Buffalo River Watershed Monitoring and Assessment Report

Minnesota Pollution Control Agency

August 2012

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Executive Summary

The Buffalo River watershed (09020106) lies in the western portion of Minnesota, originating from Tamarac Lake in eastern Becker County and flowing 88 miles into Clay County where it enters the Red River of the North approximately one mile west of Georgetown. The watershed covers approximately 709,400 acres and is comprised of 166 lakes and 41 named stream assessment units (AUIDs). The watersheds primary land use is agricultural; accounting for over 70 percent of the landscape within the watershed.

In 2009, the Minnesota Pollution Control Agency (MPCA) undertook an intensive watershed monitoring effort of the Buffalo River watershed's surface waters. Of the 41 AUIDs in the watershed, 25 had data available to assess aquatic recreation and 18 stream segments had sufficient information to assess aquatic life (not all lake and stream AUIDs were able to be assessed due to insufficient data, modified channel condition, or their status as limited resources waters) (Appendix 5). Overall, 71 sites were sampled for biology at the outlets of variable sized sub-watersheds within the Buffalo River watershed (Appendices 6 and 7). Of the biological sites sampled, data from 13 sites that were sampled in either 2005 or 2007 and two sites sampled in 2010 were also included in the assessments. As part of this effort, the MPCA also joined with local partners to complete stream water chemistry sampling at the outlets of the Buffalo River's nine major sub-watersheds (11-digit HUC). In addition to the biology and water chemistry sampling in streams, 41 lakes were also assessed in this effort to determine the suitability of lakes in the watershed to support aquatic recreation.

Of the assessable stream segments in the Buffalo River watershed, two stream AUIDs are fully supporting aquatic life, while only one is fully supporting aquatic recreation. Sixteen stream AUIDs throughout the watershed are non-supporting of aquatic life and 24 are non-supporting of aquatic recreation. Biological community impairments occur across the Buffalo River watershed in all stream types from the mainstem of the Buffalo River to unnamed tributaries, and most often these impairments are related to poor land use and/or lack of riparian and in-stream habitat. The channelized waterways throughout the watershed are generally in poor biological condition. Water chemistry impairments involving high levels of turbidity and bacteria are very common, occurring in nearly every watershed unit. In addition, impairments involving low dissolved oxygen concentrations and high amounts of nutrients were found as well but to a lesser extent across the watershed.

Of the 41 assessable lakes in the Buffalo River watershed, 16 are fully supporting aquatic recreation, 17 are non-supporting, and 8 had insufficient information to make a determination. Lake water quality in the Buffalo River watershed is modest to poor; nutrient eutrophication is the largest concern across all of the watersheds lakes.

Overall, the results from the intensive watershed monitoring and holistic assessment process reveal that the Buffalo River watershed is in poor condition. Land use and development in the region appear to affect the poor quality of the surface water resources. The main resource concerns within the watershed are wetland management, surface water quality, flood damage reduction, wildlife habitat, and soil erosion from wind and water. Land use modifications such as removal of buffers, tiling, and development result in increased sediment and pollutant loading to surface waters. In addition, hydrologic alteration, including groundwater withdrawal, may be contributing factors to the observed poor water quality conditions.

I. Introduction

Water is one of Minnesota's most abundant and precious resources. The Minnesota Pollution Control Agency (MPCA) is charged under both federal and state law with the responsibility of protecting the water quality of Minnesota's water resources. The MPCA's water management efforts are tied to the 1972 Federal Clean Water Act (CWA) requiring states to adopt water quality standards to protect their water resources and the designated uses of those waters, such as for drinking water, recreation, fish consumption and aquatic life. States are required to provide a summary of the status of their surface waters and develop a list of water bodies that do not meet established standards. Such waters are referred to as "impaired waters," and the state must take appropriate actions to restore these waters, including the development of Total Maximum Daily Loads (TMDLs). A TMDL is a comprehensive study identifying all pollution sources causing or contributing to impairment and the reductions needed to restore a water body so that it can support its designated use.

The MPCA currently conducts a variety of surface water monitoring activities that support our overall mission of helping Minnesotans protect the environment. To successfully prevent and address problems, decision makers need good information regarding the status of the resources, potential and actual threats, options for addressing the threats, and data on the effectiveness of management actions. The MPCA's monitoring efforts are focused on providing that critical information. Overall, the MPCA is striving to provide information to assess - and ultimately to restore or protect - the integrity of Minnesota's waters.

The passage of Minnesota's Clean Water Legacy Act (CWLA) of 2006 provided a policy framework and the initial resources to state and local governments to accelerate efforts to monitor, assess, restore, and protect surface waters. Funding from the Clean Water Fund created by the passage of the Clean Water, Land and Legacy Amendment to the state constitution allows a continuation of this work. In response, the MPCA has developed a watershed monitoring strategy that uses an effective and efficient integration of water monitoring programs to provide a more comprehensive assessment of water quality and expedite the restoration and protection process. This has permitted the MPCA to establish a goal to assess the condition of Minnesota's surface waters via a 10-year cycle, and provides an opportunity to more fully integrate MPCA water resource management efforts in cooperation with local government and stakeholders to allow for coordinated development and implementation of water quality restoration and improvement projects.

The rationale behind the watershed monitoring approach is to intensively monitor the streams and lakes within a major watershed to determine the overall health of water resources, identify impaired waters, and to identify waters in need of additional protection efforts. The monitoring strategy was implemented in the Buffalo River watershed beginning in the summer of 2009. This report provides a summary of all water quality assessment results in the Buffalo River watershed and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring, and monitoring conducted by local government units. Consequently, there is an opportunity to begin to address most, if not all, impairments through a coordinated TMDL process at the watershed scale, rather than the reach-by-reach and parameter-by-parameter approach. A watershed approach will more effectively address multiple impairments resulting from the cumulative effects of point and nonpoint sources of pollution, and further the CWA goal of protecting, restoring, and preserving the quality of Minnesota's water resources.

II. The Watershed Monitoring Approach

The watershed approach is a 10-year rotation for monitoring and assessing waters of the state on the level of Minnesota's 81 major watersheds (Figure 1). The primary feature of the watershed approach is that it provides a unifying focus on the water resources within a watershed as the starting point for water quality assessment, planning, implementation, and result measures. The major benefit of this approach is the integration of monitoring resources to provide a more complete and systematic assessment of water quality at a geographic scale useful for the development and implementation of effective TMDLs and protection strategies. The following paragraphs provide details on each of the four principal monitoring components of the watershed approach. For additional information see: *Watershed Approach to Condition Monitoring and Assessment* (MPCA 2008) (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

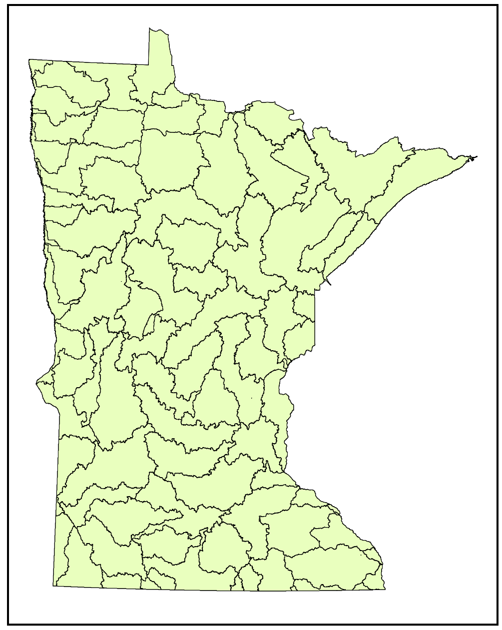

Figure 1. Major Watersheds within Minnesota (8-Digit HUC)

Watershed pollutant load monitoring network

Funded with appropriations from Minnesota's Clean Water Legacy Fund, the Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term program designed to measure and compare regional differences and long-term trends in water quality among Minnesota's major rivers including the Red, Rainy, St. Croix, Mississippi, and Minnesota, and the outlets of the major tributaries (8-digit HUC scale) draining to these rivers. Since the program's inception in 2007, the WPLMN has adopted a multi-agency monitoring design that combines site-specific stream flow data from United States Geological Survey (USGS) and Minnesota Department of Natural Resources (MDNR) flow gauging stations, with water quality data collected by the Metropolitan Council Environmental Services (MCES), local monitoring organizations, and MPCA WPLMN staff to compute annual pollutant loads at 79 river monitoring sites across Minnesota. The data from the network will also be used to assist with TMDL studies and implementation plans, watershed modeling efforts, and watershed research projects.

Intensive water quality sampling occurs year round at all WPLMN sites. Thirty-six to 55 mid-stream grab samples were collected at each site per year with a focus on periods of moderate to high flow (Figure 2). Because correlations between concentration and flow exist for many of the monitored analytes, and because these relationships can shift between storms or with season, computation of accurate load estimates requires frequent sampling of all major runoff events. Low flow periods are also sampled and are well represented, but sampling frequency tends to be less as concentrations are generally more stable when compared to periods of elevated flow. Despite discharge related differences in sample collection frequency, this staggered approach to sampling generally results in samples being well distributed over the entire range of flows.

Annual water quality and daily average discharge data are coupled in the "Flux32," pollutant load model, originally developed by Dr. Bill Walker and recently upgraded by the U.S. Army Corp of Engineers and the MPCA. Flux32 allows the user to create seasonal or discharge constrained concentration/flow regression equations to estimate pollutant concentrations and loads on days when samples were not collected. Primary outputs from the model include annual and daily pollutant loads and flow weighted mean concentrations (FWMCs) (pollutant load/total flow volume). Loads and FWMCs are calculated for total suspended solids (TSS), total phosphorus (TP), dissolved orthophosphate (DOP), nitrate plus nitrite nitrogen (nitrate-N) and total Kjeldahl nitrogen (TKN).

Intensive watershed monitoring-rivers and streams

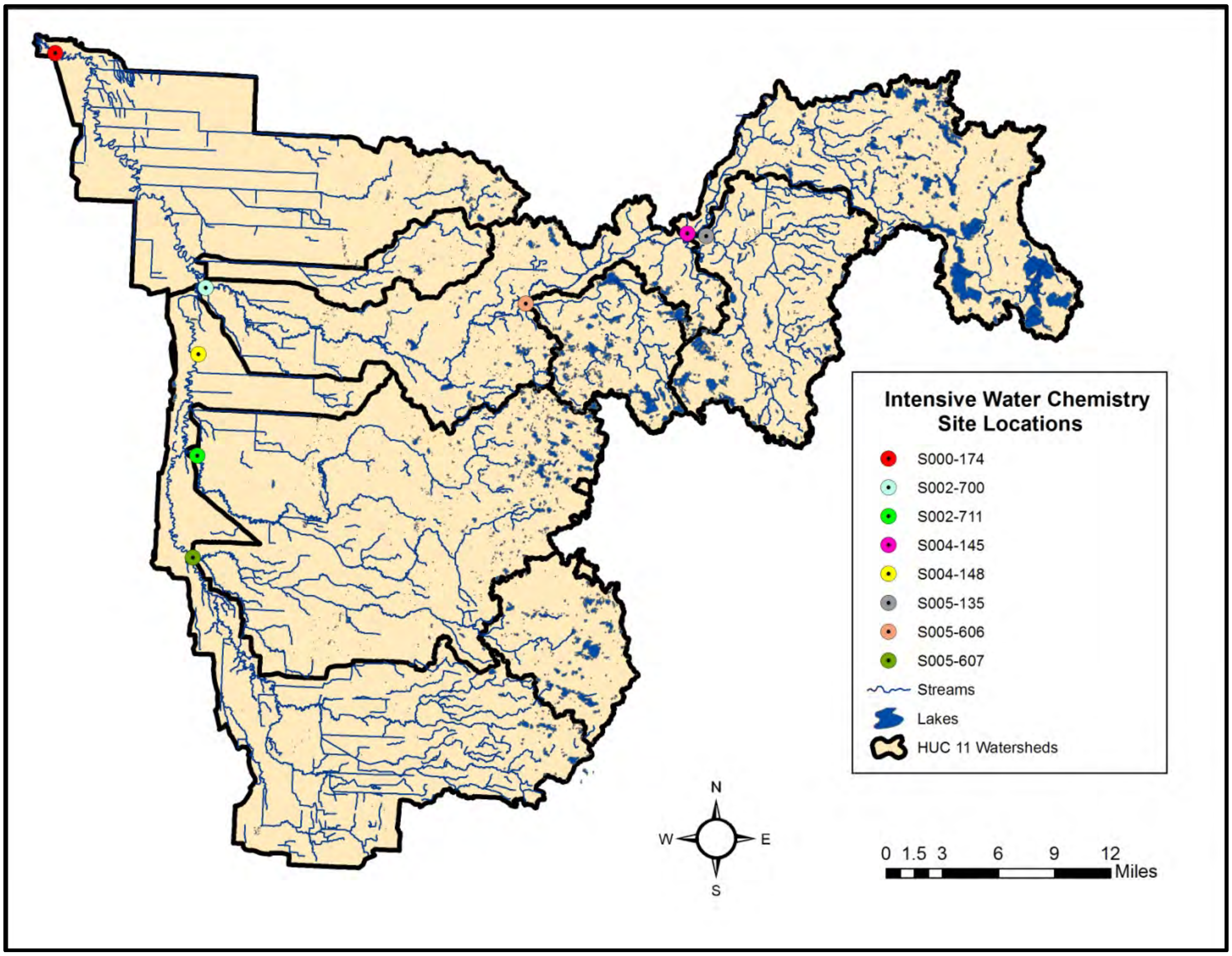

Figure 2. Intensive water chemistry site locations within the Buffalo River watershed

The intensive watershed monitoring strategy utilizes a nested watershed design allowing the aggregation of watersheds from a course to a fine scale. The foundation of this comprehensive approach is the 81 major watersheds within Minnesota (Figure 1). Streams are broken into segments by hydrologic unit codes (HUCs) to define separate waterbodies within a watershed. Sampling occurs in each major watershed once every 10 years. In this approach, intermediate-sized (approximately 11-digit HUC) and “minor” (14-digit HUC) watersheds are sampled along with the major watershed outlets to provide a complete assessment of water quality. River/stream sites are selected near the outlet at each watershed scale (8, 11, and 14 digit HUC). This approach provides a good coverage of rivers and streams without monitoring every single stream reach.

The outlet of the major watershed (red dot Figure 2) is sampled for biology, water chemistry, and fish contaminants to allow for the assessment of aquatic life, aquatic recreation, and aquatic consumption use support. Each HUC-11 outlet (all dots in Figure 2) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use support. Watersheds at this scale generally consist of major tributary streams with drainage areas ranging from 75 to 150 square miles. Lastly, most minor watersheds (typically 10-20 square miles) are sampled for biology (fish and macroinvertebrates) to assess aquatic life use support. Specific locations for sites sampled as part of the biological monitoring effort in the Buffalo River watershed can be found in Figure 3 (green dots).

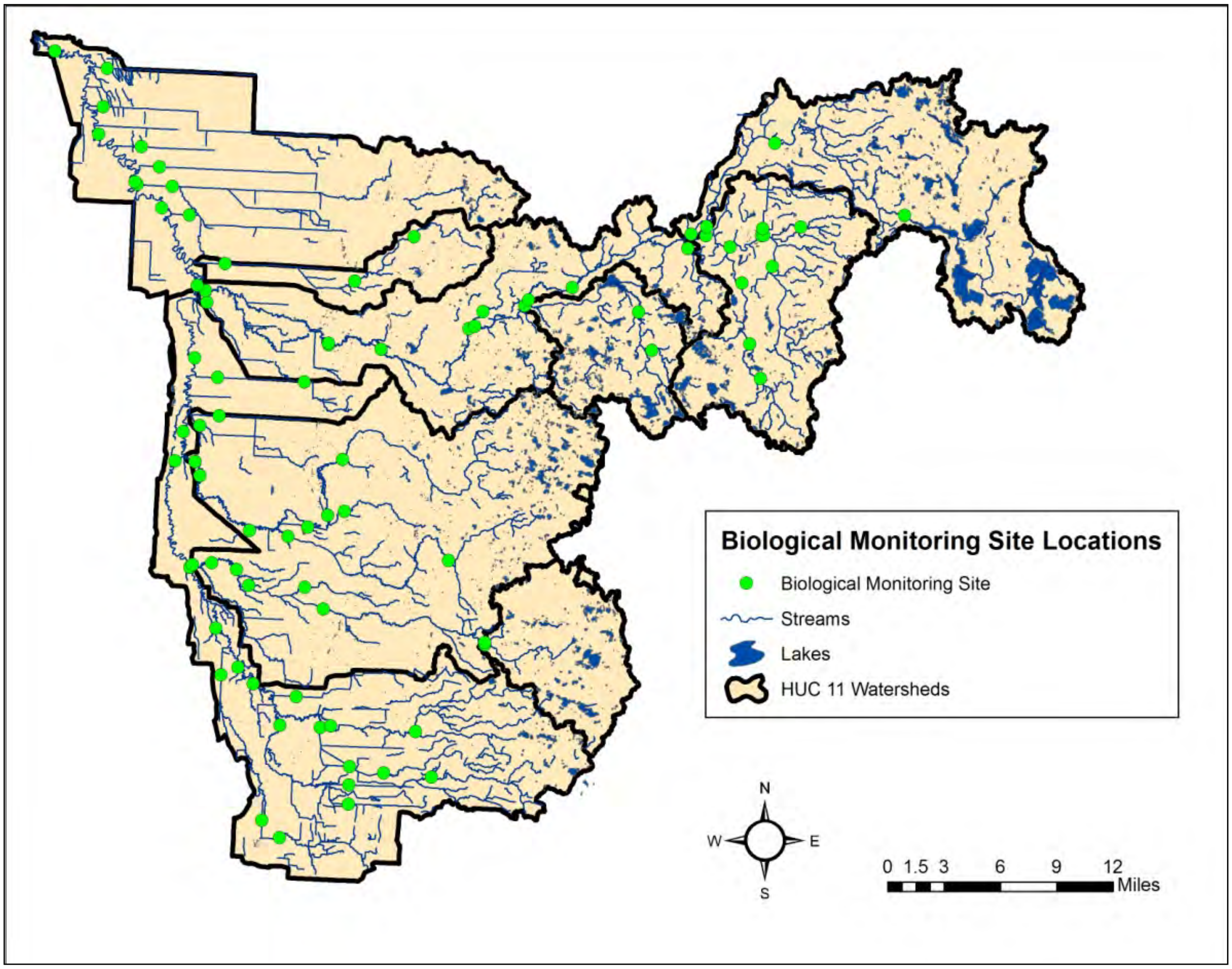

Figure 3. Biological monitoring site locations in the Buffalo River watershed

The second step of the intensive watershed monitoring effort consists of follow-up monitoring at areas determined to be impaired. This follow-up monitoring is designed to collect the information needed to identify the source(s) and cause(s) of impairment through the process of stressor identification.

Intensive watershed monitoring-lakes

The MPCA conducts and supports lake monitoring for a variety of objectives. Lake condition monitoring activities are focused on assessing the recreational use support of lakes and identifying trends over time. The MPCA also assesses lakes for aquatic consumption use support, based on fish-tissue and water-column concentrations of toxic pollutants. Lake monitoring was added to the watershed monitoring framework in 2009, so while there is some data available, not all of the lakes in the Buffalo River watershed currently have enough information for assessment.

Even when pooling MPCA and local resources, the MPCA is not able to monitor all lakes in Minnesota. The primary focus of MPCA monitoring is lakes $\geq$500 acres in size (“large lakes”). These resources typically have public access points, they generally provide the greatest aquatic recreational opportunity to Minnesota’s citizens, and these lakes collectively represent 72 percent of the total lake area (greater than 10 acres) within Minnesota. Though the primary focus is on monitoring and assessing larger lakes, the MPCA is also committed to directly monitoring, or supporting the monitoring of, the majority of lakes between 100-499 acres (“small lakes”) for assessment purposes.

Citizen and local monitoring

Citizen monitoring is an important component of the watershed monitoring approach. The MPCA coordinates two programs aimed at encouraging citizen surface water monitoring: the Citizen Lake Monitoring Program and the Citizen Stream Monitoring Program. Like the permanent load monitoring network, sustained citizen monitoring can provide the long-term picture needed to help evaluate current status and trends. The advance identification of lake and stream sites that will be sampled by agency staff provides an opportunity to actively recruit volunteers to monitor those sites, so that water quality data collected by volunteers are available for the years before and after the intensive monitoring effort by MPCA staff. This citizen-collected data helps agency staff interpret the results from the intensive monitoring effort, which only occurs one out of every 10 years. It also allows interested parties to track any water quality changes that occur in the years between the intensive monitoring events. Coordinating with volunteers to focus monitoring efforts where it will be most effective for planning and tracking purposes will help local citizens/governments see how their efforts are being used to inform water quality management decisions and affect change. Figure 4 provides an illustration of the locations where citizen monitoring data were used for assessment in the Buffalo River watershed.

The MPCA also passes through funding via Surface Water Assessment Grants (SWAGs) to local groups such as counties, soil and water conservation districts, watershed districts, nonprofits, and educational institutions to monitor lake and stream water quality. These local partners greatly expand our overall capacity to conduct sampling. Many SWAG grantees invite citizen participation in their monitoring projects.

The annual SWAG Request for Proposal (RFP) identifies the major watersheds that are scheduled for upcoming intensive monitoring activities. HUC-11 stream outlet chemistry sites and lakes less than 500 acres that need monitoring are identified in the RFP and local entities are invited to request funds to complete the sampling. SWAG grantees conduct detailed sampling efforts following the same established monitoring protocols and quality assurance procedures used by the MPCA. All of the lake and stream monitoring data from SWAG projects are combined with the MPCA’s monitoring data to assess the condition of Minnesota lakes and streams.

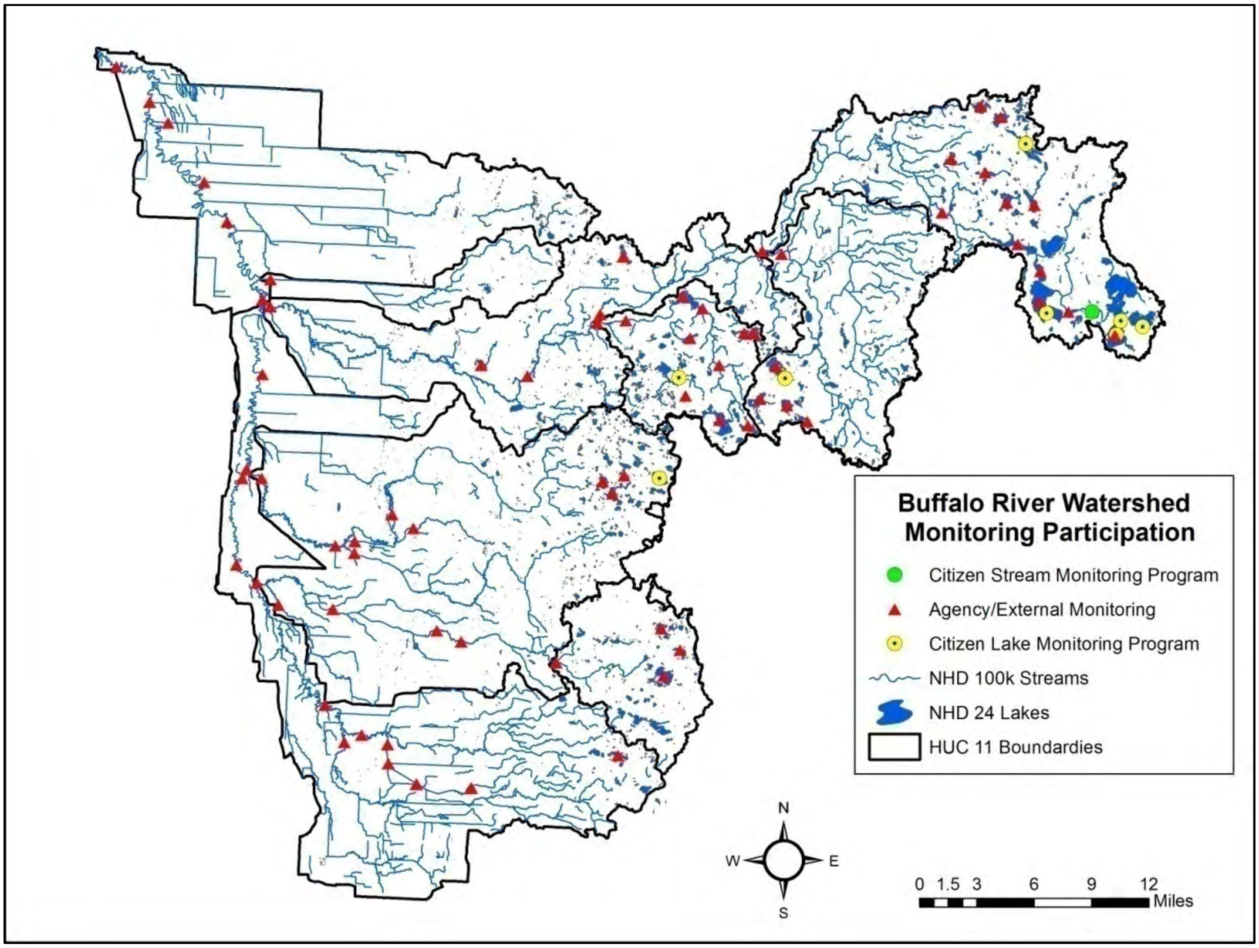

Figure 4. Monitoring locations of local groups, citizens, and the MPCA monitoring staff in the Buffalo River watershed

III. Assessment Methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters that are determined to be supporting or non-supporting of their designated uses. The assessment and listing process involves dozens of MPCA staff, other state agencies, and local partners. The goal of this effort is to use the best data and best science available to assess the condition of Minnesota's water resources. For a thorough review of the assessment methodology see: *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List* (MPCA 2012). http://www.pca.state.mn.us/index.php/view-document.html?gid=16988

Water quality standards

Water quality standards are the fundamental benchmarks by which the quality of surface waters are measured and used to determine impairment. Use attainment status describes whether or not a waterbody is supporting its designated use as evaluated by the comparison of monitoring data to criteria specified by *Minnesota Water Quality Standards* (Minn. R. ch. 7050 – 2008; https://www.revisor.leg.state.mn.us/rules/?id=7050). These standards can be numeric or narrative in nature and define the concentrations or conditions of surface waters that allow them to meet their designated beneficial uses, such as for fishing (aquatic life), swimming (aquatic recreation), or human consumption (aquatic consumption). All surface waters in Minnesota, including lakes, rivers, streams, and wetlands are protected for aquatic life and recreation where these uses are attainable. Protection of aquatic life means the maintenance of healthy, diverse, and successfully reproducing populations of aquatic organisms, including fish and invertebrates. Protection of recreation means the maintenance of conditions suitable for swimming and other forms of water recreation. Protection of consumption means protecting citizens who eat fish inhabiting Minnesota waters or receive their drinking water from waterbodies protected for this use.

Numeric water quality standards represent concentrations of specific pollutants in water that protect a specific designated use. Ideally, if the standard is not exceeded, the use will be protected. However, nature is very complex and variable; therefore, the MPCA uses a variety of tools to fully assess designated uses. Assessment methodologies often differ by parameter and designated use. Furthermore, pollutant concentrations may be expressed in different ways such as chronic value, maximum value, final acute value, magnitude, duration, and frequency. Narrative standards are statements of conditions in and on the water, such as biological condition, that protect their designated uses. Interpretations of narrative criteria for aquatic life support in streams are based on multi-metric biological indices including the Fish Index of Biological Integrity (F-IBI), which evaluates the health of the fish community, and the Macroinvertebrate Index of Biological Integrity (M-IBI), which evaluates the health of the aquatic invertebrate community. Biological monitoring is a direct means to assess aquatic life use support, as the aquatic community tends to integrate the effects of pollutants and stressors over time.

Assessment units

Assessments of use support in Minnesota are made for individual waterbodies. The waterbody unit used for river systems, lakes and wetlands is called the “assessment unit.” A stream or river assessment unit usually extends from one significant tributary stream to another or from the headwaters to the first tributary. A stream “reach” may be further divided into two or more assessment reaches when there is a change in use classification (as defined in Minn. R. ch. 7050) or when there is a significant morphological feature, such as a dam or lake, within the reach. Therefore, a stream or river is often segmented into multiple assessment units that are variable in length. The MPCA is using the 1:24,000 scale, high resolution National Hydrologic Dataset (NHD) to define and index stream, lake, and wetland assessment units. Each river or stream reach is identified by a unique waterbody identifier (known as its AUID), comprised of the USGS eight digit hydrologic unit code plus a three-character code that is unique within each HUC. Lake and wetland identifiers are assigned by the MDNR. The Protected Waters Inventory provides the identification numbers for lake, reservoirs, and wetlands. These identification numbers serve as the AUID and are composed of an eight-digit number indicating county, lake, and bay for each basin.

It is for these specific stream reaches or lakes that the data are evaluated for potential use impairment. Therefore, any assessment of use support would be limited to the individual assessment unit. The major exception to this is the listing of rivers for contaminants in fish tissue (aquatic consumption). Over the course of time it takes fish, particularly game fish, to grow to “catchable” size and accumulate unacceptable levels of pollutants, there is a good chance they have traveled a considerable distance. The impaired reach is defined by the location of significant barriers to fish movement such as dams upstream and downstream of the sampled reach and, thus, often includes several assessment units.

Determining use attainment status

Conceptually, the process for determining use attainment status of a waterbody is similar for each designated use: comparison of monitoring data to established water quality standards. However, the complexity of that process and the amount of information required to make accurate assessments varies between uses. In part, the level of complexity in the assessment process depends on the strength of the dose-response relationship; i.e., if chemical B exceeds water quality criterion X, how often is beneficial use Y truly not being attained. For beneficial uses related to human health, such as drinking water, the relationship is well understood and, thus, the assessment process is a relatively simple interpretation of numeric standards. In contrast, assessing whether a waterbody supports a healthy aquatic community is not as straightforward and often requires multiple lines of evidence to make use attainment decisions with a high degree of certainty. Incorporating a multiple lines of evidence approach into the MPCA's assessment process has been evolving over the past few years. The current process used to assess the aquatic life use of rivers and streams is outlined below and in Figure 5.

The first step in the aquatic life assessment process is a comparison of the monitoring data to water quality standards. This is largely an automated process performed by logic programmed into a database application, and the results are referred to as "pre-assessments." Pre-assessments are then reviewed by either a biologist or water quality professional, depending on whether the parameter is biological or chemical in nature. These reviews are conducted at the workstation of each reviewer (i.e., desktop) using computer applications to analyze the data for potential temporal or spatial trends, as well as gain a better understanding of any attenuating circumstances that should be considered (e.g., flow, time/date of data collection, habitat).

The next step in the process is a Comprehensive Watershed Assessment meeting where reviewers convene to discuss the results of their desktop assessments for each individual waterbody. Implementing a comprehensive approach to water quality assessment requires a means of organizing and evaluating information to formulate a conclusion utilizing multiple lines of evidence. Occasionally, the evidence stemming from individual parameters are not in agreement and would result in discrepant assessments if the parameters were evaluated independently. However, the overall assessment considers each piece of evidence to make a use attainment determination based on the preponderance of information available. See the Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA 2012) http://www.pca.state.mn.us/index.php/view-document.html?gid=16988 for guidelines and factors to consider when making such determinations.

Any new aquatic life use impairment determination (i.e., waterbody not attaining its beneficial use) is reviewed using GIS to determine if greater than 50 percent of the assessment unit is channelized. Currently, the MPCA is deferring any new impairments on channelized reaches until new aquatic life use standards have been developed as part of the tiered aquatic life use framework. For additional information, see: Tiered Aquatic Life Use (TALU) Framework (http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/the-tiered-aquatic-life-use-talu-framework.html). Since large portions of a watershed may be channelized, reaches with biological data are evaluated on a "good-fair-poor" system to help evaluate their condition (Appendix 10).

The last step in the assessment process is the Professional Judgement Group, or PJG meeting. At this meeting, results are shared and discussed with entities outside of the MPCA that may have been involved in data collection or that might have a vested interest in the outcomes of the assessment process. Information obtained during this meeting may be used to revise previous use attainment decisions. The result of this meeting is a compilation of the assessed waters that will be included in the watershed assessment report. Waterbodies that do not meet standards and, therefore, do not attain one or more of their designated uses, are considered impaired waters and are placed on the draft 303(d) Impaired Waters List.

Data management

It is MPCA policy to use all credible and relevant monitoring data to assess surface waters. The MPCA relies on data it collects along with data from other sources, such as sister agencies, local governments, and volunteers. The data must meet rigorous quality-assurance protocols before being used. All monitoring data required or paid for by the MPCA is entered into EQuIS (Environmental Quality Information System), MPCA's data system. The MPCA uploads the data from EQuIS to the U.S. Environmental Protection Agency's (EPA) STORET data warehouse. Water quality monitoring projects required to store data in EQuIS are those with federal or state funding under CWA Section 319, Clean Water Partnership, CWLA Surface Water Assessment Grants, and the TMDL program. Many local projects not funded by the MPCA choose to submit their data to the MPCA in EQuIS-ready format so that it may be utilized in the assessment process. Prior to each assessment cycle, the MPCA requests data from local entities and partner organizations using the most effective methods, including direct contacts and GovDelivery distribution lists.

Period of record

The MPCA uses data collected over the most recent 10-year period for all water quality assessments. Generally, the most recent data from the 10-year assessment period is reviewed first when assessing toxic pollutants, eutrophication, and fish contaminants. Also, the more recent data for all pollutant categories may be given more weight during the comprehensive watershed assessment or professional judgment group meetings. The goal is to use data from the 10-year period that best represents the current water quality conditions. Using data over a 10-year period provides a reasonable assurance that data will have been collected over a range of weather and flow conditions and that all seasons will be adequately represented; however, data for the entire period is not required to make an assessment.

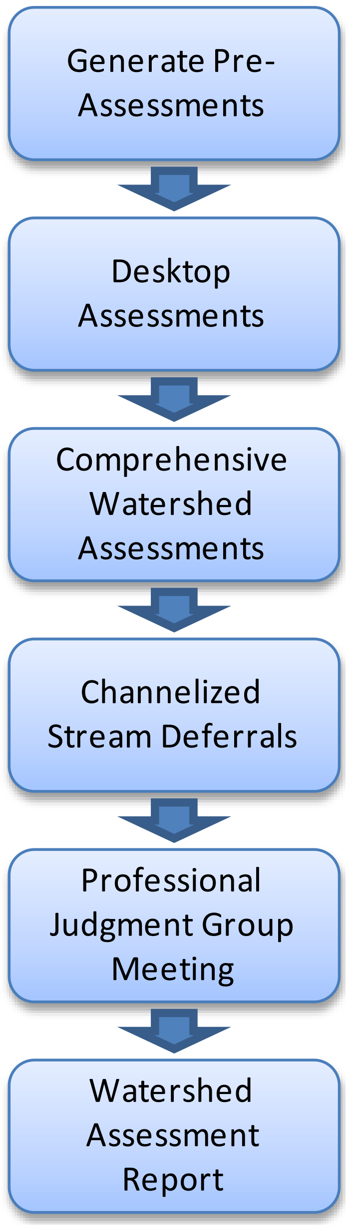

Figure 5. Flowchart of Aquatic Life Use Assessment Process

IV. Watershed Overview

Physical setting

From its source at Tamarac Lake, the Buffalo River flows 88 miles to its confluence with the Red River of the North one mile west of Georgetown. Beginning shortly downstream of the headwaters, a major transition occurs from hardwood forests with many wetlands and lakes to a prairie landscape with few wetlands and lakes. The Buffalo River watershed covers 1,108 square miles and 709,399 acres (MDNR 2003). The main portion of the Buffalo River watershed begins in eastern Becker County and encompasses portions of Clay, Otter Tail, and Wilkin Counties.

