SOURIS RIVER DISSOLVED OXYGEN STUDY IN SUPPORT OF TOTAL MAXIMUM DAILY LOAD DEVELOPMENT

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

ABSTRACT

Super, Joseph James, M.S., Environmental and Conservation Sciences, College of Graduate and Interdisciplinary Studies, North Dakota State University, August 2010. Souris River Dissolved Oxygen Study in Support of Total Maximum Daily Load Development. Major Professors: Dr. Wei Lin and Bernhardt Saini-Eidukat.

The Souris River, a slow moving praire river, originates in the Canadian province of Saskatchewan. The Souris River enters into the United States near Sherwood, North Dakota. The upper portion of the Souris River, from the border with Saskatchewan, Canada to Lake Darling, a total of 43.4 miles, has been on the North Dakota Section 303(d) Environmental Protection Agency (EPA) list of impaired waters since 1998 (NDDoH, 2008).

Low dissolved oxygen (DO) concentration in the river has been problematic, resulting in fish kills on the upper reach of the Souris River. The primary goal of the project is to determine source(s) of contaminations that cause seasonal variation in dissolved oxygen concentration. Objectives of this research include: 1) studying the nature and extent of the impairment using existing data, 2) executing a comprehensive year long sampling plan, and 3) analyzing sample data to identify the major sources of DO impairment. Results from this study will be used by North Dakota State Department of Health (DoH) for development of a Total Maximum Daily Load (TMDL) report to the EPA.

The reach was expanded into Canada, totalling 52 river miles, between Glen Ewen, Saskatchewan, CA and Mouse River Park, ND. This reach was sampled 29 times during the period of this study. During winter months, DO under the ice was constantly below 1 mg/L. During the summer diurnal swings of DO caused the stream

to fall below the designated 5 mg/L standard in the early morning hours. Sediment oxygen demand was determined to be the main stressor.

Two contaminant sources that contribute to DO variation on the Souris River were identified, livestock ranching practices and the physical alteration of the river. Ranching is the leading cause of impairment. Livestock in the riparian area contribute organic inputs and stream bank erosion. Physical alterations lead to DO variation in two ways. Upstream impoundments eliminate scouring flows allowing sediment to build up. Downstream impoundments back up water into study reach contributing to sedimentation. Low head dams create hydrologic flow issues which lead to dissolved oxygen depletion.

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CHAPTER 1. INTRODUCTION

A total of 43.4 miles of the Souris River, from the border with Saskatchewan, Canada, to Lake Darling in North Dakota, has been on state and federal listings for water quality impairments since 1998. The river reach has been identified by the North Dakota Department of Health as "fully supporting but threatened" for aquatic life and recreation use. Low dissolved oxygen concentration (<5 mg/L) has been a problem on the upper reach of the Souris River, demonstrated by fish kills in the winter.

To address water quality issues, the United States Environmental Protection Agency (USEPA) provided funding to the North Dakota Department of Health to study the upper reach of the Souris River North Dakota State University principal investigator Dr. Wei Lin was subcontracted to complete the study with the use of graduate students Results will assist the North Dakota Department of Health in completing a Total Maximum Daily Load (TMDL).

The primary goal of the project was to investigate the causes and contaminant sources of the low DO problems on the upper reach of the Souris River. Objectives included: 1) studying the nature and extent of the impairment using existing data, 2) executing a comprehensive 2 year sampling plan, and 3) completing analysis of sample data and identifying the causes and contaminant sources of the DO impairment. The study will assist U.S. and Canadian state, provincial, and federal agencies by making management recommendations and identifying areas of further study.

CHAPTER 2. BACKGROUND

In order to address the cause and nature of low DO in the upper reach of the Souris River, understanding the background of the watershed is needed. The processes whereby a river can become low in DO are also critical information for the study.

2.1. An overview of the Souris River basin

2.1.1. General characteristics

The Souris River is part of the Lake Winnipeg water basin, one of the largest in the world Lake Winnipeg drains into Hudson Bay by way of the Nelson River. The entire Souris River Watershed is approximately 24,800 mi^2 (64,200 km^2), of which 15,480 mi^2 (40,100 km^2) are in Canada and 9,320 mi^2 (24,100 km^2) are in the United States (Workman, 1988). Ancient glacial Lake Regina forms the first order streams from what used to be an extensive wetland. The Souris, or Mouse, River originates in the Yellow Grass Marshes north of Weyburn, Saskatchewan, Canada, and flows southeast (Hood, 1994). The Souris River flows from Saskatchewan across the international border into the United States near Sherwood, North Dakota It makes a 358 mile loop through North Dakota's Renville, Ward, McHenry and Bottineau Counties before exiting to the Province of Manitoba near Coulter, Manitoba (Vecchia, 2000).

The Souris River is considered a low gradient stream; the elevation drop in its 358 mile (576 km) journey through North Dakota is 194.15 feet (59.1 meters) (USGS, 2009), therefore the slope is 0.54 feet/mile (0.10 meters/kilometre). The Souris River empties into the Assiniboine River, which in turn empties into the Red River of the North (see Figure 1). As part of the 1909 transboundary water treaty between Canada

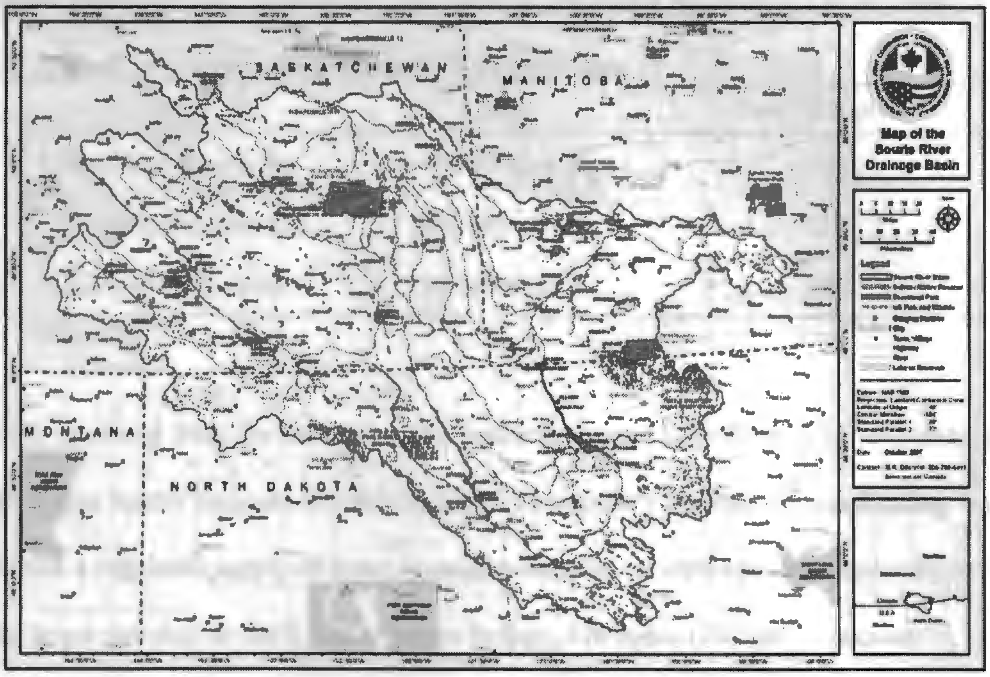

Figure 1. Souris River drainage basin (IJC, 2007)

and the United States, the province of Saskatchewan agreed to maintain a flow of 20 cubic feet per second (0.566 cubic meter per second) at the Sherwood Border Crossing for most of the year (IJC, 2007). There are three impoundments, the Boundary, Rafferty and Alameda Reservoirs (Table 1 and Figure 1), along the Souris River in Saskatchewan with total reservoir capacity of about 490,000 acre-ft. Two of these impoundments were built within the last twenty years. Some diversions for irrigation and municipal supply also exist on the river (Gilcrist, 2007).

Lake Darling is located approximately 50 river miles downstream from the Canadian border (see Figure 2). Lake Darling is formed behind a U.S. Fish and

Wildlife Service (FWS) dam built in 1936 for water supply and wildlife propagation (Wax, 2006). The water level of Lake Darling affects the Souris River level many

Table 1. Impoundments on Souris River in Canada

Name	Size	Date Completed
Boundary Reservoir	48,990 acre-ft	1958
Rafferty Reservoir	356,400 acre-ft	1991
Alameda Reservoir	85,560 acre-ft	1992

(IJC, 2007)

miles upstream from the reservoir. The land area around Lake Darling is referred to as the Upper Souris National Wildlife Refuge. The primary purpose of Lake Darling is to furnish a regulated supply of water to smaller marshes downstream and especially to the larger marshes on the J. Clark Salyer Refuge, 110 miles (177 km) downstream.

Three National Wildlife Refuges (NWRs), Des Lacs, J. Clark Salyer, and the Upper Souris, make up the refuge complex on the Souris River watershed. U.S. Fish and Wildlife Service, USGS, North Dakota Department of Health, and the ND State Water Commission have done research on Lake Darling. The upper end of Lake Darling is classified as hypereutrophic. Eutrophic can be defined as the most productive trophic state of a water body characterized by high nutrient levels leading to algae growth and resulting in oxygen depletion. The lakes in this region are very nutrient-rich, characterized by frequent and severe nuisance algal blooms and low transparency (Wax, 2006).

The Souris River is characterized as a large prairie river by the North Dakota Geologic Survey. The adjacent land is called the Northern Black Prairie, located in the

Northern Glaciated Plains ecoregion of the Dakotas (Bluemle, 1991). The river consists of large, straight oversized, valleys. The valley floor averages three-quarters of a mile wide and lies 100-200 feet below the ground moraine plain.

Figure 2. Souris River study reach (Hood, 1994)

The Souris River valley walls are fairly steep sided. This ecoregion is a transition zone between the prairie and boreal forest to the north. The elevation is 1500-1970 feet above sea level and is generally flat with simple drainage patterns and high concentrations of temporary and seasonal wetlands. The land within the flood plain is used for farming, predominately small grains, hay, and cattle ranching (Bluemle, 1991).

The Souris River lies within the Northwestern Climate Division of North Dakota. This area of the United States has the shortest growing season within the Dakotas (Haugerud, 2007), and experiences four distinct seasons, including warm summers and very cold winters. Temperatures reaching below 0 °F (-18 °C) are common during the winter, and temperatures can reach above 100 °F (37.8 °C) during the summer months. Precipitation is limited during winter months with the majority of rainfall occurring in May, June, July, and August (see Figure 3). The average rainfall at Mohall, North Dakota between 1994 and 2007 was 13.6 inches (34.5 cm) per year (NDAWN, 2009).

2.1.2. Impaired reach

The North Dakota Department of Health identified the impaired reach as 43.4 river miles (69.8 km) along the Souris River from the international border to Lake Darling. The USGS Sherwood international gaging station (511400) is the source for the majority of the existing flow and water quality data. This station is located in Renville County (Hydrologic Unit [HUC] 0901001). The USGS gaging station is on the right bank 0.8 miles (1.3 km) downstream from the international boundary, 16 miles (26 km) northwest of Sherwood, North Dakota (USGS, 2009).

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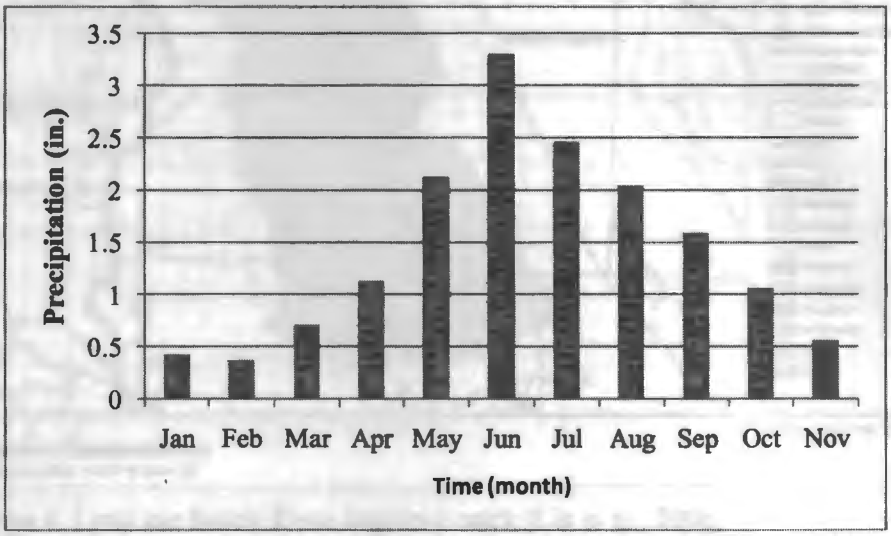

Figure 3. Average monthly precipitation data for Mohall, ND, from 1893 to 2009 (Source: High Plains Regional Climate Center)

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The areas surrounding the river are mainly cultivated agricultural lands with some small pastures and open water areas (Figure 4). Along the impaired reach, the riverbanks are mostly covered by grasses. A detailed GIS analysis of the land use shows that the predominant crops in the area are small grains with smaller areas of fallow and pasturelands (see Figure 4) (Lin et al., 2006).

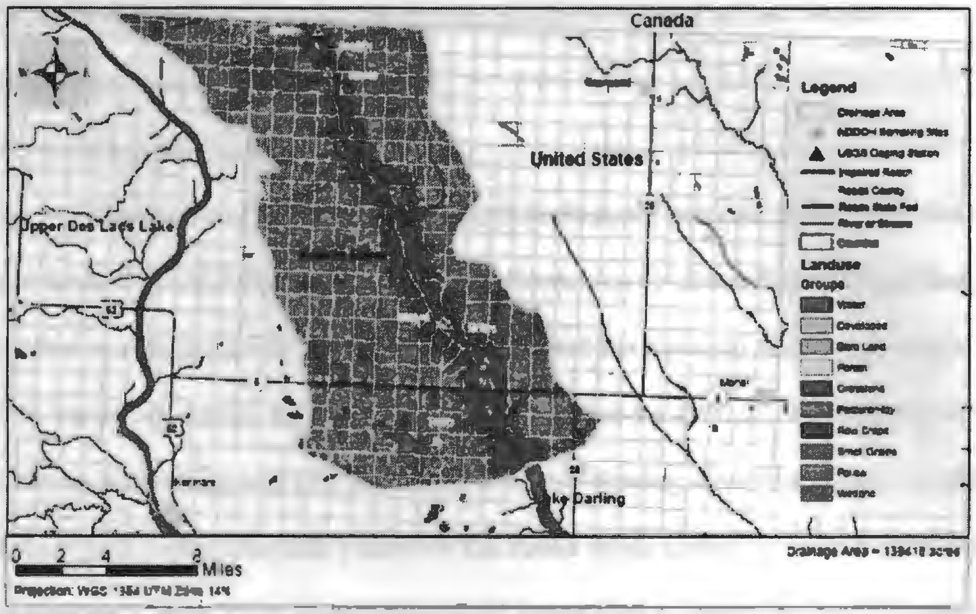

Figure 4. Land use Souris River impaired reach (Lin et al., 2006)

Members of the ISRB (Table 2) provide additional Souris River flow and water quality data.

Table 2. Membership of international Souris River board (ISRB, 2007)

Organization	Level of government
Environment Canada	Federal
Manitoba Water Stewardship	Provincial
Saskatchewan Watershed Authority	Provincial
Manitoba Water Stewardship	Provincial
Saskatchewan Environment	Provincial
ND State Water Commission	State
ND Department of Health	State
US Fish and Wildlife Service	Federal
US Army Corps of Engineers	Federal
US Geological Survey	Federal

Water issues between the United States and Canada have evolved from the original Boundary Waters Treaty of 1909,whick states that both countries shall divide the waters evenly, 50% each (IJC, 2007). Today, not only is quantity of water still a major issue, but protection of aquatic ecosystem health (water quality) has become a paramount goal.

2.1.3. Study reach

Headwaters of the Souris River basin in Saskatchewan are extensively drained and farmed (Hood, 1994). The Canadian influence on the downstream United States portion is unquestionable. North Dakota identified the impaired reach beginning at the U.S. border. However, for the water to be impaired at the 49th parallel implies that the river must have acquired this characteristic before flowing across the border. A 2007 Report card on the Canadian portion of the Souris River graded the overall river health as impaired. In its "State of the Watershed" report (SWA, 2007), the Saskatchewan Watershed Authority identified nonpoint sources of pollution including runoff from crops, grazing land, and bank erosion. Impairments included poor surface water quality, lack of permanent cover, poor range land, and riparian area health. A report card for stressors, in the same SWA report, included the following as stressors: manure application, oil and gas spills, mines, industrial waste, wetland loss, roads, groundwater allocation, aquatic habitat fragmentation, potential run off, livestock, and soil erosion. Direct impact of human population was considered low stress on the same report card for stressors (SWA, 2007).

Since 1994, the North Dakota Department of Health has operated a network of state-wide ambient monitoring sites, including sites along the Souris River. Where practical, sites are co-located with USGS gaging stations, thereby facilitating the analysis of chemical data with stream hydrologic data. In 1997, an intensive survey approach to chemical monitoring and assessment in the Souris River Basin was implemented. The approach integrated chemical monitoring at targeted sites with biological monitoring at sites along the river (NDDoH 2004). The Souris River from the U.S. border to Lake Darling has raised questions in terms of flow and water quality. This study was designed to use the existing data, execute a sampling plan and identify the nature of DO impairment.

The Souris River crosses the international border at the northern upstream end of the impaired reach. Since the river is considered impaired on both the United States and Canadian sides of the border, the study reported herein will use information from both sides of the border. The section of the river where water samples were collected for this study is termed the "study reach" (see Figure 2).

2.2. Water quality management

2.2.1. Clean water act

The Clean Water Act (CWA) of 1972 established a pollution discharge regulation structure in the United States. Section 303 of the CWA identifies water quality criterion and programs by which surface water is to meet designated uses. The CWA mandates the federal agency, Environmental Protection Agency (EPA), to develop surface water quality criteria on which the states are to base their own standards (EPA, 1991). Each state is required to set water quality standards which the EPA approves according to section 303(c) of the CWA. According to Section 303D of the CWA, each state is required to identify and list water bodies that do not meet the state's water quality standards. The National Pollutant Discharge Elimination System

(NPDES) permit program requires a permit for every discharge of pollutants from a point source to waters of the United States (EPA, 1991). Several water quality parameters have been used for assessing pollution levels and impact of human activities on the ecosystem. These parameters include: dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrients, sediment/siltation, bacteria, toxic organics, acidity/alkalinity, and habitat/hydrologic modification (EPA, 1991).

Through the basic strategy of permits using technology based standards, the CWA has accomplished many goals. For example, point source pollution was reduced by roughly 90% (Plater, 1998). However, addressing each water body and identifying nonpoint source pollution problem is a daunting task for states to accomplish. In the late 1990s, environmental groups brought litigation against the EPA mandating that the CWA be upheld. States were required to make lists of impaired waters. EPA focused on technology-based controls in the 1970s. In the 1990s more emphases were put on water quality based controls (EPA, 2000). Agriculture is the most widespread source of river pollution in the United States, accounting for 60% of the impaired river miles. Municipal sewage is the second largest source of river pollution with 17%. Closely tied for third among river polluters are urban runoff and storms sewers, resource extraction, and removal of streamside vegetation (Plater, 1998).

2.2.2. Total maximum daily load (TMDL) process

States are mandated to develop a timeline for addressing the impairments they have listed. This process, known as water quality based controls, includes Total

Maximum Daily Load (TMDL). "Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources" (EPA, 2008). The steps taken to identify and restore impaired waters are known as the TMDL process. The process to develop a TMDL is normally broken up into five activities (Table 3).

Table 3. TMDL development activities (EPA, 1991)

Step	Activity
1.	Selection of the pollutant to consider.
2.	Estimation of the water body assimilative capacity.
3.	Estimation of the pollution from all sources to the water body.
4.	Predictive analysis of pollution in the water body and determination of total allowable pollution load.
5.	Allocation (with a margin of safety) of the allowable pollution among the different pollution sources in a manner that water quality standards are achieved.

A TMDL can be expressed as the sum of all point source loads, non-point source loads, and an appropriate margin of safety. The point sources to the receiving water are defined as the Waste Load Allocation (WLA), which includes all existing or future point sources of pollution. The WLA can include waste treatment facilities for humans or domesticated animals. Non point sources and natural background sources of pollution are called Load Allocations (LA). The nonpoint sources should be distinguished from the background sources whenever possible. Since WLAs and LAs are not static, uncertainty must be accounted for in the TMDL. This is accomplished by the Margin of Safety (MOS). The goal of every TMDL is to express the state's water quality standards while identifying possible pollution source loads (EPA, 2008). The CWA and accompanying regulations require that a TMDL include a margin of safety (MOS) to account for discrepancies between load and waste load allocations and water quality.

Total Maximum Daily Load TMDL = Σ WLA+Σ LA+MOS

Where, WLA = Waste Load Allocation

LA = Load Allocation

MOS = Margin of Safety

"Margin of safety may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified" (EPA, 1991).

States submit lists of surface waters that do not meet water quality standards (impaired waters) and establish TMDLs for these waters on a prioritized schedule (EPA, 1991). These impaired water lists must be updated every two years and show that states are working to improve water quality. Each state controls how they go about implementing their TMDL.

Water quality standards or regulation that water quality standards use should have three criteria: 1) include provisions for restoring and maintaining chemical, physical, and biological integrity of state waters, 2) provide water quality for the protection and propagation of fish, shellfish, and wildlife and recreation ("fishable-swimmable"), 3) consider the use of State waters for public water supplies, propagation of fish and wildlife, recreation, agricultural and industrial purposes, and navigation (EPA, 1991). Currently, the EPA identifies water quality on a more holistic watershed scale (EPA, 2008). This watershed scale focus encompasses all natural and anthropogenic influences on water. For example, these influences include changes to air, soil quality, and land use. A TMDL under this watershed based approach will combine pollutants by linking multiple impaired reaches and then respond simultaneously to address the entire watershed (EPA, 2008).

The EPA cannot enforce the implementation of the TMDL recommendation when it applies to nonpoint sources. The state can apply for an EPA funded grant, called a Section 319 grant. These federal grant funds flow through state programs to assess and control projects to meet the WLA or LA. States then link TMDLs within watersheds together forming the Watershed Protection Approach (WPA). The WPA emphasizes all aspects of water quality including: chemical water quality, physical water quality, habitat quality, biological health and biodiversity, and subsurface biogeochemistry (EPA, 1995). The WPA is a logical conclusion to the TMDL process. Impairments identified in segments of a watershed can be linked across state and international borders, and thus management of an entire drainage basin becomes possible.

Computer modeling has become a major tool to develop TMDLs and to implement the WPAs. The EPA has developed a group of models called the TMDL Modeling Toolbox. In order to address a broad range of water body types and pollutants many different models can be used. Users must establish consistent defensible modeling tools. For these reasons the Environmental Protection Agency provides the Modeling Toolbox and training in using the models to state and private consultants (Wool, 2009). Water management personnel across state and international borders can use common computer programs, collaborate, and finally make conclusions everyone may agree upon.

Dissolved oxygen (DO) is one of the most common impairments on State Section 303(D) lists. The cause and effect relationship is not easy to establish with dissolved oxygen (Vellidis et al., 2006). The TMDL for dissolved oxygen on the Souris River reach will include allocations for sources of the DO impairment. These may be determined using a computer modeling system such as the stream water quality model QUAL2K. This receiving water model can determine the natural and human caused sources for the DO impairment (Wool, 2009). The Canadian side of the Souris River flows into the United States and would require its own remediation. Implementation in the U.S. may involve a Section 319 NPS grant and which would limit the sources of DO impairment and thereby restoring the Souris River's impaired uses.

To manage the Souris River watershed, cooperation between Canada and the United States is crucial. There are other TMDL projects on the Souris River in North Dakota and similar projects in the headwaters in Saskatchewan. Internationally regulated watersheds between Canada and the U.S. fall under the jurisdiction of the International Joint Commission (IJC). Ideally, to complete the WPA process, Saskatchewan, North Dakota, and Manitoba should cooperatively assess the Souris River Watershed.

2.3. Water quality criteria

Decision criteria in this study are based on North Dakota water quality standards, which were also used to assess the water quality for aquatic life and recreation. The criteria can be thought of as aquatic life-fishable and recreation-swimmable (safe for humans to be in the water); this fishable-swimmable shorthand is used frequently and is the goal of the federal CWA (Plater, 1998). Dissolved oxygen concentration in the Souris River is considered an aquatic life criterion. Fish and aquatic insects rely on consistent levels of dissolved oxygen in water. The water quality standard for DO concentration in aquatic systems, including the Souris River, is 5 mg/L (NDDoH, 2001).

For the aquatic life assessment, the criteria are divided into chemical assessment criteria and biological assessment criteria. Historically, chemical water quality assessment has been the standard method of determining levels of chemical pollutant. Numerical target standards are found in the North Dakota state water quality standards (NDDoH, 2001). Based on these criteria, the study reach is classified as "Fully Supporting, but Threatened" for aquatic life and recreation (NDDoH, 2008). Recreation criteria include swimming, boating, wading, or any recreational activity that relies on water. Fecal coliform was used as the water quality indicator for this water use. Fecal coliform bacteria, which are found in intestines of warm-blooded animals, are indicators of fecal contamination. The recreation criterion is limited to the recreation season from May 1 to September 30, when humans are considered to be in the water (NDDoH, 2008).

All water quality assessment information that is entered into the assessment database (ADB) for Section 305(b) and Section 303(d) TMDL listing must be based on "sufficient and credible" monitoring data (NDDoH, 2002). Sufficient and credible data are chemical, physical, and biological data that, at a minimum, are collected and analyzed by known and documented Quality Assurance/Quality Control procedures. In addition, sufficient and credible water column data should be 5 years old or less for rivers and streams and 10 years or less for lakes, unless there was adequate justification to use older data (e.g., land use or climatic conditions have not changed).

Note that in some cases there may be overwhelming evidence to list a waterbody as impaired even though there may less than 10 samples collected within a five year period. For example, if only four or five chemical samples were collected within a five year period and all of them exceeded the water quality standard, then the water body would be listed as impaired based on this "overwhelming evidence" (NDDoH, 2002). Water quality standards are defined by each state. North Dakota's water quality standards define a number of numeric standards that apply to all water bodies in North Dakota. Standards for aquatic life protection can be classified as either acute or chronic. An "acute standard" is defined as the one-hour average concentration that does not exceed the listed concentration more than once every three years. A "chronic standard" is defined as the four-day average concentration that does not exceed the listed concentration more than once every three years (NDDoH, 2001).

The Souris River is designated as a Class IA river for having suitable water quality for the propagation and/or protection of resident fish species and other aquatic biota; for swimming, boating, and other recreation; for irrigation, stock water, and wildlife without injurious effects; and for municipal water and domestic water supply after conventional treatment and water softening (NDDoH, 2001). Dissolved oxygen for Class I streams numeric standard is 5 mg/L as a daily minimum. However, up to 10% of representative samples collected during any 3-year period may be less than this value, provided that lethal conditions are avoided (NDDoH, 2001).

2.4. Dissolved oxygen

Oxygen is essential for aquatic systems. "In many regions of the U.S., low DO is a common freshwater impairment" (Vellidis, 2006). Typically, rivers and streams have dissolved oxygen (DO) concentrations expressed in milligrams per liter (mg/L), which is equivalent to parts per million (ppm). Adequate dissolved oxygen concentrations in streams is a basic requirement for a healthy ecosystem.

2.4.1. Dissolved oxygen sources

Dissolved oxygen sources include absorption of oxygen from the atmosphere (reaeration), mass transport of oxygenated water from upstream sources and photosynthetic production by algae and aquatic plants (see Figure 5). By far the largest source of dissolved oxygen in aquatic systems is reaeration. Agitation of the surface and wave actions can increase the contact surface area of water and air. These processes can significantly increase the oxygen transfer rate from air to water (Chu and Jirka, 2003). Water movement brings surface water (high in dissolved oxygen) into deeper (dissolved oxygen poor) water. The depth of the water severely limits the transport of oxygen from the surface, especially when thermal stratification exists. Ice and snow cover prevents reaeration almost completely. Diffusion without mixing can be a very slow process. Without flow in the winter, a river can become severely dissolved oxygen deprived (Tchobanoglous, 1985).

Photosynthesis by aquatic plants (macrophytes), free floating algae (phytoplankton), and attached algae (periphyton), provide a source or a sink of oxygen for aquatic systems (Vellidis et al., 2006). The growth of aquatic plants can actually supersaturate water with oxygen under the right conditions. The factors which influence these conditions include sunlight intensity, temperature, flow, plant density, and nutrient concentrations. During the summer months, if a high density of periphytes or macrophytes exists, the plants can cause oxygen levels to vary widely (Mulholland et al., 2005).

Photosynthesis allows plants to use solar radiation to fix carbon dioxide from the atmosphere with water to make carbon compounds such as glucose. Photosynthesis produces oxygen as a by-product and a source of oxygen in aquatic systems. Slow movement of water, high water temperature, high levels of nutrients, and strong solar radiation provide conditions for photosynthesis (Mulholland et al., 2005). During the night, plants undergo respiration, an oxygen dependant reaction which creates an oxygen demand. Aquatic plant respiration in the dark and photosynthesizing in the day can cause large diurnal variation in dissolved oxygen levels of aquatic systems (Mulholland et al., 2005).

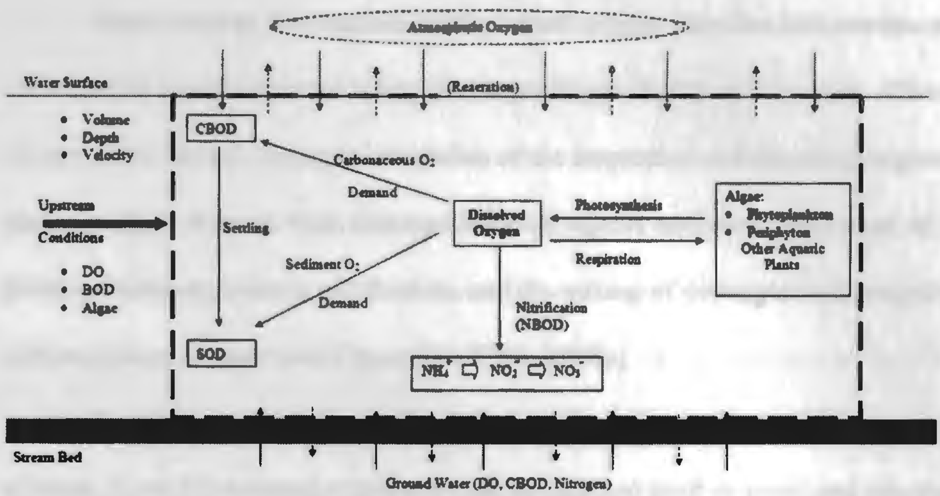

Figure 5. Schematic of the major processes influencing DO in rivers (MPCA, 2008)

Air provides the major source of oxygen for aquatic systems. Oxygen is a slightly soluble gas. Solubility of oxygen in water is related to temperature, partial pressure of oxygen, and water salinity. Henry's Law states that the amount of gas that will be absorbed into water is directly proportional to the partial pressure of the gas [oxygen] (Tchobanoglous, 1985).

Oxygen in water has saturation values that vary inversely with temperature. In cold temperatures DO saturation value is double what it would be during summer temperatures. The dissolution of oxygen is weakly exothermic so cooling shifts the reaction equilibrium more to the dissolved form (Jarvey, 2007). DO concentration could reach levels as high as 14 mg/L at 0 °C. However, ice cover prevents most reaeration during the winter months.

<u>2.4.2. Dissolved oxygen sinks</u>

Understanding the mechanisms by which oxygen transfers into streams and is consumed in aquatic systems is key to interpreting field data of this study. Dissolved oxygen sinks include biological oxidation of the suspended and dissolved organic matter, oxygen demand from decomposition of organic sediment, respiration of photosynthetic organisms, nitrification, and the mixing of deoxygenated ground water with oxygenated water (see Figure 5)(MCPA, 2008).

Two basic groups of organisms are considered for analysing DO in aquatic systems. Low DO tolerant organisms such as carp and scud or amphipod can survive in less than 4 mg/L of DO. High DO organisms such as trout and caddis fly larvae cannot tolerate low levels of DO (3-4 mg/L) for any length of time. Therefore, the EPA standard is set at 5 mg/L (Plater, 1998).

At sea level, typical DO concentrations in 100% saturated fresh water will range between 9.18 mg/L at 20 °C to 14.62 mg/L at 0 °C (Bowie et al., 1985). At levels below 4-5 mg/L, aquatic organisms become stressed. If the levels of DO remain hypoxic (DO < 2 mg/L) or anoxic (DO= 0 mg/L), higher life forms are forced to move or perish (Chambers et al., 2000). North Dakota Department of Game and Fish requires dissolved oxygen concentrations greater than 4 mg/L for warm water species of fish like northern pike and walleye (NDDoH, 2001).

For the past century many tests for the determination of oxygen demand have been developed. The tests have evolved as the treatment of wastewater has become commonplace (Vellidis, et al., 2006). The biochemical oxygen demand (BOD) test was developed to measure the oxygen demand of water samples under laboratory conditions.

BOD has been used to measure the amount of oxygen required for the biological oxidation of organic (carbon) compounds during a specific period, typically 5 days. The term carbonaceous biochemical oxygen demand (CBOD) is commonly used to distinguish it from oxygen demand from nitrification as discussed below. In rural areas, sources of oxygen-demanding substances may include diffused runoff of agricultural fertilizer and animal wastes (from manure application or grazing animals), soil erosion, and runoff from concentrated animal operations (Vellidis, 2006).

Chemical Oxygen Demand (COD) is a measure of all available organic as well as inorganic substances found in water. Potassium dichromate ($K_2Cr_2O_7$) is a strong oxidizing agent. When potassium dichromate is mixed with an acidic solution of sample water, a quick and accurate measurement of the amount of oxygen required to oxidize organic compounds to carbon dioxide, ammonia, and water is achieved (Tchobanoglous, 2003). COD is generally not an important parameter in streams without industrial pollutant sources. The test is much easier to perform than BOD and can be used as an indicator of BOD in streams with linear relationships between these two parameters (Vellidis, 2006).

