Sand Creek Impaired Water Resources Investigation

Biological Stressor Identification

Prepared for
Scott Watershed Management Organization (WMO) and Minnesota Pollution Control Agency

Funded by
Scott Watershed Management Organization (WMO) and Minnesota Pollution Control Agency Clean Water Partnership Program

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Executive Summary

In 2004, Picha Creek (AUID # 07020012-579) and Sand Creek from its mouth to the confluence with Porter Creek were placed on the Minnesota Pollution Control Agency's (MPCA) list of impaired waters in need of TMDL study for impaired biota due to low fish Index of Biotic Integrity (MRAP IBI) scores. Once water bodies are listed as impaired, stressors causing impairment must be identified, and remediation efforts, including development of TMDLs for identified pollutants, need to be initiated. Hence, a biological stressor identification of Sand Creek and its tributaries was completed as a part of a larger study, the Sand Creek Impaired Water Resources Investigation.

An evaluation of fish IBI scores from data collected by the MPCA and Department of Natural Resources (DNR) indicates the following stream reaches were impaired:

- Sand Creek reaches between Jordan and biological station 07MN055 (Figure 4), including biological monitoring stations 00MN006, 01MN044, and 07MN055 (Figure 4). Reach 90MN116 (Figure 4) was impaired, but was not used to determine impairment because the data were more than 10 years old.
- Upstream Porter Creek reach (i.e., biological station 99MN003, Figure 4)
- County Ditch Number 54 (Figure 4)
- Picha Creek (Figure 4)

Physical and water quality data as well as biological data from Sand Creek, Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek were evaluated to determine candidate causes for impairment and to determine the strength of evidence for the candidate causes of the streams' impairment. Six candidate causes were identified:

- Habitat fragmentation – Sand Creek, Picha Creek, and Porter Creek
- Inadequate baseflow – Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek
- Low dissolved oxygen – Le Sueur County Ditch Number 54 and Porter Creek
- Ionic strength - Le Sueur County Ditch Number 54

- Habitat – Le Sueur County Ditch Number 54, Picha Creek, and Porter Creek
- Sediment – Picha Creek and Porter Creek

An examination of the strength of evidence for the six candidate causes indicates the probable causes for impairment are:

- **Sand Creek** – The probable cause of impairment is habitat fragmentation. Collection of additional data is needed to determine whether sediment and ionic strength are co-stressors with habitat fragmentation. All other candidate causes were eliminated.

- **Le Sueur County Ditch Number 54** – The probable causes of impairment are inadequate baseflow and habitat. Low dissolved oxygen and ionic strength are also candidate causes, but note weaker evidence than inadequate baseflow and habitat. Collection of metals and sediment data is needed to determine whether metals and sediment are candidate causes. Collection of additional dissolved oxygen, specific conductance, and chloride data are also recommended to determine whether current oxygen and ionic strength levels are stressing the stream's fish community. Concurrent collection of fish data is recommended to determine whether the stream is currently impaired for low fish IBI as well as to determine whether dissolved oxygen concentrations and ionic strength levels are impacting the fish assemblage. Collection of additional flow data is recommended to discern the respective roles of natural limitations and anthropogenic land use changes as causes of inadequate baseflow in County Ditch Number 54.

- **Picha Creek –** The overriding probable cause of impairment is inadequate baseflow followed by habitat fragmentation, then habitat, and sediment. Multiple lines of evidence indicate Picha Creek is naturally intermittent and incapable of supporting an unimpaired fish assemblage due to natural causes. Evidence for inadequate baseflow is strongest followed by habitat fragmentation which is stronger than the evidence for habitat and sediment. Nonetheless, all four candidate causes appear to be contributing to the fish impairment of Picha Creek. Collection of additional metals and dissolved oxygen data is needed to determine whether metals and dissolved oxygen are candidate causes. Fish monitoring at additional Picha Creek locations is recommended to determine areas of Picha Creek impaired due to poor habitat as well as provide data that are representative of the Picha Creek fishery.

- **Porter Creek** – The probable cause of impairment is habitat fragmentation followed by inadequate baseflow, then habitat and sediment (equally strong), and low dissolved oxygen. The evidence for habitat fragmentation is strongest followed by inadequate baseflow. Habitat and sediment are equally strong, but not as strong as habitat fragmentation and inadequate baseflow. Lack of data for low dissolved oxygen weakens this candidate cause. Collection of additional dissolved oxygen data is recommended to determine whether current levels are stressing the stream's fish community. Collection of dissolved oxygen, flow, and fish data are recommended to determine the role of low stream gradient and low dissolved oxygen in causing a natural barrier to fish passage downstream of Bradshaw Lake WMA during low flow conditions. Flow data collection will also discern the respective roles of natural limitations and anthropogenic land use changes as causes of the stream's inadequate baseflow.

Volume 2 Feasibility Study and Implementation of this project presents a program for addressing habitat fragmentation, sediment, habitat, and recharge. Other probable stressors identified such as chlorides, ionic strength, and low dissolved oxygen will require additional investigation.

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1.0 Introduction

In 2002, Sand Creek from its mouth to the confluence with Porter Creek was placed on the Minnesota Pollution Control Agency's (MPCA) list of impaired waters in need of a Total Maximum Daily Load (TMDL) study for turbidity. In 2004, Sand Creek from its mouth to the confluence with Porter Creek and Picha Creek (AUID # 07020012-579) were placed on the MPCA's list of impaired waters in need of TMDL study for impaired biota due to low fish Index of Biotic Integrity (MRAP IBI) scores. Once water bodies are listed as impaired, stressors causing impairment must be identified, and remediation efforts, including development of TMDLs for identified pollutants, need to be initiated. Hence, a biological stressor identification of Sand Creek and its tributaries was completed as a part of a larger study, the Sand Creek Impaired Water Resources Investigation.

1.1 Stressor Identification Process

The Stressor Identification process is a formal method developed by the Environmental Protection Agency (EPA) that identifies the causes of biological impairment through a step-by-step procedure. In this process, existing biological, chemical, physical, and land-use data are analyzed to determine probable causes of impairment for aquatic organisms. This procedure lists candidate causes for impairment, examines available data for each candidate, and characterizes the probable cause(s) (Figure 1).

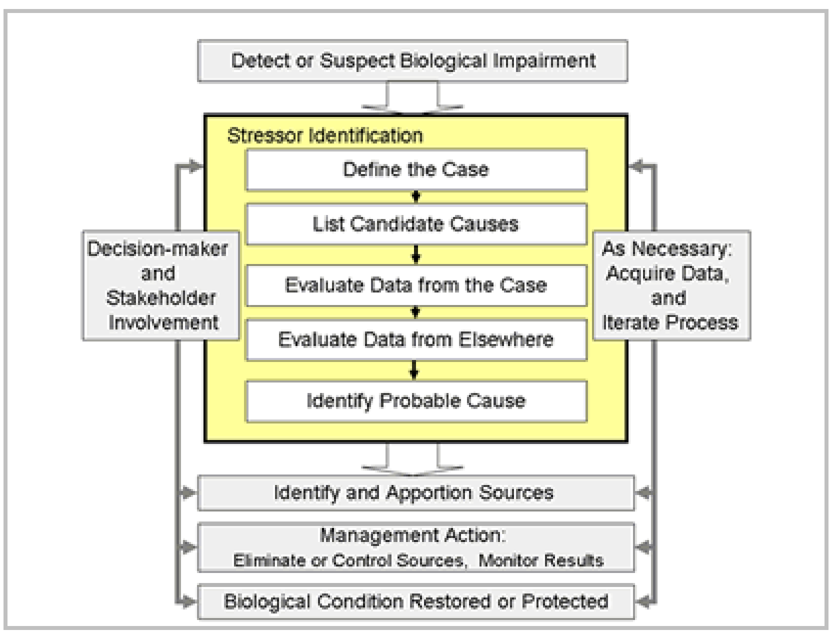

Figure 1. Stressor Identification Process

The Causal Analysis / Diagnosis Decision Information System (CADDIS) is an internet tool developed by the EPA to guide the user through the Stressor Identification Process (Figure 1). CADDIS was used to evaluate, identify, and rank the stressors causing the biological impairments in Sand Creek. The Stressor Identification (SI) process, shown in the yellow box in the center of Figure 1, follows five steps that conclude with the identification of a probable cause. The gray boxes around the Stressor Identification process show various interactions and the context for the analysis.

The first step in the SI process is defining the case which involves gathering information that sets the stage for the causal analysis. The biological impairment and its basis are defined as well as specific effects of the impairment. The purpose of the investigation is stated and the geographic area under investigation is described.

Candidate causes for impairment are determined and listed in the second step of the SI process. A CADDIS list of all common candidate causes is evaluated using data from the study area to determine possible candidate causes for impairment. The output of Step 2 includes a list of candidate causes as well as a conceptual model of each candidate cause. A list of eliminated candidate causes and the evidence for elimination is also presented. Possible candidate causes for which no data have been collected are listed with a recommendation to collect data to determine whether or not they can be eliminated.

Possible candidate causes for impairment are further evaluated in Steps 3 and 4. In Step 3, data from the case are examined to determine the strength of evidence for the candidate causes of the streams' impairment. The CADDIS system for scoring types of evidence is used to evaluate the evidence from the case. Step 3 has two goals. The first goal is to use evidence to eliminate very improbable causes. The second goal is to build a body of evidence for those candidate causes that cannot be eliminated.

Candidate causes that cannot be eliminated in Step 3 are further evaluated in Step 4. Data from other studies (i.e., laboratory studies, studies of other waterbodies) are evaluated in Step 4 to determine whether each candidate cause has a plausible mechanism and a plausible stressor response. The CADDIS system for scoring types of evidence is used to evaluate the data from other studies.

In Step 5, all of the evidence is considered to reach final conclusions about the probable cause(s) of impairment. Scores of all the types of evidence used are displayed in a table and the scores are evaluated to determine consistency and credibility of the case. The most compelling lines of evidence are determined and used to identify the probable cause(s) of impairment.

The primary limitation of the CADDIS method is data availability. The conclusions arrived at in Step 5 are dependent upon the data used for evaluation in Steps 2 through 4. The CADDIS method assumes sufficient data are available to identify a probable cause(s) of impairment in Step 5 of the Stressor Identification process.

1.2 Sand Creek Impaired Water Resources Investigation Biological Stressor Identification

This biological stressor identification study was completed as part of a larger Clean Water Partnership study of Sand Creek. The larger study included two years of data collection, assessment of data, and a detailed geomorphic assessment. Data collection efforts to support the multiple stressor analysis focused on the reaches of Sand Creek that were listed for MRAP IBI.

Portions of Sand Creek and its tributaries are considered water quality impaired for aquatic life due to turbidity or to low fish Index of Biological Integrity (MRAP IBI) scores. This report assesses the MRAP IBI impairment, and identifies probable causal factors. It is part of Volume 4 (Appendices) of the study. Other study Volumes include:

- Volume 1: Sand Creek Impaired Waters Diagnostic Study. This Volume includes an assessment of the turbidity and MRAP IBI impairments, watershed characterization, monitoring and modeling results, and the identification of priority source areas and a summary of biological stressors. Data collection methods are also presented in this volume.

- Volume 2: Sand Creek Impaired Waters Feasibility Study and Implementation Plan. This Volume includes modeling results for various potential management strategies, identification and assessment of management practices and strategies, and an implementation plan.

- Volume 3: Cedar and McMahon Lakes TMDL studies. This Volume includes Draft TMDLs for two lakes in the Sand Creek Watershed (Cedar and McMahon) that are impaired for recreation due to excess nutrients. It also includes a TMDL Implementation Plan for each Lake.

- Volume 4: Sand Creek Impaired Waters Study Appendices. This study includes various technical documents and supporting reports such as the geomorphic assessment (Inter-Fluve 2008) and a quality assurance/quality control (QA/QC) assessment of field data (Memorandum to File from Paul Nelson, February 3, 2009).

These documents are available from the Scott Watershed Management Organization at 952-496-8475. Project partners include the Scott Watershed Management Organization, Scott County, Scott Soil and Water Conservation District, Le Sueur County, Le Sueur Soil and Water Conservation District, Rice County, Rice Soil and Water Conservation District, Cedar Lake Improvement District, Metropolitan Council Environmental Services, and the Minnesota Pollution Control Agency. A portion of the funding was from the Minnesota Pollution Control Agency Clean Water Partnership program.

2.0 Background

The Sand Creek watershed, located within the Minnesota River basin, in the western Twin Cities metro area, drains an area of 271 square miles (Figure 2). Channels within the Sand Creek watershed include:

- Porter Creek – Mainstem, Major Tributary, Minor Tributary, and Duck Creek;
- Raven Stream – Mainstem, West Raven Stream, Ditch 10, and Philipps Creek;
- Sand Creek – Mainstem, Major Tributary, Minor Tributary, and Picha Creek;
- Le Sueur County Ditch Number 54.

The channels in the Sand Creek watershed flow through farmland for much of this area before flowing through the city of Jordan and emptying into the Minnesota River just south of the city of Carver. These channels are low-gradient for much of their lengths. The only sections with distinctly higher gradients occur on Sand Creek between 9.5 and 17 miles from its mouth. Porter Creek and Raven Stream join Sand Creek near the upper extent of this steeper reach, approximately 14 and 16 miles, respectively, from the mouth of Sand Creek; thus, the Porter Creek and Raven Stream reaches closest to Sand Creek are also effected by the steep bluffs and generally have higher gradients than reaches closer to the headwaters. The 9.5 miles of Sand Creek closest to its mouth flow along the historic Minnesota River floodplain and are, therefore, lower in gradient (Inter-Fluve, 2008).

Most of the arable land within, and adjacent to, the Sand Creek watershed was converted to farmland starting approximately 150 years ago; to create this farmland many of the smaller rivers and streams were straightened and ditched and most of the wetlands were drained (Inter-Fluve, 2008).

Hardwood forests dominated the Sand Creek watershed prior to the logging that began shortly after settlement in the 1850s. Today, only scattered remnants remain of what was the Big Woods ecosystem, an expansive maple-basswood forest that covered 3,400 square miles east of central Minnesota and stretching to Southern Illinois. Since most of the forests were eliminated in the late 1800s, many channels have become more stable and less complex, resulting in decreased habitat complexity and decreased biotic diversity. Some remnant Big Woods tracts are present in the Sand Creek watershed along the bluff edge from West Shakopee to the Jordan/LeSueur area. These hardwood forests provided abundant aquatic habitat with shade cover and woody debris in the form

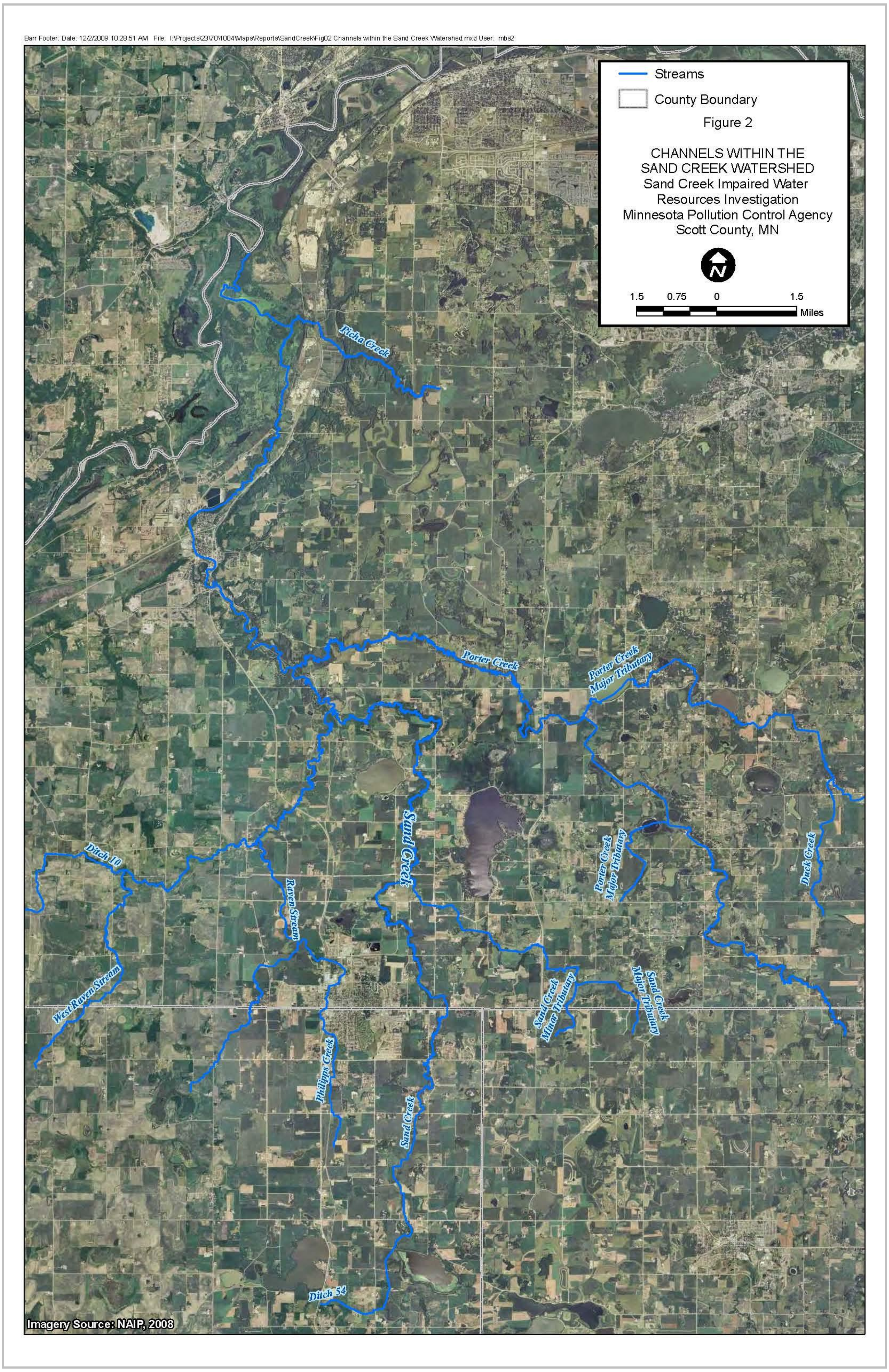

Figure 2. Channels Within the Sand Creek Watershed

of trunks, large branches, and root masses. Though much of the Sand Creek mainstem is bounded by forested floodplains and riparian buffers of variable widths, the upper portions of the Porter Creek and Raven Stream watersheds have been deforested for agriculture. This deforestation limits the upstream source of large woody debris in these watersheds (Inter-Fluve, 2008).

The distribution of land use within the Sand Creek watershed is similar to the land use distribution of Scott County, but with slightly greater amounts of agriculture or undeveloped, and lower amounts of residential. In 2005, land use in Scott County was:

- 54 percent agriculture or undeveloped;
- 20 percent residential;
- 19 percent municipal or tribal land;
- 5 percent parks and open space, and
- 1.4 percent non-residential (commercial, industrial, extraction, or utilities) (Scott County Community Development, 2007).

There is less than 1 percent impervious cover in the Sand Creek watershed, and the majority of this is within the cities of Jordan and New Prague. There has been some high density residential development in Jordan and New Prague and rural residential development in other parts of the watershed, but most development has been concentrated in Shakopee and surrounding towns located outside the Sand Creek watershed. Little of this suburban growth has reached the Sand Creek watershed (Inter-Fluve, 2008).

Scott Watershed Management Organization (WMO) completed an erosion inventory study during 2006. The results indicated a few areas of moderate erosion and one area of severe erosion. The severe erosion occurred on Raven Stream approximately 1.3 miles from its confluence with Sand Creek. This area located within the influence of the glacial terrace and resultant steep banks and bluffs is a naturally eroding bluff due to channel migration. Recommended solutions for the erosion areas identified in the inventory were a combination of riprap and bioengineering.

In the spring of 2007, the Scott Watershed Management Organization (WMO) Natural Resources Department had a fluvial geomorphic assessment completed for the Sand Creek watershed. The project was an attempt to locate channel stability problems, assess overall stream condition, and address the concerns of landowners regarding erosion, flooding and threats to infrastructure.

Assessment results indicated that the trends in channel and habitat conditions throughout the watershed generally depended on the location of the channelized reaches. Conditions along the mainstem of Sand Creek improve slightly upstream from the channelized or impounded Reaches 1 through 7 (Figure 3). The most degraded habitat on the mainstem of Porter Creek was in the few channelized reaches in the middle of the watershed. Conditions worsen upstream of Reach 3, the last sinuous reach with no unrestricted cattle grazing.

The channels throughout the Sand Creek watershed are generally stable with some natural channel migration. There is slight overall degradation that can be had in a few locations in which new inset floodplains have been built.

Though some reaches provide variable habitat conditions, have wide riparian zones with active floodplains, and have water flowing year round, many of the channels have been altered significantly. The impacts observed in the Sand Creek watershed include channelization through urban and agricultural areas, dams of various heights, perched culverts, the removal of riparian vegetation, and cattle grazing.

A total of 217 potential projects in the Sand Creek watershed were identified:

- 74 on Sand Creek and its tributaries
- 91 on Porter Creek and its tributaries
- 31 on Raven Stream and its tributaries and
- 21 at the intersection of ditches and roads in Rice and LeSueur Counties.

The project types include:

- Natural channel restoration/relocation
- Restoration of ditches including ditch improvement or diversion for public benefit
- Grade control
- Floodplain management
- Riparian management
- Crossing projects to alleviate fish barriers from perched culverts, small dams, or low flows
- Bank stabilization

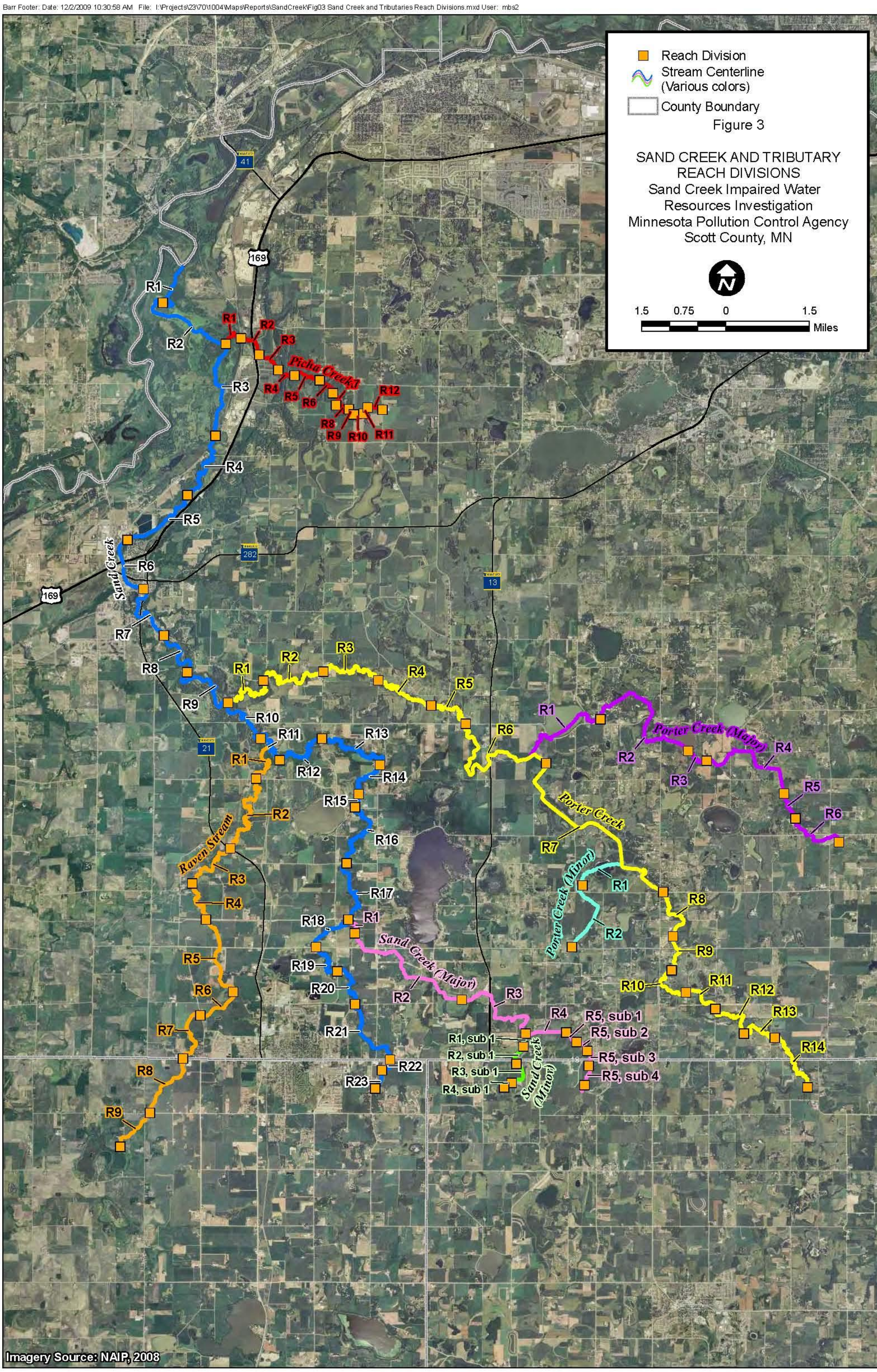

Figure 3. Sand Creek and Tributary Reach Divisions

3.0 Define the Impairment

3.1 The Biological Impairment and Its Basis

In 2002, Sand Creek was placed on the Minnesota Pollution Control Agency's (MPCA) list of impaired waters in need of a Total Maximum Daily Load (TMDL) study for turbidity. In 2004, Picha Creek (AUID # 07020012-579) and Sand Creek from its mouth to the confluence with Porter Creek were placed on the MPCA's list of impaired waters in need of a TMDL study for impaired biota due to low fish Index of Biotic Integrity (MRAP IBI) scores. In Minnesota, biological impairment for fish is defined as failing to meet the MRAP IBI impairment threshold score of 30 or greater out of a possible score of 60.

Sand Creek fish data collected by the Minnesota Department of Natural Resources (MDNR) and the Minnesota Pollution Control Agency (MPCA) were evaluated to determine the reaches of Sand Creek and its tributaries that are considered to have impaired fish assemblages (Appendix A). The data indicated that some reaches of Sand Creek and its tributaries were not impaired while other reaches were impaired.

Data were collected by the MDNR from two Sand Creek locations and two Porter Creek locations to characterize Twin Cities Metro Area streams (Schmidt et al., 2001). Data were collected by the MPCA from five Sand Creek locations, from one location on Le Sueur County Ditch Number 54, from one location on Picha Creek, and from one location on Philipps Creek, a tributary to East Raven Stream, to assess status and trends of riverine surface waters within Minnesota. Sampling dates and MRAP IBI scores are shown in Table 1. Station locations and MRAP IBI scores are shown on Figure 4. All sites meet the criteria for application of the MRAP IBI, including having a drainage area of at least 5 square miles. Only data collected during the past ten years (i.e., 1999 through 2009) were used for the assessment and impairment listing process.

Although data older than 10 years was not used to determine impairment, one data point older than ten years is shown in Table 1 and Figure 4. A comparison of the older and newer data for this reach of Sand Creek suggests the stream has remained stable over time and little change in the fish community has occurred. The Sand Creek reach monitored by sample point 90MN116 in 1990 observed a MRAP IBI score of 20 and the adjacent Sand Creek reach monitored by sample point 07MN0555 in 2007 observed a MRAP IBI score of 24. The two scores were very similar and both scores were less than the MRAP IBI impairment threshold (i.e., 30).

Table 1. 1990-2007 Sand Creek Fish Sample Locations, Dates, MRAP IBI, and Organization

Stream	Location	Date	MRAP IBI	Organization
Sand Creek (Main Stem)	90MN116	8/23/1990	20	MDNR (Schmidt)
	00MN006	9/21/2000	26	MDNR (Schmidt)
	01MN044	7/24/2001	22	MPCA
		7/25/2007	26	MPCA
	07MN033	7/26/2007	48	MPCA
	07MN034	7/26/2007	38	MPCA
	07MN055	8/2/2007	24	MPCA
	07MN056	8/02/2007	31	MPCA
County Ditch # 54 (Tributary to Sand Creek)	03MN077	7/22/2003	29	MPCA
Picha Creek	01MN058	7/24/2001	24	MPCA
		8/08/2001	24	MPCA
Porter Creek	99MN003	6/25/1999	29	MDNR (Schmidt)
	99MN004	6/25/1999	34	MDNR (Schmidt)
Tributary to East Raven Stream	03MN029	7/3/2003	34	MPCA

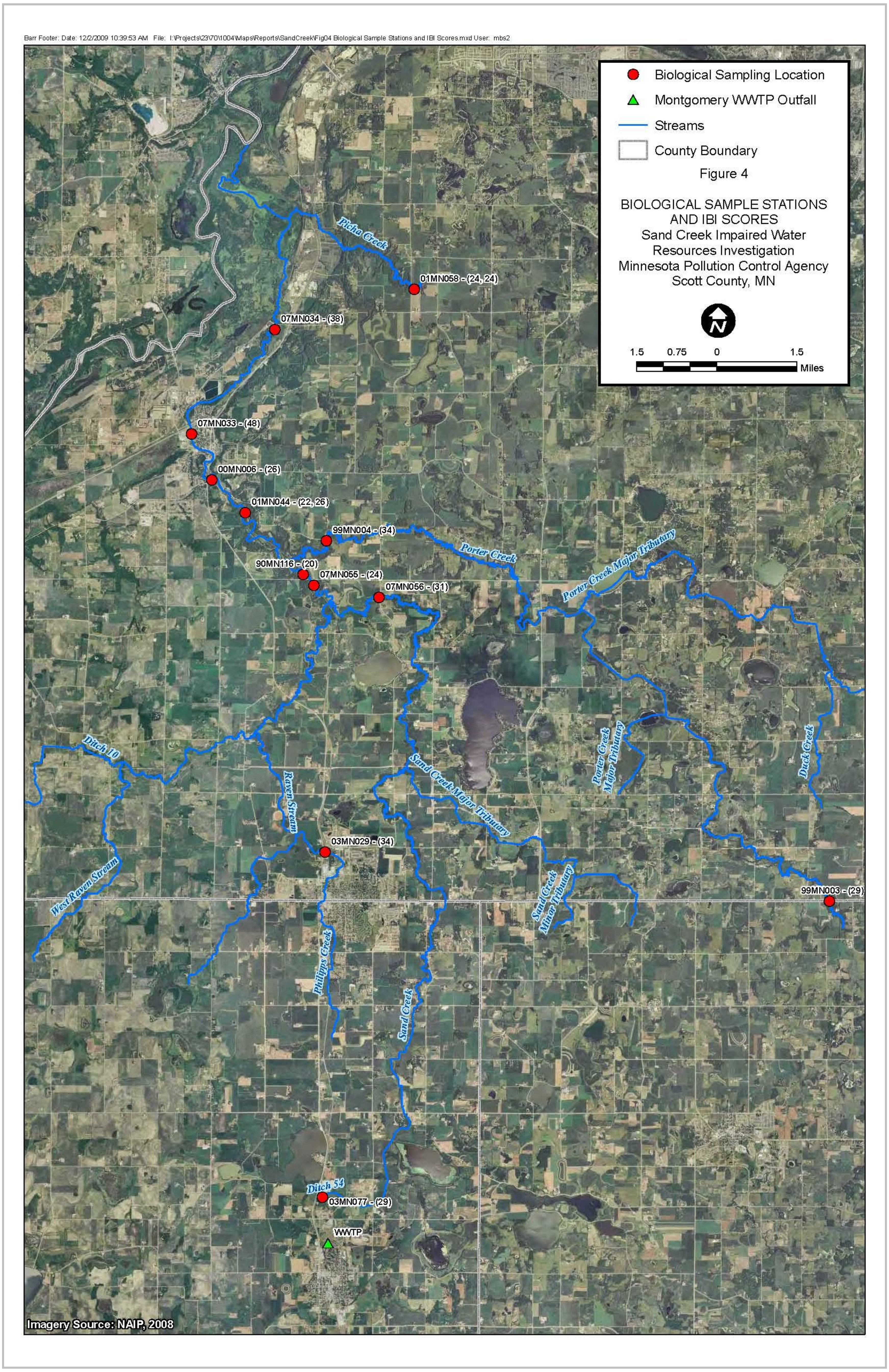

Figure 4. Biological Sample Stations and MRAP IBI Scores

Seven of the twelve monitoring locations had MRAP IBI scores below the impairment threshold of 30 or greater. The impaired locations included four of the seven locations on Main Stem of Sand Creek, one location on Le Sueur County Ditch Number 54 (i.e., a tributary to Sand Creek), one location on Picha Creek (i.e., a tributary to Sand Creek), and one of two locations on Porter Creek.

The four impaired Sand Creek locations as well as the impaired location on Le Sueur County Ditch Number 54 are located upstream from Jordan (Figure 4). Le Sueur County Ditch Number 54 is located approximately 41 miles from the mouth of Sand Creek (Figure 4). The impaired location on Picha Creek is located approximately 5 miles upstream from the stream's confluence with Sand Creek (Figure 4**).** The impaired location on Porter Creek is located approximately 24 miles upstream from the stream's confluence with Sand Creek (Figure 4).

3.2 Specific Effects

The MRAP IBI is a composite index that evaluates an array of ecological attributes of fish communities. The MRAP IBI is comprised of 12 fish community characteristics or metrics. These metrics assess species richness (number of native fish species) and composition (number of darter species, sunfish species, and either sucker species or minnow species), indicator taxa (proportion of individuals that are tolerant and number of intolerant species), trophic structure (proportion of individuals that are omnivores, specialized insectivores, top carnivores, and simple lithophils), fish abundance (catch per unit effort), and the incidence of external body anomalies (proportion of individuals with deformities, eroded fins, lesions, and tumors or DELT). The Minnesota River watershed MRAP IBI, developed by the MPCA (Bailey et al., 1993), was used to determine fish impairment within the Sand Creek watershed. The total MRAP IBI score is determined by comparing a stream's fish assemblage with MRAP IBI scoring criteria, assigning a score of 1, 3, or 5 to each of the 12 metrics, and then summing all the metric scores together. For streams with a watershed less than 100 square miles, two metrics (number of sunfish species and proportion of top carnivores) are dropped and the MRAP IBI score from 10 metrics is multiplied by 1.2 to adjust the score to be comparable with scores derived by summing 12 metrics. The total MRAP IBI score range is from 12 to 60. The impairment threshold is a score of 30 or greater. While a composite score assesses the overall fish community, disaggregation provides the opportunity to evaluate fish community details to better understand the mechanisms causing impairment within impaired fish communities.

The MRAP IBI was disaggregated and assessed to identify more specific effects that appeared to indicate distinctive impairment mechanisms (See Tables 2 and 3). Impaired reaches of Sand Creek generally noted the lowest possible score of 1 for the following metrics:

- **Number of darter species** – indicates either poor water quality or poor habitat. Darters are adapted to the coarse gravel and rubble substrates of stream riffles. They both feed and reproduce in the benthic habitat and are especially sensitive to degradation of the benthic habitat such as sedimentation.
- **Number of sunfish speci**es – indicates degradation of pool habitats, instream cover, or their preferred food items. Sunfish feed in mid-waters and surface waters.
- **Number of sucker species** – indicates either habitat or water quality degradation. Suckers feed on benthic invertebrates and are sensitive to degradation of benthic habitat such as sedimentation.
- **Number of intolerant species** – indicates degradation such as siltation, low dissolved oxygen, low flow, or toxics. Karr et al (1986) found that species sensitive to habitat degradation, especially siltation, are most likely to be identified as intolerant.
- **Percent of tolerant individuals** – indicates habitat degradation or poor water quality
- **Percent of top carnivores** – indicates degradation
- **Percent simple lithophils** – indicates sedimentation since they need clean gravel to boulder size substrate for successful reproduction.

Unimpaired and impaired sites on Sand Creek were compared to determine metric scoring differences. Unimpaired sites had higher numbers of native, darter, and sunfish species, a higher percent of insectivores, and a lower percent of tolerant species.

Unimpaired and impaired sites on Porter Creek were compared to determine metric scoring differences. The unimpaired site had higher numbers of minnows and intolerant species and fewer species with deformities, eroded fins, lesions, and tumors (DELT).

Table 2. Sand Creek Fish MRAP IBI Scores by Metric: Locations With Watershed Area Greater Than 100 Square Miles

	Stream	Sand Creek						
	Site	**90MN116**	**00MN006**	**01MN044**	**01MN044**	**07MN034**	**07MN033**	**07MN055**
	Date	8/23/1990	9/21/2000	7/24/2001	7/25/2007	7/26/2007	7/26/2007	8/2/2007
	Drainage Area (Sq. Miles)	161.4	235.1	231.0	233.8	252.4	237.0	161.2
Site Metric	**Metric Description**							
1	Total # of native species	3	3	3	3	5	5	3
2	# of darter species	1	1	1	1	5	5	1
3	# of sunfish species	1	1	1	1	5	5	1
4	# of sucker species	1	1	1	1	3	1	1
5	# of intolerant species	1	1	1	1	1	5	1
6	% of tolerant individuals	1	1	1	1	3	3	1
7	% of individuals omnivores	3	5	5	5	1	3	5
8	% of individuals insectivores	1	5	1	1	5	5	1
9	% of top carnivores	1	1	1	1	1	1	1
10	Catch per unit effort by gear type	1	1	1	5	3	5	3
11	% of individuals simple lithophils	1	1	1	1	1	5	1
12	% of individuals w/DELT	5	5	5	5	5	5	5
Site MRAP IBI Total		**20**	**26**	**22**	**26**	**38**	**48**	**24**

Table 3. Fish MRAP IBI Scores by Metric for Sand Creek and Tributary Streams: Locations With Watershed Area Less Than 100 Square Miles

Site Metric	Stream	Sand Creek	Picha Creek		Porter Creek		Trib to E. Raven Stream	Cty. Ditch #30
	Site	**07MN056**	**01MN058**	**01MN058**	**99MN003**	**99MN004**	**03MN029**	**03MN077**
	Date	8/2/2007	7/24/2001	8/8/2001	6/25/1999	6/25/1999	7/3/2003	7/22/2003
	Drainage Area (Sq. Miles)	92.9	8.0	8.0	13.2	64.0	9.4	12.3
	Metric Description							
1	Total # of native species	5	3	3	5	5	5	3
2	# of darter species*	1	1	1	3	1	3	1
3	# of sunfish species*	NA	NA	NA	NA	NA	NA	NA
4	# of minnow species**	3	1	1	1	3	5	1
5	# of intolerant species	1	1	1	1	3	1	1
6	% of tolerant individuals	1	1	1	1	1	1	1
7	% of individuals omnivores	3	5	5	5	5	1	5
8	% of individuals insectivores	3	1	1	5	5	5	5
9	% of top carnivores	NA	NA	NA	NA	NA	NA	NA
10	Catch per unit effort by gear type	3	3	1	1	1	1	1
11	% of individuals simple lithophils	1	1	1	1	1	1	1
12	% of individuals w/DELT	5	3	5	1	3	5	5
SITE MRAP IBI TOTAL	**Raw Score**	**26**	**20**	**20**	**24**	**28**	**28**	**24**
	Adjusted MRAP IBI Score* **	**31**	**24**	**24**	**29**	**34**	**34**	**29**

*excluded as per Bailey, *et al* (1994) for sites < 100 square miles;

** # of minnow species (excluding creek chub and fathead minnow) at sites with < 100 mile^2 watershed

***Adjusted score => sites w/ less than 100 sq.mi. watershed area is 1.2 x raw score = MRAP IBI score (to account for only 10 metrics)

3.3 The Investigation's Purpose

The purpose of the investigation is to identify the stressors causing the stream's biological impairment. The investigation results will be used in the Sand Creek Impaired Water Resources Investigation to identify measures to attain resolution to the impairment.

3.4 The Geographic Area Under Investigation

Sand Creek is located in the western Twin Cities metro area within Scott, Rice, and LeSueur Counties. The stream is tributary to the Minnesota River. This biological stressor investigation determines the causes of biological impairment of a portion of Sand Creek and three of its tributaries, Porter Creek, Le Sueur County Ditch Number 54, and Picha Creek. Unimpaired Sand Creek sites and an unimpaired Porter Creek site are also evaluated in this investigation for the purpose of determining differences between unimpaired and impaired sites and thereby determining the causes of impairment at the impaired sites (See Figure 4).

4.0 Candidate Causes of Biological Impairment

This section begins by looking at possible candidate causes of the biological impairment of Sand Creek, Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek. Initially, all common candidate causes listed in CADDIS were evaluated. Data were then used to either validate or eliminate candidate causes. Due to a lack of data, some candidate causes could neither be validated nor eliminated until additional data are collected. Candidate causes that were eliminated are discussed followed by a discussion of candidate causes in need of additional data to determine whether or not they can be eliminated. Possible candidate causes of biological impairment of each of the four impaired streams (i.e., Sand Creek, Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek) are then discussed separately.

The data collection design for the Sand Creek Impaired Water Resources Investigation was developed to look at the areas around Jordan that were listed as impaired for MRAP IBI. Hence, data collection in County Ditch Number 54, Picha Creek, and Porter Creek are less robust as the impaired Sand Creek areas around Jordan.

4.1 Eliminated Candidate Causes

4.1.1 Sand Creek

4.1.1.1 pH

pH was eliminated as a candidate stressor because data indicate the impaired reaches of Sand Creek consistently had pH ranges that support all aquatic life. Metropolitan Council Environmental Services (MCES) and Scott Watershed Management Organization (WMO) staff measured pH in grab samples and samples collected with automated samplers from locations within Sand Creek including 2 stations during 2005, 1 station during 2006, 13 stations during 2007, and 12 stations during 2008. Station locations are shown in Figure 5. pH measurements ranged from 7.11 to 8.86 during the period of record (Figures 6 through 9). Because all measurements were within the MPCA standard, which is a minimum of 6.5 and a maximum of 9.0 standard pH units (Minnesota Rule Chapter 7050.0222, subpart 4), pH was eliminated as a candidate stressor.