The Buffalo River has one major tributary along its course to the Red River of the North. The Buffalo River South Branch flows for 72 miles and drains 454 square miles (USGS 2011). It begins in Otter Tail County and connects with the main stem Buffalo River near Dilworth in Clay County. In addition, many smaller tributaries flow into the Buffalo River and Buffalo River, South Branch.

Land use summary

Land in the Buffalo River watershed is dominated by agriculture, comprising nearly 70 percent of the total watershed acres (MDNR 2003). Due to the high percentage of agriculture, flat topography, and poorly drained soils, the watershed is prone to severe flooding. As a result of the high percentage of agriculture and the potential for flooding, much of the landscape has been altered to aid in rapid water drainage from fields and increased agricultural production. The drainage of these lands has transformed nutrient and hydrologic dynamics, structure, function, quantity, and configuration of stream and wetland ecosystems (Blann 2009). In addition to drainage and tiling, other human activities, such as dam and road construction and converting land cover from native vegetation to cropland, have changed the landscape significantly.

The Buffalo River watershed lies within three of Minnesota’s ecoregions (Figure 6). The northeastern portion (headwaters) of the basin lies within the Northern Lakes and Forests (NLF) ecoregion. A short distance west of the headwaters, the watershed transitions to the North Central Hardwood Forest (NCHF) ecoregion. As both the northern and southern portions of the watershed proceed west there is a transition from the NCHF to the Lake Agassiz Plain (LAP) ecoregion (Natural Resources Conservation Service [NRCS] 2011).

Land cover in the watershed is distributed as follows: 65.8 percent cropland, 9.2 percent grassland, 9.5 percent forest/shrub, 6.7 percent wetland, 3.9 percent open water, and 4.8 percent residential (National Land Cover Database 2001) (Figure 7). Approximately 90 percent of the watershed’s acreage is privately owned. Farmland stretches over the countryside, comprising more than 75 percent of the watershed’s landscape. Sixty-two percent of agricultural producers in the Buffalo River watershed earn their living entirely off the land. Area farms range in size from the small family farm to operations exceeding 1,000 acres in size. Forty-two percent are less than 180 acres in size, 45 percent are between 180 and 1,000 acres, and 13 percent being over 1,000 acres, respectively (NRCS 2011).

Sixteen thousand eight hundred ninety six people reside within the Buffalo River watershed (NRCS 2011); equating to roughly 15 people per square mile. The largest population centers are located along the Highway 10 corridor (dividing the watershed in two from east to west), including Glyndon, Hawley, Lake Park, Audubon, and Barnesville, which is located along the I-94 corridor.

Vegetation: The NLF consists primarily of coniferous and northern hardwood forests, which includes tree species such as yellow birch, maples, oaks, and many pine species. The NCHF ecoregion is comprised of mixture of forests, wetlands, cropland, and grasslands (MDNR 2012). The forests consist mostly of sugar and red maples, yellow birch, aspen, spruce, hemlock, and white pine stands. A variety of wetland plant species occur, consisting mostly of rushes, cattails, and sedges (NRCS 2011). A majority of the LAP ecoregion (and portions of the NCHF ecoregion) is comprised of cropland and pasture. The cropland consists mostly of corn, soybeans, and small grains. When present, grasslands consist of bluegrass, Indian grass, and switch grasses, among other species.

Terrain: The NLF terrain consists of morainal hills, broad lacustrine basins, and sandy outwash plains with soil that is thick, lacks arability, and is considered to be nutrient poor. The NCHF is a transition between the NLF ecoregion and agricultural ecoregions where rolling hills, small plains, and lacustrine basins exist. The soil within the NCHF is considered well drained and moderate suitability for plant or crop growth. As the watershed transitions to the LAP ecoregion, land becomes flat and heavily cultivated. The soils are dominated by fine sediment and clay (NRCS 2011) with 66 percent being classified as "poorly drained" (Blann 2009).

Wildlife: Whitetail deer, pheasants, rabbits, squirrels, coyote, multiple hawk species, and a variety of waterfowl species are common wildlife in all three of the ecoregions. Common fish species include channel catfish, bullheads, common carp, freshwater drum, white sucker, northern pike, walleye, sauger and many minnow species (MDNR 2012).

Land use/human activities: Crop and dairy farming make up a majority of the land use in the watershed with state and federal lands comprising a small percentage as well. Big and small game, upland birds, and waterfowl hunting commonly take place within the watershed (NRCS 2011). Cities and towns within the Buffalo River watershed include: Barnesville, Hawley, Glyndon, Park City, Audubon, and Callaway (Figure 7). Some national, state, and provincial park and forest lands exist.

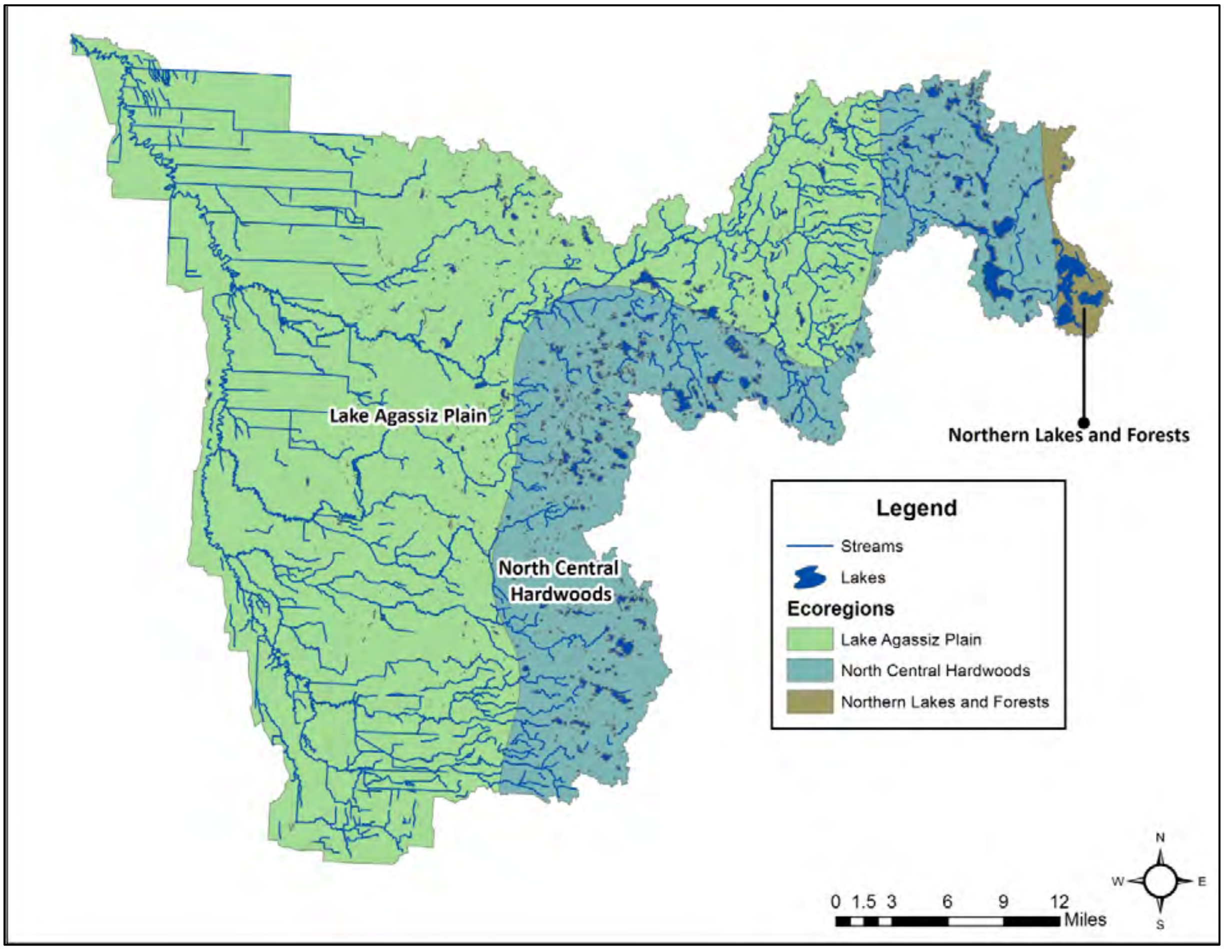

Figure 6. Ecoregions within the Buffalo River watershed

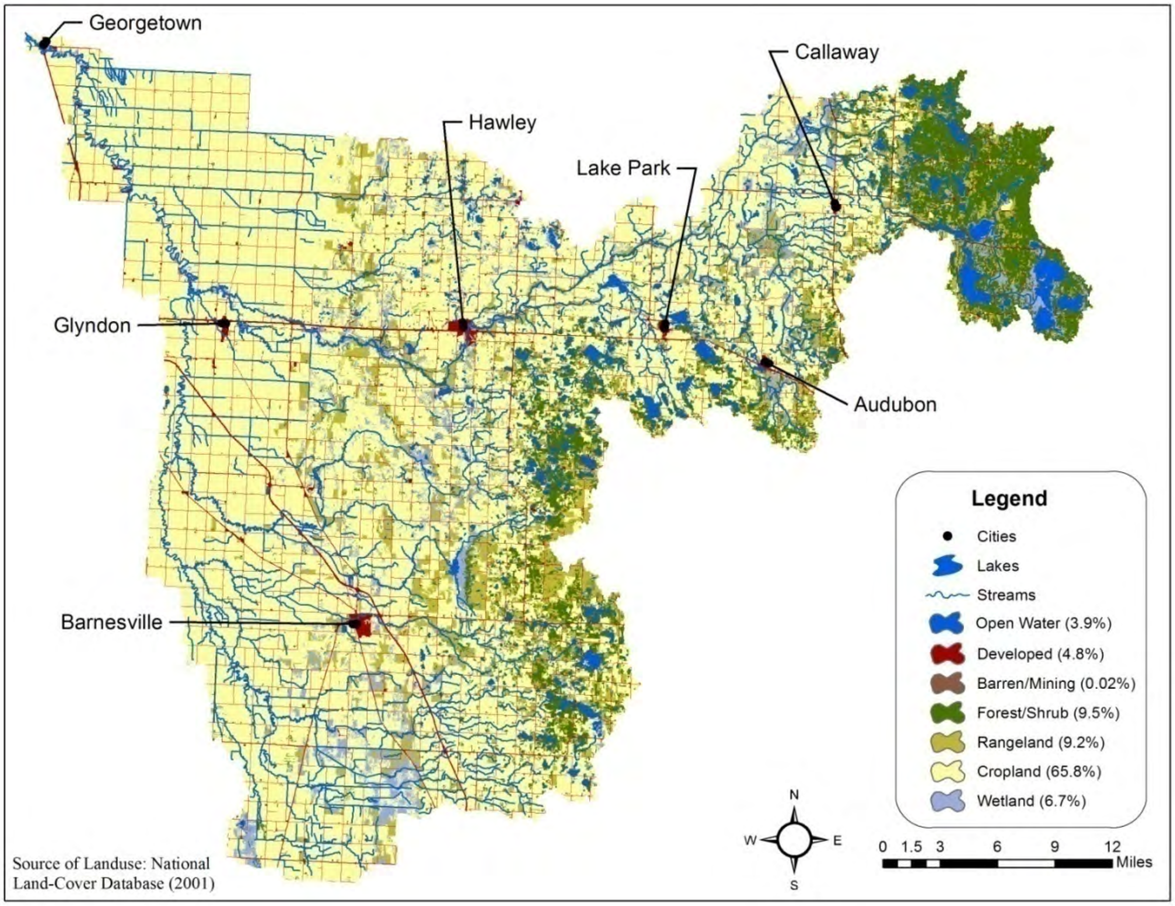

Figure 7. Land use in the Buffalo River watershed

Surface water hydrology

After originating at Tamarac Lake in Becker County, the Buffalo River continues its course flowing westerly across Clay County. In western Clay County, the Buffalo River mainstem merges with the South Branch Buffalo River, which originates in northwest Ottertail County and flows northwest through Wilkin County. After merging together, the Buffalo River mainstem meanders northwest before entering the Red River of the North one mile west of Georgetown.

The highest elevation of the Buffalo River watershed is 1,130 feet above sea level found in the northeastern portion of the watershed (NRCS 2011). Throughout its course, the river drops 635 feet, with an overall mean gradient of 7.0 feet per mile (Waters, 1977). The eastern portion of the watershed is lake-rich, with 162 lakes greater than 10 acres in size. There are few lakes in the western portion of the watershed. Some of the major lakes within the watershed include Tamarac, Buffalo, Big Sugar Bush, and Boyer Lakes. Several major tributaries feed into the Buffalo River mainstem including South Branch Buffalo River, Whiskey, Deerhorn, Stony, and Hay Creeks.

Streams within the Buffalo River watershed can be described as “flashy”, where multiple peaks occur during the year (in addition to peak spring flows) along with periods of very low discharge (MDNR 2003). Human activities such as dam and road construction, stream channelization, ditching, converting land cover from native vegetation to cropland, and draining and filling wetlands have changed the landscape and significantly altered the natural hydrology (MDNR 2003).

Climate and precipitation

The ecoregion has a continental climate, marked by warm summers and cold winters. The mean annual temperature is 5.3˚C; the mean summer temperature is 20.3˚C; and the mean winter temperature is -11.6˚ C. The frost-free period ranges from 111 to 136 days.

Precipitation in the watershed ranges from 21 to 25 inches each year (NRCS 2011) with evaporation estimates between 36 to 37 inches annually (Minnesota State Climatologists Office, 1999). Since much of the watershed lies in the Lake Agassiz Plain, it is prone to flooding (especially during spring snow melt). According to the MPCA, annual average flood damage (in 1996 dollars) in the watershed is estimated at $2,705,710 and is 99.5 percent rural damage. The Buffalo River watershed suffers, on average, 13.6 percent of the flood damage that occurs in the Red River Basin.

The October 2008 through September 2009 water year precipitation summary shows that conditions were normal to slightly more saturated than normal in the eastern portion of the watershed (Minnesota State Climatologists Office, 1999). In the western portions of the watershed, conditions were slightly to moderately more saturated than normal (Figure 8). This water year encompasses the time span in which the majority of the data used in this report was collected within the watershed.

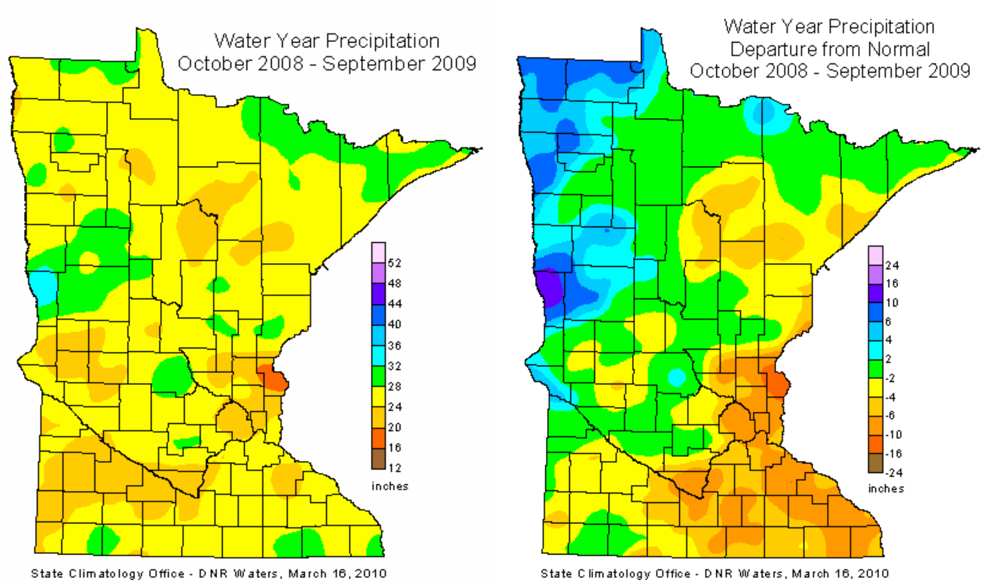

Figure 8. Statewide precipitation levels during the 2009 water year

V. Watershed Wide Data Collection Methodology

Pollutant load monitoring

The Buffalo River is monitored at MDNR gage #058033001 near Georgetown, approximately 10 miles upstream of the confluence with the Red River of the North. Annual FWMCs and pollutant loads were calculated and contrasted for years 2008 – 2010 (Figures 18-22).

To help put reported numbers into perspective, if a chronic water quality standard, draft standard, or surrogate standard exists for a pollutant, the value was inserted as a water quality threshold to provide a general guideline for relative water quality comparisons. It should be noted that while a FWMC exceeding given water quality standards is generally a good indication of non-compliance with the standard, the rule does not always hold true. Waters of the state are listed as impaired based on the percentage of individual samples exceeding a given standard, generally 10 percent and greater, over the most recent 10-year period (although data is not required for all 10 years to make an assessment) and not based on comparisons with FWMCs (MPCA 2009 – Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List). A river with an FWMC above a water quality standard, for example, would not be listed as impaired if less than 10 percent of the individual samples collected over the assessment period were below the standard.

Water quality sampling occurs year round at all WPLMP sites. Thirty to thirty-five mid-stream grab samples are collected per site per year, with sampling frequency greatest during periods of moderate to high flow. Frequent sampling during major runoff events is required to capture the largest pollutant loads and to accurately characterize shifting concentration/flow dynamics. Low flow periods are also sampled and are well represented, but sampling frequency tends to be less as concentrations are generally more stable when compared to other flow ranges. Despite discharge related differences in sample collection frequency, this staggered approach to sampling generally results in samples being well distributed over the entire range of flows.

Annual water quality and daily average discharge data are input into the “Flux32” pollutant load model to create concentration/flow regression equations. These derived equations are used to estimate pollutant concentrations and loads on days when samples are not collected. Primary outputs include: annual pollutant loads, defined as the amount (mass) of a pollutant passing a stream location over a defined period of time; and FWMCs, an estimate of the average concentration of a pollutant within the total volume of water that passed the monitoring site during the monitoring period. FWMCs are computed by dividing the pollutant load by the total seasonal flow volume. Annual pollutant loads are calculated for TSS, TP, DOP, TKN, and nitrate-N.

Stream water sampling

A total of eight water chemistry sites (Figure 2) were sampled in the summer of 2009 and 2010 throughout the Buffalo River watershed to provide data for water quality assessments. Monitoring took place cooperatively between staff from the Buffalo-Red River Watershed District, Red River Water Management Board, Barnesville River Watch citizen volunteers, and the MPCA. These water chemistry sites were located near the outlets of intermediate (HUC-11) watersheds, per the MPCA’s watershed monitoring approach.

The HUC-11 outlet water chemistry data are summarized in section six and include those parameters most closely related to the standards or expectations used for assessing aquatic life and aquatic recreational use support.

Stream biological sampling

A total of 71 biological sites (Figure 3) were established and sampled near the outlets of HUC-8, HUC-11, and most minor HUC-14 watersheds. In addition, the report included data from one site established in 1994 (revisited in 2009), thirteen sites established from 2005 to 2008 (five sites revisited in 2009), and two sites established and visited in 2010. The additional monitoring stations were initially established as part of statewide random stream surveys. While data from sites sampled within the last 10 years was used for assessment, the majority of data used for assessment was collected in 2009. A total of 41 AUIDs were sampled for biology in the Buffalo River watershed, of which 18 AUIDs had data sufficient for assessing aquatic life, and the remaining 23 AUIDs were not assessed due to channelization or insufficient information. In addition, 25 AUIDs were assessed for aquatic recreation, while the remaining 16 were not assessed due to channelization or insufficient data.

To measure the health of the biological communities at each assessable biological monitoring station, an Index of Biological Integrity (IBI) was used, specifically the Fish Index of Biological Integrity (F-IBI) and the Macroinvertebrate Index of Biological Integrity (M-IBI). Due to the natural variability in fish and macroinvertebrate community structures across the state, a classification framework was developed to partition this natural variability. For both the F-IBI and the M-IBI, Minnesota’s streams and rivers were divided into seven distinct classes, with each class having its own unique IBI. The classification factors used to produce the seven classes were drainage area size, gradient, and geographic region of the state. Fish and macroinvertebrate communities occurring at sites within each class are more similar to each other than those occurring in other classes. These classification factors are unaffected by human disturbance to ensure that the framework reflects natural variability and that the resulting IBIs reflect human-induced impacts to the waterbody. IBI development was stratified by class, with a unique suite of metrics, scoring functions, impairment thresholds, and confidence intervals identified for each. IBI scores higher than the upper confidence limit reflect good biological condition, while scores below the lower confidence limit reflect poor biological condition. When IBI scores fall within the confidence interval, interpretation and assessment of waterbody condition involves consideration of potential stressors, and draws upon additional information regarding water chemistry, physical habitat, land use activities, etc. For individual biological monitoring station IBI scores, thresholds, and confidence intervals, refer to Appendices 6 and 7.

Fish contaminants

Mercury and polychlorinated biphenyls (PCBs) were analyzed in fish tissue samples collected from the Buffalo River and two lakes in the watershed. Fish from the Buffalo River were collected in 2009 by the MPCA biological monitoring staff. The MDNR Fisheries staff collected fish from the lakes.

Captured fish were wrapped in aluminum foil and frozen until they were thawed, scaled (or skinned), filleted, and ground to a homogenized tissue sample. Homogenized fillets were placed in 125 milliliter (mL) glass jars with Teflon™ lids and frozen until thawed for laboratory analysis. The Minnesota Department of Agriculture laboratory performed all mercury and PCBs analyses of fish tissue.

The MPCA has included waters impaired for mercury in fish on the 303d Impaired Waters List since 1998. Impairment assessment for PCBs in fish tissue is based on the fish consumption advisories prepared by the Minnesota Department of Health. If the consumption advice is to restrict consumption of a particular fish species to less than a meal per week because of PCBs, the MPCA considers the lake or river impaired. The threshold concentration for impairment (consumption advice of one meal per month) is 0.22 milligrams/kilograms (mg/Kg) for PCBs.

Prior to 2006, mercury fish tissue concentrations were assessed for water quality impairment based on the Minnesota Department of Health's fish consumption advisory. Since 2006, a waterbody has been classified as impaired for mercury in fish tissue if 10 percent of the fish samples (measured as the 90^{th} percentile) exceeded 0.2 mg/Kg of mercury, which is one of Minnesota's water quality standards for mercury. At least five fish samples are required per species to make this assessment and only the last 10 years of data are used for statistical analysis. The MPCA's Impaired Waters Inventory includes waterways that were assessed as impaired prior to 2006 as well as more recently.

In the 1970s and 1980s, PCBs were the primary contaminant of concern in fish tissue. PCBs in fish have not been monitored as intensively as mercury in the last three decades. High concentrations of PCBs were only a concern downstream of large urban areas in large rivers, such as the Mississippi River, and in Lake Superior. Consequently, it was not necessary to continue widespread frequent monitoring of smaller river systems, as is done with mercury. Limited monitoring of PCBs has continued in watershed monitoring. The two largest fish of the fish species collected at the watershed outlets are analyzed for PCBs.

Lake water sampling

There are approximately 160 natural lakes greater than four hectares (10 acres) in the watershed, of which only 41 have assessment level data (summarized in section six). Most of the small lakes in the watershed have no public access and as a result, little or no historical water quality data collected. Two watersheds, County Ditch Two and the Lower Buffalo River, had no lakes with available chemistry data to review for assessments.

VI. Individual HUC-11 Watershed Results

Assessment results are presented for each of the HUC-11 watershed units within the Buffalo River Watershed. This is intended to enable the assessment of all surface waters at one time and the ability to develop comprehensive TMDL studies on a watershed basis, rather than the reach-by-reach and parameter-by-parameter. This scale provides a robust assessment of water quality condition in the HUC-11 watershed unit and is a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The primary objective is to portray all the impairments within a watershed resulting from the complex and multi-step assessment and listing process. The graphics presented for each of the HUC-11 watershed units contain the assessment results from the 2011 assessment cycle, as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2009 intensive watershed monitoring effort, but also considers available data from the last 10 years.

Given all the potential sources of data and differing assessment methodologies for indicators and designated uses, it is not currently feasible to provide results or summary tables for every monitoring station by parameter. However, in the proceeding pages, an individual account of each HUC-11 watershed is provided. Each account includes a brief description of the sub-watershed, a table summarizing stream aquatic life and aquatic recreation assessments, a table summarizing the biological condition of channelized streams and ditches, a stream habitat results table, a summary of water chemistry results for the HUC-11 outlet, a summary of lake aquatic recreation assessments, and a narrative summary of the assessment results for the sub-watershed. A brief description of each of these components is provided below.

Stream assessments

A table is provided in section six summarizing aquatic life and aquatic recreation assessments of all assessable stream reaches within the watershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2011 assessment process (2012 EPA reporting cycle); however, impairments from previous assessment cycles are also included and are distinguished from new impairments via cell shading (see footnote section of each table). These tables also denote the results of comparing each individual aquatic life and aquatic recreation indicator to their respective criteria (i.e., standards) and determinations made during the desktop phase of the assessment process. Assessment of aquatic life is derived from the analysis of biological (fish and invertebrate IBIs), dissolved oxygen, turbidity, chloride, pH and un-ionized ammonia (NH_3) data, while the assessment of aquatic recreation in streams is based solely on bacteria (*Escherichia coli*) data. Included in each table is the specific aquatic life use classification for each stream reach: cold water community (2A); cool or warm water community (2B); or indigenous aquatic community (2C). Stream reaches that do not have sufficient information for either an aquatic life or aquatic recreation assessment (from current or previous assessment cycles) are listed in a separate table and are also included in Appendix 5. Where applicable and sufficient data exists, assessments of other designated uses (e.g., drinking water and aquatic consumption) are discussed in the summary section of each HUC-11, as well as in the Watershed-Wide Results and Discussion section.

Stream habitat results

Habitat information documented during each fish sampling visit is provided in each HUC-11 section. These tables convey the results of the Minnesota Stream Habitat Assessment (MSHA) survey, which evaluates the section of stream sampled for biology and can provide an indication of potential stressors (e.g., siltation, eutrophication) impacting fish and macroinvertebrate communities. The MSHA score is comprised of five scoring categories including adjacent land use, riparian zone, substrate, fish cover, and channel morphology, which are summed for a total possible score of 100 points. Scores for each category, a summation of the total MSHA score, and a narrative habitat condition rating are provided in the tables for each biological monitoring station. Where multiple visits occur at the same station, the scores from each visit have been averaged. The final row in each table displays average MSHA scores and a rating for the HUC-11 watershed.

Channelized stream evaluations

Biological criteria have not been developed yet for channelized streams and ditches; therefore, assessment of fish and macroinvertebrate community data for aquatic life use support was not possible at some monitoring stations. A separate table provides a narrative rating of the condition of fish and macroinvertebrate communities at such stations based on IBI results. Evaluation criteria are based on aquatic life use assessment thresholds for each individual IBI class. IBI scores above this threshold are given a “good” rating, scores falling below this threshold by less than ~15 points (i.e., value varies slightly by IBI class) are given a “fair” rating, and scores falling below the threshold by more than ~15 points are given a “poor” rating. For more information regarding channelized stream evaluation criteria, refer to Appendix 10.

Watershed outlet water chemistry results

These summary tables display the water chemistry results for the monitoring station representing the outlet of the HUC-11 watershed. This data, along with other data collected within the 10-year assessment window, can provide valuable insight on water quality characteristics and potential parameters of concern within the watershed. Parameters included in these tables are those most closely related to the standards or expectations used for assessing aquatic life and recreation. While not all of the water chemistry parameters of interest have established water quality standards, McCollor and Heiskary (1993) developed ecoregion expectations for a number of parameters that provide a basis for evaluating stream water quality data and estimating attainable conditions for an ecoregion. For comparative purposes, water chemistry results for the Buffalo River watershed are compared to expectations developed by McCollor and Heiskary (1993) that were based on the 75th percentile of a long-term dataset of least impacted streams within each ecoregion.

Lake assessments

A summary of lake water quality is provided in the HUC-11 sections where available data exists. For lakes with sufficient data, basic modeling was completed; these results and the corresponding morphometric inputs to the model are available in Appendix 2.

Upper Buffalo River watershed unit HUC 09020106010

The Upper Buffalo River watershed unit, located in central Becker County, drains an area of 113.7 square miles. This watershed unit contains the headwaters of the Buffalo River, originating from Tamarac Lake. The Buffalo River flows in a westerly direction towards the town of Callaway where it turns and flows southwest to the Middle Buffalo River watershed unit. The watershed consists mostly of forests and cropland land cover, comprising 38 and 30 percent of the total land use within this watershed unit, respectively (Figure 9).

Stream assessments

Table 1. Aquatic life and recreation assessments on assessed AUIDs in the Upper Buffalo River HUC-11 watershed

AUID / ***Reach Name*** / *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Aquatic Life Indicators:** Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	**Aquatic Life**	**Aquatic Rec.**
09020106-593 / **Buffalo River** / *Buffalo Lake to Unnamed Ditch*	25.8	2B	09RD012 / 09RD024 / 09RD038	Upstream of 270th St, 5.5 mi. NE of Lake Park / Upstream of Somdahl Road, 4 mi. E of Callaway / Upstream of CR 159, 4.5 mi. NW of Callaway	EXP	EXP	IF	EXP	MTS	MTS	MTS	--	EX	NS	NS
09020106-594 / **Buffalo River** / *Unnamed Ditch to Hay Creek*	17.57	2B	09RD005	Upstream of County Hwy 9, 5 mi. NE of Lake Park	MTS	MTS	IF	EXS	MTS	MTS	MTS	--	EX	NS	NS

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

†Reach was assessed based on use class included in Table and existing use class as defined in Minn. R. ch. 7050 is different. MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Table 2. Minnesota Stream Habitat Assessment (MSHA) for the Upper Buffalo River HUC-11 watershed

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
2	09RD005	Buffalo River	0	4.75	19.25	11	22	57	Fair
2	09RD012	Buffalo River	0	6.5	16.1	7.5	9.5	39.6	Poor
1	09RD024	Buffalo River	2.5	10	17.75	17	28	75.25	Good
1	09RD038	Buffalo River	2.5	10	12	6	19	49.5	Fair
Average Habitat Results: *Upper Buffalo River HUC-11*			**1.25**	**7.81**	**16.28**	**10.38**	**19.63**	**55.34**	**Fair**

Qualitative habitat ratings:

Good: MSHA score above the median of the least-disturbed sites (≥66)

Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)

Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 3. Outlet water chemistry results for Upper Buffalo River HUC-11 watershed

Station Location	Buffalo River at County Highway 9, 5 miles northeast of Lake Park							
Storet ID	S004-145							
Station ID	09RD005							
Parameter	Units	# Samples	Minimum	Maximum	Mean	Median	WQ standard	# WQ exceedances[3]
Ammonia-nitrogen	mg/l	12	< 0.04	0.407	0.0775	< 0.04		
Chloride	mg/l	8	3.1	21.5	8.2	5.8	230	
Chlorophyll-a, corrected	ug/l	8	1	7	3.8	3.5		
Dissolved oxygen (DO)	mg/l	19	7.1	13.6	9.9	9.9	5	
Escherichia coli	MPN/100ml	12	88	> 2500	1160[1]	805	126	11[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	17	< 0.02	1.59	0.27	0.07		
Kjeldahl nitrogen	mg/l	11	0.76	1.86	0.98	0.88		
Orthophosphate	ug/l	10	22	77	42.2	38		
pH	--	19	7.8	8.8	8.2	8.2	6.5-9	
Pheophytin-a	ug/l	8	1	8	2.7	2		
Phosphorus	ug/l	17	48	254	102	88		
Specific conductance	uS/cm	19	438	753	577	583		
Temperature, water	deg C	19	5.5	23.4	16.1	17.6		
Total suspended solids	mg/l	17	7	118	36	21		
Total volatile solids	mg/l	10	< 1	17	5	4.5		
Transparency tube	cm	19	8.5	67	26.4	24.5		
Turbidity	FNU	19	6.6	69.2	22.5	13.7	25 NTU	5

1.Geometric mean of all samples is provided for *E. coli* or fecal coliform.
2.Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).
3.Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001

****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

mg/l = milligrams per liter
ug/l = micrograms per liter

Table 4. Lake Morphometric and assessment data for the Upper Buffalo River HUC-11 watershed

Lake Name	Lake ID	Lake Area (ha)	% Littoral	Max Depth (m)	Mean Depth (m)	Mean TP (ug/L)	Mean Chl-a (ug/L)	Secchi Mean (m)	Aquatic Recreation Use Support[4]
Pine	[1]03-0200-00	218.5	89.5	5.5	2.7	24	8	2.1	FS
South Tamarac	[1]03-0241-01	222.6	100	4.9	1.5	20	4	1.9	FS
North Tamarac	[1]03-0241-02	579.9	95.5	5.2	2.4	36	13	1.7	NS[5]
Rice	03-0291-00	90.8	72.9	7	2.3	28	7	2.2	FS
Rock	03-0293-00	485.7	95.5	5.5	2.4	27	7	1.8	FS
Little Round	[1]03-0302-00	219.9	100	1.7	0.8	25	3	0.8	FS
Big Sugar Bush	03-0304-00	177.4	63.1	12.8	3.4	13	3	5.6	FS
Little Sugar Bush	03-0313-00	85.7	49	8.8	3.9	22	11	3	FS
Buffalo	03-0350-00	180	51	11.2	4.4	23	9	3	FS
Island	03-0351-00	85.6	100	3	1.6	23	6	2.5	FS
Birch	03-0352-00	88.2	82.3	7.6	2	37	16	2.8	FS
O-Me-Mee	03-0428-00	54.9	100	3	1.5	68	21	1.7	IF
St. Clair	03-0430-00	43.1	88.6	5.8	1.4	24	8	3.1	FS
Mission	03-0471-00	98.6	100	2.4	1.6	120	76	0.6	NS

1. Mean depths estimated.
2. Watershed area estimated from MDNR lake catchment file
3. Due to available maps and sampling location, only the north basin was used to calculate mean depth and lake area for Lake Eleven.
4. NS = not supporting, FS = supporting, IF = insufficient information to determine support, NA = not assessed (too small or wetland-like)
5. Lake is not supporting aquatic recreation use due to natural conditions; no TMDL is required.

Summary

There is considerable variation in results of specific parameters across the upper Buffalo River watershed that in some cases appear to relate to the diversity of landscape and land use patterns within the watershed. The Upper Buffalo River watershed unit is located in the transition area between sloped landscapes with many lakes in the eastern portion to vast areas of cropland in the western section. Water quality data was available on two sections of the main stem Buffalo River, from the headwaters at North Tamarac Lake to Rock Lake. Upstream of Momb Lake, the river was meeting standards for bacteria and is supporting aquatic recreation use. No assessment of stream aquatic life could be made as the sampling locations were at lake outlets and not representative of stream conditions.

Fish and Macroinvertebrate IBI scores tended to contradict what would be expected based on land use patterns alone. Both F-IBI and M-IBI scores increased further downstream in the watershed. In fact, the lone station to meet both the F-IBI and M-IBI criteria was the outlet site (09RD005) located on the main stem of the Buffalo River (AUID 09020106-594). Overall habitat conditions as measured by the MSHA did not appear to explain the different pattern observed in the biology. Correspondence between F-IBI and M-IBI results and overall habitat score were generally weak. The highest overall habitat scores were found at the most upstream monitoring location and at the most downstream location, while F-IBI and M-IBI varied considerably at these sites (F-IBI range = 27-50, M-IBI range = 41-55). Habitat at the most downstream sites was typified by low land use and riparian cover scores, while high geomorphology and fish cover scores were more prevalent in the headwater reaches and reflected the better overall habitat conditions in the upstream portions of the watershed. Overall, the Upper Buffalo watershed unit received a fair rating for stream habitat.

