watershed Load Duration Curves. August 21, 2013.

Minnesota Pollution Control Agency (MPCA). 2012. Buffalo River Watershed Monitoring and Assessment Report. July, 10, 2012.

Minnesota Pollution Control Agency (MPCA). 2013. Buffalo River Watershed Biotic Stressor Identification. September 2013.

University of Minnesota Water Resources Center (U of MN WRC). 2012. BRRWD Social Indicators Survey Final Report. May 30, 2012.

Buffalo River Watershed Reports

All reports referenced in this watershed report are available at either the BRRWD's webpage (www.brrwd.org) or the MPCA's BRW webpage (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/buffalo-river.html). Except for the Buffalo-Red River Watershed District Revised Watershed Management Plan, June 23, 2010, and the Upper South Branch BMP Strategic Plan, October 4, 2011, the above reports are products of the Buffalo WRAPs.

Appendix

A. Buffalo River Watershed Stream TMDL/Load Allocation Tables

Table A1a. TSS TMDL allocation for AUID 09020106-501

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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 A1b. *E. coli* TMDL allocation for AUID 09020106-501

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
Lake Park WWTF	6.3	6.3	6.3	6.3	6.3
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
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
Highlevel Egg	0.0	0.0	0.0	0.0	0.0
Baers Poultry Co - New Barn Site	0.0	0.0	0.0	0.0	0.0
J & A Farms LLC	0.0	0.0	0.0	0.0	0.0
Taves Turkey Farm Inc.	0.0	0.0	0.0	0.0	0.0
Spring Prairie Colony	0.0	0.0	0.0	0.0	0.0
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	4,296.3	702.0	303.5	129.8	33.9
Margin of Safety	483.4	84.0	39.8	20.5	9.8

* See Section 3.2 of the TMDL document for allocations to this category under these flow conditions.

Table A2. TMDL allocation for AUID 09020106-502

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	259.3	108.6	49.0	25.3	8.2
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A3. TMDL allocation for AUID 09020106-503

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
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 A4. TMDL allocation for AUID 09020106-504

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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	*
Load Allocation	73.21	14.71	4.68	1.34	*
Margin of Safety	8.22	1.72	0.60	0.23	*
E. coli	**Flow Zone**				
	High Flow	**Moist Conditions**	**Average Conditions**	**Dry Conditions**	**Low Flow**
	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	*
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	1176.1	244.0	67.5	13.8	*
Margin of Safety	132.8	29.2	9.6	3.6	*

* 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 condition 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 A5. TMDL allocation for AUID 09020106-505

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
E. coli	**Flow Zone**				
	High Flow	**Moist Conditions**	**Average Conditions**	**Dry Conditions**	**Low Flow**
	Billion organisms per day				
Loading Capacity	493.0	102.9	30.1	8.8	1.5
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A6. TMDL allocation for AUID 09020106-507

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	150.5	28.2	8.6	3.0	0.9
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A7. TMDL allocation for AUID 09020106-508

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	123.2	21.0	3.9	0.7	0.1
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A8. TMDL allocation for AUID 09020106-509

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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	*	*
Load Allocation	10.99	2.65	0.87	*	*
Margin of Safety	1.30	0.38	0.18	*	*
E. coli	**Flow Zone**				
	High Flow	**Moist Conditions**	**Average Conditions**	**Dry Conditions**	**Low Flow**
	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	*	*
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	168.6	38.6	8.5	*	*
Reserve Capacity	0.00	0.00	0.00	0.00	0.00
Margin of Safety	20.8	6.4	3.0	*	*

* 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 condition 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 A9. TMDL allocation for AUID 09020106-511

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	183.4	25.6	10.1	4.9	0.2
Reserve Capacity	0.00	0.00	0.00	0.00	0.00
Margin of Safety	21.1	3.5	1.8	1.2	0.7

Table A10. TMDL allocation for AUID 09020106-515

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	381.4	82.7	53.9	31.2	12.0
Reserve Capacity	0.00	0.00	0.00	0.00	0.00
Margin of Safety	43.4	10.2	7.0	4.5	2.4

Table A11. TMDL allocation for AUID 09020106-519

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	127.5	41.4	22.1	10.6	3.1
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A12. TMDL allocation for AUID 09020106-520

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	126.2	55.4	34.5	19.2	7.4
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A13. TMDL allocation for AUID 09020106-521

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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	*	*
Load Allocation	8.88	2.25	0.71	*	*
Margin of Safety	1.07	0.33	0.16	*	*
E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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	*	*
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	140.3	31.8	6.0	*	*
Margin of Safety	17.7	5.6	2.7	*	*

* 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 condition 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 A14. TMDL allocation for AUID 09020106-523

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	101.2	33.6	9.9	2.6	0.4
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A15. TMDL allocation for AUID 09020106-531

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	52.5	8.5	2.4	0.9	0.5
Wasteload Allocation [1]					
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	47.3	7.7	2.2	0.9	0.426
Margin of Safety	5.3	0.9	0.2	0.1	0.047

[1] There are no WWTFs in this watershed.