Figure 5. Sand Creek Watershed Monitoring Locations

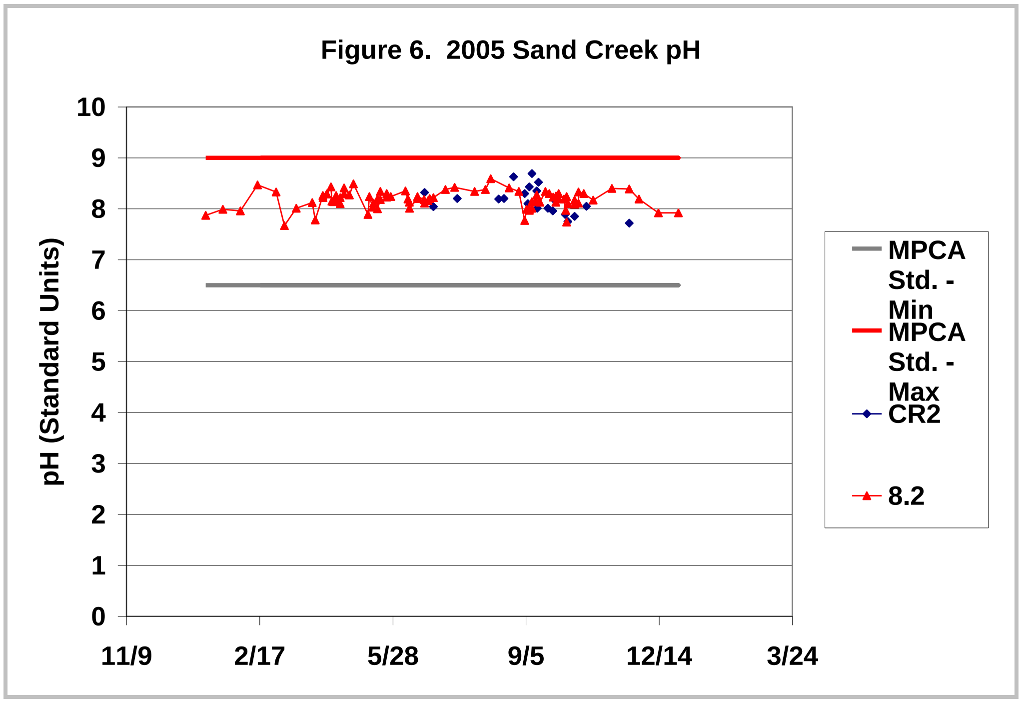

Figure 6. 2005 Sand Creek pH Data

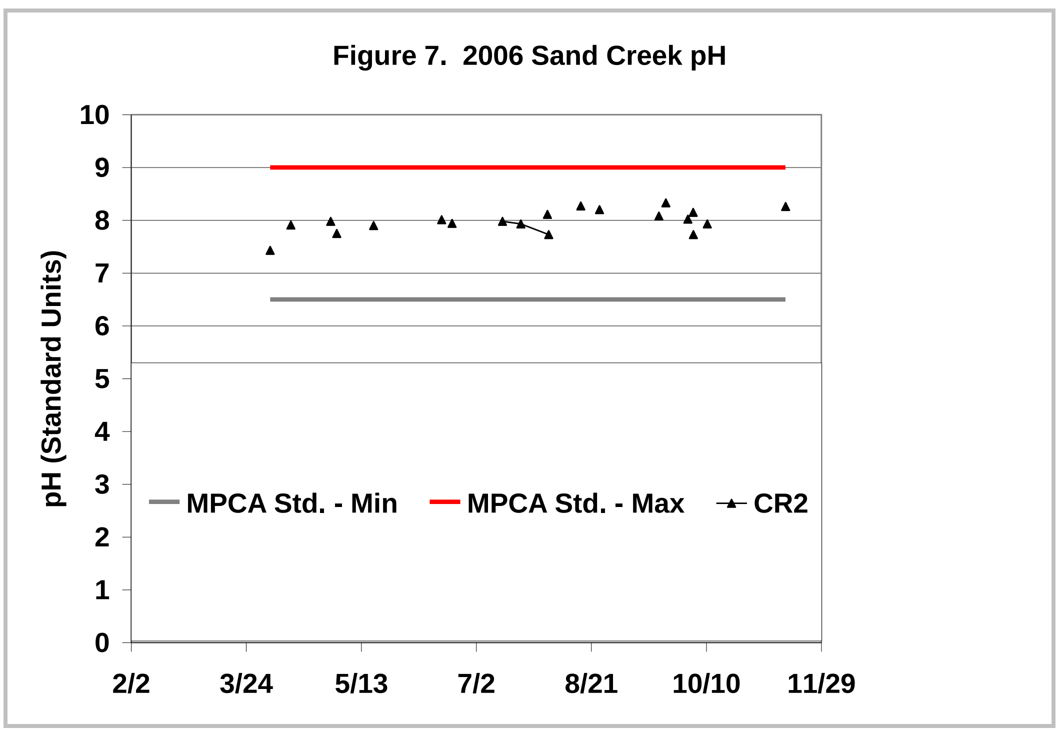

Figure 7. 2006 Sand Creek pH Data

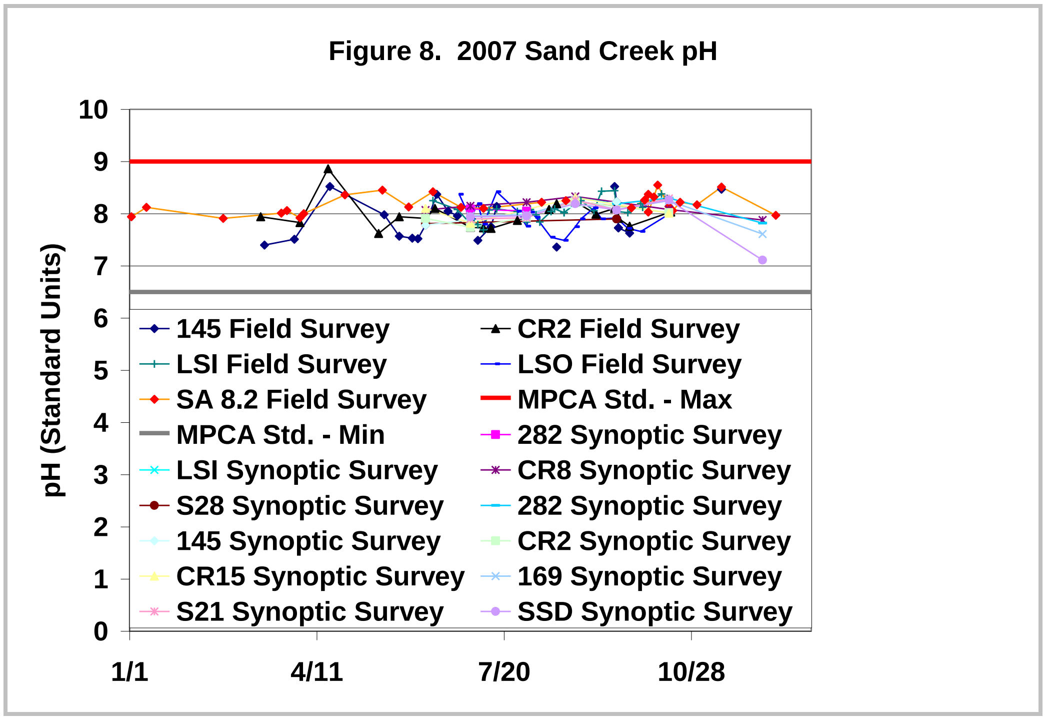

Figure 8. 2007 Sand Creek pH Data

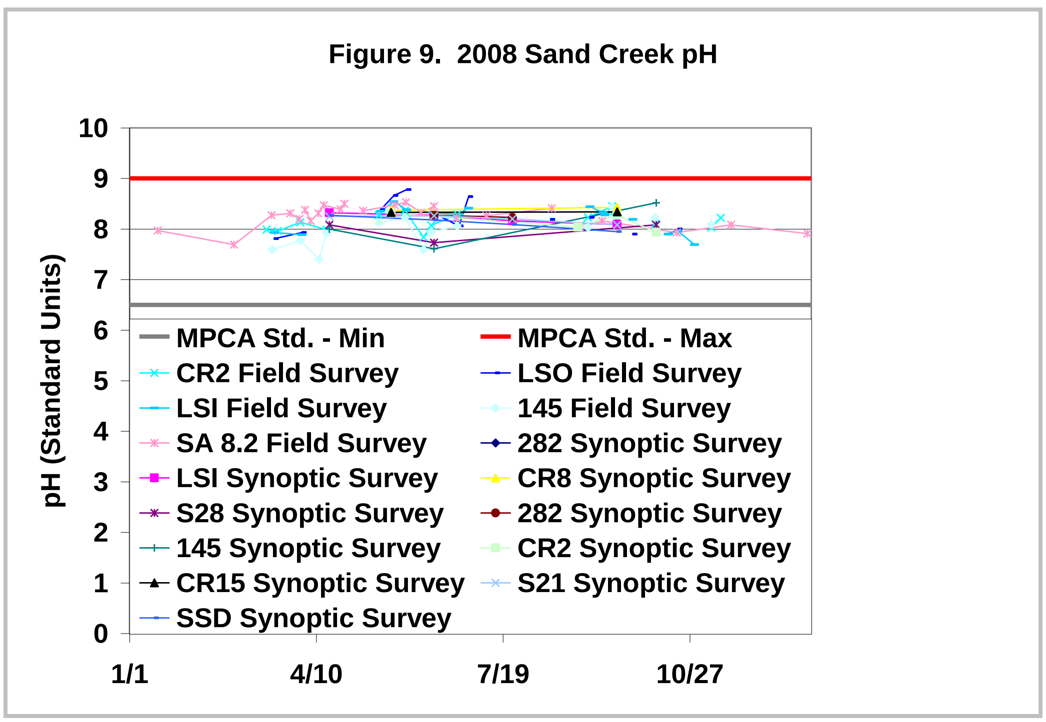

Figure 9. 2008 Sand Creek pH Data

4.1.1.2 Temperature

Temperature was eliminated as a candidate cause of impairment because temperatures in impaired reaches of Sand Creek were consistently less than the MPCA standard of a maximum temperature of 86 °F, which is 30 °C (Minnesota Rule Chapter 7050.0222, subpart 4). During 2007 and 2008, temperatures were measured at 12 Sand Creek stations. Instantaneous temperature measurements occurred at eight stations and both continuous and instantaneous temperature measurements occurred at four stations (Figure 5). Sand Creek temperature measurements met MPCA criteria at a frequency of 99.95 percent during the period of record (Figures 10 through 15). Temperatures within the impaired reaches of Sand Creek ranged from -0.36 to 30.72 °C during the period of measurement (Figures 10 through 13). Unimpaired reaches had a temperature range of -0.19 to 33.44 °C (Figures 10, 11, 14, and 15). Temperature measurements within impaired reaches exceeded the MPCA maximum standard on two days during the period of record. Station CR2 had an instantaneous temperature measurement of 30.05 °C on June 20, 2005 and Station 145 had three temperature measurements ranging from 30.21 to 30.72 °C during a forty five minute period on August 6, 2008 (Station Locations Shown in Figure 5). Temperature measurements in the unimpaired reaches of Sand Creek exceeded the MPCA standard on three days during the period of record. Station LSO had temperature measurements of 33.44 on July 6, 2007, 32.41 on June 26, 2007, and 30.04 on July 16, 2007. All other temperature measurements in Sand Creek met MPCA criteria. Because temperatures consistently met MPCA criteria and the few measurements that exceeded MPCA criteria occurred with a similar frequency in unimpaired and impaired reaches of the stream, temperature does not appear to be a stressor causing impairment of the fish community. Hence, temperature was eliminated as a candidate stressor of the fish community.

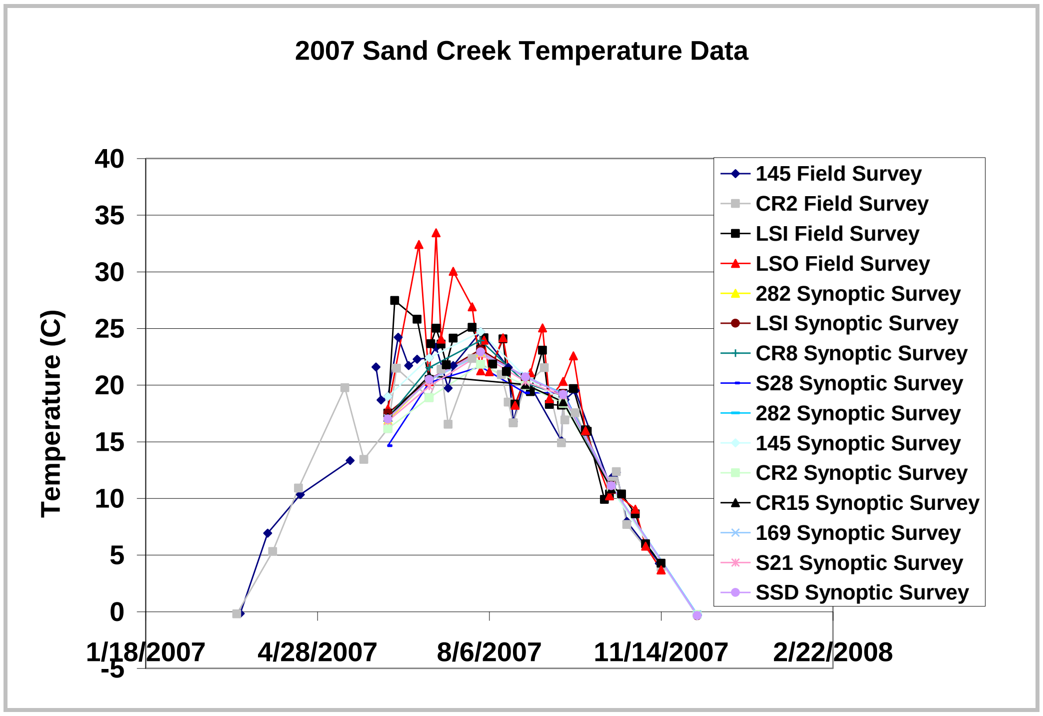

Figure 10. 2007 Sand Creek Temperature Data

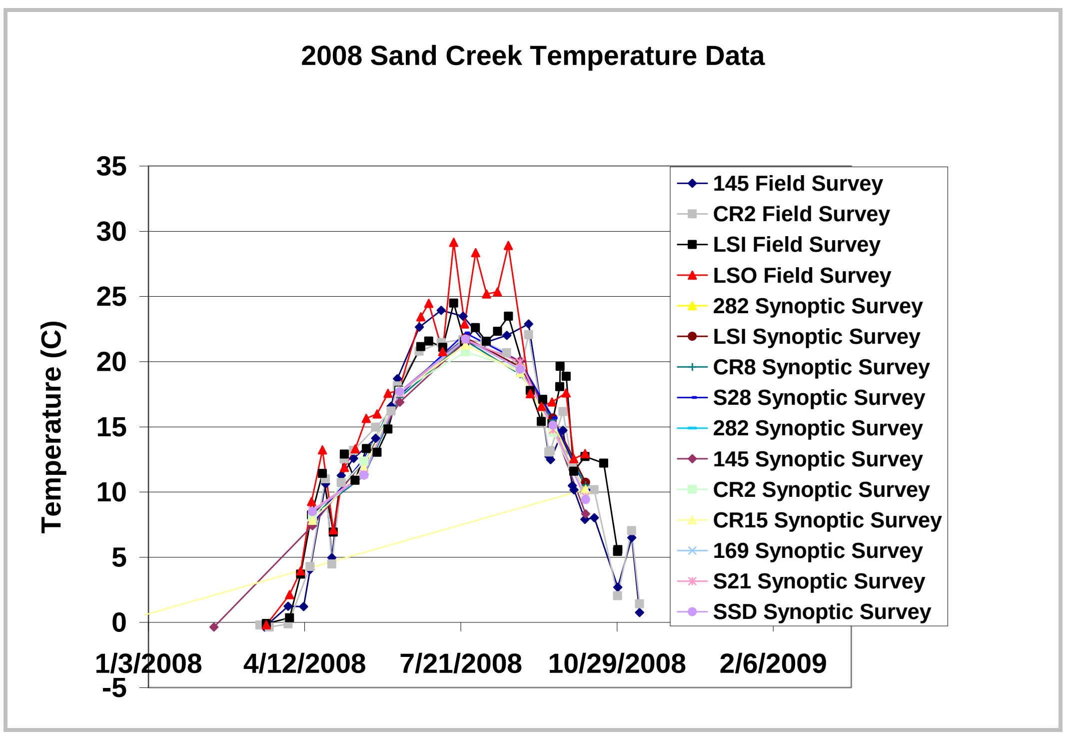

Figure 11. 2008 Sand Creek Temperature Data

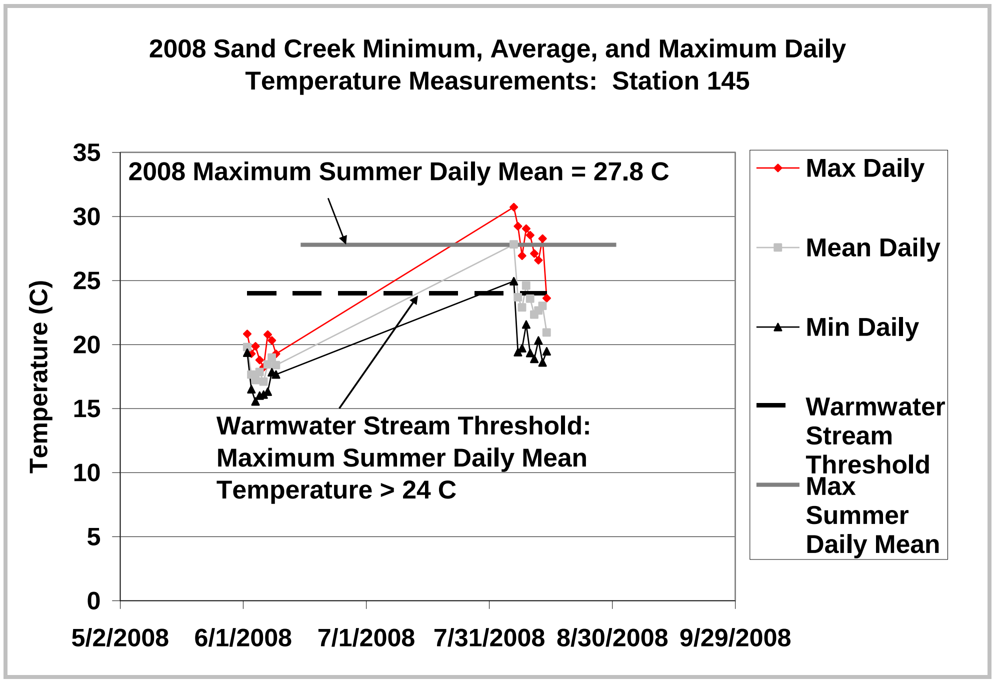

Figure 12. 2008 Sand Creek Minimum, Average, and Maximum Daily Temperature Measurements: Station 145

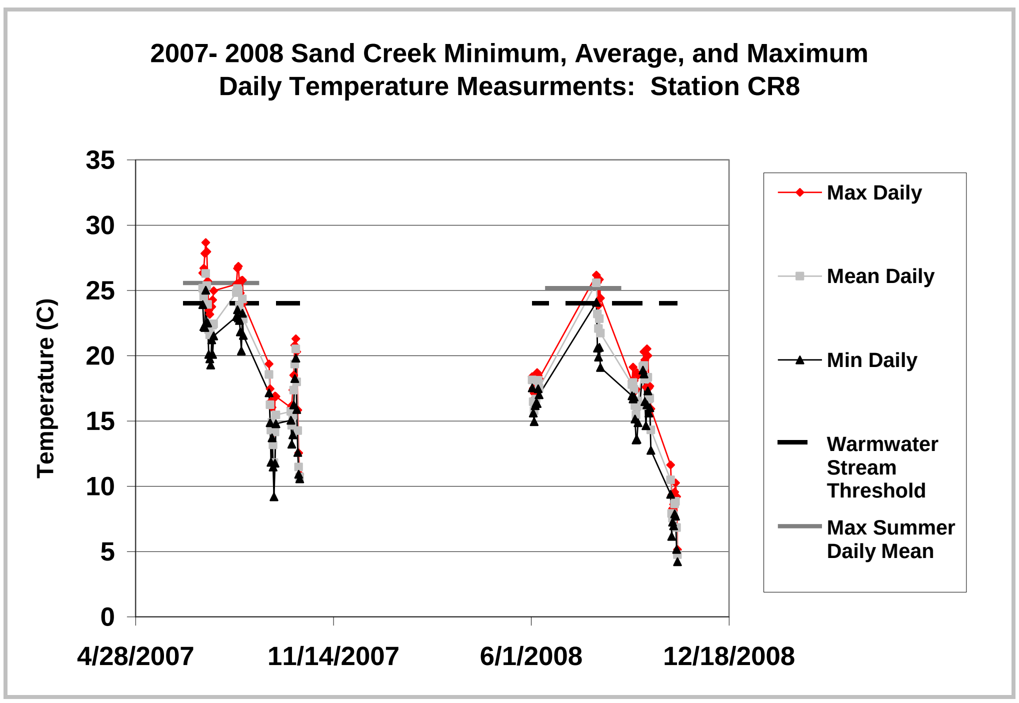

Figure 13. 2007-2008 Sand Creek Minimum, Average, and Maximum Daily Temperature Measurements: Station CR8

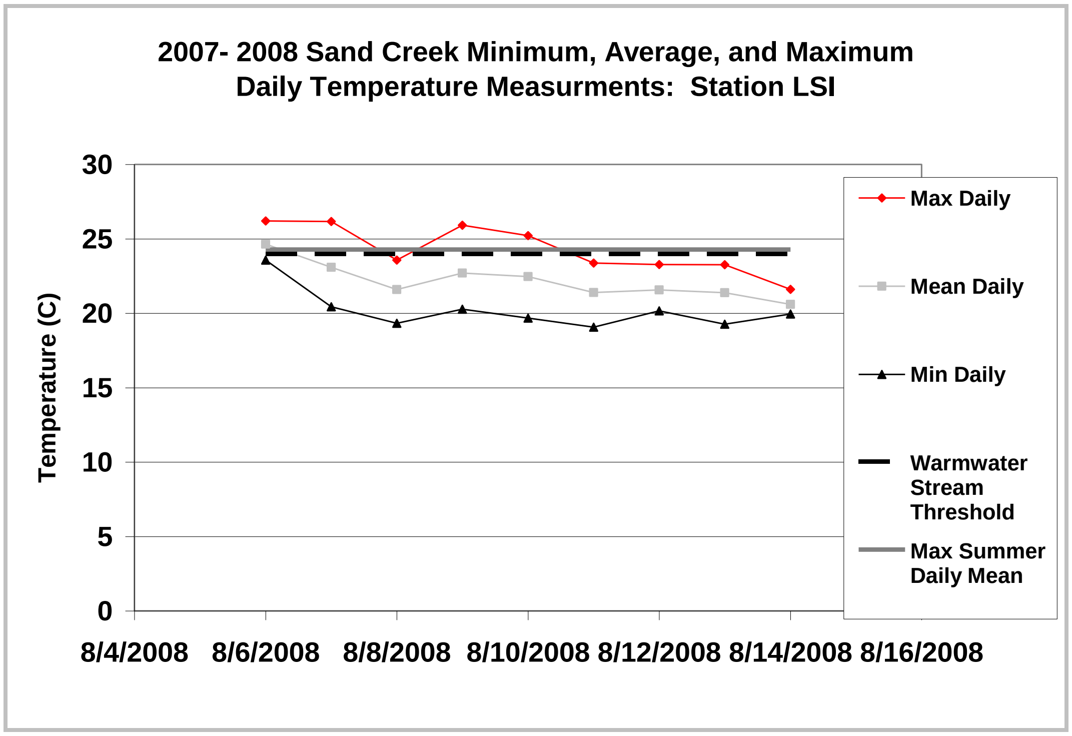

Figure 14. **2007-2008 Sand Creek Minimum, Average, and Maximum Daily Temperature Measurements: Station LSI**

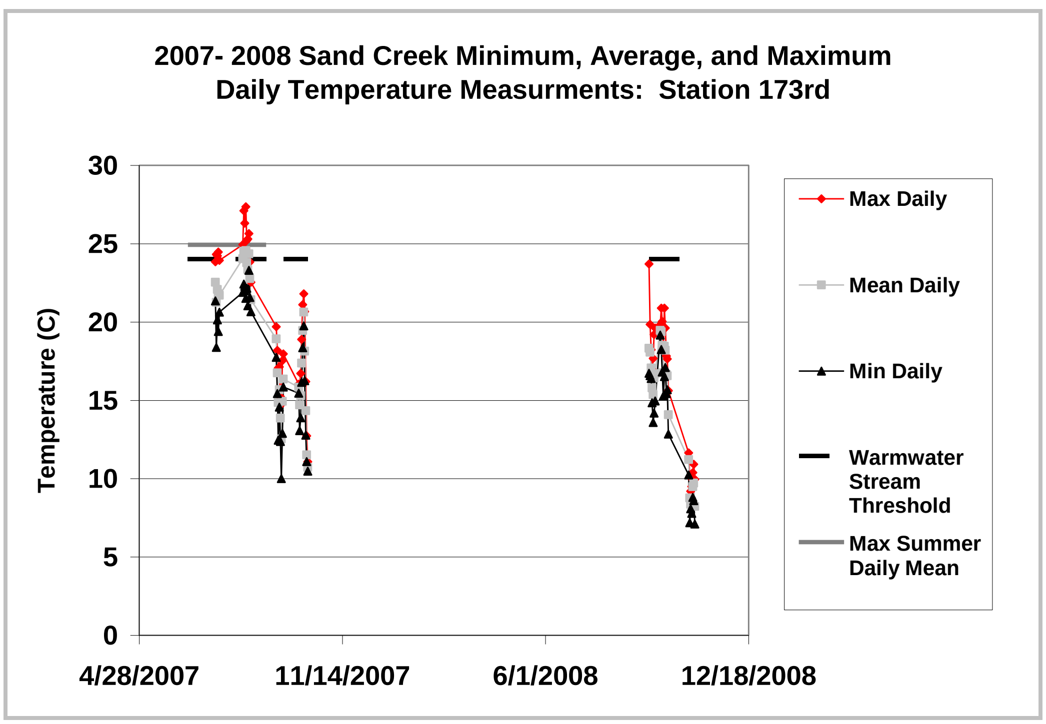

Figure 15. 2007-2008 Sand Creek Minimum, Average, and Maximum Daily Temperature Measurements: Station 173rd

4.1.1.3 Metals

Metals were eliminated as a candidate stressor because data indicate the metals concentrations in Sand Creek during years in which fish data were collected supported all aquatic life. Metals samples were collected from Station CR2 during 2005 through 2006 and from SA 8.2 during 1993 through 2008 (Figure 5). Station CR2 is located upstream from locations with impaired fish MRAP IBI scores. Station SA 8.2 is located downstream from locations with impaired fish MRAP IBI scores and upstream from locations with unimpaired fish MRAP IBI scores. Metals concentrations measured in Sand Creek were compared to both the chronic (CS) and acute toxicity (FAV) standard. Both chronic and acute toxicity standards vary with total hardness and are calculated from equations provided for each metals species (Minnesota Rule Chapter 7050.0222, subpart 4). The chronic standard protects aquatic life from long-term exposure to metals while acute toxicity standards protect aquatic life from short-term exposure to metals. The chronic standard is set at a level to protect the aquatic community from any long-term adverse effects. The acute toxicity standard (FAV) is set at a level designed to protect 95 percent of the species in an aquatic community from acute effects 95 percent of the time.

As shown in Figures 16 through 21, all metals data collected from Station CR2 were within both chronic (CS) and acute toxicity (FAV) standards (Minnesota Rule Chapter 7050.0222, subpart 4). As shown in Figures 22 through 27, all metals data collected from Station SA 8.2 during the years in which impaired MRAP IBI scores were within both chronic (CS) and acute toxicity (FAV) standards (Minnesota Rule Chapter 7050.0222, subpart 4). Although some metals data from Station SA 8.2 exceeded the chronic standard (lead) or both the chronic (CS) and acute toxicity (FAV) standards (copper and zinc) during years in which no biological data were collected, it does not appear that metals are a stressor to the biological community because all metals concentrations during years in which biological data were collected met both the chronic and acute toxicity standards. Hence, metals were eliminated as a candidate stressor.