Fourteen of the thirty-nine lakes greater than four hectares (10 acres) were reviewed for aquatic recreation use in the watershed (Table 4). The lakes are a mix of deep and shallow basins. Mission Lake is considered to be not supporting aquatic recreation use due to excess nutrients. North Tamarac, the headwaters of the Buffalo River (NRCS 2011), is also impaired for aquatic recreation use (excess nutrients), but an extensive review determined that the source of this impairment is natural (i.e., no TMDL will be required). Lake O-me-mee is right at the standards; more information will be necessary to determine if the lake is improving or declining and should be impaired. The remainder of the lakes meet aquatic recreation use standards. Most of these lakes are in a headwaters region with relatively intact watersheds. As forest is converted to cropland and developed land uses, increased runoff may cause nutrient levels in the lakes to rise. Shallow lakes have limited ability to assimilate nutrients; efforts to keep phosphorus out of the lakes will be necessary to preserve the high quality of the lakes in this watershed.

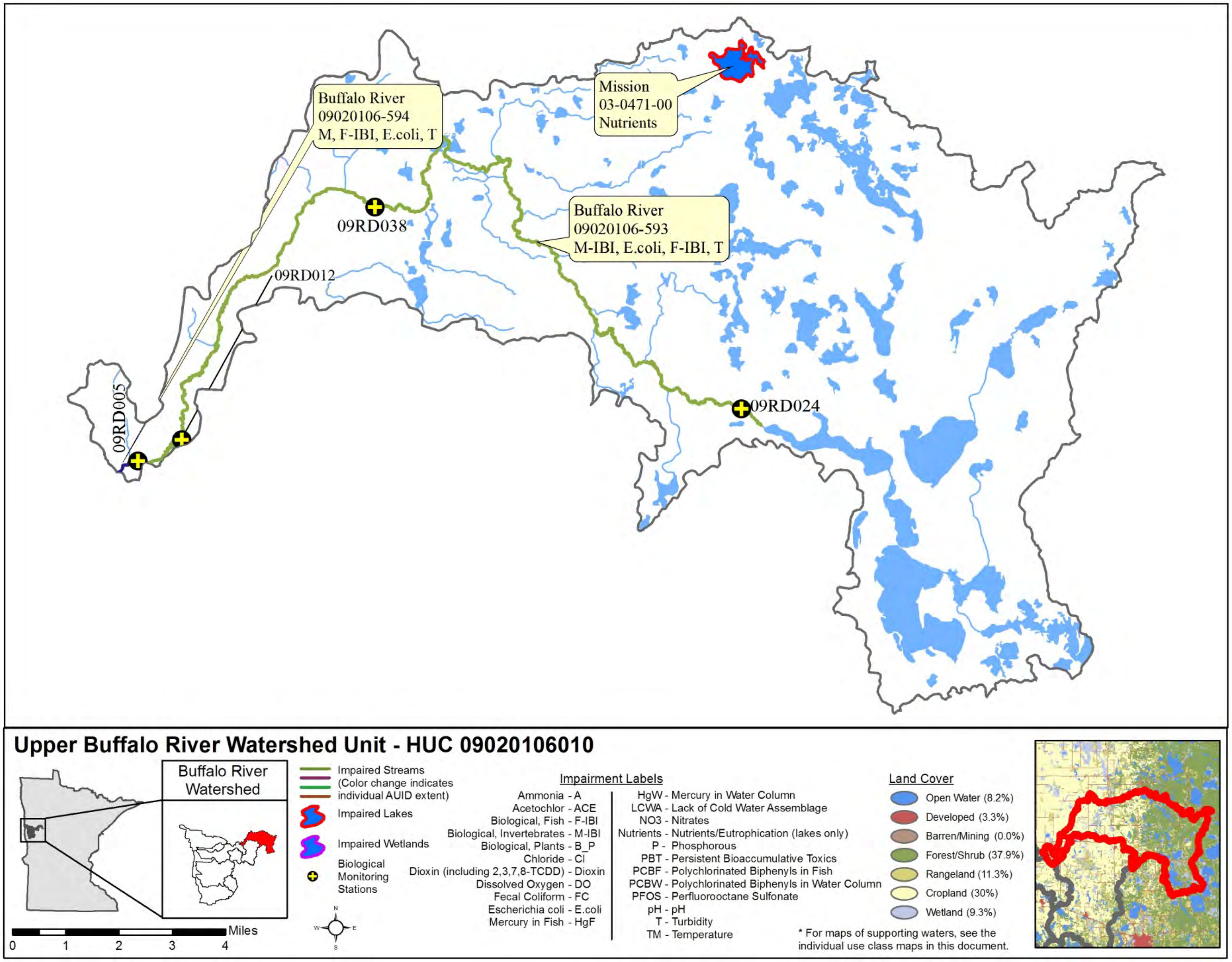

Figure 9. Currently listed impaired waters by parameter and land use in the Upper Buffalo River watershed unit

County Ditch #15 watershed unit HUC 09020106020

The County Ditch #15 watershed unit, located in west-central Becker County, encompasses an area of 94.9 square miles. The watershed unit drains to the 6.4-mile long County Ditch #15, which flows west to its confluence with the Buffalo River near County Road 9. The watershed consists predominantly of cropland and rangeland, comprising 56 and 15 percent of the watershed, respectively (Figure 10). The tributaries to the Buffalo River in this watershed unit include many unnamed ditches and creeks. The water chemistry monitoring for this watershed unit is the outlet station 09RD004 on County Ditch #15 downstream of 170th Avenue, five miles northeast of the town of Lake Park.

Stream assessments

Table 5. Aquatic life and recreation assessments on non-assessed channelized AUIDs in the County Ditch #15 HUC-11 watershed

AUID	Biological Station ID	Biological Station Location	F-IBI Quality	M-IBI Quality
09020106-514 **Unnamed Ditch** *Headwaters to Spring Lake*	09RD057	Upstream of 220th Ave, 2 mi. NE of Callaway	Fair	Not Sampled
09020106-515 **Unnamed Ditch (Becker County Ditch 15)** *Unnamed Ditch to Buffalo River*	05RD072	6 miles NE of Lake Park, MN; upstream of 260th street.	Fair (2)	Poor (2)
	07RD029	Downstream of CR 13, 6 mi. N of Audubon	Good (2)	Poor
	09RD004	Downstream of 170th Ave, 5 mi. NE of Lake Park	Good	Good (2)
	09RD026	Upstream of CR 13, 6.5 mi. N of Audubon	Fair	Fair
09020106-516 **Unnamed Ditch** *T139 R42W S9, south line to Reep Lake*	09RD058	Upstream of 210th St., 1 mi. NW of Audubon	Poor	Fair
09020106-518 **Unnamed Stream** *Reep Lake to Unnamed Ditch*	05RD045	~1 S of CR 12, 4.5 mi. NE of Lake Park	Good (2)	Poor (3)
09020106-527 **Unnamed Ditch** *Unnamed Ditch to T139 R42W S16, north line*	09RD059	Downstream of Cty Hwy 11, 1 mi S of Audubon	Good	Good
09020106-577 **Unnamed Ditch** *Unnamed Creek to Unnamed Ditch*	09RD027	Upstream of CR 13, 7 mi. N of Audubon	Fair	Not Sampled
09020106-578 **Unnamed Ditch** *Unnamed Creek to Unnamed Creek*	09RD025	Downstream of CR 12, 5 mi. N of Audubon	Poor	Poor

When multiple visits occurred, individual visit IBI scores were averaged to create a good/fair/poor rating. When applicable, the number in parenthesis indicates the number of visits to the individual site. See Appendix 10 for explanation of good/fair/poor ratings and individual site visit F-IBI and M-IBI scores.

Table 6. Minnesota Stream Habitat Assessment (MSHA) for the County Ditch #15 HUC-11 watershed

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
2	05RD045	Trib. to Buffalo River	0	5.25	15	8.5	9.5	38.25	Poor
2	05RD072	Unnamed Ditch	0	6.25	29.75	8.5	15.5	45.13	Fair
2	07RD029	Unnamed Ditch	5	12.5	9.98	9.5	15.5	52.48	Fair
1	09RD004	Trib. to Buffalo River	0	11.5	17.3	12	25	65.8	Fair
1	09RD025	Trib. to Unnamed Ditch	0	4.5	4	11	5	24.5	Poor
1	09RD026	Unnamed Ditch	5	9.5	12.25	7	8	41.75	Poor
1	09RD027	Trib. to Unnamed Ditch	2.5	8	4	12	10	36.5	Poor
1	09RD057	Unnamed Creek	0	9.5	12.35	7	17	45.85	Fair
1	09RD058	Unnamed Ditch	0	10	17.75	13	28	68.75	Good
1	09RD059	Unnamed Ditch	0	7	12.8	7	12	38.8	Poor
Average Habitat Results: *County Ditch #15 HUC-11*			**1.25**	**8.40**	**13.52**	**9.55**	**14.55**	**45.78**	**Fair**

Qualitative habitat ratings:

Good: MSHA score above the median of the least-disturbed sites (≥66)

Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)

Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 7. Outlet water chemistry results for County Ditch #15 HUC-11 watershed

Station Location	County Ditch #15 at 170th Ave, 5 miles northeast of Lake Park, MN							
Storet ID	S005-135							
Station ID	09RD004							
Parameter	Units	# Samples	Minimum	Maximum	Mean	Median	WQ standard	# WQ exceedances[3]
Ammonia-nitrogen	mg/l	12	< 0.04	0.147	0.06	0.04		
Chloride	mg/l	9	5.6	24.4	12.7	11.5	230	
Chlorophyll-a, corrected	ug/l	7	4	12	8	6		
Dissolved oxygen (DO)	mg/l	16	6.9	17.1	10.9	11.0	5	
Escherichia coli	MPN/100 ml	11	64.4	> 2500	526[1]	190	126	7[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	13	< 0.02	0.27	0.09	0.05		
Kjeldahl nitrogen	mg/l	11	0.921	1.89	1.37	1.3		
Orthophosphate	ug/l	5	41	138	76	69		
pH	--	16	7.8	8.8	8.2	8.1	6.5-9	
Pheophytin-a	ug/l	7	1	5	2.3	2		
Phosphorus	ug/l	13	73	298	147	106		
Specific conductance	uS/cm	16	534	1127	831	847		
Temperature, water	deg C	16	4.4	23.9	16.2	17.9		
Total suspended solids	mg/l	12	4	39	14	14		
Total volatile solids	mg/l	9	< 1	7	2.1	1		
Transparency tube	cm	16	19	80	50.2	50.3		
Turbidity	FNU	16	3.3	22.8	8.7	6.4	25 NTU	

1.Geometric mean of all samples is provided for *E. coli* or fecal coliform.
2.Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).
3.Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001
****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Table 8. Lake Morphometric and Assessment Data for the County Ditch #15 HUC-11 watershed

Lake Name	Lake ID	Lake Area (ha)	% Littoral	Max Depth (m)	Mean Depth (m)	Mean TP (ug/L)	Mean Chl-a (ug/L)	Secchi Mean (m)	Aquatic Recreation Use Support[4]
Canary	[1,2]03-0516-00	27.3	65	7.6	3.4			1.6	IF
Marshall	03-0526-00	75	66	6.1	3.2	42	21	1.9	NS
Gottenberg	[1]03-0528-00	46.7	100	3.4	1	68	34	0.8	NS
Boyer	03-0579-00	130.6	65.8	7.9	2.8	54	24	2.4	NS
Forget-Me-Not	03-0624-00	95.4	100	2.1	1.0	82	27	0.9	NS

1. Mean depths estimated.
2. Watershed area estimated from MDNR lake catchment file
3. Due to available maps and sampling location, only the north basin was used to calculate mean depth and lake area for Lake Eleven.
4. NS = not supporting, FS = supporting, IF = insufficient information to determine support, NA = not assessed (too small or wetland-like)
5. Lake is not supporting aquatic recreation use due to natural conditions; no TMDL is required.

Summary

The County Ditch #15 watershed unit is a largely human altered system comprised of nearly all channelized waterways and small unnamed streams. Of the seven AUIDs sampled within the watershed, only 09020106-515 was assessed for aquatic recreation. Water quality data was available on the six-mile reach immediately upstream of the Buffalo River. Bacteria levels exceeded the state standards and the reach is impaired for aquatic recreation use. Dissolved oxygen and turbidity data met standards and do not appear to be stressing aquatic life.

Fish IBI results were associated with better habitat conditions in at least one reach (09020106-515). Sites 09RD004 and 05RD029 had the highest Fish IBI and habitat scores in this reach. Other stream reaches and indicators within this watershed showed high variability depending upon site location with little relationship between habitat and IBI scores. Duplicate biological samples taken in 2005 and 2009 at two sites within the watershed indicated significant improvement at 05RD045; however, there was corresponding decline in IBI scores between 2005 and 2009 at 05RD072. Habitat did not fully explain the observed changes in biological condition as habitat improved at both sites from 2005 to 2009. Overall, the biological and habitat indicators suggest mostly poor and fair conditions as one might expect for a watershed that has undergone extensive stream modification.

Four of the twenty-eight lakes greater than four hectares (10 acres) in this watershed were assessed in the watershed (Table 8). Again, a mix of deep and shallow lakes dominates this area; however, these lakes have significantly more developed watersheds than upstream lakes. Marshall, Boyer, Gottenberg, and Forget-me-not are all exceeding aquatic recreation use eutrophication standards (excess nutrients). Reduction in overland runoff and management of internal loading of phosphorus in shallow lakes will need to be addressed to see water quality improvements in these basins.

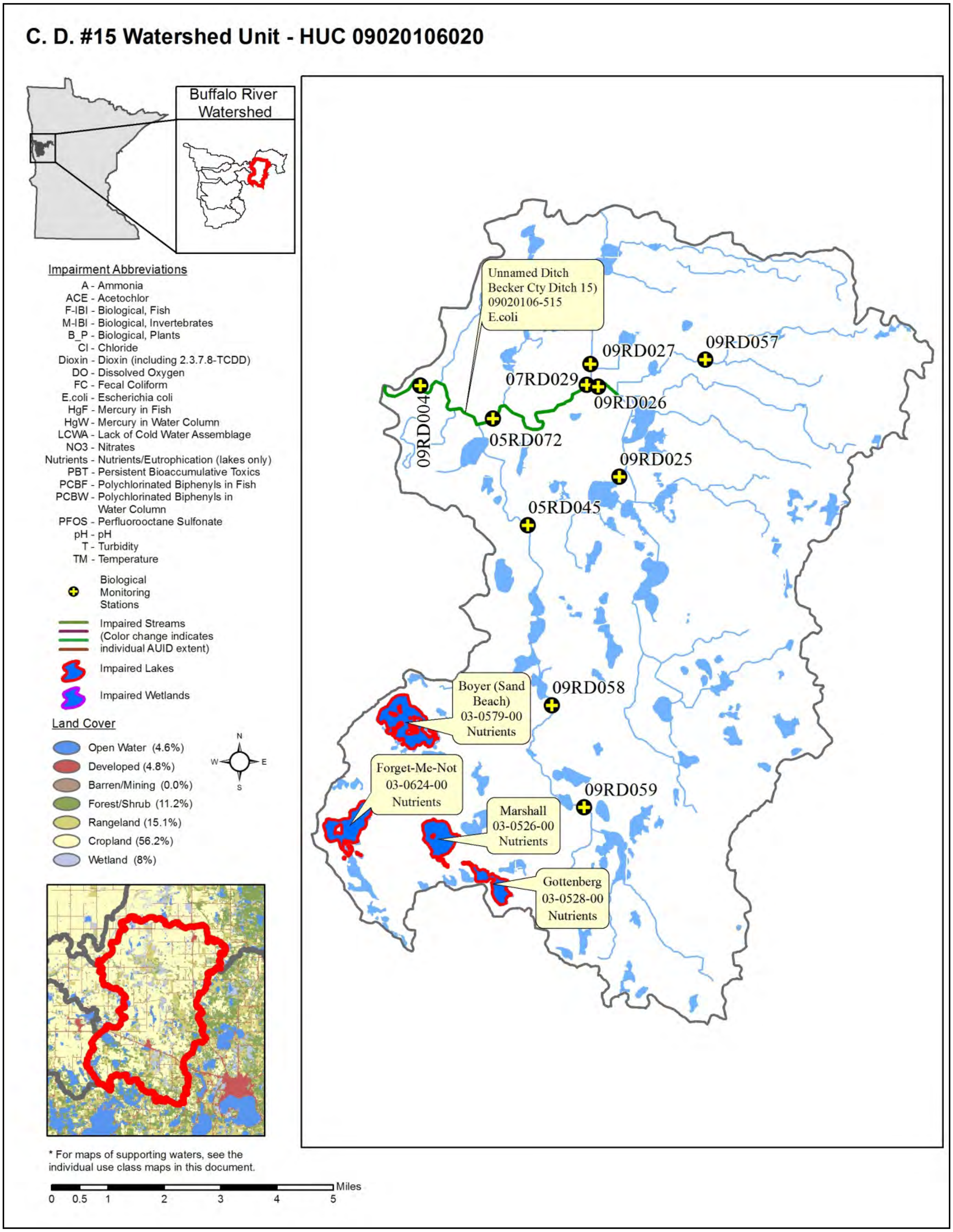

Figure 10. Currently listed impaired waters by parameter and land use in the County Ditch #15 watershed unit

Lake Park watershed unit HUC 09020106030

The Lake Park watershed unit encompasses 47.1 square miles and is located in western Becker and eastern Clay Counties. The watershed unit includes one significant tributary to the Buffalo River, Hay Creek, as well as many unnamed tributaries to Hay Creek. Hay Creek originates from Stakke Lake, near the town of Lake Park, and flows north through Stinking Lake and then flows west to its confluence with the Buffalo River near State Highway 32, northeast of Hawley. The watershed is mostly cropland landscape (59.4 percent), while forests and water comprise 12.7 and 11.6 percent of the remaining landscape, respectively (Figure 11). The water chemistry monitoring for this watershed unit is represented by the outlet station 09RD003 on Hay Creek at 265th Street North.

Stream assessments

Table 9. Aquatic life and recreation assessments on assessed AUIDs in the Lake Park HUC-11 watershed

AUID ***Reach Name*** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	**Aquatic Life Indicators:** Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	**Aquatic Life**	**Aquatic Rec.**
09020106-513 **Hay Creek** *Stinking Lake to Buffalo River*	5.35	2B	09RD003	Downstream of CR 115, 2.5 mi NE of Hawley	MTS	MTS	IF	MTS	MTS	MTS	MTS	--	--	FS	NA

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

†Reach was assessed based on use class included in Table and existing use class as defined in Minn. R. ch. 7050 is different. The MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Table 10. Aquatic life and recreation assessments on non-assessed channelized AUIDs in the Lake Park HUC-11 watershed

AUID	Biological Station ID	Biological Station Location	F-IBI Quality	M-IBI Quality
09020106-511 **Hay Creek** *Headwaters to Stinking Lake*	05RD071	Downstream of CR 102, 1 mi. NW of Lake Park	Poor (2)	Poor (2)
09020106-576 **Unnamed Creek** *Unnamed Creek to Hay Creek*	10EM069	Upstream of 140th Ave, 1 mi. S of Lake Park	Poor	Poor

When multiple visits occurred, individual visit IBI scores were averaged to create a good/fair/poor rating. When applicable, the number in parenthesis indicates the number of visits to the individual site. See Appendix 10 for explanation of good/fair/poor ratings and individual site visit F-IBI and M-IBI scores.

Table 11. Minnesota Stream Habitat Assessment (MSHA) for the Lake Park HUC-11

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	09RD003	Hay Creek	0	10	18.7	13	34	75.7	Good
2	05RD071	Hay Creek	0	10.25	14.6	8	12.5	45.35	Fair
1	10EM069	Unnamed trib. to Hay Creek	0	8	16.2	13	20	57.2	Fair
Average Habitat Results: *Lake-Park HUC-11*			**0.00**	**9.41**	**16.5**	**11.3**	**22.16**	**59.37**	**Fair**

Qualitative habitat ratings:

Good: MSHA score above the median of the least-disturbed sites (≥66)

Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)

Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 12. Outlet water chemistry results for the Lake Park HUC-11

Station Location	Hay Creek at 265th Street North, near Hawley, MN							
Storet ID	S005-606							
Station ID	09RD003							
Parameter	Units	# Samples	Minimum	Maximum	Mean	Median	WQ standard	# WQ exceedances[3]
Ammonia-nitrogen	mg/l	12	< 0.04	0.157	0.07	0.06		
Chloride	mg/l	6	8.3	18.3	13.5	13.6	230	
Chlorophyll-a, corrected	ug/l	8	1	18	6.6	5		
Dissolved oxygen (DO)	mg/l	23	4.3	12.5	8.7	8.4	5	1
Escherichia coli	MPN/100ml	14	26.2	1414	337[1]	210	126	10[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	12	< 0.02	0.28	0.1175	0.11		
Kjeldahl nitrogen	mg/l	11	0.812	2.72	1.26	1.02		
Orthophosphate	ug/l	5	53	101	88	96		
pH	--	23	7.7	8.3	8.1	8.1	6.5-9	
Pheophytin-a	ug/l	8	< 1	5	2.4	2		
Phosphorus	ug/l	12	106	437	175	151		
Specific conductance	uS/cm	23	377	822	612	629		
Temperature, water	deg C	23	7.94	24.65	17.6	17.6		
Total suspended solids	mg/l	15	3	38	17.1	15		
Total volatile solids	mg/l	11	< 1	22	6	5		
Transparency tube	cm	23	14	94	55	45		
Turbidity	FNU	22	1.8	22.3	9.8	8.4	25 NTU	

1Geometric mean of all samples is provided for *E. coli* or fecal coliform.
2Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).
3Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001
****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Table 13. Lake morphometric and assessment data for the Lake Park HUC-11 watershed

Lake Name	Lake ID	Lake Area (ha)	% Littoral	Max Depth (m)	Mean Depth (m)	Mean TP (ug/L)	Mean Chl-a (ug/L)	Secchi Mean (m)	Aquatic Recreation Use Support[4]
Sand	[1,2]03-0618-00	23.6	100	2.7	1.5	83	9	1.1	IF
Talac	[1]03-0619-00	39.7		4	2.8	93	29	1.9	NS
Sorenson	[1,2]03-0625-00	17.1	100	2.4	1.7	177	41	1.7	NS
Stakke	03-0631-00	194.5	99.3	4.6	2.1	65	30	1.5	NS
Gourd	03-0635-00	48.8	100	1.8	1.2	113	54	0.6	NS
West LaBelle	03-0645-00	40.9		5.8	1.3	89	41	1.3	NS
Lime	03-0646-00	43.4	100	2.4	1.4	138	63	0.9	NS
Stinking	03-0647-00	153.3	100	2.4	1.5	309	96	0.7	NS
East LaBelle	03-0648-00	77.8	53		3.2	38	15	2.2	IF
Sand	03-0659-00	81.4	52.3	8.5	4.3	125	28	2	NS

1. Mean depths estimated.
2. Watershed area estimated from MDNR lake catchment file
3. Due to available maps and sampling location, only the north basin was used to calculate mean depth and lake area for Lake Eleven.
4. NS = not supporting, FS = supporting, IF = insufficient information to determine support, NA = not assessed (too small or wetland-like)
5. Lake is not supporting aquatic recreation use due to natural conditions; no TMDL is required.

Summary

The Lake Park watershed unit consists of three AUIDs, of which only 09010206-513 was assessed for aquatic life due to the channelization of the remaining two. Within this watershed, a relationship between habitat and biological IBI scores exists. The most downstream site on Hay Creek (09RD003) received a good MSHA score and was also fully supporting aquatic life (Table 9). The remaining two sites both received fair MSHA scores and both received poor biological scores (Table 10). The MSHA scores increased dramatically (from 31 to 60) from 2005 to 2009 at 05RD071; however, the F-IBI scores showed no improvement.

Although a majority of the habitat scores were similar for all sites (Table 11), channel morphology at the outlet site (09RD003) was very good (34/36) and may explain why biological scores were found to be so high at this location. The meandering of this stream likely creates a variety of suitable habitat options for the biological communities that other streams lacking sinuosity do not offer. Although the overall MSHA score for this watershed was fair, the land use for each site received the lowest score, suggesting that maintenance of adequate riparian buffers around stream banks will be crucial to protecting stream resources.

Water quality data was available on two reaches of Hay Creek and one Hay Creek tributary. Upstream of Stinking Lake, Hay Creek exceeded the standard for bacteria and is considered impaired for aquatic recreation use. The same reach is considered impaired for aquatic life based on excess turbidity. Downstream of Stinking Lake to the Buffalo River, both dissolved oxygen and turbidity were identified as possible stressors to aquatic life.

Eight of the thirty-two lakes greater than four hectares (10 acres) were reviewed for aquatic recreation use in the watershed (Table 13). Of those, six were exceeding eutrophication standards and are listed as impaired for aquatic recreation use; East LaBelle is approaching the standard and a small increase in phosphorus would push the lake above the eutrophication standards. All of the lakes in this watershed are shallow except for Sand Lake (03-0659-00). Shallow lakes are particularly sensitive to watershed inputs of phosphorus; wind mixing paired with high temperatures allows sediment in the lake to release additional phosphorus (internal loading), which accelerates the increase in algae and decrease in transparency.

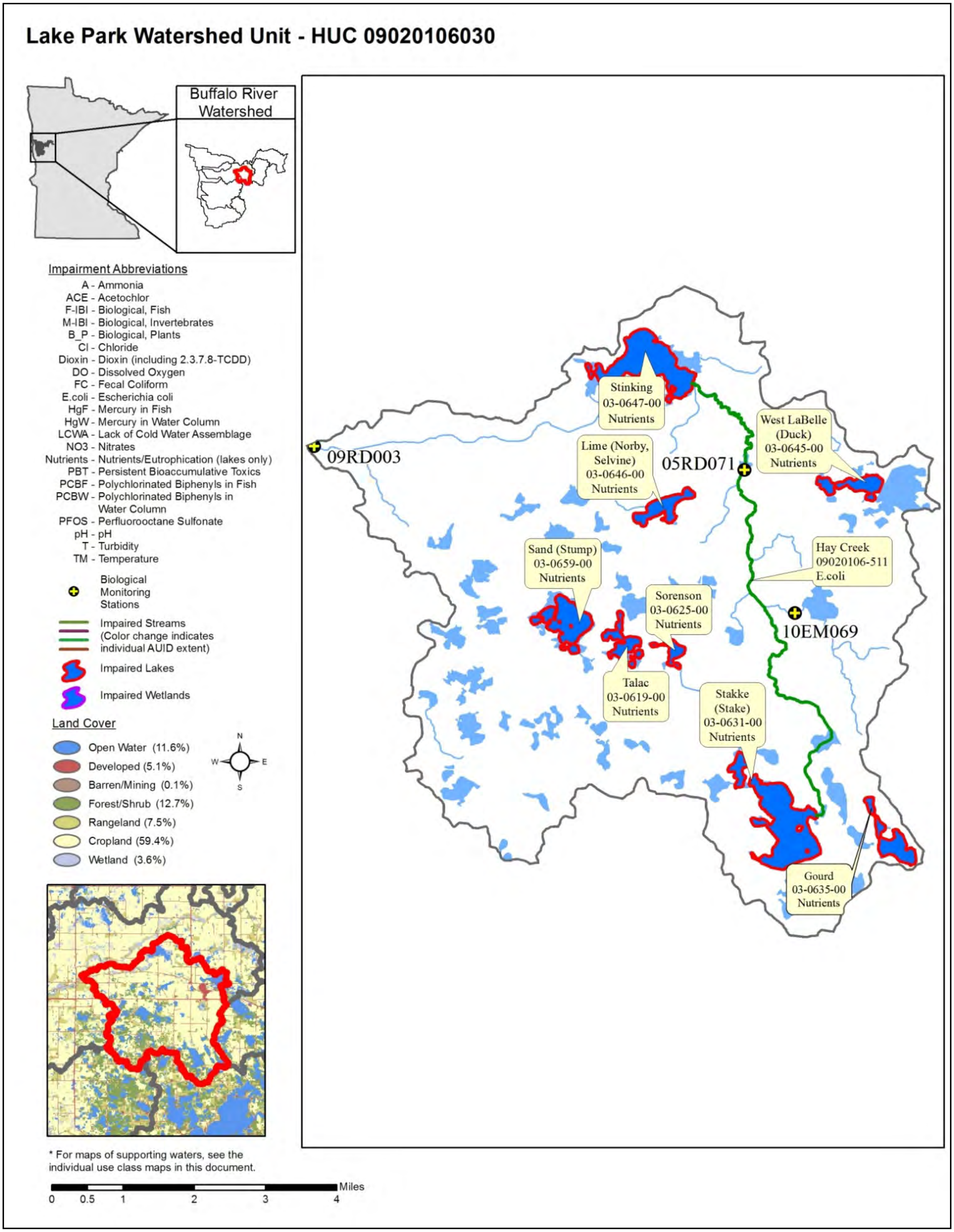

Figure 11. Currently listed impaired waters by parameter and land use in the Lake Park watershed unit

Middle Buffalo River watershed unit HUC 09020106040

The Middle Buffalo River watershed unit, immediately downstream of the Upper Buffalo River watershed unit, drains an area of 136 square miles and is located in western Becker and east-central Clay Counties. Within this watershed unit, the Buffalo River flows southwest through the town of Hawley, where it turns and begins to flow northwest. The Buffalo River, along with its tributaries, flow through a watershed that is dominated (70 percent) by cropland (Figure 12). The tributaries to the Buffalo River in this watershed unit include County Ditch 16 and many unnamed ditches and creeks. The water chemistry monitoring for this watershed unit is represented by the outlet station 09RD002 on the Buffalo River, upstream of County Highway 9, five miles northeast of Lake Park.

Stream assessments

Table 14. Aquatic life and recreation assessments on assessed AUIDs in the Middle Buffalo River HUC-11 watershed

					Aquatic Life Indicators:										
AUID ***Reach Name*** *Reach Description*	**Reach Length (miles)**	**Use Class**	**Biological Station ID**	**Location of Biological Station**	Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	**Aquatic Life**	**Aquatic Rec.**
09020106-594 **Buffalo River** *Unnamed Ditch to Hay Creek*	17.57	2B	05RD116 09RD039	1.5 mi. S of CR 24, ~ 6 mi. NE of Hawley Downstream of 28th Ave N, 5.5 mi. NE of Hawley	MTS	MTS	IF	EXS	MTS	MTS	MTS	--	EX	NS	NS
09020106-595 **Buffalo River** *Hay Creek to S Br Buffalo River*	38.4	2B	05RD110 09RD002 09RD040 09RD042	In Hawley just upstream of the Hwy 10 Bridge Upstream of CR 68, 2 mi. NW of Glyndon Downstream of 240th St N, 0.5 mi E of Hawley Downstream of Cty Hwy 23, 4.5 mi. SW of Hawley	MTS	MTS	IF	EXS	MTS	MTS	MTS	--	EX	NS	NS

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

†Reach was assessed based on use class included in Table and existing use class as defined in Minn. R. ch. 7050 is different. The MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Table 15. Aquatic life and recreation assessments on non-assessed channelized AUIDs in the Middle Buffalo River HUC-11 watershed

AUID	Biological Station ID	Biological Station Location	F-IBI Quality	M-IBI Quality
09020106-580 **Unnamed Creek** *Unnamed Creek to Buffalo Creek*	09RD013	Off of County Hwy 9, 4 mi. NE of Lake Park	Poor	Poor
09020106-581 **County Ditch 16** *Unnamed Creek to Buffalo Creek*	09RD028	Upstream of CR 115, 1 mi. NE of Hawley	Poor	Fair
09020106-582 **Unnamed Creek** *Unnamed Ditch to Buffalo Creek*	09RD017	Upstream of CR 84, 1.5 mi. NW of Glyndon	Poor	Poor

When multiple visits occurred, individual visit IBI scores were averaged to create a good/fair/poor rating. When applicable, the number in parenthesis indicates the number of visits to the individual site. See Appendix 10 for explanation of good/fair/poor ratings and individual site visit F-IBI and M-IBI scores.

Table 16. Minnesota Stream Habitat Assessment (MSHA) for the Middle Buffalo River HUC-11 watershed

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	05RD110	Buffalo River	2	6	18	9	15	50	Fair
1	05RD116	Buffalo River	5	9	14	6	7	41	Poor
1	09RD002	Buffalo River	0	9	9	6	18	42	Poor
1	09RD013	Trib. to Buffalo River	0	1	18.2	12	17	48.2	Fair
1	09RD017	Trib. to Buffalo River	0	7	7	0	15	29	Poor
1	09RD028	Trib. to Buffalo River	0	9.5	12.3	14	15	50.8	Fair
2	09RD039	Buffalo River	0	8.5	13.55	9	19	50.05	Fair
1	09RD040	Buffalo River	0.5	8.5	21.25	13	28	71.25	Good
1	09RD042	Buffalo River	3.75	7	21.5	12	22	66.25	Good
Average Habitat Results: *Middle Buffalo River HUC-11*			**1.25**	**7.28**	**14.98**	**9.00**	**17.33**	**49.84**	**Fair**

Qualitative habitat ratings:
Good: MSHA score above the median of the least-disturbed sites (≥66)
Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)
Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 17. Outlet water chemistry results for the Middle Buffalo HUC-11

Station Location	Buffalo River at County Road 68, 2 miles northwest of Glyndon							
Storet ID	S002-700							
Station ID	09RD002							
Parameter	Units	# Samples	Minimum	Maximum	Mean	Median	WQ standard	# WQ exceedances[3]
Ammonia-nitrogen	mg/l	11	< 0.04	0.062	0.044	> 0.04		
Chloride	mg/l	7	8.2	13.9	10.9	10.2	230	
Chlorophyll-a, corrected	ug/l	7	1	8	4.1	4		
Dissolved oxygen (DO)	mg/l	30	6.85	12	9.2	8.8	5	
Escherichia coli	MPN/100ml	21	35	1553	347[1]	236	126	17[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	21	< 0.02	2.21	0.22	0.07		
Kjeldahl nitrogen	mg/l	11	< 0.5	1.34	0.83	0.84		
Orthophosphate	ug/l	14	29	174	74.6	57		
pH	--	30	8.06	8.5	8.3	8.4	6.5-9	
Pheophytin-a	ug/l	7	< 1	5	3.1	3		
Phosphorus	ug/l	22	56	393	149	112		
Specific conductance	uS/cm	30	509	950	657	654		
Temperature, water	deg C	30	7.4	24.1	16.7	17.2		
Total suspended solids	mg/l	22	10	200	61.5	64.5		
Total volatile solids	mg/l	11	< 1	13	5.9	7		
Transparency tube	cm	30	8	74	28	22		
Turbidity	FNU	29	5.5	80.6	26.1	22.6	25 NTU	12

1Geometric mean of all samples is provided for *E. coli* or fecal coliform.
2Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).
3Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001
****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Figure 18. Lake morphometric and assessment data for the Middle Buffalo River HUC-11 watershed

Lake Name	Lake ID	Lake Area (ha)	% Littoral	Max Depth (m)	Mean Depth (m)	Mean TP (ug/L)	Mean Chl-a (ug/L)	Secchi Mean (m)	Aquatic Recreation Use Support[4]
Lee	14-0049-00	55.4	64.2	11	4.2	43	18	1.1	NS
Swede Grove	[1]14-0078-00	63	100	2.4	1.2	77	30	1.6	NS
Maria	[1]14-0099-00	43.6	100	2.7	1.4	199	56	1.1	NS
Silver	14-0100-00	46.5	31.6	11.9	6.8	50	17	1.8	IF

1. Mean depths estimated.
2. Watershed area estimated from MDNR lake catchment file
3. Due to available maps and sampling location, only the north basin was used to calculate mean depth and lake area for Lake Eleven.
4. NS = not supporting, FS = supporting, IF = insufficient information to determine support, NA = not assessed (too small or wetland-like)
5. Lake is not supporting aquatic recreation use due to natural conditions; no TMDL is required.