Nitrification is the process where nitrifying bacteria oxidize ammonia to nitrite, and then to nitrate. The oxygen required for this process is termed nitrogenous biochemical oxygen demand (NBOD) (Tchobanoglous, 1985).

Direct discharge of pollutants from point and nonpoint sources into a river segment adds to its CBOD and NBOD, creating an oxygen demand that may depress DO below acceptable concentrations. High nutrient (nitrogen and phosphorus) levels can, in certain rivers, cause eutrophication to generate CBOD loads from decaying algae or plants. This may not occur locally, but instead further downstream in pools where velocities are slow and algae collect (Vellidis et al., 2006).

Anthropogenic phosphorous loading has affected aquatic systems. "Human activities and hydrologic modifications exacerbate phosphorus loading, which increases primary productivity. This process, called eutriphication, has likely been accelerated in the Souris River" (IJC, 2007). Low head dams collect allowing organics to settle out, which increase phosphorous release, especially in the winter (IJC, 2007). In addition, waterfowl attracted to reservoirs contribute to organic loading. Decaying vegetation and organic debris settle into the benthic sediments representing a DO next sink, referred to as sediment oxygen demand (SOD) (Tchobanoglous, 1985). Phosphorous is a likely source of oxygen depletion.

SOD is primarily caused by the aerobic decay of organic material that has settled to the bottom of the streambed. Examples of organic materials that can act as sources of sediment oxygen demand include leaf litter, particulate BOD in wastewater discharges, and algae or plant biomass. In pools made by low head dams sediments have settled out, the oxygen demand of these sediments can contribute to SOD. SOD during the winter months, when a river is covered by ice, can cause low DO conditions. Ice and snow prevents reaeration and photosynthesis. Oxygen depletion can become widespread throughout the stream without points where water is open to the air (Parr, 2004).

Modeling the DO balance in a river can be as a simple as a plug flow reactor model. The DO sag curve (see Figure 6) based on the Streeter-Phelps model predicts the DO deficit, the difference between the saturation level in the water and the DO concentration over time or distance following an organic matter introduction (Vellidis et al., 2006). The Streeter-Phelps oxygen sag curve expresses two differential equations, one for deoxygenating and one for reoxygenation.

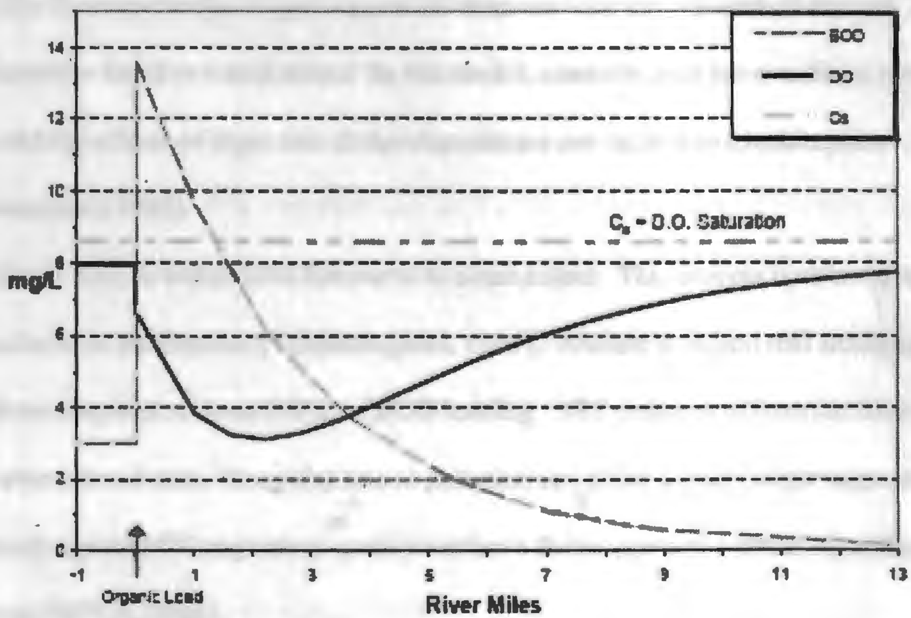

Figure 6. Stream DO response to a point source discharge (MPCA, 2008)

The amount of organic matter present in most natural water is low (Tchobanoglous, 1985). In Figure 6, zero river miles represent the river encountering an organic load. Decomposition of organic pollutants by microorganisms consumes oxygen and forms a dissolved oxygen sink. The drop in DO (0-1 river miles in Figure 6) indicates microbial aerobic respiration on the organic load. As the stream reaches a critical point (river mile 1.5), the DO concentration is at a low. At this point the deoxygenating and reoxygenation rates are equal. How low this critical point can go, and where in the river this occurs, are key questions in predicting solutions to river pollution problems. The DO begins to rebound as reoxidation rate exceeds the deoxygenation rate. This characteristic DO sag curve is the basis for most computer modelling programs used in water today.

The Streeter-Phelps oxygen-sag model does not take into account all the real world variables found in actual rivers. In this model, channels must have uniform cross section and the effects of algae and sludge deposits are not taken into consideration (Tchobanoglous, 1985).

Every stream will exhibit this curve to some extent. This process is referred to as natural stream purification (Tchobanoglous, 1985). Another common real situation comes from nonpoint sources (NPS) of BOD loading. NPS pollution affects the river system over a broad area. Nonpoint source pollution can affect a much larger segment of the river; typical NPS sag curves could be either a flatter curve or a series of smaller sag curves (MPCA, 2008).

CHAPTER 3. HISTORICAL DATA ANALYSIS

In order to complete the goal of understanding the cause of low dissolved oxygen in the Souris River, especially during winter, a historical study was completed so that a comprehensive sampling plan could be made. Since this study was conducted in North Dakota, North Dakota Department of Health water quality criteria and standards will be followed.

Water quality and quantity data on the Souris River was requested from all stakeholders. The International Souris River Board (ISRB) has representation from most parties responsible for the management of the river. These parties include: Saskatchewan Watershed Authority, Environment Canada, United States Geological Society (USGS), Army Corps of Engineering (ACE) and the North Dakota Department of Health (see Table 2). This historical data set includes water quality, flow, biological indicators, fish kills, bacterial contamination, sediment and siltation.

ISRB reported extreme hypoxia condition in the winter of 2002 at the international border station (ISRB, 2002). The ISRB suggested that the reasons for low DO could include, but were not limited to, sediment oxygen demand, macrophyte decomposition, organic enrichment, groundwater, photosynthesis suppression, low flows, or dams (Kellow and Fewless, 2002).

3.1. Hydraulic characteristics

Ten years of mean monthly flow rates recorded at the USGS Gaging Station 5114000 are shown in Figure 7. Peak flow occurs during the period of spring runoff. Very low average flow rates, often near zero flow, were observed in the winter and summer months (Figure 9). Plots of the flow rate versus time show great flow variation in the Souris River changing from almost zero to more than 565 cfs [16 m^3/s] during the high flow.

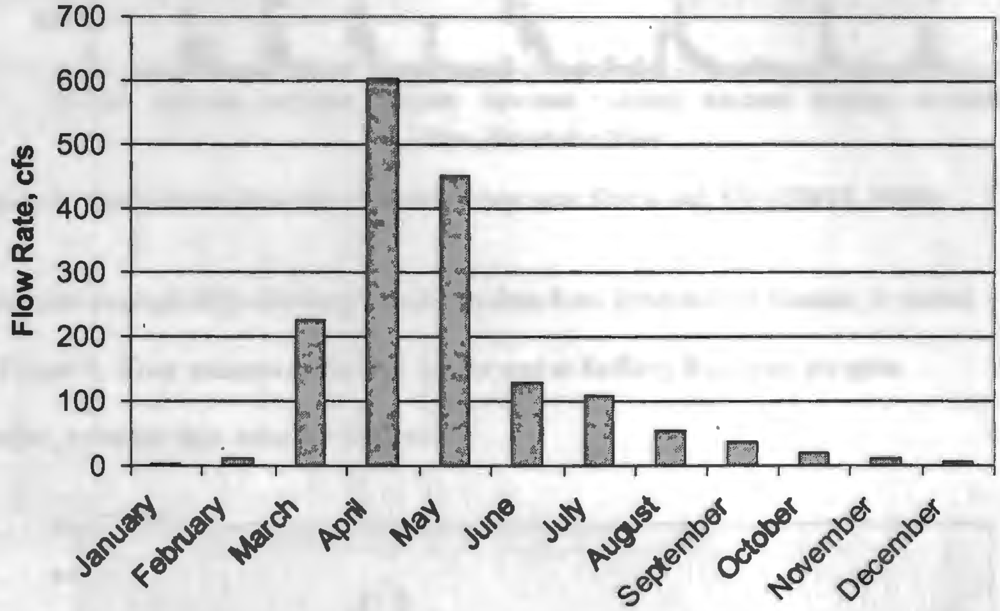

Figure 7. Monthly average flow rates from January 1995 to September 2004 gaging station near Sherwood, ND (Lin et al., 2006)

Flow from the years in question, 1995-2004, can be viewed as a collection of daily mean flow points, see Figure 8. Years such as 1998 and 2003 can have up to five times less flow than other years. Flow at this point is controlled by releases at Alameda reservoir.

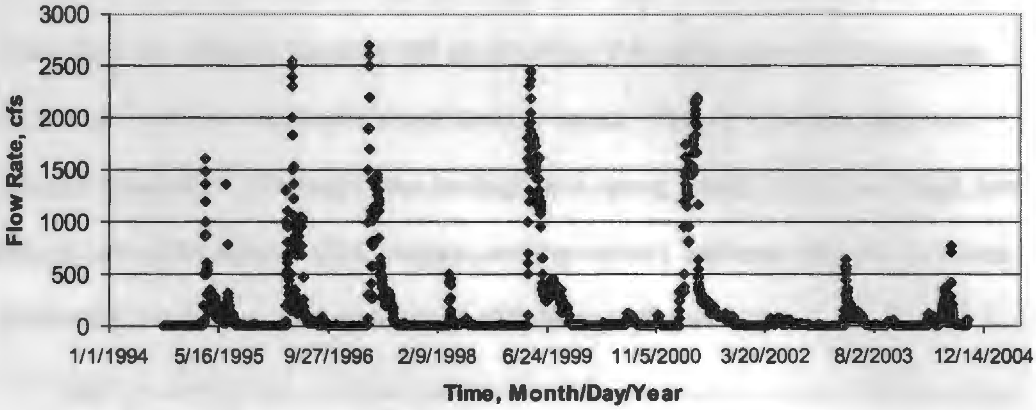

Figure 8. Daily mean flow rate of Souris River near Sherwood, ND (USGS, 2009)

Upstream average daily discharge, based on data from Environment Canada, is shown in Figure 9. Flow patterns at the U.S. border and at Rafferty Reservoir are quite similar, however flow rates are different.

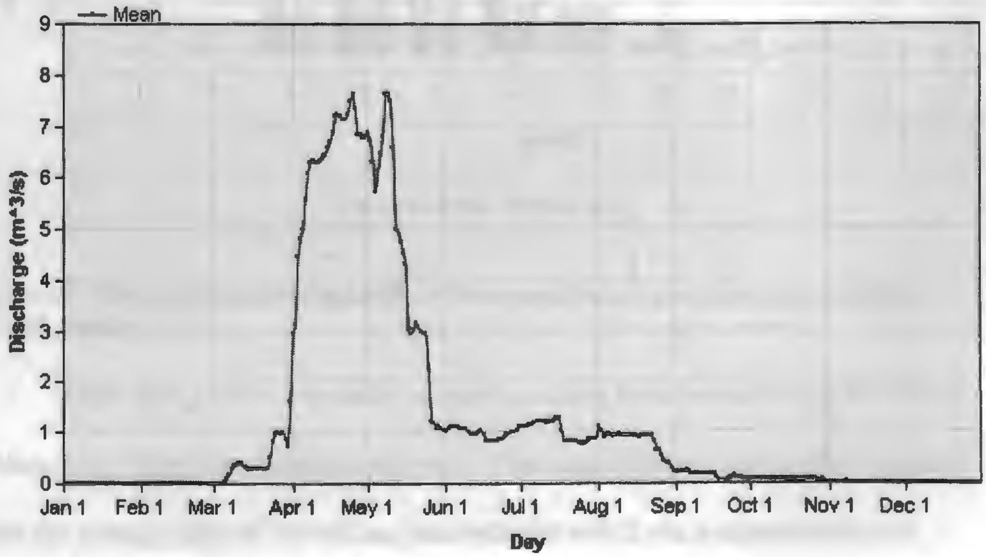

Figure 9. Daily discharge average for Souris River below Rafferty reservoir 1995-2004 05NB036 Environment Canada (Canada, 2007)

The highest monthly average discharge at the US border is 565 cfs (16 m^3/s), while flow at Rafferty is less than 283 cfs (8 m^3/s). Two other sources of water enter the Souris River between Rafferty and the U.S. border. They are the Boundary and Alameda reservoirs. Discharge rates are highest in spring months (April and May), low flow occurs in the summer (July, August, and September), and near zero flow in winter (November, December, January and part of February) (Figure 10).

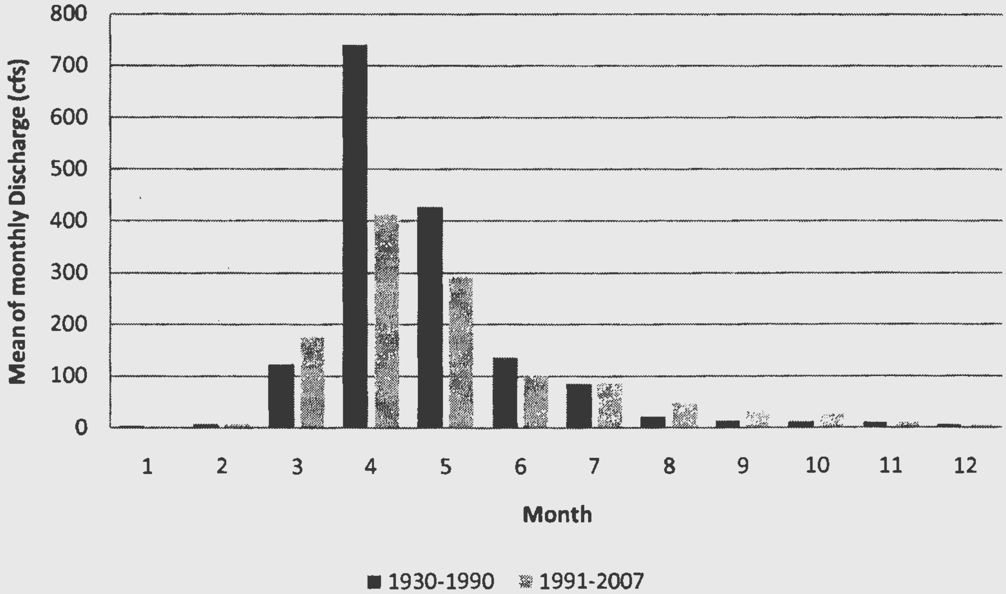

Figure 10. Mean of monthly discharge at Sherwood before and after impoundments (USGS, 2009)

High spring flows especially in April and May have been reduced 30-50% by holding water mainly in Alameda reservoir. The main difference takes place in April when the average flow of 740 cfs has been reduced to 412 cfs, a decrease of 56 %. Eliminating flow can have a negative effect on dissolved oxygen. Without spring flow, scouring of stream substrate has been eliminated. Sediment can build up and oxygen demand in the sediment (expressed as SOD), may be increased. The scouring effects of the high spring flows are no longer present. Floods that threatened North Dakota downstream municipalities are also no longer present (Hood, 1994).

3.2. Dissolved oxygen

Data collected from USGS Gaging Station 5114000 between August 1994 andSeptember 2004 were analysed for variation of dissolved oxygen (DO) levels in the Souris River (Figure 11). Generally, the DO measurements were taken at this gaging station on a monthly basis; however, fewer samples were taken during the winter months. From 1994 to 1999, a total of 115 DO samples were taken, of which 13 data points (11.3%) show DO level less than the minimum standard of 5 mg/L (see Figure 11). The lowest readings of DO were recorded on March 6, 2003 (1 mg/L) and February 15, 2001 (1.6 mg/L). These results confirm the impairment as determined by the North Dakota Department of Health.

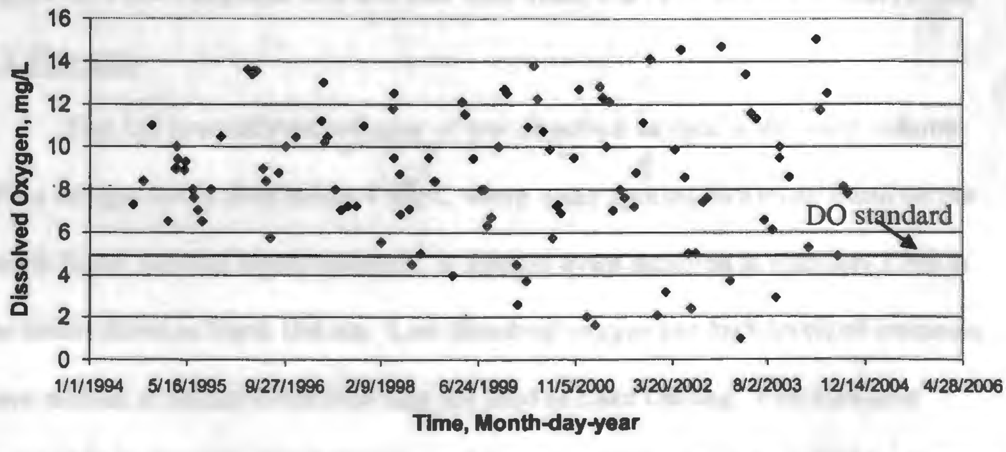

Figure 11. Dissolved oxygen levels in the Souris River 1994-2006 USGS gaging station near Sherwood, ND (USGS, 2009)

In Figure 12, DO concentration is plotted versus flow rate with winter data highlighted in squares. Figure 12 shows that most low DO readings were recorded during winter months when the river is covered by ice and flow was low. Lack of data during the coldest months of the year before 1999 (Figure 3) is due to limited sampling during this period of record.

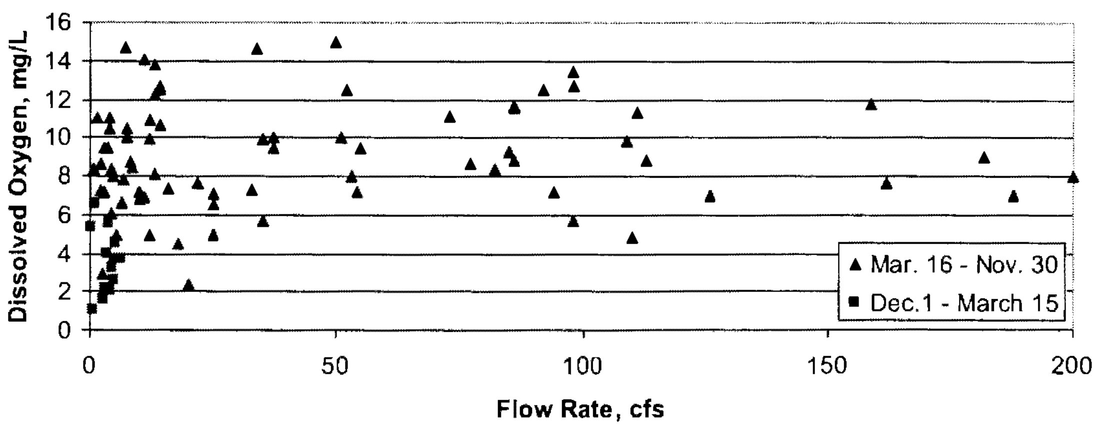

Figure 12. Flow compared with DO near Sherwood, ND 1994-2006 (Lin et al., 2006)

3.3. Fish kills

Fish kill is usually an indicator of low dissolved oxygen in the water column. When oxygen levels drop below 4 mg/L, warm water species, like those found on the Souris River, become highly stressed. A fish kill event occurred in February 1999 in the Souris River in North Dakota. Low dissolved oxygen and high levels of ammonia were noticed at Mouse River Park near the head of Lake Darling. Fish kills also occurred in 2002, 2003, 2004 (Kellow and Fewless, 2002). It can be difficult to assign a specific cause and effect relationship to fish kills; quick action is needed to determine why a particular event took place. In the winter the time frame of a fish kill is difficult to ascertain. Fish kills primarily serve as a media events indicating concern and prompting further study.

3.4. Fecal coliform

Historical fecal coliform data collected at the USGS Gaging Station 5114000are shown in Figure 13. When Criteria 1 and 2 are used to evaluate the whole data set, the water quality at this location meets both criteria for fecal coliform. However, if the data is evaluated on an annual basis, Criterion 2 has been violated in some of the years (see Figure 13).

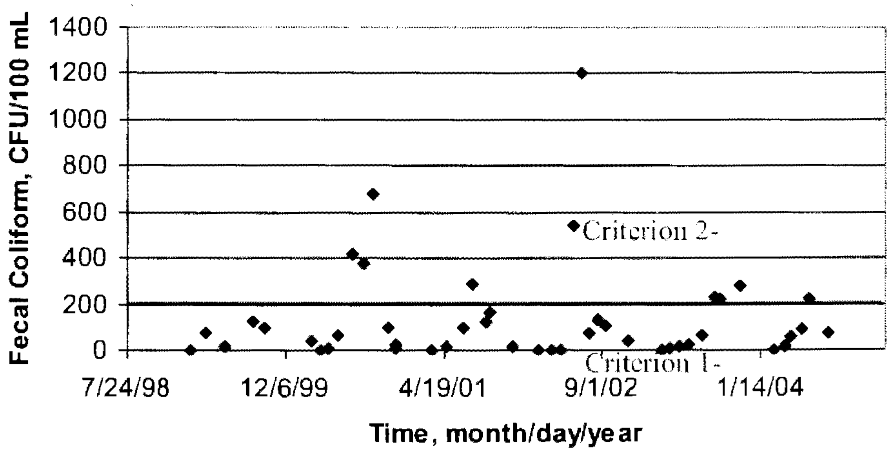

Figure 13. Fecal coliform concentration in the Souris River USGS gaging station 5114000

3.5. Phosphorus

Data for the Highway 18 Station, located approximately 30 river miles upstream from Glen Ewen, Saskatchewan, was obtained from the Saskatchewan Watershed Authority (see Figure 14). The water quality data from the period of record 1971 to 1992 include concentrations of arsenic, chromium, mercury, ammonia-nitrogen, nitrite-and nitrate-nitrogen, dissolved oxygen, sulphate, total phosphorus, pH, and total dissolved solids.

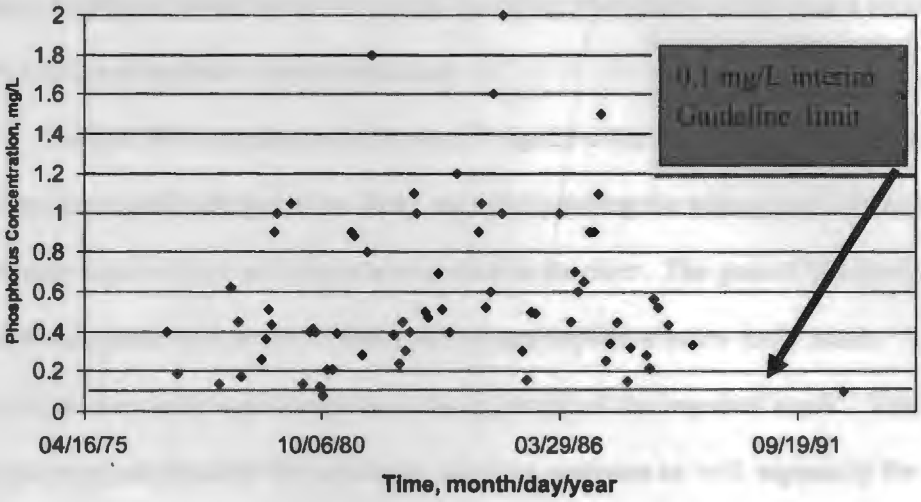

Figure 14. Souris River Canadian phosphorus concentrations at highway 18, 1974-1986 (Saskatchewan Water Authority, 2005)

High total phosphorus concentrations appear to be a problem in the Canadian water, with more than 90% of samples tested exceeding the interim North Dakota limit of 0.1 mg/L (NDDoH, 2001). Phosphorus concentrations as high as 2 mg/L have been reported in Saskatchewan, Canada (Saskatchewan Watershed Authority, 2005). Phosphorous can serve as a limiting reagent for algae growth. Therefore, excess phosphorus can result in algae blooms.

3.6. Conclusions on historical data analysis

The historical data analysis of the impaired reach and data from upstream of the reach indicates that the Souris River is impaired for aquatic life use. Specifically, periods of low DO concentration and phosphorus are pollutants of concern.

The cause of low DO may be non-point sources, such as agricultural runoff. Therefore, samples need to be taken during the spring runoff season and after rain events. Additional sampling for nutrients, including phosphorus and nitrogen could pin point sources of nonpoint source pollutants.

The low DO concentration (less than 5 mg/L) in the river is identified as a problem associated with low river flows, especially during the winter months when the river is covered with ice and no aeration occurs in the river. The goal of this study is to identify the source and extent of dissolved oxygen depletion in the study reach. Existing data analysis is primarily from the upper end of the impaired reach. This analysis suggests the need for additional sampling upstream as well, especially for identifying the reasons for oxygen depletion that resulted in low DO at the Sherwood (U.S. border) site.

CHAPTER 4. MATERIALS AND METHODS

Materials and methods discussed in this chapter consist of three parts: site selection, analytical parameters, and sampling. Procedures for field sampling and water quality monitoring are consistent with EPA and North Dakota Health Department guidelines.

The sampling plan for this study includes three areas: site selection, sample period/frequencies, and specific parameters to sample. Five primary sampling sites were chosen. All sites were identified based on spatial location and ease of access. Sampling times were selected based on winter conditions, ice out, and storm events. In addition to set sample times, three samples were to be obtained after storm events to evaluate runoff from adjacent land. Parameters were selected based on study sites ability to shed light on dissolved oxygen sinks and sources.

4.1. Field study site selection

Locations of the five primary testing locations are shown in Figure 15. Specific locations and descriptions of these sites are presented, with red stars indicating primary sampling sites (see bold stars in Figure 15). As described in Chapter 3, analysis of the historical data confirmed that further study of the river upstream of the impaired reach was also needed. For this reason, the original study area (impaired reach) was extended upstream into Saskatchewan, Canada. This 65.1 mile river reach is the study reach referred to in Section 2.1.3. The entire study reach includes Glen Ewen, SK, to County Road 3 (just upstream from Mouse River Park), near the inlet of Lake Darling. The Glen Ewen, SK site allowed for assessment of the extent and nature of the upstream impairment to the Souris River. Driving times and mileage had to be increased by approximately 15% to account for this additional sampling location in Canada. The total time and distance of travel for each sampling trip was approximately 8 hours and 250 miles, respectively. Two additional sites located upstream of Glen Ewen, not listed in Table 4, are designated Oxbow and Highway 9 (see winter sites Figure 15). These sites were used in the winter to take sediment samples and for dissolved oxygen testing.

Figure 15. Souris River study reach monitoring sites (Two additional Saskatchewan sites [bold stars] indicate extra winter extra sampling sites for field parameters only)

Sample sites were selected to represent typical river reach characteristics. Sampling sites were selected using three main criteria: quality of data, safety, and ease of access. The quality of data would depend on how evenly spaced sample sites could be placed within the reach (see Table 4). Quality monitoring assumes each site represents the typical nature of the stream found within that section of the reach. This was difficult since the easiest place to sample is from bridges, but bridges change the nature of the rivers they span. Winter sampling presents many safety issues, primarily year round access to flowing water. Therefore, the safety and ease of year round access with equipment outweighed the influence of changes in substrate due to bridge abutment and roadways.

A special site selection field outing was conducted September 23, 2006. Joe Super, Dr. Lin and Dr. Saini-Eidukat visited the entire reach choosing best possible sampling locations. Cross sections were surveyed at 4 of the 5 sampling sites in order to record accurate flow and identify river bottom change (see Figure 16). County Road 2 was not surveyed since data existed from the USGS.

Near the border the USGS gaging station near Sherwood (blue star in Figure 15) provided automated stage and flow readings dating back to 1930. This site included an automatic water quality sampler active from 1993 to 2007, the time immediately following the construction of two impoundments in Canada. Real time hourly measurements of stage, flow, DO, temperature and conductivity were posted to USGS Real-Time Water Data National Water Information System (http://nd.water.usgs.gov/) (USGS, 2009). This real time data allowed for long term recording of stage readings, storm events, and chemical variation that could never be seen using normal grab sampling methods

Table 4. Description of Souris River sampling sites

Site	Latitude Longitude	River Miles from Glen Ewan	Description
Glen Ewen	49°10'48.72"N 102° 1'39.00"W	0	Canada site surrounded by pasture, faster moving water, steeper banks in Canada, sand bottom
USGS 05114000 (USGS)	48°59'24.00"N 101°57'28.80"W	33.4	24 hr. gaging station located in dammed pool. Heavily wooded area site of log jam removal to keep station open
County Road 2 (CR2)	48°57'58.68"N 101°56'51.00"W	34.6	Just south of cattle/ sheep operation, shallow water, 2-4 ft., rocky bottom, USGS box attached to bridge
Stafford Bridge (SB)	48°55'21.72"N 101°55'35.04"W	41.5	Typical site in U.S. with woody banks, shallow water, 2-4 ft depth, rocky bottom, wood accumulating around bridge pilings
Johnson Bridge (JB)	48°52'45.12"N 101°52'4.44"W	51.8	Lake Darling level effects flow. Depth increasing, huge mass of wood accumulated around bridge pilings, mud bottom
County Road 3 (CR3)	48°45'49.20"N 101°46'33.30"W	65.1	Lake Darling drastic effect with10 ft depth and large cross sectional area, mud bottom

The North Dakota Department of Health contracted with the USGS to re-establish this auto sampler for one year of sampling, from 2006-2007. In winter actual sampling locations were dependant on finding water under the ice. If a site contained ice to the bottom of the river, a suitable substitute site was chosen within close proximity to the site originally chosen.

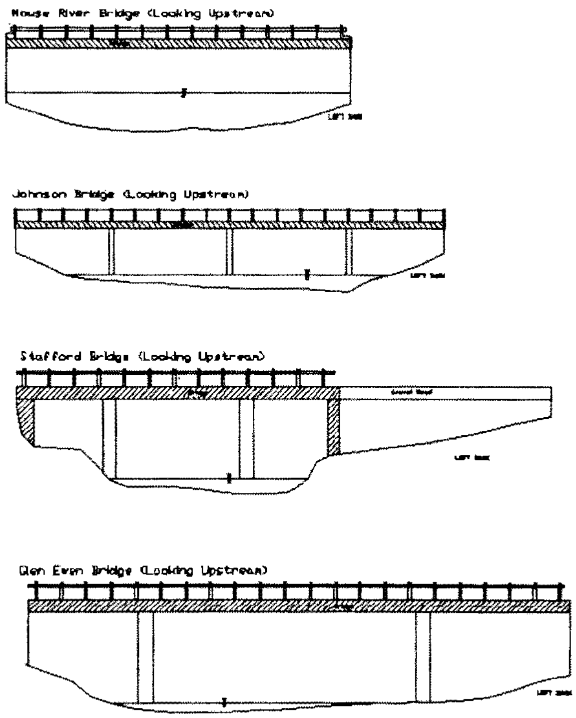

Figure 16. Surveyed profiles of sampling sites

4.2. Analytical parameters

Physical field measurements included: flow velocity, stage height, water depth, ice depth and observations of site conditions (weather, land use). Measurement of chemical parameters was carried out with two methods: on-site monitoring and grab samples for laboratory analysis (Figure 17). Chemical field measurements were collected with YSI 650 probe. Parameters measured on site included temperature, pH, conductivity, and dissolved oxygen. Parameters measured at the DoH Laboratory are listed in Figure 17.

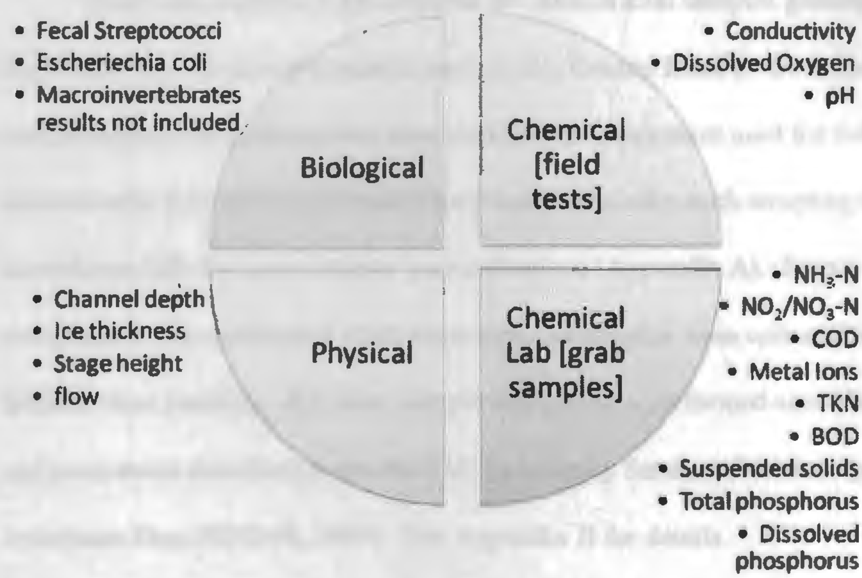

Figure 17. Parameters measured (NDDoH SOP, 2008)

4.3. Sampling methods

4.3.1. Sample handling and custody

Sampling was carried out using three methods: on site field measurement, grab water quality samples sent to the ND Department of Health Lab in Bismarck, and automatic measurement collected at the USGS station located near Sherwood on the Canadian-U.S. border. Grab samples collected at the 5 sites were filtered (if needed), preserved, and shipped in on ice to the ND Department of Health lab in Bismarck via overnight courier within 24 hours. See Appendix A for standard operating procedures. Sampling times were variable but usually carried out on weekends to accommodate the sampler's work schedule and state lab restrictions.