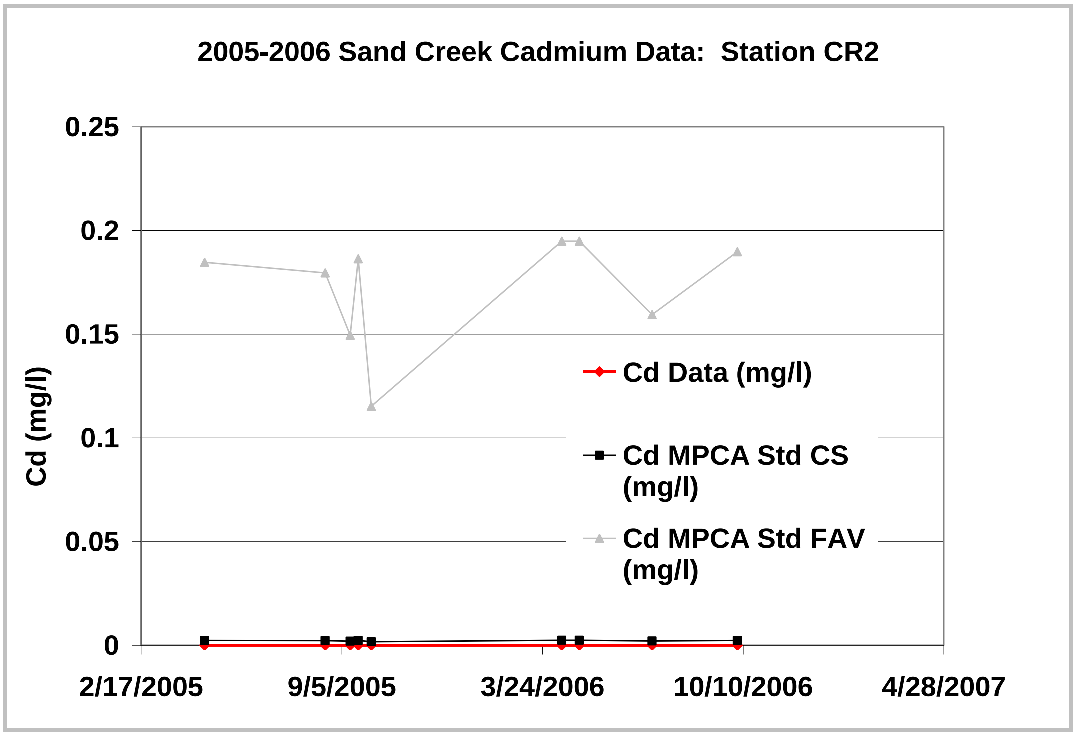

Figure 16. 2005-2006 Sand Creek Cadmium Data: Station CR2

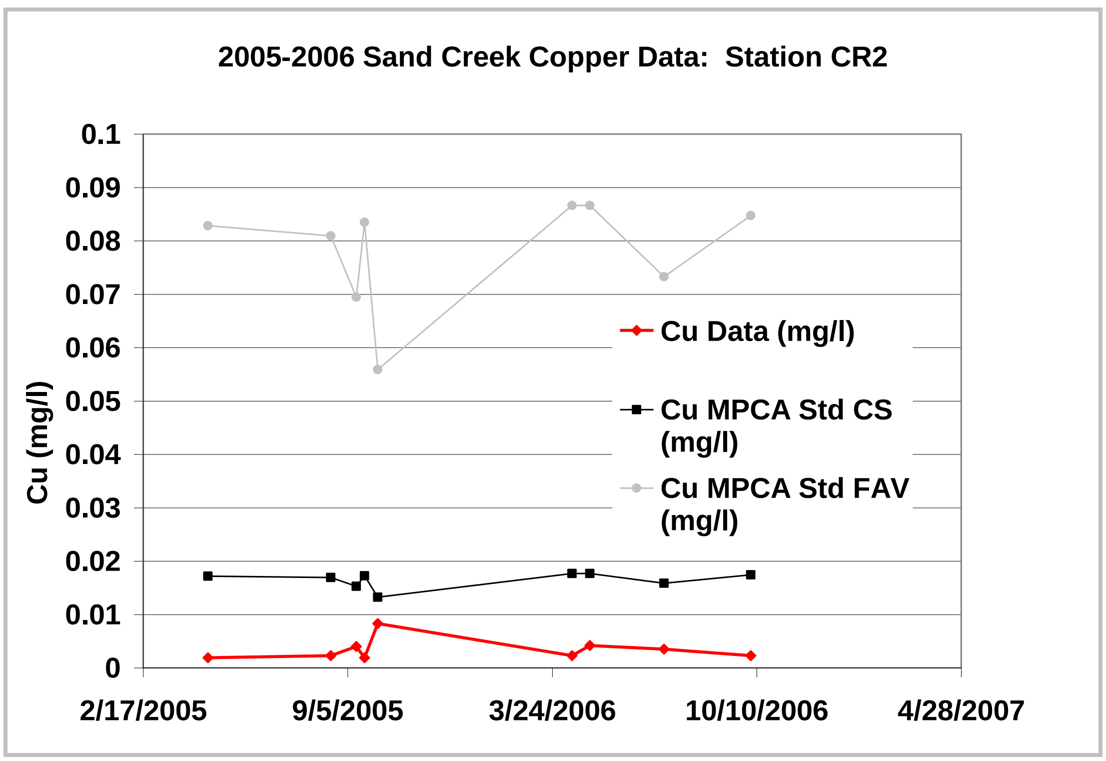

Figure 17. 2005-2006 Sand Creek Copper Data: Station CR2

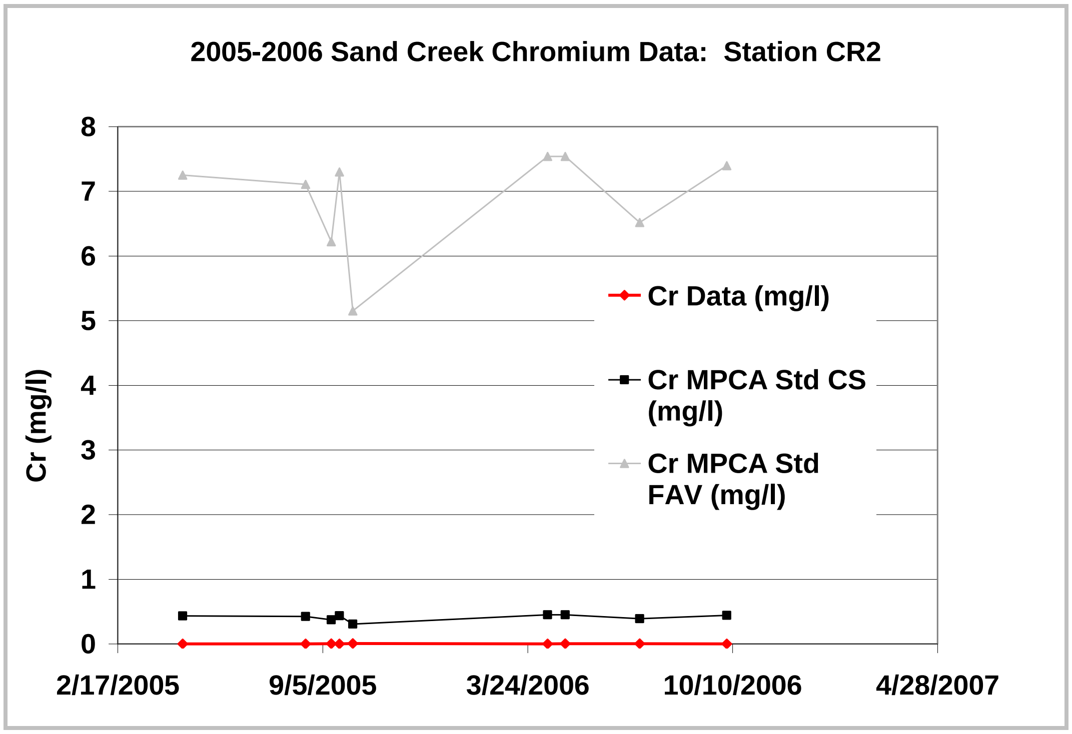

Figure 18. 2005-2006 Sand Creek Chromium Data: Station CR2

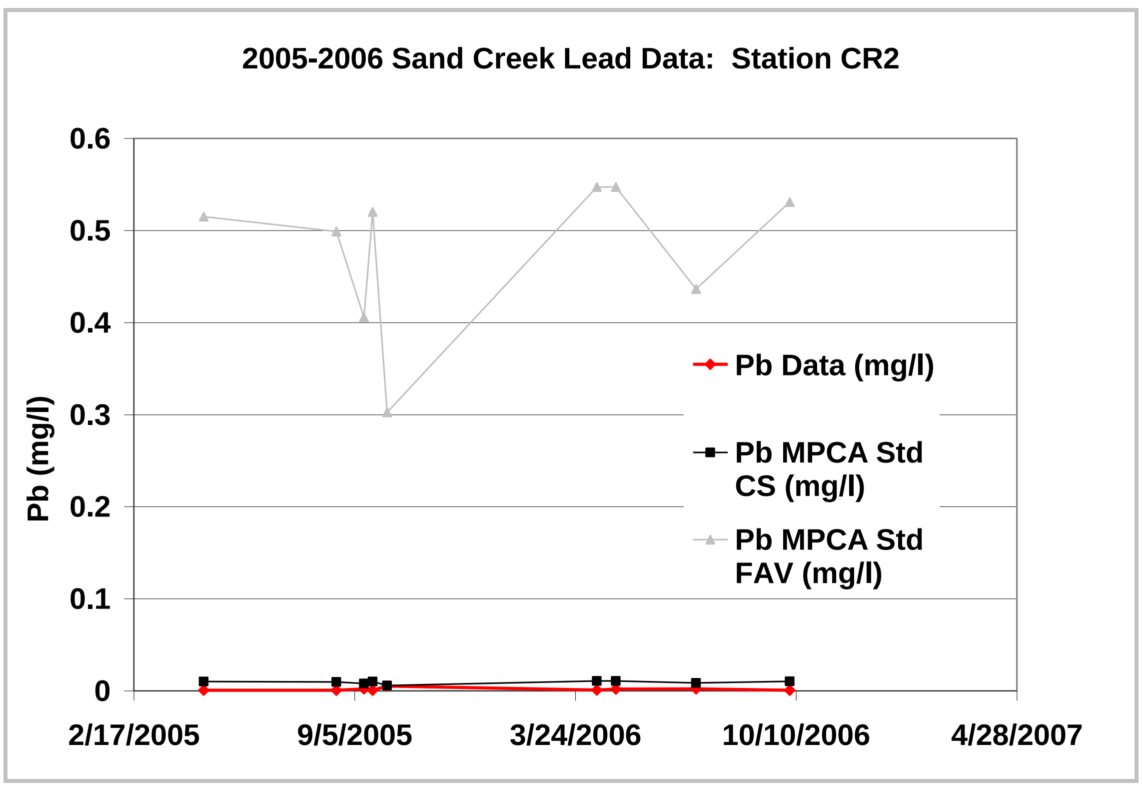

Figure 19. 2005-2006 Sand Creek Lead Data: Station CR2

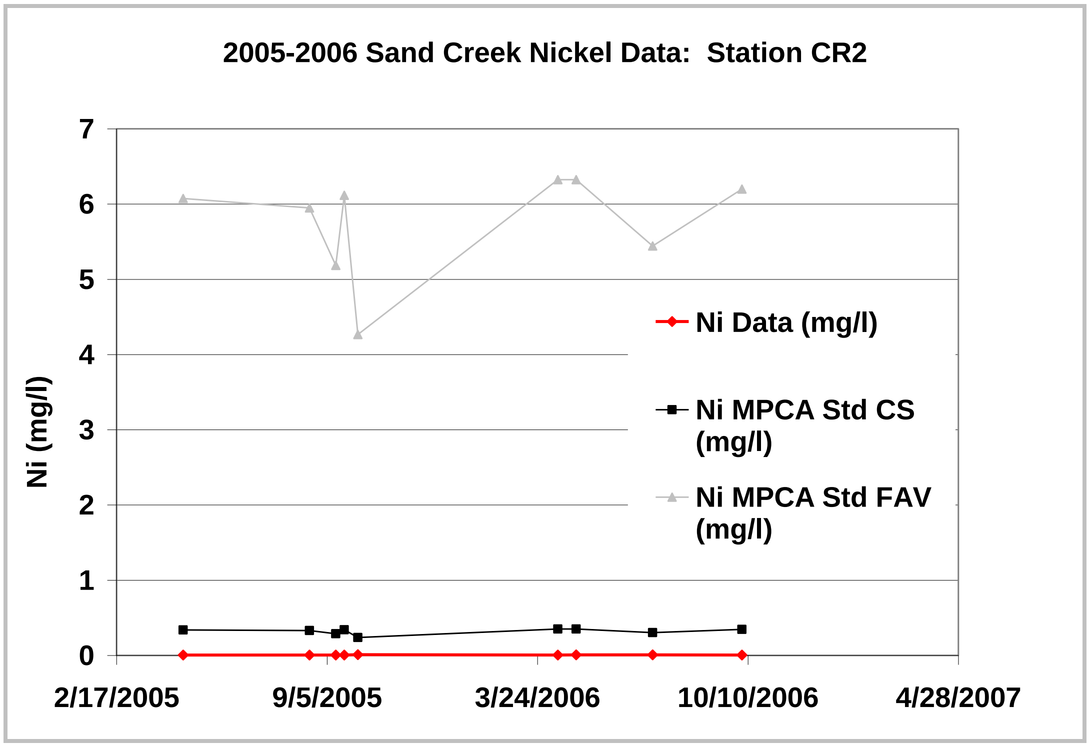

Figure 20. 2005-2006 Sand Creek Nickel Data: Station CR2

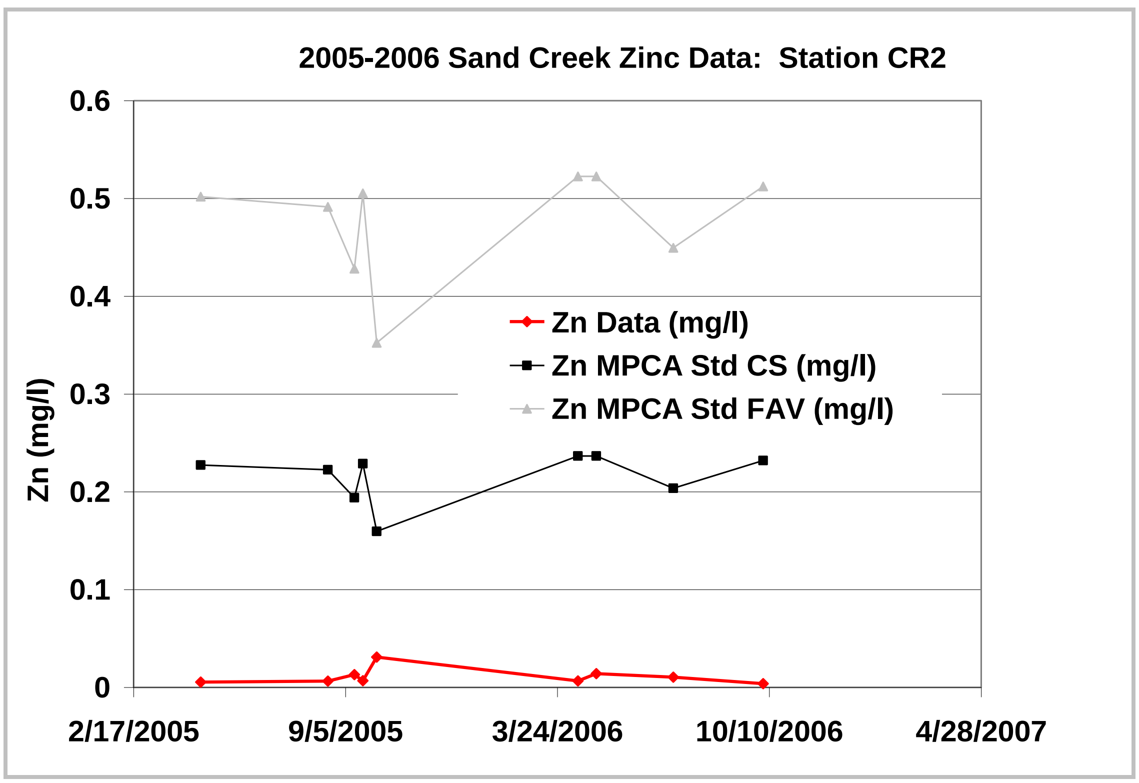

Figure 21. 2005-2006 Sand Creek Zinc Data: Station CR2

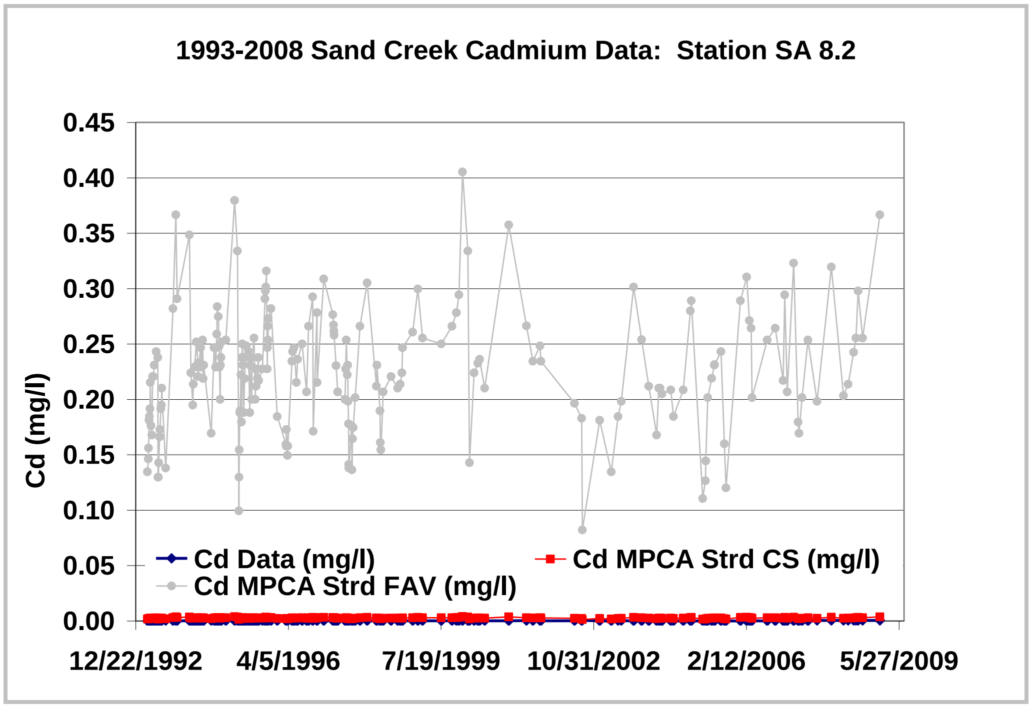

Figure 22. 1993-2008 Sand Creek Cadmium Data: Station SA 8.2

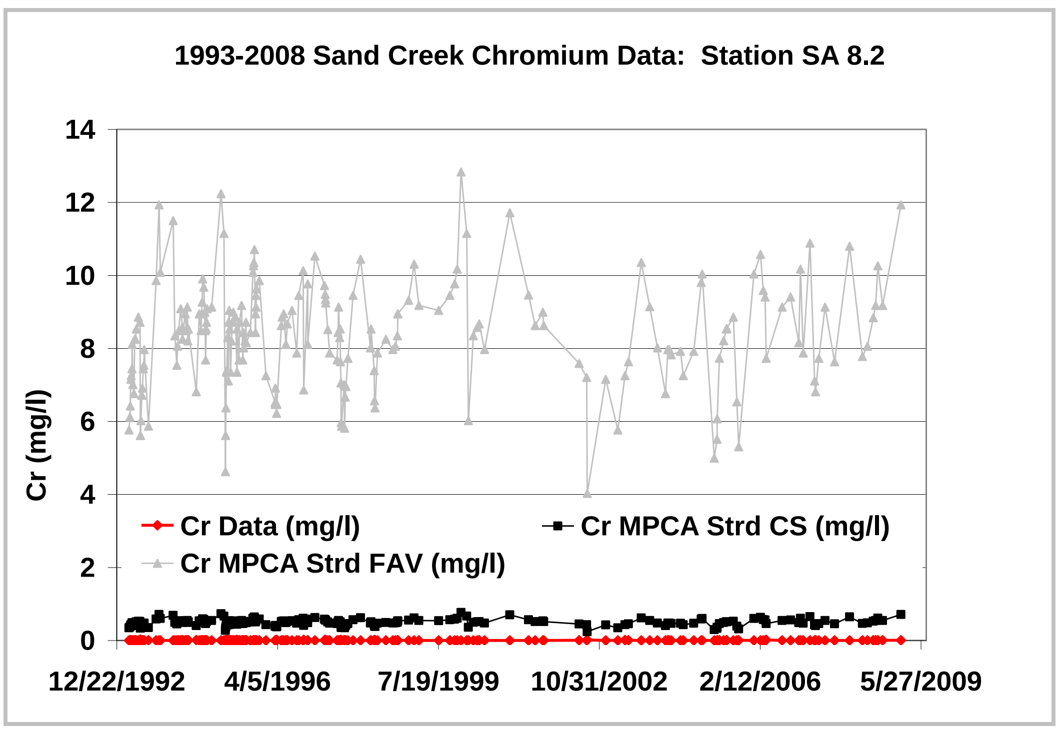

Figure 23. 1993-2008 Sand Creek Chromium Data: Station SA 8.2

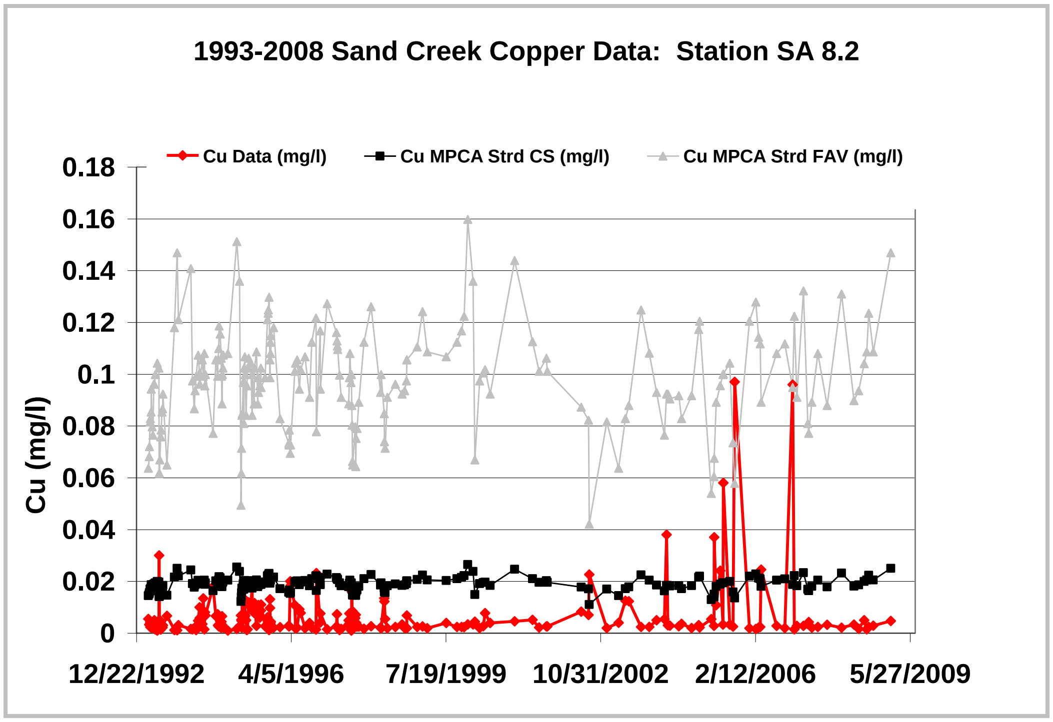

Figure 24. 1993-2008 Sand Creek Copper Data: Station SA 8.2

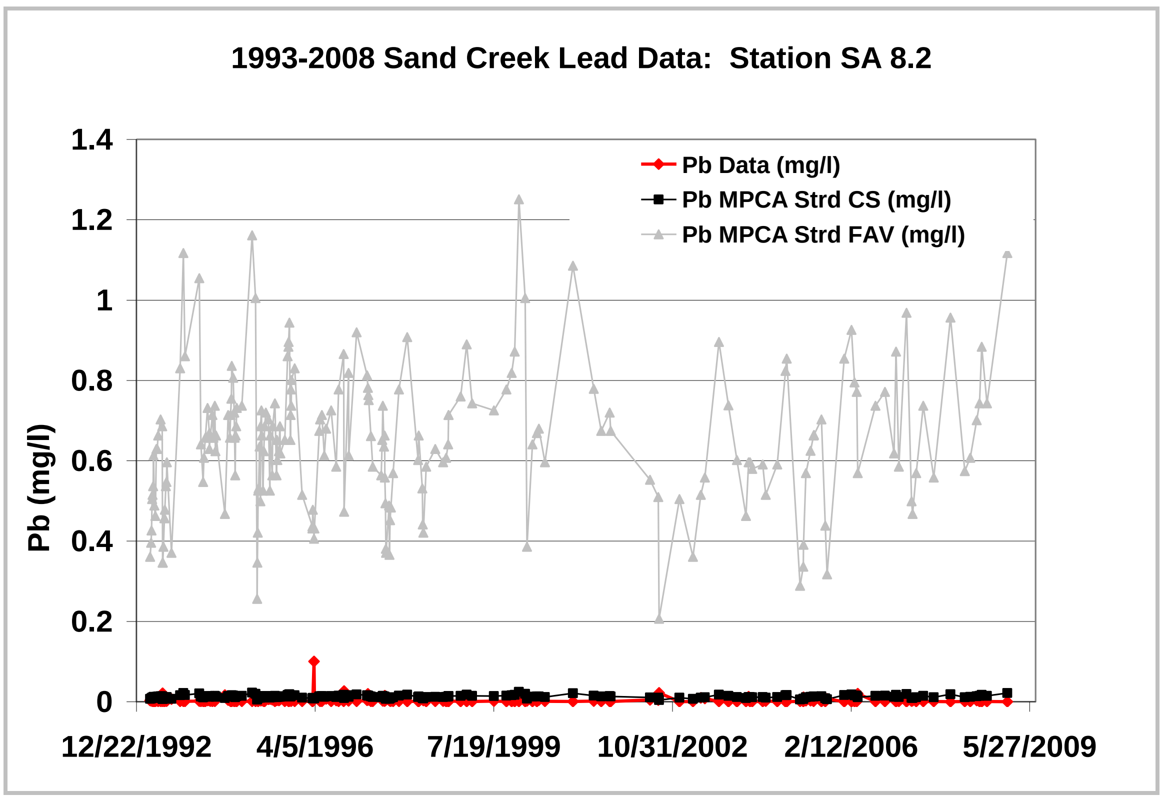

Figure 25. 1993-2008 Sand Creek Lead Data: Station SA 8.2

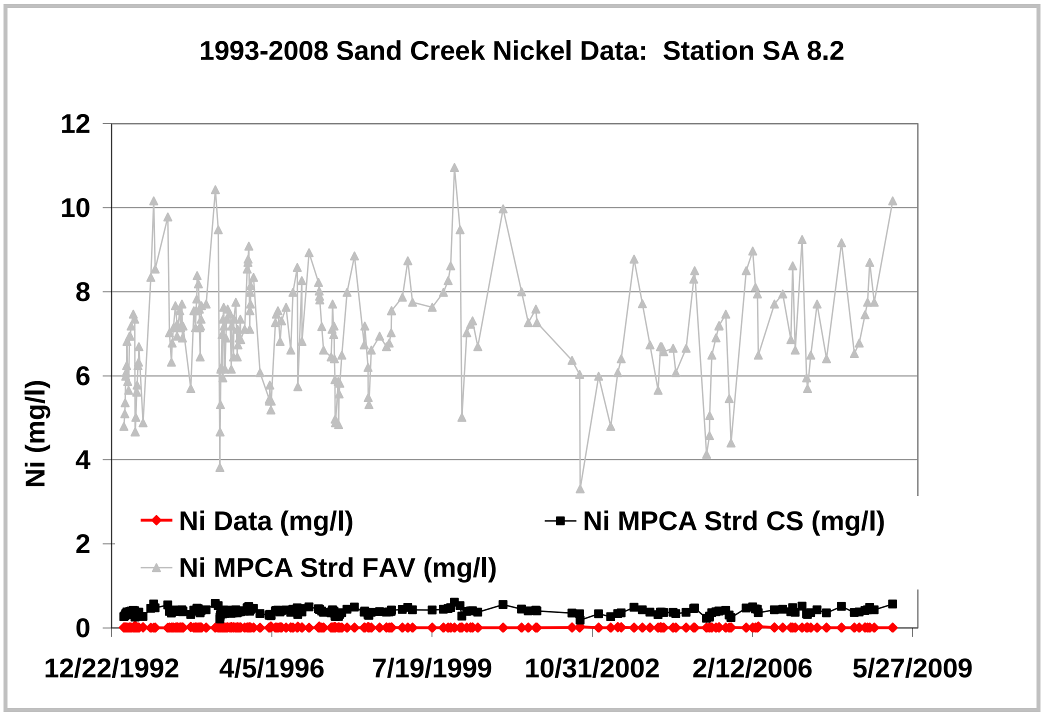

Figure 26. 1993-2008 Sand Creek Nickel Data: Station SA 8.2

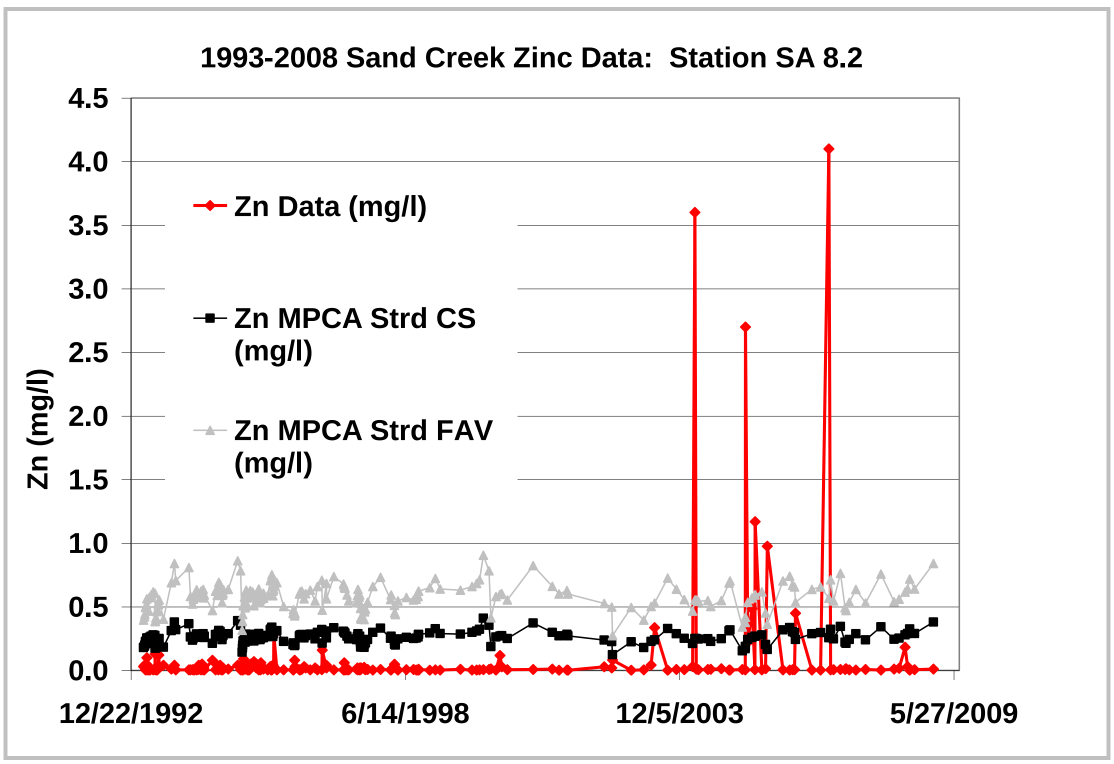

Figure 27. 1993-2008 Sand Creek Zinc Data: Station SA 8.2

4.1.1.4 Nutrients

Nutrients were eliminated as a candidate stressor because highest total phosphorus loads and concentrations consistently occurred within the reach of Sand Creek with unimpaired fish MRAP IBI scores. FLUX modeling results of total phosphorus data collected from Sand Creek during 2005 through 2008 indicate total phosphorus loads and concentrations consistently increased between upstream and downstream reaches of Sand Creek (Table 4). Station SA 8.2 consistently had the highest total phosphorus loads and flow-weighted mean concentrations (Table 4). Sand Creek biological stations downstream from Station SA 8.2 had unimpaired fish MRAP IBI scores while stations upstream had impaired fish MRAP IBI scores. Because SA 8.2, which represents the water quality of the downstream unimpaired reaches of Sand Creek, had highest total phosphorus loads and concentrations, nutrients do not appear to be a stressor causing fish MRAP IBI impairment in Sand Creek.

Table 4. Sand Creek Total Phosphorus Annual Load, Total Phosphorus Flow Weighted Mean Concentration, and Annual Flow Volume: Stations SA 8.2, CR2, and 145

	TP Annual Load (kg)			
Station	**2005**	**2006**	**2007**	**2008**
SA 8.2	65,916	41,488	48,729	31,844
CR2	18,577	11,329	13,546	9,566
145	-	-	9,129	6,687

	TP Flow-weighted Mean Concentration (ppb)			
Station	**2005**	**2006**	**2007**	**2008**
SA 8.2	487	491	499	434
CR2	411	411	411	411
145	-	-	382	302

	Annual Flow Volume (ft^3)			
Station	**2005**	**2006**	**2007**	**2008**
SA 8.2	4.78E+09	2.98E+09	3.45E+09	2.59E+09
CR2	1.60E+09	9.74E+08	1.16E+09	8.22E+08
145	-	-	9.51E+08	6.96E+08

4.1.1.5 Habitat

Habitat was eliminated as a candidate stressor because the reaches of Sand Creek with unimpaired fish MRAP IBI scores had the poorest habitat. Sand Creek habitat was assessed in the spring of 2007. Information was collected on soils, streamflow, stream bed grain size, aquatic biota, fish passage barriers, infrastructure, land use, and vegetation. This information was compiled on three forms: a customized reconnaissance form, a Minnesota Stream Habitat Assessment (MSHA) form, and a Stream Visual Assessment Protocol (SVAP) form.

The MSHA form, developed by the Minnesota Pollution Control Agency (MPCA) is based on the Qualitative Habitat Evaluation Index (QHEI) and scores the habitat based on the surrounding land use, riparian zone (riparian width, bank erosion, and shade), in-stream zone (substrate, embeddedness, cover type, cover amount), and channel morphology (channel depth variability, channel stability, velocity type, sinuosity, the ratio of pool width to riffle width, and channel development). Increasing scores indicate improving habitat while decreasing scores indicate habitat degradation. The highest possible MSHA score is 100. Analysis was completed for the MSHA forms approximately every 0.5 miles on Sand Creek downstream from the confluence with Porter Creek. Elsewhere, the reaches varied in length. Stream reaches are shown on Figure 3.

Sand Creek Reach 12, pictured above, had the highest Sand Creek MSHA score in 2007 while Reach 6, pictured below, had the lowest score (Photos from Inter-Fluve 2008).

The habitat of Sand Creek as assessed by MSHA appears to vary little from upstream to downstream reaches. Sand Creek had MSHA scores ranging from a low of 59.4 to a high of 63.9, a range of 4.5 points (Table 5) The highest MSHA score (i.e., 63.9) was found in an unimpaired stream reach containing biological station 07MN056. The two lowest MSHA scores (59.4 and 60.4) were also found in unimpaired stream reaches containing biological stations 07MN033 and 07MN034 (Table 5). Habitat does not appear to be a stressor to the biological community because the unimpaired stream reaches had both the best and the worst habitat.

Table 5. Sand Creek Fish MRAP IBI and MSHA Scores*

Fish Site	Fish MRAP IBI		MSHA Scores						
			MSHA Reach	Total	Surrounding Land Use	Riparian Zone	Substrate	Cover	Channel Morphology
03MN077	29		NA	NA	NA	NA	NA	NA	NA
07MN056	31		12	63.9	2.5	6	18.4	8	29
07MN055	24								
90MN116	20		10	62.8	2.5	6	16.8	7	30.5
01MN044	22	1							
01MN044	26	2	8a	63.5	2.5	7	19	6	29
00MN006	26		7b	63.0	2	7	17	6	31
07MN033	48		6a	59.4	2	7	19.4	5	26
07MN034	38		4b	60.4	5	5	16.4	11	23

[1]Sampled July 24, 2001
[2]Sampled July 25, 2007
*Inter-Fluve (2008)

The SVAP assessment form was developed by the U.S. Department of Agriculture (USDA) in 1989. The assessment includes channel condition, hydrologic alteration, the riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, instream fish cover, pools, invertebrate habitat, canopy cover, riffle embeddedness, and observed macroinvertebrates. Each of the first 12 assessment elements is rated with a value of 1 to 10 and observed macroinvertebrates is rated with a value of -3 to 15. Increasing scores indicate improving habitat while decreasing scores indicate habitat degradation. The highest possible SVAP

Sand Creek Reach 10, pictured above, had the highest SVAP score in 2007 (Photo from Interfluve 2008).

score for the 13 metrics is 135. The total score is then divided by 13 to determine the average score per metric. The same stream reaches assessed for MSHA were assessed for SVAP. Stream reaches are shown on Figure 3. SVAP assessment results are shown in Table 6.

Sand Creek had total SVAP scores ranging from a low of 64 to a high of 83 and overall scores (i.e., total score divided by 13 to determine average score for each metric) ranging from a low of 4.9 to a high of 6.4 (Table 6). The two highest overall SVAP scores (i.e., 6.4 and 6.2) were found in impaired stream reaches containing biological stations 07MN055, 90MN116, and 01MN044. These stations had fish MRAP IBI scores ranging from 20 to 26 (Table 6). The two lowest overall SVAP scores (4.9 and 5.1) were found in unimpaired stream reaches containing biological stations 07MN033 and 07MN034 (Table 6). These stations had fish MRAP IBI scores ranging from 38 to 48. Fish samples were collected from the biological stations with the two highest and two lowest fish MRAP IBI scores during 2007, the same year habitat was assessed. Habitat does not appear to be a stressor causing fish MRAP IBI impairment in Sand Creek because the unimpaired reaches of Sand Creek had the poorest habitat.

4.1.1.6 Flow

Flow was eliminated as a candidate stressor because Sand Creek discharge data indicate the impaired stream reach does not receive flows that are either higher or lower than unimpaired upstream and downstream reaches. Discharge data from Stations 145, CR2, and SA 8.2 from 2005 through 2008 indicate flow increases from upstream to downstream reaches (Figure 28). During periods of reduced precipitation, such as 2007, discharge in upstream reaches was reduced to less than 0.1 cfs (Figure 28). During this period, discharge at downstream SA 8.2 was consistently greater than 1 cfs. Fish data collected during the period of reduced flow in 2007 indicated the fish community at Station 07MN056, located downstream from 145 and CR2, was not impaired (Figure 4). Because flow increased from upstream to downstream reaches, impaired stream reaches located downstream from unimpaired Station 07MN056 received higher flows than unimpaired Station 07MN056 in 2007. Therefore, inadequate baseflow does not appear to be a stressor to the impaired fish community at these downstream locations.

High flows are also not considered a stressor to the Sand Creek fish community. Station SA 8.2 consistently observes higher flows than upstream reaches (Figure 28). Stations located downstream from SA 8.2 had unimpaired fish MRAP IBI scores while stations located upstream from SA 8.2 and downstream from the confluence of Raven Stream had impaired fish MRAP IBI scores (Figure 4). Because highest flows consistently occurred in unimpaired downstream reaches, high flows are not a

Table 6. Sand Creek Fish MRAP IBI and SVAP Scores

Assessment Metric	Fish MRAP IBI Sites						
	03MN077	07MN056	07MN055 & 90MN116	01MN044	00MN006	07MN033	07MN034
	Fish MRAP IBI Scores						
	29	31	20 & 20	22 & 26	26	48	34
	SVAP Scores						
	Not Assessed	Reach 12	Reach 10	Reach 8	Reach 7	Reach 6	Reach 4
Channel Condition	NA	8	7	5	3	3	3
Hydrologic Alteration	NA	8	8	8	5	5	5
Riparian Zone	NA	7	9	9	6	6	10
Bank Stability	NA	7	6	6	8	8	1
Water Appearance	NA	3	7	7	8	8	7
Nutrient Enrichment	NA	3	6	6	6	6	8
Barriers to Fish Movement	NA	10	10	10	1	3	10
Instream Fish Cover	NA	5	5	5	3	3	5
Pools	NA	7	7	7	7	7	4
Insect/Invertebrate Habitat	NA	6	6	6	4	4	3
Canopy cover	NA	1	1	1	10	1	1
Riffle Embeddedness	NA	8	9	9	8	8	5
Macro-invertebrates Had	NA	2	2	2	4	4	2
Total SVAP	NA	75	83	81	73	66	64
Overall Score (Total/13)	NA	5.8	6.4	6.2	5.6	5.1	4.9

stressor to the fish community in impaired upstream reaches since they consistently had lower flows. Therefore, flow was eliminated as a candidate stressor.

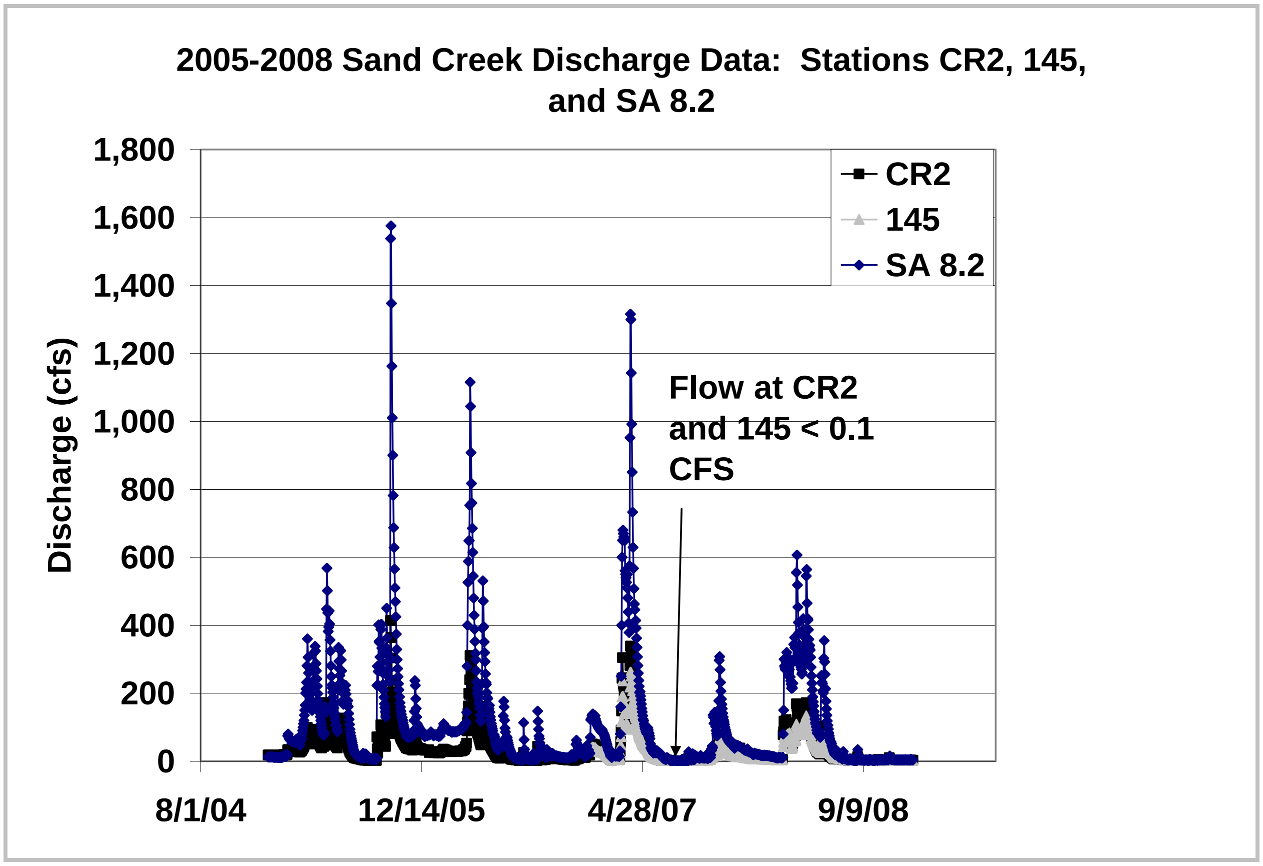

Figure 28. 2005-2008 Sand Creek Discharge Data: Stations CR2, 145, and SA 8.2

4.1.1.7 Low Dissolved Oxygen

Low dissolved oxygen concentrations in Sand Creek have been eliminated as a candidate stressor because unimpaired locations had low concentrations at the same frequency and duration as impaired locations. Hence, if low oxygen concentrations did not cause impairment in the unimpaired locations, it does not appear likely that they are the cause of impairment in the impaired locations. In addition, the relatively low frequency of occurrence of low dissolved oxygen values in the impaired reach provides further indication that low dissolved oxygen values did not cause the stream's MRAP IBI impairment.

Scott Watershed Management Organization (WMO) continuously measured dissolved oxygen at Stations LSI, 173rd Street, CR8, and 145 during selected periods of 2007 and 2008:

- 173rd/LSI– In 2007, July 12 through16, August 8 through 16, September 10 through 17, and October 2 through 11; In 2008, August 6 through 14, September 11 through 17, September 22 through 30, and October 20 through 26.

- CR8 – In 2007, July 5 through 16, August 8 through 15, September 10 through 17, and October 2 through 11; In 2008, June 2 through 9, August 6 through 10, September 11 through 17, September 22 through 30, and October 20 through 27.

- 145 – In 2008, June 2 through 9 and August 6 through 14.

Station locations are shown in Figure 29. The data, shown in Figures 30 through 34, were compared with the MPCA dissolved oxygen standard to protect all aquatic life, which is a minimum of 5 mg/L (Minnesota Rule Chapter 7050.022, subpart 4). The data indicate Sand Creek dissolved oxygen concentrations were below 5 mg/L at the following locations:

145 – During 12 of 17 days of measurement during the summer of 2008 (i.e., June 2 through 3, June 5, and August 6 through 14) minimum oxygen concentrations ranged from 1.33 mg/L to 4.77 mg/L, but maximum concentrations each day except August 14 were greater than 5 mg/L. On August 14, the maximum concentration was 4.47 mg/L. The data indicate diel oxygen changes resulted in oxygen concentrations below the standard during 71 percent of the days in which oxygen was measured and that all oxygen concentrations measured on August 14, 2008 were below the 5 mg/L standard (Figures 30 and 31).

CR8 – During July 6 through 10, 2007 minimum oxygen concentrations ranged from 3.98 to 4.99 mg/L, but maximum concentrations each day were greater than 5 mg/L. The data indicate diel oxygen changes resulted in low oxygen concentrations for portions of each day during the July 6 through 10, 2007 period (Figure 30 and 32). Dissolved oxygen concentrations failed to meet the MPCA standard at a frequency of 7 percent (5 of 75 days) during the 2007 through 2008 monitoring period.

173rd/LSI - During portions of the summers of 2007 and 2008 (i.e., July 13 through 16, 2007, August 9 through 10, 2007, and September 23, 2008) minimum oxygen concentrations ranged from 3.67 to 4.94 mg/L, but maximum concentrations each day were consistently greater than 5 mg/L. The data indicate diel oxygen changes are the cause of the low oxygen concentrations at a frequency of 11 percent (7 of 64 days) during the summers of 2007 and 2008 (Figure 30 and 33).

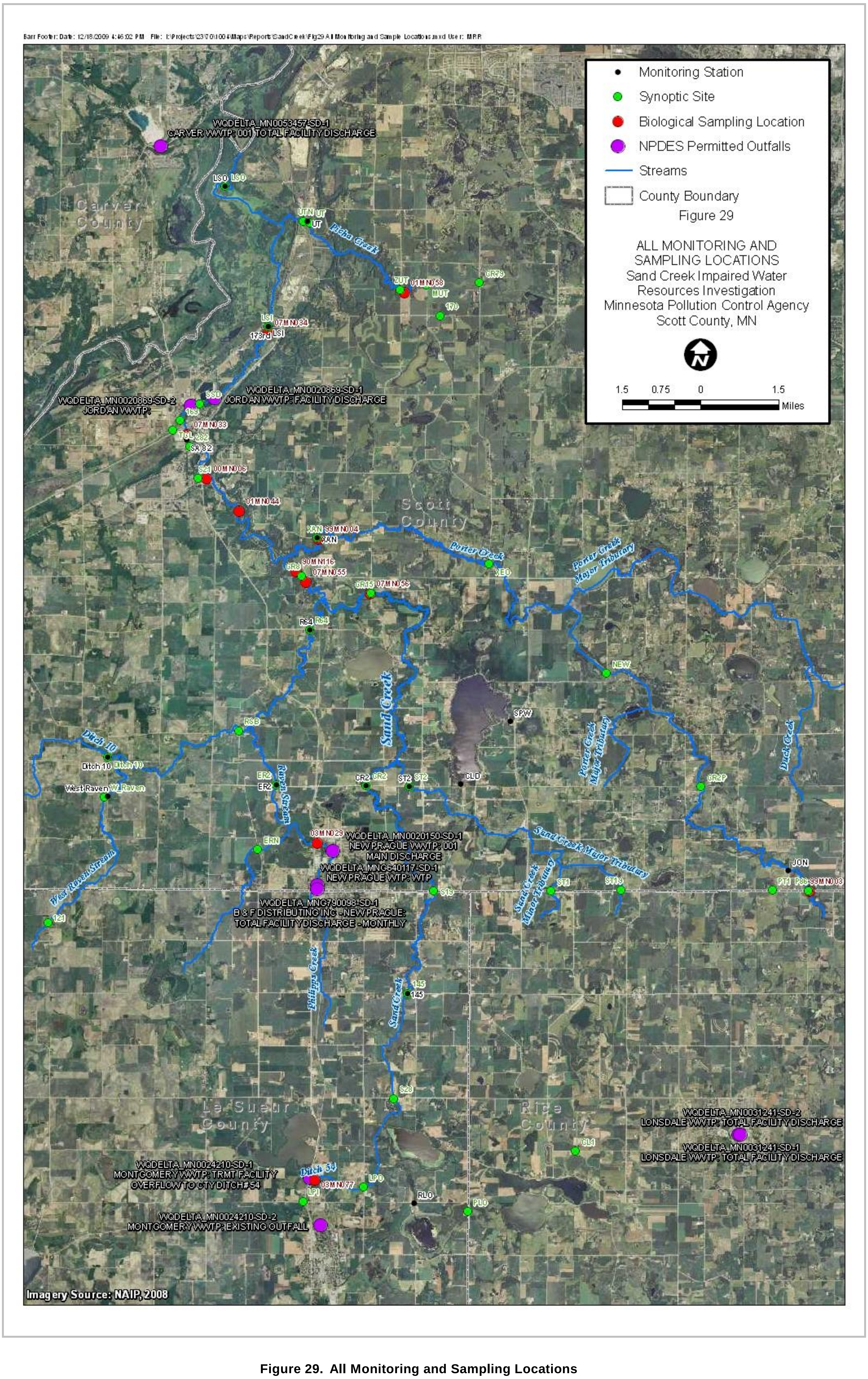

Figure 29. All Monitoring and Sampling Locations

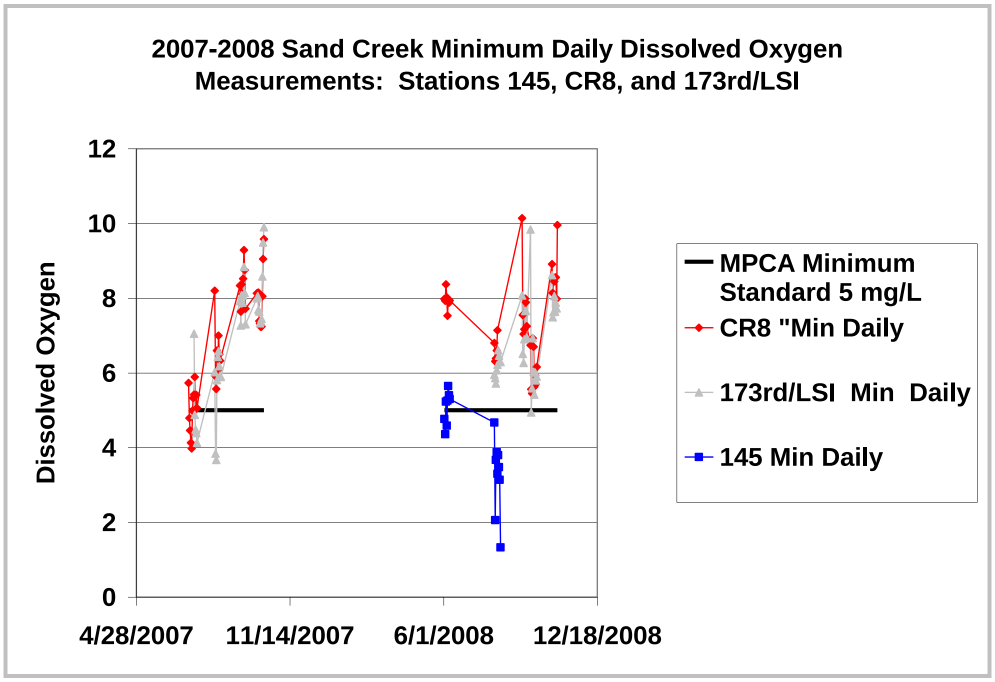

Figure 30. 2007-2008 Sand Creek Minimum Daily Dissolved Oxygen Measurements: Stations 145, CR8, and 173rd/LSI

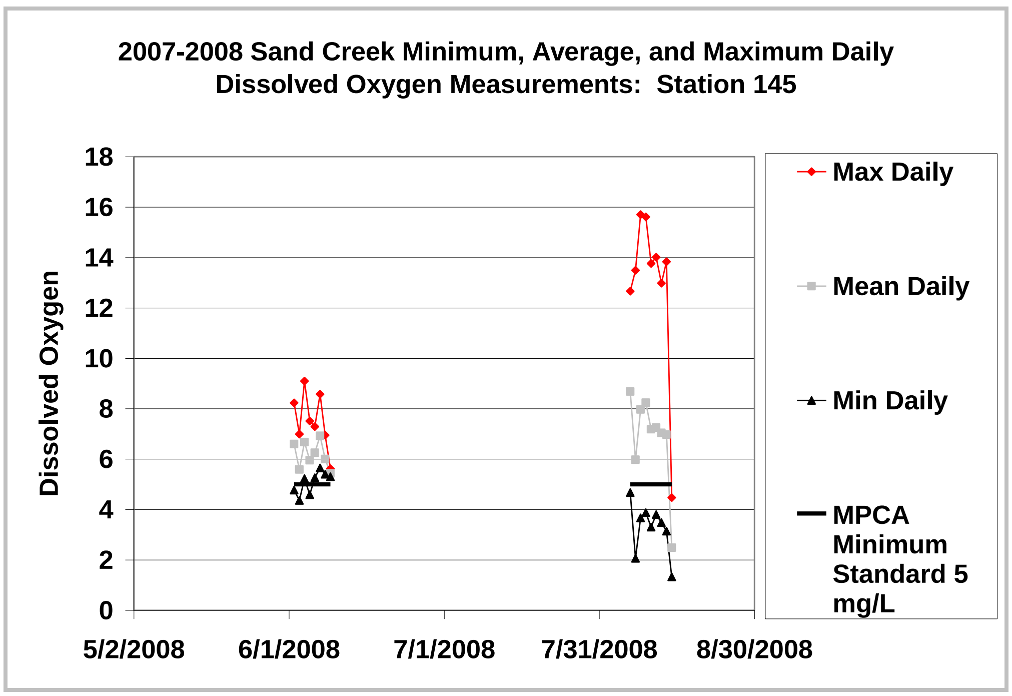

Figure 31. 2007-2008 Sand Creek Minimum, Average, and Maximum Daily Dissolved Oxygen Measurements: Station 145

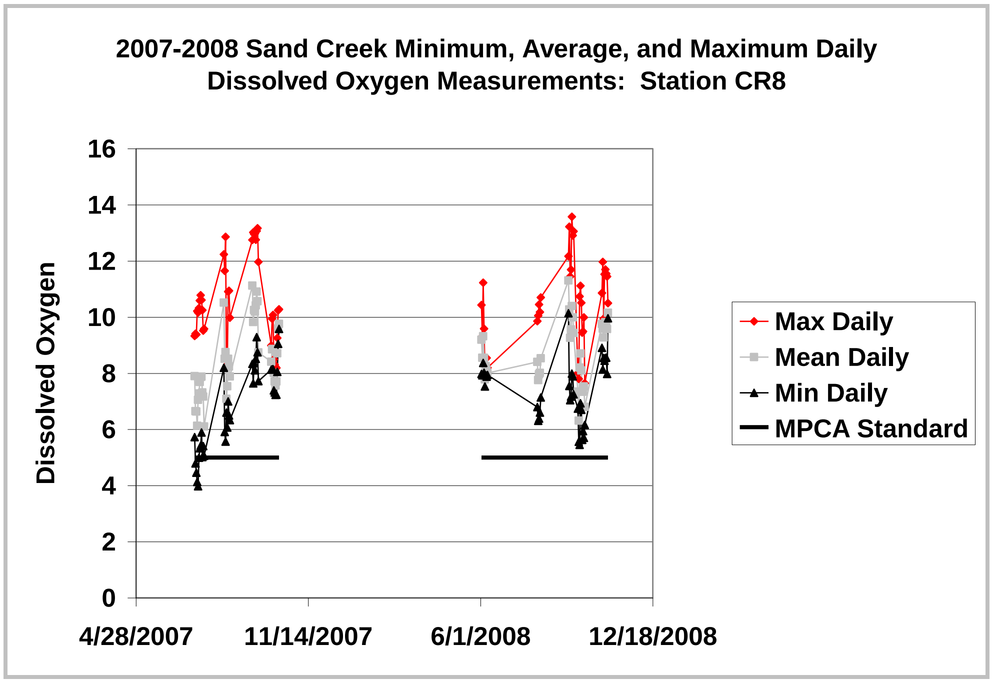

Figure 32. 2007-2008 Sand Creek Minimum, Average, and Maximum Daily Dissolved Oxygen Measurements: Station CR8

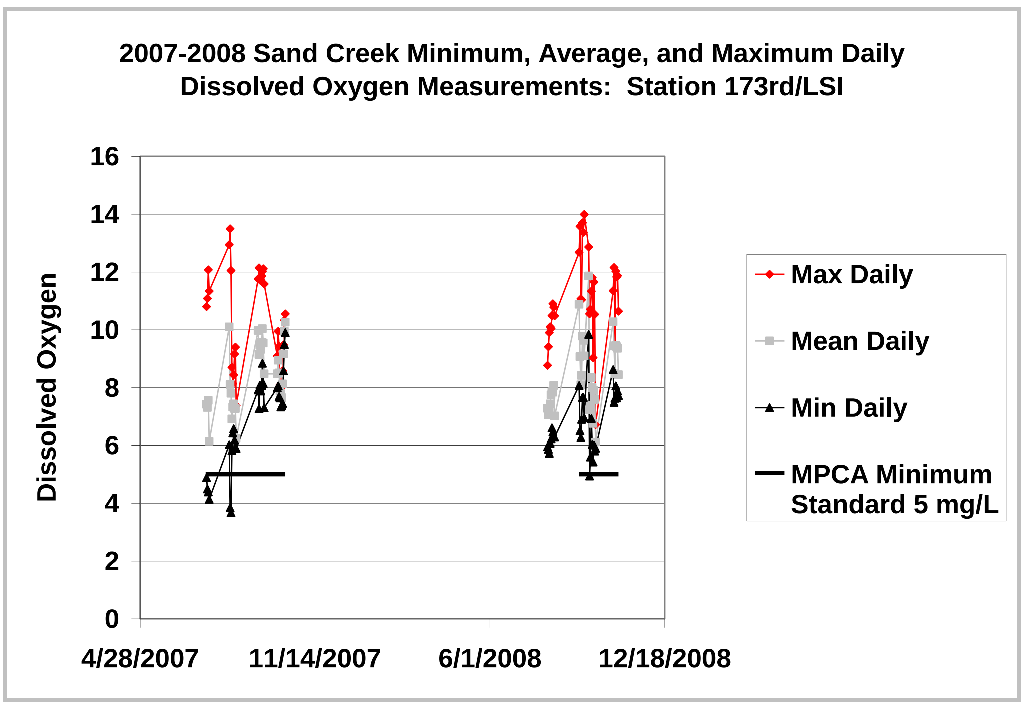

Figure 33. 2007-2008 Sand Creek Minimum, Average, and Maximum Daily Dissolved Oxygen Measurements: Station 173rd/LSI

In addition to continuous oxygen measurements at four Sand Creek locations, Scott Watershed Management Organization (WMO) completed instantaneous dissolved oxygen measurements at 10 Sand Creek locations during selected days of 2007 and 2008. Measurements generally occurred during on 6 to 8 occasions at each location during each year. The data, shown in Figure 34, were compared with the MPCA dissolved oxygen standard to protect all aquatic life, which is a minimum of 5 mg/L (Minnesota Rule Chapter 7050.022, subpart 4). Station locations are shown in Figure 29. The data indicate Sand Creek dissolved oxygen concentrations were below 5 mg/L at the following locations:

S28 – on 4 of 7 days of measurement during 2007 (i.e., 4.97 on 6/8, 4.69 on 7/2, 3.85 on 8/1, and 4.93 on 9/18) and 2 of 7 days of measurement during 2008 (i.e., 3.26 on 7/24/2008 and 4.7 on 8/28/2008). Hence, dissolved oxygen failed to meet the standard at a frequency of 57 percent in 2007 and 29 percent in 2008.