Summary

The Middle Buffalo River watershed unit has two assessable AUIDs. The biological indicators meet standards, the chemical impairments for turbidity and bacteria result in non-supporting aquatic life and recreation uses (Table 14). In general, biological condition in this watershed tended to increase with drainage area and was not strongly correlated with habitat. Biological conditions in the small tributary streams were very poor. No F-IBI score in a tributary stream scored above 22 IBI points. Conversely, IBI scores at the outlet site (09RD002) were excellent for both fish and invertebrates even though habitat was rated as poor. Habitat was generally best in the middle section of the Buffalo River in the vicinity of Hawley and tended to become worse both upstream and downstream of this reach. 09RD040 had the highest habitat score in the middle reach of the Buffalo (MSHA = 71); however, the biology, while still supporting, was not exceptional.

The two sites on the mainstem with the highest MSHA scores were found to have better in-stream habitat than other sites, receiving higher scores for substrate, fish cover, and channel morphology (Table 16). With such high scores for in-stream habitat, the biological communities should be more diverse and abundant, suggesting that factors other than habitat are impacting these reaches and are leading to biological conditions. The chemical data indicates impairment for aquatic recreation (excess bacteria) and aquatic life (excess turbidity) throughout the assessed reaches (Table 14). Overall, a majority of the remaining sites received very low scores for land use and channel morphology, leading to an overall MSHA score of fair for this watershed unit.

Four of the sixteen lakes greater than four hectares (10 acres) were reviewed for aquatic recreation use. Silver Lake exceeds only the phosphorus criteria; since the lake is not responding negatively to this increase (decreased transparency, increased algal blooms), the lake has not been listed as impaired. The remaining three lakes, Maria, Swede Grove, and Lee all exceed the eutrophication standards and are impaired for aquatic recreation use (Table 18). Maria and Swede Grove are shallow lakes that will need attention to internal loading in addition to reductions in nutrient runoff in the watershed. Lee Lake is seeing increased development pressure and is close to the standards; the lake should be protected from further increases in phosphorus laden runoff.

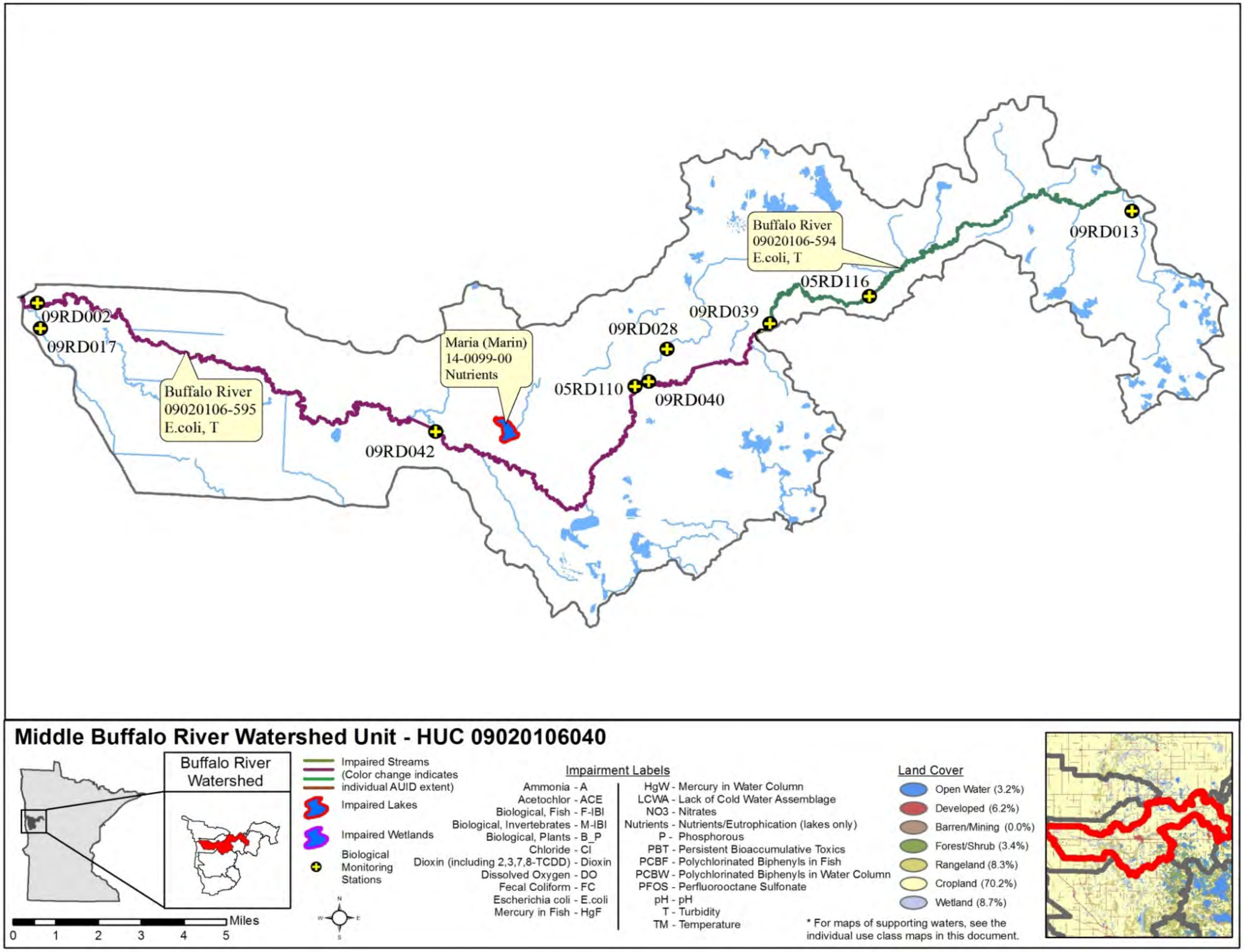

Figure 12. Currently listed impaired waters by parameter and land use in the Middle Buffalo River watershed unit

Deerhorn-Buffalo watershed unit HUC 09020106050

The Deerhorn-Buffalo watershed unit is located in northwestern Otter Tail, northeastern Wilkin, and south-central Clay Counties and encompasses an area of 222.6 square miles. The Buffalo River, South Branch is the major waterway within the watershed and originates in northwest Ottertail County, approximately three miles northeast of Rothsay. The river flows in a northwest direction through a cropland dominated landscape, making up nearly 78 percent of the watershed (Figure 13). Tributaries to the Buffalo River, South Branch include State Ditches 12, 14, and 15, Judicial Ditches 3-1 and 3-2, Deerhorn Creek, and many unnamed ditches and creeks. The water chemistry monitoring for this watershed unit is represented by the outlet station 09RD006 on the Buffalo River, South Branch at County Road 79, 1.5 miles southwest of Glyndon.

Table 19. Aquatic life and recreation assessments on assessed AUIDs in the Deerhorn-Buffalo HUC-11 watershed

AUID *Reach Name* Reach Description	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
09020106-503 **Buffalo River, South Branch** *Stony Creek to Buffalo River*	17.43	2B	08RD081 09RD006	Downstream of CR 69, 1 mi. NE of Sabin Upstream of CR 79, 1.5 mi. SW of Glyndon	MTS	MTS	EXP	EXP	MTS	MTS	MTS	--	EX	NS	NS
09020106-504 **Buffalo River, South Branch** *Whisky Creek to Stony Creek*	11.26	2B	09RD019	Upstream of CR 63, 1.5 mi. SE of Sabin	NA	NA	IF	EXP	MTS	MTS	MTS	--	EX	NS	NS
09020106-505 **Buffalo River, South Branch** *Deerhorn Creek to Whisky Creek*	18.94	2B	05RD037 05RD118 08RD080 94RD004	Upstream of CR 32, 13.5 mi NE of Kent Upstream of CR 57, 10 mi W of Barnesville Upstream of CR 51, 7.5 mi. W of Barnesville Upstream of Wilkin CR 188	MTS	EXS	IF	EXP	MTS	MTS	MTS	--	EX	NS	NS
09020106-507 **Deerhorn Creek** *Headwaters to S Branch Buffalo River*	21.86	2C	09RD047 09RD052	Downstream of 140th St, 5.5 mi. SW of Barnesville Downstream of 140th St, 1 mi. NE of Lawndale	EXS	EXS	EXS	MTS	MTS	MTS	MTS	--	EX	NS	NS
09020106-508 **Buffalo River, South Branch** *Headwaters to Deerhorn Creek*	21.18	2B	09RD051 09RD033	Upstream of 140th St , 6 mi. W of Lawndale Upstream of 170th St, 3 mi. SW of Lawndale	NA	NA	EXP	EXS	MTS	MTS	MTS	--	EX	NS	NS
09020106-531 **State Ditch 14** *Unnamed Ditch to Deerhorn Creek*	4.11	2B	09RD048	Upstream of 140th St., 6 mi. SW of Barnesville	NA	NA	IF	MTS	MTS	MTS	MTS	--	EX	FS	NS

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

†Reach was assessed based on use class included in Table and existing use class as defined in Minn. R. ch. 7050 is different. The MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Table 20. Aquatic life and recreation assessments on non-assessed channelized AUIDs in the Deerhorn-Buffalo HUC-11 watershed

AUID	Biological Station ID	Biological Station Location	F-IBI Quality	M-IBI Quality
09020106-508 **Buffalo River, South Branch** *Headwaters to Deerhorn Creek*	09RD051	Upstream of 140th St , 6 mi. W of Lawndale	Fair	Fair
	09RD033	Upstream of 170th St, 3 mi. SW of Lawndale	Good	Fair
09020106-530 **Unnamed Creek (Lawndale Creek)** *Unnamed Creek to Unnamed Ditch*	09RD056	Upstream of 270th Ave., 3 mi SW of Lawndale	Fair	Good
09020106-535 **State Ditch 15** *Unnamed Ditch to Unnamed Creek*	09RD050	Upstream of 190th St, 8.5 mi. NW of Kent	Poor	Poor
09020106-544 **Unnamed Creek** *Unnamed Ditch to S Br Buffalo River*	09RD063	Upstream of CR 32, 7.5 mi SW of Barnesville	Good	Poor
09020106-550 **County Ditch 12** *Unnamed Creek to S Br Buffalo River*	09RD036	Downstream of Cty Hwy 17, 3 mi. S of Glyndon	Poor	Fair
09020106-554 **Judicial Ditch 3-1** *Unnamed Ditch to S Br Buffalo River*	09RD032	Upstream of 240th St., 5 mi SW of Barnesville	Poor	Fair (2)
09020106-587 **Judicial Ditch 3-2** *Unnamed Creek to S Br Buffalo River*	09RD034	Upstream of 270th Ave, 3 mi. SW of Lawndale	Good (2)	Good
09020106-531 **State Ditch 14** *Unnamed Ditch to Deerhorn Creek*	09RD048	Upstream of 140th St., 6 mi. SW of Barnesville	Good (2)	Poor

When multiple visits occurred, individual visit IBI scores were averaged to create a good/fair/poor rating. When applicable, the number in parenthesis indicates the number of visits to the individual site. See Appendix 10 for explanation of good/fair/poor ratings and individual site visit F-IBI and M-IBI scores.

Table 21. Minnesota Stream Habitat Assessment (MSHA) for the Deerhorn-Buffalo HUC-11

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	94RD004	Buffalo River, South Branch	0	8	9	11	6	34	Poor
1	05RD037	Buffalo River, South Branch	0	9	8	7	14	38	Poor
2	05RD118	Buffalo River, South Branch	1.75	9	9.5	5.5	13.5	39.25	Poor
1	08RD080	Buffalo River, South Branch	0	9.5	10	8	14	41.5	Poor
1	08RD081	Buffalo River, South Branch	0	8.5	7	5	15	35.5	Poor
1	09RD006	Buffalo River, South Branch	0	5	9.1	12	8	34.1	Poor
1	09RD019	Buffalo River, South Branch	0	8.5	7	7	11	33.5	Poor
1	09RD032	Judicial Ditch 3-1	2.5	9	12.3	12	10	45.8	Fair
1	09RD033	Buffalo River, South Branch	2.5	12	9	13	7	43.5	Poor
2	09RD034	Judicial Ditch 3-2	1.88	13	16.1	13	10	53.98	Fair
1	09RD036	County Ditch 12	0	7	15.7	11	16	49.7	Fair
1	09RD047	Deerhorn Creek	0	11	12	13	13	49	Fair
1	09RD048	State Ditch 14	0	9	12	10	11	42	Poor
1	09RD050	State Ditch 15	3.75	9	4	11	10	37.75	Poor
1	09RD051	Buffalo River, South Branch	0	6.5	8	11	10	35.5	Poor
1	09RD052	Deerhorn Creek	2	11	18.8	16	12	59.8	Fair
1	09RD056	Unnamed Creek (Lawndale Creek)	5	14	12.3	11	23	65.3	Fair
1	09RD063	Unnamed Creek	0	6.5	9.7	12	11	39.2	Poor
Average Habitat Results: *Deerhorn-Buffalo HUC-11*			**1.08**	**9.19**	**10.53**	**10.47**	**11.92**	**43.19**	**Poor**

Qualitative habitat ratings:

Good: MSHA score above the median of the least-disturbed sites (≥66)

Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)

Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 22. Outlet water chemistry results for the Deerhorn-Buffalo HUC-11 watershed

Station Location	Buffalo River, South Branch at County Road 79, 1.5 miles southwest of Glyndon							
Storet ID	S004-148							
Station ID	09RD006							
Parameter	Units	# Samples	Minimum	Maximum	Mean	Median	WQ standard	# WQ exceedances[3]
Ammonia-nitrogen	mg/l	10	< 0.04	0.118	0.06	0.047		
Chloride	mg/l	6	6.7	15	11.1	11.2	230	
Chlorophyll-a, corrected	ug/l	7	4	11	7	6		
Dissolved oxygen (DO)	mg/l	29	3	11.8	7.0	6.3	5	3
Escherichia coli	MPN/100ml	20	78	727	327[1]	335	126	14[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	14	< 0.02	2.16	0.4	0.2		
Kjeldahl nitrogen	mg/l	10	0.9	1.5	1.1	1.1		
Orthophosphate	ug/l	9	53	207	129	131		
pH	--	29	7.6	8.5	8.1	8.1	6.5-9	
Pheophytin-a	ug/l	7	< 1	7	2.4	1		
Phosphorus	ug/l	14	80	300	182	177		
Specific conductance	uS/cm	29	448	1160	831	822		
Temperature, water	deg C	29	2.7	26.1	17.8	19.2		
Total suspended solids	mg/l	19	6	71	24	17		

1Geometric mean of all samples is provided for *E. coli* or fecal coliform.
2Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).
3Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001
****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Table 23. Lake morphometric and assessment data for the Deerhorn-Buffalo River HUC-11 watershed

Lake Name	Lake ID	Lake Area (ha)	% Littoral	Max Depth (m)	Mean Depth (m)	Mean TP (ug/L)	Mean Chl-a (ug/L)	Secchi Mean (m)	Aquatic Recreation Use Support[4]
Jacobs	56-1039-00	48.6	100	5.2	1.1	87	38	1.9	NS

1. Mean depths estimated.
2. Watershed area estimated from MDNR lake catchment file
3. Due to available maps and sampling location, only the north basin was used to calculate mean depth and lake area for Lake Eleven.
4. NS = not supporting, FS = supporting, IF = insufficient information to determine support, NA = not assessed (too small or wetland-like)
5. Lake is not supporting aquatic recreation use due to natural conditions; no TMDL is required.

Summary

The Deerhorn-Buffalo River watershed unit consists of 12 AUIDs, of which six were assessed for aquatic life and recreation (Table 19). Biological communities showed great variability depending on site location with F-IBI scores ranging from 2 to 81 and M-IBI scores ranging from 9 to 70 (Appendix 6). Relationships between biological communities and habitat were not evident; however, a possible relationship between F-IBI and flow may exist. Although moderate to high scores were randomly found in the small tributaries, the average score on the mainstem of the Buffalo River South Branch was 52 versus 33 on the tributaries. This may indicate that the more consistent flow on the mainstem of the river is more suitable for fish survival. In addition, AUID 09020106-531 is the only AUID to not be impaired due to turbidity and is also the only to be fully supporting of aquatic life. The low turbidity may be the reason why the site (09RD048) had the second highest F-IBI and M-IBI scores found in the watershed.

Quality stream habitat within this watershed is severely lacking with no sites receiving a good score and an overall average habitat score of poor. Though all habitat categories scored low, land use and channel morphology received the worst scores (Table 21). This is typical of areas with such high amounts of cropland and channelization.

Water quality data was available on several reaches of the South Branch Buffalo River, Deerhorn Creek, and a number of state and county ditch systems. The entire Buffalo River South Branch from the headwaters to the Buffalo River and the entire reach of Deerhorn Creek are impaired for aquatic recreation use (excess bacteria) and aquatic life (excess turbidity) use. A low dissolved oxygen impairment of aquatic life was determined for the Buffalo River South Branch upstream of Deerhorn Creek and also identified as a possible stressor on the downstream reaches (Table 22). Excessive bacteria and turbidity are found throughout the watershed, in addition to sporadic low oxygen levels (Table 22).

Only one of the six lakes greater than four hectares (10 acres) had sufficient data to review for aquatic recreation use in this watershed – Jacobs Lake. This shallow lake exceeded the eutrophication standards and is considered impaired for aquatic recreation use. Phosphorus contributions from watershed runoff and internal loading will need to be addressed to improve the recreational use of this basin.

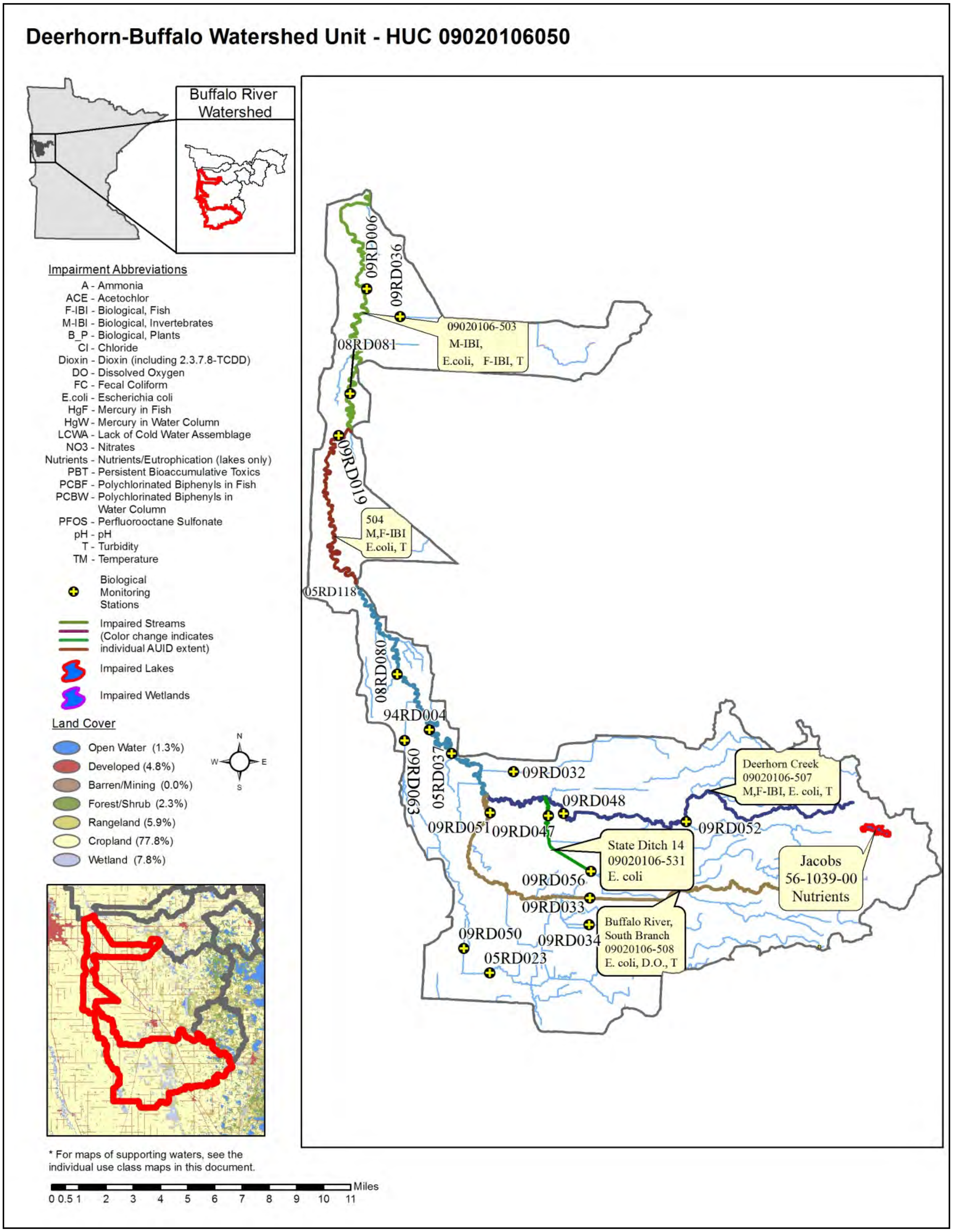

Figure 13. Currently listed impaired waters by parameter and land use in the Deerhorn-Buffalo watershed unit

South of Hawley-South Buffalo watershed unit HUC 09020106060

The South of Hawley-South Buffalo watershed unit, located in northern Wilkin, southwestern Becker, and southeastern Clay counties, is the largest watershed unit, comprising 246.7 square miles. The watershed unit includes two major tributaries to the Buffalo River, South Branch, Stony and Whisky Creeks, which both originate in the east-central portion of the watershed unit and flow westerly. Whisky Creek originates in the Olaf Grove Lakes watershed unit (09020106070), flowing west into the South of Hawley-South Buffalo watershed unit. The reach of Whisky Creek containing AUID 09020106-521 is found within both watershed units. Other tributaries within the watershed unit include Hay and Spring Creeks, County Ditch 21, and many unnamed ditches and creeks. Land use within the watershed unit is predominately crop and range land, comprising 68 and 12 percent, respectively (Figure 14). Two water chemistry monitoring locations are found in this watershed unit: station 09RD007 on Stony Creek at County Road 68, two miles southeast of Sabin, Minnesota; and station 09RD008 on Whisky Creek at 90th Street South, Baker.

Stream assessments

Table 24. Aquatic life and recreation assessments on assessed AUIDs in the South of Hawley-South Buffalo HUC-11 watershed

AUID *Reach Name* *Reach Description*	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
09020106-502 **Stoney Creek** *Hay Creek to S Br Buffalo River*	15.5	2B	09RD007 10EM172	Downstream of CR 68, 2 mi. SE of Sabin Upstream of County Road 10, 2 mi. SE of Sabin	MTS	NA	EXS	EXS	MTS	MTS	MTS	--	EX	NS	NS
09020106-534 **Spring Creek** *Unnamed Creek to Hay Creek*	4.87	2B	09RD022	Downstream of 170th St. S, 2 mi. SE of Downer	EXS	EXP	IF	MTS	MTS	MTS	MTS	--	EX	NS	NS
09020106-509 **Whisky Creek** *T137 R47W S13, east line to S Branch Buffalo River*	6.95	2B	09RD008 09RD011	Upstream of CR 68, 3 mi. SW of Baker Upstream of Cty Hwy 15, 2 mi. SW of Baker	NA	NA	IF	EXS	MTS	MTS	MTS	--	EX	NS	NS
09020106-521 **Whisky Creek** *Headwaters to T137 R46W S18, west line*	24.1	2C	05RD119 09RD021	1 mi. downstream of CR 21, 6.5 mi W of Barnesville Upstream of CR 56, 2 mi. NW of Barnesville	MTS	MTS	MTS	EXP	MTS	MTS	MTS	--	EX	NS	NS
09020106-523 **Stony Creek** *T137 R45W S3, north line to T137 R46W S5, north line*	14.32	2C	09RD046	Upstream of 140th St. S, 6.5 mi. NW of Barnesville	NA	NA	IF	EXP	MTS	MTS	MTS	--	EX	NS	NS

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

†Reach was assessed based on use class included in Table and existing use class as defined in Minn. R. ch. 7050 is different. The MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Table 25. Aquatic life and recreation assessments on non-assessed channelized AUIDs in the South of Hawley-South Buffalo HUC-11 watershed

AUID	Biological Station ID	Biological Station Location	F-IBI Quality	M-IBI Quality
09020106-510 **Stony Creek** *Headwaters to T137 R45W S2, north line*	09RD031	Upstream of CR 31, 5.5 mi. NE of Barnesville	Good (2)	Poor
09020106-519 **Hay Creek** *Unnamed Creek to Spring Creek*	09RD023	Upstream of 110th St., 1.5 mi. SE of Downer	Poor	Poor
09020106-520 **Hay Creek** *Spring Creek to Stony Creek*	07RD012	Upstream of 150th St., 2 mi. S of Downer	Fair (2)	Fair
09020106-533 **Unnamed Creek** *Headwaters to Whisky Creek*	09RD020	Upstream of 150th St. S, 3.5 mi. NW of Barnesville	Poor	Not Sampled
09020106-551 **County Ditch 21** *Unnamed Ditch to Unnamed Creek*	09RD030	Upstream of Cty Hwy 17, 5 mi S of Glyndon	Poor	Poor
09020106-592 **Unnamed Creek** *Unnamed Creek to County Ditch 21*	09RD045	Upstream of CR 68, 2 mi. NE of Sabin	Poor	Not Sampled
09020106-509 **Whisky Creek** *T137 R47W S13, east line to S Br Buffalo R*	09RD008 09RD011	Upstream of CR 68, 3 mi. SW of Baker Upstream of Cty Hwy 15, 2 mi. SW of Baker	Good	Poor
09020106-523 **Stony Creek** *T137 R45W S3, north line to T137 R46W S5, north line*	09RD046	Upstream of 140th St. S, 6.5 mi. NW of Barnesville	Fair	Not Sampled

When multiple visits occurred, individual visit IBI scores were averaged to create a good/fair/poor rating. When applicable, the number in parenthesis indicates the number of visits to the individual site. See Appendix 10 for explanation of good/fair/poor ratings and individual site visit F-IBI and M-IBI scores.

Table 26. Minnesota Stream Habitat Assessment (MSHA) for the South of Hawley-South Buffalo HUC-11 watershed

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	05RD119	Whiskey Creek	0	9	12	2	7	30	Poor
2	07RD012	Hay Creek	5	8.5	11.15	4.5	15.5	44.65	Poor
1	09RD007	Stony Creek	0	9	10	12	6	37	Poor
1	09RD008	Whiskey Creek	0	8	10	10	10	38	Poor
1	09RD011	Whiskey Creek	0	7	7	11	4	29	Poor
1	09RD020	Unnamed Creek	0	6	9	12	19	46	Fair
2	09RD021	Whiskey Creek	0	5	12.95	9	7.5	34.45	Poor
1	09RD022	Spring Creek	0	8	16.2	14	21	59.2	Fair
1	09RD023	Hay Creek	2.5	3	17.2	6	11	39.7	Poor
1	09RD030	County Ditch 21	0	7	16	12	7	42	Poor
2	09RD031	Stony Creek	1.88	12.5	12.15	13	23	71.53	Good
1	09RD045	Trib. to Buffalo River, South Branch	0	7	10	11	7	35	Poor
2	09RD046	Stony Creek	0	8.5	25.65	7	14.5	42.83	Poor
Average Habitat Results: *South of Hawley-South Buffalo 11- HUC*			**0.72**	**7.58**	**13.02**	**9.50**	**11.73**	**42.26**	**Poor**

Qualitative habitat ratings:

Good: MSHA score above the median of the least-disturbed sites (≥66)

Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)

Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 27. Outlet water chemistry results for the South of Hawley-South Buffalo HUC-11 (Stony Creek)

Station Location	Stony Creek at County Road 68, 2 miles southeast of Sabin							
Storet ID	**S002-711**							
Station ID	**09RD007**							
Parameter	**Units**	**# Samples**	**Minimum**	**Maximum**	**Mean**	**Median**	**WQ standard**	**# WQ exceedances[3]**
Ammonia-nitrogen	mg/l	11	< 0.04	0.114	0.06	0.046		
Chloride	mg/l	6	4.98	19.5	9.8	7.9	230	
Chlorophyll-a, corrected	ug/l	8	1	31	10.9	3.5		
Dissolved oxygen (DO)	mg/l	26	0.26	9.48	6.3	6.4	5	4
Escherichia coli	MPN/100ml	21	118.7	1732.9	479.8[1]	261.3	126	20[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	14	< 0.02	0.82	0.22	0.1		
Kjeldahl nitrogen	mg/l	11	0.86	1.5	1.3	1.4		
Orthophosphate	ug/l	9	38	146	88.3	76		
pH	--	26	7.8	8.4	8.1	8.1	6.5-9	
Pheophytin-a	ug/l	8	< 1	8	5.5	7		
Phosphorus	ug/l	15	13	243	135	127		
Specific conductance	uS/cm	26	484	994	719	720		
Temperature, water	deg C	26	7.8	25.6	18.6	19.4		
Total suspended solids	mg/l	15	4	60	20.1	16		
Total volatile solids	mg/l	11	< 1	11	4.5	1		
Transparency tube	cm	26	7.5	67	23	17.5		
Turbidity	FNU	26	6	54	23.2	19.2	25 NTU	10

1Geometric mean of all samples is provided for *E. coli* or fecal coliform.

2Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).

3Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001

****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Table 28. Outlet water chemistry results for the South of Hawley-South Buffalo HUC-11 (Whisky Creek)

Station Location	Whisky Creek at 90th Street South, near Baker							
Storet ID	S005-607							
Station ID	09RD008							
Parameter	Units	# Samples	Minimum	Maximum	Mean	Median	WQ standard	# WQ exceedances[3]
Ammonia-nitrogen	mg/l	11	< 0.04	0.116	0.06	0.046		
Chloride	mg/l	6	8.3	26.3	14	13.3	230	
Chlorophyll-a, corrected	ug/l	7	2	7	4	3		
Dissolved oxygen (DO)	mg/l	29	2.1	12.6	7.7	7.7	5	2
Escherichia coli	MPN/100ml	20	33	1553	343[1]	277	126	17[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	15	< 0.02	1.79	0.26	0.2		
Kjeldahl nitrogen	mg/l	11	0.752	1.37	0.99	0.95		
Orthophosphate	ug/l	9	46	171	117	112		
pH	--	29	7.6	8.5	8.2	8.3	6.5-9	
Pheophytin-a	ug/l	7	< 1	6	1.9	1		
Phosphorus	ug/l	15	111	296	186	179		
Specific conductance	uS/cm	29	323	1032	715	695		
Temperature, water	deg C	29	2.1	24.6	16.3	17.1		
Total suspended solids	mg/l	18	1	94	39	29.5		
Total volatile solids	mg/l	11	< 1	14	6.5	6		
Transparency tube	cm	29	6.5	70	21	14		
Turbidity	FNU	29	4.6	66	29	24	25 NTU	14

1Geometric mean of all samples is provided for *E. coli* or fecal coliform.
2Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).
3Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001
****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Table 29. Lake morphometric and assessment data for the South of Hawley-South Buffalo HUC-11 watershed

Lake Name	Lake ID	Lake Area (ha)	% Littoral	Max Depth (m)	Mean Depth (m)	Mean TP (ug/L)	Mean Chl-a (ug/L)	Secchi Mean (m)	Aquatic Recreation Use Support[4]
Eleven	[1,3]14-0018-00	60	100	2.4	1.4	26	6	2.2	FS
Ten	14-0021-00	62.1	90.1	5.2	1.7	57	27	1.7	IF
Unnamed (North Mayfield)	[1]14-0029-00	9.3	100	4	2.4	17	7	2.5	IF
Fifteen	14-0030-00	58.6	70.5	6.7	3.1	33	14	2.2	FS

1. Mean depths estimated.
2. Watershed area estimated from MDNR lake catchment file
3. Due to available maps and sampling location, only the north basin was used to calculate mean depth and lake area for Lake Eleven.
4. NS = not supporting, FS = supporting, IF = insufficient information to determine support, NA = not assessed (too small or wetland-like)
5. Lake is not supporting aquatic recreation use due to natural conditions; no TMDL is required.

Summary

The F-IBI scores within this watershed unit showed a positive relationship with drainage area. In general, F-IBI scores were better in the larger streams (Stony and Whisky Creeks) when contrasted with the smaller tributary streams. Since few obvious relationships were noted between IBI scores and either habitat or water chemistry variables, it is possible that altered hydrology may be a defining factor contributing to the poor scores that were observed in headwater environments.

Because of the uniformly poor conditions found throughout this watershed, relationships between water chemistry and habitat variables may be difficult to tease apart. Habitat within this watershed needs drastic improvement, with 10 of 13 sites receiving a poor score. Although nearly all categories had low scores, land use and channel morphology received the worst scores, which is typically found within heavy agricultural areas (Table 26). Excess bacteria were found throughout the watershed, with impairments of aquatic recreation use assigned to seven of the reaches. Turbidity impairments of aquatic life were found on all of sections of Whisky Creek and portions of Stony and Hay Creeks. The segment of Spring Creek that was sampled contains the Henry Detention Pond; it is possible that this detention pond would provide settling that would provide the low turbidity levels found in this reach. A low dissolved oxygen impairment of aquatic life was assigned to Stony Creek downstream of Hay Creek; dissolved oxygen was considered a possible stressor on parts of Whisky and Hay creeks.

Four of the seventeen lakes greater than four hectares (10 acres) were reviewed for aquatic recreation use in this watershed. The lakes are a mix of deep and shallow basins located in the headwaters portion of the watershed. Turtle Lake, Lake Fifteen, and Lake Eleven were all meeting the eutrophication standards and are supporting aquatic recreation use (Table 29). These lakes have relatively intact watersheds; conversion of forest to developed or agricultural land uses will likely result in a decline to water quality. Lake Ten is approaching the standards; chlorophyll-a exceeds but phosphorus and Secchi transparency meet the standards. A small increase in phosphorus concentrations would push this lake over the standards. This lake has the most cropped acreage in its watershed and is shallow, making the lake sensitive to any increases in nutrient contributions.