4.3.2. Quality control measures

Duplicate samples were collected for 10% of total samples gathered. These duplicates were taken at the same sampling site, County Road 3. Both field measurements and grab samples were duplicated. Equipment used for field measurement was calibrated immediately before and after each sampling trip in accordance with the manufacturer's specifications (Appendix A). Proper equipment maintenance was performed when necessary and samples were collected in the same fashion when possible. All water sample analysis was performed according to methods and procedures described in the NDDoH Laboratory Services Division Quality Assurance Plan (NDDoH, 2007). See Appendix B for details.

4.3.3. Sampling schedule

Sampling consisted of 29 sampling dates. An additional 12 fecal coliform sampling dates were also established during the summer months (see Table 5). Included in the sampling plan were three storm event sampling trips. A storm event is defined as a precipitation event (from either direct rainfall or snowmelt) large enough to cause a 0.2-foot increase in stream stage. The Renville County Soil Conservation District (SCD) collected additional fecal coliform samples at two sites to assure enough samples to calculate monthly geometric means. Detailed descriptions of all field-sampling methods are provided in Appendix A.

The experimental design of this project followed general guidelines established by the EPA for water sampling. Changes were made to look further into observations from field data collected as sampling events took place. Sample locations had to be modified if the ice on the site was frozen through to the bottom or the water column below the ice was too little to collect samples. Additional sites were added to study the extent and nature of the results generated in the original reach. Sediment and ground water sampling were added to identify sinks of dissolved oxygen more clearly. Winter conditions encountered on the Souris River required modifications to the existing collection procedures and went beyond the scope of manufacture instructions for some of the equipment used. Extreme cold, thick ice, and lack of flow were common challenges. Precision and accuracy were the rule but procedures had to be modified to meet these challenges.

Table 5. Site visits for sampling and observation

Date	Sampler	Time Started Sampling	Sites in order of sampling
9/23/06	Joe Super, Dr.Lin, Dr. Saini-Eidukat	10:15	CR3, JB, SB, CR2, USGS, GE
11/5/06	Joe Super	9:30	CR3, JB, SB, CR2, USGS, GE
11/19/06	Joe Super	8:45	CR3, JB, SB, CR2, USGS, GE
12/3/06	Joe Super	9:00	CR3, JB, SB, CR2, USGS, GE
12/15/06	Joe Super	8:15	CR3, JB, SB, CR2, USGS, GE
1/7/07	Joe Super	8:15	CR3, JB, SB, CR2, GE, OX, HWY9

Table 5. (Continued)

Date	Sampler	Time Started Sampling	Sites in order of sampling
1/14/07	Joe Super	7:53	CR3, JB, SB, CR2, GE
1/28/07	Joe Super,, Wei Lin	8:45	CR3, JB, SB, CR2, USGS, GE, OX, HWY9
2/11/07	Joe Super	8:00	CR3, JB, SB, CR2, USGS, GE, OX, HWY9
2/25/07	Joe Super	7:50	CR3, JB, SB, GE, OX, HWY9
3/10/07	Joe Super	9:00	CR3, JB, SB, GE, OX, HWY9
4/1/07	Joe Super	8:00	CR3, JB, SB, CR2, GE
4/9/07	Joe Super	8:30	CR3, JB, SB, CR2, GE
4/14/07	Joe Super	7:10	CR3, JB, SB, CR2, GE
4/22/07	Joe Super	7:30	CR3, JB, SB, CR2, GE
4/28/07	Joe Super	7:00	CR3, JB, SB, CR2, GE
5/5/07	Joe Super	7:30	CR3, JB, SB, CR2, GE
5/13/07	Joe Super	6:00	CR3, JB, SB, CR2, GE
5/19/07	Joe Super	8:00	CR3, JB, SB, CR2, GE
5/27/07	Joe Super, Dr. Lin,	7:15	GE
5/28/07	Joe Super, Wei Lin	6:00	CR2, SB, JB, CR3
6/3/07	Joe Super	16:45	GE, CR2, SB, JB, CR3
6/10/07	Joe Super	15:30	GE, CR2, SB, JB, CR3
6/12/07	Joe Super	14:30	GE, CR2, SB, JB, CR3
6/19/07	Dora Abernathy	-	CR3
6/24/07	Joe Super	7:15	CR3, JB, SB, CR2, GE
6/26/07	Dora Abernathy	-	CR3
7/2/07	Dora Abernathy	-	CR3
7/15/07	Joe Super	8:30	CR3, JB, SB, CR2, GE
7/16/07	Dora Abernathy	-	CR3
7/30/07	Joe Super, Matt Baker	6:30	CR3, JB, SB, CR2, GE
7/31/07	Dora Abernathy	-	CR3
8/6/07	Dora Abernathy	-	CR3
8/13/07	Dora Abernathy	-	CR3
8/19/07	Joe Super	8:00	CR3, JB, SB, CR2, GE
8/21/07	Dora Abernathy	-	CR3
9/4/07	Dora Abernathy	-	CR3
9/9/07	Joe Super	9:00	CR3, JB, SB, CR2, GE
9/10/07	Dora Abernathy	-	CR3
9/17/07	Dora Abernathy	-	CR3
9/24/07	Dora Abernathy	-	CR3
10/21/07	Joe Super	8:15	CR3, JB, SB, CR2, GE

CHAPTER 5. RESULTS

In order to identify the source and extent of low dissolved oxygen concentration in the upper reach of the Souris River two processes had to take place: historical data analysis (Chapter 3) and an intense period of sampling to fill the data gaps, especially in the winter. If the source and extent of low DO could be verified then the reasons for the observed aquatic life-threatening situation could be identified.

5.1. Hydraulic characteristics

Daily mean discharge (October 2006 to October 2007) for the Souris River at the USGS gaging station (Sherwood) is shown in Figure 18. During some of the winter months when the gage is frozen in ice the river discharge is estimated (red line Figure 18). All other times during the year the values were measured directly at the gaging station and uploaded automatically to the USGS web site. The 78-year median value is shown as a brown line. The flow range is very large, therefore, it is recorded in a logarithmic scale. The Souris River flow shows a pattern characteristic of prairie rivers. Before upstream reservoirs were built, the river would have intermittently ceased to flow for part of the year. After those impoundments were finished, regulation requirements of 20 cfs (0.566 cubic meters per second) were recommended to maintain flow. Flow has a major influence on reaeration; identifying an ideal flow could significantly decrease the chance for low DO conditions to develop.

During the winter combined effect of ice cover and low flow rate limit the transport of dissolved oxygen. Moving water improves reaeration. Ice cover prevents most reaeration. Comparing data from the automatic sampler discharge with data for dissolved oxygen provides insight. When ice first forms on the Souris River "ice in" dissolved oxygen provides insight. When ice first forms on the Souris River "ice in" (3/10/07), the DO drops below 5 mg/L in less than two weeks from "ice in". In the winter of 2006-2007 the hydraulic character of the Souris River followed a typical pattern of decreased flow, thick ice and long periods of low dissolved oxygen.

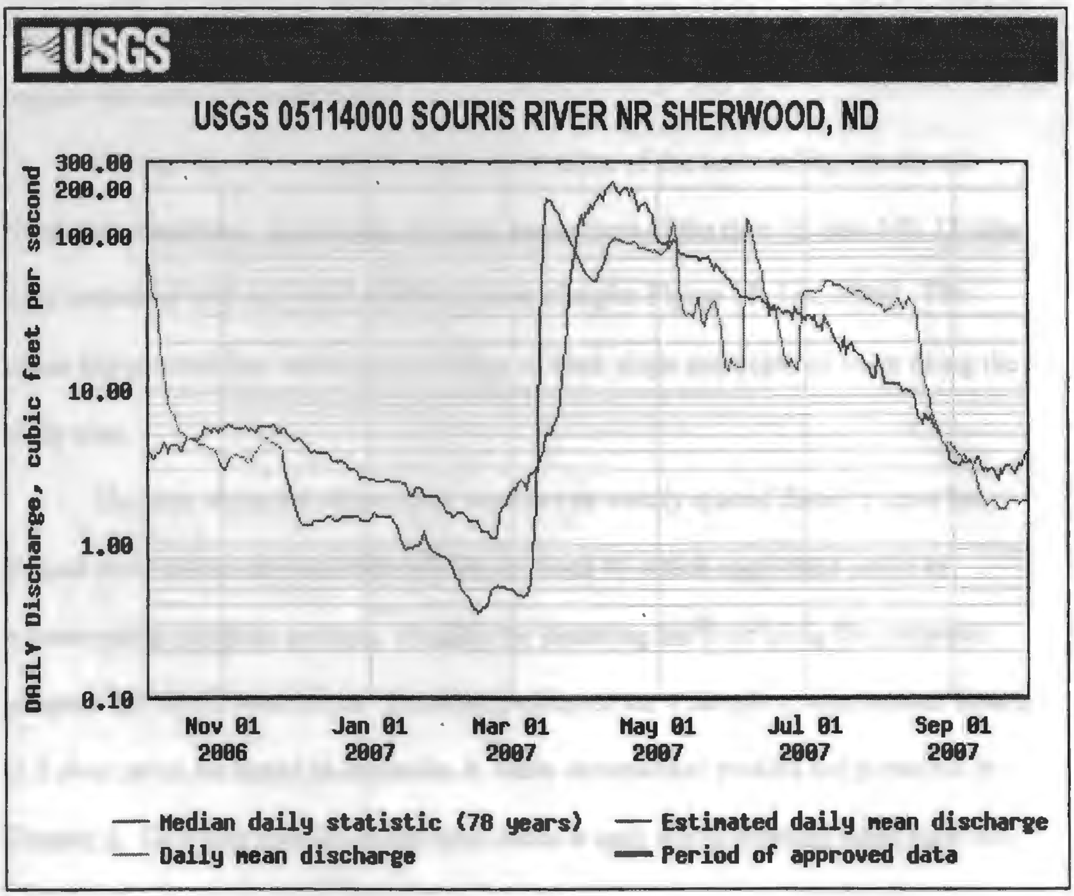

Figure 18. Daily discharge, Sherwood, automatic sampler (USGS, 2009)

On May 26, 2007, a canoe trip took place following the river from Glen Ewen to County Road 3 (See Figure 19). The purposes of the canoe trip included: observation of flow types present in river, analysis of flow blockages and related substrate issues, surveying of cross sectional transects for computer modelling, sediment sampling for SOD measurements, and identification sources of pollution.

Many logjams were encountered and recorded during the canoe trip. Logjams act as dams during flooding and hinder continuous flow. Five significant logjams were found (see black "X" Figure 19) with 2 logjams being extremely large. The largest logjam was over 150 yards long.

During this trip over 400 pictures were taken of the surrounding terrain and riverbank conditions. In addition to visual assessment of the river (Figure 19), 13 sites were evaluated with surveyed profiles (green triangles Figure 19; Lin, 2006). The canoe trip resulted in a working knowledge of bank slope and depth of water along the study area.

The sites along the canoe route were not an evenly spaced distance apart but instead were chosen for their accessibility to roads by which equipment could be maneuvred to complete surveys. Profiles for modeling the river using the computer program QUAL2K were taken. Detailed profiles of the 4 sampling sites located from 2 to 5 river miles are found in Appendix A while summarized profiles are presented in Chapter 6. GPS unit measurements were taken at each site to pinpoint exact locations.

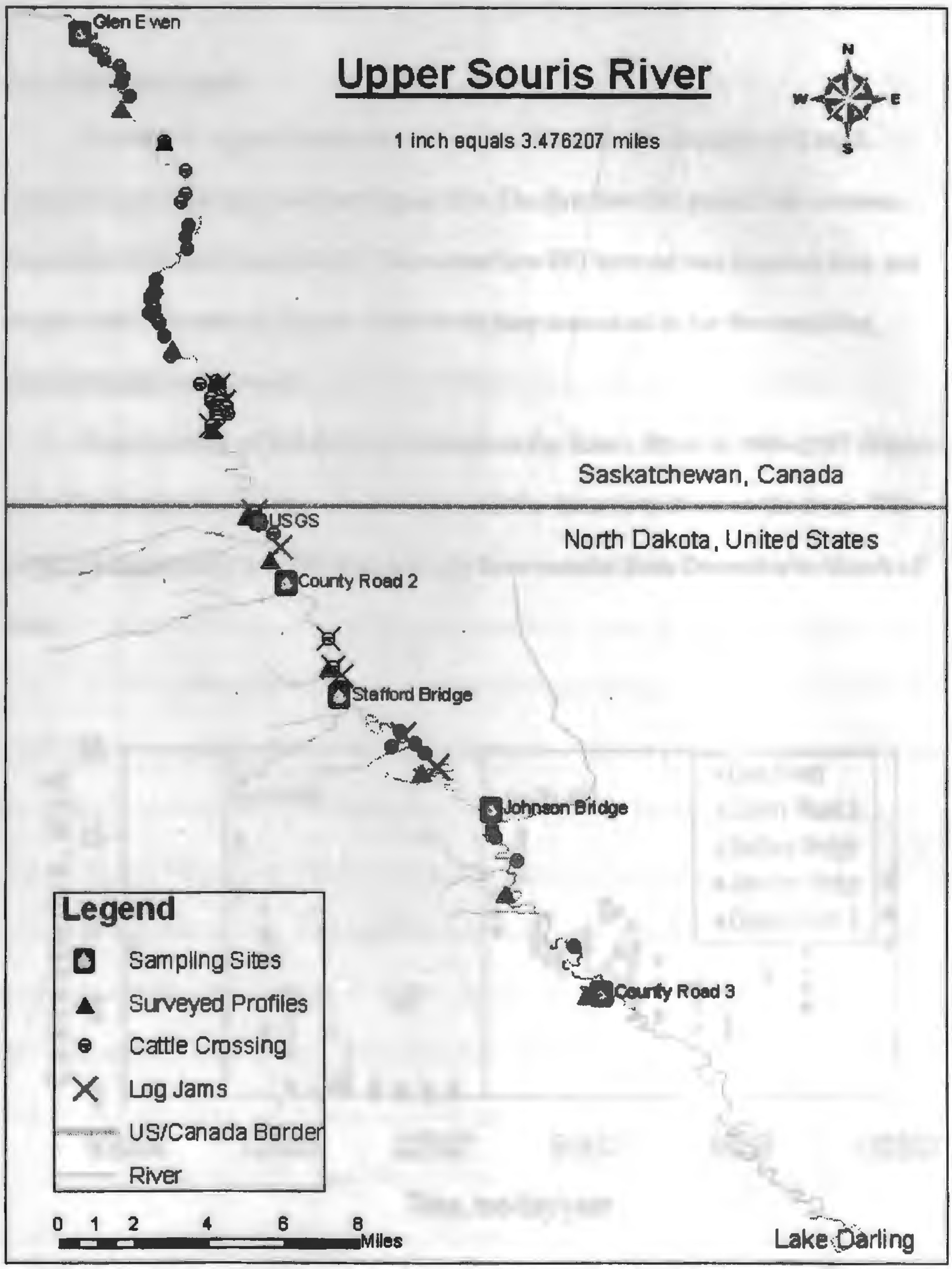

Figure 19. Summary of observations made during May 2007 canoe trip

5.2. Dissolved oxygen

Dissolved oxygen results were above the standard DO standard of 5 mg/L except for two time intervals (see Figure 20). The first low DO period was between December 2006 and March 2007. The second low DO interval was between June and August 2007. Dissolved oxygen results were very consistent in the five sampling points throughout the reach.

Two intervals of DO decline occurred on the Souris River in 2006-2007 (Figure 20). The first declining interval coincides with the formation of ice on the river. The period of dangerously low DO lasted nearly three months from December to March of 2007.

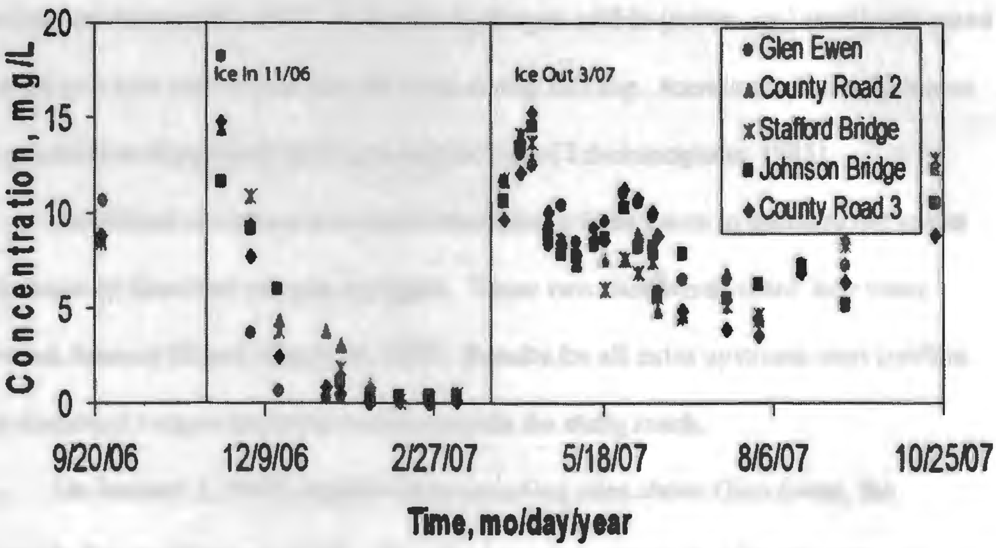

Figure 20. Dissolved oxygen concentrations for all 5 sampling sites (field results)

Dissolved oxygen results from the YSI-650 probe were so low in January that the field results were questioned. On January 28, 2007, a second site visit by principal investigator Dr. Wei Lin and graduate student Matt Baker was made to verify DO probe readings using the Winkler Titration Method.

The Winkler Method, (Azide-Modification) or iodometric method for measuring dissolved oxygen is a titrimetric procedure based on the oxidizing property of DO (Greenberg, 1992). The sample is fixed and converted to an acidic compound. This is then titrated with a known reagent to yield a stoichiometric result that is a very accurate measure of the dissolved oxygen present (see appendix B for complete SOP).

Field sampling and titration using the Winkler method confirmed the YSI-650 readings on January 28, 2007. A distinct hydrogen sulfide (rotten egg) smell was noted as soon as a hole was drilled into the river during this trip. Anoxic conditions promote the production of putritive hydrogen sulphide gas (Tchobanoglous, 1985).

Additional sites were also established above Glen Ewen to measure the extent and nature of dissolved oxygen depletion. These two sites were visited four times between January 28 and March 10, 2007. Results for all extra upstream sites confirm that dissolved oxygen depletion occurs outside the study reach.

On January 1, 2007, in addition to sampling sites above Glen Ewen, the Alameda Reservoir was sampled. Dissolved oxygen content at Alameda reservoir was 10.41 mg/L, much higher than that of the river. Alameda reservoir flows into the

Souris River above Oxbow before the highway 9 sampling site (see Figure 2). Sediment sampling was conducted at all sites for further analysis by NDSU graduate student Mathew Baker. In addition, a shallow ground water well was sampled and tested for DO.

Dissolved oxygen levels returned to acceptable levels with "ice out." The DO increase occurred so rapidly that this event was not captured through field testing. On 3/10/07 there was still approximately 1 ft of ice cover and on 4/1/07 little to no ice cover existed. Following ice out, DO levels rebounded to approximately 10 mg/L. Winter anoxic conditions mirrored the formation and exit of ice on the river. Therefore, oxygen depletion took place from water column or sediment.
The second declining interval in DO occurred slowly in the spring and summer of 2007. This interval occurred simultaneously with low flow and water temperature increase. Summer hypoxia was also distinguished by diurnal swings in DO (see Figure 21). The automatic sampler at the USGS gaging station in Sherwood provided a unique view of dissolved oxygen results at a location near the middle of the study reach (Figure 21). Note how closely the field observations of Figure 20 match those of the automatic sampler, shown in Figure 21.

Notice the drastically different winter and summer daily minimums and maximums. These differences in daily DO provide proof of different causes for summer and winter oxygen depletion. However, the automatic sampler did not continue operation throughout the entire winter. The period of approved data was interrupted by ice from February until the end of April (see Figure 21).

To clarify the difficulty of interpreting Figure 21, a definition of the calculation of the median daily values is necessary. "The median daily dissolved oxygen is

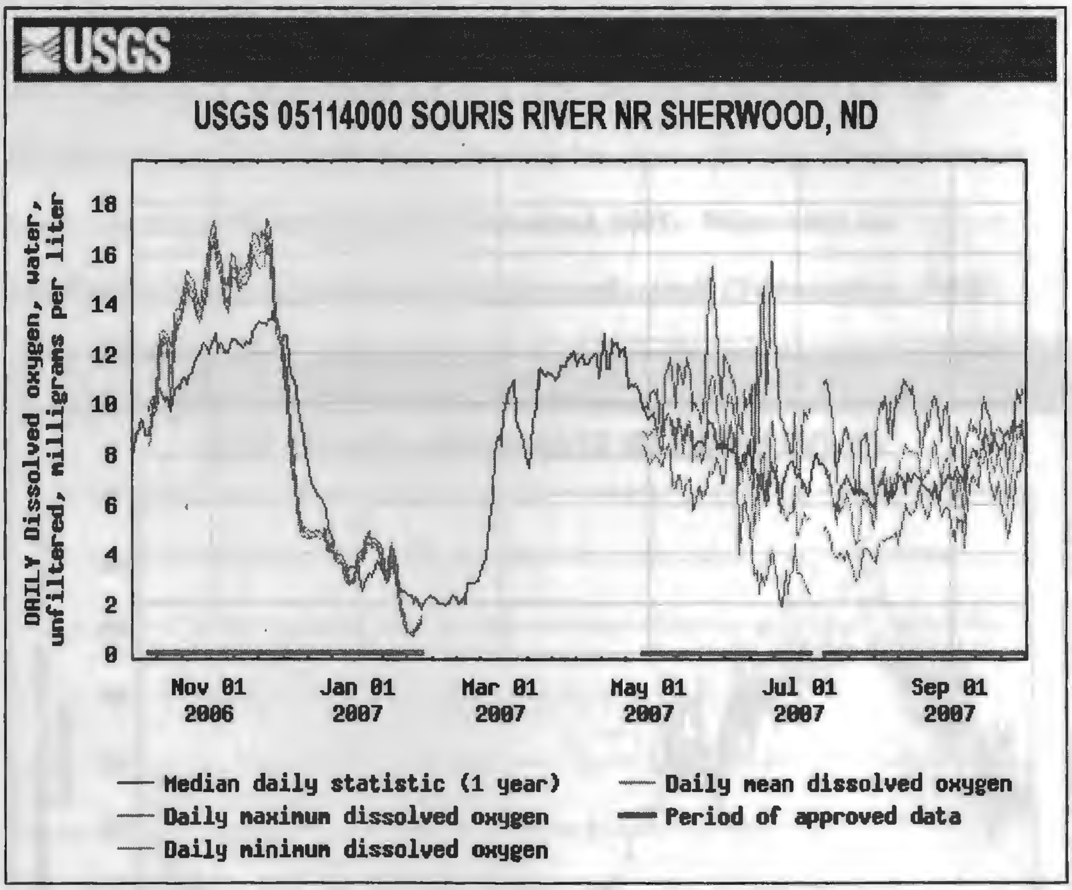

Figure 21. Maximum and minimum DO Sherwood automatic sampler (USGS, 2009)

calculated from a continuous recording instrument that recorded dissolved oxygen at some interval, in this case hourly readings. A daily mean was calculated from the hourly readings. The median daily values were calculated as the 50th percentile (median) of the daily mean values for each day for the number of years of record" (Galloway, 2010). Therefore, even if the instrument was not functioning this year, other years of continuous operation can give an estimated value for the mean daily statistic, shown as a brown line in Figure 21.

Figure 22 shows that during winter there is no significant difference in daily water temperatures. In the summer there is large variation in daily low and high dissolved oxygen in the Souris River. Research has shown that large summer variation is due to excess autotroph production (Mulholland, 2005). Warm water can significantly increase metabolism of both plants and animals (Tchbanoglous, 1985).

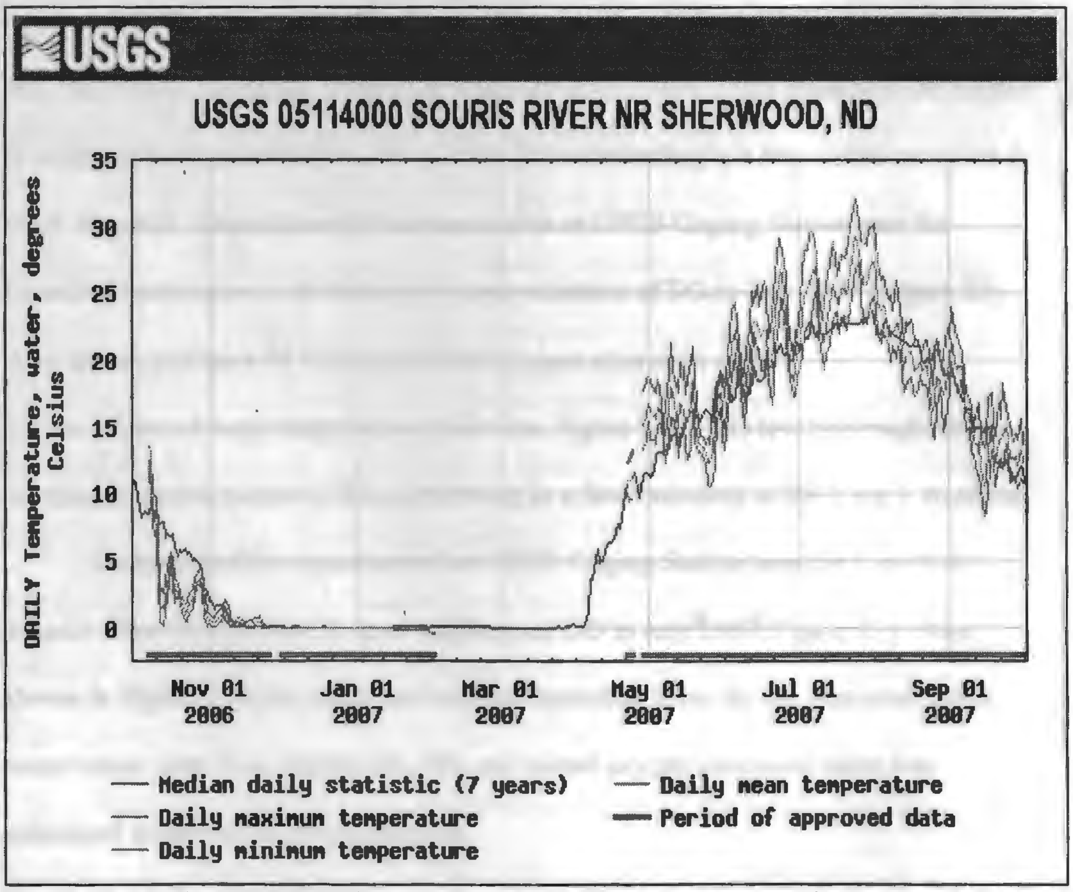

Figure 22. Maximum and minimum temperature, Sherwood, automatic sampler (USGS, 2009)

During July and August 2007 water temperatures and DO varied inversely to one another. As water temperature increases from 10 – 23 Celsius, the DO drops from 10 – 6 mg/L (see Figures 22, 23). Daily minimum DO drops as low as 2 mg/L, hypoxic conditions for aquatic life.

5.3. Diurnal dissolved oxygen variation

Photosynthesis and respiration of plants living in the water are additional factors in dissolved oxygen variation. In the summer, aquatic plants can cause large diurnal variation in DO values within the river. Algae perform photosynthesis during the day and respiration (consumes oxygen) at night (MCPA, 2008). Field measured DO levels throughout the summer show a decrease in DO culminating in a few violations of the 5 mg/L standard. Continuous DO measurements at USGS Gaging Station near the Canadian border show a prominent 24-hour variation of DO in July 2007 (Figure 23). Also shown in Figure 23 is the calculated oxygen saturation value

for the measured water temperature (pink line, Figure 23). DO levels throughout the summer show a decrease in DO culminating in a few violations of the 5 mg/L standard.

Continuous DO measurements at USGS Gaging Station near the Canadian boarder show a prominent 24-hour variation of DO in July 2007 (Figure 23). Also shown in Figure 23 is the calculated oxygen saturation value for the measured water temperature (pink line, Figure 23). The calculated oxygen saturation value was calculated using the following equation.

$$DO_{sat} = \frac{0.678\,(P_{atm} - P_{water\ vapor})}{(Temp + 35)}$$

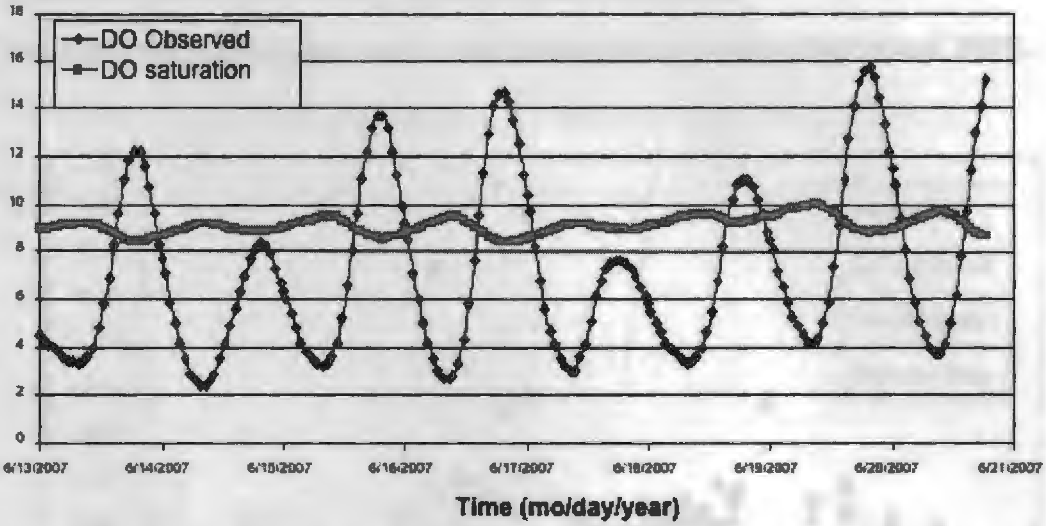

Figure 23. Diurnal dissolved oxygen variation at USGS gaging station (USGS, 2009)

Note these values are for one 7 day period for the Souris River. Large differences in dissolved oxygen levels occur at predictable daily times; this is referred to as diurnal DO variation and indicates significant algal growth in the river (Tchbanoglous, 1985). During the day plants carry out photosynthesis and respiration allowing excess oxygen to increase the DO levels in the river. At night, plants respire only; consequently, the DO levels at night drop. The lowest point in the dissolved oxygen levels occurs just before dawn (Mulholland, 2005). This observation provided evidence that autotroph (plant) growth is a source of dissolved oxygen depletion at night on the Souris River.

The main oxygen sink in the summer on the Souris River is the respiration of algae at night. Recall that in the historical analysis of Souris River water quality data (Chapter 3) phosphates levels have been elevated in this stream reach. Data collected in this study show that elevated levels of phosphorus (Figure 24) in the impaired reach are consistent with historic data. Warm water, low flow, and increased phosphorus levels combine to cause algae growth and diurnal oxygen variation (Mulholland, 2005).

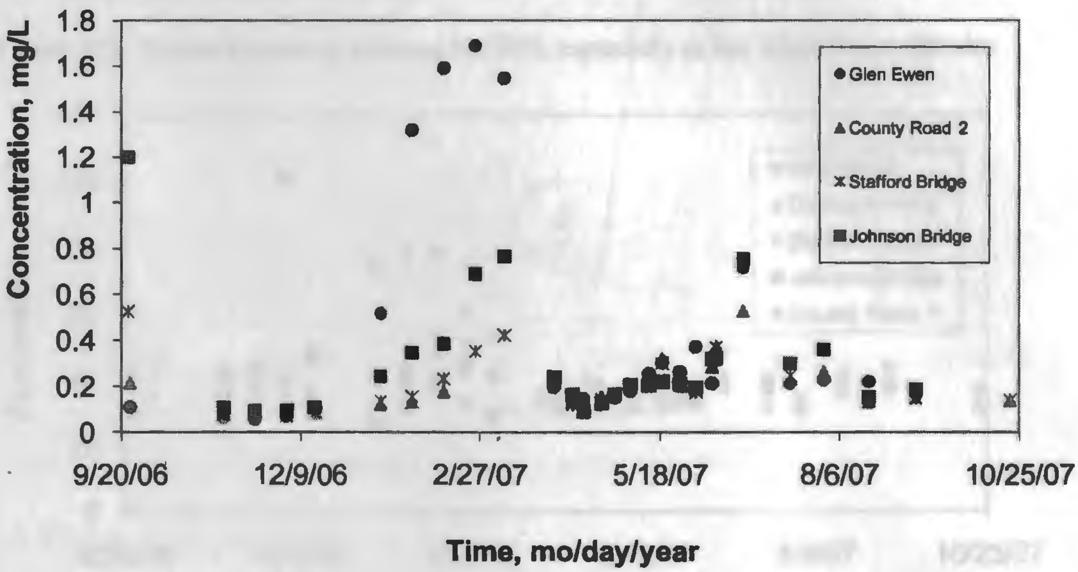

Figure 24. Phosphorus levels Souris River study reach 2006-2007

In the summer of 2007, as probably happens most summers, on the impaired reach of the Souris River these same stressors come together to form a very stressful ecosystem for life. Trends in phosphorus levels at County Road 2 (Figure 24) indicate a second increase in phosphorus concentration in the winter when ice covers the Souris River. Phosphate in sediment could increase SOD using the DO in the water column.