145 – on 4 of 7 days of measurement during 2007 (i.e., 4.31 on 6/8, 4.72 on 7/2, 3.86 on 8/1, and 3.9 on 8/27) and 2 of 7 days of measurement during 2008 (i.e., 3.63 on 7/24 and 4.68 on 8/28). Hence, dissolved oxygen failed to meet the standard at a frequency of 57 percent in 2007 and 29 percent in 2008. During 2007 site 145 was under the influence of a beaver dam constructed downstream of the site. This created backwater conditions at the site that, in combination with the low flows during 2007, contributed to the low dissolved oxygen (Nelson et al., 2009). Because this was not a typical condition, only the 2008 values should be considered for stressor identification purposes.

S19 – on 1 of 6 days of measurement during 2007 (i.e., 1.79 on 8/1/2007), a frequency of 17 percent.

CR2 – on 1 of 7 days of measurement during 2007 (4.38 on 8/1/2007), a frequency of 14 percent.

CR8 – on 1 of 7 days of measurement during 2007 (4.99 on 7/2/2007), a frequency of 14 percent.

173rd/LSI – on 1 of 7 days of measurement during 2007 (4.06 on 8/1/2007), a frequency of 14 percent.

As shown on Figure 29, Station CR8 is located immediately downstream from impaired biological sample station 07MN055 and upstream from all other impaired Sand Creek biological stations. Stations 173rd/LSI monitor unimpaired biological station 07MN034. A comparison of the frequency of low oxygen concentrations at these two locations indicates low oxygen concentrations occurred at a similar frequency. Specifically, 14 percent of instantaneous measurements failed to meet the standard at both CR8 and 173rd/LSI; 11 percent of continuous measurements at 173rd Street failed to meet the standard compared with 5 percent at CR8. Hence, the data indicate the impaired reach of Sand Creek had low oxygen concentrations at a similar or lower frequency as unimpaired location 07MN034. Because low oxygen concentrations did not cause impairment at Station 07MN034, it does not appear that low oxygen concentrations caused impairment at other Sand Creek locations observing low oxygen concentrations at a similar or lower frequency. In addition, the relatively low frequency of occurrence of low dissolved oxygen values in the impaired reach provides further indication that low dissolved oxygen values did not cause impairment.

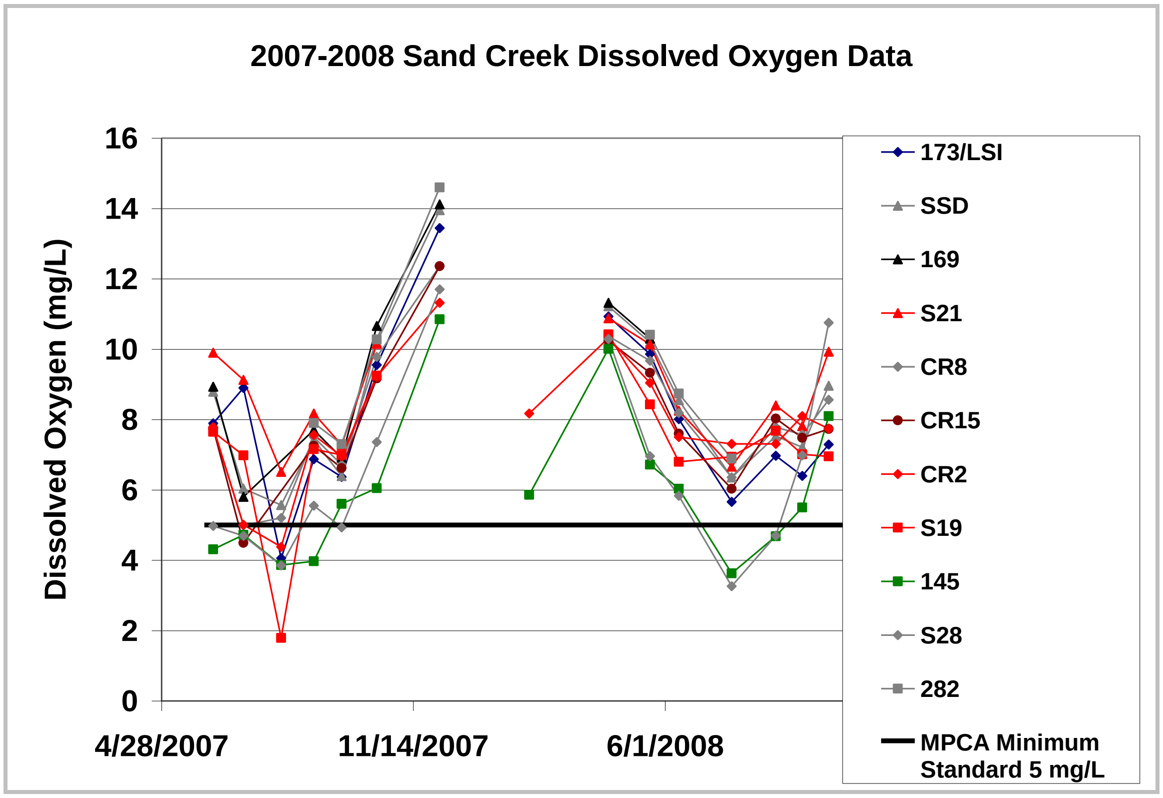

Figure 34. 2007-2008 Sand Creek Dissolved Oxygen Data

4.1.2 Picha Creek

4.1.2.1 pH

pH was eliminated as a candidate stressor because data indicate Picha Creek consistently had pH ranges that support all aquatic life. pH measured at Station 01MN058 (Figure 29) on July 24, 2001 (8.25) and August 8, 2001 (8.63) when fish samples were collected met the MPCA standard (Minnesota Rule Chapter 7050.0222, subpart 4). In 2007 through 2008, Scott Watershed Management Organization (WMO) staff measured pH at Station UT in grab samples and in samples collected with automated samplers. During this period, staff also measured pH in grab samples collected from five additional locations within Picha Creek. Station locations are shown in Figure 29. pH measurements ranged from 7.18 to 8.72 (Figure 35). Because all measurements were within the MPCA standard, which is a minimum of 6.5 and a maximum of 9.0 standard pH units (Minnesota Rule Chapter 7050.0222, subpart 4), pH was eliminated as a candidate stressor.

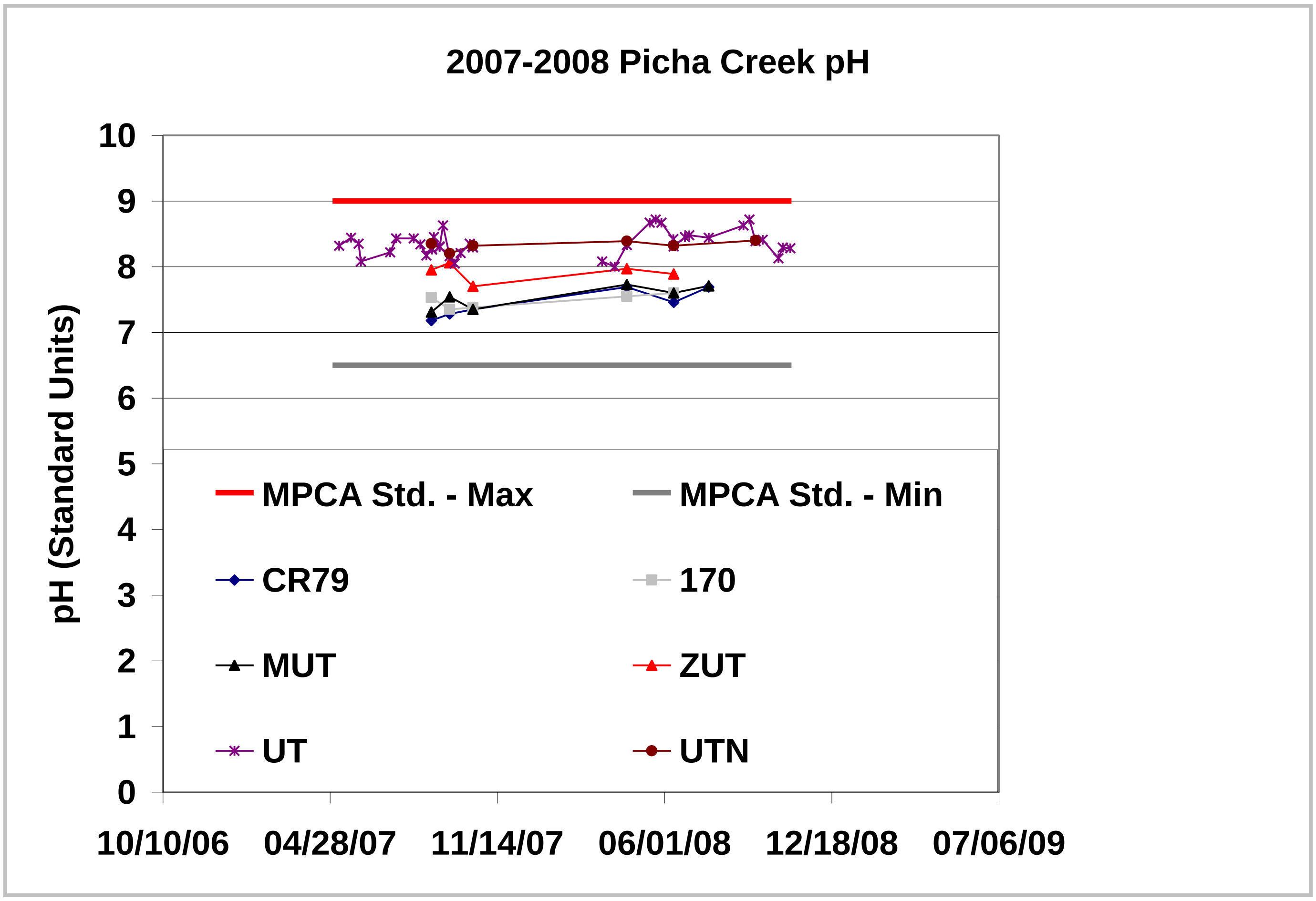

Figure 35. 2007-2008 Picha Creek pH

4.1.2.2 Temperature

Temperature was eliminated as a candidate cause of impairment because Picha Creek data indicate anthropogenic temperature changes have not occurred. The stream's summer temperatures during 2007 through 2008 are within the range of reference streams within the Minnesota River Basin and indicate it is a stream with coldwater temperature (Figure 36).

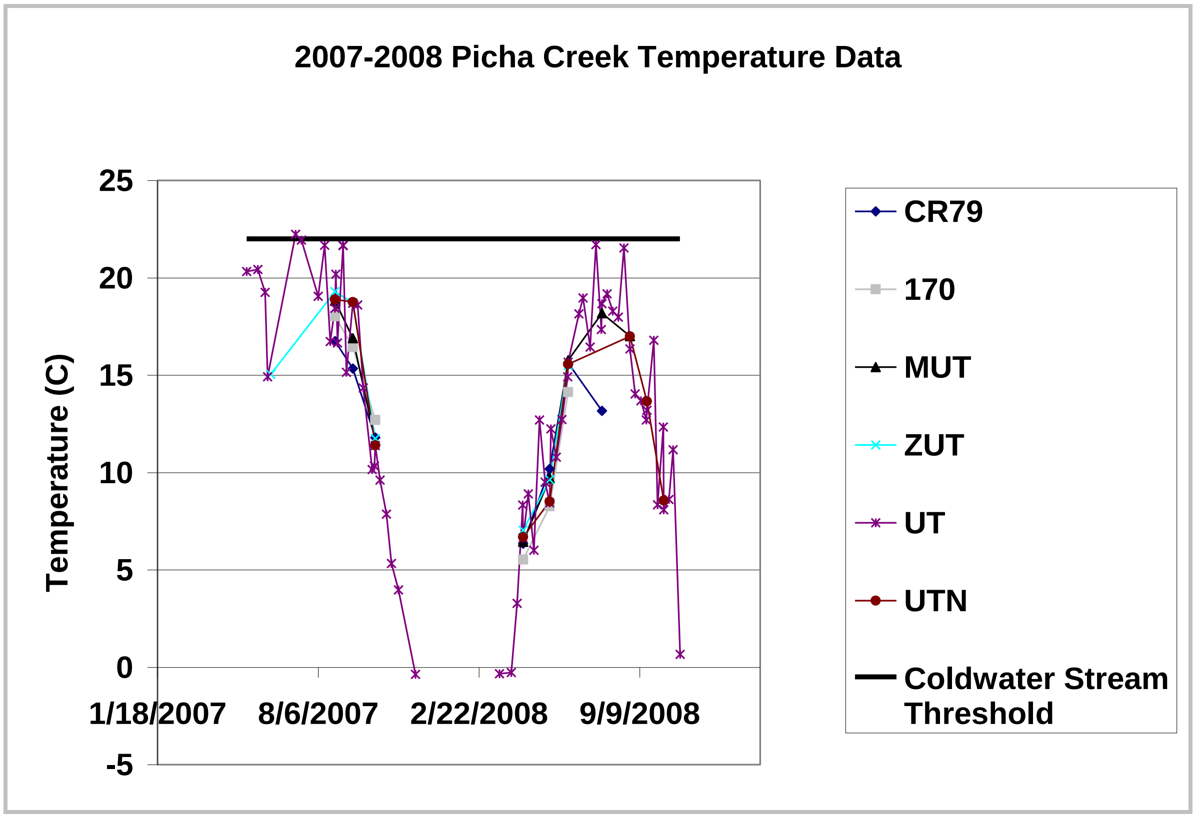

Figure 36. 2007-2008 Picha Creek Temperature Data

Although temperature is eliminated as a candidate cause of stream impairment, temperature is, and will be, an important consideration in impairment evaluation of Picha Creek. The stream's impairment was determined by evaluating the stream's fishery with the MRAP IBI. This MRAP IBI was developed from a mixture of warmwater, coolwater, and streams with coldwater temperatures in the Minnesota River Basin. Mundahl et al. (1998) have indicated a coldwater IBI is the appropriate tool to evaluate a stream with coldwater temperature and advised against using an IBI developed from a mixture of stream types (Mundahl et al., 1998). Because Picha Creek is a stream with coldwater temperature, further evaluation of the appropriate IBI is recommended to determine whether the MRAP IBI is an appropriate evaluation tool or whether a coldwater IBI that will be developed by the MPCA should be used to evaluate Picha Creek.

Streams are classified into one of three categories based upon temperature. Coolwater streams have a mean maximum daily temperature between 22 and 24°C during a normal summer, coldwater streams normally have summer maximum daily means below 22°C, and warmwater streams exceed 24°C (Lyons, 1992). During 2007 and 2008, Scott Watershed Management Organization (WMO) staff measured temperature at six stations. Measurements ranged from -0.37 to 22.23 °C. With the exception of a measurement of 22.23 °C at Station UT on July 9, 2007, all summer measurements were less than 22 °C (Figure 41). These data indicate Picha Creek is a stream with coldwater temperature. The data indicate that stream temperature is primarily determined by groundwater rather than surface flows. Hence, the stream does not show evidence of anthropogenic temperature alteration resulting from stormwater runoff.

Picha Creek has some coldwater temperature conditions that may support more of a coldwater fish assemblage. Coldwater and warmwater streams can support substantially different fish assemblages. For this reason, many of the metrics used in a warmwater version of the IBI may be inappropriate for assessment of a stream with coldwater temperatures (Steedman, 1988; Lyons, 1992; Lyons et al., 1996). In addition, the reduced taxa richness characteristic of coldwater fish assemblages has made it difficult to devise very many potential metrics that successfully detect impairment within streams with coldwater temperatures (Simon and Lyons, 1995; Lyons et al., 1996). Consequently, some investigators have developed versions of the IBI that are being used to assess both warmwater and coldwater assemblages within the same region (Hughes and Gammon, 1987; Langdon, 1988; Steedman, 1988; Oberdorff and Hughes, 1992). Since coldwater fish assemblages respond differently to impairment than do warmwater assemblages (Lyons, 1992; Lyons et al., 1996), the combination of warmwater/coldwater IBIs might not be well-suited to detect impairment in streams with coldwater temperatures. Mundahl and Simon (1998) recommend the use of a coldwater IBI for assessment of streams with coldwater temperatures. The MPCA is working to develop a coldwater IBI. The IBI that will be developed by the MPCA should be used to evaluate Picha Creek.

Picha Creek's biological impairment was based upon an evaluation using the MRAP IBI which was developed from streams with a combination of coldwater, coolwater, and warmwater temperatures. Reference reaches used to develop the MRAP IBI included 5 streams with coldwater temperatures, 6 streams with coolwater temperatures, and 17 streams with warmwater temperatures (MPCA, 2008). Non-reference streams within the Minnesota River Basin sampled during MRAP IBI development included streams with a combination of warmwater, coolwater, and coldwater temperature conditions. Temperatures of these streams were measured at the time of fish sampling for development of the MRAP IBI during 1990 through 1992 (Bailey et al., 1994). Stream temperatures at the time of sample collection indicated that 61 (47 percent) were streams with coldwater temperature conditions, 20 (16 percent) were streams with coolwater temperature conditions, 11 (9 percent) were streams with warmwater temperature conditions, and stream type for 35 could not be determined because temperatures were not measured (Bailey et al., 1994). Because the MRAP IBI was developed from a mixture of stream types, it may not be the best evaluation tool for Picha Creek.

The coldwater IBI that will be developed by the MPCA should be used to evaluate Picha Creek. Use of the MPCA coldwater IBI to evaluate Picha Creek is recommended because of the unique characteristics of a coldwater fishery.

The MPCA is working to revise its water quality standards to incorporate a tiered aquatic life use framework for rivers and streams and is developing IBIs for all stream types in Minnesota. This work will help guide future management of appropriate Picha Creek fish populations. Similar to all TMDL Projects, the TMDL Report and Implementation Plan for Picha Creek can be reevaluated and revised as needed to reflect new policies, standards, classifications, and additional monitoring.

4.1.2.3 Nutrients

Although Picha Creek had high nutrient concentrations, nutrients are eliminated as a stressor because the data indicate their presence in the stream has not stressed the biological community. High nutrient loadings entering a stream can accelerate primary production and increase biological activities. When excess plants and algae result from high nutrients, oxygen depletion problems may result when plants and algae die. Bacteria decomposing the plant tissue deplete dissolved oxygen and at the same time release nutrients into the water column resulting in oxygen poor conditions for aquatic life and a nutrient rich environment which fuels additional plant and algae growth.

Nutrients and primary productivity in an unimpaired reach of Sand Creek were compared with levels in Picha Creek to determine whether nutrients are a candidate stressor for the impaired fish community of Picha Creek. 2007 and 2008 data from Sand Creek Station LSI, located immediately downstream from unimpaired Sand Creek biological station 07MN034, were compared with 2007 and 2008 data from Picha Creek Station UT, located downstream from impaired biological station 01MN058 (Figure 29). Concentrations of chlorophyll *a*, total Kjeldahl nitrogen, and total phosphorus were consistently higher at Sand Creek Station LSI than Picha Creek Station UT (Figures 37 through 39).

Total phosphorus and nitrate nitrogen concentrations were measured at Station 01MN058 when fish samples were collected on July 24 and August 8, 2001. The data were compared with total phosphorus and nitrate nitrogen concentrations at Sand Creek Station SA 8.2, located upstream from unimpaired biological Stations 07MN033 and 07MN034. Total phosphorus and nitrate nitrogen concentrations in Picha Creek were lower than concentrations generally occurring at Station SA 8.2 (Figures 40 and 41). Because the fish communities of unimpaired reaches of Sand Creek were consistently exposed to higher concentrations of nutrients and chlorophyll than were observed in

Picha Creek and these concentrations did not cause impairment in Sand Creek, it does not appear that the lower levels generally measured within Picha Creek would cause impairment of the stream's biological community. Hence, nutrients were eliminated as a candidate stressor.

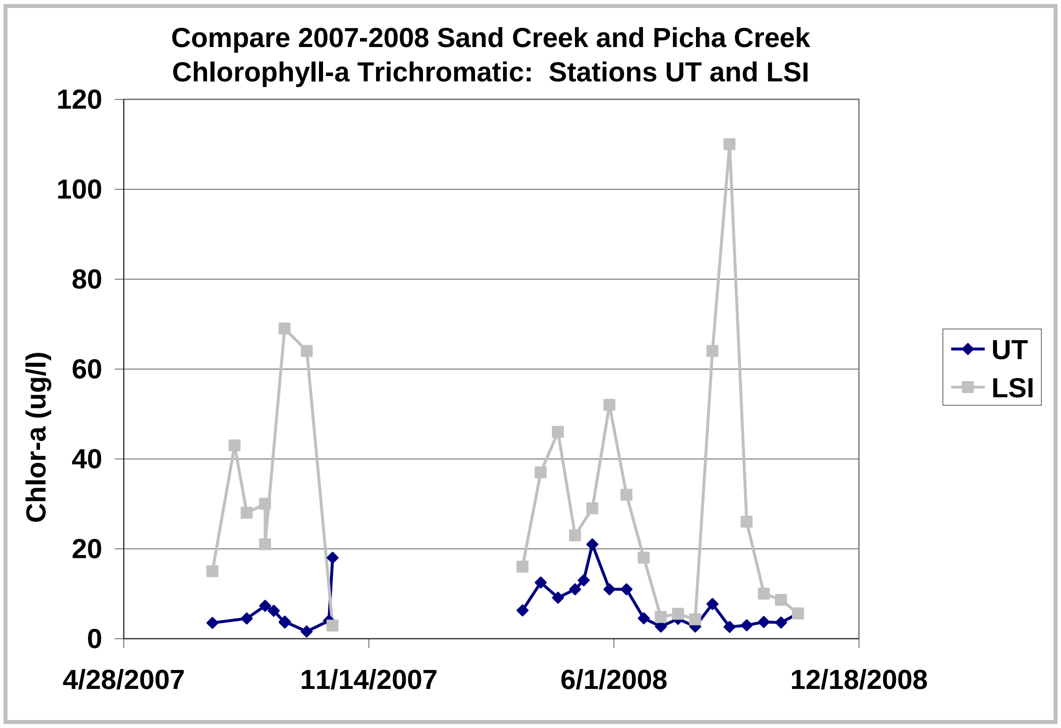

Figure 37. Compare 2007-2008 Sand Creek and Picha Creek Chlorophyll-*a* Trichromatic: Stations UT and LSI

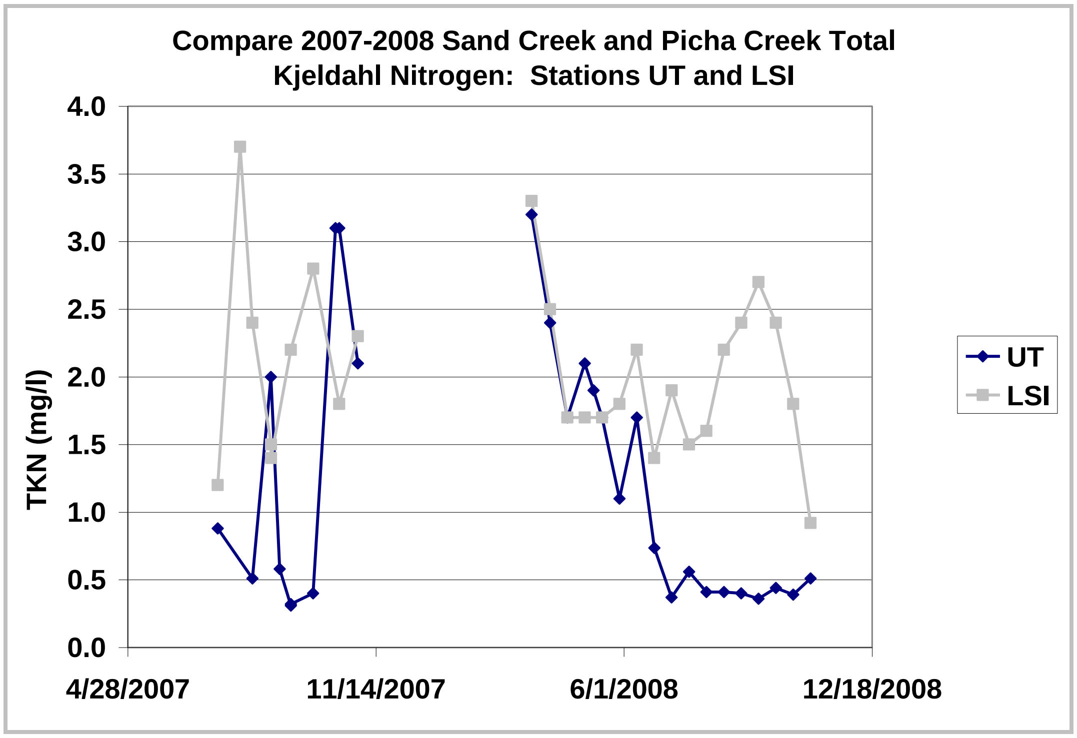

Figure 38. Compare 2007-2008 Sand Creek and Picha Creek Total Kjeldahl Nitrogen: Stations UT and LSI

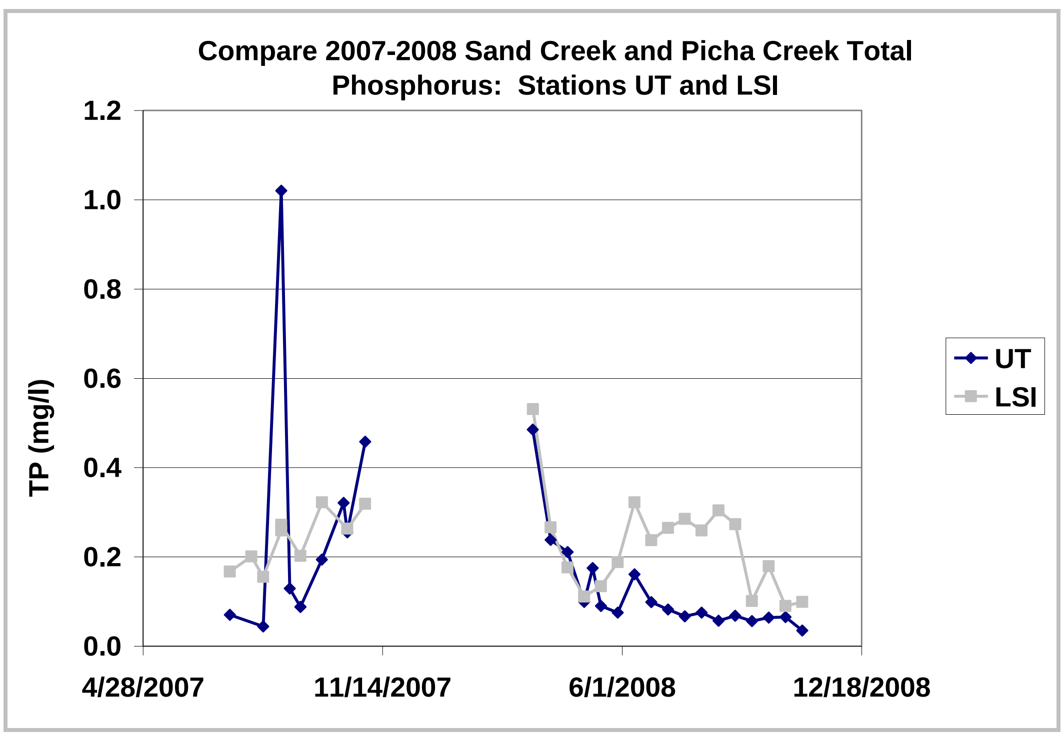

Figure 39. Compare 2007-2008 Sand Creek and Picha Creek Total Phosphorus: Stations UT and LSI

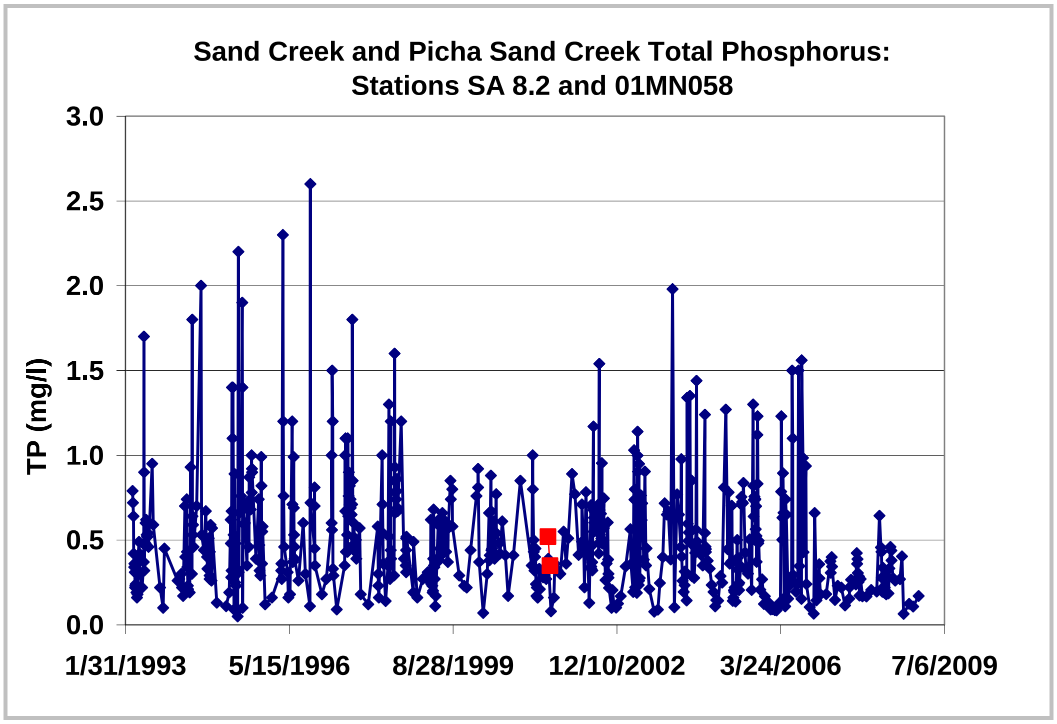

Figure 40. Sand Creek and Picha Creek Total Phosphorus: Stations SA 8.2 and 01MN058

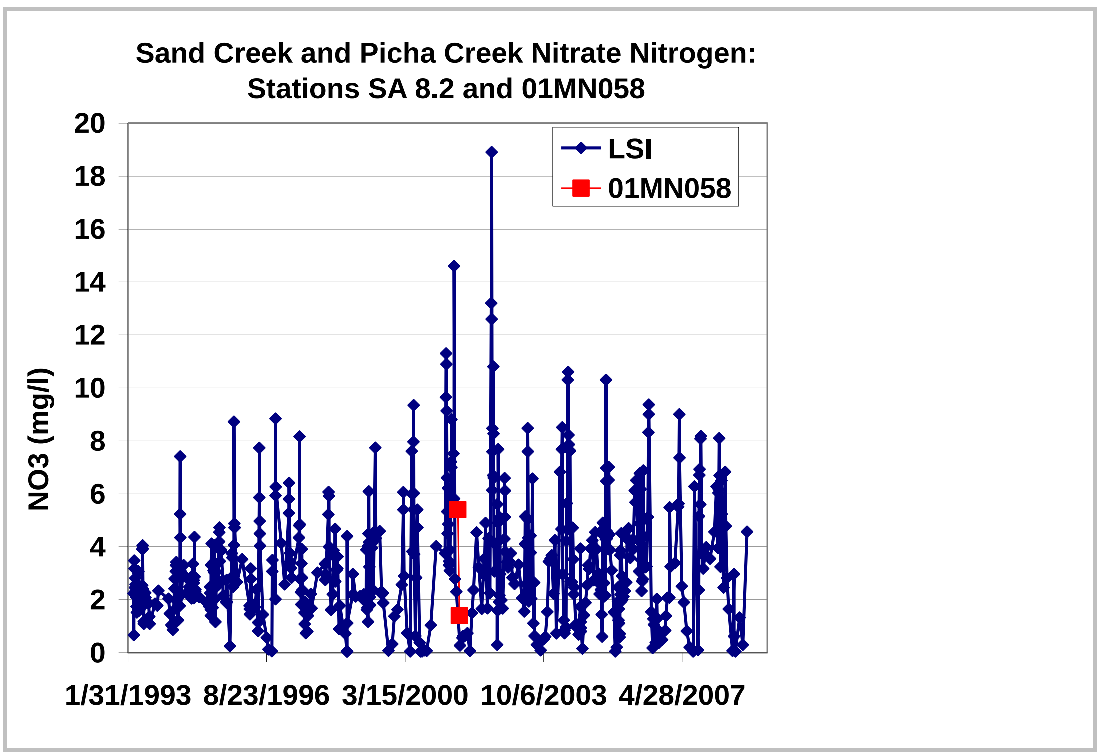

Figure 41. Sand Creek and Picha Creek Nitrate Nitrogen: Stations SA 8.2 and 01MN058

4.1.3 Le Sueur County Ditch Number 54

4.1.3.1 pH

pH was eliminated as a candidate stressor because data indicate Le Sueur County Ditch Number 54 had pH ranges that consistently support all aquatic life. pH measured at Station 03MN077 on July 22, 2003 when fish samples were collected was 8.39. Scott Watershed Management Organization (WMO) staff measured pH in grab samples from Station LPO of Ditch Number 54 during 2007 and 2008 (Figure 29). pH measurements during this period ranged from 7.39 to 8.10 (Figure 42). Because all measurements were within the MPCA standard, which is a minimum of 6.5 and a maximum of 9.0 standard pH units (Minnesota Rule Chapter 7050.0222, subpart 4), pH was eliminated as a candidate stressor.

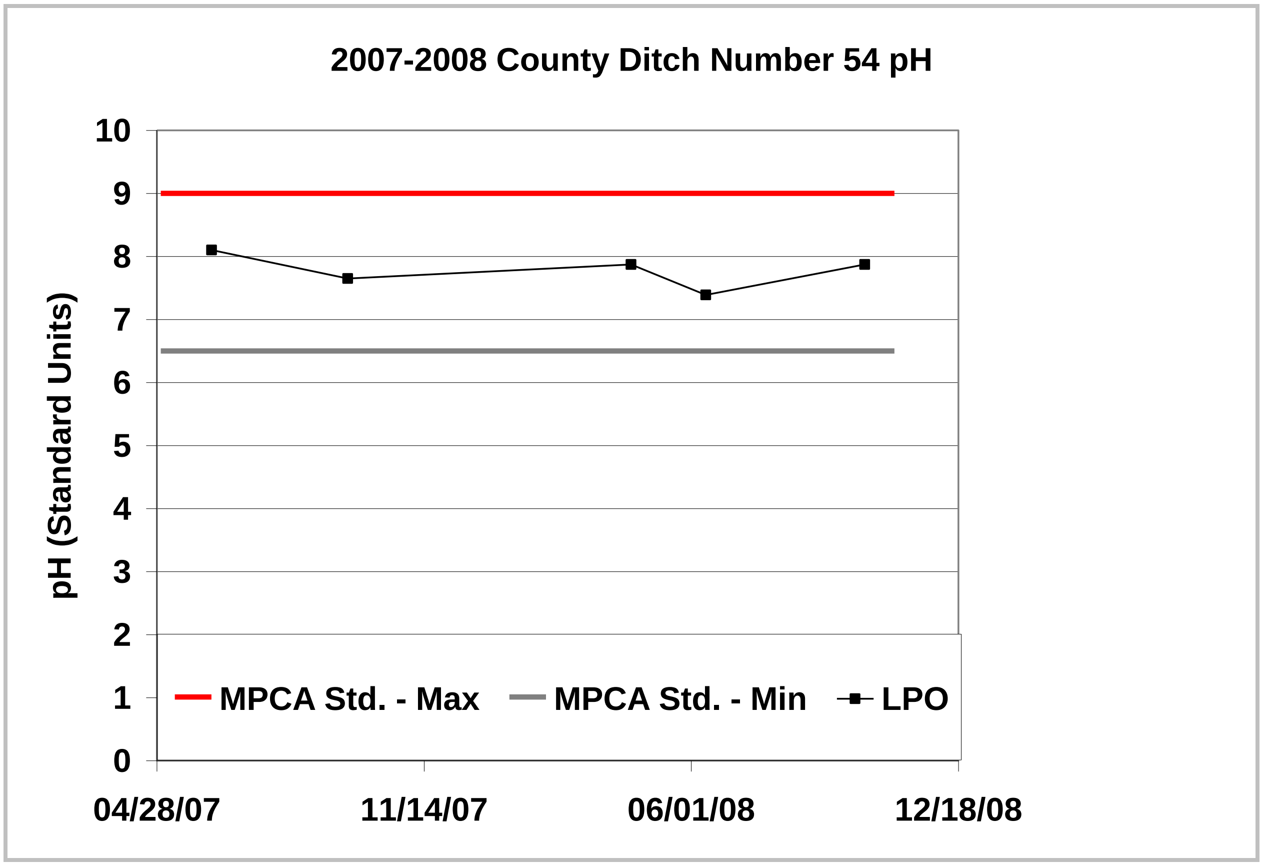

Figure 42. 2007-2008 Le Sueur County Ditch Number 54 pH

4.1.3.2 Temperature

Temperature was eliminated as a candidate cause of impairment because the data from Le Sueur County Ditch Number 54 indicate anthropogenic temperature changes have not occurred. The stream's summer temperatures during 2007 through 2008 are within the range of reference streams within the Minnesota River Basin and indicate it is a stream with coldwater temperature (Figure 43). As discussed previously in Section 4.1.2.2, streams are classified into one of three categories based upon temperature. Coolwater streams have a mean maximum daily temperature between 22 and 24°C during a normal summer, coldwater streams normally have summer maximum daily means below 22°C, and warmwater streams exceed 24°C (Lyons, 1992). During 2007 through 2008, temperatures measured in Le Sueur County Ditch Number 54 ranged from 5.58 through 21.59 °C (Figure 43). Because all temperatures, including summer temperatures, were less than 22°C, Le Sueur County Ditch Number 54 is a stream with coldwater temperature.