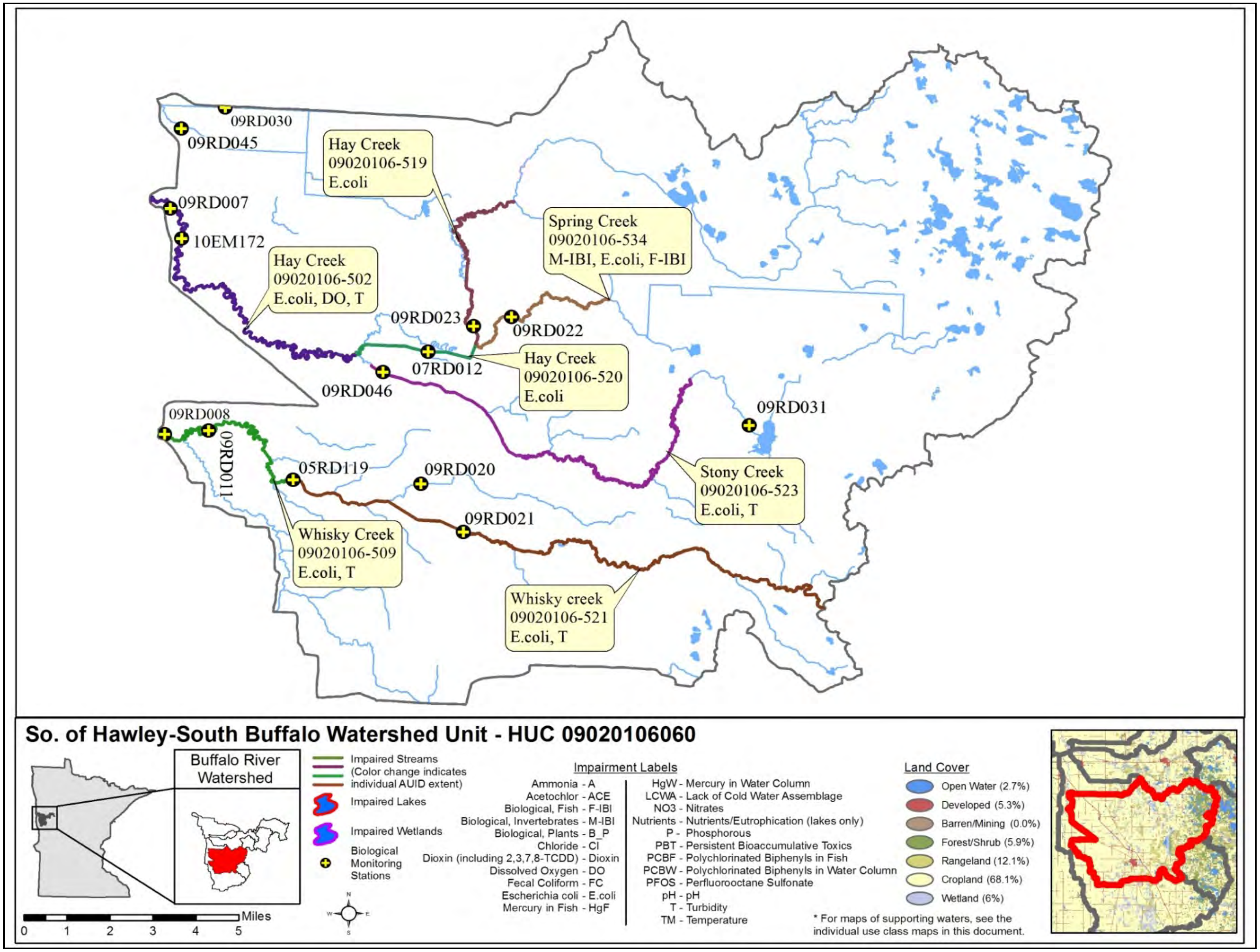

Figure 14. Currently listed impaired waters by parameter and land use in the South of Hawley-South Buffalo watershed unit

Olaf Grove Lakes watershed unit HUC 09020106070

The Olaf Groves Lakes watershed unit, located in northwestern Otter Tail and southeastern Clay Counties, is comprised of 49.8 square miles. The watershed unit encompasses the headwaters of Whisky Creek, which flows west, where it enters the South of Hawley-South Buffalo watershed unit. Land use within the watershed unit is largely a mix of three types: Forest (25 percent), Range (24.3 percent), and Cropland (34.2 percent) (Figure 15). There are no named tributaries to Whisky Creek, but multiple unnamed ditches and creeks.

Stream assessments

Table 30. Aquatic life and recreation assessments on assessed AUIDs in the Olaf Grove Lakes HUC-11 watershed

AUID *Reach Name* *Reach Description*	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
09020106-521 ***Whisky Creek*** *Headwaters to T137 R46W S18, west line*	24.1	2C	09RD001	Downstream of CR 127, 6.5 mi. E of Barnesville	MTS	MTS	MTS	EXP	MTS	MTS	MTS	--	EX	NS	NS

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

†Reach was assessed based on use class included in Table and existing use class as defined in Minn. R. ch. 7050 is different. The MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Table 31. Aquatic life and recreation assessments on non-assessed channelized AUIDs in the South of Hawley-South Buffalo HUC-11 watershed

AUID	Biological Station ID	Biological Station Location	F-IBI Quality	M-IBI Quality
09020106-586 **Unnamed Creek** *Headwaters to Whisky Creek*	09RD053	Upstream of CR 31, 5.5 mi. NE of Barnesville	Good (2)	Poor

When multiple visits occurred, individual visit IBI scores were averaged to create a good/fair/poor rating. When applicable, the number in parenthesis indicates the number of visits to the individual site. See Appendix 10 for explanation of good/fair/poor ratings and individual site visit F-IBI and M-IBI scores.

Table 32. Minnesota Stream Habitat Assessment (MSHA) for the Olaf Grove Lakes HUC-11 watershed

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	09RD001	Whiskey Creek	1.25	11	19.1	15	31	77.35	Good
1	09RD053	Trib. to Whiskey Creek	0	12.5	18.8	16	14	61.3	Fair
Average Habitat Results: *Olaf Grove Lakes HUC-11*			**0.63**	**11.75**	**18.95**	**15.50**	**22.50**	**69.33**	**Good**

Qualitative habitat ratings:
Good: MSHA score above the median of the least-disturbed sites (≥66)
Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)
Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 33. Outlet water chemistry results for the Olaf Grove Lakes HUC-11 watershed

Station Location	Whisky Creek at CR-127 (250th St S), near Barnesville							
Storet ID	S005-611							
Station ID	09RD001							
Parameter	**Units**	**# Samples**	**Minimum**	**Maximum**	**Mean**	**Median**	**WQ standard**	**# WQ exceedances[3]**
Ammonia-nitrogen	mg/l	11	< 0.04	0.06	0.04	< 0.04		
Chloride	mg/l	7	2.18	4.2	3.5	3.6	230	
Dissolved oxygen (DO)	mg/l	29	5.3	11.4	8.4	8.2	5	
Escherichia coli	MPN/100ml	20	10	1200	286[1]	221	126	15[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	16	< 0.02	0.05	0.02	< 0.02		
Kjeldahl nitrogen	mg/l	9	0.65	0.90	0.77	0.78		
Orthophosphate	ug/l	10	14	48	30	31		
pH	--	29	7.2	9.1	7.9	7.8	6.5-9	1
Phosphorus	ug/l	16	41	324	69	53		
Specific conductance	uS/cm	29	138	588	528	554		
Temperature, water	deg C	29	3.9	21.1	14.2	15.9		
Total suspended solids	mg/l	20	3	33	9.8	7.5		
Transparency tube	cm	29	52.8	> 100	94	> 100		
Turbidity	NTRU	29	3.8	13.7	5.8	5.6	25 NTU	

1Geometric mean of all samples is provided for *E. coli* or fecal coliform.
2Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).
3Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001
****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Table 34. Lake morphometric and assessment data for the Olaf Grove Lakes HUC-11 watershed

Lake Name	Lake ID	Lake Area (ha)	% Littoral	Max Depth (m)	Mean Depth (m)	Mean TP (ug/L)	Mean Chl-a (ug/L)	Secchi Mean (m)	Aquatic Recreation Use Support[4]
Harrison (Helgeson)	[1]56-0934-00	44.1	100	3.7	1.9	54	33	1.4	IF
Pete	56-0941-00	40.3	100	4.9	0.9	54	12	3	FS
West Olaf	56-0950-01	58.2		18.6	3.7	30	11	2.4	FS
Grove	56-0952-00	165.9	99.5	4.6	1.2	41	14	3.1	FS

1. Mean depths estimated.
2. Watershed area estimated from MDNR lake catchment file
3. Due to available maps and sampling location, only the north basin was used to calculate mean depth and lake area for Lake Eleven.
4. NS = not supporting, FS = supporting, IF = insufficient information to determine support, NA = not assessed (too small or wetland-like)
5. Lake is not supporting aquatic recreation use due to natural conditions; no TMDL is required.

Summary

The Olaf Groves Lakes watershed unit is in a transition zone from woods and lakes in the east to more cropland with fewer lakes in the western portion. Only two sites were sampled, both near the watershed outlet, making it difficult to make watershed wide conclusions. With the exception of the M-IBI score at 09RD053, the high IBI scores coincide with the generally good habitat and water chemistry conditions in this watershed (Table 31 and 32).

Water quality data was available on only one reach of Whiskey Creek. The water chemistry exceedances for turbidity in Whiskey Creek (09020106-521) can be attributed to the fact that the AUID extends west into the South of Hawley-South Buffalo watershed unit (09020106060). The sole water chemistry station in 09020106-521(09RD001/S005-611) was meeting standards for turbidity; however, as you move downstream into the South of Hawley-South Buffalo subwatershed, the turbidity increases and the standards are exceeded. Future assessments may consider splitting this AUID between watershed units and assess each separately. Bacteria levels do exceed standards at the water chemistry site and are an accurate reflection of aquatic recreation use non-support for this watershed.

Four of the twenty lakes greater than four hectares (10 acres) were reviewed for aquatic recreation use in the watershed. This is a headwaters watershed with a relatively high portion in forested land uses. Lake Pete, Grove Lake, and West Olaf Lake all met eutrophication standards and are supporting aquatic recreation use (Table 34). Lake Harrison (Helgeson) exceeds the chlorophyll-a-standards but phosphorus and Secchi are meeting standards. The lake is shallow; a small increase in phosphorus would likely push the lake over the eutrophication standards. Maintaining or reducing phosphorus runoff and careful management of land use conversion will be important to preserving the quality of the lakes in this watershed.

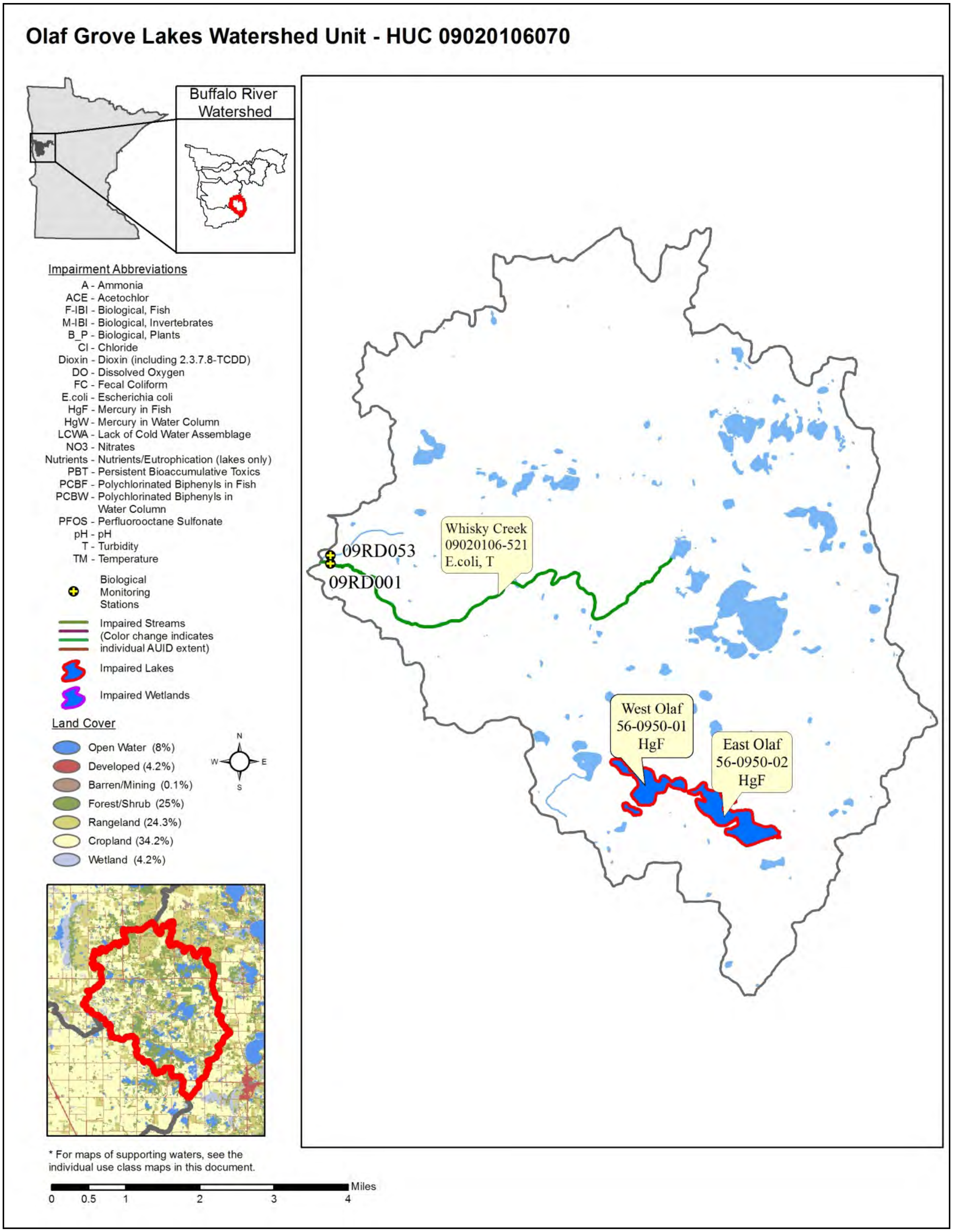

Figure 15. Currently listed impaired waters by parameter and Land use in the Olaf Grove Lakes watershed unit

County Ditch #2 watershed unit HUC 09020106080

The County Ditch #2 watershed unit, located in central Clay County, is the smallest of the watershed units, encompassing 32.9 square miles. The watershed unit includes one main tributary, County Ditch #2, which flows west until its confluence with the Red River. No named tributary flows into County Ditch #2; however, one main unnamed creek flows into the ditch, with multiple smaller unnamed ditches and creeks flowing into it. The watershed unit is largely dominated by cropland, making up 81.6 percent of the total land use (Figure 16). There was no Intensive Watershed Monitoring (IWM) water monitoring site established in 2012 within this watershed unit; however, water chemistry data was taken and has been reported in Table 37.

Stream assessments

Table 35. Aquatic life and recreation assessments on non-assessed channelized AUIDs in the County Ditch #2 HUC-11 watershed

AUID	Biological Station ID	Biological Station Location	F-IBI Quality	M-IBI Quality
09020106-555 **Unnamed Creek** *Headwaters to Clay Cty Ditch 2*	09RD062	Upstream of CR 86, 5.5 mi NW of Hawley	Poor	Poor
09020106-556 **County Ditch 2** *Unnamed Creek to Buffalo River*	09RD037	Upstream of 100th St. N, 3 mi N of Glyndon	Good	Fair

When multiple visits occurred, individual visit IBI scores were averaged to create a good/fair/poor rating. When applicable, the number in parenthesis indicates the number of visits to the individual site. See Appendix 10 for explanation of good/fair/poor ratings and individual site visit F-IBI and M-IBI scores.

Table 36. Minnesota Stream Habitat Assessment (MSHA) for the County Ditch #2 HUC-11 watershed

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	09RD037	County Ditch 2	0	8	7	10	13	38	Poor
2	09RD062	Trib. to County Ditch 2	1.88	13.5	11.6	12	21	59.98	Fair
Average Habitat Results: *County Ditch #2 HUC-11*			**0.94**	**10.75**	**9.30**	**11.00**	**17.00**	**48.99**	**Fair**

Qualitative habitat ratings:
Good: MSHA score above the median of the least-disturbed sites (≥66)
Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)
Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 37. Point water chemistry results for the County Ditch #2 HUC-11 watershed

Station Location	County Ditch #2 at 90th St N, near Glyndon							
Storet ID	S005-609							
Station ID	09RD037							
Parameter	**Units**	**# Samples**	**Minimum**	**Maximum**	**Mean**	**Median**	**WQ standard**	**# WQ exceedances[3]**
Ammonia-nitrogen	mg/l	7	< 0.04	0.06	0.04	< 0.04		
Chloride	mg/l	7	7.7	16.2	11.1	10.7	230	
Dissolved oxygen (DO)	mg/l	26	6.7	18.5	10.9	10.7	5	
Escherichia coli	MPN/100ml	15	13	727	272[1]	186	126	9[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	12	< 0.02	0.52	0.11	< 0.03		
Orthophosphate	ug/l	13	5	108	37	23		
pH	--	26	7.9	8.7	8.3	8.3	6.5-9	
Phosphorus	ug/l	13	28	137	62	52		
Specific conductance	uS/cm	26	513	781	676	688		
Temperature, water	deg C	26	1.8	28.7	18.6	19.5		
Total suspended solids	mg/l	18	2	15	5.9	5		
Transparency tube	cm	26	41	> 100	75.8	82		
Turbidity	FNU	25	1.2	11.1	4.7	3.4	25 NTU	

1Geometric mean of all samples is provided for *E. coli* or fecal coliform.
2Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).
3Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001
****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Summary

The County Ditch #2 watershed unit consists of very few waterways and is dominated by cropland (82 percent). The biological communities at the two sites sampled were more robust at the outlet site (09RD037) than in the tributary (09RD062), even though the habitat at the outlet site was significantly worse (Table 36). With the exception of some elevated bacteria concentrations that indicate an aquatic recreation impairment, all the water chemistry parameters used to assess aquatic life use support were fairly good and did not exceed standards. The lack of correspondence between biology and habitat, coupled with the generally good water chemistry data, suggests that hydrologic factors may play a large role in explaining the biological results in this watershed.

The County Ditch #2 watershed unit does not include any lakes.

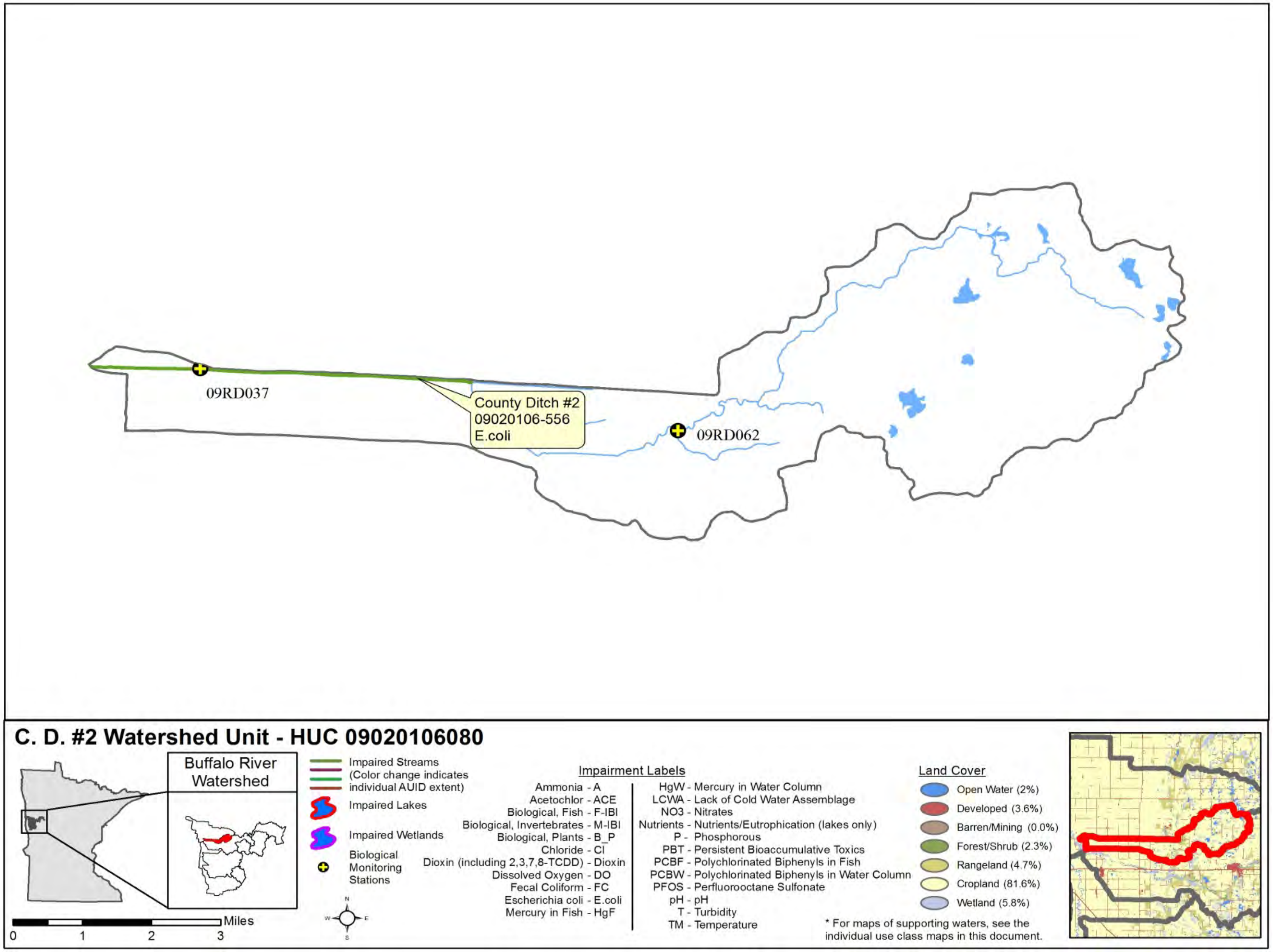

Figure 16. Currently listed impaired waters by parameter and land use in the County Ditch #2 watershed unit

Lower Buffalo River watershed unit HUC 09020106090

The Lower Buffalo River watershed unit, located in north central Clay County, covers an area of 167.7 square miles. The watershed begins in the south where the Buffalo River, South Branch merges with the Buffalo River main stem. From this point, it flows in a northwest direction until its confluence with the Red River of the North one mile west of the town of Georgetown. The watershed is largely made up of ditches that contribute to the Buffalo River, including County Ditches 3, 5, 6, 10, 25, 38, 39, 49, and 59. The water chemistry monitoring for this watershed unit is represented by the outlet station 09RD009 on the Buffalo River upstream of the Highway 75 bridge, one-half mile southeast of Georgetown.

Stream assessments

Table 38. Aquatic life and recreation assessments on assessed AUIDs in the Lower Buffalo River HUC-11 watershed

AUID *Reach Name* *Reach Description*	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
09020106-501 ***Buffalo River, South Branch*** *S. Br. Buffalo River to Red River*	46.51	2B	05RD120 09RD009 09RD018 09RD043	Upstream of 220th Ave., 2 mi NE of Calloway Upstream of Hwy 75, 0.5 mi SE Georgetown Upstream of Cty Hwy 18, 3 mi NW of Glyndon Upstream of Cty Rd 94, 7 mi NE of Moorhead	MTS	MTS	MTS	EXS	MTS	MTS	MTS	--	EX	NS	NS

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = previous impairment or deferred impairment prior to 2012 reporting cycle; = new impairment; = full support of designated use.

*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

†Reach was assessed based on use class included in Table and existing use class as defined in Minn. R. ch. 7050 is different. The MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Table 39. Aquatic life and recreation assessments on non-assessed channelized AUIDs in the Lower Buffalo HUC-11 watershed

AUID	Biological Station ID	Biological Station Location	F-IBI Quality	M-IBI Quality
09020106-538 **County Ditch 25** *County Ditch 26 to Buffalo River*	09RD016	5 mi. NW of Averill	Poor	Poor
09020106-557 **County Ditch 3** *Headwaters to Buffalo River*	09RD044	Upstream of 80th St. N, 4.5 mi SW of Averill	Poor	Poor
09020106-559 **County Ditch 39** *Headwaters to Buffalo River*	09RD055	Upstream of 60th St. N, 4 mi. E of Kragnes	Good (2)	Poor
09020106-560 **County Ditch 59** *Headwaters to Buffalo River*	09RD015	Upstream of Cty Hwy 28, 3 mi. NE of Kragnes	Poor	Poor
09020106-562 **County Ditch 10** *Unnamed Creek to Unnamed Ditch*	09RD014	Downstream of County Hwy 5, 3 mi. NE of Kragnes	Fair	Poor
09020106-563 **County Ditch 5 (County Ditch 8)** *Headwaters to Buffalo River*	09RD029	Upstream of County Hwy 5, 3 mi. SE of Georgetown	Poor	Poor

When multiple visits occurred, individual visit IBI scores were averaged to create a good/fair/poor rating. When applicable, the number in parenthesis indicates the number of visits to the individual site. See Appendix 10 for explanation of good/fair/poor ratings and individual site visit F-IBI and M-IBI scores.

Table 40. Minnesota Stream Habitat Assessment (MSHA) for the Lower Buffalo River HUC-11 watershed

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	05RD120	Buffalo River	0	7	3	12	11	33	Poor
1	09RD009	Buffalo River	0	6.5	7.15	6	21	40.65	Poor
1	09RD014	County Ditch 10	0	9	9	12	13	43	Poor
1	09RD015	County Ditch 59	0	8	9	11	7	35	Poor
1	09RD016	County Ditch 25	0	7.5	7	0	10	24.5	Poor
1	09RD018	Buffalo River	0	7	7	6	11	31	Poor
1	09RD029	County Ditch 5 (County Ditch 8)	0	9	9	9	9	36	Poor
1	09RD043	Buffalo River	0	6	7	10	18	41	Poor
1	09RD044	County Ditch 3	0	11	7	14	7	39	Poor
2	09RD055	County Ditch 39	0	7.25	8.63	6	12.5	34.38	Poor
Average Habitat Results: *Lower Buffalo RiverHUC-11*			**0.00**	**7.83**	**7.38**	**8.60**	**11.95**	**35.75**	**Poor**

Qualitative habitat ratings:

Good: MSHA score above the median of the least-disturbed sites (≥66)

Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45-65)

Poor: MSHA score below the median of the most-disturbed sites (≤44)

Table 41. Outlet water chemistry results for the Lower Buffalo River watershed HUC-11 watershed

Station Location	Buffalo River at US Hwy 75 near Georgetown							
Storet ID	S000-174							
Station #	09RD009							
Parameter	Units	# Samples	Minimum	Maximum	Mean	Median	WQ standard	# WQ Exceedances[3]
Ammonia-nitrogen	mg/l	10	< 0.04	0.131	0.06	> 0.04		
Chloride	mg/l	6	7.8	15.2	11.8	12.05	230	
Chlorophyll-a, corrected	ug/l	7	2	21	12.6	12		
Dissolved oxygen (DO)	mg/l	28	5.2	11.96	8.6	8.5	5	
Escherichia coli	MPN/ 100ml	20	23.1	365.4	177.7[1]	137.5	126	12[2]
Inorganic nitrogen (nitrate and nitrite)	mg/l	15	< 0.02	1.86	0.37	0.12		
Kjeldahl nitrogen	mg/l	10	0.817	1.78	1.1	1.0		
Orthophosphate	ug/l	9	44	118	87.3	105		
pH	--	28	7.8	8.5	8.2	8.3	6.5-9	
Pheophytin-a	ug/l	7	1	6	3.3	3		
Phosphorus	ug/l	15	108	359	180.5	159		
Specific conductance	uS/cm	28	474	1056	758	738		
Temperature, water	deg C	28	3.73	24.73	18.3	19.6		
Total suspended solids	mg/l	19	5	152	59.3	58		
Total volatile solids	mg/l	9	< 1	13	7.8	8		
Transparency tube	cm	28	5.5	31	11.8	9.8		
Turbidity	FNU	28	8.1	101.2	46	44.8	25 NTU	20

1Geometric mean of all samples is provided for *E. coli* or fecal coliform.

2Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).

3Exceedances for parameters that do not have water quality standards are based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW EPA 822 B-01-015. 2001

****Data found in the Table above was compiled using the results from data collected in 2008 and 2009 at the outlet monitoring station. This site specific data does not necessarily reflect all data that was used to assess the AUID.**

Summary

The Lower Buffalo River watershed unit contains the highest percentage of cropland (87 percent) throughout the Buffalo River watershed, and is made up of many channelized waterways, which all flow directly into the Buffalo River mainstem (Figure 17). The sites sampled on the mainstem of the Buffalo River show F-IBI scores higher (62 to 71) than those in the tributaries (34 to 68) and M-IBI scores also higher in the mainstem (29 to 47 versus 4.8 to 12.3, respectively) (Appendix 6). Although the sites on the Buffalo River met their respective biological thresholds, AUID 09020106-501 was determined to be non-supportive of aquatic life and recreation due to turbidity and bacteria impairments.

Habitat scores were uniformly poor throughout the watershed (Table 40). Each site scored a zero for land use and received scores well under half of what was possible for substrate and channel morphology. Aquatic communities in the mainstem Buffalo might be propped up by the relatively stable flows in the mainstem of the Buffalo River, when contrasted with flows in the tributaries.

Water quality data was available on County Ditch 39, County Ditch 10, and the Buffalo River from the confluence of the Buffalo River South Branch to the Red River of the North. County Ditch 39 and 10 both were considered impaired for aquatic recreation use (excess bacteria) and for aquatic life use (turbidity); the turbidity impairment is deferred at this time until standards are revised. There are several significant ditches without chemistry data draining this watershed. It is likely that the turbidity and bacteria problems found on the larger reaches are also present on these reaches in this heavily altered watershed.

The Lower Buffalo River watershed unit does not contain any lakes.

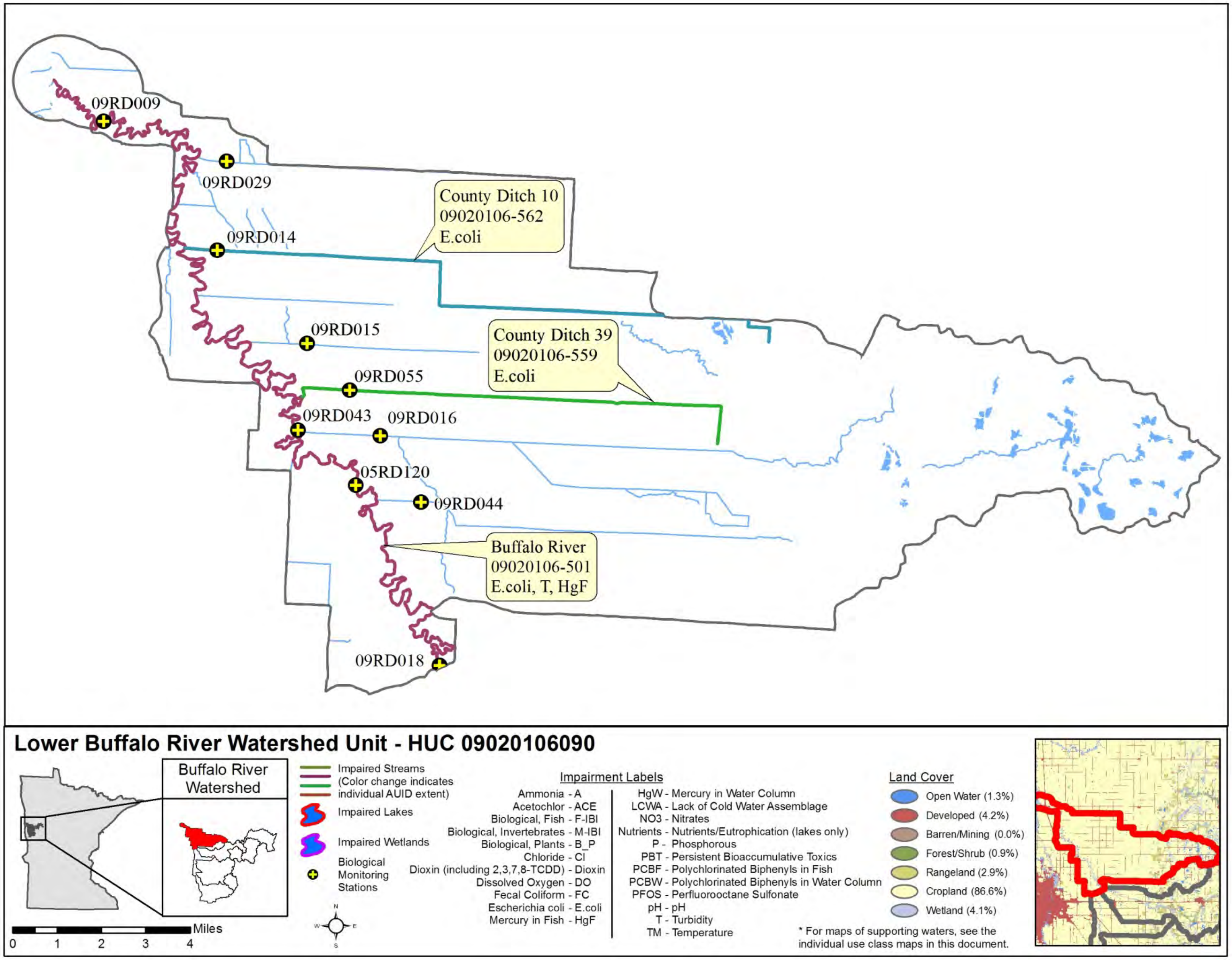

Figure 17. Currently listed impaired waters by parameter and land use in the Lower Buffalo River watershed unit

VII. Watershed Wide Results and Discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed unit of the Buffalo River, grouped by sampling type. Summaries are provided for aquatic life and recreation uses in streams and lakes throughout the watershed. Summaries for aquatic consumption (fish contaminants) and load monitoring (FWMCs) are based on data collected near the mouth of the 8 digit HUC outlet. Following the results are a series of graphics that provide an overall summary of assessment results by designated use, impaired waters and waters fully supporting beneficial uses within the entire Buffalo River watershed.

Pollutant load monitoring

Total Suspended Solids

Currently, the State of Minnesota does not have a river standard for TSS but does have one for turbidity. Because turbidity is an optical measurement and not a measure of mass, TSS "surrogate" standards for turbidity were developed for ecoregions of the state and are applicable to water quality data collected within each respective ecoregion. TSS concentrations in the Buffalo River watershed with greater than 10 percent of the samples at or above 60 mg/L are considered out of compliance with the turbidity standard of 25 Nephelometric Turbidity Units (NTUs) for waters within the Lake Agassiz Plain Ecoregion (MPCA 2009). In 2008, the percent of TSS samples that exceeded the 25 mg/L surrogate standard in the Buffalo River was 88 percent while the FWMC was 82.9 mg/L. In 2009, 42 percent of the samples collected exceeded the standard and the FWMC was 54.5 mg/L. In 2010, 78 percent of the samples collected exceeded the standard and the FWMC was 65.3 mg/L. Estimated TSS loads from 2008-2010 were similar to those reported by the USGS based on sampling from the 1970s (57,000 tons, or 51,700,000 kilograms; Tornes, 1986).