Table A16. TMDL allocation for AUID 09020106-534

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	47.4	4.9	1.3	0.3	0.005
Wasteload Allocation [1]					
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	42.6	4.4	1.2	0.2	0.004
Margin of Safety	4.7	0.5	0.1	0.0	0.000

[1] There are no WWTFs in this watershed.

Table A17. TMDL allocation for AUID 09020106-556

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	355.4	49.5	13.9	4.9	0.2
Wasteload Allocation [1]					
Spring Prairie Colony	0.0	0.0	0.0	0.0	0.0
"Straight pipe septic systems"	0.0	0.0	0.0	0.0	0.0
Load Allocation	319.9	44.5	12.5	4.4	0.2
Margin of Safety	35.5	4.9	1.4	0.5	0.0

[1] There are no WWTFs in this watershed.

Table A18. TMDL allocation for AUID 09020106-559

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	146.9	22.2	6.2	1.9	0.2
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A19. TMDL allocation for AUID 09020106-562

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	78.6	10.2	1.4	0.1	0.0
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A20. TMDL allocation for AUID 09020106-593

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	Billion organisms per day				
Loading Capacity	370.8	152.8	104.7	48.0	16.8
Wasteload Allocation [1]					
"Straight pipe septic systems"	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 A21. TMDL allocation for AUID 09020106-594

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
E. coli	**Flow Zone**				
	High Flow	**Moist Conditions**	**Average Conditions**	**Dry Conditions**	**Low Flow**
	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
"Straight pipe septic systems"	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 A22. TMDL allocation for AUID 09020106-595

Total Suspended Solids	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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

E. coli	Flow Zone				
	High Flow	Moist Conditions	Average Conditions	Dry Conditions	Low Flow
	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
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
Highlevel Egg	0.0	0.0	0.0	0.0	0.0
Baers Poultry Co - New Barn Site	0.0	0.0	0.0	0.0	0.0
J & A Farms LLC	0.0	0.0	0.0	0.0	0.0
Taves Turkey Farm Inc.	0.0	0.0	0.0	0.0	0.0
"Straight pipe septic systems"	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

B. Buffalo River Watershed Lakes TMDL/Load Allocation Tables

Table B1. TMDL allocation for Lake ID 03-0579-00 (Boyer)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.16	58.2
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.0001	0.0
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 B2. TMDL allocation for Lake ID 03-0624-00 (Forget-me-Not)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	3.03	1,106.7
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	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 B3. TMDL allocation for Lake ID 03-0528-00 (Gottenberg)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	1.20	438.7
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	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 B4. TMDL allocation for Lake ID 03-0635-00 (Gourd)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.17	61.7
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	0.1
Load Allocation	0.14	52.9
Margin of Safety	0.02	8.8

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

Table B5. TMDL allocation for Lake ID 56-1039-00 (Jacobs)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.13	48.5
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	0.0
Load Allocation	0.11	39.6
Margin of Safety	0.02	8.8

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

Table B6. TMDL allocation for Lake ID 03-0646-00 (Lime)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	10.29	3,754.5
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.01	3.4
Load Allocation	9.24	3,374.1
Margin of Safety	1.03	377.0

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

Table B7. TMDL allocation for Lake ID 14-0099-00 (Maria)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	4.41	1,609.4
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	1.5
Load Allocation	4.09	1,493.2
Margin of Safety	0.31	114.6

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

Table B8. TMDL allocation for Lake ID 03-0526-00 (Marshall)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.76	277.8
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	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 B9. TMDL allocation for Lake ID 03-0471-00 (Mission)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.28	101.4
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	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 B10. TMDL allocation for Lake ID 03-0659-00 (Sand (Stump))

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	1.81	659.2
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	0.6
Load Allocation	1.54	563.8
Margin of Safety	0.26	94.8

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

Table B11. TMDL allocation for Lake ID 03-0625-00 (Sorenson (Lee))

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.51	187.4
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	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 B12. TMDL allocation for Lake ID 03-0631-00 (Stakke)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	6.18	2,255.3
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.01	2.1
Load Allocation	5.86	2,138.5
Margin of Safety	0.31	114.6

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

Table B13. TMDL allocation for Lake ID 03-0647-00 (Stinking)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	13.36	4,876.6
Wasteload Allocation [1]		0.0
Lake Park WWTF [2]	10.95	462.4
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	4.1
Load Allocation	12.53	4,568.3
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 3.2 for discussion of daily and annual WLAs for the Lake Park WWTF.

Table B14. TMDL allocation for Lake ID 03-0619-00 (Talac)

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	2.62	954.6
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	0.9
Load Allocation	2.45	894.2
Margin of Safety	0.16	59.5

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

Table B15. TMDL allocation for Lake ID 03-0645-00 (West Labelle (Duck))

Total Phosphorus	lbs/day	lbs/yr
Loading Capacity	0.21	75.0
Wasteload Allocation [1]		
"Straight Pipe" Septic Systems	0.00	0.0
Construction/Industrial Stormwater	0.00	0.1
Load Allocation	0.19	70.5
Margin of Safety	0.01	4.4

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