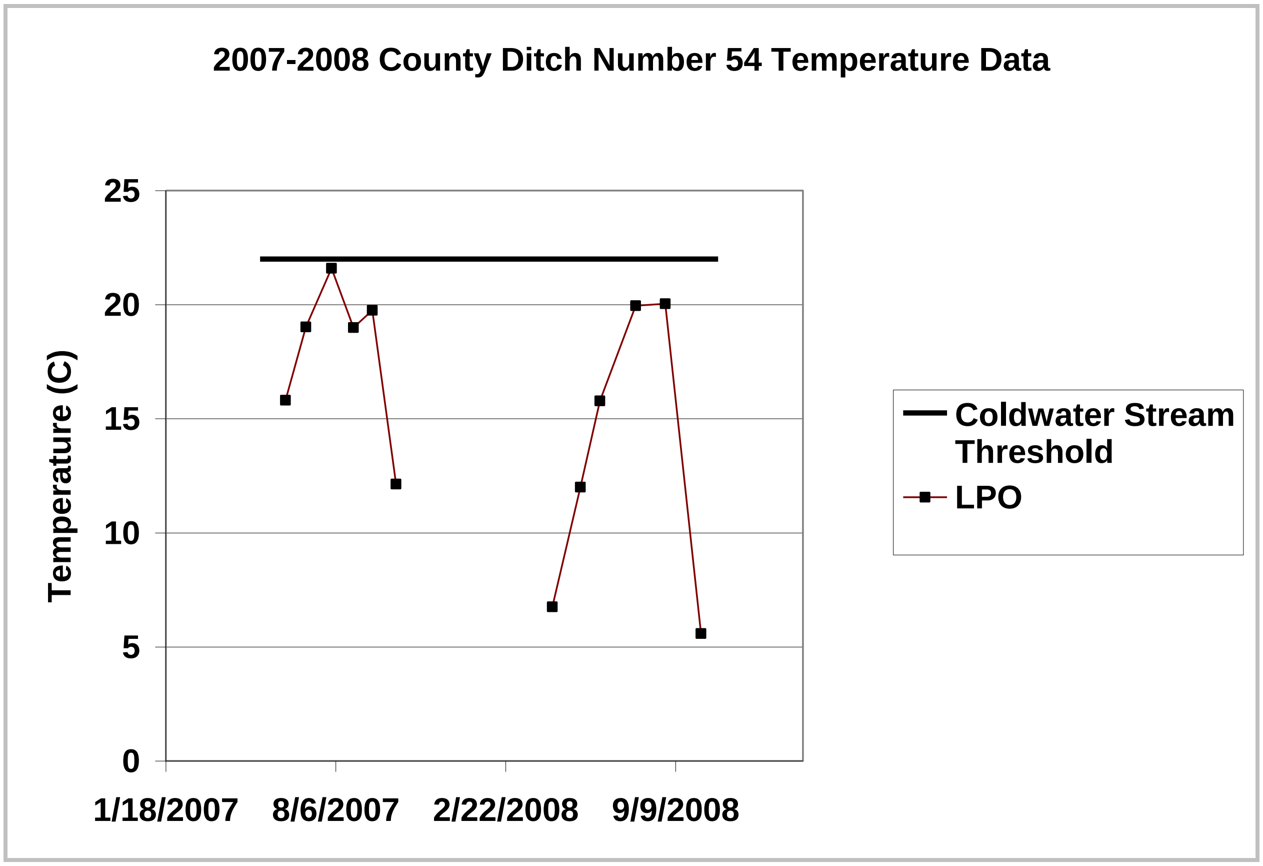

Figure 43. 2007-2008 Le Sueur County Ditch Number 54 Temperature Data

The biological impairment of Le Sueur County Ditch Number 54 was based upon an evaluation using the MRAP IBI which was developed from streams with a combination of coldwater, coolwater, and warmwater temperatures. Because the MRAP IBI was developed from a mixture of stream types, it may not be the best evaluation tool for Le Sueur County Ditch Number 54. The MPCA is currently developing a coldwater IBI. When completed, use of this MPCA coldwater IBI to evaluate Le Sueur

County Ditch Number 54 is recommended because it is a stream with coldwater temperature. The stream's cold temperature may be limiting its fish assemblage.

The MPCA is working to revise its water quality standards to incorporate a tiered aquatic life use framework for rivers and streams and is developing IBIs for all stream types in Minnesota. This work will help guide future management of appropriate Le Sueur County Ditch Number 54 fish populations. Similar to all TMDL Projects, the TMDL Report and Implementation Plan for Le Sueur County Ditch Number 54 can be reevaluated and revised as needed to reflect new policies, standards, classifications, and additional monitoring.

4.1.3.3 Nutrients

Nutrient data were collected from Le Sueur County Ditch Number 54 on July 22, 2003 when fish samples were collected. Nitrate nitrogen and total phosphorus concentrations in July of 2003 were lower in Le Sueur County Ditch 54 than Sand Creek SA 8.2 (Figures 44 and 45). The higher concentrations measured at Sand Creek SA 8.2 did not cause impairment since the biological stations downstream from SA 8.2 are not impaired. Nitrogen and phosphorus concentrations at Le Sueur County Ditch Number 54 are unlikely to stress the fish assemblage since much higher concentrations at Sand Creek SA 8.2 have not caused impairment. Hence, nutrients were eliminated as a candidate stressor.

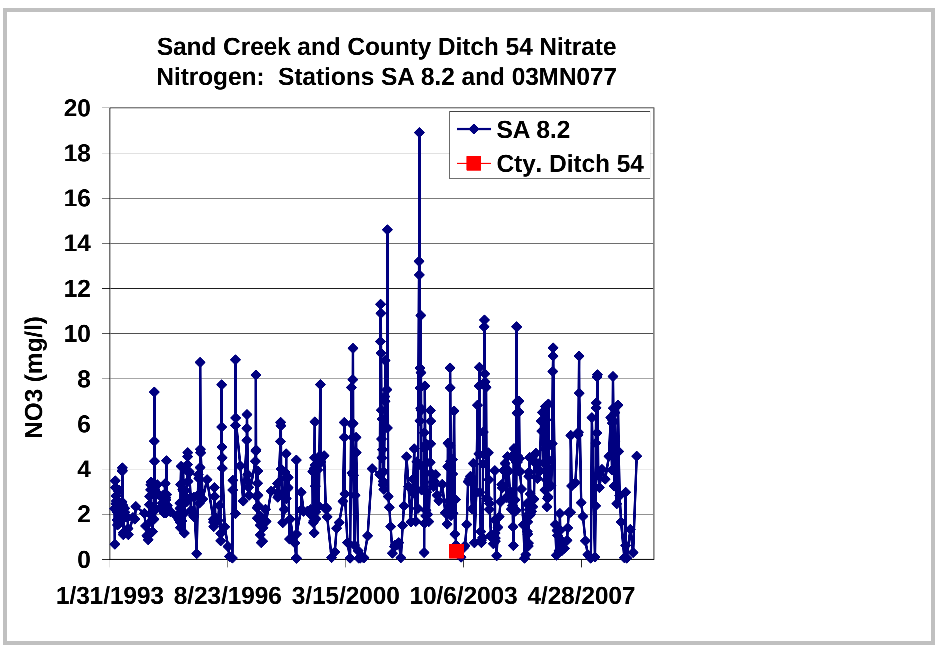

Figure 44. Sand Creek and Le Sueur Le Sueur County Ditch Number 54 Nitrate Nitrogen: Stations SA 8.2 and 03MN077

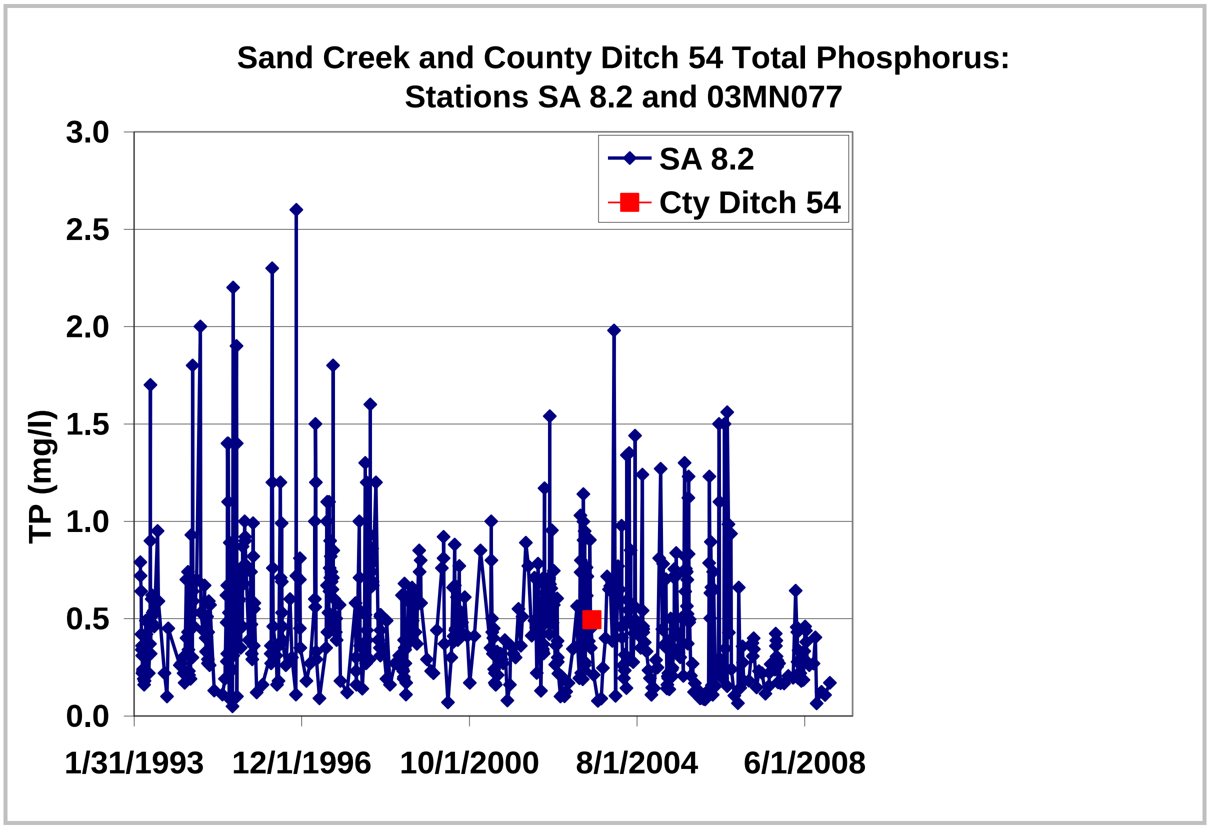

Figure 45. Sand Creek and Le Sueur Le Sueur County Ditch Number 54 Total Phosphorus: Stations SA 8.2 and 03MN077

4.1.4 Porter Creek

4.1.4.1 pH

pH was eliminated as a candidate stressor because data indicate Porter Creek had pH ranges that consistently support all aquatic life. pH was measured when fish samples were collected from Porter Creek on June 25, 1999. Station 99MN003 had a pH of 7.82 and Station 99MN004 had a pH of 7.88. Scott Watershed Management Organization (WMO) staff measured pH from six Porter Creek locations during 2007 and 2008. pH measurements during this period ranged from 7.29 to 8.38 (Figure 46). Because all measurements

Porter Creek, pictured above, had pH measurements that met the MPCA standard at all locations on all sample dates (Picture from Interfluve 2008).

were within the MPCA standard, which is a minimum of 6.5 and a maximum of 9.0 standard pH units (Minnesota Rule Chapter 7050.0222, subpart 4), pH was eliminated as a candidate stressor.

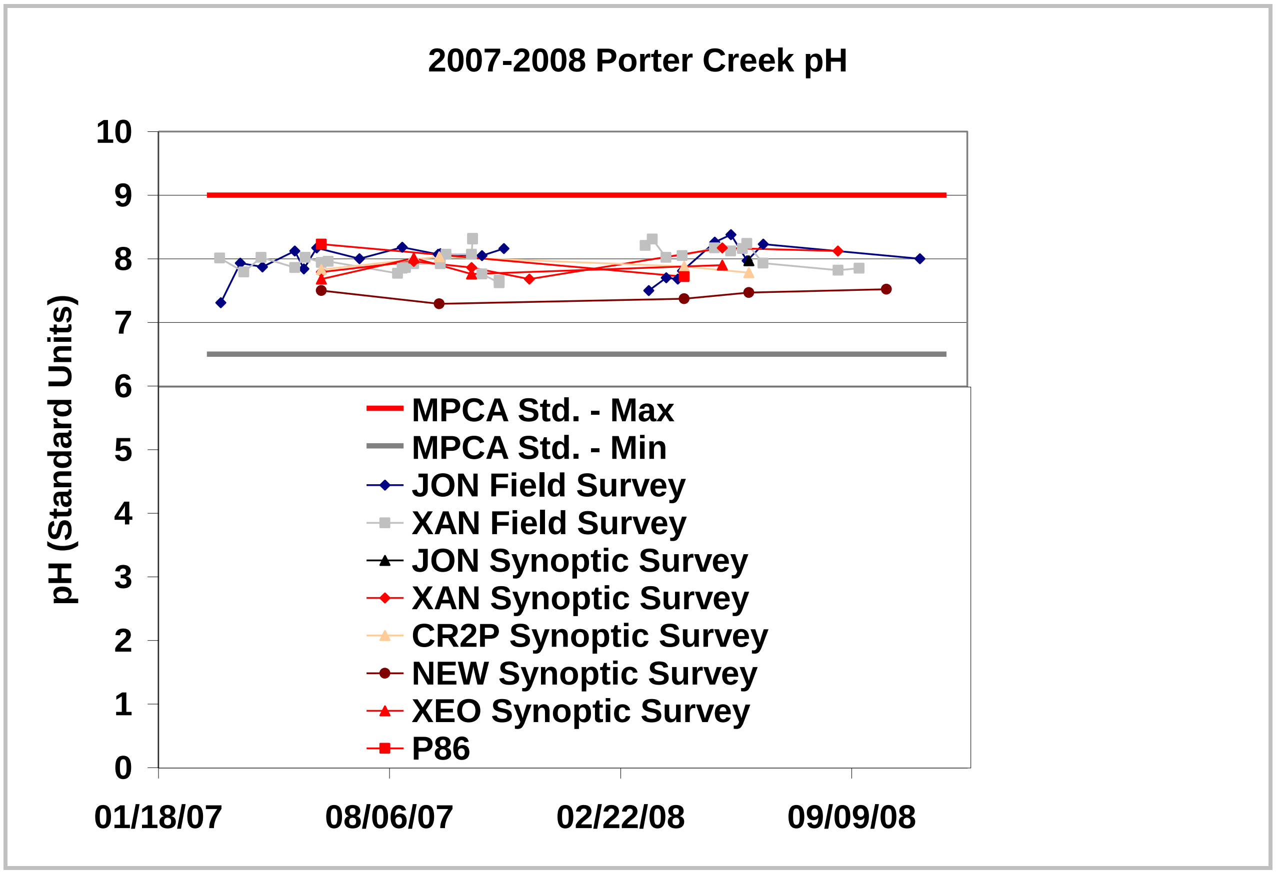

Figure 46. 2007-2008 Porter Creek pH

4.1.4.2 Temperature

Temperature was eliminated as a candidate cause of impairment because all temperature measurements in Porter Creek during 2007 and 2008 were less than the MPCA maximum temperature standard of 86 °F, which is 30 °C (Minnesota Rule Chapter 7050.0222, subpart 4)). During 2007 and 2008, instantaneous temperatures were measured at 6 Porter Creek stations and continuous measurements occurred during July of 2008 at Station XAN (Figure 29). Temperatures in Porter Creek ranged from -0.35 to 26.41°C during the period of measurement (Figures 47 and 48). The maximum summer daily mean temperature at Station XAN during 2008 was 24.1 °C (Figure 48). The data indicate Porter Creek is a warmwater stream. Coolwater streams have a mean maximum daily temperature between 22 and 24°C during a normal summer, coldwater streams normally have summer maximum daily means below 22°C, and warmwater streams exceed 24°C (Lyons, 1992).

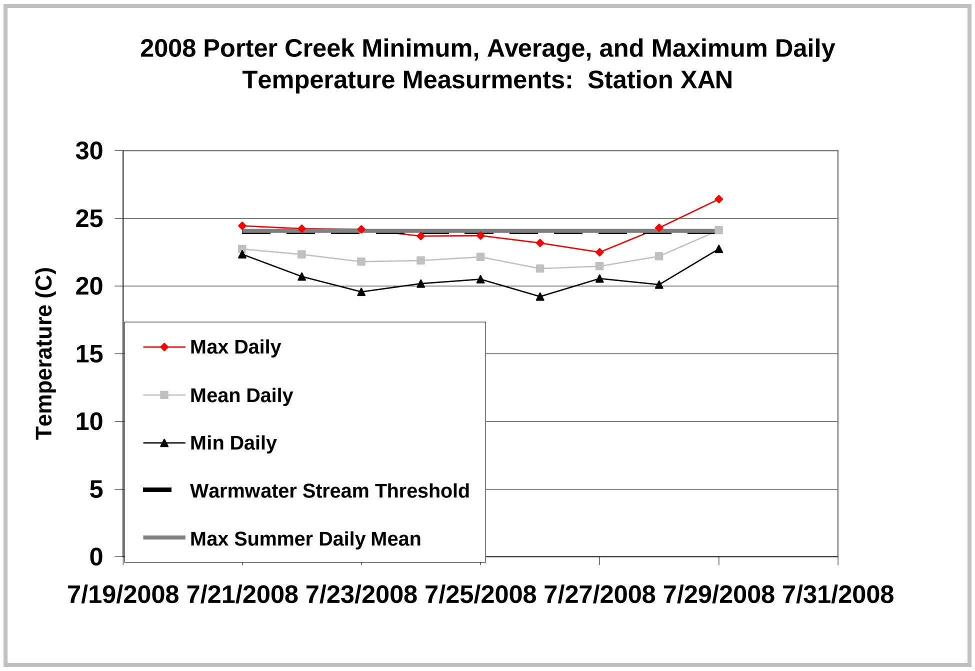

Figure 47. 2008 Porter Creek Minimum, Average, and Maximum Daily Temperature Measurements: Station XAN

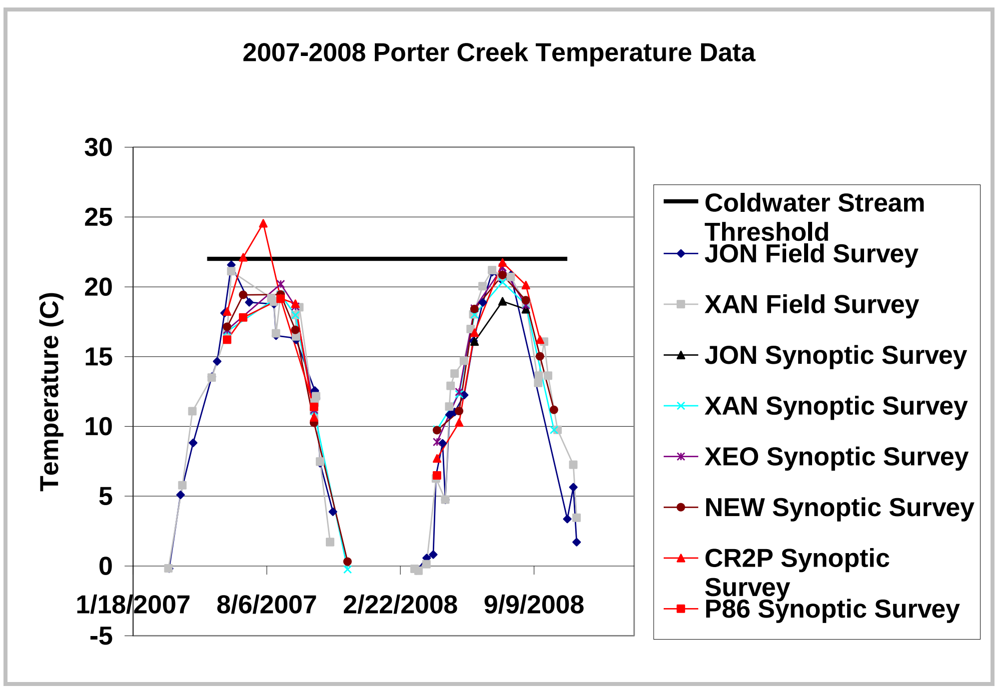

Figure 48. 2007-2008 Porter Creek Temperature Data

Porter Creek temperatures at Station XAN, pictured above, ranged from -0.35 to 26.41 °C during 2007 through 2008 (Picture from Interfluve 2008).

Instantaneous temperature measurements from impaired (i.e., Stations JON and P86) and unimpaired (Station XAN) reaches of Porter Creek were generally similar during 2007 and 2008 (Figures 48 and 49). Because temperature measurements consistently met MPCA criteria and temperatures in unimpaired and impaired reaches of Porter Creek were similar, temperature was eliminated as a candidate stressor of the fish community.

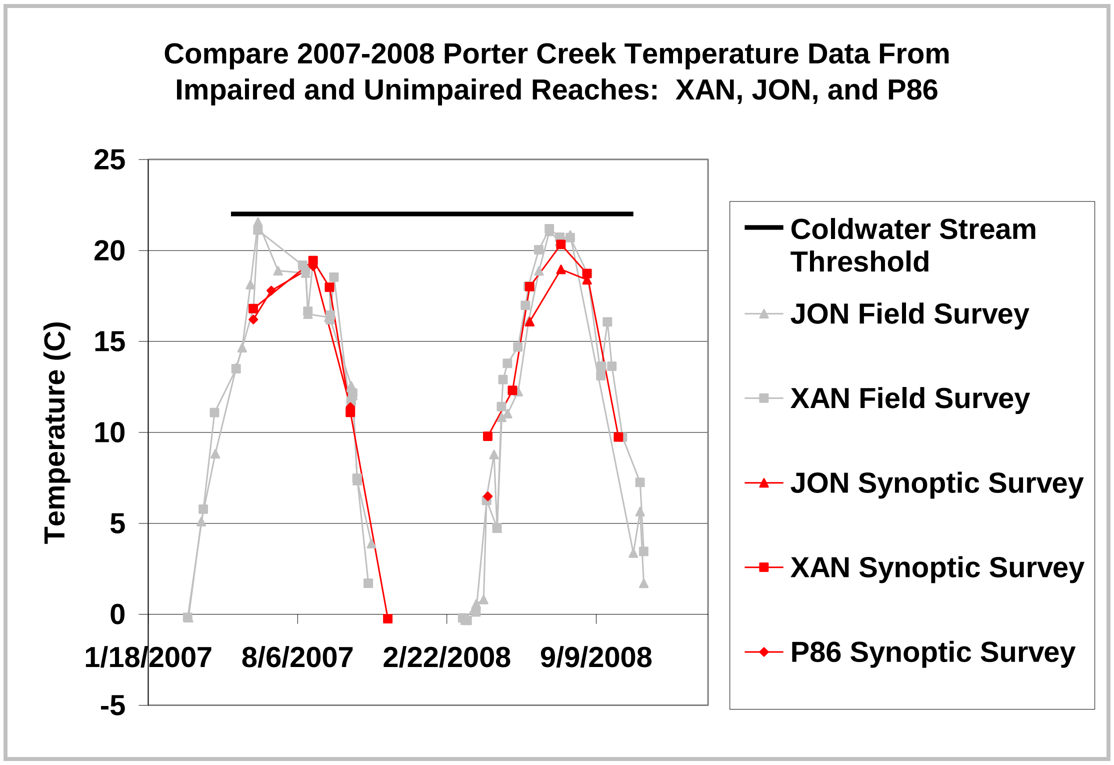

Figure 49. Compare 2007-2008 Porter Creek Temperature Data From Impaired and Unimpaired Reaches: XAN, JON, and P86

4.1.3.3 Ionic Strength

Ionic strength was eliminated as a candidate stressor because data indicate Porter Creek had specific conductance and chloride levels that consistently support all aquatic life. Specific conductance was measured when fish samples were collected from Porter Creek on June 25, 1999. Station 99MN003 had a specific conductance of 695 and Station 99MN004 had a specific conductance of 502 µhoms/cm @ 25 °C which are less than the MPCA standard of 1,000 µhoms/cm @ 25 °C (Minnesota Rule Chapter 7050.0224, Subpart 2). As shown in Figure 50, specific conductance levels measured at six Porter Creek locations during 2007 and 2008 were consistently less than the MPCA standard of 1,000 µhoms/cm @ 25 °C (Minnesota Rule Chapter 7050.0224, Subpart 2). Measurements ranged from a low of 419 µhoms/cm @ 25 °C to a high of 948 µhoms/cm @ 25 °C. Chloride measurements at Stations JON and XAN during 2005 through 2008 met both acute and chronic standards (Minnesota Rule Chapter 7050.0222, Subpart 4). Measurements ranged from a low of 8 mg/L to a high of 88 mg/L (Figure 51). Four day average chloride concentrations were estimated from continuous specific conductance measurements at Station XAN during July of 2008. As shown in Figure 52, all estimated values were less than the MPCA chronic standard of 230 mg/L that is based upon a 4-day average (Minnesota Rule Chapter 7050.0222, subpart 4). Because neither specific conductance nor chloride exceeded the MPCA standards which protect all aquatic life, ionic strength was eliminated as a candidate stressor.

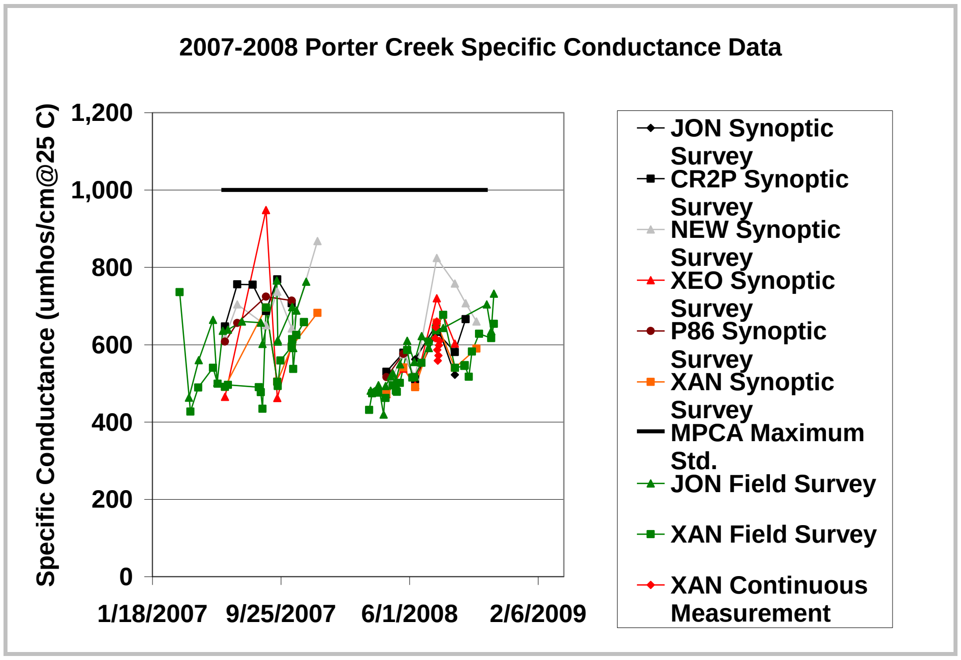

Figure 50. 2007-2008 Porter Creek Specific Conductance Data

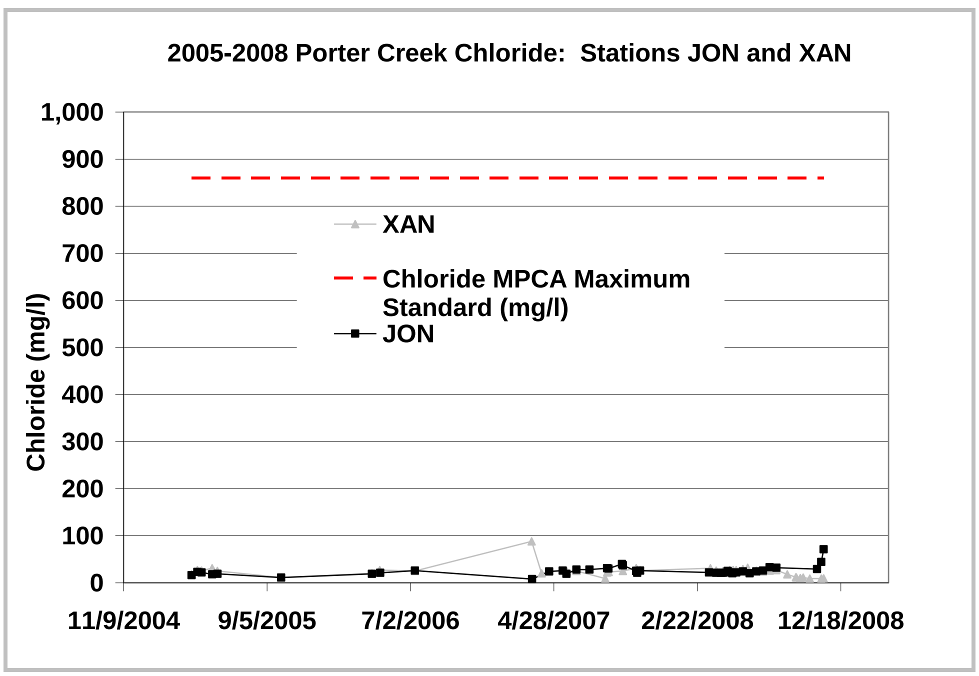

Figure 51. 2005-2008 Porter Creek Chloride: Stations JON and XAN

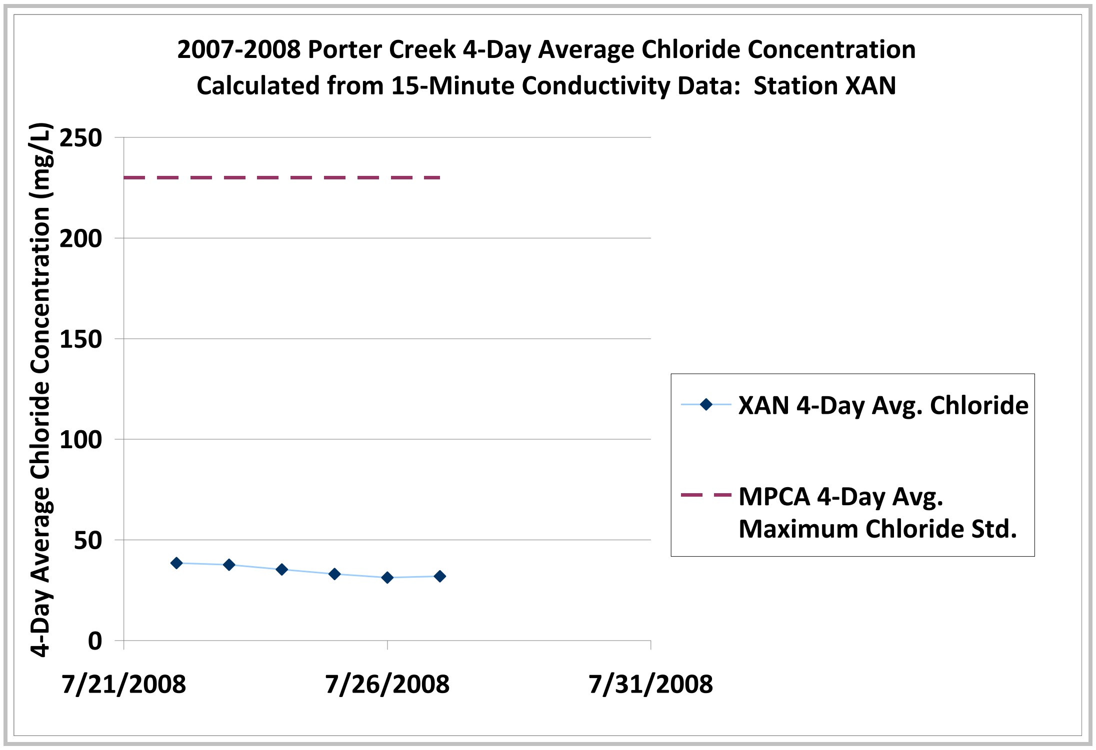

Figure 52. 2008 Porter Creek 4-Day Average Chloride Concentration Calculated from 15-Minute Conductivity Data: Station XAN

4.1.3.4 Nutrients

Nutrients were eliminated as a candidate stressor because the unimpaired reach of Porter Creek consistently had highest total phosphorus loads and flow weighted mean concentrations. FLUX modeling results of total phosphorus data collected from Porter Creek during 2005 through 2008 indicate total phosphorus loads and concentrations consistently increased between upstream and downstream reaches of Porter Creek (Table 7). Unimpaired Station XAN consistently had highest total phosphorus loads and concentrations and impaired Station JON consistently had lowest loads and concentrations (Table7). Because the unimpaired reach of Porter Creek had the highest phosphorus loads and flow weighted concentrations, nutrients do not appear to be a stressor causing fish MRAP IBI impairment in the stream.

Table 7. Porter Creek Total Phosphorus Annual Load, Total Phosphorus Flow Weighted Mean Concentration, and Annual Flow Volume: Stations JON and XAN

Station	TP Annual Load (kg)			
	2005	2006	2007	2008
JON	2,059	1,152	1,907	1,321
XAN	18,227	8,902	9,497	8,456

Table 7 (Continued). Porter Creek Total Phosphorus Annual Load, Total Phosphorus Flow Weighted Mean Concentration, and Annual Flow Volume: Stations JON and XAN

Station	TP Flow-weighted Mean Concentration (ppb)			
	2005	2006	2007	2008
JON	323	330	355	321
XAN	423	414	421	424

Station	Annual Flow Volume (ft^3)			
	2005	2006	2007	2008
JON	2.25E+08	1.23E+08	1.90E+08	1.45E+08
XAN	1.52E+09	7.60E+08	7.96E+08	7.05E+08

4.1.3.5 Metals

Metals were eliminated as a candidate stressor because metals have generally met the MPCA standard and the few exceedances that have occurred are associated with sample quality issues.

Metals samples were collected from Stations JON and XAN (Figure 29) during 2005 through 2006. Station JON is located downstream from impaired biological station 99MN003 and Station XAN is located at unimpaired biological station 99 MN004. Metals concentrations measured in Porter Creek were compared to both the chronic (CS) and acute toxicity (FAV) standard. Both chronic and acute toxicity standards vary with total hardness and are calculated from equations provided for each metals species (Minnesota Rule Chapter 7050.0222, subpart 4). The chronic standard protects aquatic life from long-term exposure to metals while acute toxicity standards protect aquatic life from short-term exposure to metals. The chronic standard is set at a level to protect the aquatic community from any long-term adverse effects. The acute toxicity standard (FAV) is set at a level designed to protect 95 percent of the species in an aquatic community from acute effects 95 percent of the time.

As shown in Figures 53 through 64, all metals data from Porter Creek met the acute toxicity standard (FAV) during all sample events. However, on October 5, 2005 one copper and one lead value from Station JON and one lead value from Station XAN failed to meet the chronic standard. The Minneapolis and St. Paul International Airport repots 4.61 inches of precipitation occurred on October 4, 2005. Hence, the samples failing to meet the chronic standard were stormwater samples. Sample quality issues are the likely cause of the high metals concentrations in these samples. Per personal communication with Scott County staff, the intake hose of the composite sampler was likely close to the bottom of the stream and then when the stormflow occurred, a lot of sediment was picked up in the sample (Nelson, 2009). The metals sampling effort was repeated in 2006 and no exceedances were observed.