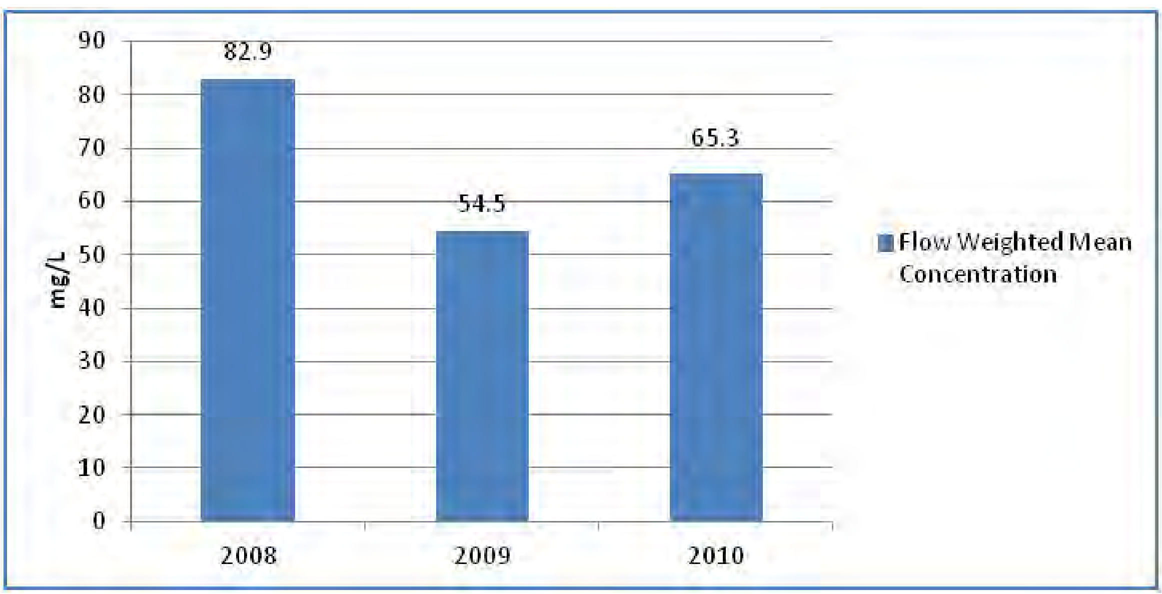

Figure 18. Total Suspended Solids Flow Weighted Mean Concentrations for the Buffalo River near Georgetown, MN, 2008-2010.

Total Phosphorus

TP standards for Minnesota's rivers are currently moving from the "development phase" into the "approval phase." Many years of water quality data collected throughout Minnesota combined with previous analysis of Minnesota's ecoregion patterns, resulted in the development of three "River Nutrient Regions" (RNR), each with unique standards. Of the state's three proposed RNRs, the Buffalo River load monitoring station is located within the South RNR which has a TP draft standard of 0.150 mg/L as a summer average. It must be noted that the TP standard is yet to be approved and this threshold must be considered draft until final approval. Summer average violations of one or more "response" variables (pH, biological oxygen demand (BOD), dissolved oxygen flux, chlorophyll-a) must also occur along with the TP numeric violation for the water to be listed. In 2008 the percent of TP samples that exceeded the 0.150 mg/L proposed standard was 77 percent while the FWMC was 0.257 mg/L. In 2009, 75 percent of the samples collected exceeded the standard and the FWMC was 0.219 mg/L. In 2010 75 percent of the samples collected exceeded the standard and the FWMC was 0.233 mg/L. Observations of Figure 19 shows all annual TP FWMCs substantially above the draft standard.

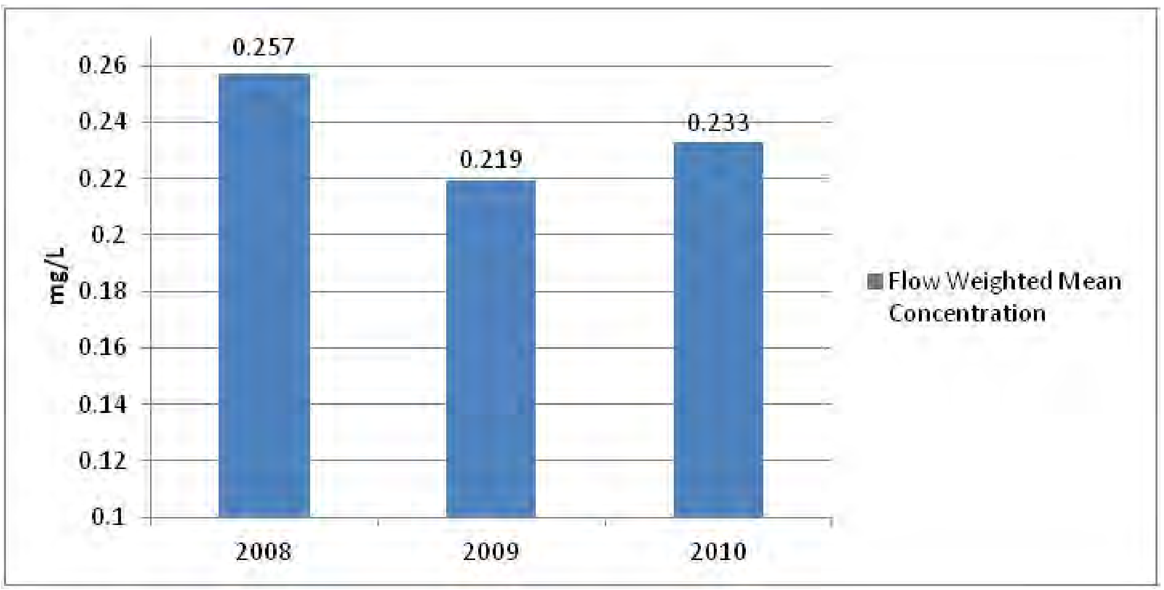

Figure 19. Total Phosphorus Flow Weighted Mean Concentrations for the Buffalo River near Georgetown, Minnesota, 2008-2010

Dissolved orthophosphate

Computation of DOP/TP ratios from 2008 to 2010 show 46 to 61 percent of TP is in the orthophosphate form.

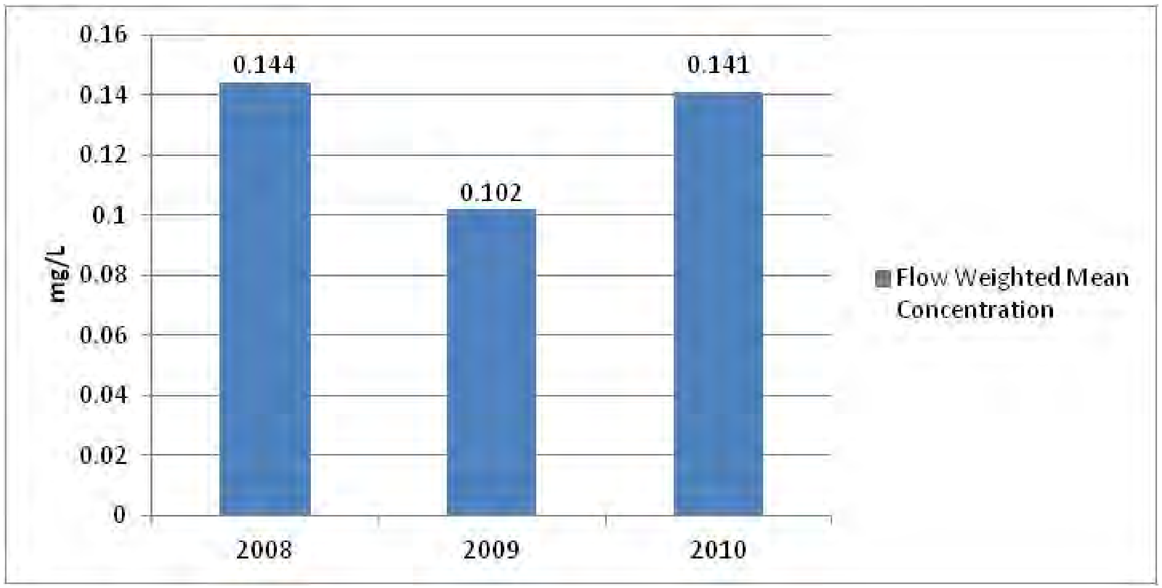

Figure 20. Dissolved Orthophosphate Flow Weighted Mean Concentrations for the Buffalo River near Georgetown, MN, 20082010

Nitrate plus nitrite - nitrogen

Currently nitrate-N standards are absent for Minnesota Rivers, but are in the "development phase," with a scheduled adoption of September 2012. The draft acute nitrate-N value (maximum standard) is 41 mg/L for a one-day duration, and the draft chronic value is 4.9 mg/L nitrate-N for a four-day duration. In addition, a draft chronic value of 3.1 mg/L nitrate- N (four-day duration) was determined for protection of class 2A surface waters. Observation of annual FWMCs of nitrate-N within the Buffalo River (21), show concentrations below the proposed acute and chronic nitrate-N standards.

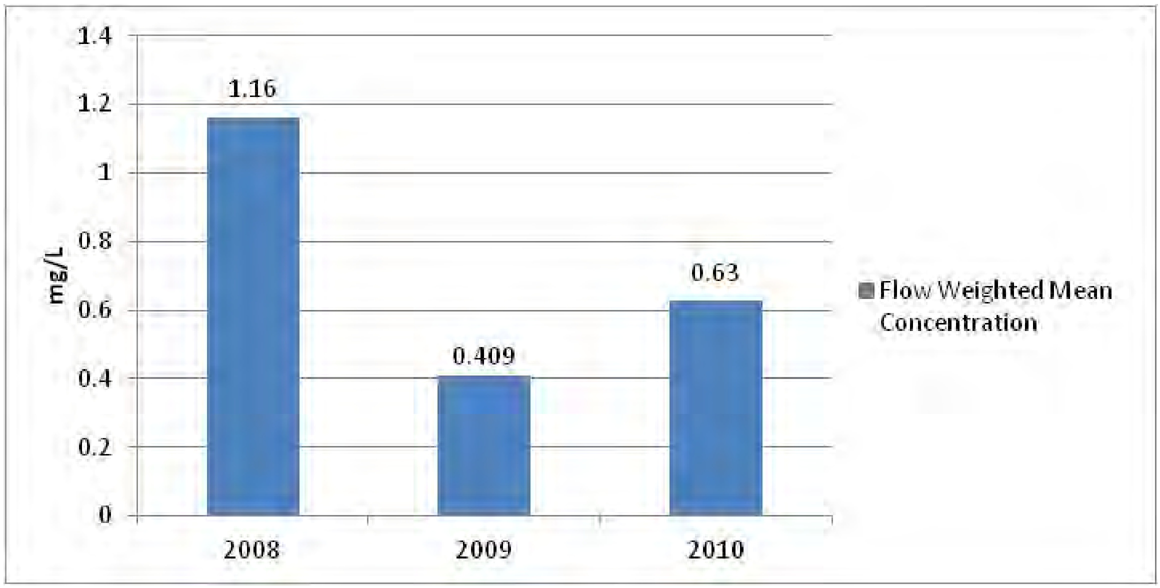

Figure 21. Nitrate + nitrite nitrogen flow weighted mean concentrations for the Buffalo River near Georgetown, Minnesota, 2008-2010

Table 42. Annual pollutant loads by parameter calculated for the Buffalo River near Georgetown, Minnesota, 2008-2010

	2008		2009		2010	
Parameter	**Mass (kg)**	**FWM (mg/L)**	**Mass (kg)**	**FWM (mg/L)**	**Mass (kg)**	**FWM (mg/L)**
Total Suspended Solids	29,389,665	82.9	32,453,762	54.2	39,793,122	65.3
Total Phosphorus	90,941	0.257	130,505	0.219	142,060	0.233
Ortho Phosphorus	51,071	0.144	60,541	0.102	86,168	0.141
Nitrate + Nitrite Nitrogen	410,810	1.16	239,600	0.409	383,419	0.63

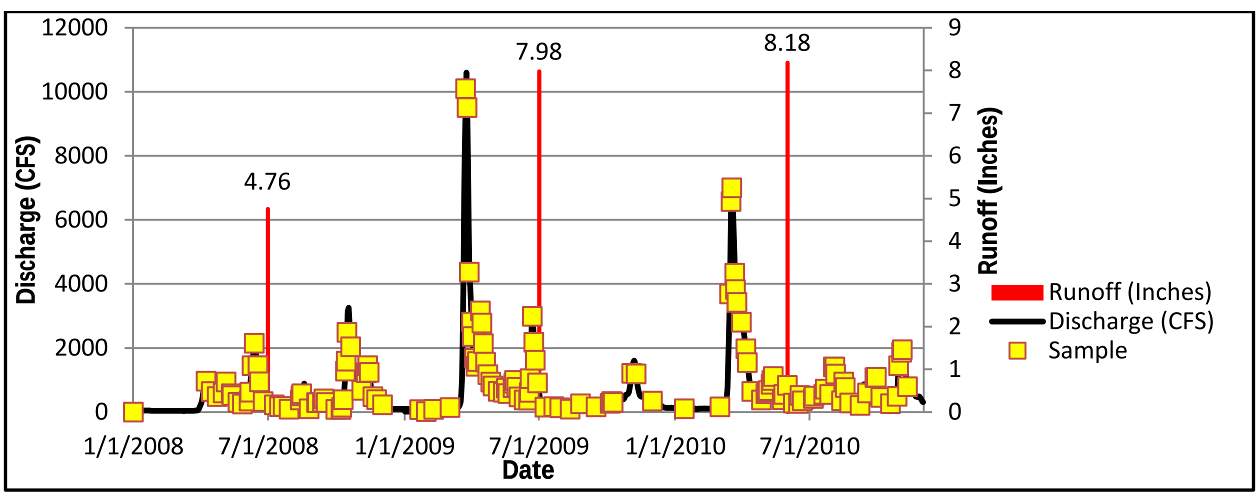

Figure 22. Discharge, runoff, and sample dates for the Buffalo River at Georgetown, Minnesota, 2008-2010

Stream water quality

Overall, water quality conditions are poor, and are reflective of the intensive cultivated land uses, altered watercourses and hydrology, and consistent lack of riparian cover found on many of the lakes and streams in the watershed. TSS and turbidity are elevated in most tributaries and Buffalo River mainstem reaches. The sources of sediment and turbidity, in addition to the naturally occurring fine silts and clays, are overland runoff and streambank scouring from hydrologic modifications in the watershed. Average nutrient concentrations of phosphorus were approaching or exceeding the proposed eutrophication threshold of 150 µg/L across the watershed. However, the chlorophyll-a yields were low as a result of the light attenuating turbidity levels. Elevated bacteria levels were found in nearly all the subwatersheds and aquatic recreation use impairments were found in all but the Upper Buffalo River subwatershed. Dissolved oxygen typically met standards; in a few subwatersheds, it was identified as a potential stressor to aquatic life.

Lake Water Quality

Buffalo River watershed lakes were assessed against the North Central Hardwood Forest ecoregion Class 2B standards for deep and shallow lakes (Appendix 2). Based on recent monitoring, more than one-third of all monitored lakes (16 of 43) exceed the eutrophication standard and are impaired for aquatic recreation use, and several more are very close to the standard. Impairments are found across the watershed, with the exception of the two eastern subwatersheds that are headwaters in nature, with more intact (forested) watersheds than the rest of the agriculturally dominated watersheds. As expected in transitional watersheds, a mix of deep and shallow lakes occurs naturally in this part of Minnesota. Shallow lakes are particularly sensitive to disturbances in the watershed as they have little ability to assimilate external inputs of phosphorus. In addition, shallow lakes are susceptible to internal loading of phosphorus, with wind mixing causing the continual resuspension of sediments and release of phosphorus into the water column. With the intensive land alteration in this watershed, and the shallow nature of the lakes, extra care should be taken to reduce watershed loading of phosphorus.

Biological monitoring

Fish

Historically, throughout the Red River Basin, there have been 86 different species of fish sampled. Although the Buffalo River watershed only encompasses a small portion of the Red River Basin, many of these species were found during the sampling for this report. Of the 86 species found within the Red River Basin, 57 were sampled within the Buffalo River watershed. Some species were found at many sites in high densities, while other species were found at limited sites and in low numbers. This watershed does not have any fish species identified by the Minnesota Department of Natural Resources as endangered; however, it does have three species identified as special concern: lake sturgeon, least darter, and pugnose shiner. With the exception of the introduced common carp, no known invasive fish or aquatic plant species are known to exist in this watershed.

The most commonly found fish species within the watershed was the white sucker, which was sampled at 67 of the 71 sites, totaling 1,553 individuals. Other species that were commonly found within the watershed included brook stickleback, creek chub, and fathead minnow, all of which were sampled at roughly 75 percent of the sites. A number of species were only sampled at one site and totaled only one individual such as chestnut lamprey, greater redhorse, mooneye, silver chub, and yellow bullhead. In contrast, the species with the highest total density was the fathead minnow, which was found at 57 sites and had 6,208 individuals sampled. A complete list of the species sampled, how many sites each species was sampled at, and the total numbers of individuals can be found in Appendix8.

Macroinvertebrates

Invertebrate species found within the Buffalo River watershed ranged from some with very low tolerance levels to high tolerance levels of pollutants or impairments. Invertebrate species were sampled from many types of habitat within the watershed. Given the location and land use characteristics of this watershed, the most common habitats sampled were stream banks and aquatic macrophytes, although other habitats sampled included wood, riffles/rocks, and/or leaf packs.

The number and types of macroinvertebrates found was very site specific, much like the fish samples, again perhaps indicating localized impairments or flow related problems. Overall, 122 different families of macroinvertebrates were found throughout the watershed. The most commonly sampled invertebrates were from the Hyalellidae Family, commonly known as scuds, consisting of over 4.5 million individuals. In contrast, many macroinvertebrate families had less than 400 individuals sampled throughout the watershed, such as Isotomidae (Springtails), Saldidae (Shore Bugs), and Tetrastemmatidae (Ribbon Worms), among others. This sharp contrast in numbers found is directly dependent on the habitat found at each location and the tolerance levels of the individual species.

Watershed-wide

The fish and macroinvertebrate data throughout the watershed suggests that species richness within a given waterway is dependent on that particular waterway’s habitat, water quality, and flow. A possible explanation for sites or AUIDs with poor scores may be due to flow or the lack thereof. Depending on time of year sampled, some small tributaries and/or channelized reaches within the watershed may have had little to no flow, which may have had an impact on the number of individuals and/or species found. Little to no flow data is available, however, for nearly all reaches, so this is not conclusive.

On the waterways that were able to be assessed for fish, 11 AUIDs met their respective thresholds for F-IBI with four AUIDs exceeding their F-IBI thresholds. For those waterways that were not able to be assessed for fish due to channelization, 19 sites had poor, 9 had fair, and 13 had good F-IBI ratings. Invertebrates showed similar results for assessed AUIDs, with seven meeting respective M-IBI thresholds and six exceeding their M-IBI thresholds. For those waterways not assessed for invertebrates, 23 sites received poor, 9 had fair, and 6 had good M-IBI ratings, and 2 were not sampled.

Fish contaminants

A summary of descriptive statistics for mercury and PCBs (Table 43) indicates the 90th percentile of mercury concentration exceeded the threshold of 0.2 mg/Kg in channel catfish from the Buffalo River. PCBs were not detected in the two largest catfish (reporting limit = 0.025 mg/Kg). Consequently, the Buffalo River was added to the draft 2012 Impaired Waters Inventory because of mercury in fish tissue (http://www.pca.state.mn.us/enzq94b).

Fish collected from Tamarac Lake (03024100) in 2003 were well below the impairment threshold for mercury and PCBs were not tested (Table 43). Fish collected from Olaf Lake (56095000) in 1995 had 90th percentile mercury concentrations in largemouth bass, northern pike, and walleye that exceeded the 0.2 mg/Kg threshold. Given the fish from Olaf Lake were collected over 10 years ago and the mercury concentrations were high, Olaf Lake fish should be scheduled for another collection and mercury analysis as soon as possible.

Table 43. Descriptive Statistics of Mercury and PCB Concentrations in Fish Species in the Buffalo River and Lakes within the Buffalo River watershed

						Length (in)			Mercury (mg/Kg)					PCBs (mg/Kg)			
Waterway	AUID	Species	Year	Total Fish	Samples	Mean	Min	Max	Mean	90th Pctl	Median	Min	Max	N	Mean	Min	Max
Buffalo River*	09020106-501	Channel catfish	2009	13	13	18.3	15.6	22.3	0.277	0.417	0.247	0.165	0.476	2	< 0.025	< 0.025	< 0.025
		Golden redhorse	2009	5	5	12.5	11.1	14.1	0.182	0.197	0.186	0.158	0.197	2	< 0.025	< 0.025	< 0.025
		Shorthead redhorse	2009	1	1	15.2			0.375								
Tamarac Lake	03024100	Bluegill sunfish	2003	8	1	7.8			0.056								
		Largemouth bass	2003	5	5	9.9	8.7	11.1	0.048	0.055	0.046	0.045	0.055				
		Northern pike	2003	5	5	18.6	16.8	21.7	0.082	0.135	0.074	0.055	0.135				
		Walleye	2003	5	5	17.6	14.9	20.8	0.095	0.118	0.089	0.079	0.118				
Olaf Lake *	56095000	Bluegill sunfish	1995	9	1	7.0			0.160								
		Largemouth bass	1995	3	2	14.4	11.8	16.9	0.325	0.400	0.325	0.250	0.400				
		Northern pike	1995	3	3	21.2	17.1	24.9	0.337	0.560	0.320	0.130	0.560				
		Walleye	1995	3	2	23.3	20.1	26.4	0.675	0.990	0.675	0.360	0.990	1	< 0.01		
		Yellow bullhead	1995	8	1	11.2			0.200								

* Impaired for mercury in fish tissue

Transparency trends

The MPCA calculates trends on transparency data collected on lakes and streams annually. A minimum of eight years of data is required to provide a statistically significant trend; for this analysis a seasonal Kendal test is run using the statistical package "R." Of the 78 stream sites with transparency tube data in the watershed, two had no trend and one had an improving trend; the rest did not have sufficient data for trend analysis (Appendix 3). Eight lakes had sufficient data for trend analysis; two had improving trends (Talac and Turtle) and the remainder had no significant trend (Appendix 3).

Stressor ID

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

Channelization and the resultant loss of habitat is one of the primary biological stressors within the Buffalo River watershed. A review of the biological data finds that 18 of the channelized reaches are found to have poor ratings. Those channelized portions that do contain healthy fish communities are typically reaches that have not been "maintained" or excavated at all or for a relatively long time. Given time and a watershed that is not contributing heavy sediment loads, these streams can recover biologically and sometimes contain good fish communities with strong IBI scores. Streams that tend to receive heavy sediment loading from either in-stream or external sources are typically cleaned out on a more regular basis and often are not able to recover biologically between clean outs.

Hydrologic modification is also a primary stressor in the Buffalo River watershed. The flashy hydrograph associated with intensive drainage tends to erode the stream banks and beds, resulting in unstable stream channels. The banks and beds of streams in this condition can contribute significant sediment loads downstream. In addition, the loss of bank and bed habitat through sloughing, erosion, and deposition results in less than ideal conditions for most species. Tiling has contributed to the altered hydrograph in recent years and the trend for increased tiling in the watershed will likely worsen the situation. In addition, the loss of base flow that results from intensive drainage can have significant impacts on the biota during dry years when stream temperatures and flow rates can impact the more sensitive members of the aquatic communities.

Erosion and the resulting sedimentation from agricultural field sources also play an important role in biological impairments within this watershed. Many examples have been documented where spring runoff and summer storm events have resulted in hundreds of tons of sediment washing off fields and into watercourses. The Stream Power Index tool helps to identify where slope and flow conditions are such that the potential for significant erosion exists. Reconnaissance surveys have determined that when sufficient vegetation is in place in the form of grassed waterways or buffers, the erosion is typically minimal. In contrast, where the vegetative buffers are poor or not present, we have found significant erosion sources in the form of blowouts, gullies, and head cuts. One of the primary issues we have identified is the farming through first order streams. These intermittent streams tend to erode annually and become a significant source of nutrients and sediment to the receiving waters. Restoring vegetation to these streams will be a priority in this watershed during implementation.