5.4. BOD and COD

Recall that Chemical Oxygen Demand [COD] and Biochemical OxygenDemand [BOD] make up a sink for dissolved oxygen called carbonaceous deoxygenation. Identifying anthropogenic sources for COD and BOD can lead to management solutions.

COD for all sites in the sample section were low except for a few outliers (Figure 25). Winter caused an increase in COD, especially at the, Glen Ewen, SK site.

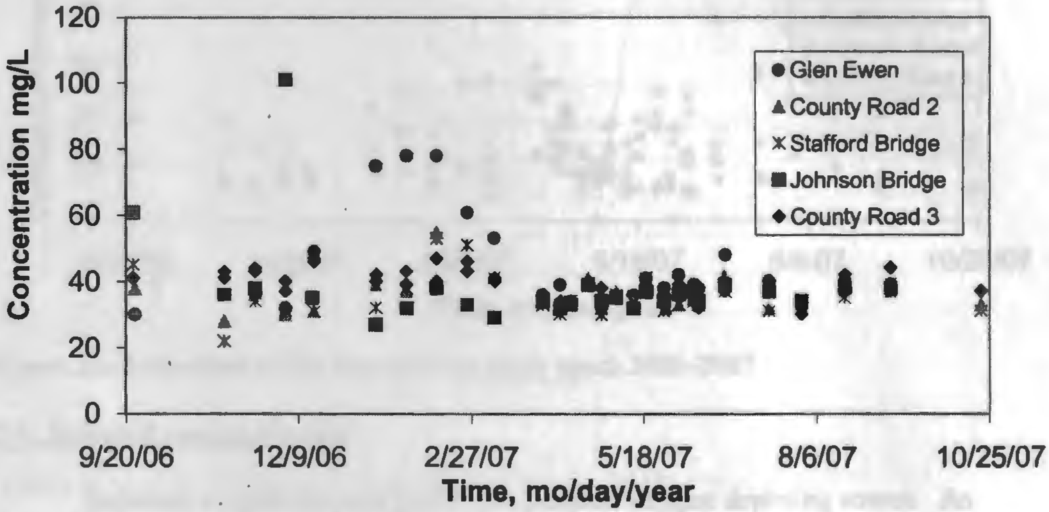

Figure 25. Chemical oxygen demand results for all 5 sampling sites

COD levels for all sites are low throughout the entire year, therefore COD is not found to be a source of the DO depletion on the upper Souris River study reach.

BOD_5 results for the Souris River are inconclusive. Long holding time made some results of BOD test fail quality assurance requirements. The BOD results from the state lab analysis were below detection limits.

5.5. Suspended solids

Suspended Solids (SS) results are shown in Figure 26. The data show a general trend of higher concentration of suspended matter at the upstream sampling locations. This observation could also be related to the nature of the downstream sites (County

Road 3 and Johnson Bridge), which are affected by Lake Darling reservoir levels. Water backed up from Lake Darling allows suspended matter to settle out into the sediment, resulting in a decrease in the suspended solid concentration.

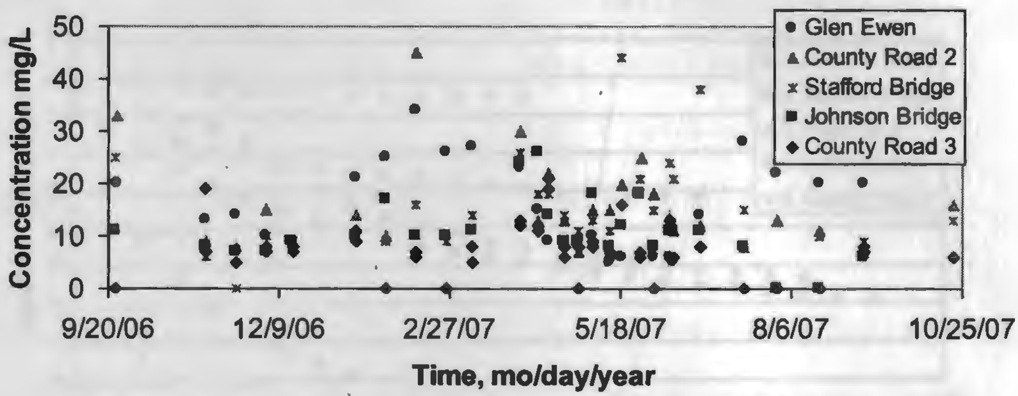

Figure 26. Suspended solids Souris River study reach 2006-2007

5.6. Sediment oxygen demand

Sediment oxygen demand (SOD) is a possible oxygen depleting source. An observation of the sediment during field visits indicated sediments were black in color and smelled of hydrogen sulphide gas (H_2S), which is a indication of the sediment anaerobic decomposition of organic material (Tchbanoglous, 1985). Following this observation, sediment samples were gathered at each site for analysis in the Environmental Engineering Lab at NDSU. Oxygen consumptions for samples from five of these sites are displayed in Figure 27. Graduate student Matt Baker conducted experiments on the sediment to determine the oxygen depletion rate. The higher the organic content in the soil, the faster oxygen is depleted.

Characteristics of the sediment tested are shown in Table 6. The sites with lower percent organics consisted more of rocky and sandy sediment while the higher percent organic sediments were black in color and made up of finer material.

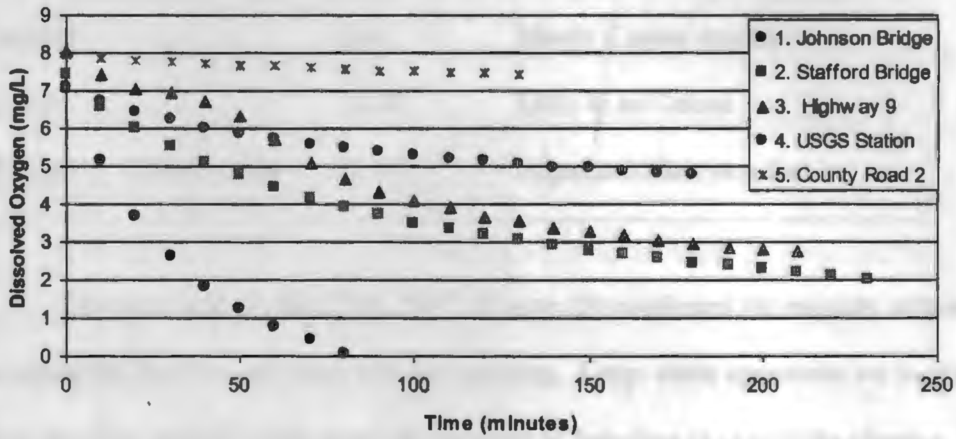

Figure 27. Oxygen depletion from sediment in completely mixed reactors

The higher percent organic soil was found where the water was deep and wide. Lower velocity water allows sediments to settle out in larger pools (Tchbanoglous, 1985). Oxygen depletion tests on sediment were conducted by using a completely mixed method (see Appendix B).

Organic sediment is identified as a leading DO sink on the study reach. As sediments build up, the oxygen demand becomes greater. The higher percent organic matter samples were observed in the sites that are affected by Lake Darling impoundment (lower 1/3 section of the study reach). Water is the deepest in this section of reach and flow was the least. These stream characteristics allow sediments to settle out creating higher sediment oxygen demand in this section of the study reach.

Table 6. Characteristics of sediment samples (July 30, 2008)

Site	Site Location	% Organic	Coarse Composition Observed
Hwy 9	Upstream	9.45	Very Little Coarse (twigs)
USGS		6.1	No Coarse Retained
County 2		2.61	Mostly Coarse Aggregate
Stafford		13.23	Little to no Coarse
Johnson	Downstream	14.91	Algae and Plant remains

The canoe trip on May 26th, 2007, (Figure 18) confirmed the majority of land use along the Souris river valley is cattle ranching. Large cattle operations are located along the river and the cattle spend the majority of their time in or near the riparian area. Cattle can cause problems directly from animal waste, and indirectly from increased erosion of banks from loss of plants by livestock browsing and trampling. Observations point toward nonpoint sources, specifically cattle operations, as the largest cause of impairment along the Souris River and contribute the majority of the sediment loading. Further analysis of the sediments and computer modelling using river and stream water quality model (QUAL2K) was completed by other researchers, but is not presented here.

CHAPTER 6. DISCUSSION

A year long field study of the upper reach of the Souris River provided evidence to identify periods of low dissolved oxygen levels. In North Dakota the designated use of the Souris River, sustaining aquatic organisms, does not take place consistently throughout the year. Objectives completed in this study, including a study of historical data, one year of sampling, and analysis of study reach data, have led to the identification of the impairments to the river.

Previous sampling data and modelling work on the impaired reach has been sporadic and inconsistent. Previous computer modelling water trend analysis (Vecchia, 2000) has been questioned by other stakeholders (Kellow and Fewless, 2002). Computer modeling (QUAL2K) work in conjunction with the TMDL will clearly identify impairments, but these results are beyond the scope of this study.

The previous work on the Souris River by the United States and Canada as part of the International Joint Commission (IJC) identified dissolved oxygen (especially in the winter) as a problem. The study reach of the Souris River has had a history of fish kills in the winter. IJC concludes "The factors contributing to the low oxygen levels were not determined; however, they could include, but are not limited to, sediment oxygen demand, macrophyte decomposition, organic enrichment, ground water, photosynthesis suppression, low flows, or dams" (Kellow and Fewless, 2002).

Sampling during winter months of 2007 confirms that sinks for DO are caused by sediment contributing to SOD. Long term sampling and field observations have identified agriculture as the source of nonpoint pollution in the Souris River. Cattle operations contribute to organic matter in the river and to bank erosion. The intermittent flow pattern of the Souris River combined with biological oxidation of organic matter in the sediments result in long periods of low dissolved oxygen concentrations, especially in the winter. Results confirm the impairment occurs two times annually. First, in the winter, when ice covers the river and flow is minimal; this is the longest sustained low DO period. Second, the summer diurnal DO fluctuation becomes problematic on the study reach of the Souris River.

Winter dissolved oxygen depletion problems occur during ice cover. When flow rates are the least, and the surface is covered with ice and snow, the DO levels are all below 5mg/L, and most readings are less than 0.5 mg/L DO. Recall that Alameda Reservoir was sampled one time in January 2007 and had a DO concentration 10.41 mg/L; the main source of Souris River does not have a winter hypoxic problem. However, Souris River hypoxic conditions are deadly to aquatic organisms. The oxygen depletion which leads to these low DO levels may be attributed to three factors: ice prevents reaeration, low flow rates, and cattle operations that contribute organic material in sediments leading to increased SOD.

Summer creates another environment for periodic low DO conditions to occur. Warm water temperature, low flow rates, and elevated phosphorus level promote algae growth in the summer on the Souris River. This growth, while making oxygen during the day, uses oxygen at night. Diurnal variation of dissolved oxygen levels result in stressful aquatic conditions (see Figure 28).

Anthropogenic nonpoint source pollution has led to excess phosphorous and organic matter in the Souris River. Sedimentation from hydrological flow alteration and livestock management practices have contributed to bedded stream sediment increase in the Souris River. Sediment oxygen demand rates have increased and are the main stressor in the aquatic environment.

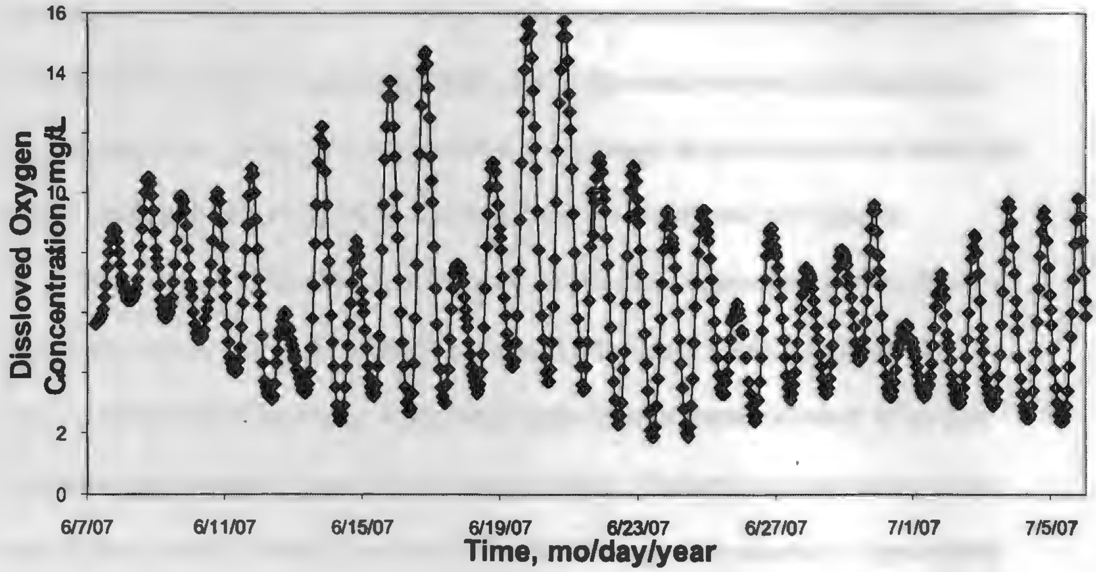

Figure 28. DO June-July 2007 USGS auto sampler, Sherwood, ND

Anthropogenic effects on the DO balance are difficult to assess. What would the Souris River have looked like without humans? This question assumes there was a time when the ecosystem had constant dissolved oxygen rates that could sustain fish populations. Records of the prehuman conditions do not exist. Conversations with land owners in the study reach confirm that fish populations historically were higher. Studying the historic nature of ecosystem may shed light on the nature of Study Reach before European settlement.

Usually, human interaction with streams leads to physical, chemical, and biological alteration of natural conditions. Years of anthropogenic alterations have led to problematic change. First, two impoundments upstream from study reach, Alameda and Rafferty impoundments, have reduced peak flows (see Figure 2). The absence of large spring scouring flows has led to more sediment build up. Second, the downstream impoundment, Lake Darling, backs water into the bottom third of the study reach, creating settling of sediment. Third, within the reach are many lowhead dams trapping sediment. Finally, allowing livestock free range in riparian area has increased organic loading, increased erosion of stream banks and decreased tree canopy.

Impoundments, farming, and livestock have added large amounts of sediment containing nutrient and organic matter to streams (Hubbard, 2004). These conditions lead to a phenomenon known as cultural eutrophication or overenrichment of surface water with plant nutrient, caused by human activities. "Cultural eutrophication results from human endeavours such as construction activities, sewage discharge, agricultural practices, and residential development" (EPA 2000). Usually this term is reserved for lakes, but streams that have little or no flow also can be termed eutrophic (Parr, 2004).

To collect data and identify potential point and nonpoint sources of pollutants a canoe trip of the entire 60 mile reach was conducted in the late spring of 2007 (see Figure 19). Physical parameters were measured and samples collected to be analysed at NDSU. Numerous cattle operations along the study reach qualitatively identified livestock as a source of organic waste and erosion. Sediment samples collected quantitatively identified sediment oxygen demand as a source of oxygen depletion (see Figure 27).

Restoring the river to its natural state is neither possible nor plausible; instead a balancing point could be attained through implementation of Best Management Practices (BMP). The stakeholders seem to sit at opposite ends of this balancing point. The largest stakeholder is the land owner; this side uses the river as part of their agrarian lifestyle. At the other end of the balancing point is the recreational stakeholder. Recreational stakeholders require consistent water quality and habitats for fishing and waterfowl production.

Common BMPs include:

1. Fencing livestock from the riparian area and providing alternate watering methods, removing the largest source of sediment.
2. Buffer zones adjacent to wetlands prevent nutrients and sediment from entering the aquatic system.
3. Hydrologic flow management to simulate natural conditions and maintain DO reaeration.

All BMPs need stakeholder agreement. Internationally agreed upon BMPs would best serve the river and all of its inhabitants. Balancing the health of the stream with the land users needs creates a solution that can benefit all who use the stream.

The upper reach of the Souris River flows through large areas of Saskatchewan and North Dakota that are very remote. Human interaction with the river has been for flood control and ranching. Dissolved oxygen depletion on the study reach is an ongoing problem. The TMDL process is a U.S. EPA program designed to address issues such as dissolved oxygen depletion. If all stakeholders involved can agree upon the conclusions of the TMDL, then the future of the Souris River can include consistent dissolved oxygen for all the waters inhabitants.

CHAPTER 7. CONCLUSIONS

The primary goal of this project was to provide information on the problems associated with low dissolved oxygen in the upper reach of the Souris River. A number of objectives were accomplished to reach this goal. First, the nature and extent of the impairment was determined using existing data. Second, field sampling results confirmed impairments. Third, the causes of low DO were determined.

One year, 2006-2007, of intense field and automatic sampling provided insight into the low DO problem. Winter dissolved oxygen levels became very low with the first ice forming in late 2006. The impaired reach ended at the Canadian border, but additional sampling sites upstream (Canadian sites) were added. Sediment samples were taken and analysed at NDSU. Results from sediment sampling analysis confirmed SOD as the major cause of low dissolved oxygen during winter months.

Sediment oxygen demand in the winter when ice prevents reaeration is the largest problem on the upper reach of the Souris River. This SOD comes from the build up of organic matter. As soon as ice melted, the DO level in the river returned to normal. Based on field inspections, cattle range operations along the river was identified as the major source of sediment organic matter. Spring flood is effectively controlled by upstream dams, reducing property damage and erosion. However, lowered river discharge and flow velocity together with impoundments caused by downstream reservoirs resulted in more sediment accumulation in the study reach.

Diurnal DO variation was found to be an additional stressor to aquatic organisms in the summer months. Increased phosphorus levels suggest diurnal variation is due to algae growth. Twice during the year aquatic organisms are stressed on the study reach of the Souris River. This document can lead to further study and a new chapter in international environmental relations. In the 1980s the United States solved flooding problems in North Dakota by supporting Canadian impoundment construction. Similar cooperation could result in a Souris River that exceeds designated use criteria and benefits all water stakeholders.

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Forms

Upper Souris River TMDL Field Monitoring Log

Date ________ Sampler(s) ________ Departure Time ________ Return Time ________

Vehicle: State Personal Mileage: Start odometer reading ________ End odometer reading ________ Miles ________

Weather Condition ________ Atmospheric Pressure ________ Air Temperature ________ °F Wind ________

Site Name	Time arrive/depart	Water Flow Measurements				Water Quality Monitoring**					Notes and Observations
		Water Surf. from Bridge, ft	River Depth ft*	Ice in.	Velocity clicks/sec ft/s	Sample Depth ft***	Temp C	Sp. Cond. µS/cm	DO mg/L	pH	
Mouse River Bridge 385220											
Mouse River (Dup)											
Johnson Bridge 385402											
Stafford Bridge 385403											
Co Rd 2 Bridge 380091											
Glen Ewen Culvert 385404											

Additional Sampling Sites Date ______________ Sampler(s) ______________________

Site Name	Time arrive/depart	Water Flow Measurements				Water Quality Monitoring**					Notes and Observations
		Long. and Lat.	River Depth ft*	Ice in.	Velocity clicks/sec ft/s	Sample Depth ft***	Temp °C	Sp. Cond. µS/cm	DO mg/L	pH	
		Longitude:									
		Latitude:									
		Longitude:									
		Latitude:									
		Longitude:									
		Latitude:									
		Longitude:									
		Latitude:									
		Longitude:									
		Latitude:									

* Please indicate the method of measurement: from the bridge (B), in stream measurement (S)

** Please record replicates readings in the same cells and indicate in the Notes column how replicates were taken (different depth or location)

*** Sample depth is typically set at 0.6 of the water depth. If multiple readings are made using the Sonde, all the measurements should be taken below the bottom of the ice cover.

Depth measurements from ice surface

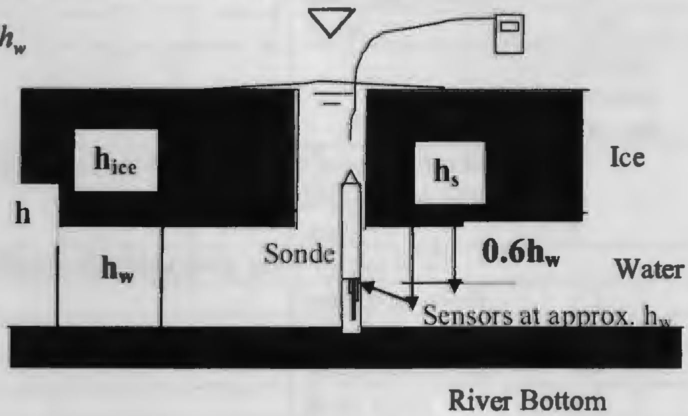
h = total depth or river depth as shown in the table, ft

h_{ice} = thickness of ice cover, in.

h_w = water depth = $h - \frac{h_{ice}}{12}$, ft

h_s = sampling depth (from where water sample is taken for lab analysis), ft

$$h_s = \frac{h_{ice}}{12} + 0.6h_w$$



Example:

From field measurements: h = 12.3 ft, h_{ice} = 12 in. Determine water depth and sampling depth.

Solution:

$$h_w = 12.3ft - \frac{12in}{12in/ft} = 11.3 \text{ ft}$$

$$h_s = \frac{12in}{12in/ft} + 0.6(11.3ft) = 7.78 \text{ ft}$$

Revised 01/10/08

Sampling frequency water quality monitoring

Frequency	**Date**	**Sampling times**
Scheduled Sampling Events for all Sites		
October – November 2006	once per month	2
December 2006 – March 2007(ice covered)	twice per month	8
April (ice off) – June 4, 2007	once per week	9
June 5 – August 20, 2007	twice per month	9
September 2006	once per month	1
	Total	29
Any Summer Months		three storm events
Additional DO sampling based on real-time state data	Once per week when DO is at or below 5 mg/L	
Additional fecal coliform data collections (two sites) by the SCD		
April – May 2007	once per month	2
June 2007	twice	2
July – August 2007	twice per month	4
September 2007	Four times	4
(Lin, W., et al., 2006)	Total	12

Note: This schedule is to only as a guide. Actual sampling dates differ due to climatic and ice conditions. Under NO conditions was sampler safety to be compromised!

Souris River sampling/field investigation sites

Source: NDSU

Location: Glen Ewen, Canada to County Road 3, US

Period: September 2006, May 2007

Surveyed profiles of sampling sites, County road 3

Site Number: 382020

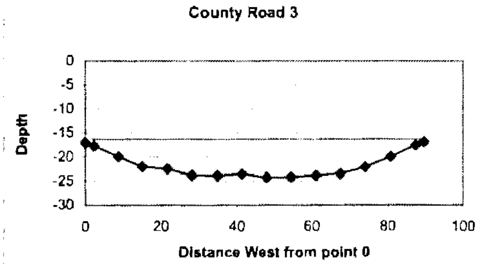
Site Location: DLAT: N 48°48' 510"

DLONG: W 101°49' 514"

Point	Distance from East Bank	Profile of River Bottom
0	0	-17.120
1	2.283	-17.711
2	8.812	-19.937
3	15.169	-22.017
4	21.641	-22.503
5	28.206	-23.800
6	34.808	-23.886
7	41.334	-23.486
8	48.076	-24.297
9	54.547	-24.183
10	61.111	-23.890
11	67.537	-23.483
12	74.128	-22.119
13	80.847	-19.946
14	87.579	-17.570
15	89.685	-16.869

Conditions of river on 9/23/06

	Station 4	Station10
Width of Bridge	32.22'	32.15
T/ °C	12.99	13.00
Cond/μS/cm	1836	1834
DO%:	84.1	83.4
DO / mg/L:	8.78	8.73
Depth/m:	1.991	2.006
pH:	8.64	8.66



Date: Sept, 23 2006

Measured by: Dr. Wei Lin, Dr. B.Sini-Eidukat, Joe Super

Recorded by: Dr. B.Sini-Eidukat

measured from top of metal rail

	V-A	H-A	hor. angle	tape hor.	Water Surface	river bed	ave corrected +0.25
0	1.944	24.328	296° 63' 48"	0	14.25	17.12	17.1
1	3.753	26.611		2.3'	15.880	19.520	
2	3.787	33.140		8.85'	15.950	21.780	21.82'
3	3.837	39.497		15.45'	16.100	23.910	23.92'
4	3.881	45.969		22.08'	16.110	24.440	24.43'
5	3.894	52.534		28.65'	16.120	25.750	25.78'
6	3.938	59.136		35.24'	16.150	25.880	25.90'
7	3.958	65.662		41.82'	16.125	25.500	25.50'
8	3.977	72.404	303°4'5"	48.35'	16.145	26.330	26.32'
9	3.951	78.875	303°25'52"	54.90'	16.255	26.190	26.17'
10	3.924	85.439	303°34'58"	61.50'	16.130	25.870	25.85'
11	3.901	91.865	303°58'18"	68.10'	16.115	25.440	25.48'
12	3.855	98.456	304°24'47"	74.70'	16.060	24.030	24.04'
13	3.803	105.175	304°35'28"	81.25'	15.990	21.805	21.785'
14	3.754	111.907	304°42'08"	87.85'	15.920	19.380	19.39'
15	2.135	114.013	304°48'05"	90.15'	14.350	17.060	

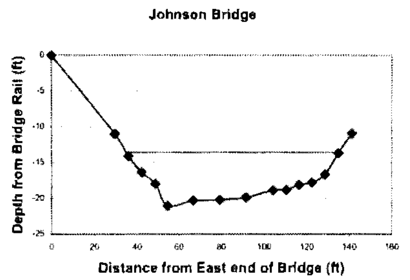
Surveyed profiles of sampling sites, Johnson bridge

Site Number: 385402
Site Location: DLAT: N 48°52' 752"
DLONG: W 101°52' 071"

	Point	Distance from East Bank	Profile of River Bottom
	1	0	0
	2	29.600	-11.020
	3	35.944	-14.130
	4	42.105	-16.413
	5	48.520	-17.977
	6	54.392	-21.080
	8	66.782	-20.331
	10	79.383	-20.237
	12	91.579	-19.907
	14	104.083	-18.891
	15	110.377	-18.812
	16	116.360	-18.131
	17	122.632	-17.789
	18	128.911	-16.667
WE	19	135.064	-13.709
	20	141.362	-10.958

Souris River measurements

T/ °C	12.6
Cond/µS/cm	2274
DO%:	86.5
DO / mg/L:	9.11
Depth/m:	1.265
pH:	8.58
Time:	6:00pm



Date: Sept, 23 2006
Measured by: Dr. Wei Lin, Dr. B.Sini-Eidukat, Joe Super
Recorded by: Dr. B.Sini-Eidukat
measurement using 5' staff

		S-A	H-A	V-A	V-Angle	HAR H-Angle	measurement bed
	1	not measured					
	2	29.619	29.600	1.058	2°2'50"	0°2'28"	11.2
	3	35.959	35.944	1.058	1°38'16"	359°56'35"	14.31
	4	42.117	42.105	0.995	1°21'15"	0°0'0"	16.53
	5	48.529	48.520	0.966	1°08'25"	359°57'07"	18.07
	6	54.399	54.392	0.878	0°55'29"	359°59'43"	21.08
	7	66.788	66.782	0.917	0°47'11"	359°58'01"	20.37
	8	79.388	79.383	0.921	0°39'54"	359°58'02"	20.28
	12	91.584	91.579	0.971	0°36'27"	359°58'47"	20.00
	14	104.088	104.083	1.027	0°33'54"	359°57'30"	19.04
	15	110.382	110.377	1.026	0°31'58"	359°57'38"	18.96
	16	116.365	116.360	1.047	0°30'54"	359°59'59"	18.30
	17	122.637	122.632	1.049	0°29'23"	359°58'04"	17.96
	18	128.916	128.911	1.051	0°28'01"	359°56'47"	16.84
WE	19	135.068	135.064	1.029	0°26'11"	359°56'46"	13.86
	20	141.366	141.362	1.030	0°25'02"	359°55'51"	11.11

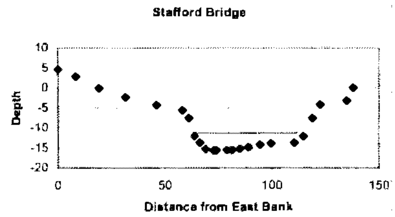
Surveyed profiles of sampling sites, Stafford bridge

Site Number: 485403
Site Location: DLAT: N 48°55' 362"
DLONG: W 101°55' 582"

	Point	Distance from East Bank	Profile or River Bottom
	0	138.119	0
	1	134.905	-3.175
	2	122.517	-4.206
	3	118.844	-7.721
WE	4	114.716	-12.158
	5	110.431	-13.664
	6	99.731	-13.894
	7	94.861	-14.242
	8	89.113	-14.822
	9	85.112	-15.195
	10	81.484	-15.503
	11	79.037	-15.534
	12	74.07	-15.600
	13	72.912	-15.711
	14	68.878	-15.325
	15	66.217	-13.708
WE	16	63.716	-12.054
	17	61.17	-7.435
	18	58.022	-5.715
	19	46.034	-4.199
	20	31.779	-2.476
	21	19.494	-0.037
	22	8.756	2.840
	23	0.000	4.545
	Bridge bolt	99.351	10.777

Souris River water Data

T/ °C	11.85
Cond/μS/cm	1767
DO%:	78.4
DO / mg/L:	8.42
pH:	8.2
time:	3:58pm
bolt to water surface	22.12 feet
bolt to water bed	25.55 feet



Date: Sept. 23 2006
Measured by: Dr. Wei Lin, Dr. B.Sini-Eidukat, Joe Super
Recorded by: Dr. B.Sini-Eidukat

	Point	S-A	H-A	V-A	V-Angle	HAR H-Angle	
	0	85.455	85.257	5.812	3°54'0"	11'42"	
	1	82.086	82.043	2.637	1°50'26"	4'46"	
	2	69.674	69.655	1.606	1°19'13"	15'52"	
	3	66.010	65.982	-1.909	358°20'34"	0'39"	
WL	4	62.179	61.854	-6.346	354°8'30"	3'35"	
	5	58.102	57.569	-7.852	352°14'0"	359°59'13"	
	6	47.561	46.869	-8.082	350°13'01"	359°52'24"	
	7	42.837	41.999	-8.430	348°39'02"	359°52'24"	
	8	37.354	36.251	-9.010	346°2'34"	0°0'49"	
	9	33.587	32.250	-9.383	343°46'43"	359°35'19"	
	10	30.218	28.622	-9.691	341°17'44"	359°42'31"	
	11	27.923	26.175	-9.722	339°37'30"	359°54'27"	
	12	23.358	21.208	-9.788	335°13'32"	359°38'33"	
	13	22.361	20.050	-9.899	333°43'27"	359°14'21"	
	14	18.629	16.016	-9.513	329°17'29"	359°39'22"	
	15	15.515	13.355	-7.896	329°24'22"	0°15'40"	
WE	16	12.521	10.854	-6.242	330°05'48"	0°0'02"	
	17	8.465	8.308	-1.623	348°56'47"	359°45'25"	
	18	5.161	5.160	0.097	1°4'49"	359°29'21"	
	19	7.016	6.828	1.613	13°17'31"	180°20'40"	
	20	21.345	21.083	3.336	8°59'31"	180°04'45"	
	21	33.864	33.368	5.775	9°49'06"	180°44'38"	
	22	44.946	44.106	8.652	11°05'54"	180°19'44"	
	23	53.867	52.862	10.357	11°05'07"	180°45'42"	
	Additional point, surveyed later						
	stn 8.5	35.816	34.643	-9.093	345°17'34"	359°05'26"	staff resting on bed
	stn 8.5	35.028	34.534	-5.862	350°21'56"	359°09'25"	staff on water surface
	CL bridge bolt	49.360	46.489	16.589	19°38'22"	329°30'07"	staff on center bolt

Surveyed profiles of sampling sites, Glen Ewen

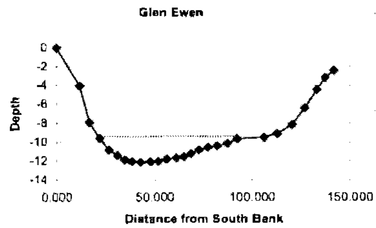
Site Number: 385405
Site Location: DLAT: N 49°10' 811"
DLONG: W 102°01' 650"
(All measurements at 6 foot staff transect location is 150' E of Bridge)

River Bottom Profile as of 9/24/06

	Point	Distance from South bank	Profile of river bottom
	1	0.000	0
	2	11.771	-4.074
	3	16.649	-7.932
WE	4	21.964	-9.634
	5	26.673	-10.882
	6	31.114	-11.437
	7	34.655	-11.908
	8	38.242	-12.101
	9	42.785	-12.150
	10	47.647	-12.092
	11	51.759	-12.066
	12	55.905	-11.819
	13	60.935	-11.688
	14	64.984	-11.576
	15	68.705	-11.249
	16	72.820	-10.868
	17	77.521	-10.600
WE	18	82.234	-10.433
	19	87.463	-10.162
	20	92.580	-9.668
	21	106.100	-9.518
	22	112.739	-9.151
	23	120.363	-8.213
	24	126.755	-6.426
	25	132.799	-4.456
	26	137.148	-3.194
	27	141.831	-2.423

Conditions of river

T/ °C	12.94
Cond/μS/cm	1053
DO%:	101.30%
DO / mg/L:	10.67
Depth:	1.00
pH:	8.57



Date: 9/24/2006
Measured by: Dr. Wei Lin, Dr. B.Sini-Eidukat, Joe Super
Recorded by: Dr. B.Sini-Eidukat

	S-A	H-A	V-A	V-Angle	HAR hor-Angle
1	151.172	151.162	1.784	0°40'35"	0°0'0"
2	139.401	139.383	-2.290	359°03'33"	0°0'16"
3	134.523	134.382	-6.148	357°22'49"	359°48'20"
4	129.208	128.969	-7.850	356°30'59"	359°44'52"
5	124.499	124.166	-9.098	355°48'33"	359°54'26"
6	120.058	119.669	-9.653	355°23'18"	359°53'34"
7	116.517	116.076	-10.124	355°00'55"	0°6'34"
8	112.930	112.458	-10.317	354°45'29"	0°18'13"
9	108.387	107.890	-10.366	354°30'43"	0°9'15"
10	103.525	103.011	-10.308	354°17'09"	0°05'56"
11	99.413	98.880	-10.282	354°03'49"	0°18'04"
12	95.267	94.737	-10.035	353°57'12"	0°10'50"
13	90.237	89.692	-9.904	353°41'57"	0°15'39"
14	86.188	85.630	-9.792	353°28'35"	0°26'09"
15	82.467	81.922	-9.465	353°24'33"	0°23'01"
16	78.352	77.823	-9.084	353°20'32"	0°15'00"
17	73.651	73.122	-8.816	353°07'30"	0°17'17"
18	68.938	68.394	-8.649	352°47'34"	0°0'19"
19	63.709	63.156	-8.378	352°26'36"	0°02'15"
20	58.592	58.059	-7.884	352°16'00"	359°48'30"
21	45.072	44.403	-7.734	350°07'09"	359°59'36"
22	38.433	37.720	-7.367	348°56'58"	0°31'30"
23	30.809	30.131	-6.429	347°57'21"	0°19'04"
24	24.417	23.972	-4.642	349°02'28"	1°03'12"
25	18.373	18.177	-2.672	351°38'22"	0°50'58"
26	14.024	13.953	-1.410	354°13'40"	0°20'45"
27	9.341	9.319	-0.639	356°04'26"	0°01'49"

APPENDIX B. STANDARD OPERATING SUMMARY

Stream and river grab samples collected for chemical and biological analysis should be representative of the entire stream or river. To be representative, samples must be carefully collected, properly preserved, and appropriately analyzed. In general samples should be collected from the main current of the stream or river at 60% of the total stream depth. In ideal conditions grab samples are only collected on low gradient and slow moving streams.