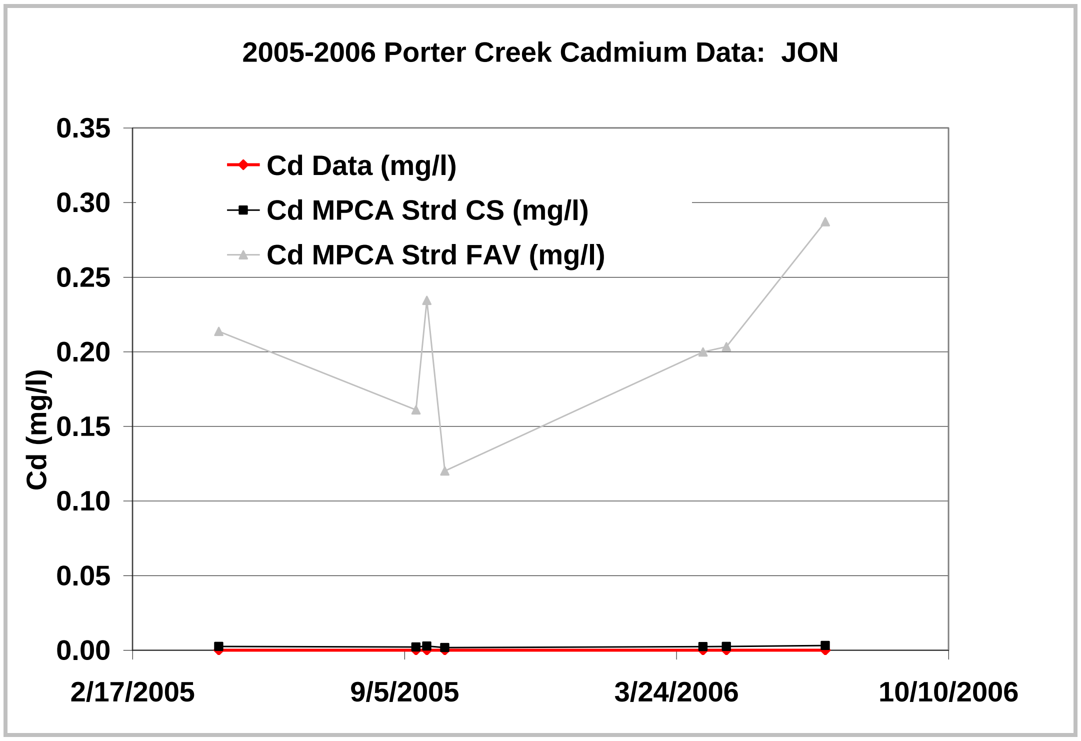

Figure 53. 2005-2006 Porter Creek Cadmium Data: JON

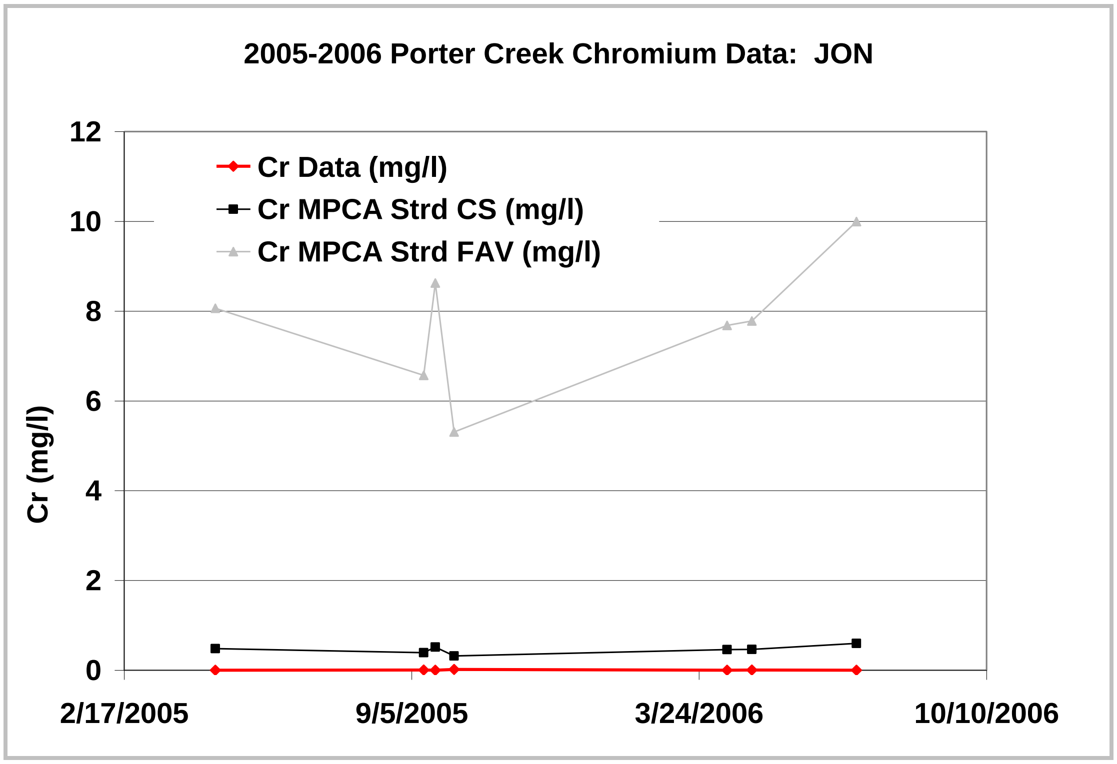

Figure 54. 2005-2006 Porter Creek Chromium Data: JON

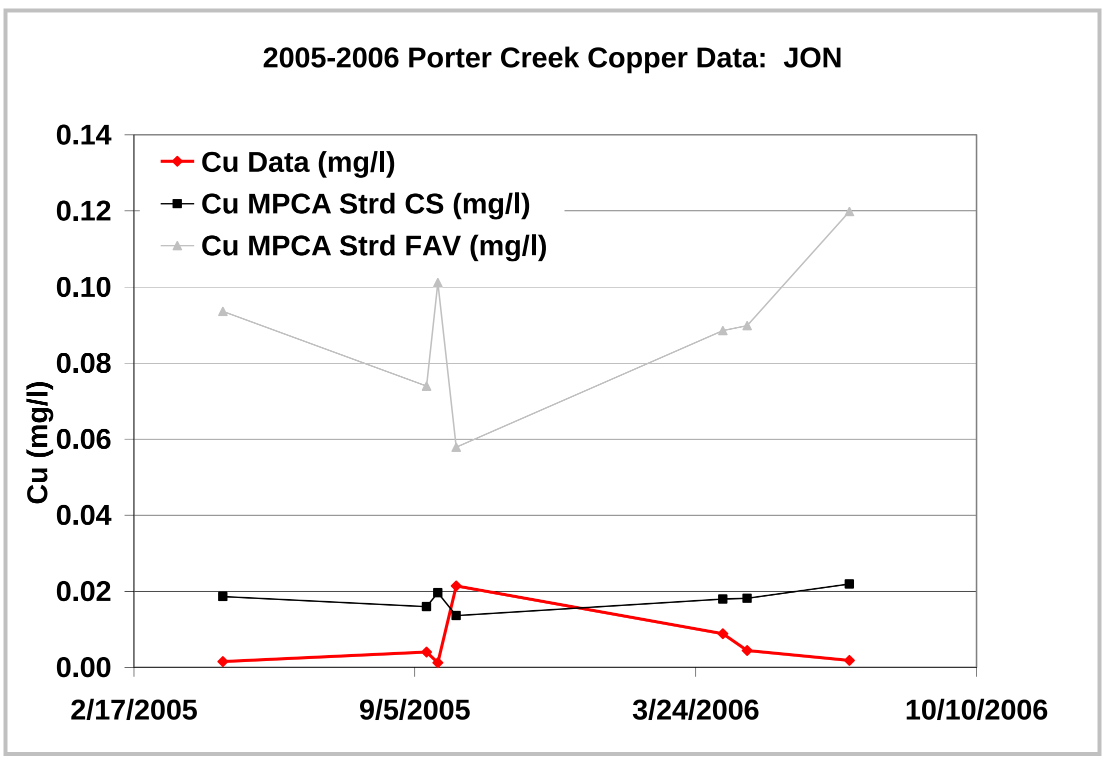

Figure 55. 2005-2006 Porter Creek Copper Data: JON

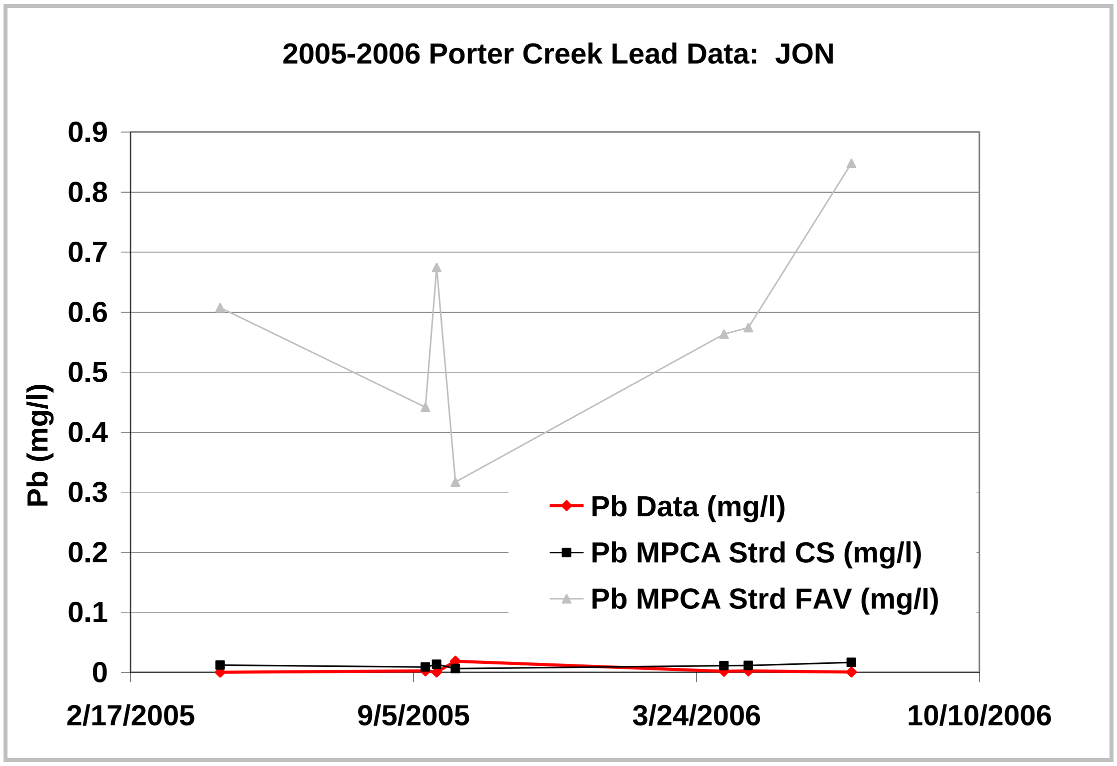

Figure 56. 2005-2006 Porter Creek Lead Data: JON

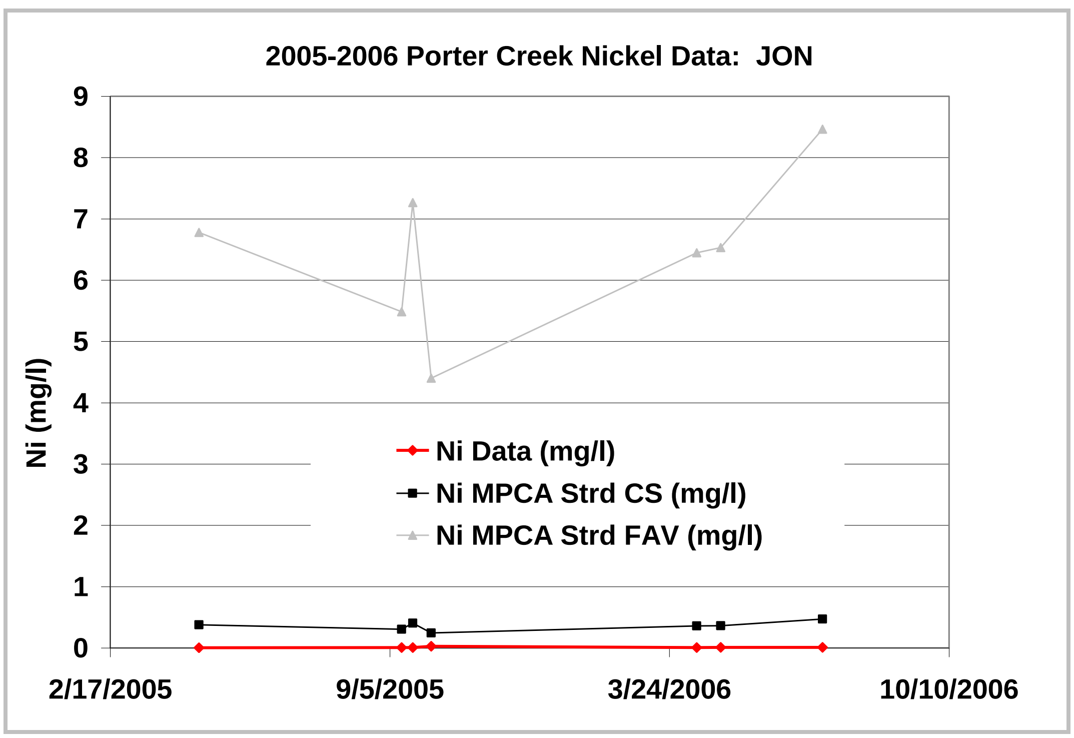

Figure 57. 2005-2006 Porter Creek Nickel Data: JON

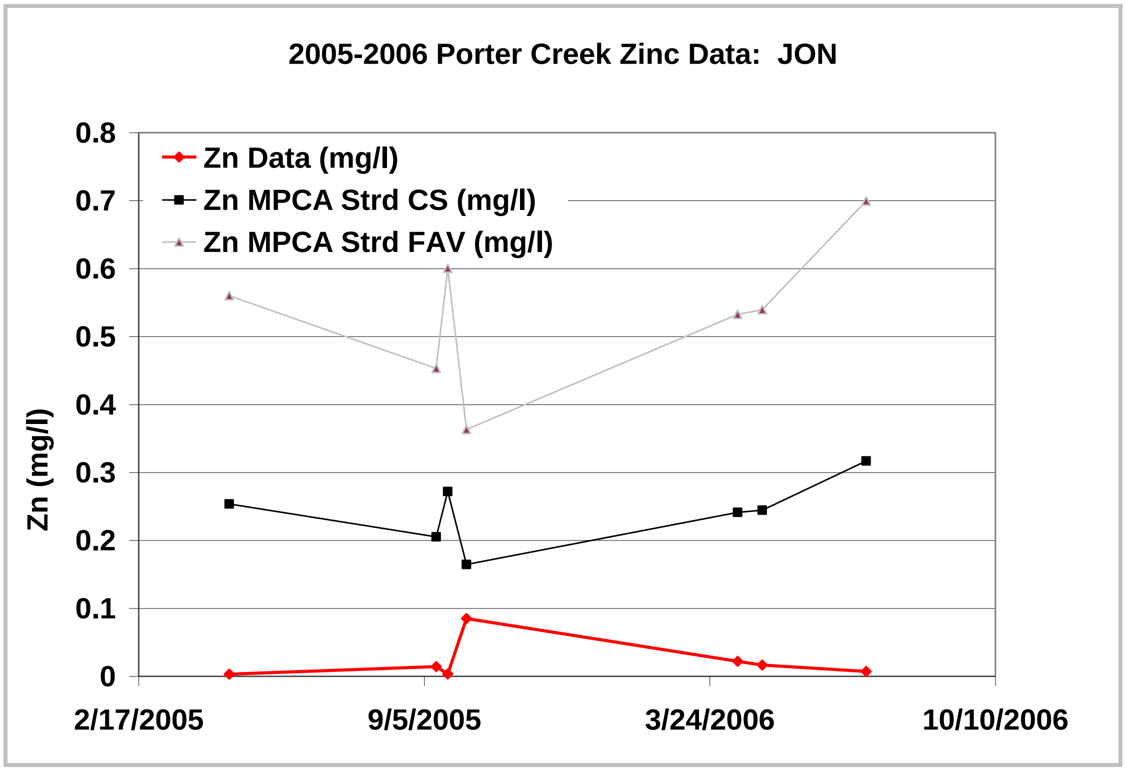

Figure 58. 2005-2006 Porter Creek Zinc Data: JON

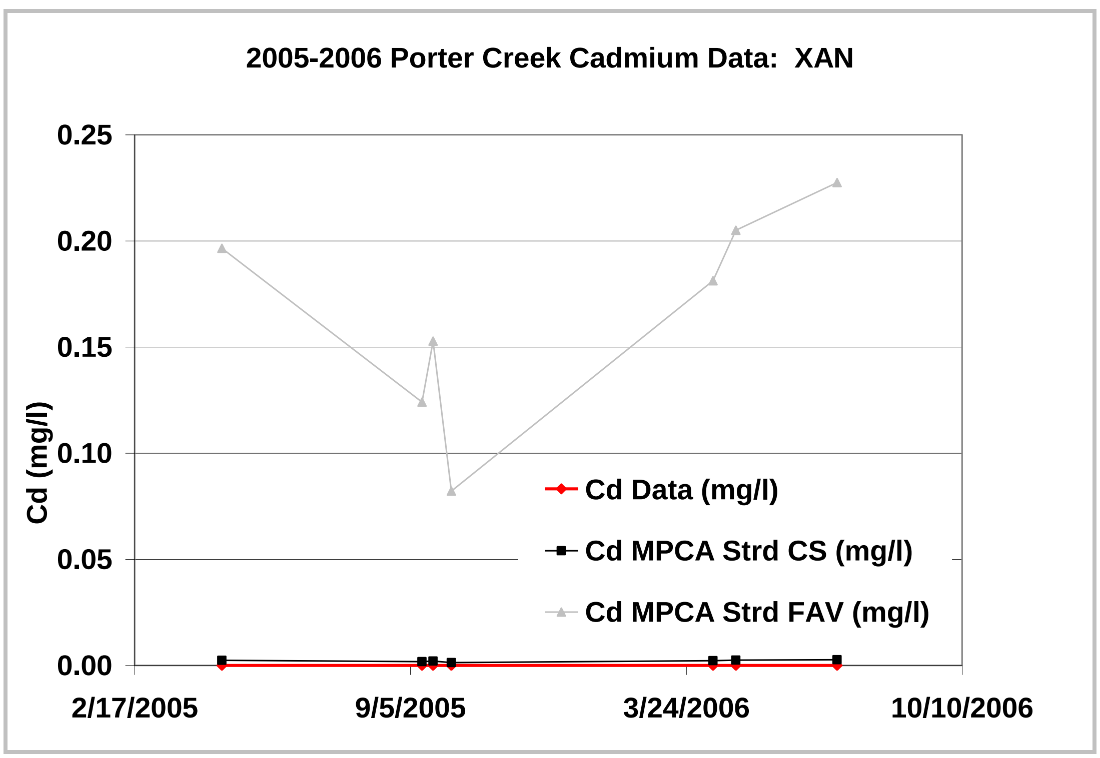

Figure 59. 2005-2006 Porter Creek Cadmium Data: XAN

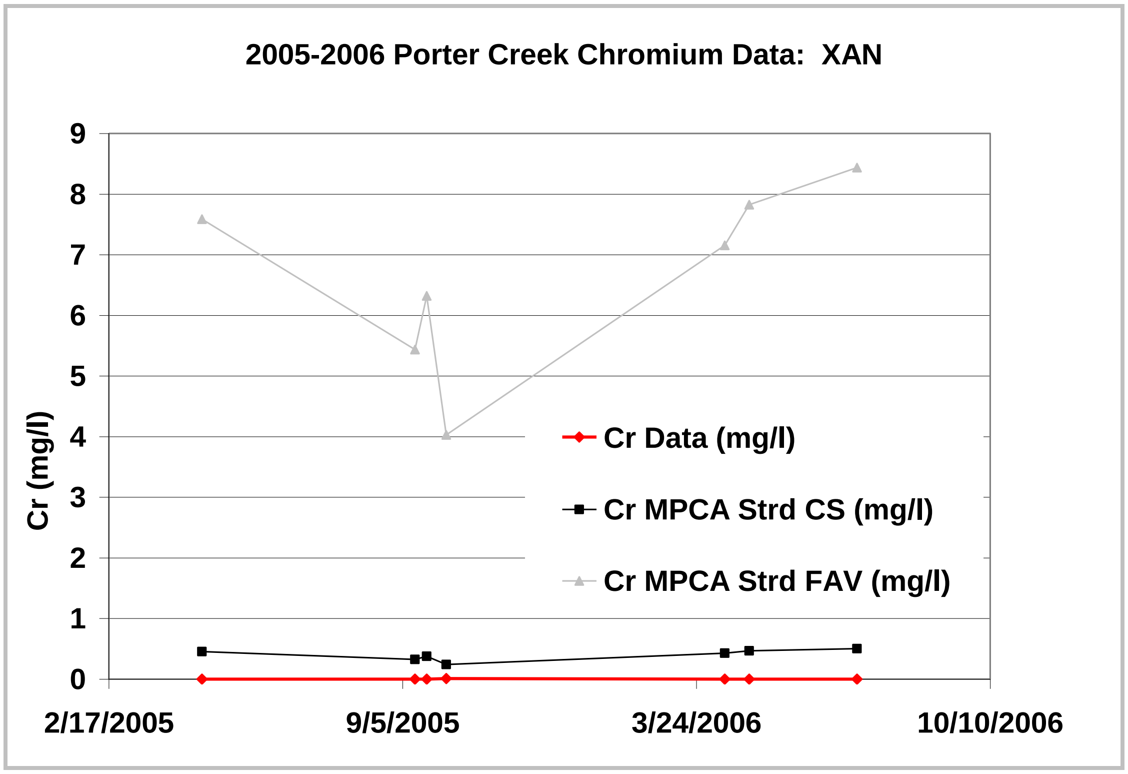

Figure 60. 2005-2006 Porter Creek Chromium Data: XAN

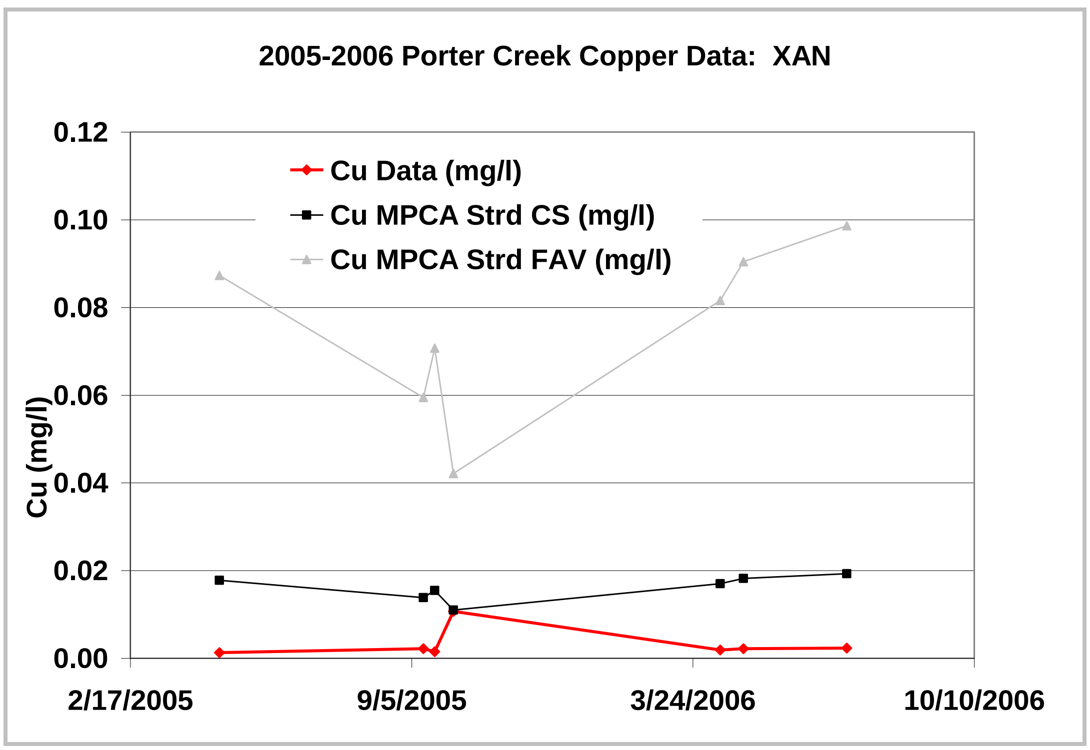

Figure 61. 2005-2006 Porter Creek Copper Data: XAN

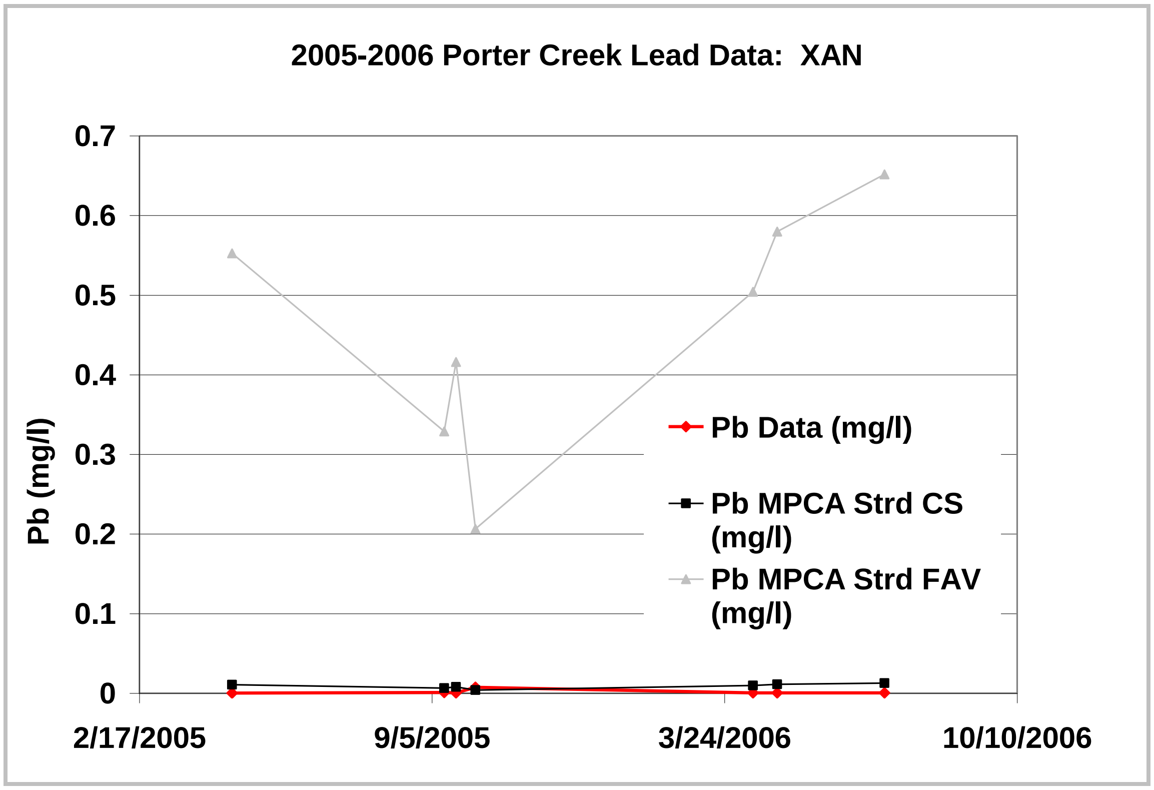

Figure 62. 2005-2006 Porter Creek Lead Data: XAN

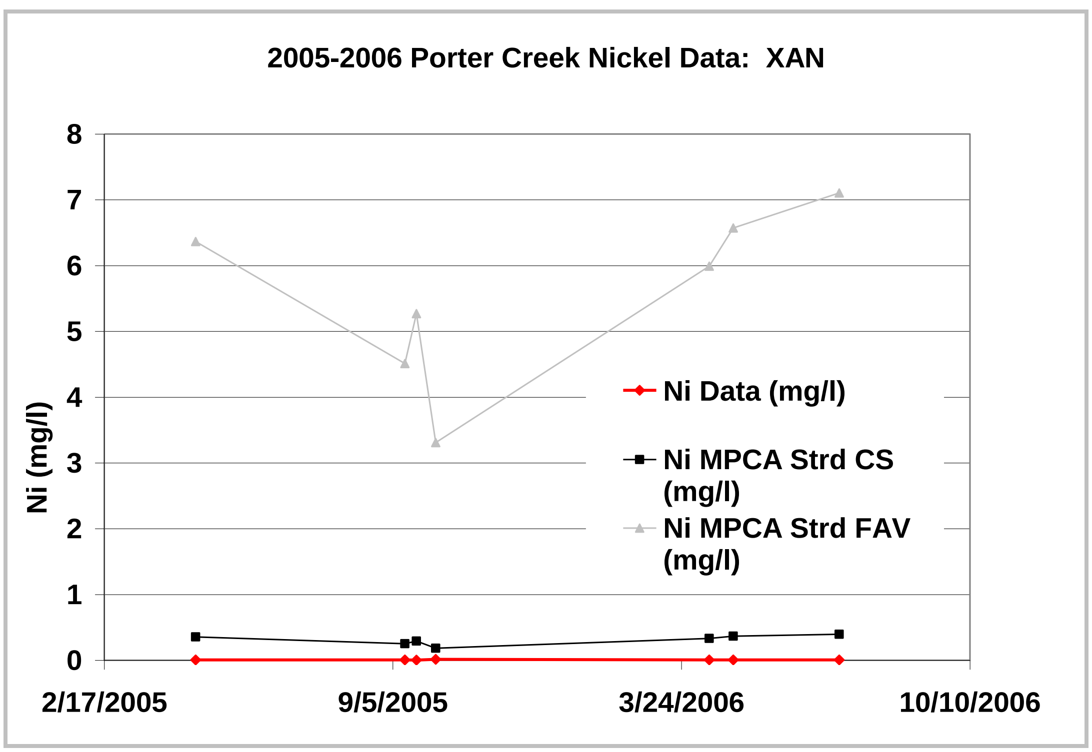

Figure 63. 2005-2006 Porter Creek Nickel Data: XAN

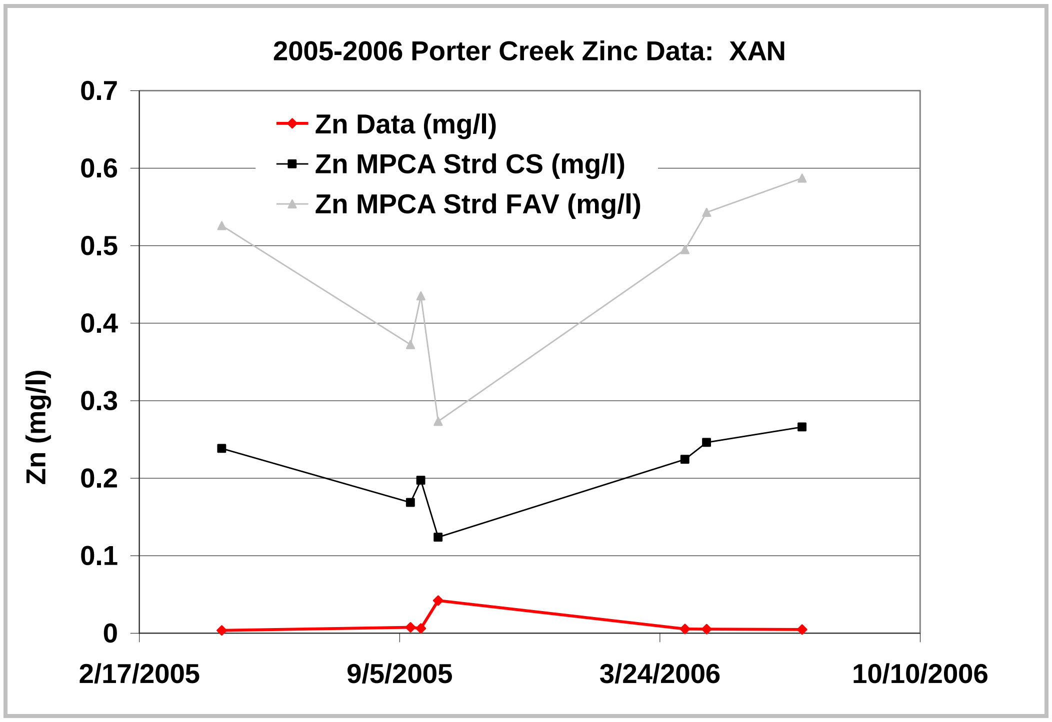

Figure 64. 2005-2006 Porter Creek Zinc Data: XAN

4.2 Data Collection Needed

4.2.1 Sand Creek

4.2.1.1 Sediment

Sediment can neither be eliminated as a candidate stressor nor validated until additional data are collected. Current data indicates that sediment alone is not a cause of the stream's fish impairment. However, data are not available to either confirm or negate the hypothesis that sediment and habitat fragmentation are co-stressors. It is possible that sediment stresses fish both upstream and downstream of The Falls, but that the fish community downstream from The Falls is replenished by fish migration from the Minnesota River. If additional data collection validates this hypothesis, then sediment and habitat fragmentation would both be candidate causes of impairment. Hence, flow and fish data should be collected concurrently with sediment data to determine sediment impacts upon fish and to determine whether migration of fish from the Minnesota River can replenish the stream's fishery downstream from The Falls.

Sediment without the effect of habitat fragmentation was eliminated as a candidate stressor because the reach of Sand Creek with unimpaired fish MRAP IBI scores consistently had the highest sediment concentrations and highest total suspended solids and volatile suspended solids loads.

FLUX modeling results of total suspended solids and volatile suspended solids data collected from Sand Creek during 2005 through 2008 indicate both total and volatile suspended solids loads and flow-weighted mean concentrations consistently increased between upstream and downstream reaches of Sand Creek (Table 8). Station SA 8.2 consistently had highest loads (Table 8).

Table 8. Sand Creek Total and Volatile Suspended Solids Annual Loads, Total and Volatile Suspended Solids Flow Weighted Mean Concentrations, and Annual Flow Volume: Stations SA 8.2, CR2, and 145

	TSS Annual Load (kg)			
Station	2005	2006	2007	2008
SA 8.2	43,075,590	27,437,870	32,872,030	17,393,790
CR2	5,469,196	3,460,729	4,268,613	2,601,617
145	-	-	1,172,961	856,926

	TSS Flow-weighted Mean Concentration (ppb)			
Station	2005	2006	2007	2008
SA 8.2	318,152	324,857	336,424	237,268
CR2	120,968	125,517	129,478	111,743
145	-	-	43,565	43,456

	VSS Annual Load (kg)			
Station	2005	2006	2007	2008
SA 8.2	4,662,852	2,629,190	3,324,963	2,305,579
CR2	1,053,356	703,986	731,644	475,057
145	-	-	389,638	282,978

	VSS Flow-weighted Mean Concentration (ppb)			
Station	2005	2006	2007	2008
SA 8.2	34,439	31,129	34,029	31,450
CR2	23,298	25,533	22,193	20,404
145	-	-	14,472	14,350

	Annual Flow Volume (ft^3)			
Station	2005	2006	2007	2008
SA 8.2	4.78E+09	2.98E+09	3.45E+09	2.59E+09
CR2	1.60E+09	9.74E+08	1.16E+09	8.22E+08
145	-	-	9.51E+08	6.96E+08

Sand Creek biological stations downstream from Station SA 8.2 experienced unimpaired fish MRAP IBI scores while upstream stations had impaired fish MRAP IBI scores. Because SA 8.2, which represents the water quality of the downstream unimpaired reaches of Sand Creek, had highest sediment loads and concentrations, sediment does not appear to be a stressor causing fish MRAP IBI impairment in Sand Creek. However, as noted above, additional data collection is needed to determine whether sediment and habitat fragmentation are co-stressors in the impaired stream reach upstream from The Falls.

4.2.1.2 Ionic Strength

Ionic strength can neither be eliminated as a candidate stressor nor validated until additional data are collected. Current data indicates that ionic strength alone is not a cause of the stream's fish impairment. However, data are not available to either confirm or negate the hypothesis that ionic strength and habitat fragmentation are co-stressors. It is possible that ionic strength stresses fish both upstream and downstream of The Falls, but that the fish community downstream from The Falls is replenished by fish migration from the Minnesota River. If additional data collection validates this hypothesis, then ionic strength and habitat fragmentation would both be candidate causes of impairment. Hence, flow and fish data should be collected concurrently with specific conductance and chloride data to determine ionic strength impacts upon fish and to determine whether migration of fish from the Minnesota River can replenish the stream's fishery downstream from The Falls.

Ionic strength (i.e., without the effect of habitat fragmentation) would be eliminated as a candidate stressor because the reach of Sand Creek with unimpaired fish MRAP IBI scores consistently had the highest frequency of high specific conductance levels. Relatively high (>1,000 µmhos/cm @ 25° C) specific conductance values have been measured in both impaired and unimpaired reaches of Sand Creek. Minnesota Rule Chapter 7050 (Minn. R. 7050) specifies standards applicable to Minnesota streams to protect aquatic life. Sand Creek is required to meet the most restrictive water quality standard for Classes 2B, 2C, or 2D; 3A, 3B, 3C,or 3D; 4A and 4B or 4C; and 5 (Minn. R. Pt. 7050.0220 and Minn. R. Pt. 7050.040). Hence, the specific conductance standard applicable to Sand Creek is the standard specified for Class 4A waters – values are not to exceed 1,000 µmhos/cm @ 25° C (Minnesota Rule Chapter 7050.0224 Subpart 2).

The Scott County WMO continuously measured specific conductance at Sand Creek Stations 145, CR8, and LSI during selected periods of 2008:

- 145 – June 2 through 9
- CR8 – July 5 through16, August 8 through 15, September 10 through 17, and October 2 through11
- LSI – August 6 through14

As shown in Figure 29, Station 145 is located upstream from unimpaired Station 07MN056, Station CR8 is located immediately downstream from impaired Station 07MN055, and LSI is located at unimpaired Station 07MN034. The data, shown in Figure 65 were compared with the MPCA specific conductance standard to protect all aquatic life, which is a maximum of 1,000 µmhos/cm @ 25° C (Minnesota Rule Chapter 7050.0224 Subpart 2). The data indicate Sand Creek specific conductance values were above the MPCA standard at the following frequencies:

- 145 – 22 percent (2 of 9 days)
- CR8 – 51 percent (19 of 37 days)
- LSI – 67 percent (6 of 9 days)

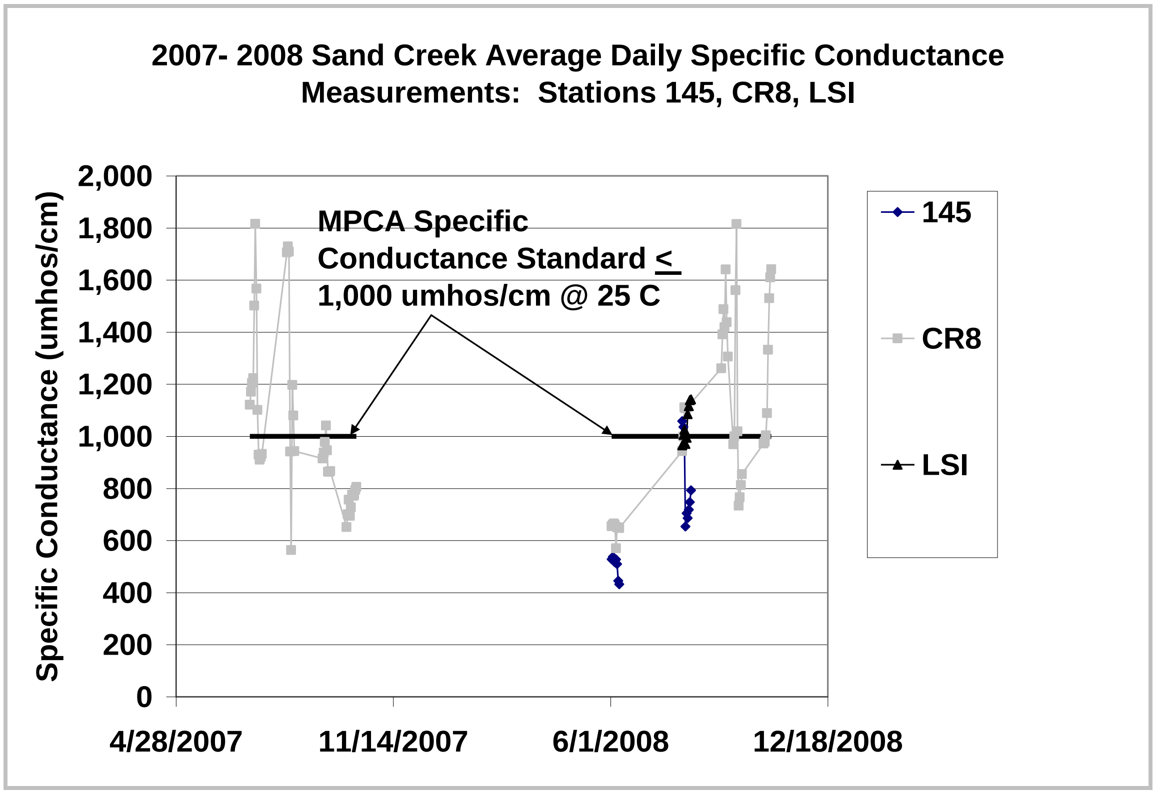

Figure 65. 2007-2008 Sand Creek Average Daily Specific Conductance Measurements: Stations 145, CR8, and LSI

The data indicate the impaired reach of Sand Creek (CR8) failed to meet the MPCA standard more than half of the days in which measurements occurred, while a downstream unimpaired reach (LSI) failed to meet the MPCA standard during two thirds of the days in which measurements occurred.

In addition to continuous specific conductance measurements at three Sand Creek locations, Scott County WMO completed instantaneous specific conductance measurements at 3 locations during selected days of 2005 through 2008. As shown in Figure 29, Stations 145 and CR2 are located upstream from unimpaired Station 07MN056 and Station LSI is located at unimpaired Station 07MN034. A total of 56 measurements were taken at Station 145 during 2007 through 2008, 105 measurements at Station CR2 during 2005 through 2008, and 66 measurements at Station LSI during 2007 through 2008. The data, shown in Figure 66 were compared with the MPCA specific conductance standard to protect all aquatic life, which is a maximum of 1,000 µmhos/cm @ 25° C (Minnesota Rule Chapter 7050.0224 Subpart 2). The data indicate Sand Creek specific conductance values were above the MPCA standard at the following frequencies:

- 145 – 36 percent (20 of 56 measurements) during 2007 through 2008;
- CR2 – 25 percent (14 of 56 measurements) during 2007 through 2008 and 14 percent (15 of 105 measurements) during 2005 through 2008;
- LSI – 41 percent (27 of 66 measurements) during 2007 through 2008.

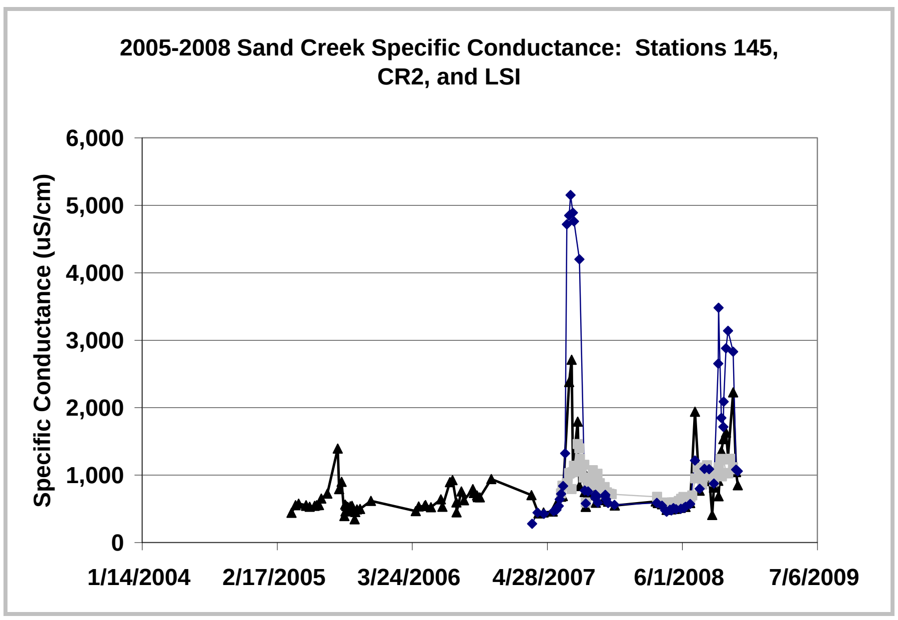

Figure 66. 2005-2008 Sand Creek Specific Conductance: Stations 145, CR2, and LSI

The data indicate the unimpaired reaches of Sand Creek consistently observed high specific conductance measurements during 2007 and 2008. Because high specific conductance levels were consistently observed at both impaired and unimpaired locations, ionic strength in the absence of habitat fragmentation does not appear to be a candidate stressor.

An evaluation of Sand Creek chloride data indicates chloride is not the ion causing Sand Creek specific conductance levels to exceed MPCA standards. As shown in Figure 67, chloride concentrations measured at Stations CR2 and SA 8.2 (locations shown on Figure29) during 2005 through 2008 were less than the MPCA acute maximum standard of 860 mg/L (Minnesota Rule Chapter 7050.0222, subpart 4). However, eight analytical results from CR2 during the 2007 through 2008 period exceeded the chronic standard of 230 mg/L (Minnesota Rule Chapter 7050.0222, subpart 4). The high values ranged from 283 mg/L (September 24, 2008) to 724 mg/L (July 9, 2007) (Figure 69). These high chloride values have caused a portion of Sand Creek (i.e., from the South Line to Raven Stream shown in Figure 68) to be listed on the 2010 draft list of impaired waters for chloride. A stream is impaired when two or more of the analytical results are greater than the 230 mg/L chronic standard for chloride in consecutive three year periods during the most recent ten year period or one analytical result is greater than the 860 mg/L acute standard (MPCA, 2007). The chronic standard is based upon a 4-day average. The reach of stream impaired for chlorides includes unimpaired biological station 07MN056. Because higher chloride concentrations in this reach have not resulted in an impaired fish MRAP IBI, ionic strength does not appear to be a candidate cause of fish impairment.