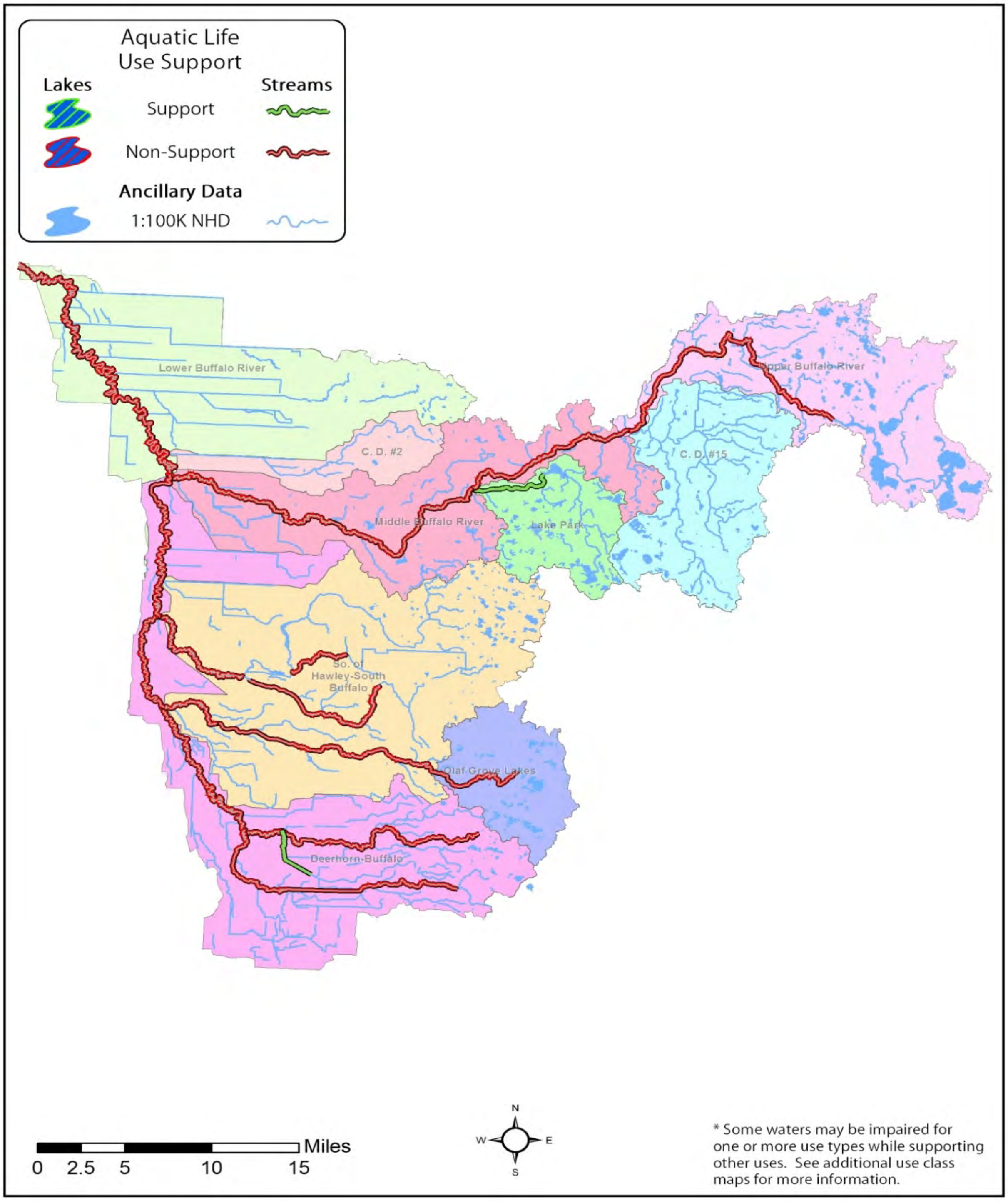

Figure 23. Aquatic life use support in the Buffalo River watershed

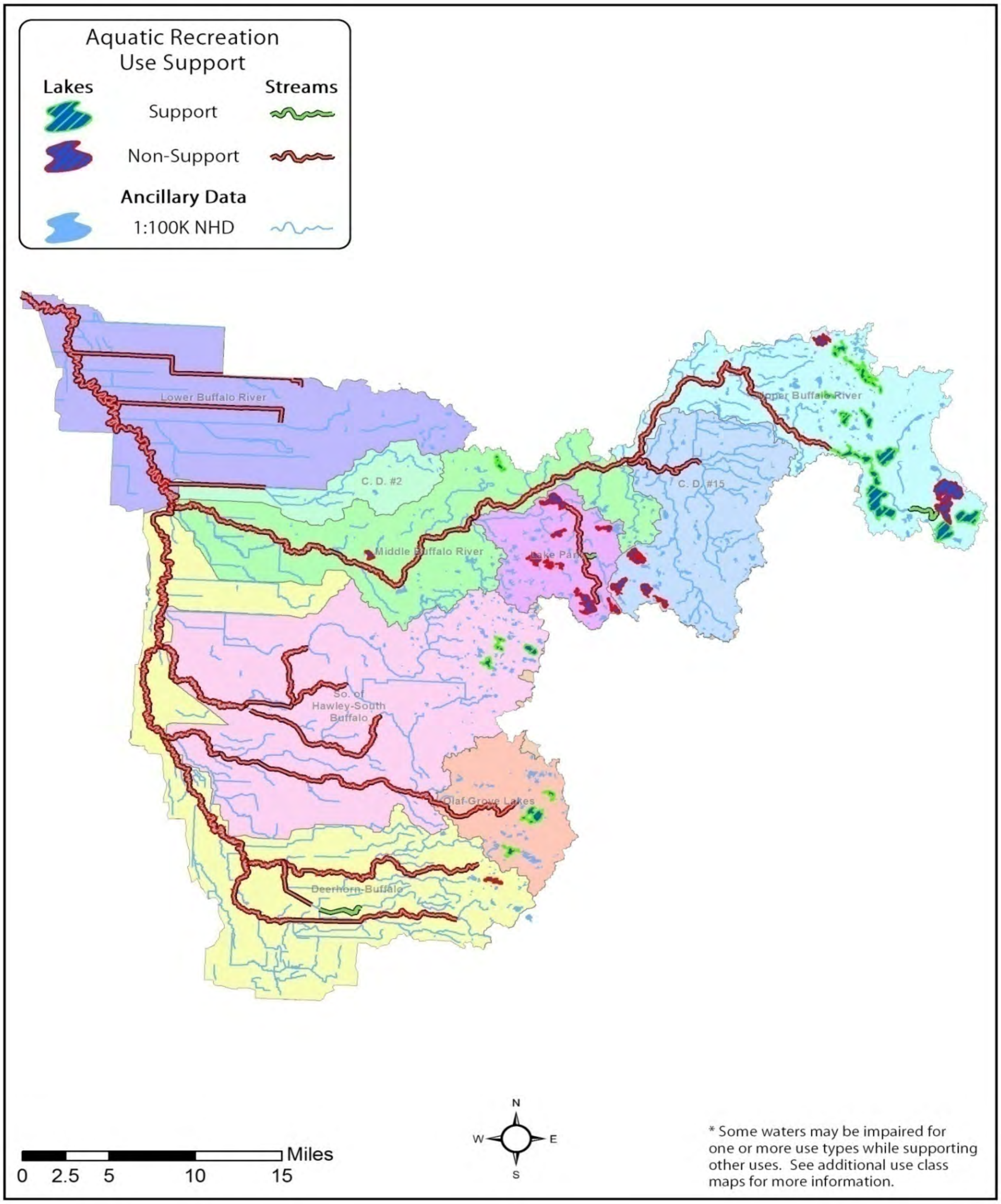

Figure 24. Aquatic recreation use support in the Buffalo River watershed

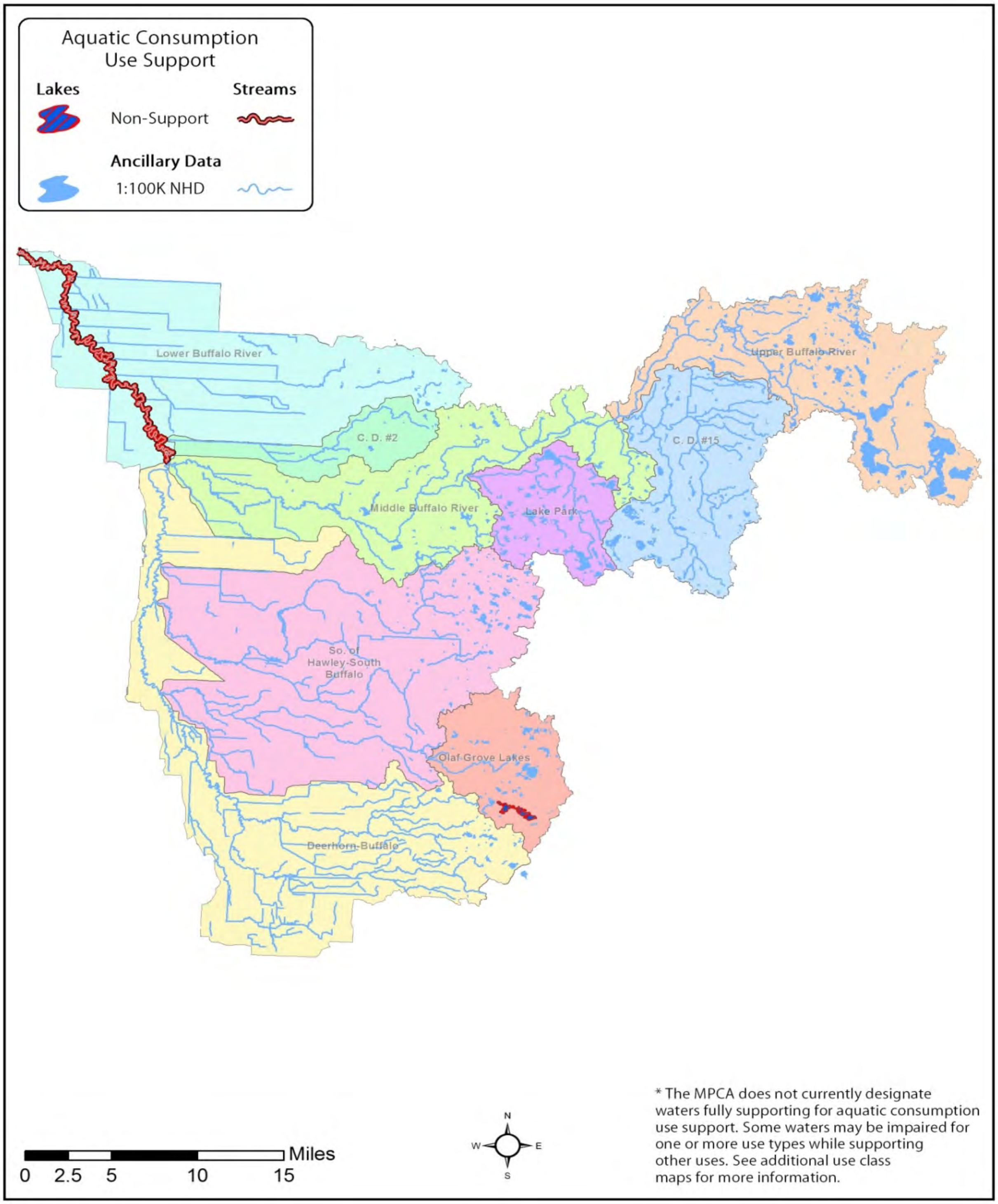

Figure 25. Aquatic consumption use support in the Buffalo River watershed

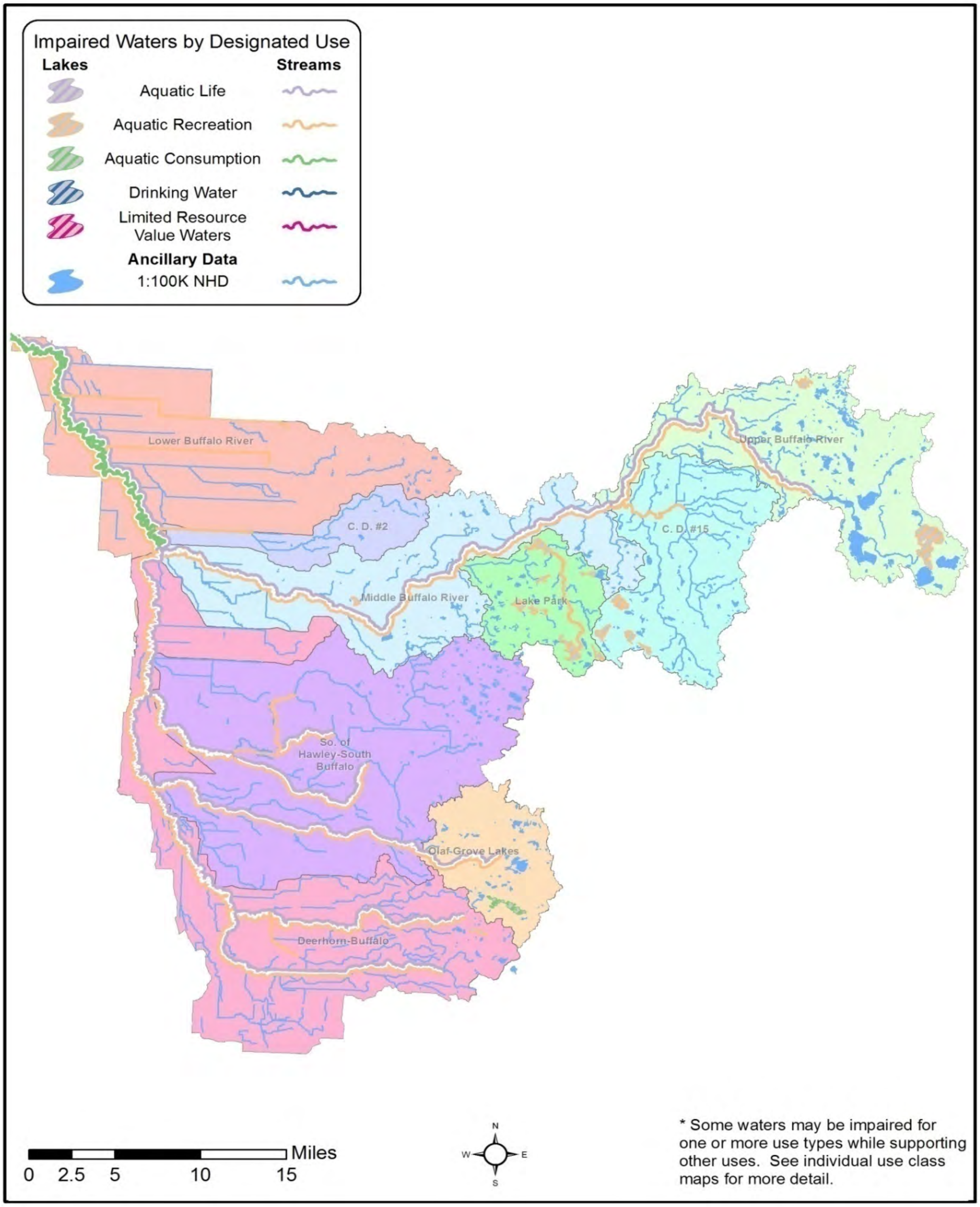

Figure 26. Impaired waters by designated use in the Buffalo River watershed

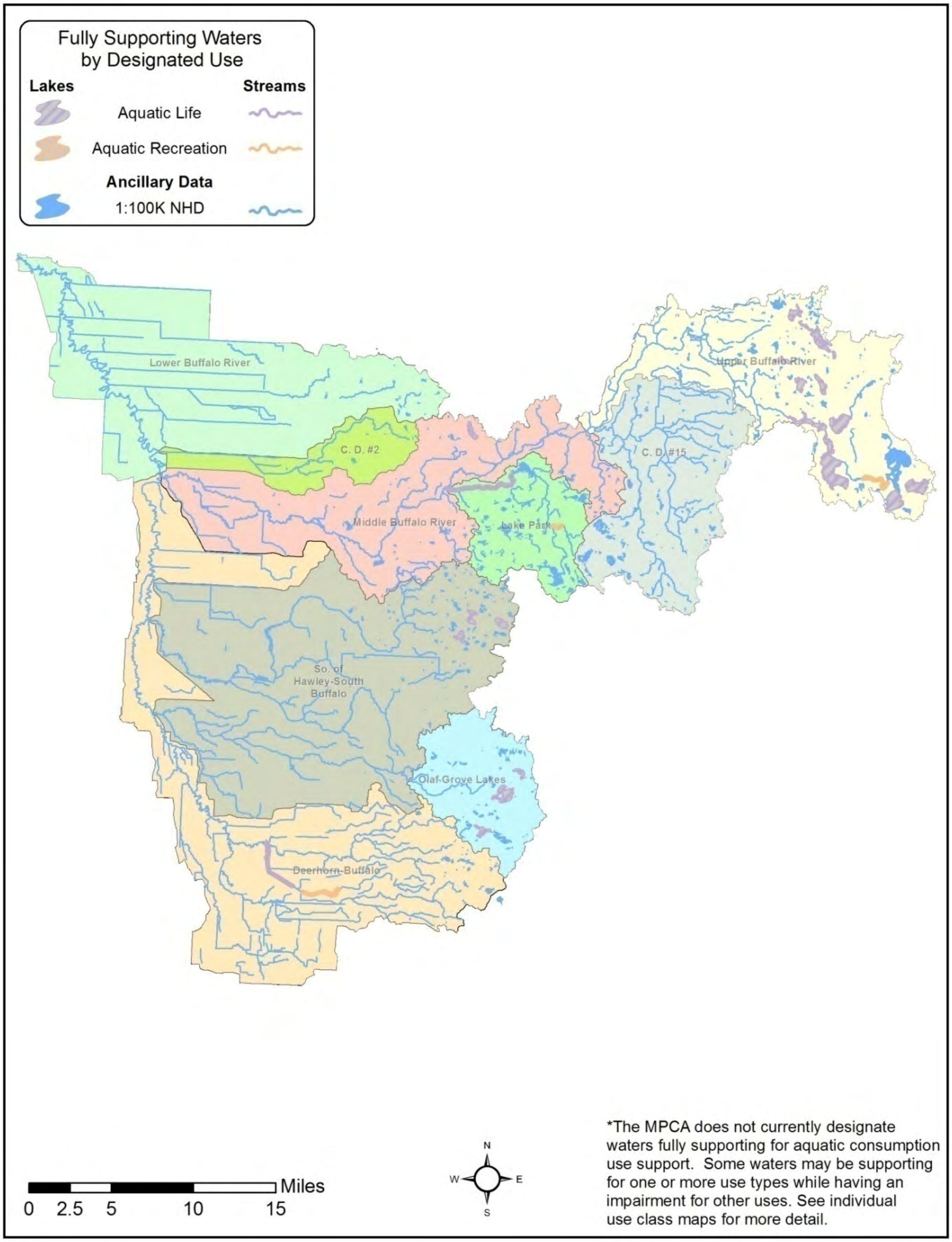

Figure 27. Fully supporting waters by designated use in the Buffalo River watershed

VIII. Summaries and Recommendations

Although the Buffalo River watershed begins in a forested and lake rich region of the state, the watershed quickly turns to a region dominated by agriculture. At the point of transition, the landscape within the watershed is dominated by cropland and rangeland, commonly combining for over 70 percent of individual HUC-11 watershed units. Due to the high degree of channelization and agricultural drainage in the watershed, combined with inadequate riparian buffers, many of the streams in the watershed have become destabilized. As a result, dramatic fluctuations of water levels result in more water discharge, typified by higher, peak flows and lower base flows.

As a result of the channel manipulation and intensive land use within the watershed, 18 AUIDs within the watershed are not meeting the state's turbidity standard. In addition to turbidity impairments, excess levels of bacteria (*Escherichia coli)* are an even larger issue within the watershed. In 24 AUIDs, the bacteria values exceeded the state standard, at some stations exceeding the standard by more than 20 times. Although the number of standard exceedances was less than turbidity and bacteria, dissolved oxygen levels are also an area of concern. Dissolved oxygen concentrations often exceeded 12 mg/L (7 of 10 outlet sites sampled), with a maximum of 18.5 mg/L and a minimum of 0.26 mg/L. With such variable concentrations occurring, these sites are possibly nutrient enriched, causing algae to produce excessive levels during the day, which results in low levels over night. Not only is nutrient loading a concern within the rivers and streams, but also in the lakes where phosphorus levels reach high concentrations, often leading to impairment. Other aquatic life indicators used for assessments in the Buffalo River watershed showed mixed results. When sampled, chloride, pH, and NH_3 all met their respective state thresholds at each site. In total, the AUIDs assessed for aquatic life within the watershed resulted in 16 being non-supporting and two being fully supporting. Assessed AUIDs for aquatic recreation resulted in 24 sites being non-supporting and one fully supporting.

Habitat, in general was poor throughout the watershed with the majority of locations receiving poor MSHA scores. As a result, it is possible that the overwhelming influence of the poor habitat conditions that dominated many stream segments combined with flow instability (particularly in headwater areas) negated the positive influence of the few isolated areas with good habitat. On the other hand, the higher IBI scores sometimes found in larger streams suggest that the year round flows found in these larger systems provide a degree of stability for aquatic communities that can, at times, offset the negative influence of poor habitat.

Dams are a large component of hydrology, which can both positively and negatively impact waterways. Dams create recreational opportunities such as areas for fishing and camping and also aid in water storage and flood control. However, dams can also restrict water flow to downstream areas, create impoundments upstream, alter stream flow, and prevent fish migration, among other impacts. Certain species of fish migrate upstream to reach suitable spawning habitat; however, some dams create barriers and prevent the fish from reaching such areas. Within the Buffalo River watershed, there are 23 dams (Boyle 2012) located on waterways ranging in size from small tributaries and ponds that flow into the Buffalo River to dams located on the mainstem of the Buffalo River. Although we did not note any direct influence of impoundments on the aquatic communities, future monitoring should focus on hydrologic connectivity issues where we have found impairments.

The high volumes of suspended sediment and nutrients found in the Buffalo River watershed pose negative impacts to not only the river's aesthetic and recreational value, but to its adjoining downstream waters and the biological communities that reside there. In order to bring turbidity and bacteria values back into compliance with the state standard, considerable measures must be taken on a watershed wide scale to better define critical areas contributing to the impairment. In addition, steps must also be taken to improve the habitat within the streams, as well as the buffer and land use around the streams.

Examples of actions that could help improve the issues listed above include:

- Establish or repair riparian zones using native vegetation and/or trees
- Protect any current riparian buffer zones and quality stream habitat
- Establish more best management practices to reduce sedimentation and erosion
- Reduce and/or limit the amount of channelization, drainage, and tiling occurring within the watershed
- Reduce the amount of agricultural, livestock, and urban runoff occurring
- Improve fish and macroinvertebrate habitat within the waterways
- Evaluate dam locations and possible negative effects on fish/macroinvertebrate communities
- Install dissolved oxygen meters at the site locations that had excess or insufficient amounts of dissolved oxygen to compare night concentrations
- Continued monitoring to evaluate and document declining or improving conditions

Progress is currently being made to complete a watershed-wide TMDL and Water Restoration and Protection Strategy, with an anticipated completion date of early 2014. The TMDL will primarily focus on the ongoing turbidity and bacteria impairments within the watershed. Since over 70 percent of the watershed is agricultural lands and nearly all sources of suspended sediment are from runoff, the TMDL will focus on the reduction of runoff to waterways. The TMDL should also incorporate additional monitoring along the Buffalo River mainstem, as well as downstream of its confluence with the Buffalo River South Branch to explain potential downstream effects of mitigations efforts that will be installed on the landscape in the future as a result of TMDL implementation activities.

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X. Appendices

Appendix 1. Water Chemistry Parameter Definitions

Dissolved oxygen (DO) - Oxygen dissolved in water required by aquatic life for metabolism. Dissolved oxygen enters into water from the atmosphere by diffusion and from algae and aquatic plants when they photosynthesize. Dissolved oxygen is removed from the water when organisms metabolize or breathe. Low DO often occurs when organic matter or nutrient inputs are high, and light inputs are low.

Escherichia coli (E. coli) - A type of fecal coliform bacteria that comes from human and animal waste. E. coli levels aid in the determination of whether or not fresh water is safe for recreation. Disease-causing bacteria, viruses and protozoan's may be present in water that has elevated levels of E. coli.

Nitrate plus Nitrite – Nitrogen - Nitrate and nitrite-nitrogen are inorganic forms of nitrogen present within the environment that are formed through the oxidation of ammonia-nitrogen by nitrifying bacteria (nitrification). Ammonia-nitrogen is found in fertilizers, septic systems and animal waste. Once converted from ammonia-nitrogen to nitrate and nitrite-nitrogen, these species can stimulate excessive levels of algae in streams. Because nitrate and nitrite-nitrogen are water soluble, transport to surface waters is enhanced through agricultural drainage. The ability of nitrite-nitrogen to be readily converted to nitrate-nitrogen is the basis for the combined laboratory analysis of nitrate plus nitrite-nitrogen (nitrate-N), with nitrite-nitrogen typically making up a small proportion of the combined total concentration. These and other forms of nitrogen exist naturally in aquatic environments; however concentrations can vary drastically depending on season, biological activity, and anthropogenic inputs.

Orthophosphate - Orthophosphate (OP) is a water soluble form of phosphorus that is readily available to algae (bioavailable). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from waste water treatment plants, noncompliant septic systems and fertilizers in urban and agricultural runoff.

pH - A measure of the level of acidity in water. Rainfall is naturally acidic, but fossil fuel combustion has made rain more acid. The acidity of rainfall is often reduced by other elements in the soil. As such, water running into streams is often neutralized to a level acceptable for most aquatic life. Only when neutralizing elements in soils are depleted, or if rain enters streams directly, does stream acidity increase.

Specific Conductance - The amount of ionic material dissolved in water. Specific conductance is influenced by the conductivity of rainwater, evaporation and by road salt and fertilizer application.

Temperature - Water temperature in streams varies over the course of the day similar to diurnal air temperature variation. Daily maximum temperature is typically several hours after noon, and the minimum is near sunrise. Water temperature also varies by season as does air temperature.

Total Kjeldahl Nitrogen (TKN) - The combination of organically bound nitrogen and ammonia in wastewater. TKN is usually much higher in untreated waste samples then in effluent samples.

Total Phosphorus (TP) - Nitrogen (N), phosphorus (P) and potassium (K) are essential macronutrients and are required for growth by all animals and plants. Increasing the amount of phosphorus entering the system therefore increases the growth of aquatic plants and other organisms. Excessive levels of Phosphorous overstimulate aquatic growth and resulting in the progressive deterioration of water quality from overstimulation of nutrients, called eutrophication. Elevated levels of phosphorus can result in: increased algae growth, reduced water clarity, reduced oxygen in the water, fish kills, altered fisheries and toxins from cyanobacteria (blue green algae) which can affect human and animal health.

Total Suspended Solids (TSS) – TSS and turbidity are highly correlated. Turbidity is a measure of the lack of transparency or "cloudiness" of water due to the presence of suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter and plankton or other microscopic organisms. The greater the level of TSS, the murkier the water appears and the higher the measured turbidity. Higher turbidity results in less light penetration which may harm beneficial aquatic species and may favor undesirable algae species. An overabundance of algae can lead to increases in turbidity, further compounding the problem.

Total Suspended Volatile Solids (TSVS) - Volatile solids are solids lost during ignition (heating to 500 degrees C.) They provide an approximation of the amount of organic matter that was present in the water sample. ‘‘Fixed solids’’ is the term applied to the residue of total, suspended, or dissolved solids after heating to dryness for a specified time at a specified temperature. The weight loss on ignition is called ‘‘volatile solids.’’

Unionized Ammonia (NH3) - Ammonia is present in aquatic systems mainly as the dissociated ion $NH4^+$, which is rapidly taken up by phytoplankton and other aquatic plants for growth. Ammonia is an excretory product of aquatic animals. As it comes in contact with water, ammonia dissociates into $NH4^+$ ions and ^-OH ions (ammonium hydroxide). If pH levels increase, the ammonium hydroxide becomes toxic to both plants and animals.

Appendix 2. Lake Morphometric and Assessment Data for the Buffalo River Watershed

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Mean Depth (m)	Watershed Area (ha)	% Littoral	Aquatic Recreation Use Support[4]
[1]03-0200-00	Pine	Becker	9020106010	NLF	218.5	5.5	2.7	521	89.5	FS
[1]03-0241-01	South Tamarac	Becker	9020106010	NLF	222.6	4.9	1.5	829	100	FS
[1]03-0241-02	North Tamarac	Becker	9020106010	NLF	579.9	5.2	2.4	3659	95.5	NS[5]
03-0243-00	Mary Yellowhead	Becker	9020106010	NLF	13.8					
03-0290-00	Spring	Becker	9020106010	NCHF	21.9	18.3			40	
03-0291-00	Rice	Becker	9020106010	NCHF	90.8	7	2.3	8154	72.9	FS
03-0293-00	Rock	Becker	9020106010	NCHF	485.7	5.5	2.4	7868	95.5	FS
03-0294-00	Momb	Becker	9020106010	NCHF	18.5	8.2			62.4	
03-0295-00	North Twin	Becker	9020106010	NCHF	8.5					
03-0298-00	Werk	Becker	9020106010	NCHF	38.5					
03-0299-00	Rochert	Becker	9020106010	NCHF	8.3					
03-0301-00	North Momb	Becker	9020106010	NCHF	11.6					
[1]03-0302-00	Little Round	Becker	9020106010	NCHF	219.9	1.7	0.8	4398	100	FS
03-0304-00	Big Sugar Bush	Becker	9020106010	NCHF	177.4	12.8	3.4	1344	63.1	FS
03-0312-00	Bullhead	Becker	9020106010	NCHF	13.4					
03-0313-00	Little Sugar Bush	Becker	9020106010	NCHF	85.7	8.8	3.9	2370	49	FS
03-0314-00	Fish	Becker	9020106010	NCHF	32.8	18			51.4	
03-0316-00	Mud	Becker	9020106010	NCHF	20.2	2.4			100	
03-0318-00	Eagen	Becker	9020106010	NCHF	30.9	4.9			97.5	
03-0319-00	Blackberry	Becker	9020106010	NCHF	25.2					
03-0325-00	Cranberry	Becker	9020106010	NCHF	14.3					
03-0344-00	Unnamed	Becker	9020106010	NCHF	6.6					
03-0350-00	Buffalo	Becker	9020106010	NCHF	180	11.2	4.4	13969	51	FS
03-0351-00	Island	Becker	9020106010	NCHF	85.6	3	1.6	739	100	FS
03-0352-00	Birch	Becker	9020106010	NCHF	88.2	7.6	2	724	82.3	FS
03-0406-00	Houg	Becker	9020106010	NCHF	18.1					
03-0427-00	Unnamed	Becker	9020106010	NCHF	4.9					
03-0428-00	O-Me-Mee	Becker	9020106010	NCHF	54.9	3	1.5	2287	100	IF

-continued-

Appendix 2 (continued)

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Mean Depth (m)	Watershed Area (ha)	% Littoral	Aquatic Recreation Use Support[4]
03-0429-00	Fairbank's	Becker	9020106010	NCHF	39.1					
03-0430-00	St. Clair	Becker	9020106010	NCHF	43.1	5.8	1.4	3254	88.6	FS
03-0432-00	Anderson	Becker	9020106010	NCHF	15.3					
03-0436-00	Unnamed (Kutz)	Becker	9020106010	NCHF	7.6	4.9			94	
03-0438-00	Unnamed	Becker	9020106010	NCHF	8.3					
03-0439-00	Carrott	Becker	9020106010	NCHF	16.6					
03-0440-00	Squash	Becker	9020106010	NCHF	11.3					
03-0442-00	Unnamed	Becker	9020106010	NCHF	7.1					
03-0471-00	Mission	Becker	9020106010	NCHF	98.6	2.4	1.6	350	100	NS
03-0558-00	Unnamed	Becker	9020106010	LAP	8.2					
03-0559-00	Unnamed (Skaeim)	Becker	9020106010	LAP	15.7					
03-0562-00	Trotochaud	Becker	9020106010	LAP	37					
03-0390-00	Wheeler	Becker	9020106020	NCHF	25	13.1			81.6	
03-0393-00	Unnamed	Becker	9020106020	NCHF	4.3					
03-0414-00	Gandrud	Becker	9020106020	NCHF	10					
03-0508-00	Unnamed	Becker	9020106020	LAP	12.7					
03-0513-00	Reep	Becker	9020106020	LAP	19.3					
[1,2]03-0516-00	Canary	Becker	9020106020	NCHF	27.3	7.6	3.4	143	65	IF
03-0517-00	Gilbertson	Becker	9020106020	NCHF	17.9					
03-0519-00	Bluebird	Becker	9020106020	LAP	6.4					
03-0521-00	Audubon	Becker	9020106020	NCHF	31.6					
03-0524-00	North Barnes	Becker	9020106020	NCHF	17	5.5			93.8	
03-0525-00	South Barnes	Becker	9020106020	NCHF	31.8	3			100	
03-0526-00	Marshall	Becker	9020106020	NCHF	75	6.1	3.2	215	66	NS
[1]03-0528-00	Gottenburg	Becker	9020106020	NCHF	46.7	3.4	1	502	100	NS
03-0529-00	South McKinstry	Becker	9020106020	NCHF	4.7	1.8			100	
03-0531-00	Minnetonka	Becker	9020106020	NCHF	16.5	6.7			81.8	
03-0532-00	Jay	Becker	9020106020	NCHF	9.6					
03-0533-00	Unnamed	Becker	9020106020	NCHF	6					

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Appendix 2 (continued)

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Mean Depth (m)	Watershed Area (ha)	% Littoral	Aquatic Recreation Use Support[4]
03-0535-00	Berseth	Becker	9020106020	NCHF	8.9					
03-0536-00	Pierce	Becker	9020106020	LAP	35.8					
03-0550-00	Seabold	Becker	9020106020	LAP	39.6					
03-0578-00	Unnamed	Becker	9020106020	LAP	9.6					
03-0579-00	Boyer	Becker	9020106020	NCHF	130.6	7.9	2.8	843	65.8	NS
[1]03-0624-00	Forget-Me-Not	Becker	9020106020	NCHF	95.4	2.1	1	859	100	
03-0634-00	Orange	Becker	9020106020	NCHF	24.2					
03-0767-00	Unnamed	Becker	9020106020	LAP	9.6					
03-0768-00	Unnamed	Becker	9020106020	LAP	4.2					
03-0948-00	Unnamed	Becker	9020106020	NCHF	7.2					
[1,2]03-0618-00	Sand	Becker	9020106030	NCHF	23.6	2.7	1.5	79	100	IF
[1]03-0619-00	Talac	Becker	9020106030	NCHF	39.7	4	2.8	2194		NS
03-0621-00	Lund Brothers Marsh	Becker	9020106030	NCHF	12.1					
03-0622-00	Unnamed	Becker	9020106030	NCHF	11.4					
[1,2]03-0625-00	Sorenson	Becker	9020106030	NCHF	17.1	2.4	1.7	382	100	NS
03-0627-00	Unnamed	Becker	9020106030	NCHF	7.7					
03-0628-00	Unnamed	Becker	9020106030	NCHF	6.8					
03-0631-00	Stakke	Becker	9020106030	NCHF	194.5	4.6	2.1	1230	99.3	NS
03-0632-00	Prune	Becker	9020106030	NCHF	13					
03-0633-00	Horan	Becker	9020106030	NCHF	30.8					
03-0635-00	Gourd	Becker	9020106030	NCHF	48.8	1.8	1.2	146	100	NS
03-0636-00	Engebretson	Becker	9020106030	NCHF	12.4	2.6				
03-0638-00	Beseau	Becker	9020106030	NCHF	88.8	8.2	3.1		53.1	
03-0643-00	Brannigan	Becker	9020106030	NCHF	19.8					
03-0645-00	West LaBelle	Becker	9020106030	NCHF	40.9	5.8	1.3	780		NS
03-0646-00	Lime	Becker	9020106030	NCHF	43.4	2.4	1.4	2785	100	NS
03-0647-00	Stinking	Becker	9020106030	NGP	153.3	2.4	1.5	6263	100	NS
03-0648-00	East LaBelle	Becker	9020106030	LAP	77.8		3.2	614	53	IF

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Appendix 2 (continued)

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Mean Depth (m)	Watershed Area (ha)	% Littoral	Aquatic Recreation Use Support[4]
03-0651-00	Unnamed	Becker	9020106030	LAP	5.6					
03-0659-00	Sand	Becker	9020106030	NCHF	81.4	8.5	4.3	1483	52.3	NS
03-0660-01	Axberg (Main Basin)	Becker	9020106030	NCHF	13.2					
03-0660-02	Axberg (West Basin)	Becker	9020106030	NCHF	4.8					
03-0662-00	Cuba	Becker	9020106030	NCHF	21.1					
03-0920-00	Unnamed	Becker	9020106030	NCHF	5.7					
14-0003-00	Anderson	Clay	9020106030	NCHF	8.9					
14-0045-00	Unnamed	Clay	9020106030	NCHF	14					
14-0047-00	Moe	Clay	9020106030	NCHF	18.4					
14-0052-00	Solum	Clay	9020106030	NCHF	10.3					
14-0053-00	Christ Olson	Clay	9020106030	NCHF	27.4					
14-0054-00	Hoe	Clay	9020106030	NCHF	21					
14-0061-00	Erickson	Clay	9020106030	NCHF	22.2					
14-0062-00	Jergenson	Clay	9020106030	NCHF	24.8	2.1			100	
03-0514-00	Unnamed	Becker	9020106040	LAP	4.8					
03-0545-00	Lee Marshes	Becker	9020106040	LAP	8.9					
03-0552-00	Unnamed	Becker	9020106040	LAP	9.1					
03-0612-00	Little Boyer	Becker	9020106040	NCHF	6.9					
03-0650-00	Unnamed	Becker	9020106040	LAP	21.8					
03-1118-00	Unnamed	Becker	9020106040	LAP	5.5					
14-0049-00	Lee	Clay	9020106040	NCHF	55.4	11	4.2	1904	64.2	NS
14-0050-00	Unnamed	Clay	9020106040	NCHF	6.5					
14-0056-00	Knudson	Clay	9020106040	NCHF	13.2					
14-0058-00	Perch	Clay	9020106040	NCHF	16	5.2			83.9	
14-0059-00	Unnamed	Clay	9020106040	NCHF	5.2					
[1]14-0078-00	Swede Grove	Clay	9020106040	NCHF	63	2.4	1.2	619	100	NS
14-0079-00	Meyer	Clay	9020106040	NCHF	27.5					
14-0089-00	Doran	Clay	9020106040	NCHF	31.4					
[1]14-0099-00	Maria	Clay	9020106040	NCHF	43.6	2.7	1.4	542	100	NS

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Appendix 2 (continued)

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Mean Depth (m)	Watershed Area (ha)	% Littoral	Aquatic Recreation Use Support[4]
14-0100-00	Silver	Clay	9020106040	NCHF	46.5	11.9	6.8	1791	31.6	IF
56-1019-01	Grena	Otter Tail	9020106050	NCHF	38.3					
56-1026-00	Sands	Otter Tail	9020106050	NCHF	22.7					
56-1037-00	Colness	Otter Tail	9020106050	NCHF	34.3	1.8			100	
56-1039-00	Jacobs	Otter Tail	9020106050	NCHF	48.6	5.2	1.1	2345	100	NS
56-1046-00	Unnamed	Otter Tail	9020106050	NCHF	17.9					
84-0012-00	Unnamed	Wilkin	9020106050	NCHF	6.9					
[2]03-0657-00	Turtle	Becker	9020106060	NCHF	74.4	22.3	8.2	366	38	
03-0658-00	Long	Becker	9020106060	NCHF	40	4			100	
03-0661-00	Pump	Becker	9020106060	NCHF	26.3					
[1,3]14-0018-00	Eleven	Clay	9020106060	NCHF	60	2.4	1.4	2647	100	FS
14-0019-00	Three	Clay	9020106060	NCHF	37.8					
14-0020-00	Unnamed	Clay	9020106060	NCHF	6.8					
14-0021-00	Ten	Clay	9020106060	NCHF	62.1	5.2	1.7	4686	90.1	IF
14-0026-00	Thirteen	Clay	9020106060	NCHF	20.2					
[1]14-0029-00	Unnamed (North Mayfield)	Clay	9020106060	NCHF	9.3	4	2.4	19094	100	IF
14-0030-00	Fifteen	Clay	9020106060	NCHF	58.6	6.7	3.1	4309	70.5	FS
14-0038-00	Laura	Clay	9020106060	NCHF	23					
14-0063-00	Overson	Clay	9020106060	NCHF	21.8	3.7			100	
14-0065-00	Burke	Clay	9020106060	NCHF	14.7					
14-0068-00	Unnamed (Jetvig)	Clay	9020106060	NCHF	9.7	3.7				
14-0069-00	Abrahamson	Clay	9020106060	NCHF	5.9					
14-0071-00	Ness	Clay	9020106060	NCHF	32.1					
14-0096-00	Bjorndahl	LAP	9020106060	NCHF	5.7					
14-0143-00	Unnamed	LAP	9020106060	NCHF	9.2					
14-0001-00	Maple	Clay	9020106070	NCHF	15.8					
14-0009-00	Solem	Clay	9020106070	NCHF	27.9					
14-0012-00	Whiskey	Clay	9020106070	NCHF	13.8					
14-0014-00	Unnamed	Clay	9020106070	NCHF	5.3					

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Appendix 2 (continued)

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Mean Depth (m)	Watershed Area (ha)	% Littoral	Aquatic Recreation Use Support[4]
56-0933-00	Unnamed	Otter Tail	9020106070	NCHF	7.7					
[1]56-0934-00	Harrison (Helgeson)	Otter Tail	9020106070	NCHF	44.1	3.7	1.9	752	100	IF
56-0935-00	Rankle	Otter Tail	9020106070	NCHF	14.1					
56-0936-00	Businger	Otter Tail	9020106070	NCHF	18.4					
56-0941-00	Pete	Otter Tail	9020106070	NCHF	40.3	4.9	0.9	1802	100	FS
56-0950-01	West Olaf	Otter Tail	9020106070	NCHF	58.2	18.6	3.7	2227		FS
56-0950-02	East Olaf	Otter Tail	9020106070	NCHF	93.1					
56-0951-00	Deadman	Otter Tail	9020106070	NCHF	9.1					
56-0952-00	Grove	Otter Tail	9020106070	NCHF	165.9	4.6	1.2	3486	99.5	FS
56-1021-00	Unnamed	Otter Tail	9020106070	NCHF	4.9					
56-1022-00	Alfred	Otter Tail	9020106070	NCHF	13.5					
56-1030-00	Gaards	Otter Tail	9020106070	NCHF	23.1					
56-1031-00	Unnamed	Otter Tail	9020106070	NCHF	12.6					
56-1033-00	Unnamed	Otter Tail	9020106070	NCHF	6.6					
56-1600-00	Unnamed	Otter Tail	9020106070	NCHF	8.5					
14-0090-00	Solwald	Clay	9020106090	LAP	24.6					
14-0091-00	Buhaug	Clay	9020106090	LAP	8.3					
14-0092-00	Tatlie	Clay	9020106090	LAP	24.2					
14-0102-00	Unnamed	Clay	9020106090	LAP	10					
14-0103-00	Cromwell	Clay	9020106090	LAP	11.6					
14-0106-00	Hotsie	Clay	9020106090	LAP	12.5					
14-0107-00	Unnamed	Clay	9020106090	LAP	5.1					
14-0336-00	Hartke	Clay	9020106090	LAP	6.8					

1. Mean depths estimated.
2. Watershed area estimated from MDNR lake catchment file
3. Due to available maps and sampling location, only the north basin was used to calculate mean depth and lake area for Lake Eleven.
4. NS = not supporting, FS = supporting, IF = insufficient information to determine support, NA = not assessed (too small or wetland-like)
5. Lake is not supporting aquatic recreation use due to natural conditions; no TMDL is required.