The grab sample can be collected either by wading or by lowering a sampling device such as a Kemmerer sampler, Van Dorn sampler or weighted, open bucket from a bridge crossing. When collecting the sample by wading, enter the stream slightly down current from the appropriate sampling site, then wade to the area with the greatest current. Rinse each sample bottle and lid 3 times with stream water prior to collecting the sample. Place lid on sample bottle then submerge to approximately 60 percent of the stream depth; remove the lid and allow the bottle to fill facing towards the current. Replace the lid prior to removing bottle from the stream. A small portion of the sample will need to be decanted off prior to preserving and/or placing in a cooler. Note: In very shallow streams care must be taken not to contaminate the sample with bottom sediments.

When collecting from a bridge using a Kemmerer or Van Dorn sampler, lower the device into the stream and trip the sampler at 60 percent of the total stream depth. If using a weighted, open mouthed bucket, allow the bucket to descend nearly the entire stream depth and then rapidly retrieve.

<u>Equipment and supplies</u>

1. Sample containers (see Table 3.1, Standard Operation for Field Procedures)
2. Acid for sample preservation (see Table 3.1, Standard Operation for Field Procedures)
3. Sample labels.
4. Clear Tape for sample containers
5. Coolers with ice and/or frozen gel pack(s).
6. Deionized water for sample blanks and decontamination.
7. Filter apparatus.
8. 2.2. or 3.2 liter non-metallic sampler (e.g., Kemmerer or Van Dorn samplerwith ropemarked at 0.5-meter depth intervals and a messenger)

Macro invertebrate sample processing

Use a closed bottom or sieve bottom bucket while sampling to carry the composite sample to the next transect. Alternatively, place each sample in a five-gallon bucket and use a soil sieve (500 µm = 0.5 mm) to cull-down the sample before it is packed and preserved in a Nalgene container(s) upon completion (Figure 7.17.2). Record the composite sample tracking information on a field recording form shown in Figure 7.17.3.

1. Pour the entire contents of the bucket through a sieve (or into a sieve bucket) with 500 µm mesh size. Remove any large objects and wash any clinging organisms back into the sieve before discarding.

2. Use a wash bottle filled with stream water to rinse all the organisms from the bucket into the sieve. This is the composite reach-wide sample for the site.

3. Estimate the total volume of the sample in the sieve and determine how large a jar will be needed for the sample (500-mL or 1-L) and how many jars will be required.

4. Wash the contents of the sieve to one side by gently agitating the sieve in the water. Wash the sample into a jar using as little water from the wash bottle as possible. Use a large-bore funnel if necessary. If the jar is too full, pour off some water through the sieve until the jar is not more than ½ full, or use a second jar if a larger one is not available. Carefully examine the sieve for any remaining organisms and use watchmakers forceps to place them into the sample jar.

5. Completely fill the jar(s) with 95% ethanol (no headspace). It is very important that sufficient ethanol be used or the organisms will not be properly preserved.

NOTE: Prepared composite samples can be transported back to the vehicle before adding ethanol if necessary. Fill the jar with stream water, which is then drained using the net across the opening to prevent loss of organisms, and replaced with ethanol.

Water sampling equipment and supply list

1. Personal flotation device
2. Waders
3. Maintenance kit (KCl solution, spare membranes, batteries, battery charger)
4. Project area map depicting monitoring stations
5. Power ice auger (winter sampling)
6. Ice skimmer (winter sampling)
7. Meter stick (winter sampling)
8. Sled (winter sampling).
9. 3.2L Beta Water Samplers, Horizontal Acrylic Kit: [Includes carry case with rope marked at 1.0 depth intervals and a messenger]
10. Sample containers
11. Acid for sample preservation
12. Sample labels
13. 2 coolers with frozen gel packs.
14. 100 ft. fiberglass tape (marked in 1/10 and 1/100 ft) with 500 g weight
15. Deionized water for sample blanks and decontamination
16. Power drive (Compact Cat No. P-07533-50 or equivalent)
17. Peristalic head (Masterflex L/S 12 V DC pump with Easy-Load II pump head)
18. In-line 0.45 micrometer cartridge filters (Geotech dispos-a-filter or equivalent)

19. Tubing (Masterflex silicone Cat No. P-96400-24 or equivalent). 75 ft cut into 2ft sections

20. Churn Splitter(505-289 8L Churn Splitter 7 lbs).

21. Field report form

22. Sample ID/Custody Record

23. Black ballpoint pen or mechanical pencil.

24. Sample and blank log forms

25. Meter equipment

26. Temperature/Dissolved Oxygen /conductivity/pH meter.[YSI 650]

27. Field report form (Figures 1 and 2)

28. Pen

29. 100 ft. measuring wire marked in 1/10 ft.

30. Kemmerer BTL 2.2L vertical water sampler kit (100 feet of braided line, messenger and orange carrying case)

31. Sled Winter

32. Pygmy meter, USGS with magnetic head

33. Plastic case [PELICAN] for both Pygmy and AA price meter

34. Eye glass screw driver

35. Wading rod, 4 ft top set

36. Head phones, 2 ear piece with volume control

37. Stop watch

38. Price AA meter

39. Bridge board attachment

40. 30 lb sounding weight

41. Hanger bar

42. Hanger bar pin

43. Sounding Reel

44. Female Head phone jack

45. Speaker Wire

Calibration and cleaning sampling tubes (Wilde, 2004)

Cleaning procedures for the Nalgene tubing used with peristolic pump and filters

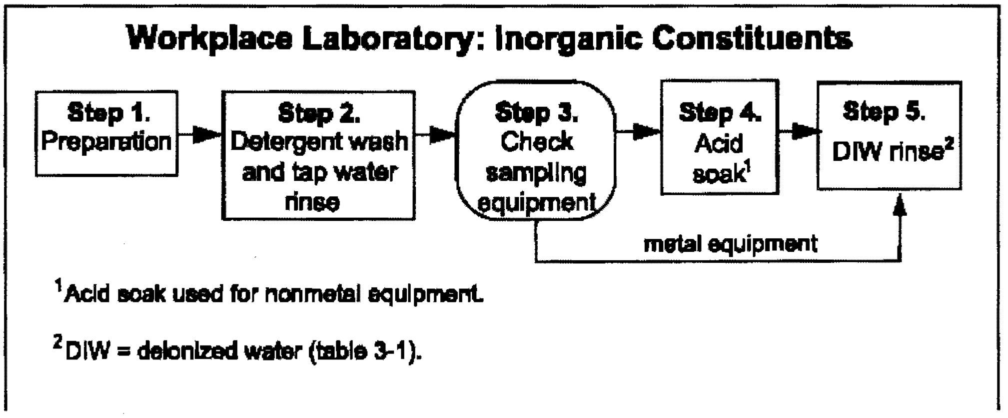
Source: Chemistry Division SOPs - Inorganic Methods, Organic Methods http://www.ndhealth.gov/lab/Methods/SOPTOCIN.HTM

Cleaning procedures are described below for the tubing and nozzles used with peristaltic and valveless metering pumps. Cleaning procedures for submersible pump tubing are described in section 3.3.10.B. Wear appropriate, disposable, powderless gloves throughout the cleaning process, changing gloves with each change in cleaning solution (section 3.2). Preclean the number of tubing sections needed at each site in the workplace laboratory rather than recleaning tubing in the field, in order to save time during field work. Place tubing into doubled plastic bags and store tubing dry or store wet tubing chilled to prevent bacterial growth. If bacterial growth is present, reclean tubing before use. Use disposable tubing if possible, especially at contaminated sites, to avoid the cleaning process and prevent the possibility of cross contamination

Steps to cleaning sampling tubing

1. Pump 1 L of 5-percent HCl solution through the tubing, discharging the used acid solution into a neutralization container. Pinch and release tubing near tubing outlet while pumping the acid through to ensure that all interior surfaces are acid rinsed.

2. Pump 2 L of DIW through tubing, using the pinch-and-release method. Discharge used DIW to an acid-neutralization container, and check that the rinse-water pH is greater than 6.0 or the original DIW pH.
3. Discard neutralized solutions appropriately.
4. Clean stainless steel connections or metal tubing using detergent-wash and tap water/DIW-rinse procedures.



(Wilde, 2004)

YSI 650 Standard operating procedures [SOPS].

YSI model 6-Series Sondes (which include the 600R, 600XL, 600XLM, 6820, 6920 and 6600 models), and the YSI 650 MDS (Multi parameter DisplaySystem) display/logger. The general calibration processes discussed herein are applicable to other manufactures sondes and displays/loggers. Consult the manufacturer's instruction manuals for specific procedures.

Summary

Temperature and dissolved oxygen measurements can provide some of the most important limnological information of a water body. Temperature and dissolved oxygen measurements provide valuable information about the biological and biochemical reactions going on in a water body. Generally, one temperature and dissolved oxygen measurement is collected at fifty percent total water column depth from the wetlands deepest most open area in the largest aquatic zone present. Shallow wetlands are waded or canoed for sample collection. Care must be taken to sample undisturbed water not influenced by bottom sediments stirred up by mucking about. This often requires collecting a mobile sample where the sampler continues to move in a forward direction away from the sediment plume.

The electrode membrane is permeable to other gases besides oxygen, such as hydrogen sulfide (H_2S). Caution should be taken when using the membrane electrode in low dissolved oxygen waters since the presence of H_2S may lower the cell sensitivity. This interference can be reduced by frequently changing and calibrating the membrane electrode.

Procedure

1. Locate the main aquatic zone and wade or paddle out to its center. If winter sampling, make every attempt not to disturb the water column with undue agitation when drilling ice hole.
2. Fill out the field log including ambient weather information and water depth (Figure 7.03.1). Measure and record ice thickness and snow depth (winter sampling).

3. Calibrate the meter following the manufacturer's recommended procedures for field calibration.
4. Lower the probe to that depth which is approximately fifty percent the total water depth below the surface. For example, if the column is two feet deep, take the measurement one foot below the surface.
5. Switch the display to read temperature, wait for the temperature reading to stabilize (30 seconds minimum), record the temperature reading on the field report form, switch the display to read dissolved oxygen, allow the dissolved oxygen reading to stabilize and record the dissolved oxygen concentration on the field report form. Note: To achieve an accurate reading some units require a stirring unit or for the sampler to gently move the probe up and down two to three inches to circulate water across the membrane.

<u>Health and Safety Warnings</u>

1. All proper personal protection clothing and equipment is to be worn.
2. The standard solutions for calibrating conductivity contain Iodine and Potassium Chloride. When using the standards, avoid inhalation, skin contact, eye contact or ingestion. If skin contact occurs, remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the Material Data Safety Sheets (MSDS) for prompt action, and in all cases seek medical attention immediately.

3. The standard solutions for calibrating turbidity contain Styrene divinylbenzene copolymer spheres. While the material is not volatile and has no known physical effects on skin, eyes, or on ingestion, general health and safety precautions should be adopted to minimize unnecessary contact. If skin contact occurs, remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the Material Data Safety Sheets (MSDS) for prompt action, and in all cases seek medical attention immediately
4. All standard solutions for calibration pH contain the following compounds: pH 4 Solutions: Potassium Hydrogen Phthalate, Formaldehyde, Water, pH 7 Solutions: Sodium Phosphate (dibasic), Potassium Phosphate (Monobasic), Water, pH 10 Solutions: Potassium Borate (Tetra), Potassium Carbonate, Potassium Hydroxide, Sodium (di) Ethylenediamine Tetraacetate, Water.

Calibration of YSI XL and QS 600 Series Sonde w/ 650 MDS Handheld

Calibration Tips

1. If you use the calibration cup for dissolved oxygen (DO) calibration, make certain to loosen the seal to allow pressure equilibration before calibration. The DO calibration is a water-saturated air calibration.
2. The key to successful calibration is to insure that the sensors are completely submersed when calibration values are entered. Set calibration standards out

ahead of time in the room where calibration is to occur for temperature stability.

3. You may use previously used calibration solution to pre-rinse the sonde. You may wish to save recently used or expired calibration standards for this purpose.
4. Fill a bucket or sink with ambient temperature tap water to rinse the sonde between calibration solutions or rinse with room temp tap water in sink between calibration solutions.
5. Shake excess rinse water off the sonde, especially when the probe guard is installed. You may use clean, absorbent paper towels or cotton cloths to dry off the outside of the sonde and probe guard between rinses and calibration solutions. Drying the sonde reduces carry-over contamination of calibrator solutions and increases calibration accuracy.
6. Remove the stainless steel weight from the sonde bottom by turning the weight counterclockwise. When the weight is removed, the calibration solutions have access to the sensors without displacing a lot of fluid. This also reduces the amount of liquid that is carried between calibrations.
7. Make certain that port plugs are installed in all ports where probes are not installed. It is extremely important to keep these electrical connectors dry. (Red River Basin Monitoring Network, 2008)

YSI handheld and sonde equipment set-up prior to calibration and sampling

Once this set-up is initially done, it will not be necessary to go through these set-up procedures each time calibration is done:

- Press the Power (Green "①") button to turn the YSI 650 MDS handheld on.
- From the "650 Main Menu" select Sonde menu.
- From the "Main" menu screen scroll down and select Advanced.
- From the "Advanced Menu" scroll down and select Setup.
- From the "Advanced Setup" menu ensure that Auto sleep RS232 and Auto sleep SD112 are not enabled. It is also suggested that Power up to Run be selected in this screen.
- Press Escape twice to return to "Main" menu and select Report.
- From the "Report setup" menu scroll through and minimally enable by selecting the following: Temp C; SpCond uS/cm; DOsat %; DO mg/L; DO Charge; pH; and pH mV. Enable other options as per your instrument capabilities and your monitoring program reporting needs.
- While selecting SpCond in the "Report setup" menu, select "SpCond uS/cm" as the unit to display.
- Press Escape and turn power off or begin calibration process. The sonde is now set up for calibration and sampling.

Conductivity calibration

Calibrate conductivity first to avoid contamination of the standard. For maximum accuracy, the conductivity standard you choose should be within the same conductivity range as the water you are preparing to sample. However, it is not recommended to calibrate with conductivity standards that are less than 1.0 millisiemens/cm (mS/cm) [which is equal to 1,000 microsiemens (μS/cm)]. These low standards are easily contaminated and can be interfered with by outside noise sources (RF, etc.)

TIP: During calibration for conductivity and pH, you may remove the stainless steel weight (600QS model) from the bottom of the sonde by unscrewing the weight counterclockwise. When the weight is removed, the calibration solutions have access to the sensors while displacing less fluid. This also reduces the amount of liquid that is potentially carried between calibrations.

Remove the sponge from the calibration bottle and pour 1-2 inches of conductivity calibration solution into the bottle. If you have used conductivity solution saved from your last calibration, you can use it for this rinsing process.
Put the sonde in the bottle, screw the cap on firmly and shake the solution around to rinse the sonde and bottle. Unscrew the bottle and pour out the solution. Repeat this rinse process once more and then do a third rinse with fresh conductivity calibration solution.

Fill the calibration bottle about ¾ full with fresh conductivity calibration solution. Insert the sonde back in the bottle. Gently rotate and/or move the sonde up and down to remove any bubbles from the conductivity cell. The conductivity port in the side of the sonde must be completely submerged in calibration solution and not have any trapped bubbles in the opening.

Allow at least one minute for temperature equilibrium before proceeding.

With the YSI 650 MDS Handheld on, scroll to "Sonde menu" and press the Enter key. The handheld will make a sound that indicates you are actively connected to the sonde and its menus. From the displayed screen, scroll to "Calibrate" and press the Enter key. Scroll to "Conductivity" and press Enter to access the Conductivity calibration procedure.

From the next "Cond Calibration" screen scroll to SpCond and press Enter to access the specific conductance calibration procedure. Then enter the calibration value of the standard you are using. Note: The sonde requires the input in milliSiemens (mS/cm). 1,000 microsiemens (μS/cm) = 1 millisiemen thus when using a 1,000 microSiemen/cm standard, enter 1.000. Record the conductivity of the standard being used on the calibration worksheet. Press Enter. The current value of all enabled sensors will appear on the screen and will change with time as they stabilize.

If the sonde should report "Out Of Range", investigate the cause. Never override a calibration error message without fully understanding the cause. Typical causes for error messages are incorrect entries, for example, entering 1000 microSiemens instead of 1.0 milliSiemens. Other causes of error are low fluid level and/or air bubbles in the sonde conductivity port.

Observe the readings under Specific Conductance or Conductivity and when they show no significant change for approximately 30 seconds, record the temperature and conductivity value being displayed as the "pre-calibration conductivity" on the calibration worksheet, then press Enter. The top of the screen will show "Calibrated" which indicates that the calibration has been accepted. Record the conductivity value being displayed as the "post-calibration conductivity" on the calibration worksheet, then press Enter again to continue and return to the Calibrate menu.

When the calibration has been accepted, check the conductivity cell constant, which can be found by pressing Escape three times to return to the sonde's "Main Menu." Scroll to Advanced at the bottom and press Enter. Press "Cal Constants" and record the conductivity cell constant value on the calibration worksheet. The acceptable range is 5.0 +/- 0.5. Numbers outside of this range usually indicate a problem in the calibration process or a contaminated standard was used. If cell constant is out of range or is significantly different than its historic range, clean and recalibrate.

At this point rinse the sonde with tap water and turn the Power off or press Escape two times to return to the "Main" menu and select "Calibrate" to proceed with calibration for other variables as needed, or replace sponge and silver weight and screw on calibration bottle for transport or storage.

pH calibration tips

If initial set-up has not been done, go to the sondes report menu and turn on the pH mv output. This will allow the sonde to display the millivolts or the probes raw output, as well as the pH units during the calibration process.

Note: In most cases, a two point calibration using pH buffers 7 and 10 will be used to cover conditions generally found in the Red River Basin.

If not already done, remove the sponge from the calibration bottle and the silver weight from the bottom of the sonde (600QS model). Pour 1-2 inches of pH 7 buffer solution into the bottle. If you have used pH 7 buffer solution saved from your last calibration, you can use it for this rinsing process.

Put the sonde in the bottle, screw the cap on firmly and shake the solution around to rinse the sonde and bottle. Unscrew the bottle and pour out the solution. Repeat this rinse process once more and then do a third rinse with fresh pH 7 buffer solution.

Fill the calibration bottle about ½ full with fresh pH 7 buffer solution. Place the sonde in the bottle and screw the cap back on. Gently rotate and/or move the sonde up and down to remove any bubbles from the sensors. Ensure that the pH reference and glass sensor as well as the temperature sensor are completely submerged in solution.

With the YSI 650 MDS Handheld on, scroll to "Sonde menu" and press the Enter key. From the displayed "Main" menu screen, scroll to "Calibrate" and press Enter. Scroll to "ISE1 pH" and press Enter to access the pH calibration menu. From the "pH calibration" screen scroll to 2 point and press Enter to access the screen to enter your first pH buffer value. Enter 7.00 (or the proper pH value adjusted to the temperature of the calibration standard if other than 25°C (see side of pH buffer solution bottle for temperature adjustments) and press Enter. Record the temperature and pH value of the pH Buffer 7 that you entered on the calibration worksheet in the "Cal. Standard" section.

Watch for the pH value and temperature to stabilize. When stable, record the pH and mV meter readings as the pH Buffer 7 "Pre-Calibration" values on the calibration worksheet. Press Enter and record the pH and mV meter readings as the pH Buffer 7

"Post-Calibration" values on the calibration worksheet.. Press Enter again and screen will prompt you to "Enter 2nd pH." At this time, remove sonde from calibration bottle and pour out the pH 7 buffer. (Note: Consider pouring into a container marked "used pH 7 buffer" which can be used as the pre-rinse for the next time pH calibration is done.)

Enter 10.00 for the 2nd pH value (or the proper pH value adjusted to the temperature of the calibration standard if other than 25°C) and press Enter. Pre-rinse the calibration bottle and sonde with used and fresh pH 10 buffer as you did for the pH 7 buffer. When you put the pH 10 buffer in for the first rinse, watch the pH display to see if it responds and rises quickly to near the pH 10 level which is an indicator that the pH sensors are in good condition. Discard the first three rinses and then pour enough fresh pH 10 buffer into the pre-rinsed calibration cup to cover the pH sensors.

Fill the calibration bottle about ½ full with fresh pH 10 buffer solution. Place the sonde in the bottle and screw the cap back on. Gently rotate and/or move the sonde up and down to remove any bubbles from the sensors. Insure that the pH reference and glass sensor as well as the temperature sensor are completely submerged in solution. Record the temperature and pH value of the pH Buffer 10 that you entered on the calibration worksheet in the "Cal. Standard" section.

Watch for the pH value and temperature to stabilize. When stable, record the pH and mV meter readings as the pH Buffer 10 "Pre-Calibration" values on the calibration worksheet. Press Enter and record the pH and mV meter readings as the pH Buffer 10 "Post-Calibration" values on the calibration worksheet.

Remove sonde from calibration bottle and pour out pH 10 buffer. (Note: Consider pouring into a container marked "used pH 10 buffer" which can be used as the pre-rinse for the next time pH calibration is done.) Rinse calibration bottle and sonde with tap water, replace sponge and silver weight and store sonde in bottle with wet sponge or place sonde in wet towel for short-term storage and transport. Assess slope as per discussion below.

After recording the pH millivolts for the calibration points, you must determine the slope of the sensor. This is done by determining the difference between the two calibration points that were used, for example, if buffer 7 was +3 mV and buffer 10 was –177mV, the slope would be 180. The millivolts help tell us the present status of the probe; a good set of numbers to use are as follows:

- Buffer 4 = + 180 +/- 50 mv
- Buffer 7 = 0 +/- 50 mv
- Buffer 10 = - 180 +/- 50 mv

The ideal numbers when a probe is new are between 0 and 180, but as the probe begins to age, the numbers will move and shift to the higher side of the tolerance. The acceptable range for the slope is 165 to 180. Once the slope drops below a span of 165, the sensor should be taken out of service. Recondition the probe if a slow response in the field has been reported. The procedure can be found in the YSI sonde manual under the "Sonde Care and Maintenance Section".

Never override any calibration errors or warnings without fully understanding the reason for the message. Proper storage of the sensor when not in service will greatly extend the life of the probe.

<u>Dissolved oxygen calibration tips</u>

DISCRETE MONITORING (Spot Sampling) PREPARATION. Preparing to calibrate Dissolved Oxygen:

Inspect the DO probe anodes, recondition using the 6035 reconditioning kit if they are darkened or gray in color. (see instructions on pg. 90 of YSI Environmental Operations Manual). If you have resurfaced your DO sensor, it is recommended to run the probe continuously for 15-30 minutes or until good stability is realized. After a membrane change only, allow the sonde to run (burn in) for 10 minutes.

It is recommended to change the DO membranes every 30 days. Also inspect O-ring and replace if not providing a tight seal. (See DO membrane installation procedure). After installing a new membrane, make sure that it is tightly stretched, wrinkle free, and has no trapped air bubbles. Note: DO membranes will be slightly unstable during the first 3 to 6 hours after they are installed; it is suggested that the final calibration of the DO sensor take place after this time period.

Note, if you do not have barometric pressure (BP): If your YSI handheld does not have BP built into it you will need to obtain a local BP reading from a local source. If you get BP from a weather service, it is often in inches Hg and also corrected to sea level. First you need to convert it to mm Hg by multiplying the inches Hg by 25.4; (Then to "uncorrect" for sea level use the following formula:

True BP in mm Hg = [BP in mm Hg] – [2.5 * (Local Altitude/100)]

Example: (using BP from www.weatherunderground.com)

-BP and elevation from website for Fosston is reported as 30.14 inches and 1,276 feet respectively.

1. convert inches to mm: 30.14 in HG x 25.4 mm/in = 765.6 mm Hg
2. sea level correction factor: 2.5 x (1,276/100) = 2.5 x 12.76 = 31.9
3. calculate True BP = 765.6 - 31.9 = 733.7 mm Hg (value to enter in handpad for D.O. calibration)

<u>Dissolved Oxygen Calibration</u>

Note: Calibration should occur on-site in the atmospheric conditions which sampling will occur. Carefully remove the sensor guard and inspect the membrane to ensure that no water droplets are on the membrane—as needed, wash off with wash bottle or gently dab with Kimwipe or other lens tissue to absorb the water droplets. Also dry the silver thermistor (temperature sensor) for accurate temperature measurements. Carefully replace the sensor guard and place the sonde in the calibration bottle with the wet sponge and approximately 1/8 inch of water or you may use the wet towel method if you prefer. Do not allow water to touch the membrane and make sure no water droplets are on the membrane. If using the calibration bottle, unscrew the cap slightly to relieve pressure, allowing equilibrium to be reached with atmospheric pressure. The sonde must now sit in this saturated environment for at least 10 minutes before the DO calibration can begin—both the DO reading and the temperature need to stabilize before starting the calibration sequence. From the "Main" menu, scroll to and select Sonde menu. From the "Sonde Main" menu scroll to and select Calibrate. From the "Calibrate" menu scroll to and select Dissolved Oxy. The next "DO calibration" menu will offer the option of calibrating in % saturation or mg/L—calibrating either of the choices will automatically calibrate the other. Select DO % saturation.

The next "DO Calibration" menu will require barometric pressure to be entered. If your handheld does not have barometric pressure built into it, be sure to enter your local barometric pressure in mm Hg as explained above. If your handheld does have barometric pressure built in, it will be displayed. Record the barometric pressure on your calibration worksheet. Press Enter. Then monitor the stabilization of the DO % readings. After no changes occur for approximately 30-60 seconds, record the Pre-Calibration DO% on the calibration worksheet.

Press Enter to complete the calibration. Then record the Post-Calibration DO% value and the DO Charge on the calibration worksheet. Press Enter again to return to the "DO calibration" menu. Press Escape twice to return to the "Main" menu.

From the "Main" menu scroll down to the bottom and select Advanced. From the "Advanced" menu select "Cal constants" and record the DO Gain on the calibration worksheet. The gain should be 1.0 with a Range of -0.3 to +0.5. The probe should now be successfully calibrated and ready for discrete sampling. Press Escape twice to get back to the "Main" menu or turn the power off until ready to use. As with the other parameters any warning messages displayed by the sonde during the calibration are a cause for concern and must be investigated before deploying the sonde.

DO output sensor check: After calibration, turn the power off and wait several minutes. Then turn the power on and from the sonde run mode start the probe in the "Discrete Run" mode. Immediately watch the DO% display to check the DO sensor output performance. Observe and/or write down the first 10 DO % numbers. The numbers must start at a high number and drop with each four second sample, example: 110, 105, 102, 101.5, 101.1, 101.0, 100.8, 100.4, 100.3, 100.1. It does not matter if the numbers do not reach 100% or they are below 100%, or that they do not drop each time; it is only important that they have a high to low trend. (Note: Initial power-up can make the first two DO % samples read low; disregard low numbers in this position.) Should the output display a negative value or start at a low number and climb up to the calibration point, check Reject on the calibration worksheet and examine the probe anodes, membrane, or other possible errors; do not deploy the probe. If the display declines as it should, check Accept on the calibration worksheet.

End of Day Calibration Check: It is recommended that at the end of your sample run to perform a DO calibration check (or mid-day if out for a long sample day or weather conditions change). Remove the sensor guard and inspect the DO membrane to ensure that no water droplets are on the membrane; as needed, wash off with wash bottle or gently dab with lens tissue to absorb the water droplets. Also dry the silver thermistor (temperature sensor). Carefully replace the sensor guard and place the sonde in the calibration bottle with the wet sponge or wrap in the wet towel if using this method. If using the calibration bottle, unscrew the cap slightly to allow equilibrium to be reached with atmospheric pressure. Allow 10 minutes for dissolved oxygen saturation and temperature to stabilize. Put in Run mode and when readings stabilize, record the DO% on your calibration worksheet as "End of Day D.O. calibration check." This result should be within 2% of your post-calibration value from your calibration at the start of the day.

<u>Dissolved Oxygen Discrete Sampling Tips:</u>

1. Always prepare the equipment the day before the expected field study. Membrane changes should be done the day prior to the study to minimize any drift.
2. For YSI Model 6820 or similar sondes that have a separate sensor guard, the transfer of the sonde from the storage/calibration cup to the sensor guard puts the sonde and sensors at risk during the process. Usually, this is when most accidents occur, so it is best to avoid removing the protective sensor guard when in the field. A recommended procedure is to carry the sonde in a 5 gallon pail with the sonde wrapped in a wet towel that covers the entire unit. The towel wrapped around the sonde will protect it during transport from shock and vibration and will keep the sonde in the perfect saturated environment for pre and post calibration checks as needed.
3. When arriving on site, turn on the sonde and allow it to warm up for approximately 4 to 5 minutes. Next, check the DO output. It should measure saturation in your local environment or barometric pressure setting, plus or minus the instrument's tolerance of 2 percent. If you should find that the DO

has drifted, then simply recalibrate on the spot and record the amount of drift that was witnessed.

4. The sonde will then be deployed and the measurements automatically taken. Remember to allow the sonde a few minutes to equilibrate to the water temperature before taking the reading. Once the data has been collected, wrap the sonde again in the wet towel and perform a dissolved oxygen post calibration. Again, the sonde should return to saturation, plus or minus the tolerance of 2 percent, within a few minutes.
5. If you are logging the information, it is recommended that you store this pre- and post-calibration data in the actual site data file. Otherwise, if you are manually recording the data, record the information in your log sheet. This assures anyone who might look at the records at a later time that the sonde was indeed calibrated and working correctly. The additions of these steps add very little time to the collection process and can actually save time when unexpected results are witnessed.

Calibration work sheets

Date of Calibration: ______________________ Sonde SN: ______________________

Handpad SN: ______________________ Technician: ______________________

Conductivity Calibration: Date: Technician: Sonde SN: Handpad SN:

Conductivity Std. Being Used:	Cal. Standard °C	Adj. Cond (µS/cm)	Pre-Calibration Conductivity (µS/cm)	Post-Calibration Conductivity (µS/cm)	Conductivity Cell Constant (Range 5.0 +/- .5)
1,000 µS/cm	NA	NA			

NOTES:

pH Calibration: Date: Technician: Sonde SN:
Handpad SN:

	Cal. Standard °C	Adj. pH	Pre-Calibration pH	Pre-Calibration mV	Post-Calibration pH	Post-Calibration mV	
pH Buffer 7							Range 0 MV ± 50 MV
pH Buffer 10							Range -180 ± 50 MV

Milli-volt span between pH 7 and 10 should be = 165 to 180 MV

The ideal numbers when a probe is new are between 0 and 180, but as the probe begins to age, the numbers will move and shift to the higher side of the tolerance. The acceptable range for the slope is a span of 165 to 180. Once the slope drops below a span of 165, the sensor should be taken out of service if maintenance cannot bring it back into range.

NOTES:

Cal. Constants (optional)
pH offset:
pH gain:

Dis. Oxygen Calib: Date: Technician: Sonde SN:
Handpad SN:

DO membrane changed? Y N Note: After membrane change, should wait 6 to 8 hours before final DO calibration, run sensor for 15 minutes in Discrete Run to accelerate burn-in.

Corrected* Barometric Pressure (Inches Hg)	x 25.4 =	Barometric Pressure mm Hg	- [Sea level correction] Local [2.5*(Altitude/100)]	= True Bar.Pres.	Pre-Calib. D.O. %	Post-Calib D.O.%	DO Charge Range: 50 +/-25	DO Gain = 1 (Range: .7 to 1.5)
	x 25.4 =		-					

dissolved oxygen sensor output test (after do calibration probe in saturated air)
After calibration, did the DO % output display the proper declining high to low trend? If so, check ACCEPT. Should the output display a negative number or start at a low number and climb up to the calibration point, check REJECT and do not deploy the probe.

____ ACCEPT

____ REJECT

NOTES: (End of Day D.O. calibration check: ______)

*Generally weather service barometric pressure readings are corrected to sea level, and cannot be used until they are "uncorrected."

North Dakota Department of Health
Division of Water Quality
Lake and Wetland Profile Field Log
Telephone: 701.328.5210
Fax: 701.328.5200

Project Code:		Project Name:	
Site Identification:		Site Description:	
Date: / /	Time: :	Ambient Temp:	Wind Speed:
Wind Direction:	%Cloud Cover:	Secchi Disk: (m)	Baro: (mm/Hg)
Chlorophyll-a:	Phytoplankton:	Initial DO:	Final DO:
Sample Depths:	Meters	Meters	Meters
Sampler(s):			
Comments:			

Depth (m)	Temp (c)	DO (Mg/L)	pH	Specific Conduct.	Comments

Figure 7.03.1 Wadable wetland field log.