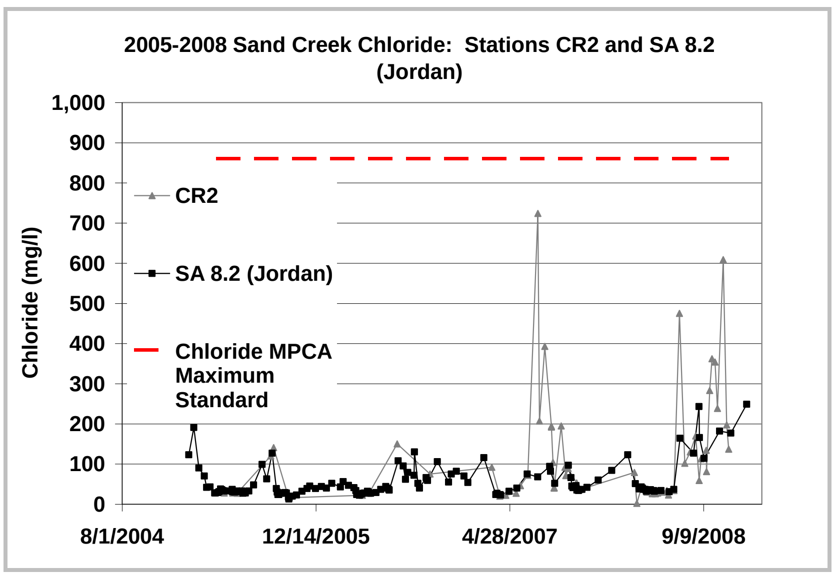

Figure 67. 2005-2008 Sand Creek Chloride: Stations CR2 and SA 8.2 (Jordan)

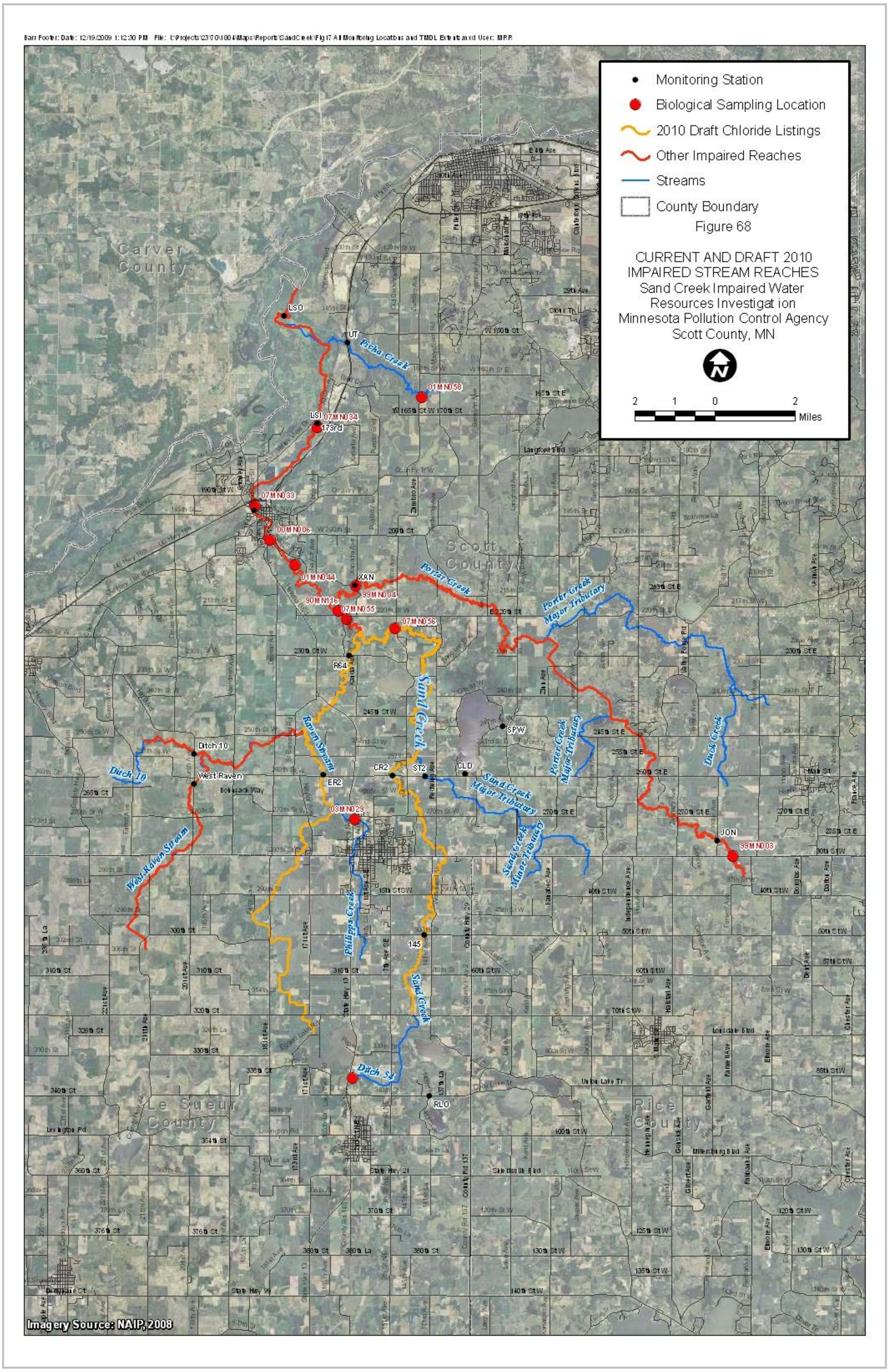

Figure 68. Current and Draft 2010 Impaired Stream Reaches

Data indicate that chloride concentrations generally decreased from upstream to downstream and further indicate that upstream station 145 did not experience high concentrations. Chloride concentrations measured at Station SA 8.2 were generally lower than concentrations measured at upstream Station CR2 (Figure 16). Four day average chloride concentrations were estimated from continuous specific conductance measurements at Stations CR8 and 173 during 2007 through 2008 and at Stations 145 and LSI during 2008. As shown in Figures 69 through 71, all estimated values were less than the MPCA chronic standard of 230 mg/L (Minnesota Rule Chapter 7050.0222, subpart 4). The data indicate that problematic chloride concentrations were limited to the reach of Sand Creek downstream from 145 and upstream from the confluence of Raven Stream. This reach of Sand Creek includes unimpaired biological station 07MN056. Stream reaches containing impaired biological stations did not observe problematic chloride concentrations. Hence, the data indicate ionic strength is not a stressor to the biological community of the impaired reaches of Sand Creek in the absence of habitat fragmentation.

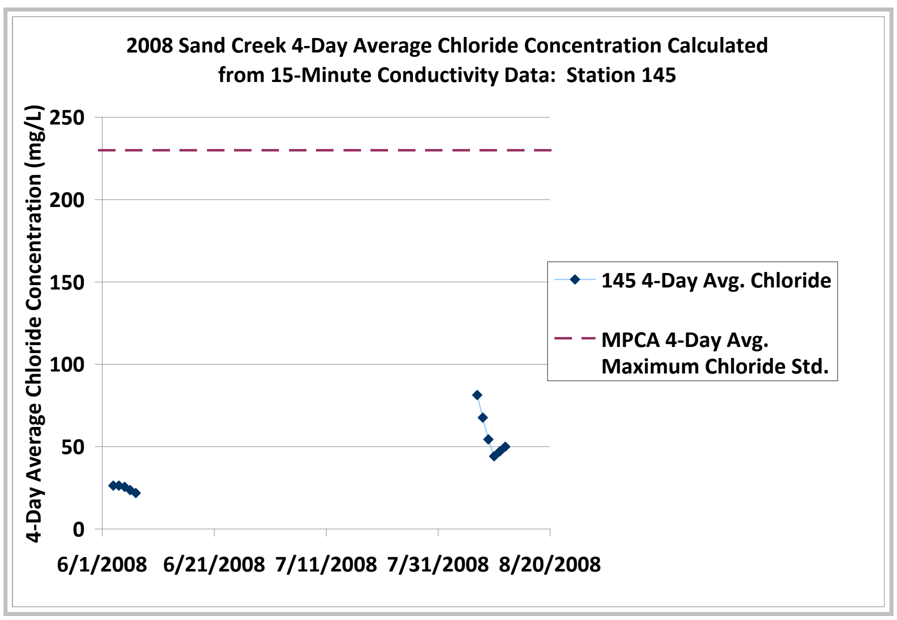

Figure 69. 2008 Sand Creek 4-Day Average Chloride Concentration Calculated from 15-Minute Conductivity Data: Station 145

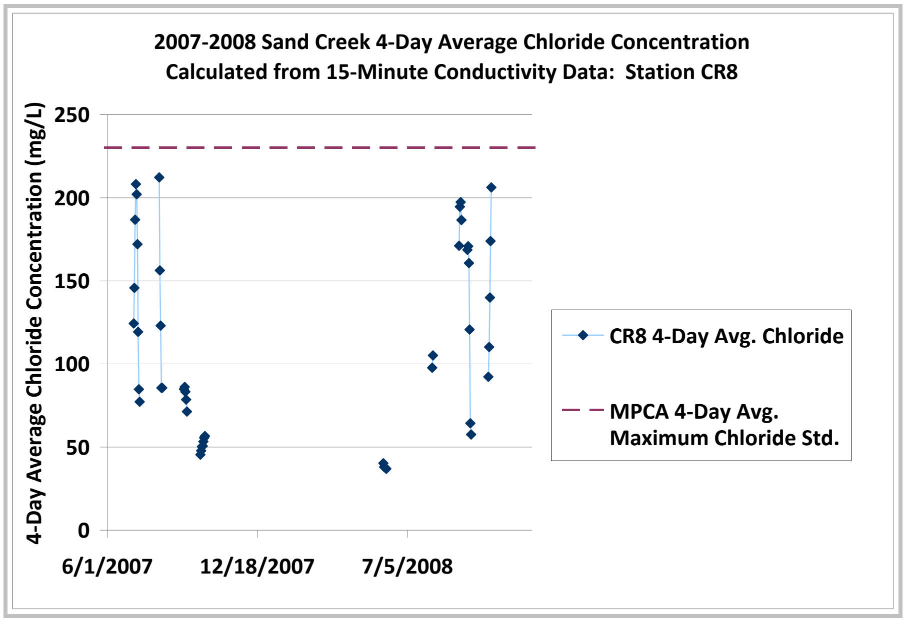

Figure 70. 2007-2008 Sand Creek 4-Day Average Chloride Concentration Calculated from 15-Minute Conductivity Data: Station CR8

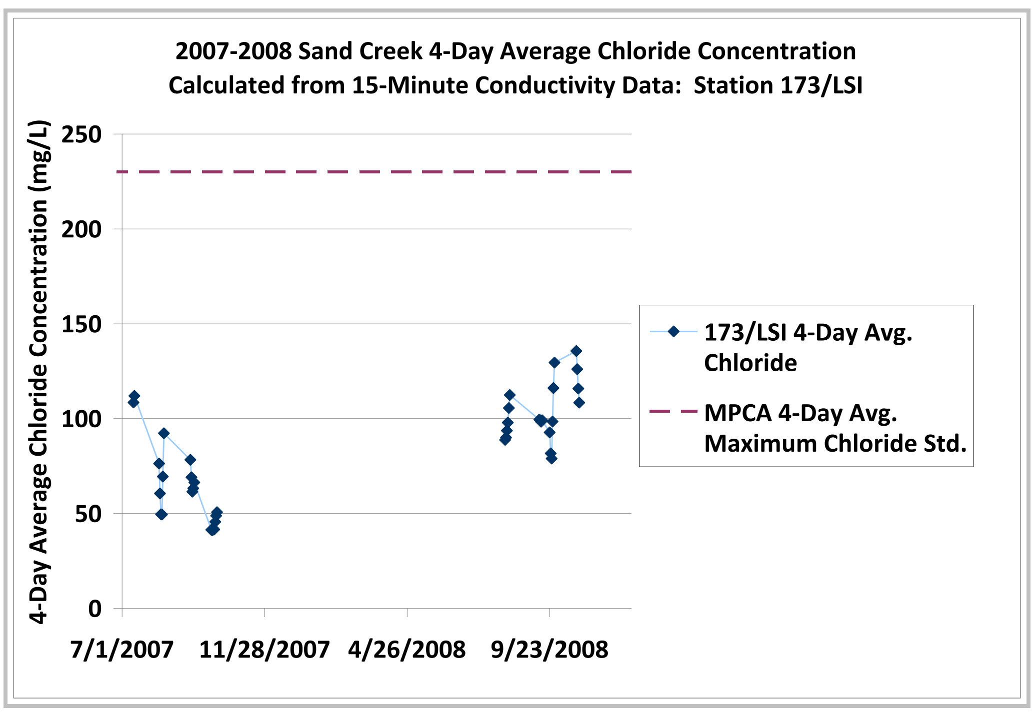

Figure 71. 2007-2008 Sand Creek 4-Day Average Chloride Concentration Calculated from 15-Minute Conductivity Data: Station 173/LSI

4.2.2 County Ditch Number 54

4.2.2.1 Metals

Metals data collection is needed because metals data were not collected from Le Sueur County Ditch Number 54. Because data are not available, it is not possible to determine whether metals are a stressor or can be eliminated as a candidate cause. Hence, collection of metals data is recommended to determine whether metals are a stressor to the Le Sueur County Ditch Number 54 biological community.

4.2.2.2 Sediment

Sediment data collection is needed because not enough data have been collected to determine whether sediment is a candidate stressor for County Ditch Number 54. Sediment data were collected from Le Sueur County Ditch Number 54 on July 22, 2003 when fish samples were collected. Total suspended solids and turbidity levels in July of 2003 were 60 mg/L and 30.3 NTU, respectively. However, it is not possible to determine whether or not sediment is a candidate cause for impairment from 2003 data collected from a single sample date. 2003 was a dry climatic year and the samples may have been collected under low flow condition where sediment accumulations and resuspensions may not be represented in sample results. Scott County staff has observed significant sediment accumulation in County Ditch Number 54 that could be resuspended during higher flows. Hence, collection of additional data is recommended to determine whether or not sediment is a candidate stressor.

4.2.3 Picha Creek

4.2.3.1 Metals

Metals data collection is needed because metals data were not collected from Picha Creek. Because data are not available, it is not possible to determine whether metals are a stressor or can be eliminated as a candidate cause. Hence, collection of metals data is recommended to determine whether metals are a stressor to the Picha Creek biological community.

4.2.3.2 Low Dissolved Oxygen

Dissolved oxygen data collection is needed because dissolved oxygen measurements prior to 9 AM have not occurred in Picha Creek. Hence, diel oxygen changes are unknown and it is not known whether full support of aquatic life occurs during diel changes. Dissolved oxygen concentrations in Picha Creek were measured during 2001, 2007, and 2008. However, measurement times during 2001 are unknown and measurements during 2007 and 2008 occurred between 9 AM and noon. Hence, oxygen was not measured during the period of time when diel changes can cause low oxygen levels.

Continuous measurement of oxygen during a summer period is recommended to determine whether Picha Creek oxygen concentrations fully support aquatic life during diel changes.

All dissolved oxygen concentrations measured at biological Station 01MN058 (Figure 29) and downstream station ZUT (Figure 29) have met the MPCA minimum standard of 5 mg/L for full support of all aquatic life (Minnesota Rule Chapter 7050.0222, subpart 4). Station 01MN058 had dissolved oxygen concentrations of 7.80 and 17.40 on July 24 and August 8, 2001, respectively, the dates when fish samples were collected. Scott Watershed Management Organization (WMO) staff measured dissolved oxygen at Station ZUT, located immediately downstream from biological Station 01MN058, during 2007 and 2008. Dissolved oxygen measurements ranged from 5.27 to 10.59 mg/L. However, these measurements occurred between 9 AM and noon and do not indicate concentrations during diel changes. Additional data collection will determine the impact of diel changes and whether dissolved oxygen is a candidate stressor.

4.2.3.3 Ionic Strength

Ionic strength can neither be eliminated as a candidate stressor nor validated until additional data are collected. Because specific conductance levels met MPCA criteria during July and August of 2001 when impaired fish IBI occurred, ionic strength does not appear to be a stressor causing the impaired fish IBI during 2001. However, data collected on 11 sample dates between 2007 and 2008 indicate specific conductance levels occasionally exceeded the MPCA standard. Additional collection of specific conductance data and fish data are needed to determine whether ionic strength is a candidate stressor. The following discussion presents the ionic strength data collected during 2001, 2007, and 2008.

Data collected in 2001 indicate specific conductance measurements met the MPCA standard of 1,000 µmhos/cm at 25° C (Minnesota Rule Chapter 7050.0224, Subpart 2) when fish samples were collected on July 24 (882 µmhos/cm at 25° C) and August 8 (773µmhos/cm at 25° C). Although 2001 specific conductance measurements met the MPCA standard, 2007 and 2008 data indicate specific conductance levels have occasionally exceeded the MPCA standard. Scott Watershed Management Organization (WMO) staff measured specific conductance at 6 stations along Picha Creek during 2007 and 2008. The data indicate specific conductance values exceeded 1,000 µmhos/cm at 25° C on August 27, 2007 at CR79, on September 18, 2007 at CR79, MUT, and ZUT, and on July 24, 2008 at CR79 (Figure 72, Station Locations Shown on Figure 29). Because Minneapolis/St. Paul precipitation data indicate 0.71 inches of precipitation occurred on August 27, 2007 and 1.77 inches of precipitation occurred on September 18, 2007, it appears that stormwater runoff conveyed to the stream caused the high specific conductance levels in 2007 (Minnesota Climatology Working Group, 2009). Because July of 2008 was a dry month and only a trace of precipitation occurred on July 24, 2008, it appears that the high specific conductance value during 2008 was not associated with stormwater runoff

Chloride does not appear to be the ion causing the elevated specific conductance measurements in Picha Creek. As shown in Figure 73, chloride concentrations measured at Station UT (location shown on Figure 29) during 2007 through 2008 were less than the MPCA maximum standard of 860 mg/L which protects aquatic life (Minnesota Rule Chapter 7050.0222, subpart 4).

Because specific conductance levels met MPCA criteria during July and August of 2001 when impaired fish MRAP IBI occurred, ionic strength does not appear to be a cause of the fish impairment. Furthermore, the higher specific conductance levels during 2007 and 2008 were generally associated with precipitation events and stormwater runoff. It seems unlikely that ionic strength was a stressor causing impairment in 2001 because precipitation was below normal during July (i.e., 1.41 inches below normal) and August (i.e., 1.31 inches below normal) when fish samples were collected. Nonetheless, additional data collection is needed to determine whether ionic strength is a candidate stressor to the Picha Creek fish assemblage.

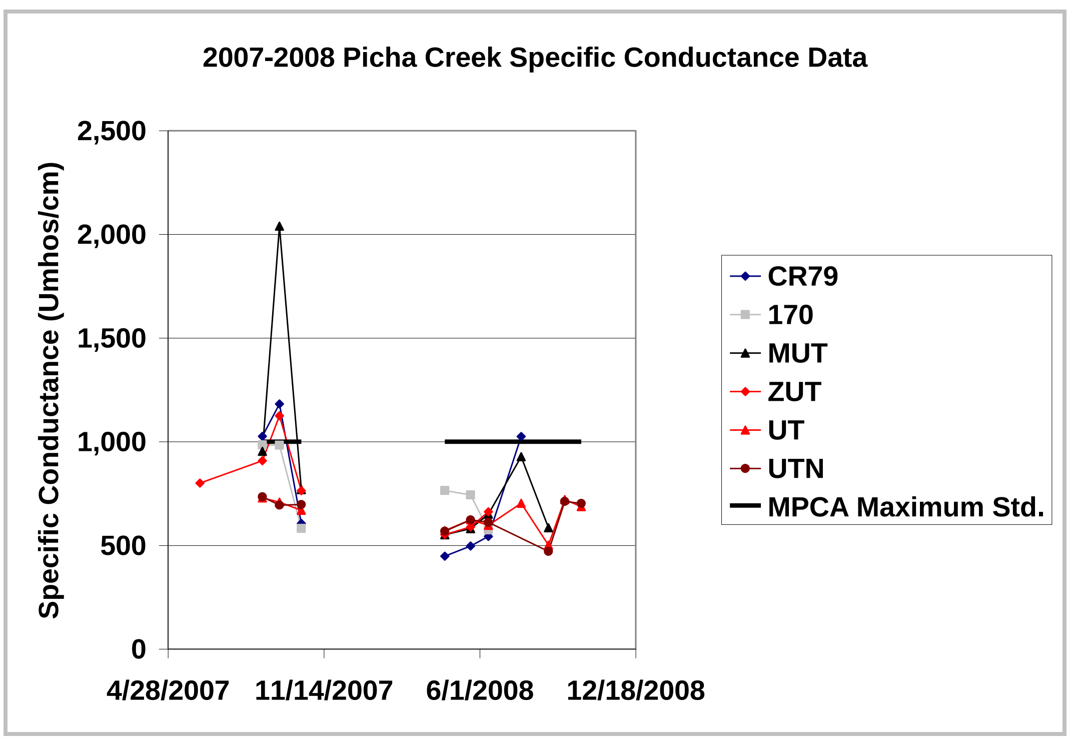

Figure 72. 2007-2008 Picha Creek Specific Conductance Data

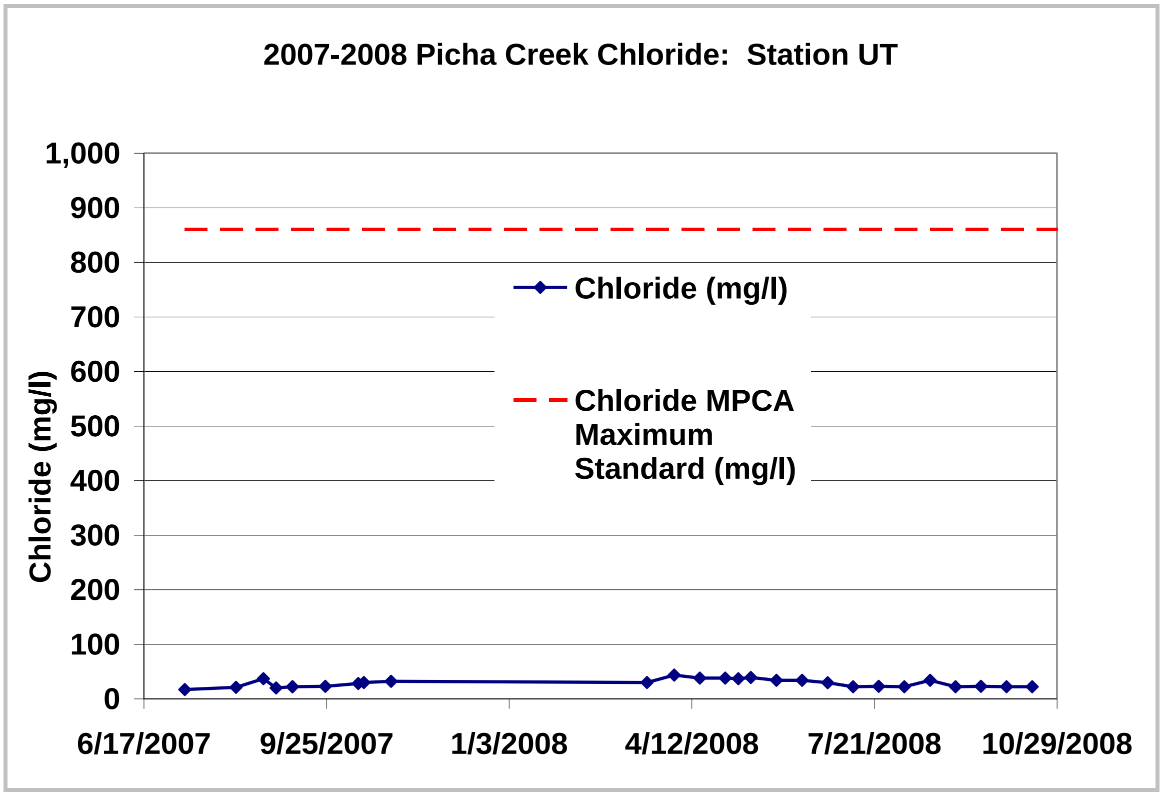

Figure 73. 2007-2008 Sand Creek and Picha Creek Chloride: Station UT

4.3 Candidate Causes of Biological Impairment

4.3.1 Sand Creek

4.3.1.1 Habitat Fragmentation

Habitat fragmentation is considered a possible stressor because a 15-foot tall natural waterfalls, pictured to the right and known locally as The Falls, is located 10 miles from the mouth of Sand Creek. The Falls interrupts the connectivity of Sand Creek. This interruption of connectivity prevents passage of fish between upstream and downstream reaches of Sand Creek.

The distribution of species across fragmented streams has been explained in terms of the size, quality, and connectivity of habitats (Fahrig and Merriam 1994; Rieman and Dunham 2000).

A 15-foot tall natural waterfalls, pictured above, interrupts the connectivity of Sand Creek and is considered a candidate cause of impairment. (Photo from Interfluve 2008)

Barriers, such as The Falls on Sand Creek, prevent movement between habitat patches (Porto et al., 1999). Factors such as patch area, duration of isolation, and connectivity to neighboring populations have influenced fish distribution patterns (Reid et al., 2008). Within watersheds, structures such as dams and natural waterfalls are considered responsible for extirpations of fish populations (Winston et al., 1991; Lutterall et al., 1999). Hypothesized causes for extirpations include: (1) restricted access to, and/or alteration of spawning habitats; (2) increased numbers of predators due to the creation of lentic habitats; (3) the creation of small isolated populations that are more vulnerable to extinction events; and, (4) the prevention of re-colonization from other populations after local extinction events due to barriers, such as a dam or natural waterfalls (Winston et al, 1991; Rieman and Dunham, 2000; Schrank et al., 2001; Hill et al., 2002).

Natural waterfalls and dams adversely affect warmwater stream fish and macroinvertebrate communities by degrading habitat and water quality and fragmenting streams (Santucci, V.J. et al., 2005). In a study of impacts of low head dams on the fish community of the Fox River of Illinois, data indicated free-flowing areas downstream from dams had higher species richness, substantially higher overall and harvestable-sized sport fish abundance, and more sucker species and intolerant fish species. Samples from free-flowing areas also contained a higher percentage of insectivorous minnows, such as spotfin shiners and sand shiners. In contrast, stations upstream from dams had a predominance of tolerant and omnivorous species, such as the common carp, bluntnose minnow, quillback, and green sunfish. Dams appeared to have altered distributions of nearly one-third of Fox River fishes by acting as barriers to upstream movement. Ten species were not found above the lowermost dam on the Fox River located in Dayton, Illinois. Negative impacts from dams were not just observed in the most impacted areas immediately above dams, but were observed for a considerable distance of the upstream segment. Conversely, positive impacts of the free-flowing segment below dams were not only observed immediately below dams, but were observed throughout free-flowing reaches. The data indicated that even low-head dams with relatively small impoundments can have profound detrimental effects on the biotic integrity of warmwater rivers (Santucci, V.J. et al., 2005).

Evaluation of Sand Creek stream reaches upstream and downstream from The Falls indicates stream reaches downstream from The Falls had unimpaired fish MRAP IBI scores while stream reaches upstream from The Falls to the confluence of Raven Stream had impaired MRAP IBI scores. Biological stations 07MN033 and 07MN034 (Figure 29), located downstream from The Falls, had MRAP IBI scores of 48 and 38, respectively, which are above the MRAP IBI impairment threshold of 30 or greater. Biological stations 90MN116, 00MN006, 01MN044, and 07MN055 (Figure 29), located upstream from The Falls, had MRAP IBI scores of 20 through 26, which are less than the MRAP IBI impairment threshold of 30 or greater. The data indicate habitat fragmentation has adversely impacted the Sand Creek fishery and has resulted in impairment of stream reaches located between The Falls and the confluence of Raven Stream.

An assessment of Sand Creek fish communities upstream and downstream from The Falls indicates stream reaches downstream from The Falls had a higher number of species, a higher percentage of insectivores, and a lower percentage of tolerant species (Table 9). Reaches upstream from The Falls had a total of 16 species compared with 34 species downstream from The Falls. A total of 14 species were observed both upstream and downstream from The Falls, 20 species were only found downstream from The Falls, and two species were only found upstream from The Falls (Table 9).

Studies have shown that seven Sand Creek fish species only found downstream from The Falls have been negatively impacted by habitat fragmentation in other streams (Miller et al., 2005; Reid et al., 2008; Roberts et al., 2008; Santucci, V.J. et al., 2005; Catalano et al., 2007). These species are golden redhorse, shorthead redhorse, logperch, hornyhead chub, blackside darter, pumpkinseed, and emerald shiner:

- **Redhorse Species** –In the Grand River watershed, redhorse were absent upstream of major barriers along the upper reaches of the Conestogo River and Grand River and completely absent from the highly fragmented Speed River Subwatershed (Reid et al., 2008).

- **Hornyhead Chub -**A technical conservation assessment of the hornyhead chub concluded: *In instances where habitat is fragmented and populations are isolated, the probability that genetic "bottlenecks" will occur becomes more pronounced and single catastrophic events may extirpate populations from entire drainages"* (Miller et al., 2005). The study identified habitat fragmentation as a major threat to the hornyhead chub (Miller et al., 2005).

- **Blackside Darter and Pumpkinseed -** In the Fox River, blackside darter and pumpkinseed were not found in a section of the river with a high density of low head dams (i.e., 8 dams in 22 rkm), but were found in a free flowing downstream section of the river (Santucci et al., 2005).

Table 9 Comparison of Sand Creek Fish Species Upstream and Downstream From The Falls

Species Scientific Name	Species Common Name	Downstream From The Falls		Upstream From The Falls						Fish Present		
		07MN033	07MN034	00MN006	01MN044 (2001)	01MN044 (2007)	90MN116	07MN055	07MN056	Only DS	Only UPS	Both UPS and DS
Umbra limi	Central mudminnow	2	17		2		3	1	5			X
Cyprinus carpio	Common carp	2	69							X		
Hybognathus hankinsoin	Brassy minnow	27	110	2	9		1	3	2			X
Rhinichthys atratulus	Blacknose dace	172	2	33	35	389	14	169	79			X
Nocomis biguttatus	Hornyhead chub	11								X		
Notropis atherinoides	Emerald shiner	1,671	352							X		
Notropis Stramineus	Sand shiner	86	220		1							X
Notropis dorsalis	Bigmouth Shiner	103	181	9	2	30	15	22	171			X
Notropus cornutus	Common shiner						23				X	
Campostoma anomalum	Central stoneroller	370	1	15	10	836	51	187	18			X
Pimephales notatus	Bluntnose minnow	151	89							X		
Pimephales promelas	Fathead minnow	479	104	32	2	1	43	1	17			X
Semotilus atromaculatus	Creek Chub		79	59	65	1,064	68	341	229			X
Cyprinella spiloptera	Spotfin shiner	131	73							X		
Noturus flavus	Stonecat	20		6	6	24	1	8	3			X
Carpiodes cyprinus	Quillback		13							X		
Moxostoma macrolepidotum	Shorthead redhorse		4							X		
Moxostoma erythrurum	Golden redhorse		1							X		
Noturus gyrinus	Tadpole madtom		1							X		
Ameiurus melas	Black bullhead	14	4	1			1	1	12			X
Lepomis cyanellus	Green sunfish	12	8	124			14	5	27			X
Lepomis gibbosus	Pumpkinseed sunfish	4	6							X		
Lepomis humilis	Orangespotted sunfish	29	1							X		
Lepomis sp.	Hybrid sunfish		1							X		
Lepomis macrochirus	Bluegill		2						6	X		

Table 9 Comparison of Sand Creek Fish Species Upstream and Downstream From The Falls (Continued)

Species Scientific Name	Species Common Name	Downstream From The Falls		Upstream From The Falls								
		07MN033	07MN034	00MN006	01MN044 (2001)	01MN044 (2007)	90MN116	07MN055	07MN056	Only DS	Only UPS	Both UPS and DS
Pomoxis nigromaculatus	Black crappie	5	1						6			X
Perca flavescens	Yellow perch		1							X		
Morone chrysops	White bass		12							X		
Etheostoma nigrum	Johnny darter	141	45	5	5	147	9	49	112			X
Percina caprodes	Logperch	174	19							X		
Percina maculate	Blackside darter	23								X		
Percina phoxocephala	Slenderhead darter	96	3							X		
Aplodinotus grunniens	Freshwater drum	3	2							X		
Catostomus commersonnii	White sucker	90	23	11	3	141	21	6	25			X
Sander vitreus	Walleye		1							X		
Culaea inconstans	Brook stickleback				1						X	
Total		**3,816**	**1,447**	**297**	**141**	**2,632**	**264**	**793**	**712**	**20**	**2**	**14**

- **Logperch -** A study of logperch in the Roanoke River concluded the greatest overall loss of logperch habitat and reduction in this species' range occurred when construction of the Smith Mountain and Leesville dams was completed in 1963. The dams increased the vulnerability of logperch to extirpation and eliminated the possibility of recolonization from downstream (Hester et al., 2007).

- **Emerald shiner -** An evaluation of the effects of dam removal on fish assemblage structure and spatial distributions in the Barraboo River, Wisconsin indicated emerald shiners were not found upstream of the dam prior to removal, but recolonized 16 upstream sites and were collected 123 km upstream from the dam within the first year after removal (Catalano et al., 2007).

Sand Creek upstream from The Falls, pictured above, had fewer fish species, fewer insectivores, and a higher percentage of tolerant species than locations downstream from The Falls (Picture from Interfluve 2008).

A study of changes in fish assemblages following dam removal in the Baraboo River Wisconsin indicated biotic integrity scores (possible range = 0-100) increased by 35 to 50 points at three of the four impoundments as a result of decreases in percent tolerant species, increases in the number of intolerant species, and in some cases, increases in species richness. After dam removal, 10 species that were found below, but not above the most downstream dam before removal, were collected at new sites upstream from the dam (Catalano et al., 2007).

Because Sand Creek stream reaches downstream from The Falls had a higher number of species, a higher percentage of insectivores, and a lower percentage of tolerant species, the Sand Creek data indicate habitat fragmentation is a candidate cause of Sand Creek's impaired fish assemblage in the reach upstream from The Falls and downstream from the confluence of Raven Stream. A conceptual model of candidate cause 1, habitat fragmentation, is shown in Figure 74. The model shows that habitat fragmentation from The Falls causes a loss of connectivity that reduces fish refuge and migration as well as the number of sensitive species and insectivores. The resultant reduction in species richness and number of fish causes impairment.

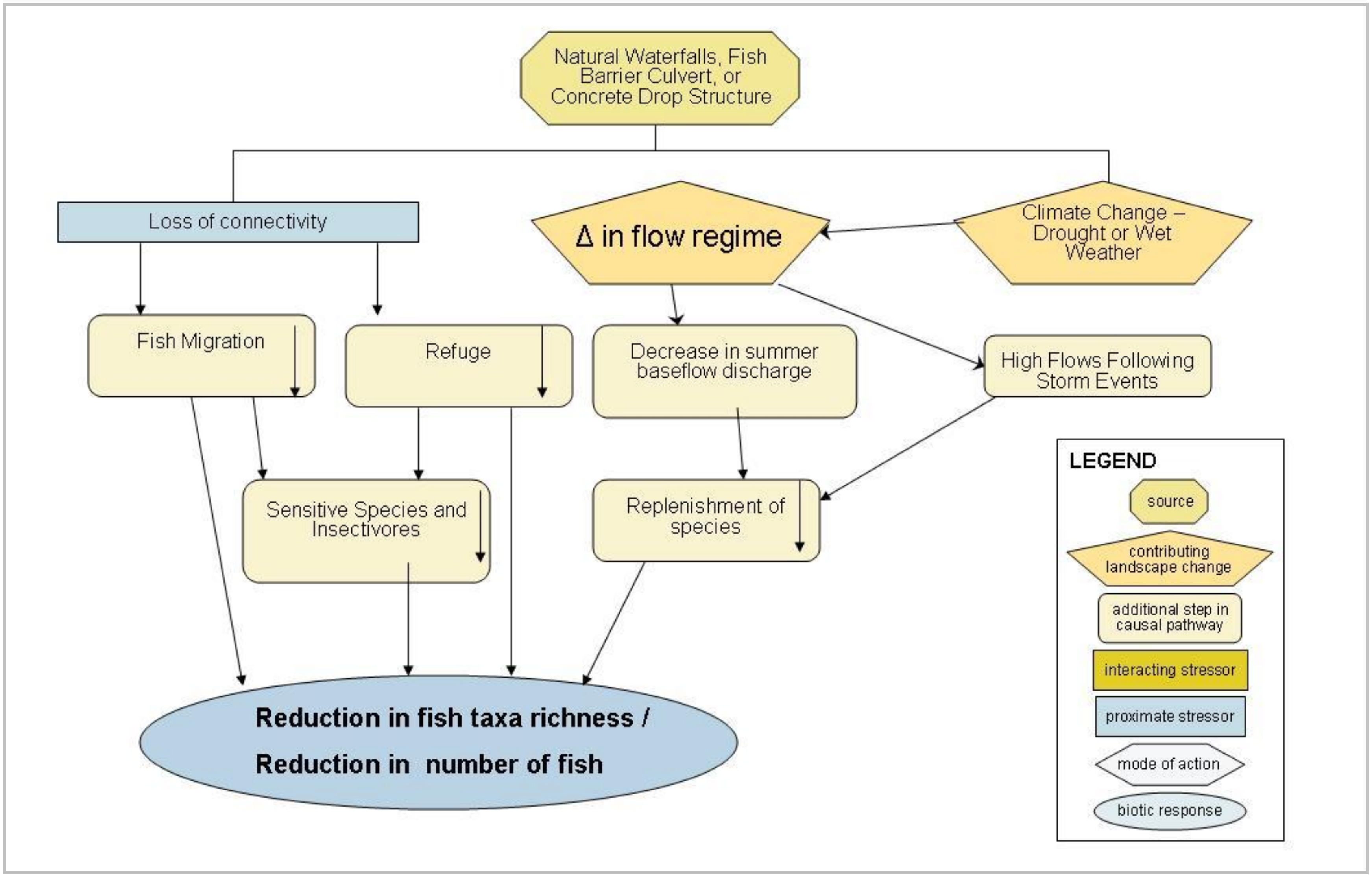

Figure 74. Conceptual Model of Habitat Fragmentation

4.3.2 Picha Creek

4.3.2.1 Habitat Fragmentation

Habitat fragmentation is a candidate stressor because a perched culvert at Zumbro Avenue and a concrete drop structure under a private driveway are fish barriers that prevent the passage of fish between upstream and downstream reaches of Picha Creek. The Zumbro Avenue culvert, located immediately downstream from biological Station 01MN058, is a 10 foot by 6-foot concrete box culvert with a 1-foot drop structure to enter the culvert at the upstream end. A concrete drop structure under a private driveway at the downstream end of Reach 3 (Figure 3) notes two separate drops that total 3 vertical feet beneath the bridge (pictured above). The concrete drop structure was built by a landowner to stem the incision and recurring destruction of his bridge. As discussed in the previous section, studies have shown that habitat fragmentation increases tolerant species and reduces species richness and the number of intolerant species upstream from fish barriers such as the Zumbro culvert and concrete drop structure (Catalano et al., 2007). These changes in fish assemblage cause a reduction in fish MRAP IBI scores (Catalano et al., 2007). Hence, habitat fragmentation is a candidate stressor for the fish impairment at Picha Creek.

A concrete drop structure under a private driveway, pictured above, is a fish passage barrier on Picha Creek (Picture from Interfluve 2008).

A conceptual model of candidate cause 1 is shown in Figure 74. The model shows that habitat fragmentation from the Zumbro Avenue culvert and concrete drop structure cause a loss of connectivity that reduces fish refuge and migration as well as the number of sensitive species and insectivores. The resultant reduction in species richness and number of fish causes impairment.

4.3.2.2 Inadequate Baseflow

Inadequate baseflow is considered a candidate stressor because the United States Geological Survey National Hydrography Dataset (USGS NHD) indicates Picha Creek is an intermittent stream. In addition, no flow was observed in Picha Creek fish samples were collected in July and August of

2001. Per personal communication with Scott County staff, County and Soil and Water Conservation District (SWCD) staff did not see any flow in 2006 and rarely observed flow in 2007 (Nelson, 2009). In the summer of 2007, the MPCA visited Picha Creek and found it dry. While collecting samples from Picha Creek, Scott County WMO staff found that Picha Creek frequently experienced periods of no flow and sometimes dried up during periods of reduced precipitation. No flow or a dry streambed occurred during 25 to 50 percent of Picha Creek sample events in 2007 and 2008 (Table 10). Station ZUT located immediately downstream from biological station 01MN058 (Figure 29), had no flow during July and August sample events of 2007 and during September and October sample events of 2008. The data indicate the stream has inadequate baseflow to support an unimpaired fish assemblage during periods of reduced precipitation.

Table 10 2007-2008 No Flow Observations on Picha Creek

Location	Date	No Flow	Dry
CR79	6/8/2007	X	
	7/2/2007	X	
	8/1/2007	X	
	9/18/207	X	
	10/9/2008	X	
170	6/8/2007	X	
	7/2/2007	X	
	8/1/2007	X	
	7/24/2008	X	
	9/18/2008	X	
	10/9/2008		X
MUT	6/8/2007	X	
	7/2/2007	X	
	8/1/2007	X	
	9/18/2007	X	
	10/19/2008		X
ZUT	7/2/2007	X	
	8/1/2007	X	
	7/24/2008	X	
	9/18/2008		X
	10/9/2008		X
UT	6/8/2007	X	
	7/2/2007	X	
	8/1/2007	X	
UTN	6/8/2007	X	
	7/2/2007	X	
	8/1/2007	X	
	7/24/2007	X	

Dry climate conditions occurred during 2001, the year in which Picha Creek had impaired fish MRAP IBI scores. Precipitation at the Minneapolis St. Paul International Airport was 2.12 inches during July and 2.31 inches during August. Below normal precipitation occurred during both months – 1.41 inches below normal during July and 1.31 inches below normal during August. No flow (i.e., a flow of 0 cfs) was observed on July 24 and August 8 of 2001 when fish were sampled. Because Picha Creek had no flow when fish samples were collected in 2001 and frequently had no flow during periods of reduced precipitation in 2007 and 2008, inadequate baseflow is a candidate stressor for the stream's impairment during July and August of 2001.

Picha Creek, including Reach 10 pictured above, was not flowing during nearly half of 2007 and 2008 sample events. Reach 10 is the location of impaired biological station 01MN058. No flow occurred at this location in July and August of 2001 when an impaired fish MRAP IBI occurred. (Photo from Interfluve, 2008)

Per personal communication with Scott County staff, there is some sustained groundwater discharge to the unnamed tributary, but it comes into the tributary well downstream of the MRAP IBI sampling site where some permeable horizons daylight in the side of the bluff (Nelson, 2009).