Appendix 3. MINLEAP Modeling Results for the Buffalo River Watershed, 2012

Lake ID	Lake Name	Obs TP	MINLEAP TP	Obs Chl-a	MINLEAP Chl-a	Obs Secchi	MINLEAP Secchi	Average TP Inflow	TP Load	Background TP	P Retention	Outflow	Residence Time	Areal Load
		ug/L	ug/L	ug/L	ug/L	m	m	ug/L	kg/yr	ug/L	%	hm3/yr	years	m/yr
03-0200-00	Pine	24	19	8	5	2.1	3.0	64	95	30.3	70	1.48	4.0	0.68
03-0241-01	South Tamarac	20	26	4	8	1.9	2.3	60	133	36.0	57	2.2	1.5	0.99
03-0241-02	North Tamarac	36	25	13	7	1.7	2.4	57	525	31.3	56	9.17	1.5	1.58
03-0291-00	Rice	28	90	7	47	2.2	0.8	150	1596	-	40	10.64	0.2	11.71
03-0293-00	Rock	27	58	7	25	1.8	1.2	159	1660	-	64	10.42	1.1	2.15
03-0302-00	Little Round	25	80	3	40	0.8*	0.9	157	912	41.0	49	5.81	0.4	2.64
03-0304-00	Big Sugar Bush	13	40	3	14	5.6	1.6	171	312	-	77	1.82	3.3	1.02
03-0313-00	Little Sugar Bush	22	57	11	24	3.0	1.2	155	482	-	63	3.12	1.1	3.64
03-0350-00	Buffalo	23	74	9	36	3.0	0.9	150	2742	-	51	18.23	0.4	10.13
03-0351-00	Island	23	56	6	24	2.5	1.2	169	168	-	67	0.99	1.4	1.16
03-0352-00	Birch	37	51	16	20	2.8	1.3	170	166	-	70	0.98	1.8	1.11
03-0428-00	O-Me-Mee	68	84	21	43	1.7	0.8	152	456	-	45	3.00	0.3	5.46
03-0430-00	St. Clair	24	97	8	52	3.1	0.8	150	639	-	36	4.25	0.1	9.85
03-0471-00	Mission	120	44	76	17	0.6	1.5	196	97	-	77	0.49	3.2	0.50
03-0516-00	Canary					1.6		181	36	-	-	0.20	4.7	0.72
03-0526-00	Marshall	42	31	21	10	1.9	2.0	206	64	-	85	0.31	7.8	0.41
03-0528-00	Gottenburg	68	69	34	32	0.8	1.0	165	111	-	58	0.67	0.7	1.44
03-0579-00	Boyer	54	41	24	15	2.4	1.6	175	201	-	76	1.15	3.2	0.88
03-0624-00	Forget-Me-Not	82	66	27	30	0.9	1.0	168	194	-	60	1.15	0.8	1.21
03-0618-00	Sand	83	45	9	17	1.1	1.5	199	22	-	77	0.11	3.2	0.48
03-0619-00	Talac	93	77	29	38	1.9	0.9	151	434	-	49	2.87	0.4	7.22
03-0625-00	Sorenson	177	70	41	33	1.7	1.0	156	79	-	55	0.50	0.6	2.94
03-0631-00	Stakke	65	46	30	18	1.5	1.4	179	295	-	0.74	1.68	2.4	0.86
03-0635-00	Gourd	113	48	54	19	0.6	1.4	204	43	-	76	0.21	2.8	0.43
03-0645-00	West LaBelle	89	73	41	35	1.3	1.0	158	162	-	53	1.03	0.5	2.52
03-0646-00	Lime	138	94	63	50	0.9	0.8	151	549	-	38	3.64	0.2	8.38
03-0647-00	Stinking	309	312	96	289	0.7	0.3	1609	4743	-	81	2.95	0.8	1.92
03-0648-00	East LaBelle	38	42	15	15	2.2	1.6	171	141	-	76	0.83	3.0	1.07
03-0659-00	Sand	125	49	28	19	2.0	1.4	158	310	-	69	1.96	1.8	2.41
14-0049-00	Lee	43	60	18	26	1.1	1.1	153	383	-	61	2.5	0.9	4.51
14-0078-00	Swede Grove	77	186	30	136	1.6	0.4	2066	483	-	91	0.23	3.2	0.37
14-0099-00	Maria	199	192	56	142	1.1	0.4	1919	420	-	90	0.22	2.8	0.50
14-0100-00	Silver	50	53	17	22	1.8	1.3	153	369	-	66	2.35	1.3	5.05
56-1039-00	Jacobs	87	93	38	50	1.9	0.8	152	466	-	39	3.07	0.2	6.31
03-0657-00	Turtle	12	24	4	7	6.6	2.5	183	93	-	87	0.51	12.1	0.68
14-0018-00	Eleven[1]	26	103	6	57	2.2	0.7	150	517	-	31	3.45	0.1	14.2
14-0021-00	Ten	57	93	27	49	1.7	0.8	150	920	-	38	6.12	0.2	9.85
14-0029-00	Unnamed	17	132	7	82	2.5	0.6	148	3676	-	11	24.83	-	266.95
14-0030-00	Fifteen	33	80	14	40	2.2	0.9	151	847	-	47	5.63	0.3	9.6

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Appendix 3 (continued)

Lake ID	Lake Name	Obs TP	MINLEAP TP	Obs Chl-a	MINLEAP Chl-a	Obs Secchi	MINLEAP Secchi	Average TP Inflow	TP Load	Background TP	P Retention	Outflow	Residence Time	Areal Load
56-0934-00	Harrison (Helgeson)	54	63	33	28	1.4	1.1	159	158	-	60	1	0.8	2.26
56-0941-00	Pete	54	96	12	52	3	0.8	152	359	-	37	2.36	0.2	5.85
56-0950-01	West Olaf	30	64	11	29	2.4	1.1	153	446	-	58	2.92	0.7	5.01
56-0952-00	Grove	41	77	14	37	3.1	0.9	157	720	-	51	4.6	0.4	2.77

Appendix 4. Intensive Water Chemistry Monitoring Stations in the Buffalo River Watershed

Biological Station ID	STORET ID	Stream Name	Sample Location	HUC-11
09RD005	S004-145	Buffalo River	At Cty Hwy 9, 5 mi. S of Lake Park	9020106010
09RD004	S005-135	County Ditch #15	At 170th Ave, 5 mi. NE of Lake Park	9020106020
09RD003	S005-606	Hay Creek	At 265th St. N, Near Hawley	9020106030
09RD002	S002-700	Buffalo River	At Cty Rd 68, 2 mi. NW of Glyndon	9020106040
09RD006	S004-148	Buffalo River	At Cty Rd 79, 1.5 mi. SW of Glyndon	9020106050
09RD007	S002-711	Stony Creek	At Cty Rd 68, 2 mi. SE of Sabin	9020106060
09RD008	S005-607	Whisky Creek	At 90th St. South, near Baker	9020106060
09RD009	S000-174	Buffalo River	At US Hwy 75, near Georgetown	9020106090

Appendix 5. AUID Table of Results by Parameter and Beneficial Use for the Buffalo River Watershed

					USES			BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS											
Stream Segment AUID	Stream Segment Name	Stream Segment Description	NHD Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Aquatic Consumption	Fish	Macro-invertebrates	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc	Chloride	Escherichia coli	pH	Turbidity	Un-ionzed ammonia	Dissolved Oxygen
HUC-11: 09020106010 (Upper Buffalo River)																					
09020106-593	Buffalo River	Buffalo Lake to Unnamed Ditch	25.8	2B	NS	NS	NA	-	-							+	-	FS	-	FS	IF
09020106-594	Buffalo River	Unnamed Ditch to Hay Creek	17.57	2B	NS	NS	NA	+	+							+	-	+	-	+	IF
HUC-11: 09010206020 (County Ditch #15)																					
09020106-515	Unnamed Ditch (Becker Cty Ditch #15)	Unnamed Ditch to Buffalo River	6.35	2B	IF	NS	NA	NA	NA							+	-	+	+	+	IF
09020106-516	Unnamed Ditch	T139 R42W S9, south line to Reep Lake	2.4	7	NA	NA	NA	NA	NA												
09020106-518	Unnamed Stream	Reep Lake to Unnamed Ditch	5.05	2B	NA	NA	NA	NA	NA												
09020106-527	Unnamed Ditch	Unnamed Ditch to T139 R42 S16, north line	1.97	2B	NA	NA	NA	NA	NA												
09020106-577	Unnamed Ditch	Unnamed Creek to Unnamed Ditch	2.2	2B	NA	NA	NA	NA	NA												
09020106-578	Unnamed Ditch	Unnamed Creek to Unnamed Ditch	1.51	2B	NA	NA	NA	NA	NA												
09020106-514	Unnamed Ditch	Headwaters to Spring Lake	4.01	7	NA	NA	NA	NA	NA												
HUC-11: 09020106030 (Lake Park)																					
09020106-511	Hay Creek	Headwaters to Stinking Lake	8.9	2B	IF	NS	NA	NA	NA							+	-	+	+	+	+
09020106-576	Unnamed Creek	Unnamed Creek to Hay Creek	0.98	2B	IF	FS	NA	NA	NA							+	+	+	+	+	IF
09020106-513	Hay Creek	Stinking Lake to Buffalo River	5.35	2B	FS	NA	NA	FS	NA							+		+	+	+	IF
HUC-11: 09020106040 (Middle Buffalo River)																					
09020106-594	Buffalo River	Unnamed Ditch to Hay Creek	17.57	2B	NS	NS	NA	+	+							+	-	+	-	+	IF
09020106-595	Buffalo River	Hay Creek to S Branch Buffalo R	38.4	2B	NS	NS	NA	+	+							+	-	+	-	+	IF
09020106-580	Unnamed Creek	Unnamed Creek to Buffalo Creek	3.19	2B	NA	NA	NA	NA	NA												
09020106-581	County Ditch 16	Unnamed Creek to Buffalo Creek	6.77	2B	NA	NA	NA	NA	NA												
09020106-582	Unnamed Creek	Unnamed Creek to Buffalo Creek	4.45	2B	NA	NA	NA	NA	NA												

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets Standards or Ecoregion Norms (+); Exceeds Standards or Ecoregion Norms (-); Channelized streams were not assessed for aquatic life.

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Appendix 5 (continued)

					USES			BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS											
Stream Segment AUID	Stream Segment Name	Stream Segment Description	NHD Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Aquatic Consumption	Fish	Macroinvertebrates	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc	Chloride	Escherichia coli	pH	Turbidity	Un-ionzed ammonia	Dissolved Oxygen
HUC-11: 09020106050 (Deerhorn-Buffalo)																					
09020106-503	Buffalo River, South Branch	Stony Creek to Buffalo River	17.43	2B	NS	NS	NA	+	+							+	-	+	-	+	-
09020106-504	Buffalo River, South Branch	Whisky Creek to Stony Creek	11.26	2B	NS	NS	NA	NA								+	-	+	-	+	-
09020106-505	Buffalo River, South Branch	Deerhorn Creek to Whisky Creek	18.94	2B	NS	NS	NA	+	-							+	-	+	-	+	-
09020106-507	Deerhorn Creek	Headwaters to S Branch Buffalo R	21.86	2C	NS	NS	NA	-	-							+	-	+	-	+	-
09020106-508	Buffalo River, South Branch	Headwaters to Deerhorn Creek	21.18	2B	NS	NS	NA	NA	NA							+	-	+	-	+	-
09020106-531	State Ditch 14	Unnamed Ditch to Deerhorn Creek	4.11	2B	FS	NS	NA	NA	NA							+	-	+	+	+	+
09020106-530	Unnamed Creek (Lawndale Creek)	Unnamed Creek to Unnamed Ditch	0.57	1A, 2B	NA	NA	NA	NA	NA								NA	+		+	
09020106-535	State Ditch 15	Unnamed Ditch to Unnamed Creek	4.4	2B	IF	NA	NA	NA	NA									+	IF		IF
09020106-544	Unnamed Creek	Unnamed Ditch to S Br Buffalo R	3.18	2B	NA	NA	NA	NA	NA												
09020106-550	County Ditch 12	Unnamed Creek to S Br Buffalo R	7.26	2B	NA	NA	NA	NA	NA												
09020106-554	Judicial Ditch 3-1	Unnamed Ditch to S Br Buffalo R	5.24	2B	NA	NA	NA	NA	NA												
09020106-587	Judicial Ditch 3-2	Unnamed Creek to S Br Buffalo R	3.18	2B	NA	NA	NA	NA	NA												

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets Standards or Ecoregion Norms (+); Exceeds Standards or Ecoregion Norms (-); Channelized streams were not assessed for aquatic life.

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Appendix 5 (continued)

					USES			BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS											
Stream Segment AUID	**Stream Segment Name**	**Stream Segment Description**	**NHD Length (Miles)**	**Use Class**	**Aquatic Life**	**Aquatic Recreation**	**Aquatic Consumption**	**Fish**	**Macroinvertebrates**	**Arsenic**	**Cadmium**	**Copper**	**Lead**	**Nickel**	**Zinc**	**Chloride**	**Escherichia coli**	**pH**	**Turbidity**	**Un-ionzed ammonia**	**Dissolved Oxygen**
HUC-11: 09020106060 (South of Hawley-South Buffalo)																					
09020106-502	Stony Creek	Hay Creek to Buffalo River	15.5	2B	NS	NS	NA	+	NA							+	-	+	-	+	-
09020106-534	Spring Creek	Unnamed Creek to Hay Creek	4.87	2B	NS	NS	NA	-	-							+	-	+	+	+	IF
09020106-509	Whisky Creek	T137 R47W S13, E line to S Br Buffalo River	6.95	2B	NS	NS	NA	NA	NA							+	-	+	-	+	IF
09020106-519	Hay Creek	Unnamed Creek to Spring Creek	7.01	2C	IF	NS	NA	NA	NA							+	-	+	+	+	IF
09020106-520	Hay Creek	Spring Creek to Stony Creek	3.5	2C	IF	NS	NA	NA	NA							+	-	+	-	+	IF
09020106-521	Whisky Creek	Headwaters to T137 R46W S18, W line	24.1	2C	NS	NS	NA	+	+							+	-	+	-	+	+
09020106-523	Stony Creek	T137 R45W S3, N line to T137 R46W S5, N line	14.32	2C	NS	NS	NA	NA	NA							+	-	+	-	+	IF
09020106-510	Stony Creek	Headwaters to T137 R45W S2, N line	2.09	2C	NA	NA	NA														
09020106-533	Unnamed Creek	Headwaters to Whisky Creek	7.43	2B	NA	NA	NA	NA	NA												
09020106-551	County Ditch 21	Unnamed Ditch to Unnamed Creek	3.42	2B	NA	NA	NA	NA	NA												
09020106-592	Unnamed Creek	Unnamed Creek to County Ditch 21	1.82	2B	NA	NA	NA	NA	NA												
HUC-11: 09020106070 (Olaf Groves Lakes)																					
09020106-586	Unnamed Creek	Headwaters to Whisky Creek	2.12	2B	IF	NA	NA	+	-												
09020106-521	Whisky Creek	Headwaters to T137 R46W S18, W line	24.1	2C	NS	NS	NA	+	+							+	-	+	-	+	+
HUC-11: 09020106080 (County Ditch #2)																					
09020106-555	Unnamed Creek	Headwaters to Clay Cty Ditch 2	15.17	2B	IF	NA	NA	-	-									+	+	+	
09020106-556	County Ditch 2	Unnamed Creek to Buffalo River	5.58	2B	IF	NS	NA	NA	NA							+	-	+	+	+	IF

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets Standards or Ecoregion Norms (+); Exceeds Standards or Ecoregion Norms (-); Channelized streams were not assessed for aquatic life.

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Appendix 5 (continued)

					USES			BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS											
Stream Segment AUID	Stream Segment Name	Segment Description	NHD Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Aquatic Consumption	Fish	Macroinvertebrates	Arsenic	Cadmium	Copper	Lead	Nickel	Zinc	Chloride	Escherichia coli	pH	Turbidity	Un-ionzed ammonia	Dissolved Oxygen
HUC-11: 09020106090 (Lower Buffalo River)																					
09020106-501	Buffalo River, South Branch	S Br Buffalo River to Red River	46.51	2B	NS	NS	NA	+	+							+	-	+	-	+	+
09020106-562	Headwaters to Buffalo River	Unnamed Creek to Unnamed Ditch	14.72	2B	IF	NS	NA	NA	NA							+	-	+	-	+	IF
09020106-559	County Ditch 39	Headwaters to Buffalo River	10.55	2B	IF	NS	NA	NA	NA							+	-	+	-	+	IF
09020106-560	County Ditch 59	Headwaters to Buffalo River	5.12	2B	NA	NA	NA	NA	NA												
09020106-563	County Ditch 5 (Cty Ditch 8)	Headwaters to Buffalo River	6.78	2B	NA	NA	NA	NA	NA												
09020106-538	County Ditch 25	County Ditch 26 to Buffalo River	4.8	2B	NA	NA	NA	NA	NA												
09020106-557	County Ditch 3	Headwaters to Buffalo River	9.78	2B	NA	NA	NA	NA	NA												

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets Standards or Ecoregion Norms (+); Exceeds Standards or Ecoregion Norms (-); Channelized streams were not assessed for aquatic life.

Appendix 6. Biological Sampled Sites and F-IBI Scores in the Buffalo River Watershed

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Fish Class	Threshold	F-IBI	Visit Date
HUC-11: 09020106-010 (Upper Buffalo River)							
09020106-593	09RD012	Buffalo River	127.75	5	50	51	23-Jul-09
09020106-593	09RD012	Buffalo River	127.75	5	50	38	30-Jun-09
09020106-593	09RD024	Buffalo River	54.28	5	50	27	29-Jun-09
09020106-593	09RD038	Buffalo River	110.68	5	50	42	29-Jun-09
09020106-594	09RD005	Buffalo River	215.91	5	50	50	23-Jul-09
09020106-594	09RD005	Buffalo River	215.91	5	50	47	30-Jun-09
HUC-11: 09020106-020 (County Ditch #15)							
09020106-514*	09RD057	Unnamed creek	5.74	6	-	29	08-Jun-09
09020106-515*	05RD072	Unnamed ditch	54.78	5	-	36	09-Jun-09
09020106-515*	05RD072	Unnamed ditch	54.78	5	-	58	28-Jun-05
09020106-515*	07RD029	Unnamed ditch	48.67	6	-	71	20-Aug-07
09020106-515*	07RD029	Unnamed ditch	48.67	6	-	64	07-Aug-07
09020106-515*	09RD004	Trib. to Buffalo River	86.39	5	-	50	29-Jun-09
09020106-515*	09RD026	Unnamed ditch	38.90	6	-	36	08-Jun-09
09020106-516*	09RD058	Unnamed ditch	19.26	6	-	24	10-Jun-09
09020106-518*	05RD045	Trib. to Buffalo River	25.94	6	-	67	09-Jun-09
09020106-518*	05RD045	Trib. to Buffalo River	25.94	6	-	25	20-Jul-05
09020106-527*	09RD059	Unnamed ditch	14.03	6	-	72	10-Jun-09
09020106-577*	09RD027	Trib. to unnamed ditch	7.28	7	-	37	09-Jun-09
09020106-578*	09RD025	Unnamed Ditch	1.51	6	-	29	08-Jun-09
HUC-11: 09020106-030 (Lake Park)							
09020106-511*	05RD071	Hay Creek	18.83	6	-	12	13-Jul-09
09020106-511*	05RD071	Hay Creek	18.83	6	-	19	20-Jul-05
09020106-513	09RD003	Hay Creek	6.35	6	40	67	7-Jul-09
09020106-576*	10EM069	Unnamed trib. to Hay Creek	6.30	6	-	0	09-Jun-10
HUC-11: 09020106-040 (Middle Buffalo River)							
09020106040-580*	09RD013	Trib. to Buffalo River	11.21	7	-	22	9-Jun-09
09020106040-581*	09RD028	Trib. to Buffalo River	6.47	7	-	14	10-Jun-09
09020106040-582*	09RD017	Trib. to Buffalo River	5.87	7	-	0	14Jul-09
09020106040-594	05RD116	Buffalo River	254.75	7	40	38	22-Aug-09
09020106040-594	09RD039	Buffalo River	257.24	7	40	33	30-Jun-09
09020106040-595	09RD040	Buffalo River	308.63	5	50	40	21-Jul-09
09020106040-595	09RD042	Buffalo River	360.11	5	50	58	21-Jul-09
09020106040-595	05RD110	Buffalo River	315.95	5	50	44	26-Jul-09
09020106040-595	09RD002	Buffalo River	399.47	7	40	76	20-Jul-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating scores.**

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Appendix 6 (continued)

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Fish Class	Threshold	F-IBI	Visit Date
HUC-11: 09020106-050 (Deerhorn-Buffalo)							
09020106050-503	08RD081	Buffalo River, South Branch	461.84	7	40	71	9-Sep-09
09020106050-503	09RD006	Buffalo River, South Branch	506.32	2	45	58	16-Jul-09
09020106050-504	09RD019	Buffalo River, South Branch	300.23	7	40	0.00	8-Sept-09
09020106050-505	05RD037	Buffalo River, South Branch	124.64	7	40	69	28-Jun-09
09020106050-505	05RD118	Buffalo River, South Branch	171.39	7	40	53	26-Jul-09
09020106050-505	08RD080	Buffalo River, South Branch	164.18	7	40	70	25-Aug-09
09020106050-505	94RD004	Buffalo River, South Branch	126.74	7	40	65	13-Aug-09
09020106050-507	09RD052	Deerhorn Creek	30.75	7	40	2	15-Jun-09
09020106050-507	09RD047	Deerhorn Creek	35.04	7	40	0	8-Jul-09
09020106050-508*	09RD051	Buffalo River, South Branch	38.64	7	-	36	16-Jun-09
09020106050-508*	09RD033	Buffalo River, South Branch	14.88	7	-	51	15-Jun-09
09020106050-530*	09RD050	State Ditch 15	23.12	7	-	7	8-Jul-09
09020106050-530*	09RD056	Unnamed Creek (Lawndale Creek)	12.71	9	-	30	15-Jun-09
09020106050-531*	09RD048	State Ditch 14	19.21	7	-	73	16-Jun-09
09020106050-550*	09RD036	County Ditch 12	11.29	7	-	16	15-Jul-09
09020106050-554*	09RD063	Unnamed creek	33.36	7	-	49	22-Jul-09
09020106050-554*	09RD032	Judicial Ditch 3-1	14.75	7	-	35	8-Jul-09
09020106050-587*	09RD034	Trib. to Buffalo River, South Branch	4.09	7	-	81	16-Jun-09
09020106050-587*	09RD034	Trib. to Buffalo River, South Branch	4.09	7	-	46	15-Jul-09
HUC-11: 09020106-060 (South of Hawley-South Buffalo)							
09020106-502	09RD007	Stony Creek	157.87	2	45	72	01-Sep-09
09020106-509*	09RD008	Whiskey Creek	113.84	2	-	69	14-Jul-09
09020106-509*	09RD011	Whiskey Creek	90.55	2	-	45	01-Jul-09
09020106-510*	09RD031	Stony Creek	25.29	3	-	68	15-Jul-09
09020106-510*	09RD031	Stony Creek	25.29	3	-	65	10-Jun-09
09020106-519*	09RD023	Hay Creek	75.17	2	-	0	09-Jul-09
09020106-520*	07RD012	Hay Creek	87.79	2	-	36	22-Aug-07
09020106-520*	07RD012	Hay Creek	87.79	2	-	30	09-Aug-07
09020106-521	09RD021	Whiskey Creek	69.13	2	45	34	12-Aug-09
09020106-521	09RD021	Whiskey Creek	69.13	2	45	58	08-Jul-09
09020106-521	05RD119	Whiskey Creek	84.45	2	45	47	25-Aug-05
09020106-523*	09RD046	Stony Creek	46.42	2	-	42	12-Aug-09
09020106-523*	09RD046	Stony Creek	46.42	2	-	41	09-Jul-09
09020106-533*	09RD020	Unnamed creek	4.85	3	-	0	08-Jul-09
09020106-534	09RD022	Spring Creek	9.22	3	51	43	09-Jul-09
09020106-551*	09RD030	County Ditch 21	5.34	3	-	0	13-Jul-09
09020106-592*	09RD045	Trib. to Buffalo River, South Branch	13.25	3	-	0	13-Jul-09
HUC-11: 09020106-070 (Olaf Groves Lakes)							
09020106-521	09RD001	Whiskey Creek	35.93	6	40	63	11-Jun-09
09020106-586	09RD053	Trib. to Whiskey Creek	14.33	6	40	60	10-Jun-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating scores.**

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Appendix 6 (continued)

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Fish Class	Threshold	F-IBI	Visit Date
HUC-11: 09020106-080 (County Ditch #2)							
09020106-555	09RD062	Trib. to County Ditch 2	23.34	6	40	11	13-Aug-09
09020106-555	09RD062	Trib. to County Ditch 2	23.34	6	40	13	13-Jul-09
09020106-556*	09RD037	County Ditch 2	35.97	2	-	50	22-Jul-09
HUC-11: 09020106-090 (Lower Buffalo River)							
09020106-501	05RD120	Buffalo River	987.76	1	39	78	21-Aug-06
09020106-501	09RD009	Buffalo River	1129.35	1	39	62	10-Sep-09
09020106-501	09RD043	Buffalo River	1016.92	1	39	73	10-Sep-09
09020106-501	09RD018	Buffalo River	921.71	1	39	72	09-Sep-09
09020106-538*	09RD016	County Ditch 25	15.94	7	-	0	14-Jul-09
09020106-557*	09RD044	County Ditch 3	22.10	3	-	0	07-Jul-09
09020106-559*	09RD055	County Ditch 39	42.24	2	-	68	14-Jul-09
09020106-559*	09RD055	County Ditch 39	42.24	2	-	43	17-Jun-09
09020106-560*	09RD015	County Ditch 59	8.68	3	-	0	17-Jun-09
09020106-562*	09RD014	County Ditch 10	20.35	3	-	48	17-Jun-09
09020106-563*	09RD029	County Ditch 5 (County Ditch 8)	12.95	3	-	34	17-Jun-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating scores.**

Appendix 7. Biological Sampled Sites and M-IBI Scores for the Buffalo River Watershed

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Invert Class	Threshold	M-IBI	Visit Date
HUC-11: 09020106-010 (Upper Buffalo River)							
09020106010-593	09RD012	Buffalo River	127.75	7	38.3	48.28	25-Aug-09
09020106010-593	09RD024	Buffalo River	54.28	6	46.8	40.86	24-Aug-09
09020106010-593	09RD038	Buffalo River	110.68	7	38.3	25.70	26-Aug-09
09020106010-594	09RD005	Buffalo River	215.91	7	38.3	54.51	25-Aug-09
HUC-11: 09020106-020 (County Ditch #15)							
09020106020-515*	05RD072	Unnamed ditch	54.78	7	-	31.51	25-Aug-05
09020106020-515*	05RD072	Unnamed ditch	54.78	7	-	12.06	25-Aug-09
09020106020-515*	05RD072	Unnamed ditch	54.78	7	-	19.52	23-Aug-05
09020106020-515*	07RD029	Unnamed ditch	48.67	7	-	30.82	15-Aug-07
09020106020-515*	09RD004	Trib. to Buffalo River	86.39	7	-	35.81	25-Aug-09
09020106020-515*	09RD004	Trib. to Buffalo River	86.39	7	-	42.87	25-Aug-09
09020106020-515*	09RD026	Unnamed ditch	38.90	7	-	37.41	24-Aug-09
09020106020-516*	09RD058	Unnamed ditch	19.26	7	-	37.70	24-Aug-09
09020106020-518*	05RD045	Trib. to Buffalo River	25.94	7	-	13.55	25-Aug-05
09020106020-518*	05RD045	Trib. to Buffalo River	25.94	7	-	11.24	22-Aug-05
09020106020-518*	05RD045	Trib. to Buffalo River	25.94	7	-	30.47	24-Aug-09
09020106020-527*	09RD059	Unnamed ditch	14.03	7	-	46.76	24-Aug-09
09020106020-578*	09RD025	Trib. to unnamed Ditch	23.25	7	-	16.17	24-Aug-09
HUC-11: 09020106-030 (Lake Park)							
09020106030-511*	05RD071	Hay Creek	18.83	6	-	25.84	25-Aug-05
09020106030-511*	05RD071	Hay Creek	18.83	6	-	18.69	22-Aug-05
09020106030-576*	10EM069	Unnamed Creek	6.3	5	-	19.39	15-Sep-10
HUC-11: 09020106-040 (Middle Buffalo River)							
09020106040-580*	09RD013	Trib. to Buffalo River	11.21	7	-	12.83	25-Aug-09
09020106040-581*	09RD028	Trib. to Buffalo River	6.47	7	-	26.01	25-Aug-09
09020106040-582*	09RD017	Trib. to Buffalo River	5.87	7	-	6.47	22-Sep-10
09020106040-594	05RD116	Buffalo River	254.75	7	38.3	65.54	25-Aug-05
09020106040-594	09RD039	Buffalo River	257.24	7	38.3	60.78	28-Sep-09
09020106040-595	09RD040	Buffalo River	308.63	5	35.9	38.91	25-Aug-09
09020106040-595	09RD042	Buffalo River	360.11	5	35.9	42.86	25-Aug-09
09020106040-595	05RD110	Buffalo River	315.95	5	35.9	52.66	25-Aug-05
09020106040-595	09RD002	Buffalo River	399.47	7	38.3	46.62	31-Aug-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating scores.**

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Appendix 7 (continued)

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Invert Class	Threshold	M-IBI	Visit Date
HUC-11: 09020106-050 (Deerhorn-Buffalo)							
09020106050-503	08RD081	Buffalo River, South Branch	461.84	7	38.3	31.84	29-Sep-09
09020106050-503	09RD006	Buffalo River, South Branch	506.32	2	30.7	37.02	29-Sep-09
09020106050-504	09RD019	Buffalo River, South Branch	300.23	7	38.3	0.00	04-Aug-10
09020106050-505	05RD037	Buffalo River, South Branch	124.64	7	38.3	21.00	28-Sep-05
09020106050-505	05RD118	Buffalo River, South Branch	171.39	7	38.3	31.93	28-Sep-05
09020106050-505	08RD080	Buffalo River, South Branch	164.18	7	38.3	24.51	25-Aug-09
09020106050-505	94RD004	Buffalo River, South Branch	126.74	7	38.3	40.50	23-Sep-10
09020106050-507	09RD052	Deerhorn Creek	30.75	7	38.3	24.32	25-Aug-09
09020106050-507	09RD047	Deerhorn Creek	35.04	7	38.3	9.04	25-Aug-09
09020106050-508*	09RD051	Buffalo River, South Branch	38.64	7	-	30.07	25-Aug-09
09020106050-508*	09RD033	Buffalo River, South Branch	14.88	7	-	28.07	26-Aug-09
09020106050-530*	09RD050	State Ditch 15	23.12	7	-	12.60	25-Aug-09
09020106050-530*	09RD056	Unnamed Creek (Lawndale Creek)	12.71	9	-	69.46	25-Aug-09
09020106050-531*	09RD048	State Ditch 14	19.21	7	-	55.69	23-Sep-10
09020106050-550*	09RD036	County Ditch 12	11.29	7	-	31.20	26-Aug-09
09020106050-554*	09RD063	Unnamed creek	33.36	7	-	16.37	25-Aug-09
09020106050-554*	09RD032	Judicial Ditch 3-1	14.75	7	-	16.14	26-Aug-09
09020106050-554*	09RD032	Judicial Ditch 3-1	14.75	7	-	26.45	26-Aug-09
09020106050-587*	09RD034	Trib. to Buffalo River, South Branch	4.09	7	-	55.03	25-Aug-09
HUC-11: 09020106-060 (South of Hawley-South Buffalo)							
09020106060-509*	09RD008	Whiskey Creek	113.84	7	-	19.47	31-Aug-09
09020106060-509*	09RD011	Whiskey Creek	90.55	7	-	31.74	31-Aug-09
09020106060-510*	09RD031	Stony Creek	25.29	5	-	12.91	26-Aug-09
09020106060-519*	09RD023	Hay Creek	75.17	7	-	18.71	25-Aug-09
09020106060-520*	07RD012	Hay Creek	87.79	7	-	44.00	15-Aug-07
09020106060-521	05RD119	Whiskey Creek	84.45	7	38.3	22.00	28-Sep-05
09020106060-521	09RD021	Whiskey Creek	69.13	7	38.3	28.76	26-Aug-09
09020106060-534	09RD022	Spring Creek	9.22	5	38.3	30.92	25-Aug-09
09020106060-551*	09RD030	County Ditch 21	5.34	7	-	21.90	25-Aug-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating score.**

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Appendix 7 (continued)

Stream Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area (Mi^2)	Invert Class	Threshold	M-IBI	Visit Date
HUC-11: 09020106-070 (Olaf Groves Lakes)							
09020106070-521	09RD001	Whiskey Creek	35.93	7	38.3	44.49	26-Aug-09
09020106070-586	09RD053	Trib. to Whiskey Creek	14.33	7	38.3	24.24	26-Aug-09
HUC-11: 09020106-080 (County Ditch #2)							
09020106080-555	09RD062	Trib. to County Ditch 2	23.34	7	38.3	35.00	26-Aug-09
09020106080-556*	09RD037	County Ditch 2	35.97	7	-	24.85	24-Aug-09
HUC-11: 09020106-090 (Lower Buffalo River)							
09020106090-501	05RD120	Buffalo River	987.76	2	30.7	29.32	28-Sep-05
09020106090-501	05RD120	Buffalo River	987.76	2	30.7	38.82	20-Sep-05
09020106090-501	09RD018	Buffalo River	921.71	2	30.7	46.78	29-Sep-09
09020106090-501	09RD043	Buffalo River	1016.92	2	30.7	42.83	29-Sep-09
09020106090-501	09RD009	Buffalo River	1129.35	2	30.7	44.61	29-Sep-09
09020106090-562*	09RD014	County Ditch 10	20.35	7	-	9.54	24-Aug-09
09020106090-560*	09RD015	County Ditch 59	8.68	7	-	0.00	24-Aug-09
09020106090-538*	09RD016	County Ditch 25	15.94	7	-	7.61	24-Aug-09
09020106090-563*	09RD029	County Ditch 5 (County Ditch 8)	12.95	7	-	0.00	24-Aug-09
09020106090-557*	09RD044	County Ditch 3	22.10	7	-	4.83	24-Aug-09
09020106090-559*	09RD055	County Ditch 39	42.24	7	-	12.39	24-Aug-09

***Indicates non-assessed AUID with no threshold rating. Refer to Appendix 10 for good/fair/poor rating scores.**

Appendix 8. Fish Species, Site, and Total Number of Individuals Collected in the Buffalo River Watershed

Common Name	Sites Collected At	Total Number Collected
Bigmouth Shiner	18	289
Black Bullhead	36	143
Black Crappie	4	4
Blackchin Shiner	2	3
Blacknose Dace	27	840
Blacknose Shiner	15	137
Blackside Darter	39	245
Bluegill	17	234
Brook Stickleback	49	2824
Brown Bullhead	1	2
Central Mudminnow	42	384
Channel Catfish	6	33
Chestnut Lamprey	1	1
Common Carp	15	269
Common Shiner	41	3754
Creek Chub	56	2007
Emerald Shiner	1	4
Fathead Minnow	57	6208
Finescale Dace	4	327
Freshwater Drum	2	2
Gen: Percina	1	1
Gen: Redhorses	1	1
Golden Redhorse	17	144
Golden Shiner	6	7
Goldeye	9	29
Greater Redhorse	1	1
Green Sunfish	21	205
Hornyhead Chub	19	360
Hybrid Sunfish	3	7
Iowa Darter	10	72
Johnny Darter	43	837
Largemouth Bass	7	69
Longnose Dace	10	556
Mooneye	1	1
Northern Pike	44	185
Northern Redbelly Dace	23	991
Orangespotted Sunfish	1	3
Pearl Dace	13	151
Pumpkinseed	4	7
Quillback	3	6
Rock Bass	24	151
Sand Shiner	18	283
Sauger	5	9
Shorthead Redhorse	16	166
Silver Chub	1	1
Silver Lamprey	2	2
Silver Redhorse	7	32
Smallmouth Bass	2	3
Spotfin Shiner	27	1223
Spottail Shiner	14	171
Stonecat	9	18
Tadpole Madtom	9	39
Trout-Perch	18	93
Walleye	12	23
White Sucker	67	1553
Yellow Bullhead	1	1
Yellow Perch	13	75

Appendix 9. Minnesota Statewide IBI Thresholds and Confidence Limits, 2012

Class	Class Name	Use Class	Threshold	Confidence Limit	Upper	Lower
Fish						
1	Southern Rivers	2B	46	±11	57	35
2	Southern Streams	2B	45	±9	54	36
3	Southern Headwaters	2B	51	±7	58	44
4	Northern Rivers	2B	35	±9	44	26
5	Northern Streams	2B	50	±9	59	41
6	Northern Headwaters	2B	40	±16	56	24
7	Low Gradient	2B	40	±10	50	30
10	Southern Coldwater	2A	45	±13	58	32
11	Northern Coldwater	2A	37	±10	47	27
Invertebrates						
1	Northern Forest Rivers	2B	43.0	±10.8	53.8	32.2
2	Prairie Forest Rivers	2B	30.7	±10.8	41.5	19.9
3	Northern Forest Streams RR	2B	50.3	±12.6	62.9	37.7
4	Northern Forest Streams GP	2B	52.4	±13.6	66	38.8
5	Southern Streams RR	2B	35.9	±12.6	48.5	23.3
6	Southern Forest Streams GP	2B	46.8	±13.6	60.4	33.2
7	Prairie Streams GP	2B	38.3	±13.6	51.9	24.7
8	Northern Coldwater	2A	26	±12.4	38.4	13.6
9	Southern Coldwater	2A	46.1	±13.8	59.9	32.3

Appendix 10. Good/Fair/Poor Thresholds for Biological Monitoring Stations on Non-Assessed Channelized AUIDs, 2012

Class	Class Name	Good	Fair	Poor
Fish				
1	Southern Rivers	>38	38-24	<24
2	Southern Streams	>44	44-30	<30
3	Southern Headwaters	>50	50-36	<36
4	Northern Rivers	>34	34-20	<20
5	Northern Streams	>49	49-35	<35
6	Northern Headwaters	>39	39-25	<25
7	Low Gradient	>39	39-25	<25
10	Southern Coldwater	>45	45-30	<30
11	Northern Coldwater	>37	37-22	<22
Invertebrates				
1	Northern Forest Rivers	>51	52-36	<36
2	Prairie Forest Rivers	>31	31-16	<16
3	Northern Forest Streams RR	>50	50-35	<35
4	Northern Forest Streams GP	>52	52-37	<37
5	Southern Streams RR	>36	36-21	<21
6	Southern Forest Streams GP	>47	47-32	<32
7	Prairie Streams GP	>38	38-23	<23
8	Northern Coldwater	>26	26-11	<11
9	Southern Coldwater	>46	46-31	<31

Ratings of Good for channelized streams are based on Minnesota's general use threshold for aquatic life. Stations with IBIs that score above this general threshold would be given a rating of Good. The Fair rating is calculated as a 15 point decrease from the general use threshold. Stations with IBI scores below the general use threshold, but above the Fair threshold would be given a rating of Fair. Stations scoring below the Fair threshold would be considered Poor.