APPENDIX C. SAMPLING DATA

Source: NDSU
Location: Glen Ewen, Canada to County Road 3, US
Period: September 2006, May 2007

On site sampling sata 9/06 to 10/07, County Road 3

	Flow Measurement				Field Monitoring Data								
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Avg. Water Temp.	Temperature	pH	Avg DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius	Celcius		mg/L	mg/L	µS/cm	
9/23/06	10:15						13.00	13.00	8.66	8.75	8.75	1835	
11/5/06	9:30	14.6		10	0.5		3.70	3.70	8.61				
11/19/06	8:45	14.7		10	0.5		3.90	3.90	8.60	14.70	14.70	1336	
12/3/06	9:00	14.5		5.6	0.6		4.33	4.33	8.21	7.63	7.63	1662	
12/16/06	8:15	14.1	0.188*	12.7	0.9		4.78	4.78	8.21	2.41	2.41	1553	
1/7/07	8:15	14.8		12.3	1	10.00	4.37	5.45	8.20	0.82	0.23	1843	
1/7/07						4.00		4.30	8.00		0.80	1448	
1/7/07						3.00		3.71	7.96		1.25	1340	
1/7/07				13.1	1	9.00		5.27	8.20		0.11	1830	
1/7/07						3.00		3.12	7.96		1.73	1301	
1/14/07	7:53			12.2	1.75	7.20	4.47	4.38	8.14	0.45	0.33	1666	
1/14/07						6.40		4.54	8.13		0.25	1621	
1/14/07						4.40		3.31	7.90		1.11	1339	
1/14/07						9.00		4.91	8.13		0.65	1860	
1/14/07				12.8	1.1	8.00		4.94	8.07		0.14	1683	
1/14/07						10.00		5.32	8.08		0.08	1813	
1/14/07						6.00		4.79	8.60		0.20	1660	
1/14/07						4.00		3.59	7.82		0.83	1324	
1/28/07	8:45			11.9	1.4	7.7	4.63	5.7	8.09	0.14529	0.23	1781	
1/28/07				11.9	1.4	11.7		5.7	8.09		0.09	1870	
1/28/07				11.9	1.4	9.7		5.69	8.1		0.07	1869	
1/28/07				11.9	1.4	7.7		5.08	8.13		0.08	1736	
1/28/07				11.9	1.4	5.7		4.24	7.97		0.11	1560	
1/28/07				11.9	1.4	3.7		2.52	7.75		0.35	1385	
1/28/07				13.4	1.3	8.5		5.52	8.12		0.08	1851	
1/28/07				13.4	1.3	2		1.56	7.77		0.35	1403	
1/28/07				13.4	1.3	4		2.88	7.74		0.17	1359	
1/28/07				13.4	1.3	6		4.29	8.11		0.07	1673	
1/28/07				13.4	1.3	8		4.97	8.13		0.05	1756	
1/28/07				13.4	1.3	10		5.46	8.11		0.06	1833	
1/28/07				13.4	1.3	12		5.58	8.11		0.08	1859	
1/28/07				13.4	1.3	13		5.63	8.09		0.08	1863	
1/28/07				11.9		10				0	0		Titration
1/28/07				11.9		7				0.3	0.3		Titration
1/28/07				11		4				0.3	0.3		Titration
2/11/07				11.6	1.3	7.5	5.111666667	5.54	8.1	0.10833	0.14	1830	
2/11/07				11.6	1.3	9.5		5.72	8.1		0.1	1853	
2/11/07				11.6	1.3	5.5		4.32	8.05		0.23	1649	
2/11/07				12.7	1.3	7.75		5.05	8.15		0.06	1737	
2/11/07				12.7	1.3	9.75		5.52	8.11		0.08	1828	
2/11/07				12.7	1.3	5.75		4.52	8.06		0.04	1642	
2/25/07	7:50	13		11.3	1.7	7.5	5.228333333	5.33	8.2	0.05167	0.08	1839	
2/25/07				11.3	1.7	9.5		5.74	8.2		0.08	1905	
2/25/07				11.3	1.7	5.5		4.13	8		0.04	1651	
2/25/07				12.6	1.6	8		5.65	8.21		0.04	1886	
2/25/07				12.6	1.6	10		5.76	8.2		0.03	1903	
2/25/07				12.6	1.6	6		4.76	8.19		0.04	1749	
3/10/07	9:00	13		11.2	1.2	7.2	5.151666667	5.06	7.96	0.135	0.04	1828	
3/10/07				11.2	1.2	9.2		5.69	7.98		0.05	1880	
3/10/07				11.2	1.2	5.2		3.65	7.69		0.08	1572	
3/10/07				12.6	1.6	8		5.89	8.01		0.16	1870	
3/10/07				12.6	1.6	10		5.95	7.99		0.25	1896	
3/10/07				12.6	1.6	6		4.68	7.86		0.23	1662	
4/1/07	8:00	13.5		12.2		7.32	0.82	0.9	7.85	9.625	9.61	688	
4/1/07	8:30			12.1		7.2		0.74	7.85		9.64	679	
4/9/07	8:30	15.35		10.65		6.4	2.145	2.18	8.11	12.085	12.16	885	
4/9/07		15.8		11		6.6		2.11	8.1		12.01	884	
4/14/07	7:10	14.95		11		6.6	4.17	4.19	8.64	15.255	15.14	998	
4/14/07	7:30	15.1		10.6		6.36		4.15	8.64		15.37	1000	
4/22/07	7:23	14.5		12.3		6.38	11.305	11.37	8.63	10.05	10.87	1049	
4/22/07	7:40	14.9		12		7.2		11.24	8.63		9.23	1028	
4/28/07	6:42	14.1		11.6		7.08	14.095	14.01	8.63	8.455	8.35	1181	
4/28/07	7:40	14.2		11.65		6.99		14.18	8.55		8.56	1181	
5/5/07	7:30	14		12		7.2	17.27	17.3	8.33	7.745	7.7	1093	
5/5/07	7:40	14		12.8		7.68		17.24	8.36		7.79	1092	
5/13/07	6:00	14.3		11.7		6	16.645	16.65	8.36	8.485	8.53	1080	
5/13/07	6:30	14		11.6		6		16.64	8.37		8.44	1080	
5/19/07	8:00	14		12		7.2	16.61	16.19	8.44	8.59	8.35	1168	
5/19/07	8:30	14				7.2		17.03	8.48		8.83	1175	
5/28/07	17:00	14		12		7.2	15.48	15.91	8.56	11.21	11.33	1029	
5/28/07	17:30	14.2		12.1		7.26		15.05	8.58		11.09	1029	
6/3/07	21:15	14.1		11.8		7.26	16.45	16.6	8.58	10.705	11.06	1019	
6/3/07	21:30	14.2				7.08		16.3	8.55		10.35	1017	
6/10/07	21:00	14.8	0.2226	11.8		7.06	19.22	19.6	8.38	10.05	10.23	1138	
6/10/07	21:30	14.8	0.238	11.2		6.72		18.84	8.39		9.87	1139	
6/12/07	14:30	14	0.0913	12		7.2	20.49	20.77	8.21	8.755	8.96	1242	
6/12/07	14:50	14	0.0913	11.8		7.08		20.21	8.16		8.55	1243	
6/24/07	7:15	14.1		11.9		7.14	20.815	21.2	8.34	4.935	5.89	1315	
6/24/07	7:20	14.1		12.4		7.44		20.43	8.2		3.98	1300	
7/15/07	8:30	14.3		11.7		6	23.085	23.37	8.6	3.91	4.8	1780	
7/15/07	8:30	14.3		11.6		6		22.8	8.48		3.02	1776	
7/30/07	6:30	14.5		12.5		7.5	25.336	25.17	8.24	3.575	3.47	1130	
7/30/07	7:00	14.5		11.15		6.9		25.5	8.25		3.68	1126	
8/19/07	8:00	14.2		13.3		7.98	20.285	20.27	8.55	6.8	6.76	1090	
8/19/07	8:30	14.1		11.8		7.08		20.3	8.56		6.84	1091	
9/9/07	9:00	13.6		12.6		7.56	16.67	16.67	8.63	6.39	6.43	1098	
9/9/07	9:30	13.2		12.4		7.5		16.67	8.64		6.35	1100	
10/21/07	7:30	16.6		9.4		5.6	8.55	8.62	8.6	8.74	8.77	1089	
10/21/07	8:15	16.4		10.3		6.18		8.48	8.6		8.71	1082	

On site sampling data 9/06 to 10/07, Johnson bridge

	Flow Measurement				Field Mornitoring Data							
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius			mg/L	µS/cm	
9/23/06	18:00						12.60	8.58	8.58	8.58	2274	
11/5/06	10:30	15.9		4.5	0.5		3.48	8.59				
11/19/06	10:30	17		4.3	0.25		3.45	8.29	11.60	11.60	1126	
12/3/06	11:30	16.5		2.85	0.8		2.55	8.08	9.11	9.11	1229	
12/15/06	9:30	17.2	0.00*	4.3	0.7		1.92	7.82	5.99	5.99	1291	
1/14/07	10:15			4.2	1.25	2.4	1.37	7.45	1.05	0.77	1524	
1/14/07						2	0.99	7.44		0.72	1530	
1/14/07				2.4	1.15	1.15	1.12	7.45		0.77	1526	
1/14/07						1,2	0.66	7.45		1.92	1832	
1/28/07	10:00			3.9	1.45	3.00	1.10	7.44	0.29	0.35	1871	
1/28/07				3.9	1.45	2.50	0.80	7.45		0.17	1880	
1/28/07				4.3	1.4	3.50	0.96	7.45		0.53	1871	
1/28/07				4.3	1.4	2.50	0.93	7.45		0.17	1877	
1/28/07				3.9	1.45	1.90			0.20	0.20		Titrition method
1/28/07				3.9	1.45	2.90			0.30	0.30		Titrition method
1/28/07				3.9	1.45	3.70			0.30	0.30		Titrition method
2/11/07	9:00	16.6		4.1	1.6	3.10	0.36	7.49	0.35	0.32	2032	
2/11/07				4.1	1.6	2.10	0.15	7.49		0.23	2036	
2/11/07				3.9	1.6	3.00	0.56	7.50		0.42	2006	
2/11/07				3.9	1.6	2.00	0.22	7.90		0.42	2029	
2/25/07	9:11	16.6		3.8	1.7	3.00	1.34	7.55	0.32	0.35	2121	
2/25/07				4.1	1.7	3.00	1.22	7.55		0.28	2117	
3/10/07	11:45	16.6		3.8	1.6	3.00	1.33	7.39	0.39	0.40	2295	
3/10/07				3.8	1.6	2.00	0.73	7.41		0.42	2239	
3/10/07				3.2	1.7	2.60	1.04	7.41		0.50	2271	
3/10/07				3.2	1.7	3.00	1.16	7.41		0.24	2268	
4/1/07	9:00	16.5		5.6		3.36	0.38	8.02	10.58	10.58	866	
4/9/2007	9:50	14.9		5.6		3.36	1.18	8.25	13.36	13.36	1046	
4/14/2007	8:10	14.6		6.1		3.66	5.15	8.71	14.54	14.54	1057	
4/22/2007	9:00	16.4		8		4.8	11.13	8.64	8.79	8.79	1079	
4/28/2007	8:35	15		5.6		3.36	14.25	8.4	7.84	7.84	1188	
5/5/2007	9:15	16	0,263	6		3.6	16.72	8.34	7.65	7.65	1071	
5/13/2007	7:10	16.7	0.105	5.3		3.18	15.85	8.36	8.29	8.29	1044	
5/19/2007	9:00	16.5		5.6		3	16.38	8.36	8.69	8.69	1197	
5/28/2007	15:20	16.7		5		3	15.1	8.26	10.19	10.19	1176	
6/3/2007	19:45	16.9		5.1		3.06	18.06	8.2	8.22	8.22	1096	
6/10/2007	19:30	16.3	0.146	5.7		3.42	20.52	8.35	8.12	8.12	1309	
6/12/2007	16:15	16.5	0.23	5.5		3.3	20.38	8.06	5.64	5.64	1433	
6/24/2007	8.20	17.4		5.5		3.12	24.36	8.62	7.80	7.8	1670	
7/15/2007	9:44	15.3	0.153	5.4		3.24	24.03	8.38	5.48	5.48	1109	
7/30/2007	8:16	15.3	0.106	5.7		3.42	25.77	8.31	6.24	6.24	1121	
8/19/2007	9:00	15.3	0.116	5.1		3.06	19.36	8.63	6.99	6.99	979	
9/9/2007	10:00	15.9		4.2		2.52	15.48	8.42	5.14	5.14	1006	
10/21/2007	9:00	16		4.5		2.7	7.66	8.59	10.53	10.53	1056	

On site sampling data 9/06 to 10/07, Stafford bridge

	Flow Measurement				Field Mornitoring Data							
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	mg/L	µS/cm	
9/23/06	15:15						11.85	8.29	8.42	8.42	1767	
11/5/06	11:30	23.4		2			3.48	8.52				
11/19/06	11:30	23.25		2			2.03	8.29	14.45	14.45	1193	
12/3/06	12:30	23.3		2.8	0.9		0.31	8.11	10.87	10.87	1354	
12/16/06	10:15	23	0.163	2.8	0.7		0.40	7.65	3.73	3.73	1459	
1/14/07	11:46			2.7	0.8	0.60	0.23	7.49	1.85	1.89	1810	
1/14/07						1.20	0.12	7.43		1.94	1680	
1/14/07						0.60	0.13	7.42		1.81	1821	
1/14/07						1.80	0.14	7.42		1.74	1809	
1/28/07	10:50			2.7	1	2.00	0.22	7.40	0.54	0.56	2146	
1/28/07				2.7	1	1.50	0.16	7.40		0.53	2148	
1/28/07				2.65	1	2.00	0.12	7.45		0.69	2158	
1/28/07				2.65	1	1.50	-0.10	7.45		0.60	2159	
1/28/07				2.7	1	2.00		7.45	0.50	0.50		Titration
1/28/07				2.7	1	2		7.45	0.35	0.35		Titration
2/11/07	10:00	23		2.8	1.5	2	0.3	7.49	0.18	0.21	2458	
2/11/07				2.8	1.5	2.5	0.25	7.49		0.2	2460	
2/11/07				2.7	1.5	2	0.23	7.5		0.14	2476	
2/11/07				2.7	1.5	2.5	0.22	7.49		0.15	2472	
2/25/07	9;50	23		2.7	1.2	2	0.14	7.52	0.23	0.13	2709	
2/25/07				2.7	1.2	2.3	0.13	7.52		0.24	2710	
2/25/07				2.65	1	2	0.13	7.52		0.32	2710	
3/10/07	13:00	23		2.8	1	1.72	0.27	7.41	0.45	0.35	2466	
3/10/07				2.8	1	1.2	0.76	7.41		0.34	2594	
3/10/07				2.5	0.5	1.7	0.83	7.39		0.57	2583	
3/10/07				2.5	0.5	2.2	0.51	7.4		0.52	2600	
4/1/07	9:30	22.1		3.4		2	1.53	8.1	11.66	11.66	905	
4/9/07	10:30	22	1.27	1.8		1.8	1.27	8.45	14.06	14.06	889	
4/14/07	9:10	22.4	0.603	3.2		1.92	4.96	8.73	13.66	13.66	1066	
4/22/07	9:41	22.5	0.707	3		1.8	10.02	8.5	9.71	9.71	1070	
4/28/07	9:40	22.5	0.707	3		1.8	11.8	8.44	8.50	8.5	13.95	
5/5/07	10:10	22.5	0.66	3		2	16.45	8.36	7.38	7.38	1057	
5/13/07	7:51	23	0.568	2.5		1.5	15.28	8.31	8.95	8.95	1084	
5/19/07	10:00	23.7	0.2	1.3		0.78	15.81	8.11	6.02	6.02	1341	
5/28/07	8:22	23	0.338	2.6		1.56	15.5	8.19	7.51	7.51	1158	
6/3/07	19:18	23.3	0.3345	2.6		1.56	22	7.98	6.89	6.89	1097	
6/10/07	18:30	22.6	0.8	3.1		1.86	21.65	8.37	7.49	7.49	1345	
6/12/07	17:00	23	0.741	2.5		1.5	22.56	8.23	5.61	5.61	1413	
6/24/07	8:50	23	0.187	2.2		1.32	25.48	8.63	4.48	4.48	1850	
7/15/07	11:00	22.7	0.561	2.9		1.74	24.15	8.39	5.13	5.13	1129	
7/30/07	9:00	22.9	0.383	2.9		1.74	25.32	8.26	4.60	4.6	1099	
8/19/07	9:55	23	0.145	3.1		1.86	19.23	8.56	7.20	7.2	969	
9/9/07	10:30	23.4	0.175	2.1		1.26	14.85	8.41	8.33	8.33	1058	
10/21/07	9:30	23.2	0.101	2.2		1.32	7.43	8.48	12.82	12.82	1120	

On site sampling data 9/06 to 10/07, County Road 2

	Flow Measurement				Field Momitoring Data							
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	mg/L	µS/cm	
9/24/06												
11/5/06	12.30	30.7		1	1		2.17	8.57				
11/19/06	13:00	30.8		2			2.03	8.29	14.45	14.45	1193	
12/3/06	13:30	30.8		1.4	0.6		0.00	8.01	9.57	9.57	893	
12/16/06	10:50	32	0.125		0.9		0.01	7.62	4.37	4.37	1482	
1/7/07	11:30	31.8		0.8	open		-0.40	7.54	3.79	3.82	1814	
1/7/07	11:30	31.8		0.8	open		-0.04	7.54		3.76	1813	
1/14/07	13:00			1.3	0.6	0.40	0.15	7.32	3.01	2.99	1936	
1/14/07	13.00					0.60	0.01	7.35		2.94	1941	
1/14/07	13:00			1.7	1.2	0.30	-0.80	7.35		3.06	1951	
1/14/07	13 00					0.20	-0.02	7.36		3.04	1944	
1/28/07	11.30			1.3	1	1.20	-0.03	7.41	0.94	1.02	2294	
1/28/07				1	0.8	1.00	-0.04	7.41		1.02	2296	
1/28/07				1.3	1				0.80	0.80		Titration
1/28/07				1.3	1				0.90	0.90		Titration
2/11/07												Too shallow to sample
2/25/07												Too shallow to sample
3/10/07	No water present											
4/1/07	10:00	29		2.9		1.74	1.01	8.10	11.66	11.66	928	
4/9/07	11:50	27.4	2.17,1.75,2.07	3.4		2.00	1.13	8.40	13.99	13.99	985	
4/14/07	11.00	28	0.946	3		1.8	4.44	8.67	12.86	12.86	1065	
4/22/07	10:42	28.5	0.94	4		2.4	9.64	8.55	9.51	9.51	1072	
4/28/07	10:20	28.5	0.94	3		1.8	13.17	8.44	8.66	8.66	1051	
5/5/07	11:00	32	0.741	3		1.8	15.69	8.36	7.29	7.29	1055	
5/13/07	8.39	26.3	0.237	2.3		1.38	15.04	8.33	8.93	8.93	1083	
5/19/07	11:00	29.5	0.645	2		1.2	14.34	8.29	7.60	7.6	1354	
5/28/07	6:23	29.5		1.8		1	15.72	8.28	7.60	7.6	1164	
6/3/07	16:29	31.3	0.255	1.5		0.9	23.51	8.29	8.92	8.92	1163	
6/10/07	18:00	31	0.8	3		1.8	21.86	8.36	7.95	7.95	1371	
6/12/07	18:00	28	0.765	3.3		1.98	23.02	8.3	4.82	4.82	1436	
6/24/07	9:38	28	0.475	1.8		1.08	25	8.64	4.79	4.79	1950	
7/15/07	12:00	28.9	0.666	2.4		1.44	24.56	8.42	6.79	6.79	1116	
7/30/07	10:00	29.3	0.546	2.1		1.26	25.87	8.37	4.40	4.4	1088	
8/19/07	10.30	29.4	0.5	2		1.2	19.17	8.71	7.19	7.19	961	
9/9/07	11:30	29.7	0.183	1.5		0.9	14.48	8.36	8.62	8.62	1045	
10/21/07	10:30	29.8	0.183	1.4		0.84	7.52	8.62	12.28	12.28	1673	

On site sampling data 9/06 to 10/07, Glen Ewen

	Flow Measurement				Field Mornitoring Data							
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	mg/L	µS/cm	
9/24/06	13:30						12.94	8.57	10.67	10.67	1053	
11/5/06	13:30	26.8		-	0.17		2.00	8.56				
11/19/06	13:00	26.8	*	surface	0.25		1.11	8.35	18.12	18.12	1833	
12/3/06	15:47	26.5		2.6	0.8		0.02	7.75	3.71	3.71	1667	
12/16/06	13:30	28*	0.383**	surface	0.8		0.00	7.59	0.59	0.59	1990	
1/7/07	13:30	29.7		4.8	1.3		-0.04	7.58	0.19	0.23	2586	
1/7/07	7:12	29.7		3.6	1.8		-0.05	7.58		0.14	2582	
1/14/07	15:15			2.5	1.8	2.02	-0.12	7.45	0.41	0.93	2958	
1/14/07						2.35	-0.09	7.51		0.30	2976	
1/14/07						0.80	-0.08	7.55		0.20	2980	
1/14/07						0.10	-0.08	7.50		0.22	2980	
1/28/07	15:09			8.8	1.7	5.90	0.41	7.50	0.19	0.37	3111	at a culvert about
1/28/07				8.8	1.7	8.00	0.15	7.50		0.16	3076	1 km down stream
1/28/07				8.8	1.7	5.00	0.10	7.50		0.11	3085	of the bridge because
1/28/07				8.8	1.7	3	0.07	7.5		0.13	3085	site is frozen through
1/28/07				8.8		4			0.00	0		Titration
1/28/07				8.8		8			0.00	0		Titration
2/11/07	12:45			8.8	2.3	6.1	0.18	7.57	0.19	0.34	3191	Smelly black water
2/11/07				8.8	2.3	8	0.32	7.57		0.12	3209	
2/11/07				8.8	2.3	4	0.24	7.57		0.1	3188	
2/25/07	12:30			8.5	2	6	0.97	7.69	0.13	0.16	2952	
2/25/07				8.5	2	8	0.98	7.7		0.17	2945	
2/25/07				8.5	2	4	0.74	7.7		0.07	2925	
3/10/07	14:30			8.5	2.2	6	1.42	7.51	0.18	0.24	2663	
3/10/07				8.5	2.2	8	1.42	7.51		0.16	2670	
3/10/07				8.5	2.2	4	1.14	7.52		0.14	2803	
4/1/07	11:30	26		3.6		1.56	0.47	7.99	11.62	11.62	1013	Back to original location
4/9/07	13:50	25.4	2.47	4		2.4	2.61	8.32	13.09	13.09	1041	
4/14/07	12:30	25.5	1.17	4		2.4	5.39	8.48	12.42	12.42	1087	
4/22/07	12:23	25.5	0.68	3.5		2.1	9.92	8.54	8.31	8.31	1068	
4/28/07	12:30	26	0.68	4		2.4	13.11	8.42	10.33	10.33	1118	
5/5/07	13:05	27	0.635	3		1.8	15.08	8.42	8.44	8.44	1003	
5/13/07	11:00	26.3	0.271	3.4		2	14.63	8.64	9.14	9.14	1202	
5/19/07	12:30	26	0.334	3.5		2.1	11.89	8.59	9.53	9.53	1276	
5/27/07	7:15	29.6	0.28	2.9		1.8	13.52	8.78	10.99	10.99	1127	
6/3/07	16:44	23.65	0.238	6		3.6	23.59	8.71	10.48	10.48	1268	
6/10/07	15:30	25.5	0.8	4.5		2.7	20.79	8.67	9.75	9.75	1425	
6/12/07	20:00	25.9	0.345	3.7		2.22	23.13	8.55	5.91	5.91	1929	
6/24/07	11:00	26.9	0.168	2.9		1.74	25.25	8.84	6.41	6.41	1888	
7/15/07	14:00	26	0.539	3.6		2.16	26.15	8.61	6.43	6.43	1134	
7/30/07	12:35	26.1	0.442	3.6		1.56	26.15	8.49	4.38	4.38	1056	
8/19/07	12:30	26.6	0.111	3		1.8	18.75	8.71	7.28	7.28	1012	
9/9/07	14:30	26.9	0.15	1.8		1.8	15.06	8.2	7.21	7.21	1418	
10/21/07	12:00	27.2	0.15	2.2		1.32	7.61	8.62	12.28	12.28	1673	

On site sampling data 9/06 to 10/07, Highway 9 bridge

		Flow Measurement				Field Mornitoring Data					
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	µS/cm	
1/7/07	16:00			3.7	0.8	2.20	0.14	8.29	0.71	3741	
1/7/07	16:00			3.8	0.7	2.00	0.16	8.29	0.42	3740	
1/28/07	16:20			2.9	1	2.20	0.26	8.10	0.26	3756	
1/28/07				2.9	1	2.50	0.23	8.10	0.19	3730	
1/28/07				2.9	1	1.50	0.14	8.10	0.30	3729	
1/28/07				2.9	1				0.2		Titration
1/28/2007				2.9	1				0.1		Titration
2/11/2007	14:00			3.2	1.6	2.9	0.02	8.02	0.2	3853	Black smelly water
2/11/2007				3.2	1.6	1.9	0.01	8.02	0.16	3854	
2/11/2007				3.2	1.6	2.8	0.02	8.02	0.14	3853	
2/25/2007	14:00			2.7	1.1	2	0.14	8.3	0.32	3939	
2/25/2007				3	1.3	2.3	0.13	8.14	0.27	3939	
3/10/2007	17:00			3.3	1	2.4	0.6	7.86	0.1	3842	
3/10/2007				3.3	1	1.4	0.35	7.86	0.1	3869	
3/10/2007				3.3	1	3.1	0.36	7.85	0.14	3860	

On site sampling deata 9/06 to 10/07, other sampling locations

Description					Flow Measurement				Field Mornitoring Data				
Site Name	Latitude	Longitude	Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	DO	Conductivity
					ft.	fps	ft.	ft.	ft	Celcius		mg/L	µS/cm
Alameda Res	49.262	-102.237	1/7/07	15:15			29.7	1.8	18	1.45	1027	10.25	8.36
N of 05114000	48.274	-101.433	1/7/2007	10:15			1.3	1		-0.04	1876	4.04	7.54
N of 05114000	48.274	-101.433	1/7/2007	10:30			1.3	1		-0.04	1654	4.06	7.54

USGS Souris River daily mean flow rate

Location: USGS Gaging Station 5114000, near Sherwood, ND

Period: September 1994 – September 2004

Date	Flowrate	Date	Flowrate	Date	Flowrate	Date	Flowrate	Date	Flowrate	Date	Flowrate	Date	Flowrate	Date	Flowrate	Date	Flowrate	Date	Flowrate
m/d/yr	cfs	m/d/yr	cfs	m/d/yr	cfs	m/d/yr	cfs	m/d/yr	cfs	m/d/yr	cfs	m/d/yr	cfs	m/d/yr	cfs	m/d/yr	cfs	m/d/yr	cfs
9/1/94	2.3	10/19/94	1	12/6/94	1.3	1/23/95	1	3/12/95	26	4/29/95	274	6/16/95	40	8/3/95	24	9/20/95	4.1	11/7/95	7.2
9/2/94	2.1	10/20/94	0.9	12/7/94	1.3	1/24/95	1	3/13/95	80	4/30/95	260	6/17/95	36	8/4/95	21	9/21/95	4	11/8/95	6.8
9/3/94	2.2	10/21/94	0.98	12/8/94	1.3	1/25/95	1	3/14/95	200	5/1/95	266	6/18/95	33	8/5/95	19	9/22/95	4.3	11/9/95	6.6
9/4/94	2.3	10/22/94	1	12/9/94	1.4	1/26/95	1	3/15/95	600	5/2/95	261	6/19/95	31	8/6/95	23	9/23/95	4.3	11/10/95	6.8
9/5/94	1.9	10/23/94	0.96	12/10/94	1.5	1/27/95	1	3/16/95	870	5/3/95	244	6/20/95	30	8/7/95	26	9/24/95	4.4	11/11/95	6.1
9/6/94	1.8	10/24/94	0.84	12/11/94	1.6	1/28/95	1	3/17/95	1200	5/4/95	119	6/21/95	30	8/8/95	23	9/25/95	4.4	11/12/95	6
9/7/94	1.8	10/25/94	0.89	12/12/94	1.4	1/29/95	1	3/18/95	1600	5/5/95	93	6/22/95	33	8/9/95	22	9/26/95	4.4	11/13/95	5.9
9/8/94	1.7	10/26/94	1.1	12/13/94	1.4	1/30/95	1	3/19/95	1480	5/6/95	83	6/23/95	59	8/10/95	20	9/27/95	4.8	11/14/95	5.8
9/9/94	1.7	10/27/94	1.1	12/14/94	1.3	1/31/95	1	3/20/95	1370	5/7/95	79	6/24/95	1370	8/11/95	19	9/28/95	4.7	11/15/95	5.8
9/10/94	1.5	10/28/94	1.2	12/15/94	1.3	2/1/95	1	3/21/95	1000	5/8/95	90	6/25/95	786	8/12/95	18	9/29/95	4.7	11/16/95	5.8
9/11/94	1.2	10/29/94	0.83	12/16/94	1.3	2/2/95	1	3/22/95	880	5/9/95	92	6/26/95	276	8/13/95	16	9/30/95	4.6	11/17/95	5.7
9/12/94	1.1	10/30/94	0.88	12/17/94	1.2	2/3/95	1.1	3/23/95	600	5/10/95	86	6/27/95	112	8/14/95	15	10/1/95	4.5	11/18/95	5.7
9/13/94	1.2	10/31/94	0.74	12/18/94	1.2	2/4/95	1.1	3/24/95	570	5/11/95	83	6/28/95	87	8/15/95	14	10/2/95	4.7	11/19/95	5.9
9/14/94	1.2	11/1/94	0.76	12/19/94	1.3	2/5/95	1.2	3/25/95	540	5/12/95	80	6/29/95	236	8/16/95	14	10/3/95	5.2	11/20/95	5.8
9/15/94	1.8	11/2/94	0.76	12/20/94	1.3	2/6/95	1.2	3/26/95	530	5/13/95	73	6/30/95	313	8/17/95	14	10/4/95	5	11/21/95	5.9
9/16/94	1.2	11/3/94	0.89	12/21/94	1.3	2/7/95	1.2	3/27/95	500	5/14/95	70	7/1/95	249	8/18/95	14	10/5/95	5.1	11/22/95	5.5
9/17/94	1.2	11/4/94	0.96	12/22/94	1.4	2/8/95	1.2	3/28/95	500	5/15/95	71	7/2/95	103	8/19/95	12	10/6/95	5.2	11/23/95	5.4
9/18/94	1.2	11/5/94	0.85	12/23/94	1.3	2/9/95	1.2	3/29/95	300	5/16/95	79	7/3/95	159	8/20/95	12	10/7/95	5.2	11/24/95	5.3
9/19/94	1.2	11/6/94	0.86	12/24/94	1.2	2/10/95	1.2	3/30/95	200	5/17/95	71	7/4/95	139	8/21/95	11	10/8/95	5.6	11/25/95	5.2
9/20/94	1.1	11/7/94	0.88	12/25/94	1.2	2/11/95	1.2	3/31/95	150	5/18/95	69	7/5/95	124	8/22/95	11	10/9/95	6.3	11/26/95	5.1
9/21/94	1.2	11/8/94	0.89	12/26/94	1.1	2/12/95	1.2	4/1/95	130	5/19/95	69	7/6/95	103	8/23/95	9.7	10/10/95	6.7	11/27/95	5
9/22/94	1	11/9/94	0.69	12/27/94	1.2	2/13/95	1.2	4/2/95	140	5/20/95	71	7/7/95	97	8/24/95	9.4	10/11/95	7	11/28/95	5
9/23/94	0.99	11/10/94	0.76	12/28/94	1.2	2/14/95	1.2	4/3/95	200	5/21/95	71	7/8/95	96	8/25/95	8.7	10/12/95	7	11/29/95	5
9/24/94	0.96	11/11/94	1.1	12/29/94	1.3	2/15/95	1.2	4/4/95	130	5/22/95	81	7/9/95	75	8/26/95	8.1	10/13/95	7	11/30/95	5
9/25/94	0.92	11/12/94	1.3	12/30/94	1.3	2/16/95	1.1	4/5/95	140	5/23/95	84	7/10/95	80	8/27/95	7.9	10/14/95	8.9	12/1/95	5
9/26/94	0.81	11/13/94	1.5	12/31/94	1.2	2/17/95	1.1	4/6/95	150	5/24/95	96	7/11/95	63	8/28/95	7.7	10/15/95	7.5	12/2/95	5
9/27/94	0.74	11/14/94	1.5	1/1/95	1.2	2/18/95	1.1	4/7/95	340	5/25/95	102	7/12/95	49	8/29/95	7.1	10/16/95	7.9	12/3/95	5
9/28/94	0.68	11/15/94	1.4	1/2/95	1.2	2/19/95	1.1	4/8/95	300	5/26/95	163	7/13/95	60	8/30/95	6.5	10/17/95	7.4	12/4/95	4.8
9/29/94	0.56	11/16/94	1.2	1/3/95	1.2	2/20/95	1.1	4/9/95	310	5/27/95	187	7/14/95	43	8/31/95	6.2	10/18/95	7.9	12/5/95	4.5
9/30/94	0.43	11/17/94	1	1/4/95	1.2	2/21/95	1.2	4/10/95	330	5/28/95	187	7/15/95	42	9/1/95	5.4	10/19/95	7.0	12/6/95	3.8
10/1/94	0.44	11/18/94	0.8	1/5/95	1.1	2/22/95	1.4	4/11/95	355	5/29/95	186	7/16/95	61	9/2/95	5.2	10/20/95	7.1	12/7/95	3.5
10/2/94	0.64	11/19/94	0.8	1/6/95	1.1	2/23/95	1.6	4/12/95	294	5/30/95	181	7/17/95	126	9/3/95	5	10/21/95	6.6	12/8/95	3.5
10/3/94	0.65	11/20/94	0.8	1/7/95	1.1	2/24/95	1.7	4/13/95	274	5/31/95	177	7/18/95	93	9/4/95	4.7	10/22/95	6.6	12/9/95	3.5
10/4/94	0.63	11/21/94	0.78	1/8/95	1.1	2/25/95	1.7	4/14/95	277	6/1/95	172	7/19/95	100	9/5/95	4.8	10/23/95	7.3	12/10/95	3.5
10/5/94	0.64	11/22/94	0.75	1/9/95	1.1	2/26/95	1.7	4/15/95	282	6/2/95	90	7/20/95	86	9/6/95	4.5	10/24/95	7.2	12/11/95	3.6
10/6/94	0.61	11/23/94	0.8	1/10/95	1.1	2/27/95	1.7	4/16/95	289	6/3/95	44	7/21/95	82	9/7/95	4.8	10/25/95	6.7	12/12/95	3.6
10/7/94	0.6	11/24/94	0.9	1/11/95	1.1	2/28/95	1.8	4/17/95	289	6/4/95	36	7/22/95	50	9/8/95	5	10/26/95	6.8	12/13/95	3.5
10/8/94	0.56	11/25/94	1	1/12/95	1.1	3/1/95	1.7	4/18/95	284	6/5/95	52	7/23/95	44	9/9/95	6.8	10/27/95	6.8	12/14/95	3.8
10/9/94	0.47	11/26/94	1	1/13/95	1.1	3/2/95	1.6	4/19/95	280	6/6/95	67	7/24/95	41	9/10/95	6.7	10/28/95	6.4	12/15/95	3.6
10/10/94	0.44	11/27/94	1.1	1/14/95	1.1	3/3/95	1.6	4/20/95	276	6/7/95	54	7/25/95	42	9/11/95	7.6	10/29/95	6.9	12/16/95	3.5
10/11/94	0.42	11/28/94	1.1	1/15/95	1.1	3/4/95	1.5	4/21/95	278	6/8/95	60	7/26/95	39	9/12/95	6.7	10/30/95	9.6	12/17/95	3.5
10/12/94	0.42	11/29/94	1.2	1/16/95	1.1	3/5/95	10	4/22/95	279	6/9/95	62	7/27/95	33	9/13/95	5.7	10/31/95	10	12/18/95	3.5
10/13/94	0.67	11/30/94	1.4	1/17/95	1.1	3/6/95	50	4/23/95	281	6/10/95	54	7/28/95	25	9/14/95	5.1	11/1/95	8.6	12/19/95	3.4
10/14/94	0.74	12/1/94	1.5	1/18/95	1.1	3/7/95	45	4/24/95	280	6/11/95	55	7/29/95	22	9/15/95	5	11/2/95	8.3	12/20/95	3.4
10/15/94	0.76	12/2/94	1.6	1/19/95	1.1	3/8/95	40	4/25/95	284	6/12/95	53	7/30/95	26	9/16/95	5.2	11/3/95	7.7	12/21/95	3.4
10/16/94	0.86	12/3/94	1.6	1/20/95	1.1	3/9/95	33	4/26/95	280	6/13/95	53	7/31/95	28	9/17/95	4.0	11/4/95	6.0	12/22/95	3.4
10/17/94	0.78	12/4/94	1.6	1/21/95	1	3/10/95	28	4/27/95	283	6/14/95	54	8/1/95	48	9/18/95	4.8	11/5/95	7.3	12/23/95	3.4
10/18/94	0.88	12/5/94	1.4	1/22/95	1	3/11/95	25	4/28/95	281	6/15/95	51	8/2/95	33	9/19/95	4.4	11/6/95	7.8	12/24/95	3.4

Flow rate continued

Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs
12/25/95	3.3	2/11/96	1.6	3/30/96	300	5/17/96	1010	7/4/96	26	8/21/96	6.2	10/8/96	6.6	11/25/96	3.8	1/12/97	3.6	3/1/97	3.6
12/26/95	3.3	2/12/96	1.6	3/31/96	260	5/18/96	999	7/5/96	25	8/22/96	7	10/9/96	5.5	11/26/96	3.8	1/13/97	3.6	3/2/97	3.5
12/27/95	3.3	2/13/96	1.6	4/1/96	230	5/19/96	1020	7/6/96	24	8/23/96	33	10/10/96	6.2	11/27/96	3.8	1/14/97	3.6	3/3/97	3.5
12/28/95	3.2	2/14/96	1.6	4/2/96	220	5/20/96	1060	7/7/96	23	8/24/96	68	10/11/96	6.2	11/28/96	3.8	1/15/97	3.7	3/4/97	3.5
12/29/95	3.2	2/15/96	1.6	4/3/96	200	5/21/96	1030	7/8/96	24	8/25/96	77	10/12/96	6.2	11/29/96	3.8	1/16/97	3.8	3/5/97	3.5
12/30/95	3.1	2/16/96	1.6	4/4/96	190	5/22/96	988	7/9/96	34	8/26/96	82	10/13/96	4.9	11/30/96	4	1/17/97	4	3/6/97	3.5
12/31/95	3.1	2/17/96	1.6	4/5/96	180	5/23/96	1020	7/10/96	35	8/27/96	86	10/14/96	4.7	12/1/96	4	1/18/97	4	3/7/97	3.5
1/1/96	3	2/18/96	1.6	4/6/96	170	5/24/96	1050	7/11/96	36	8/28/96	87	10/15/96	4.5	12/2/96	4	1/19/97	4	3/8/97	3.5
1/2/96	3	2/19/96	1.6	4/7/96	160	5/25/96	1020	7/12/96	37	8/29/96	87	10/16/96	5.5	12/3/96	4	1/20/97	4	3/9/97	3.5
1/3/96	2.9	2/20/96	1.6	4/8/96	150	5/26/96	1030	7/13/96	38	8/30/96	69	10/17/96	6	12/4/96	4	1/21/97	3.9	3/10/97	3.5
1/4/96	2.8	2/21/96	1.6	4/9/96	500	5/27/96	1030	7/14/96	37	8/31/96	73	10/18/96	6.2	12/5/96	4	1/22/97	3.9	3/11/97	3.5
1/5/96	2.8	2/22/96	1.6	4/10/96	1500	5/28/96	961	7/15/96	38	9/1/96	50	10/19/96	4.9	12/6/96	4	1/23/97	3.9	3/12/97	3.5
1/6/96	2.8	2/23/96	1.7	4/11/96	2000	5/29/96	778	7/16/96	35	9/2/96	47	10/20/96	5.2	12/7/96	4	1/24/97	3.8	3/13/97	3.5
1/7/96	2.8	2/24/96	1.7	4/12/96	2400	5/30/96	688	7/17/96	35	9/3/96	47	10/21/96	6.4	12/8/96	4	1/25/97	3.8	3/14/97	3.5
1/8/96	2.8	2/25/96	1.7	4/13/96	2560	5/31/96	468	7/18/96	36	9/4/96	49	10/22/96	6.8	12/9/96	4	1/26/97	3.8	3/15/97	3.5
1/9/96	2.7	2/26/96	1.8	4/14/96	2550	6/1/96	259	7/19/96	35	9/5/96	61	10/23/96	7	12/10/96	4	1/27/97	3.8	3/16/97	3.5
1/10/96	2.7	2/27/96	1.8	4/15/96	2310	6/2/96	202	7/20/96	41	9/6/96	67	10/24/96	7.1	12/11/96	4	1/28/97	3.8	3/17/97	3.5
1/11/96	2.7	2/28/96	1.8	4/16/96	1840	6/3/96	188	7/21/96	39	9/7/96	60	10/25/96	7.4	12/12/96	4	1/29/97	3.8	3/18/97	3.5
1/12/96	2.7	2/29/96	1.8	4/17/96	1530	6/4/96	182	7/22/96	37	9/8/96	50	10/26/96	7.2	12/13/96	4	1/30/97	3.8	3/19/97	3.5
1/13/96	2.7	3/1/96	1.8	4/18/96	1370	6/5/96	177	7/23/96	33	9/9/96	32	10/27/96	6.9	12/14/96	3.9	1/31/97	3.8	3/20/97	3.5
1/14/96	2.5	3/2/96	1.7	4/19/96	1220	6/6/96	130	7/24/96	32	9/10/96	25	10/28/96	6.5	12/15/96	3.9	2/1/97	3.8	3/21/97	4
1/15/96	2.5	3/3/96	1.7	4/20/96	1060	6/7/96	100	7/25/96	31	9/11/96	23	10/29/96	6.6	12/16/96	3.8	2/2/97	3.8	3/22/97	7
1/16/96	2.5	3/4/96	1.7	4/21/96	973	6/8/96	101	7/26/96	32	9/12/96	21	10/30/96	6.4	12/17/96	3.8	2/3/97	3.8	3/23/97	10
1/17/96	2.5	3/5/96	1.7	4/22/96	957	6/9/96	128	7/27/96	36	9/13/96	18	10/31/96	7.6	12/18/96	3.8	2/4/97	3.8	3/24/97	10
1/18/96	2.5	3/6/96	1.6	4/23/96	795	6/10/96	133	7/28/96	36	9/14/96	13	11/1/96	6.9	12/19/96	3.8	2/5/97	3.8	3/25/97	12
1/19/96	2.5	3/7/96	1.6	4/24/96	348	6/11/96	131	7/29/96	33	9/15/96	11	11/2/96	7.9	12/20/96	3.8	2/6/97	3.7	3/26/97	80
1/20/96	2.5	3/8/96	1.6	4/25/96	308	6/12/96	127	7/30/96	32	9/16/96	9.4	11/3/96	7.6	12/21/96	3.8	2/7/97	3.7	3/27/97	300
1/21/96	2.4	3/9/96	1.5	4/26/96	744	6/13/96	100	7/31/96	31	9/17/96	9.7	11/4/96	7.1	12/22/96	3.8	2/8/97	3.7	3/28/97	1000
1/22/96	2.3	3/10/96	1.5	4/27/96	851	6/14/96	107	8/1/96	31	9/18/96	11	11/5/96	6.7	12/23/96	3.8	2/9/97	3.7	3/29/97	1500
1/23/96	2.2	3/11/96	1.6	4/28/96	864	6/15/96	100	8/2/96	31	9/19/96	11	11/6/96	6.5	12/24/96	3.8	2/10/97	3.7	3/30/97	1900
1/24/96	2.1	3/12/96	2	4/29/96	837	6/16/96	83	8/3/96	31	9/20/96	11	11/7/96	6.4	12/25/96	3.8	2/11/97	3.7	3/31/97	2200
1/25/96	2	3/13/96	13	4/30/96	702	6/17/96	73	8/4/96	30	9/21/96	10	11/8/96	6.3	12/26/96	3.8	2/12/97	3.7	4/1/97	2600
1/26/96	2	3/14/96	60	5/1/96	266	6/18/96	70	8/5/96	29	9/22/96	9.7	11/9/96	6.1	12/27/96	3.8	2/13/97	3.7	4/2/97	2700
1/27/96	2	3/15/96	200	5/2/96	177	6/19/96	80	8/6/96	27	9/23/96	9.5	11/10/96	5.9	12/28/96	3.8	2/14/97	3.7	4/3/97	2500
1/28/96	2	3/16/96	500	5/3/96	149	6/20/96	65	8/7/96	26	9/24/96	8.6	11/11/96	5.6	12/29/96	3.8	2/15/97	3.7	4/4/97	2200
1/29/96	2	3/17/96	1000	5/4/96	126	6/21/96	60	8/8/96	27	9/25/96	7.6	11/12/96	6.3	12/30/96	3.8	2/16/97	3.7	4/5/97	1900
1/30/96	2	3/18/96	1300	5/5/96	203	6/22/96	57	8/9/96	25	9/26/96	7	11/13/96	5	12/31/96	3.8	2/17/97	3.7	4/6/97	1700
1/31/96	2	3/19/96	1100	5/6/96	687	6/23/96	65	8/10/96	19	9/27/96	6.8	11/14/96	4.8	1/1/97	3.8	2/18/97	3.7	4/7/97	1400
2/1/96	2	3/20/96	950	5/7/96	757	6/24/96	81	8/11/96	16	9/28/96	6.5	11/15/96	4.6	1/2/97	3.8	2/19/97	3.7	4/8/97	1100
2/2/96	2	3/21/96	800	5/8/96	865	6/25/96	82	8/12/96	14	9/29/96	6.6	11/16/96	4.5	1/3/97	3.8	2/20/97	3.7	4/9/97	800
2/3/96	2	3/22/96	700	5/9/96	774	6/26/96	61	8/13/96	9.7	9/30/96	7.5	11/17/96	4.4	1/4/97	3.8	2/21/97	3.7	4/10/97	570
2/4/96	2	3/23/96	650	5/10/96	868	6/27/96	41	8/14/96	6.7	10/1/96	7.3	11/18/96	4.3	1/5/97	3.8	2/22/97	3.7	4/11/97	413
2/5/96	2	3/24/96	600	5/11/96	926	6/28/96	38	8/15/96	5.4	10/2/96	7.2	11/19/96	4.2	1/6/97	3.8	2/23/97	3.7	4/12/97	387
2/6/96	2	3/25/96	530	5/12/96	980	6/29/96	31	8/16/96	4.6	10/3/96	6.9	11/20/96	4.1	1/7/97	3.8	2/24/97	3.7	4/13/97	288
2/7/96	1.8	3/26/96	480	5/13/96	1020	6/30/96	40	8/17/96	4	10/4/96	6.6	11/21/96	4	1/8/97	3.8	2/25/97	3.7	4/14/97	288
2/8/96	1.7	3/27/96	440	5/14/96	971	7/1/96	34	8/18/96	3.6	10/5/96	6.8	11/22/96	4	1/9/97	3.8	2/26/97	3.7	4/15/97	284
2/9/96	1.6	3/28/96	380	5/15/96	976	7/2/96	30	8/19/96	5.4	10/6/96	6.7	11/23/96	4	1/10/97	3.6	2/27/97	3.7	4/16/97	576
2/10/96	1.6	3/29/96	320	5/16/96	996	7/3/96	27	8/20/96	14	10/7/96	6.3	11/24/96	3.9	1/11/97	3.6	2/28/97	3.7	4/17/97	772

Flow rate continued

Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs
8/11/98	4	9/28/98	2.3	11/15/98	4.8	1/2/99	3.5	2/19/99	3.3	4/8/99	2300	5/26/99	1150	7/13/99	371	8/30/99	215	10/17/99	16
8/12/98	3.7	9/29/98	2.3	11/16/98	6.8	1/3/99	3.4	2/20/99	3.3	4/9/99	2460	5/27/99	1080	7/14/99	368	8/31/99	141	10/18/99	16
8/13/98	3.1	9/30/98	2.3	11/17/98	5.9	1/4/99	3.3	2/21/99	3.4	4/10/99	2440	5/28/99	952	7/15/99	357	9/1/99	137	10/19/99	16
8/14/98	2.8	10/1/98	2.1	11/18/98	5.5	1/5/99	3.2	2/22/99	3.4	4/11/99	2360	5/29/99	648	7/16/99	431	9/2/99	202	10/20/99	16
8/15/98	2.7	10/2/98	2.3	11/19/98	5.4	1/6/99	3.2	2/23/99	3.6	4/12/99	2180	5/30/99	502	7/17/99	458	9/3/99	233	10/21/99	16
8/16/98	2.5	10/3/98	1.9	11/20/98	5.9	1/7/99	3.2	2/24/99	3.8	4/13/99	2050	5/31/99	409	7/18/99	445	9/4/99	237	10/22/99	15
8/17/98	2.4	10/4/98	2.1	11/21/98	6	1/8/99	3.1	2/25/99	3.8	4/14/99	1950	6/1/99	381	7/19/99	411	9/5/99	221	10/23/99	15
8/18/98	3.1	10/5/98	2.7	11/22/98	6.2	1/9/99	2.9	2/26/99	4	4/15/99	1880	6/2/99	355	7/20/99	407	9/6/99	200	10/24/99	15
8/19/98	3.1	10/6/98	3	11/23/98	6.2	1/10/99	2.6	2/27/99	4.2	4/16/99	1840	6/3/99	358	7/21/99	430	9/7/99	188	10/25/99	15
8/20/98	3.2	10/7/98	2.9	11/24/98	6.5	1/11/99	2.3	2/28/99	4.1	4/17/99	1810	6/4/99	414	7/22/99	454	9/8/99	181	10/26/99	14
8/21/98	5.8	10/8/98	3.1	11/25/98	7.2	1/12/99	2.2	3/1/99	4.2	4/18/99	1810	6/5/99	406	7/23/99	457	9/9/99	173	10/27/99	14
8/22/98	6.7	10/9/98	3.1	11/26/98	7.3	1/13/99	2.1	3/2/99	4.1	4/19/99	1810	6/6/99	349	7/24/99	448	9/10/99	168	10/28/99	14
8/23/98	6.1	10/10/98	3.1	11/27/98	7.5	1/14/99	2	3/3/99	4	4/20/99	1810	6/7/99	323	7/25/99	430	9/11/99	167	10/29/99	14
8/24/98	5.5	10/11/98	4.6	11/28/98	7.6	1/15/99	2	3/4/99	3.9	4/21/99	1810	6/8/99	317	7/26/99	412	9/12/99	170	10/30/99	14
8/25/98	5.2	10/12/98	4.8	11/29/98	7.7	1/16/99	3.1	3/5/99	3.9	4/22/99	1800	6/9/99	318	7/27/99	390	9/13/99	175	10/31/99	14
8/26/98	4.6	10/13/98	5.7	11/30/98	7.5	1/17/99	2.1	3/6/99	4	4/23/99	1800	6/10/99	314	7/28/99	366	9/14/99	178	11/1/99	14
8/27/98	4.3	10/14/98	6.3	12/1/98	7.2	1/18/99	2.1	3/7/99	4	4/24/99	1790	6/11/99	300	7/29/99	342	9/15/99	175	11/2/99	13
8/28/98	3.8	10/15/98	6	12/2/98	6.9	1/19/99	2.1	3/8/99	4	4/25/99	1790	6/12/99	288	7/30/99	328	9/16/99	173	11/3/99	14
8/29/98	3.4	10/16/98	6.7	12/3/98	6.9	1/20/99	2.1	3/9/99	4	4/26/99	1790	6/13/99	284	7/31/99	318	9/17/99	164	11/4/99	14
8/30/98	3.3	10/17/98	5	12/4/98	6.8	1/21/99	2.2	3/10/99	4	4/27/99	1780	6/14/99	274	8/1/99	311	9/18/99	162	11/5/99	14
8/31/98	3.3	10/18/98	4.4	12/5/98	7	1/22/99	2.3	3/11/99	4	4/28/99	1780	6/15/99	263	8/2/99	309	9/19/99	166	11/6/99	14
9/1/98	3	10/19/98	3.9	12/6/98	7.7	1/23/99	2.3	3/12/99	4	4/29/99	1770	6/16/99	254	8/3/99	307	9/20/99	167	11/7/99	14
9/2/98	2.9	10/20/98	3.9	12/7/98	6.8	1/24/99	2.2	3/13/99	4.1	4/30/99	1720	6/17/99	250	8/4/99	305	9/21/99	168	11/8/99	14
9/3/98	2.4	10/21/98	4.4	12/8/98	7.6	1/25/99	2.2	3/14/99	4.2	5/1/99	1620	6/18/99	247	8/5/99	303	9/22/99	170	11/9/99	14
9/4/98	2.4	10/22/98	4.7	12/9/98	8.5	1/26/99	2.3	3/15/99	4.4	5/2/99	1540	6/19/99	251	8/6/99	304	9/23/99	171	11/10/99	14
9/5/98	2.5	10/23/98	6.3	12/10/98	7.5	1/27/99	2.4	3/16/99	4.5	5/3/99	1500	6/20/99	254	8/7/99	308	9/24/99	171	11/11/99	14
9/6/98	2.2	10/24/98	6.2	12/11/98	7.8	1/28/99	2.5	3/17/99	4.5	5/4/99	1480	6/21/99	249	8/8/99	305	9/25/99	172	11/12/99	14
9/7/98	1.9	10/25/98	6.9	12/12/98	7.1	1/29/99	2.5	3/18/99	4.5	5/5/99	1480	6/22/99	250	8/9/99	316	9/26/99	178	11/13/99	14
9/8/98	1.8	10/26/98	6.9	12/13/98	6.6	1/30/99	2.8	3/19/99	4.6	5/6/99	1500	6/23/99	246	8/10/99	326	9/27/99	186	11/14/99	14
9/9/98	1.8	10/27/98	6.8	12/14/98	7.2	1/31/99	3	3/20/99	4.8	5/7/99	1420	6/24/99	246	8/11/99	333	9/28/99	189	11/15/99	14
9/10/98	1.8	10/28/98	6.5	12/15/98	7.1	2/1/99	3.2	3/21/99	5.5	5/8/99	1270	6/25/99	246	8/12/99	346	9/29/99	104	11/16/99	14
9/11/98	1.7	10/29/98	6.2	12/16/98	8.7	2/2/99	3.4	3/22/99	8	5/9/99	1180	6/26/99	247	8/13/99	363	9/30/99	51	11/17/99	16
9/12/98	1.7	10/30/98	4.9	12/17/98	8.4	2/3/99	3.6	3/23/99	10	5/10/99	1160	6/27/99	253	8/14/99	387	10/1/99	39	11/18/99	17
9/13/98	2.5	10/31/98	4.6	12/18/98	6.4	2/4/99	3.6	3/24/99	20	5/11/99	1240	6/28/99	258	8/15/99	365	10/2/99	33	11/19/99	17
9/14/98	5	11/1/98	4.5	12/19/98	5.3	2/5/99	3.6	3/25/99	100	5/12/99	1280	6/29/99	267	8/16/99	384	10/3/99	30	11/20/99	16
9/15/98	4.5	11/2/98	4.4	12/20/98	4.7	2/6/99	3.6	3/26/99	500	5/13/99	1280	6/30/99	281	8/17/99	364	10/4/99	28	11/21/99	15
9/16/98	4	11/3/98	4.2	12/21/98	4.2	2/7/99	3.6	3/27/99	600	5/14/99	1280	7/1/99	289	8/18/99	363	10/5/99	26	11/22/99	15
9/17/98	3.6	11/4/98	4.1	12/22/98	4.1	2/8/99	3.6	3/28/99	700	5/15/99	1600	7/2/99	294	8/19/99	362	10/6/99	24	11/23/99	15
9/18/98	3.3	11/5/98	4	12/23/98	4	2/9/99	3.6	3/29/99	1000	5/16/99	1620	7/3/99	304	8/20/99	362	10/7/99	23	11/24/99	14
9/19/98	3.2	11/6/98	3.9	12/24/98	4	2/10/99	3.5	3/30/99	1600	5/17/99	1410	7/4/99	319	8/21/99	358	10/8/99	22	11/25/99	14
9/20/98	3	11/7/98	3.8	12/25/98	4	2/11/99	3.7	3/31/99	1800	5/18/99	1300	7/5/99	335	8/22/99	367	10/9/99	20	11/26/99	13
9/21/98	2.8	11/8/98	3.8	12/26/98	4	2/12/99	4.2	4/1/99	1500	5/19/99	1240	7/6/99	344	8/23/99	365	10/10/99	19	11/27/99	13
9/22/98	2.5	11/9/98	3.8	12/27/98	4	2/13/99	4.2	4/2/99	1300	5/20/99	1230	7/7/99	338	8/24/99	363	10/11/99	18	11/28/99	13
9/23/98	2.4	11/10/98	3.9	12/28/98	3.8	2/14/99	4	4/3/99	1200	5/21/99	1210	7/8/99	338	8/25/99	352	10/12/99	17	11/29/99	12
9/24/98	2.4	11/11/98	3.8	12/29/98	3.8	2/15/99	3.7	4/4/99	1300	5/22/99	1200	7/9/99	306	8/26/99	353	10/13/99	17	11/30/99	12
9/25/98	2.3	11/12/98	3.8	12/30/98	3.8	2/16/99	3.5	4/5/99	1570	5/23/99	1180	7/10/99	381	8/27/99	343	10/14/99	17	12/1/99	12
9/26/98	2.3	11/13/98	4.1	12/31/98	3.7	2/17/99	3.5	4/6/99	1680	5/24/99	1150	7/11/99	379	8/28/99	291	10/15/99	17	12/2/99	12
9/27/98	2.3	11/14/98	4.3	1/1/99	3.6	2/18/99	3.4	4/7/99	1940	5/25/99	1120	7/12/99	378	8/29/99	246	10/16/99	17	12/3/99	12

<u>Flow rate continued</u>

Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs
12/4/99	11	1/21/00	4.5	3/9/00	19	4/26/00	11	6/13/00	11	7/31/00	38	9/17/00	3.3	11/4/00	33	12/22/00	4	2/8/01	3.3
12/5/99	11	1/22/00	4.5	3/10/00	23	4/27/00	11	6/14/00	10	8/1/00	36	9/18/00	3.2	11/5/00	28	12/23/00	4	2/9/01	3.3
12/6/99	11	1/23/00	4.5	3/11/00	20	4/28/00	11	6/15/00	10	8/2/00	34	9/19/00	2.9	11/6/00	28	12/24/00	4	2/10/01	3.2
12/7/99	11	1/24/00	4.5	3/12/00	20	4/29/00	11	6/16/00	12	8/3/00	33	9/20/00	3	11/7/00	27	12/25/00	4	2/11/01	3.2
12/8/99	11	1/25/00	4.3	3/13/00	19	4/30/00	11	6/17/00	13	8/4/00	32	9/21/00	3.4	11/8/00	25	12/26/00	4.2	2/12/01	3.1
12/9/99	10	1/26/00	4.4	3/14/00	18	5/1/00	10	6/18/00	13	8/5/00	31	9/22/00	3.7	11/9/00	25	12/27/00	4.4	2/13/01	3.1
12/10/99	10	1/27/00	4.4	3/15/00	18	5/2/00	11	6/19/00	13	8/6/00	31	9/23/00	3.6	11/10/00	80	12/28/00	4.5	2/14/01	3
12/11/99	10	1/28/00	4.5	3/16/00	17	5/3/00	10	6/20/00	13	8/7/00	32	9/24/00	3.7	11/11/00	110	12/29/00	4.5	2/15/01	3
12/12/99	10	1/29/00	4.6	3/17/00	16	5/4/00	9.9	6/21/00	13	8/8/00	33	9/25/00	4	11/12/00	100	12/30/00	4.5	2/16/01	2.9
12/13/99	9.5	1/30/00	4.6	3/18/00	15	5/5/00	10	6/22/00	25	8/9/00	31	9/26/00	6.7	11/13/00	100	12/31/00	4.5	2/17/01	2.9
12/14/99	8	1/31/00	4.6	3/19/00	15	5/6/00	10	6/23/00	35	8/10/00	27	9/27/00	8.7	11/14/00	100	1/1/01	4.4	2/18/01	2.8
12/15/99	7	2/1/00	4.8	3/20/00	15	5/7/00	9.4	6/24/00	38	8/11/00	23	9/28/00	8.6	11/15/00	100	1/2/01	4.4	2/19/01	2.8
12/16/99	6	2/2/00	5	3/21/00	15	5/8/00	9.1	6/25/00	36	8/12/00	20	9/29/00	8.2	11/16/00	100	1/3/01	4.3	2/20/01	5
12/17/99	6	2/3/00	4.8	3/22/00	15	5/9/00	8.9	6/26/00	35	8/13/00	17	9/30/00	8.1	11/17/00	100	1/4/01	4.3	2/21/01	75
12/18/99	6	2/4/00	4.6	3/23/00	15	5/10/00	8.8	6/27/00	34	8/14/00	14	10/1/00	7.6	11/18/00	100	1/5/01	4.3	2/22/01	150
12/19/99	6	2/5/00	4.5	3/24/00	15	5/11/00	9.1	6/28/00	34	8/15/00	12	10/2/00	7	11/19/00	99	1/6/01	4.3	2/23/01	250
12/20/99	5.4	2/6/00	4.5	3/25/00	16	5/12/00	10	6/29/00	82	8/16/00	13	10/3/00	6.2	11/20/00	98	1/7/01	4.4	2/24/01	330
12/21/99	4.5	2/7/00	4.4	3/26/00	16	5/13/00	14	6/30/00	117	8/17/00	13	10/4/00	6.3	11/21/00	95	1/8/01	4.4	2/25/01	340
12/22/99	4.7	2/8/00	4.5	3/27/00	15	5/14/00	14	7/1/00	117	8/18/00	13	10/5/00	5.9	11/22/00	80	1/9/01	4.5	2/26/01	335
12/23/99	5	2/9/00	4.5	3/28/00	13	5/15/00	15	7/2/00	107	8/19/00	12	10/6/00	5.1	11/23/00	25	1/10/01	4.6	2/27/01	330
12/24/99	5	2/10/00	4.6	3/29/00	12	5/16/00	15	7/3/00	102	8/20/00	12	10/7/00	4.9	11/24/00	15	1/11/01	4.5	2/28/01	330
12/25/99	5	2/11/00	4.5	3/30/00	13	5/17/00	14	7/4/00	102	8/21/00	11	10/8/00	4.6	11/25/00	12	1/12/01	4.4	3/1/01	330
12/26/99	5	2/12/00	4.4	3/31/00	14	5/18/00	13	7/5/00	101	8/22/00	11	10/9/00	4.3	11/26/00	11	1/13/01	4.2	3/2/01	335
12/27/99	5	2/13/00	4.4	4/1/00	14	5/19/00	16	7/6/00	100	8/23/00	11	10/10/00	4.1	11/27/00	10	1/14/01	4.1	3/3/01	340
12/28/99	5	2/14/00	4.3	4/2/00	15	5/20/00	20	7/7/00	98	8/24/00	12	10/11/00	3.9	11/28/00	10	1/15/01	4	3/4/01	330
12/29/99	5	2/15/00	4.3	4/3/00	15	5/21/00	21	7/8/00	95	8/25/00	11	10/12/00	3.7	11/29/00	9.7	1/16/01	4.6	3/5/01	325
12/30/99	5.5	2/16/00	4.3	4/4/00	15	5/22/00	20	7/9/00	79	8/26/00	10	10/13/00	3.8	11/30/00	9	1/17/01	4.5	3/6/01	330
12/31/99	6	2/17/00	4.3	4/5/00	16	5/23/00	18	7/10/00	78	8/27/00	9.5	10/14/00	3.6	12/1/00	9	1/18/01	4.3	3/7/01	330
1/1/00	6	2/18/00	4.3	4/6/00	15	5/24/00	19	7/11/00	87	8/28/00	8.5	10/15/00	3.4	12/2/00	8.5	1/19/01	4.2	3/8/01	335
1/2/00	6	2/19/00	4.2	4/7/00	14	5/25/00	18	7/12/00	94	8/29/00	7.8	10/16/00	3.4	12/3/00	8	1/20/01	4.1	3/9/01	340
1/3/00	5.6	2/20/00	4.2	4/8/00	14	5/26/00	18	7/13/00	98	8/30/00	7.5	10/17/00	3.1	12/4/00	7	1/21/01	4	3/10/01	350
1/4/00	5.5	2/21/00	4.4	4/9/00	13	5/27/00	18	7/14/00	99	8/31/00	6.7	10/18/00	2.9	12/5/00	7.5	1/22/01	4.1	3/11/01	340
1/5/00	5.3	2/22/00	4.8	4/10/00	13	5/28/00	18	7/15/00	101	9/1/00	6.5	10/19/00	3.6	12/6/00	7.5	1/23/01	4.2	3/12/01	340
1/6/00	5.3	2/23/00	5.1	4/11/00	13	5/29/00	18	7/16/00	104	9/2/00	6.5	10/20/00	8.7	12/7/00	7.3	1/24/01	4.1	3/13/01	330
1/7/00	5.4	2/24/00	5.3	4/12/00	14	5/30/00	16	7/17/00	106	9/3/00	6.6	10/21/00	8.9	12/8/00	7	1/25/01	4	3/14/01	330
1/8/00	5.6	2/25/00	5.8	4/13/00	13	5/31/00	14	7/18/00	107	9/4/00	6.9	10/22/00	7.1	12/9/00	6.7	1/26/01	3.9	3/15/01	380
1/9/00	5.6	2/26/00	7.5	4/14/00	13	6/1/00	13	7/19/00	106	9/5/00	6.9	10/23/00	7.5	12/10/00	6.5	1/27/01	3.8	3/16/01	500
1/10/00	5.6	2/27/00	9	4/15/00	13	6/2/00	13	7/20/00	103	9/6/00	6.6	10/24/00	7.3	12/11/00	6	1/28/01	3.9	3/17/01	950
1/11/00	5.3	2/28/00	10	4/16/00	13	6/3/00	13	7/21/00	93	9/7/00	6.9	10/25/00	7.7	12/12/00	6	1/29/01	3.8	3/18/01	1200
1/12/00	5	2/29/00	11	4/17/00	13	6/4/00	13	7/22/00	81	9/8/00	6.8	10/26/00	8.8	12/13/00	5.5	1/30/01	3.7	3/19/01	1480
1/13/00	5	3/1/00	12	4/18/00	13	6/5/00	13	7/23/00	70	9/9/00	5.6	10/27/00	11	12/14/00	5	1/31/01	3.6	3/20/01	1620
1/14/00	5	3/2/00	13	4/19/00	13	6/6/00	13	7/24/00	61	9/10/00	5.7	10/28/00	12	12/15/00	4.5	2/1/01	3.5	3/21/01	1750
1/15/00	5	3/3/00	15	4/20/00	13	6/7/00	13	7/25/00	54	9/11/00	5.1	10/29/00	13	12/16/00	4.3	2/2/01	3.6	3/22/01	1740
1/16/00	5	3/4/00	17	4/21/00	13	6/8/00	12	7/26/00	49	9/12/00	4.4	10/30/00	14	12/17/00	4.1	2/3/01	3.7	3/23/01	1620
1/17/00	5	3/5/00	21	4/22/00	13	6/9/00	12	7/27/00	45	9/13/00	4.1	10/31/00	16	12/18/00	4	2/4/01	3.6	3/24/01	1440
1/18/00	4.8	3/6/00	24	4/23/00	12	6/10/00	12	7/28/00	42	9/14/00	4.3	11/1/00	25	12/19/00	4	2/5/01	3.5	3/25/01	1380
1/19/00	4.5	3/7/00	29	4/24/00	11	6/11/00	12	7/29/00	40	9/15/00	3.5	11/2/00	30	12/20/00	4	2/6/01	3.5	3/26/01	1280
1/20/00	4.5	3/8/00	29	4/25/00	11	6/12/00	11	7/30/00	38	9/16/00	3.5	11/3/00	29	12/21/00	4	2/7/01	3.4	3/27/01	1320

Flow rate continued

Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs
3/28/01	1350	5/15/01	1170	7/2/01	230	8/19/01	98	10/6/01	87	11/23/01	11	1/10/02	6.1	2/27/02	4.4	4/16/02	57	6/3/02	19
3/29/01	1320	5/16/01	629	7/3/01	228	8/20/01	98	10/7/01	88	11/24/01	11	1/11/02	6.2	2/28/02	4.2	4/17/02	61	6/4/02	16
3/30/01	1320	5/17/01	544	7/4/01	197	8/21/01	98	10/8/01	88	11/25/01	11	1/12/02	6.3	3/1/02	4.2	4/18/02	81	6/5/02	13
3/31/01	1290	5/18/01	488	7/5/01	138	8/22/01	98	10/9/01	89	11/26/01	10	1/13/02	6.5	3/2/02	4.1	4/19/02	89	6/6/02	12
4/1/01	1150	5/19/01	408	7/6/01	128	8/23/01	98	10/10/01	87	11/27/01	9.8	1/14/02	6.2	3/3/02	4.1	4/20/02	65	6/7/02	11
4/2/01	952	5/20/01	384	7/7/01	122	8/24/01	97	10/11/01	86	11/28/01	9.5	1/15/02	6	3/4/02	4	4/21/02	64	6/8/02	10
4/3/01	825	5/21/01	370	7/8/01	118	8/25/01	96	10/12/01	85	11/29/01	8.9	1/16/02	6.9	3/5/02	3.8	4/22/02	57	6/9/02	10
4/4/01	798	5/22/01	356	7/9/01	117	8/26/01	94	10/13/01	86	11/30/01	9.3	1/17/02	6.8	3/6/02	3.8	4/23/02	53	6/10/02	11
4/5/01	806	5/23/01	347	7/10/01	117	8/27/01	94	10/14/01	87	12/1/01	9.4	1/18/02	6.5	3/7/02	3.9	4/24/02	47	6/11/02	12
4/6/01	951	5/24/01	313	7/11/01	118	8/28/01	94	10/15/01	87	12/2/01	9.7	1/19/02	6.1	3/8/02	4	4/25/02	40	6/12/02	12
4/7/01	1260	5/25/01	307	7/12/01	124	8/29/01	95	10/16/01	85	12/3/01	10	1/20/02	5	3/9/02	3.8	4/26/02	34	6/13/02	12
4/8/01	1450	5/26/01	313	7/13/01	124	8/30/01	95	10/17/01	85	12/4/01	10	1/21/02	4.9	3/10/02	3.7	4/27/02	30	6/14/02	13
4/9/01	1500	5/27/01	304	7/14/01	123	8/31/01	94	10/18/01	73	12/5/01	10	1/22/02	4.8	3/11/02	3.6	4/28/02	30	6/15/02	13
4/10/01	1510	5/28/01	299	7/15/01	128	9/1/01	95	10/19/01	84	12/6/01	11	1/23/02	4.7	3/12/02	3.6	4/29/02	29	6/16/02	13
4/11/01	1520	5/29/01	297	7/16/01	136	9/2/01	95	10/20/01	86	12/7/01	9.9	1/24/02	4.6	3/13/02	3.6	4/30/02	26	6/17/02	12
4/12/01	1530	5/30/01	302	7/17/01	166	9/3/01	94	10/21/01	87	12/8/01	9.1	1/25/02	4.5	3/14/02	3.7	5/1/02	25	6/18/02	12
4/13/01	1540	5/31/01	303	7/18/01	182	9/4/01	94	10/22/01	87	12/9/01	9.6	1/26/02	5	3/15/02	3.8	5/2/02	22	6/19/02	12
4/14/01	1550	6/1/01	288	7/19/01	160	9/5/01	95	10/23/01	87	12/10/01	9.4	1/27/02	5.8	3/16/02	3.9	5/3/02	18	6/20/02	12
4/15/01	1560	6/2/01	274	7/20/01	146	9/6/01	98	10/24/01	70	12/11/01	8.8	1/28/02	5.8	3/17/02	4	5/4/02	17	6/21/02	12
4/16/01	1550	6/3/01	264	7/21/01	153	9/7/01	95	10/25/01	37	12/12/01	8.7	1/29/02	5.7	3/18/02	4	5/5/02	14	6/22/02	13
4/17/01	1640	6/4/01	242	7/22/01	143	9/8/01	96	10/26/01	28	12/13/01	8	1/30/02	6.7	3/19/02	4.1	5/6/02	13	6/23/02	12
4/18/01	1480	6/5/01	227	7/23/01	136	9/9/01	100	10/27/01	22	12/14/01	7.7	1/31/02	6.6	3/20/02	4.1	5/7/02	13	6/24/02	12
4/19/01	1450	6/6/01	223	7/24/01	128	9/10/01	107	10/28/01	19	12/15/01	8.3	2/1/02	6.5	3/21/02	4.1	5/8/02	13	6/25/02	13
4/20/01	1450	6/7/01	219	7/25/01	122	9/11/01	112	10/29/01	17	12/16/01	8.3	2/2/02	6.4	3/22/02	4.1	5/9/02	13	6/26/02	16
4/21/01	1490	6/8/01	234	7/26/01	121	9/12/01	113	10/30/01	16	12/17/01	8.2	2/3/02	6.3	3/23/02	4.1	5/10/02	13	6/27/02	20
4/22/01	1530	6/9/01	233	7/27/01	130	9/13/01	112	10/31/01	15	12/18/01	7.5	2/4/02	6.2	3/24/02	4.1	5/11/02	14	6/28/02	17
4/23/01	1540	6/10/01	236	7/28/01	165	9/14/01	112	11/1/01	15	12/19/01	7	2/5/02	6.1	3/25/02	4.1	5/12/02	53	6/29/02	37
4/24/01	1500	6/11/01	235	7/29/01	185	9/15/01	112	11/2/01	14	12/20/01	6.9	2/6/02	5	3/26/02	4.1	5/13/02	74	6/30/02	55
4/25/01	1480	6/12/01	215	7/30/01	155	9/16/01	112	11/3/01	14	12/21/01	6.7	2/7/02	4.9	3/27/02	4.2	5/14/02	74	7/1/02	49
4/26/01	1660	6/13/01	209	7/31/01	142	9/17/01	113	11/4/01	14	12/22/01	6.3	2/8/02	4.8	3/28/02	5	5/15/02	76	7/2/02	43
4/27/01	1740	6/14/01	215	8/1/01	142	9/18/01	113	11/5/01	13	12/23/01	6	2/9/02	4.8	3/29/02	12	5/16/02	77	7/3/02	39
4/28/01	1790	6/15/01	218	8/2/01	143	9/19/01	114	11/6/01	13	12/24/01	5.6	2/10/02	4.7	3/30/02	16	5/17/02	74	7/4/02	38
4/29/01	1820	6/16/01	214	8/3/01	139	9/20/01	115	11/7/01	13	12/25/01	5.2	2/11/02	4.7	3/31/02	12	5/18/02	75	7/5/02	34
4/30/01	1820	6/17/01	210	8/4/01	122	9/21/01	112	11/8/01	13	12/26/01	4.9	2/12/02	4.6	4/1/02	9	5/19/02	75	7/6/02	36
5/1/01	1640	6/18/01	208	8/5/01	112	9/22/01	98	11/9/01	13	12/27/01	4.6	2/13/02	4.6	4/2/02	9	5/20/02	74	7/7/02	38
5/2/01	1960	6/19/01	207	8/6/01	107	9/23/01	74	11/10/01	13	12/28/01	4.2	2/14/02	4.6	4/3/02	10	5/21/02	76	7/8/02	48
5/3/01	2030	6/20/01	207	8/7/01	107	9/24/01	57	11/11/01	13	12/29/01	3.8	2/15/02	4.7	4/4/02	12	5/22/02	79	7/9/02	45
5/4/01	2070	6/21/01	206	8/8/01	113	9/25/01	48	11/12/01	14	12/30/01	3.6	2/16/02	4.7	4/5/02	11	5/23/02	80	7/10/02	57
5/5/01	2130	6/22/01	203	8/9/01	112	9/26/01	65	11/13/01	13	12/31/01	3.4	2/17/02	4.8	4/6/02	10	5/24/02	79	7/11/02	62
5/6/01	2160	6/23/01	199	8/10/01	108	9/27/01	94	11/14/01	13	1/1/02	3.3	2/18/02	5	4/7/02	10	5/25/02	78	7/12/02	54
5/7/01	2150	6/24/01	195	8/11/01	105	9/28/01	94	11/15/01	12	1/2/02	3.2	2/19/02	5.2	4/8/02	12	5/26/02	78	7/13/02	48
5/8/01	2160	6/25/01	199	8/12/01	103	9/29/01	94	11/16/01	12	1/3/02	3.2	2/20/02	5.4	4/9/02	15	5/27/02	79	7/14/02	42
5/9/01	2160	6/26/01	193	8/13/01	101	9/30/01	93	11/17/01	12	1/4/02	3.3	2/21/02	5.7	4/10/02	18	5/28/02	79	7/15/02	37
5/10/01	2190	6/27/01	197	8/14/01	101	10/1/01	92	11/18/01	12	1/5/02	3.5	2/22/02	5.9	4/11/02	23	5/29/02	80	7/16/02	33
5/11/01	2200	6/28/01	238	8/15/01	100	10/2/01	91	11/19/01	11	1/6/02	4.2	2/23/02	6	4/12/02	25	5/30/02	79	7/17/02	29
5/12/01	2170	6/29/01	234	8/16/01	99	10/3/01	89	11/20/01	11	1/7/02	5	2/24/02	6.8	4/13/02	36	5/31/02	68	7/18/02	25
5/13/01	1930	6/30/01	213	8/17/01	98	10/4/01	89	11/21/01	11	1/8/02	5.5	2/25/02	6.2	4/14/02	79	6/1/02	37	7/19/02	22
5/14/01	1660	7/1/01	214	8/18/01	98	10/5/01	87	11/22/01	11	1/9/02	6	2/26/02	4.8	4/15/02	73	6/2/02	23	7/20/02	19

Flow rate continued

Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs	Date m/d/yr	Flowrate cfs
7/21/02	17	9/7/02	20	10/25/02	6.1	12/12/02	4.8	1/29/03	1.8	3/18/03	90	5/5/03	80	6/22/03	17	8/9/03	7.1	9/26/03	37
7/22/02	16	9/8/02	20	10/26/02	6.1	12/13/02	4.8	1/30/03	1.8	3/19/03	150	5/6/03	79	6/23/03	18	8/10/03	7.4	9/27/03	37
7/23/02	15	9/9/02	19	10/27/02	5.2	12/14/02	5	1/31/03	1.8	3/20/03	300	5/7/03	96	6/24/03	16	8/11/03	7.4	9/28/03	38
7/24/02	14	9/10/02	21	10/28/02	5.8	12/15/02	5	2/1/03	1.7	3/21/03	800	5/8/03	130	6/25/03	16	8/12/03	8.2	9/29/03	38
7/25/02	14	9/11/02	22	10/29/02	5.5	12/16/02	5	2/2/03	1.7	3/22/03	570	5/9/03	142	6/26/03	16	8/13/03	4.6	9/30/03	39
7/26/02	15	9/12/02	22	10/30/02	5.5	12/17/02	4.6	2/3/03	1.6	3/23/03	630	5/10/03	142	6/27/03	15	8/14/03	4	10/1/03	40
7/27/02	14	9/13/02	22	10/31/02	5.4	12/18/02	5.3	2/4/03	1.5	3/24/03	550	5/11/03	132	6/28/03	14	8/15/03	3.7	10/2/03	41
7/28/02	12	9/14/02	22	11/1/02	6.4	12/19/02	5.2	2/5/03	1.5	3/25/03	500	5/12/03	130	6/29/03	13	8/16/03	4.5	10/3/03	42
7/29/02	11	9/15/02	20	11/2/02	5.8	12/20/02	5.3	2/6/03	1.4	3/26/03	440	5/13/03	134	6/30/03	12	8/17/03	6.2	10/4/03	42
7/30/02	9.3	9/16/02	18	11/3/02	5.8	12/21/02	5.8	2/7/03	1.4	3/27/03	360	5/14/03	139	7/1/03	11	8/18/03	6.1	10/5/03	42
7/31/02	11	9/17/02	18	11/4/02	6.1	12/22/02	5.7	2/8/03	1.4	3/28/03	334	5/15/03	140	7/2/03	11	8/19/03	5.9	10/6/03	41
8/1/02	12	9/18/02	17	11/5/02	6.2	12/23/02	5.6	2/9/03	1.3	3/29/03	273	5/16/03	143	7/3/03	12	8/20/03	6.4	10/7/03	41
8/2/02	12	9/19/02	17	11/6/02	6.3	12/24/02	5.8	2/10/03	1.3	3/30/03	235	5/17/03	139	7/4/03	10	8/21/03	4.3	10/8/03	42
8/3/02	11	9/20/02	17	11/7/02	6.3	12/25/02	5.5	2/11/03	1.3	3/31/03	220	5/18/03	131	7/5/03	8.6	8/22/03	3.9	10/9/03	42
8/4/02	11	9/21/02	16	11/8/02	6.3	12/26/02	5.5	2/12/03	1.2	4/1/03	174	5/19/03	125	7/6/03	7.9	8/23/03	3.3	10/10/03	43
8/5/02	11	9/22/02	15	11/9/02	6.5	12/27/02	5.6	2/13/03	1.2	4/2/03	96	5/20/03	119	7/7/03	8.8	8/24/03	2.9	10/11/03	43
8/6/02	9.9	9/23/02	15	11/10/02	6.6	12/28/02	5.8	2/14/03	1.2	4/3/03	156	5/21/03	119	7/8/03	8.1	8/25/03	3.1	10/12/03	43
8/7/02	11	9/24/02	16	11/11/02	6.8	12/29/02	6	2/15/03	1.2	4/4/03	150	5/22/03	117	7/9/03	8.5	8/26/03	2.6	10/13/03	44
8/8/02	14	9/25/02	15	11/12/02	6.5	12/30/02	5.6	2/16/03	1.1	4/5/03	186	5/23/03	113	7/10/03	6.9	8/27/03	2.2	10/14/03	44
8/9/02	35	9/26/02	15	11/13/02	6.7	12/31/02	5.5	2/17/03	1.1	4/6/03	178	5/24/03	113	7/11/03	8.4	8/28/03	2	10/15/03	44
8/10/02	29	9/27/02	16	11/14/02	6.7	1/1/03	6.8	2/18/03	1.1	4/7/03	70	5/25/03	109	7/12/03	6.8	8/29/03	1.8	10/16/03	44
8/11/02	21	9/28/02	15	11/15/02	6.4	1/2/03	5.9	2/19/03	1.2	4/8/03	58	5/26/03	108	7/13/03	5.9	8/30/03	1.6	10/17/03	44
8/12/02	18	9/29/02	15	11/16/02	6.3	1/3/03	6.1	2/20/03	1.2	4/9/03	76	5/27/03	110	7/14/03	6.7	8/31/03	1.6	10/18/03	44
8/13/02	17	9/30/02	15	11/17/02	6.2	1/4/03	6.2	2/21/03	1.1	4/10/03	218	5/28/03	111	7/15/03	5.3	9/1/03	1.0	10/19/03	45
8/14/02	18	10/1/02	14	11/18/02	6.4	1/5/03	6.1	2/22/03	1	4/11/03	215	5/29/03	104	7/16/03	4.7	9/2/03	1.6	10/20/03	44
8/15/02	15	10/2/02	13	11/19/02	6.7	1/6/03	6	2/23/03	1	4/12/03	177	5/30/03	103	7/17/03	4.4	9/3/03	1.5	10/21/03	44
8/16/02	15	10/3/02	11	11/20/02	7.1	1/7/03	6.2	2/24/03	0.97	4/13/03	153	5/31/03	98	7/18/03	4.3	9/4/03	1.6	10/22/03	44
8/17/02	16	10/4/02	10	11/21/02	7.7	1/8/03	6.2	2/25/03	0.93	4/14/03	172	6/1/03	98	7/19/03	4.4	9/5/03	1.6	10/23/03	51
8/18/02	17	10/5/02	9	11/22/02	8.1	1/9/03	5.5	2/26/03	0.9	4/15/03	156	6/2/03	101	7/20/03	4.3	9/6/03	1.5	10/24/03	56
8/19/02	18	10/6/02	8.3	11/23/02	8.3	1/10/03	6.2	2/27/03	0.88	4/16/03	137	6/3/03	106	7/21/03	4.2	9/7/03	1.5	10/25/03	49
8/20/02	18	10/7/02	7.5	11/24/02	8	1/11/03	5	2/28/03	0.85	4/17/03	122	6/4/03	83	7/22/03	4.1	9/8/03	1.4	10/26/03	47
8/21/02	17	10/8/02	7	11/25/02	7.7	1/12/03	4.6	3/1/03	0.83	4/18/03	111	6/5/03	49	7/23/03	4	9/9/03	1.5	10/27/03	47
8/22/02	16	10/9/02	6.1	11/26/02	7.1	1/13/03	4.1	3/2/03	0.78	4/19/03	119	6/6/03	39	7/24/03	3.9	9/10/03	2.6	10/28/03	48
8/23/02	17	10/10/02	5.2	11/27/02	6.6	1/14/03	3.4	3/3/03	0.75	4/20/03	133	6/7/03	43	7/25/03	3.6	9/11/03	3.7	10/29/03	49
8/24/02	19	10/11/02	5.8	11/28/02	6.3	1/15/03	3.2	3/4/03	0.72	4/21/03	124	6/8/03	39	7/26/03	3.6	9/12/03	3.6	10/30/03	49
8/25/02	18	10/12/02	5.7	11/29/02	6.1	1/16/03	3.1	3/5/03	0.7	4/22/03	117	6/9/03	39	7/27/03	4.2	9/13/03	3.3	10/31/03	33
8/26/02	17	10/13/02	5.6	11/30/02	6	1/17/03	3	3/6/03	0.7	4/23/03	113	6/10/03	38	7/28/03	3.8	9/14/03	3.2	11/1/03	19
8/27/02	17	10/14/02	5.5	12/1/02	6.1	1/18/03	3	3/7/03	0.69	4/24/03	109	6/11/03	38	7/29/03	3.4	9/15/03	2.8	11/2/03	14
8/28/02	19	10/15/02	5.4	12/2/02	6.8	1/19/03	2.9	3/8/03	0.65	4/25/03	103	6/12/03	40	7/30/03	12	9/16/03	2.8	11/3/03	12
8/29/02	23	10/16/02	5.2	12/3/02	5.8	1/20/03	2.6	3/9/03	0.64	4/26/03	98	6/13/03	37	7/31/03	18	9/17/03	2.2	11/4/03	10
8/30/02	26	10/17/02	5.1	12/4/02	5.3	1/21/03	2.4	3/10/03	0.62	4/27/03	98	6/14/03	35	8/1/03	19	9/18/03	2.2	11/5/03	8
8/31/02	33	10/18/02	6.2	12/5/02	5	1/22/03	2.3	3/11/03	0.61	4/28/03	94	6/15/03	29	8/2/03	19	9/19/03	2.1	11/6/03	6
9/1/02	27	10/19/02	5	12/6/02	4.9	1/23/03	2.2	3/12/03	0.6	4/29/03	88	6/16/03	25	8/3/03	17	9/20/03	1.8	11/7/03	4
9/2/02	24	10/20/02	4.8	12/7/02	3.8	1/24/03	2.1	3/13/03	0.68	4/30/03	86	6/17/03	25	8/4/03	14	9/21/03	2.6	11/8/03	3.1
9/3/02	21	10/21/02	4.7	12/8/02	3.4	1/25/03	2	3/14/03	0.9	5/1/03	83	6/18/03	23	8/5/03	11	9/22/03	1.5	11/9/03	2.6
9/4/02	19	10/22/02	4.9	12/9/02	4.7	1/26/03	2	3/15/03	5	5/2/03	83	6/19/03	21	8/6/03	9.4	9/23/03	1.4	11/10/03	2.6
9/5/02	20	10/23/02	4.9	12/10/02	4.8	1/27/03	2	3/16/03	30	5/3/03	65	6/20/03	18	8/7/03	7.9	9/24/03	23	11/11/03	2.5
9/6/02	19	10/24/02	4.9	12/11/02	4.8	1/28/03	1.9	3/17/03	60	5/4/03	81	6/21/03	17	8/8/03	6.8	9/25/03	35	11/12/03	2.4

Souris River water quality data

Source: USGS

Location: Gaging Station 5114000, near Sherwood, ND

Period: 1994 – 2004

Souris River Fecal Coliform, Ammonia, Copper, and Organic Carbon Data and Calculated Standards for Ammonia and Copper

Date	Flow Rate cfs	Water Temp C	pH	Ammonia nitrogen mg/L	fecal coliform CFU/100ml	Hardness mg/L as $CaCO_3$	Org. carbon unfiltrd mg/L	Copper g/L	Ammonia Standard Acute mg/L	Ammonia Standard Chronic mg/L	Cu standards CMC g/L	Cu standards CCC g/L
10/6/98	3	8.5	8.1			--	--	--				
11/3/98	4.2	--	8.4	0.023		350	11	1	3.88	1.20	44.03419	26.1221
2/9/99	3.6	0	7.4	1.84	K4	430	18	2	22.97	4.70	53.47138	31.1459
3/30/99	1600	0.5	8.1	0.185	K77	62	17	4	6.95	2.02	8.60466	5.952518
4/13/99	2050	7.5	8			190	--	4	8.41	2.36	24.74679	15.49876
5/26/99	1100	16.3	8.1	0.039	K15	190	52	4	6.95	1.81	24.74679	15.49876
7/6/99	344	19.9	8.1			--	--	--	6.95	1.44		
7/20/99	407	23.1	8.2			220	14	4	5.73	1.00	28.41698	17.56719
8/5/99	303	24.1	8.1			--	--	--	6.95	1.11		
8/24/99	353	20.9	8.3	<.020	120	--	--	--	4.71	0.97		
9/30/99	51	7.5	7.9	0.042	100	310	15	7	10.13	2.73	39.27101	23.5489
10/27/99	14	0.1	8.1	<.020	100	400	14	--	6.95	2.02	49.94521	29.27941
11/16/99	14	0	8.2	<.020	K8	410	19	--	5.73	1.71	51.12221	29.90376
1/6/00	5.3	0.1	7.4	--	--	--	--	1	22.97	4.70		
1/12/00	5	0.1	7.4	--	--	--	--	--	22.97	4.70		
2/23/00	5.1	5.3	7.5	0.951	42	460	11	1	19.89	4.32	56.98363	32.99352
3/1/00	12	10.1	7.7	--	--	--	--	2	14.44	3.52		
3/28/00	13	16	8.3	<.020	<2	320	13	2	4.71	1.31	40.46491	24.19651
4/19/00	13	19.1	8.4	--	K9	320	--	--	3.88	0.91	40.46491	24.19651
5/17/00	14	23.5	8.4	<.020	64	370	14	3	3.88	0.69	46.40399	27.39242
6/26/00	35	24.6	8.3	--	--	--	--	--	4.71	0.77		
7/7/00	98	22.8	8.2	0.167	420	290	19	--	5.73	1.02	36.87658	22.24442
7/25/00	54	21.5	8.3	--	--	--	--	--	4.71	0.93		
8/8/00	33	19.7	8.4	<.020	K380	--	20	--	3.88	0.87		
8/15/00	12	--	--	--	--	--	--	4				
8/22/00	11	5.2	8.3	--	--	--	--	2	4.71	1.44		
9/6/00	6.6	2.9	8.3	0.118	680	370	19	1	4.71	1.44	46.40399	27.39242

Water quality continued

Date	Flow Rate cfs	Water Temp C	pH	Ammonia nitrogen mg/L	fecal coliform CFU/100ml	Hardness mg/L as $CaCO_3$	Org. carbon unfltrd mg/L	Copper µg/L	Ammonia Standard Acute mg/L	Ammonia Standard Chronic mg/L	Cu standards CMC µg/L	Cu standards CCC µg/L
10/19/00	3.6	9.2	8.3	--	--	--	--	--	4.71	1.44		
11/20/00	98	0	8.3	0.114	E21	330	17	1.6	4.71	1.44	41.6567	24.84118
1/4/01	4.3	0	7.6	--	--	--	--	--	17.03	3.93		
2/15/01	3	0	7.5	--	--	--	--	--	19.89	4.32		
3/9/01	340	0	8.2	0.046	E4	360	18	1.1	5.73	1.71	45.22002	26.75855
3/22/01	1740	0	8	0.139	E3	170	15	2.9	8.41	2.36	22.28194	14.09356
3/29/01	1320	0.1	--	--	--	--	--	--				
4/5/01	806	4.8	--	--	--	--	--	--				
4/12/01	1530	7.3	8.1	--	--	--	--	--	6.95	2.02		
4/24/01	1500	8.6		--	E20	180	--	4.1			23.51631	14.799
5/9/01	2180	11	--	--	--	--	--	--				
5/16/01	629	18.1	7.9	--	--	--	--	--	10.13	2.47		
6/20/01	207	18.4	8.1	E 034	96	280	14	2.8	6.95	1.58	35.67589	21.58731
7/18/01	162	26.2	8.3	< 040	290	220	14	3.2	4.71	0.70	28.41698	17.56719
8/31/01	94	17.8	8.3	E 022	120	--	14	--	4.71	1.17		
9/12/01	113	14.4	8.3	< 040	160	210	13	4.8	4.71	1.45	27.19694	16.88256
10/18/01	73	5.8	8.5			--			3.20	1.00		
11/19/01	11	0.6	8.3	e 03	13k	390	11	1.8	4.71	1.44	48.76653	28.65278
1/3/02	3.2	0	7.4			--			22.97	4.70		
2/13/02	4.6	0	7.5	0.81	<2	430	10.2	1.6	19.89	4.32	53.47138	31.1459
3/29/02	12	0.1	7.6			-			17.03	3.93		
4/17/02	61	2.2				--						
4/25/02	34	5.5	8.6	< 04	<2	230	12.9	1.5	2.65	0.82	29.63388	18.24729
5/16/02	77	10.9	8.3			--			4.71	1.44		
6/6/02	12	19.9	8		540	340		2.4	8.41	1.68	42.84643	25.48301
6/18/02	12	22.1				--						
6/27/02	20	26.7	7.9	0.39	>1200	340	15.5	2.9	10.13	1.35	42.84643	25.48301
7/18/02	25	26.2	8.3	e 04	75	290	21.9	3.6	4.71	0.75	36.87658	22.24442
8/22/02	16	17.1	8.6	< 04	135	290	15.5	1.8	2.65	0.71	36.87658	22.24442
9/11/02	22	19.2	8.3	0.05	104	--	14.9		4.71	1.08		

Water quality continued

Date	Flow Rate cfs	Water Temp C	pH	Ammonia nitrogen mg/L	fecal coliform CFU/100ml	Hardness mg/L as $CaCO_3$	Org. carbon unfltrd mg/L	Copper µg/L	Ammonia Standard Acute mg/L	Ammonia Standard Chronic mg/L	Cu standards CMC µg/L	Cu standards CCC µg/L
10/8/02		6	--	--	--	--	--	--				
11/20/02	7.1	8	8.7	<0.04	42	500	15.3	1	5.73	1.71	61.84658	35.43006
1/8/03	6.2	0	7.6	--	--	--	--	--	17.03	3.93		
3/6/03	0.7	0	7.6	1.34	<2k	590	18.1	0.8	17.03	3.93	72.06349	40.81268
3/26/03		0	--	--	--	--	--	--				
4/2/03	98	6	8.1	0.18	6k	210	19.4	2.6	6.95	2.02	27.19694	16.88256
4/18/03		10	--	--	--	--	--	--				
4/30/03	86	16	8.4		17k	330	--	2.3	3.88	1.10	41.6567	24.84118
5/28/03	111	27	8.4	<0.04	21k	320	16.8	6	3.88	0.56	40.46491	24.19651
7/11/03	6.4	21	8.3	E.03	62	360	21.1	3.1	4.71	0.96	45.22002	26.75855
8/21/03	4.3	27	8.4	0.04	232	--	22.6	--	3.88	0.56		
9/10/03	2.6	16	8.3	0.08	220	380	22.7	4.3	4.71	1.31	47.58614	28.02381
9/26/03	37	15	8.7	--	--	--	--	--	2.20	0.66		
9/26/03	37	16	8.8	-	--				1.84	0.52		
11/13/03	2.3	0.5	8	<0.04	280k	450	21.5	4	8.41	2.36	55.81436	32.37966
1/14/04	0.81	1	7.6	--	--	--	--	--	17.03	3.93		
2/26/04	0.43	1.1	7.7	0.73	4	580	19.5	2.1	14.44	3.52	70.91078	40.22085
3/24/04	5	0	--	--	--	--	--	--				
4/1/04	50	0.5	8.5	E.03n	20k	320	30.2	3.2	3.20	1.00	40.46491	24.19651
4/22/04	86	7.9	8.7	--	54	390	--	2.8	2.20	0.68	48.76653	28.65278
5/26/04	52	13	8.7	<0.04	92	390	19.6	3.5	2.20	0.68	48.76653	28.65278
6/16/04	333	19	--	--	--	--	--	--				
7/21/04	110	24.5	7.6	0.12	220	310	24.3	5.5	17.03	2.06	39.27101	23.5489
8/17/04	13	20.5	7.5	<0.04	70k	--	19.2	--	19.89	2.95		
9/8/04	6.9	14.3	7.8	<0.04		400	23.4	4.1	12.14	3.17	49.94521	29.27941
9/13/04	5.8	16	--	--	--			--				

Souris River dissolved oxygen and nutrients data (1994 – 2004)

Sample Date	Sample Time	DO mg/L	NO_2 NO_3 Nitrogen mg/L	Phosphorus mg/L	Sample Date	Sample Time	DO mg/L	NO_2,NO_3 Nitrogen mg/L	Phosphorus mg/L
2/22/94	12:30	4.5	0.26	0.23	8/27/96	12:00	8.8	< .05	0.3
3/16/94	13:00	12	1.4	0.6	10/1/96	9:00	10		
3/21/94	14:30	12	0.47	0.33	11/21/96	10:00	10.5	0.07	0.1
3/24/94	10:30	13	0.35	0.27	4/1/97	11:00	11.2	0.61	0.37
4/1/94	11:00	11.9	0.37	0.25	4/10/97	11:00	13	0.27	0.2
5/2/94	13:00	10.9	< .050	0.28	4/16/97	11:00	10.2	0.35	0.19
6/20/94	13:30	9.8	< .050	0.36	5/6/97	13:30	10.5	0.14	0.16
7/18/94	13:00	8.5			6/16/97	13:30	8		
8/8/94	12:00	7.3			7/15/97	10:00	7	< .05	0.15
10/3/94	12:30	8.4			8/19/97	10:00	7.2	< .05	0.17
11/14/94	12:30	11	< .05	0.17	9/30/97	10:30	7.2		
2/6/95	13:00	6.5	0.19	0.3	11/4/97	11:00	11	0.07	0.1
3/16/95	11:00	9	0.69	0.74	2/10/98	10:00	6.5	0.28	0.09
3/20/95	11:00	9	0.59	0.31	4/7/98	10:00	11.8	0.51	0.22
3/23/95	11:30	10	< .05	0.29	4/9/98	10:00	12.5	0.54	0.08
3/27/95	15:00	9.4	0.69	0.34	4/14/98	10:00	9.5	0.36	0.15
5/2/95	13:00	8.9	0.3	0.19	5/11/98	10:00	8.7		
5/10/95	12:00	9.3			5/20/98	11:30	6.8	< .05	0.24
6/12/95	12:00	8	< .05	0.21	6/30/98	12:00	7.1		
6/25/95	14:00	7.6	0.35	0.42	7/14/98	10:00	4.5	< .05	0.03
7/17/95	12:00	7			8/25/98	10:00	5	0.05	0.24
8/7/95	12:00	6.5			10/6/98	14:00	9.5		
9/18/95	12:00	8			11/3/98	10:10	8.4	< .05	0.08
11/6/95	12:30	10.5	1.1	0.15	2/9/99	10:00	4	0.08	0.1
2/12/96	12:30		0.25	0.22	3/30/99	11:00	12.1	0.31	0.3
3/19/96	10:00	13.6	0.35	0.28	4/13/99	10:30	11.5		
4/12/96	10:30	13.4	0.34	0.33	5/26/99	17:00	9.4	0.07	0.16
4/16/96	12:00	13.5	0.17	0.31	7/6/99	13:15	8		
4/30/96	10:30	13.5	0.1	0.2	7/20/99	17:00	8		
6/4/96	11:00	9	< .05	0.21	8/5/99	16:00	6.3		
6/25/96	14:00	8.4			8/24/99	11:15	8.7	< .05	0.2
7/16/96	9:30	5.7	0.06	0.21	9/30/99	11:20	10	0.12	0.19