A conceptual model of candidate cause 2, inadequate baseflow, is shown in Figure 75. The model shows that reduced groundwater discharge to the stream occurs because groundwater layers of limestone bedrock horizontally conduct water and many of these come out in the bluff area. Hence, they prevent a sustained baseflow from occurring until well down into the gully. Then, at the base of the bluff, the Minnesota River terraces limit baseflow because sandy soil infiltrates the water. Climate changes further impact baseflow. Reduced precipitation diminishes discharge to the stream from upstream sources resulting in a decrease of both summer and winter baseflows. The reduction in baseflows changes the physical and chemical properties of the water and the structural habitat of

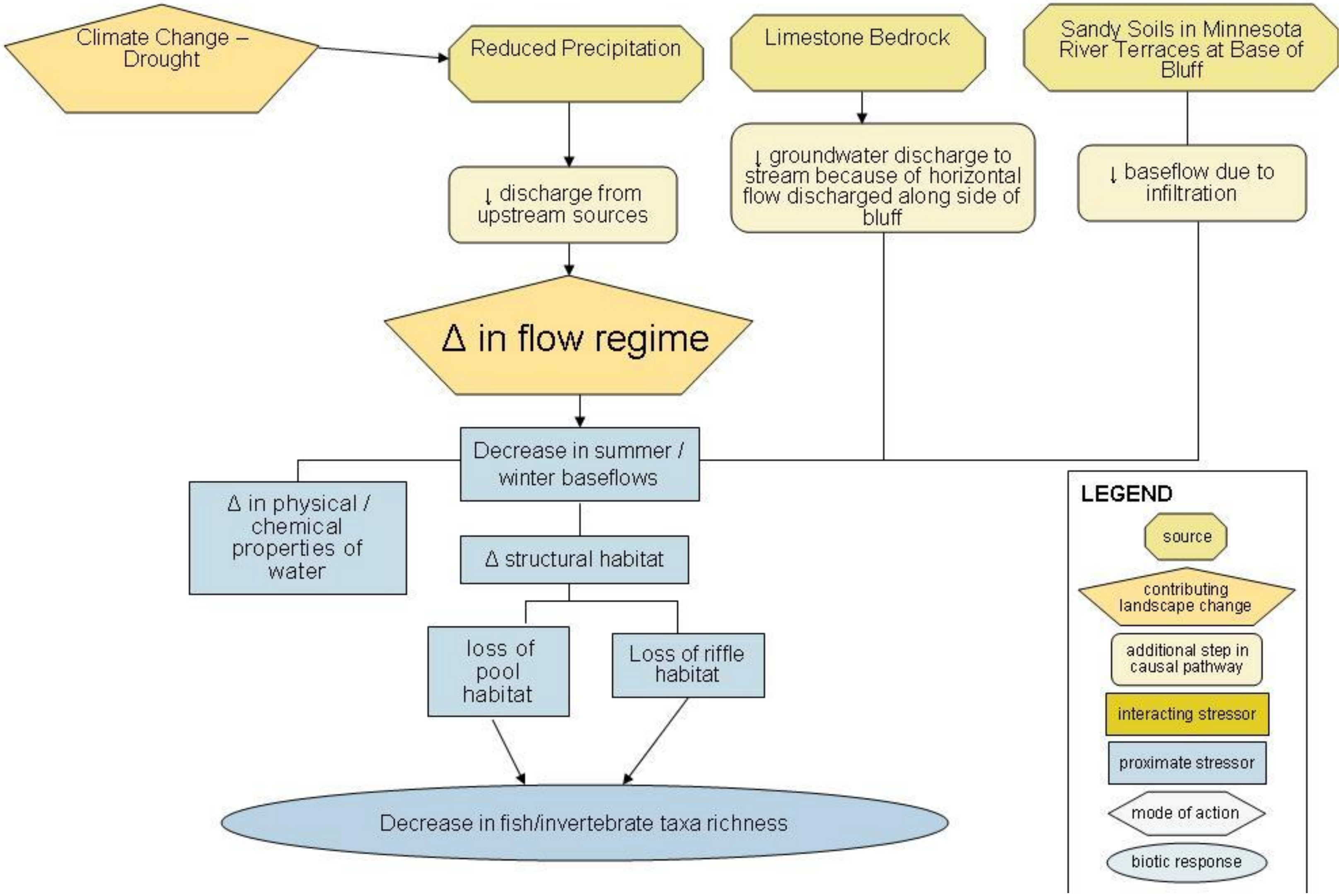

Figure 75. Conceptual Model of Inadequate Baseflow in Picha Creek

the stream. The resultant loss of pool and riffle habitat causes a decrease in fish and invertebrate taxa richness. The loss of fish taxa richness causes a low fish MRAP IBI score that fails to meet the MRAP IBI impairment threshold of 30 or greater.

4.3.2.3 Habitat

Habitat is considered a candidate stressor because Reach 10 of Picha Creek (i.e., biological Station 01MN058) observed poor habitat including MSHA and SVAP scores that were much lower than scores from Sand Creek biological stations. As shown in Table 11, Picha Creek had an MSHA score of 37.9 and Sand Creek had MSHA scores ranging from 59.4 to 63.9. Picha Creek had lower scores for all MSHA categories indicating all aspects of the stream's habitat were poorer than Sand Creek. Because Picha Creek had lower MSHA scores than unimpaired reaches of Sand Creek as well as impaired reaches of Sand Creek, habitat is considered a candidate stressor of the stream's fish impairment.

Table 11.   Picha Creek and Sand Creek Fish MRAP IBI and MSHA Scores (Interfluve 2008)*

Fish Site	Fish MRAP IBI		MSHA Scores						
			MSHA Reach	Total	Surrounding Land Use	Riparian Zone	Substrate	Cover	Channel Morphology
			Picha Creek						
01MN058	24 24	[1] [2]	10	37.9	0	3.5	11.4	4	19
			Sand Creek						
03MN077	29		NA	NA	NA	NA	NA	NA	NA
07MN056	31		12	63.9	2.5	6	18.4	8	29
07MN055	24		10	62.8	2.5	6	16.8	7	30.5
90MN116	20								
01MN044	22	[1]	8a	63.5	2.5	7	19	6	29
01MN044	26	[3]							
00MN006	26		7b	63.0	2	7	17	6	31
07MN033	48		6a	59.4	2	7	19.4	5	26
07MN034	38		4b	60.4	5	5	16.4	11	23

[1]Sampled July 24, 2001
[2]Sampled August 8, 2001
[3]Sampled July 25, 2007

Table 12. Picha Creek and Sand Creek Fish MRAP IBI and SVAP Scores

	Fish MRAP IBI Sites							
	01MN058	**03MN077**	**07MN056**	**07MN055 & 90MN116**	**01MN044**	**00MN006**	**07MN033**	**07MN034**
	Fish MRAP IBI Scores							
	24 & 24	**29**	**31**	**20 & 20**	**22 & 26**	**26**	**48**	**34**
	SVAP Scores							
	SVAP Reach 10	**Not Assessed**	**SVAP Reach 12**	**SVAP Reach 10**	**SVAP Reach 8**	**SVAP Reach 7**	**SVAP Reach 6**	**SVAP Reach 4**
Channel Condition	6	NA	8	7	5	3	3	3
Hydrologic Alteration	7	NA	8	8	8	5	5	5
Riparian Zone	1	NA	7	9	9	6	6	10
Bank Stability	2	NA	7	6	6	8	8	1
Water Appearance	3	NA	3	7	7	8	8	7
Nutrient Enrichment	4	NA	3	6	6	6	6	8
Barriers to Fish Movement	2	NA	10	10	10	1	3	10
Instream Fish Cover	5	NA	5	5	5	3	3	5
Pools	6	NA	7	7	7	7	7	4
Insect/Invertebrate Habitat	6	NA	6	6	6	4	4	3
Canopy cover	1	NA	1	1	1	10	1	1
Riffle Embeddedness	4	NA	8	9	9	8	8	5
Macro-invertebrates Had	-3	NA	2	2	2	4	4	2
Total SVAP	44	NA	75	83	81	73	66	64
Overall Score (Total/13)	3.4	NA	5.8	6.4	6.2	5.6	5.1	4.9

As shown in Table 12, Reach 10 of Picha Creek (i.e., biological Station 01MN058) had a total SVAP score of 44 and Sand Creek biological stations had SVAP scores of 64 to 83. A comparison of scores for individual metrics indicates Reach 10 of Picha Creek had lower scores than all Sand Creek biological locations for riparian zone, riffle embeddedness, and macroinvertebrates. Unrestricted grazing of livestock was occurring at Reach 10 of Picha Creek when the 2007 habitat survey was completed. Grazing had reduced natural vegetation such that it occurred on less than one third of the active channel width on each side causing the filtering function to be severely compromised. Cattle entering and leaving the stream had destabilized streambanks and numerous slope failures were observed. In addition to unstable streambanks, the straight reaches and both inside and outside bends were eroding.

Slope failures and bank erosion added sediment to the stream which caused the embeddedness at Reach 10 of Picha Creek to be higher than at both impaired and unimpaired Sand Creek biological Stations. The impaired reach of Picha Creek had from 40 to 90 percent embeddedness compared with from less than 20 percent to 40 percent at Sand Creek biological stations (Inter-Fluve 2008).

Higher MSHA and SVAP scores in stream reaches located upstream and downstream from Reach 10 indicate the poor habitat observed at Reach 10 due to cattle impacts is a localized problem. Cattle access to Picha Creek is limited to a reach about one third mile in length. Reaches 11 and 12, located upstream from Reach 10, observed 2007 MSHA scores of 53.8 to 55.6 (Inter-Fluve, 2008). Reaches 4 through 9, located downstream from Reach 10, observed 2007 MSHA scores of 71.8 through 84.5(Inter-Fluve, 2008). 2007 SVAP scores in reaches upstream and downstream from Reach 10 were also higher. Upstream Reaches 11 and 12 observed total SVAP scores of 68 to 77, while downstream Reaches 4 through 9 observed total SVAP scores of 86 to 114. The higher MSHA and SVAP scores in upstream and downstream reaches indicate improved fisheries habitat occurred in stream reaches without cattle access. The data also indicate Reach 10 may not be representative sample location for Picha Creek. Additional fish monitoring at locations upstream and downstream from Reach 10 would determine whether impairment occurs in reaches with improved habitat. The data would determine the extent of impairment and better define the impact of habitat on the stream's fishery.

Because Reach 10 of Picha Creek had poorer habitat than both impaired and unimpaired Sand Creek biological stations, habitat is a candidate stressor. A conceptual model of candidate cause 3, habitat, is shown in Figure 76. The model shows that cattle grazing necessitated a watershed land cover alteration that resulted in increased sediment delivery to Picha Creek. Unrestricted cattle grazing

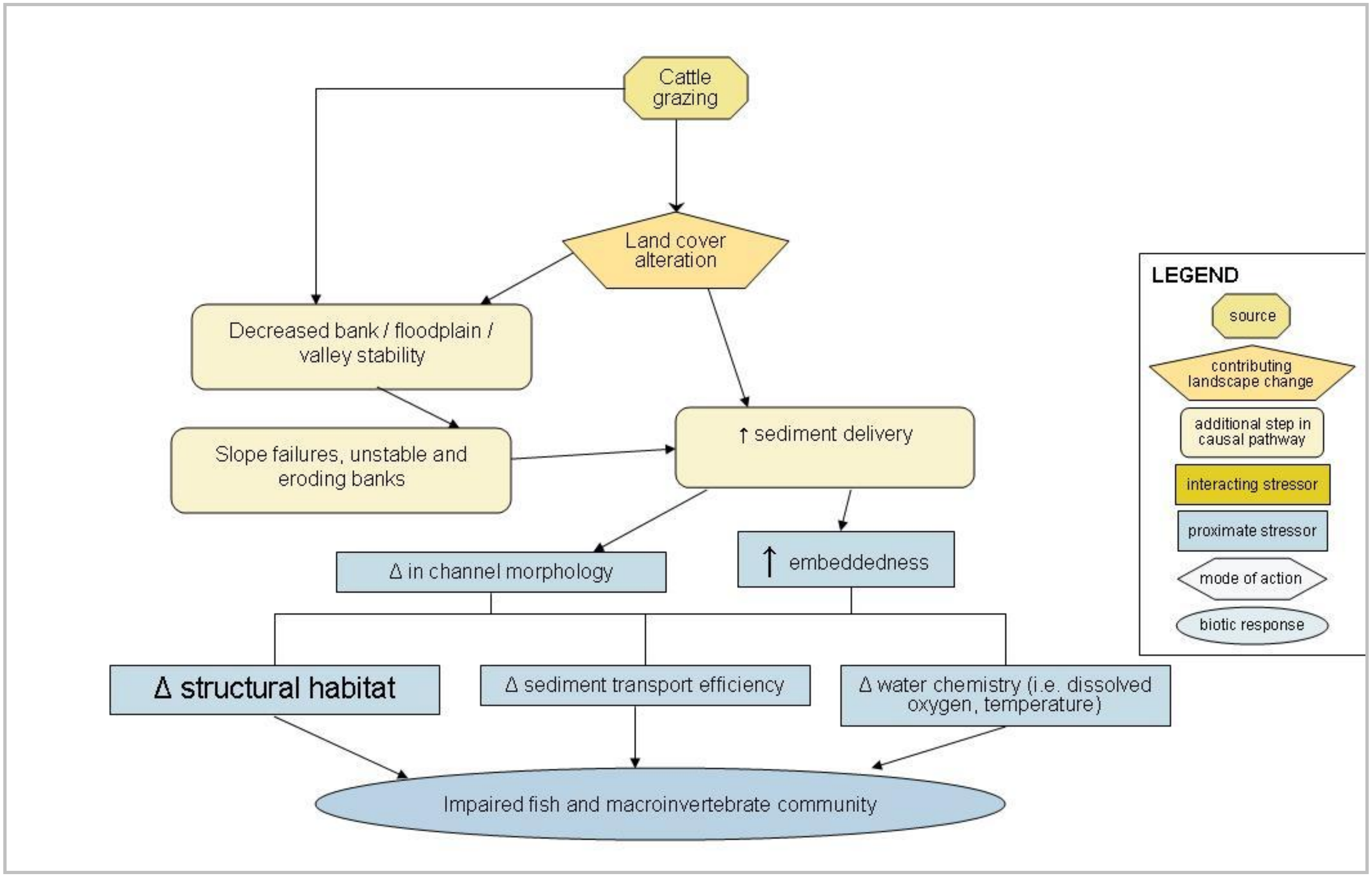

Figure 76. Conceptual Model of Poor Habitat in Picha Creek

decreased streambank stability and resulted in slope failures, unstable and eroding banks as well as increased sediment delivery to the stream. This, in turn, contributed to an impaired fish community through increased embeddedness and a change in channel morphology as well as a change in structural habitat, sediment transport efficiency, and water chemistry. As noted previously, the poor habitat caused by cattle access at Reach 10 may be localized and not representative of habitat conditions throughout Picha Creek. Fish monitoring at additional Picha Creek locations is recommended to determine areas of Picha Creek impaired due to poor habitat as well as provide data that are representative of the Picha Creek fishery.

4.3.2.4 Sediment

Sediment is a candidate stressor because biological Station 01MN058 (Figure 29) on Picha Creek had higher sediment embeddedness than both impaired and unimpaired Sand Creek biological stations. As discussed in the previous section, Station 01MN058 on Picha Creek had 40 to 90 percent embeddedness and Sand Creek biological stations had embeddedness ranging from less than 20 percent to 40 percent.

Although bedded sediment is considered a stressor, suspended sediment is not considered a stressor. Total suspended solids and turbidity were measured at Station 01MN058 (Figure 29) on July 24 and August 8, 2001 when fish samples were collected. The total suspended solids and turbidity levels in the impaired reach of Picha Creek were compared with total suspended solids and turbidity levels in an unimpaired reach of Sand Creek, Station SA 8.2 (Figure 29). The comparison indicates the impaired reach of Picha Creek had lower levels of total suspended solids and turbidity than Sand Creek Station 8.2 (Figures 77 and 78). Because the fish communities of unimpaired reaches of Sand Creek were exposed to higher levels of total suspended solids and turbidity than were observed in Picha Creek and these levels did not cause impairment in Sand Creek, it does not appear that the lower levels of total suspended solids and turbidity observed within Picha Creek would cause impairment of the stream's biological community (Figures 77 and 78).

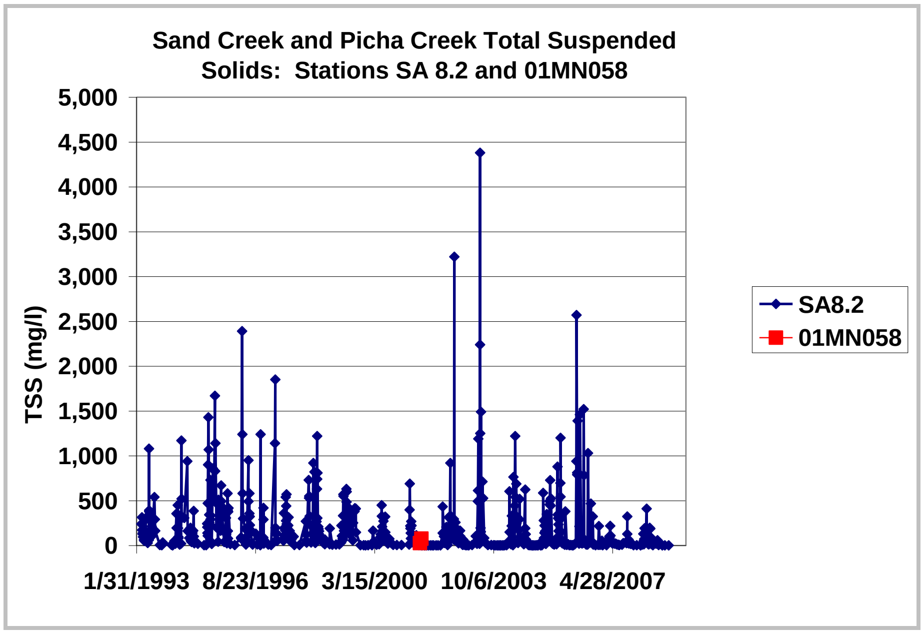

Figure 77. Compare 2007-2008 Sand Creek and Picha Creek Total Suspended Solids: Stations UT and LSI

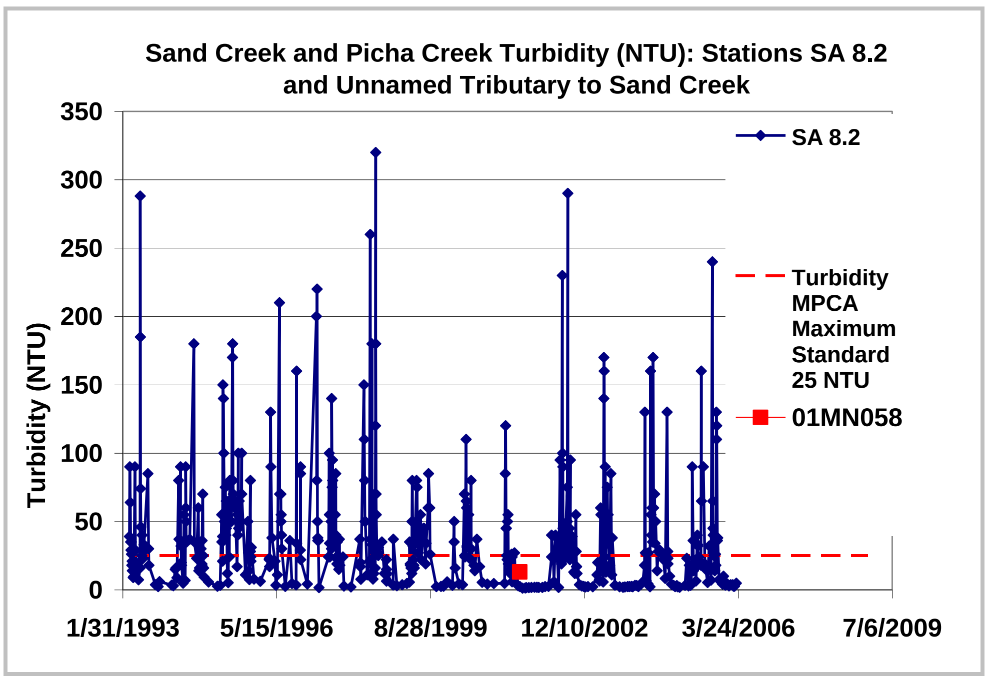

Figure 78. Compare 2007-2008 Sand Creek and Picha Creek Turbidity: Stations UT and LSI

Because Picha Creek had higher sediment embeddedness than Sand Creek biological stations, sediment is a candidate stressor. A conceptual model of candidate cause 4, sediment, is shown in

Figure 79. The model shows that cattle have removed vegetation which reduced sediment buffering and increased sediment delivery to the stream. Cattle entering and leaving the stream trampled streambanks and hillslopes, increased mobilization of bank and channel sediment to the stream, and increased sediment delivery to the stream. Increased sediment delivery to the stream increased deposited and bedded sediments. Increased coverage by fines, reduced interstitial spaces, and reduced substrate size from deposited and bedded sediments have reduced substrate diversity and stability, reduced spawning areas for simple lithophils, degraded habitat, increased pool-filling, burial, and fine substrate habitats. Habitat changes resulting from increased sediment delivery to the stream have contributed to a biologically impaired fish assemblage.

As noted previously, the higher sediment embeddedness caused by cattle access at Reach 10 may be localized and not representative of habitat conditions throughout Picha Creek. Fish monitoring at additional Picha Creek locations is recommended to determine areas of Picha Creek impaired due to poor habitat as well as provide data that are representative of the Picha Creek fishery.

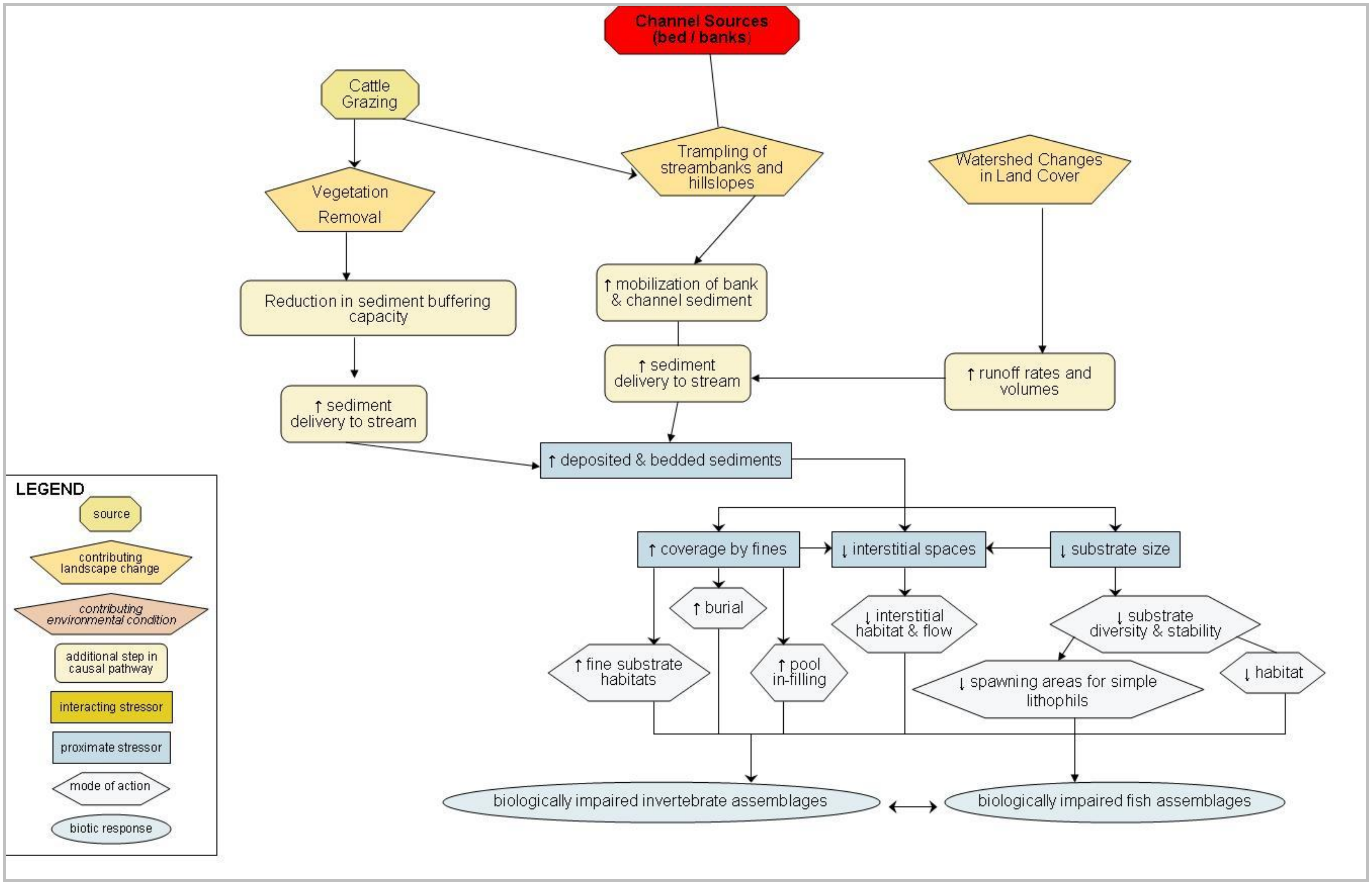

Figure 79. Conceptual Model of Sediment in Picha Creek

4.3.3 Le Sueur County Ditch Number 54

4.3.3.1 Inadequate Baseflow

Inadequate baseflow is considered a candidate stressor because Le Sueur County Ditch 54 sometimes has no flow and sometimes dries up during periods of reduced precipitation. Discharge was 0.08 cfs at Station 03MN077 (Figure 29) on July 22, 2003, when fish samples were collected, which is less than 0.1 cfs, the threshold for support of fish (Ball 1982). Scott Watershed Management Organization (WMO) collected samples from Station LPO on Le Sueur County Ditch Number 54 on twelve occasions during 2007 and 2008 (Figure 29). Samples could not be collected from Station LPO during September 18, 2008 because the stream had dried up. 2003 and 2008 were both dry years. Precipitation at the Minneapolis St. Paul International Airport was 6.68 inches below normal during 2003 and was 7.50 inches below normal in 2008. July precipitation was 1.98 inches below normal in 2003 and was 1.91 inches below normal in 2008. Because 2003 and 2008 were dry years, the stream dried up in 2008, and flows less than 0.1 cfs were measured in July of 2003 when fish samples were collected, inadequate baseflow is a candidate stressor for the stream's 2003 impaired fish MRAP IBI score.

Inadequate baseflow in Le Sueur County Ditch 54 may be due in part to natural conditions. Prior to creation of the ditch, the low area between Lake Pepin, Dietz, and Sanborne Lakes consisted of diffuse drainage ways/low gradient swales that naturally limited baseflow. Future monitoring is recommended to discern the respective roles of natural limitations and anthropogenic land use changes as causes of inadequate baseflow in County Ditch 54.

A conceptual model of candidate cause 1, inadequate baseflow, is shown in Figure 80. The model shows two natural causes of inadequate baseflow, drought conditions and natural watershed limitations (i.e., diffuse drainage ways/low gradient swales). The model shows one anthropogenic cause, changes in native land cover that reduced infiltration due to increased runoff. Reduced infiltration in combination with the two natural causes, reduced precipitation and natural watershed limitations, resulted in decreased summer and winter baseflows as well as changed structural habitat. The decreased baseflows have also changed the physical and chemical properties of the water. Structural habitat changes have caused a loss of pool and riffle habitat and a resultant decrease in fish and invertebrate taxa richness. The loss of fish taxa richness caused a low fish IBI score that fails to meet the MRAP IBI impairment threshold of 30 or greater.

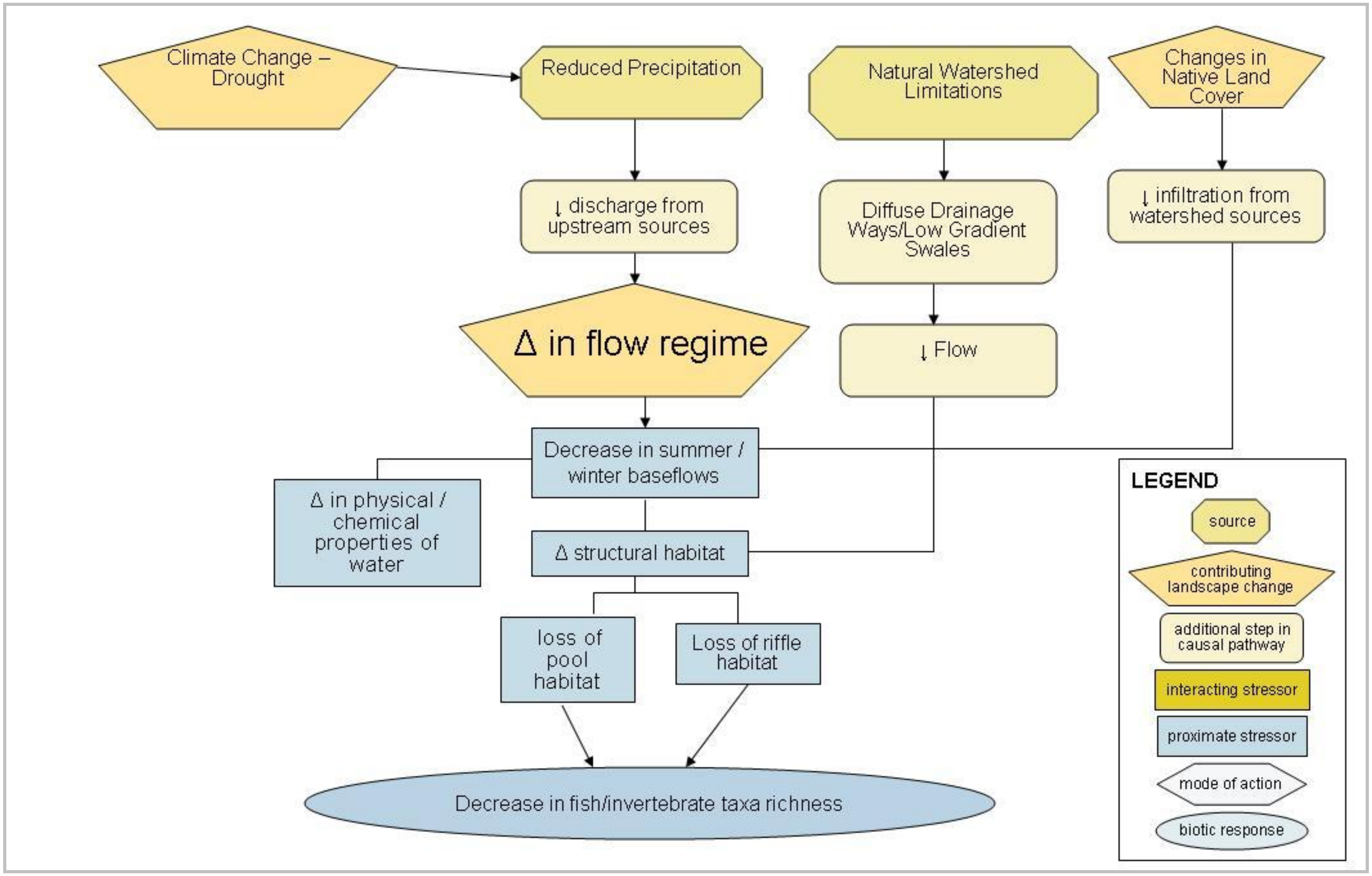

Figure 80. Conceptual Model of Inadequate Baseflow in County Ditch Number 54

4.3.3.2 Ionic Strength

Even though ionic strength levels in Le Sueur County Ditch Number 54 fully supported aquatic life when 2003 fish samples were collected, ionic strength is a candidate stressor because data indicate Le Sueur County Ditch Number 54 had specific conductance levels during 2007 and 2008 that did not always meet the MPCA maximum standard of 1,000 µmhos/cm at 25° C (Minnesota Rule Chapter 7050.0224, Subpart 2). Le Sueur County Ditch Number 54 had a specific conductance level of 708 µmhos/cm at 25° C on July 22, 2003, when fish samples were collected. This ionic strength level fully supports aquatic life. Scott Watershed Management Organization (WMO) staff measured specific conductance at Station LPO (Figure 29) located downstream from biological station 03MN077 on twelve occasions during 2007 through 2008. As shown in Figure 81, a specific conductance value exceeded 1,000 µmhos/cm at 25° C:

- At Station LPO in 2007 on July 2 (5,899 µmhos/cm at 25° C), August 1 (3,527 µmhos/cm at 25° C), and September 18 (1,919 µmhos/cm at 25° C);
- At Station LPO in 2008 on July 24 (4,118 µmhos/cm at 25° C) and October 9 (3,562 µmhos/cm at 25° C).

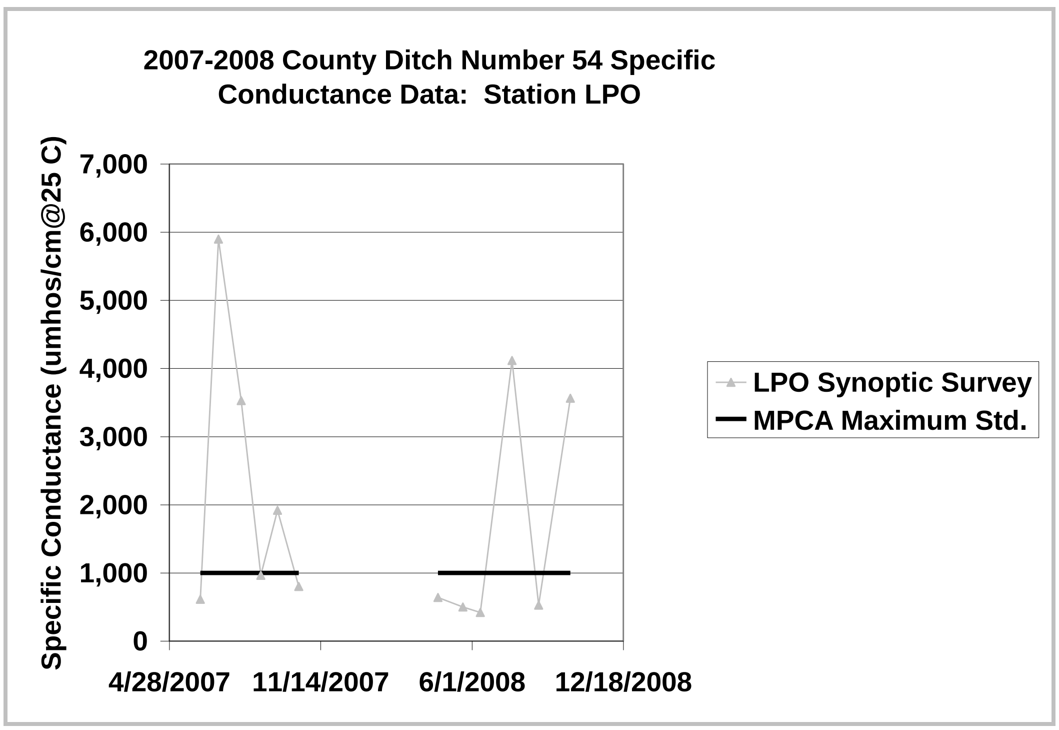

Figure 81. 2007-2008 Le Sueur County Ditch Number 54 Specific Conductance Data: Station LPO

When Station LPO had specific conductance levels that exceeded the MPCA standard of 1,000 µmhos/cm at 25° C, the stream had ionic strength levels that did not support aquatic life. Station LPO generally had levels greater than the MPCA maximum standard of 1,000 µmhos/cm at 25° C. Ionic strength is a candidate stressor because Le Sueur County Ditch Number 54 consistently had ionic strength levels that did not support aquatic life during 2007 and 2008. Although ionic strength was not a stressor on the day that 2003 fish samples were collected, the single measurement in 2003 does not indicate the levels of ionic strength in the stream prior to the collection of fish samples. Additional data collection is recommended to determine the frequency of occurrence of high ionic strength levels in the stream as well as the specific ions associated with the high levels.

A conceptual model of candidate cause 2, ionic strength, is shown in Figure 82. The model shows that effluent from the Montgomery wastewater treatment plant is discharged to the stream. In addition, road salt and deicers from the Minnesota Department of Transportation facility in Montgomery and a nearby highway are conveyed to the stream via stormwater discharge. Increased ions either discharged to the stream or conveyed to the stream via stormwater drainage change the ion content of the stream. This ion content increases ionic strength fluctuation, osmotic stress, ion exchange, and competition for anionic gill sites. As a result, a decrease of mayflies, soft bodied organisms, ion-sensitive taxa, and ion-sensitive life stages occurs and an increase in ion-tolerant taxa and ion-tolerant life stages also occurs. The change in ionic composition increases toxicity of specific ions and increases specific ion toxins within the stream. Changes resulting from increased ionic strength cause biologically impaired fish assemblages, biologically impaired invertebrate assemblages, and other biological impairments.

4.3.3.3 Low Dissolved Oxygen

Even though Le Sueur County Ditch Number 54 had sufficient dissolved oxygen when 2003 fish samples were collected to fully support aquatic life, low dissolved oxygen is a candidate stressor because the stream had oxygen concentrations below 5 mg/L, the threshold for full support of aquatic life (Minnesota Rule Chapter 7050.0222, subpart 4), in 2007 and 2008. In addition, 2003 macroinvertebrate data indicated low oxygen concentrations had preceded the 2003 fish sampling that indicated the stream had an impaired fish MRAP IBI score.

Station 03MN077 had a dissolved oxygen concentration of 7.80 mg/L on July 22, 2003, when fish samples were collected. This dissolved oxygen concentration fully supported aquatic life. However, low flow conditions also occurred when fish samples were collected. Flow was 0.08 cfs.

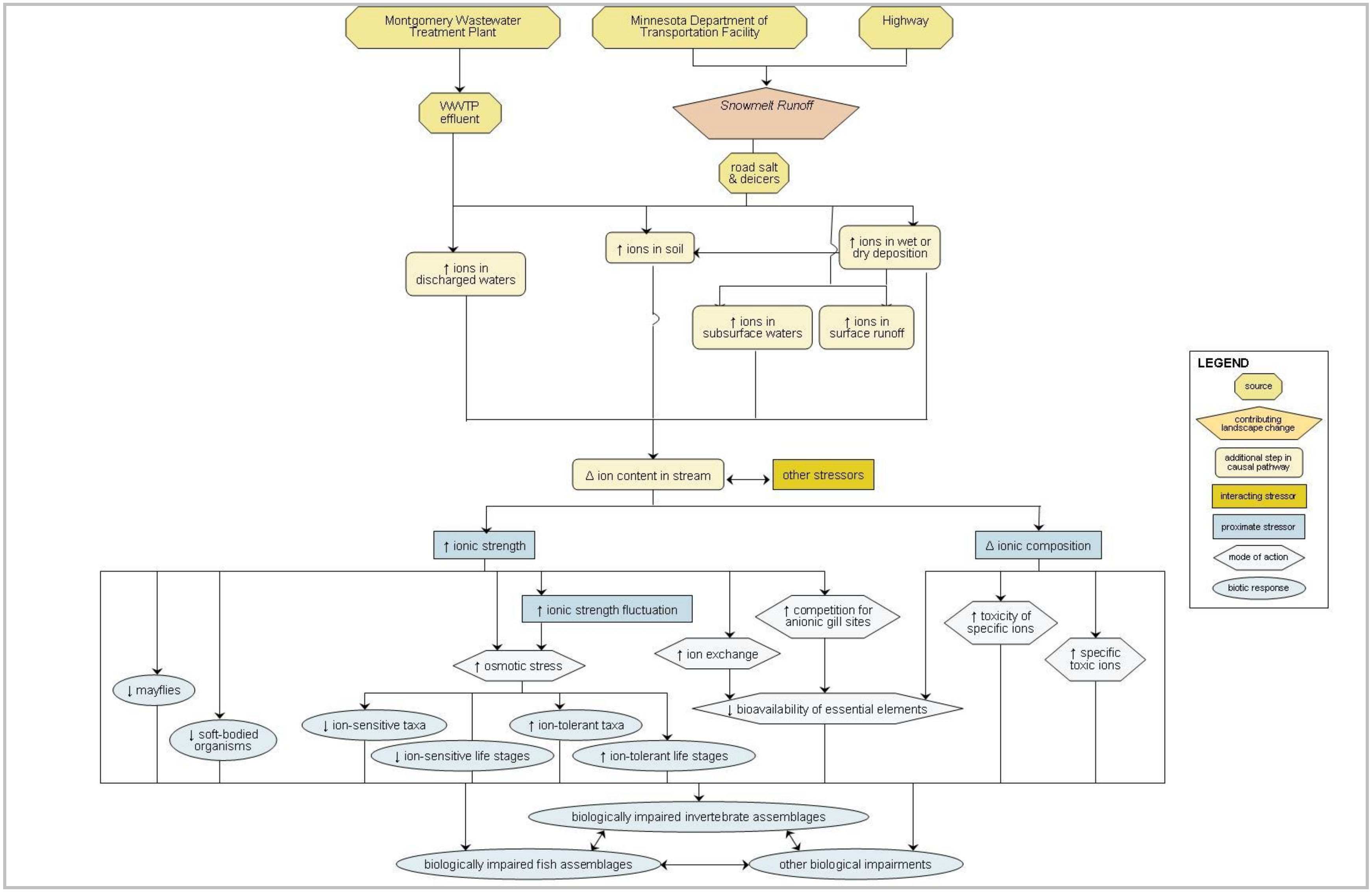

Figure 82. Conceptual Model of Ionic Strength

Scott Watershed Management Organization (WMO) staff measured dissolved oxygen at Station LPO (Figure 29) on twelve occasions during 2007 and 2008. Station LPO had dissolved oxygen concentrations less than 5 mg/L on one occasion during 2007 and on two occasions during 2008. A concentration of 1.62 mg/L occurred on August 1, 2007 and concentrations of 1.12 mg/L and 4.86 mg/L occurred on July 24, 2008 and August 28, 2008, respectively (Figure 83). The data indicate low oxygen values that are stressful to the fish community have occurred in Le Sueur County Ditch Number 54. The low oxygen values have occurred during the summer period and have either occurred during periods of below normal precipitation and low flow conditions or following a period of above average precipitation.

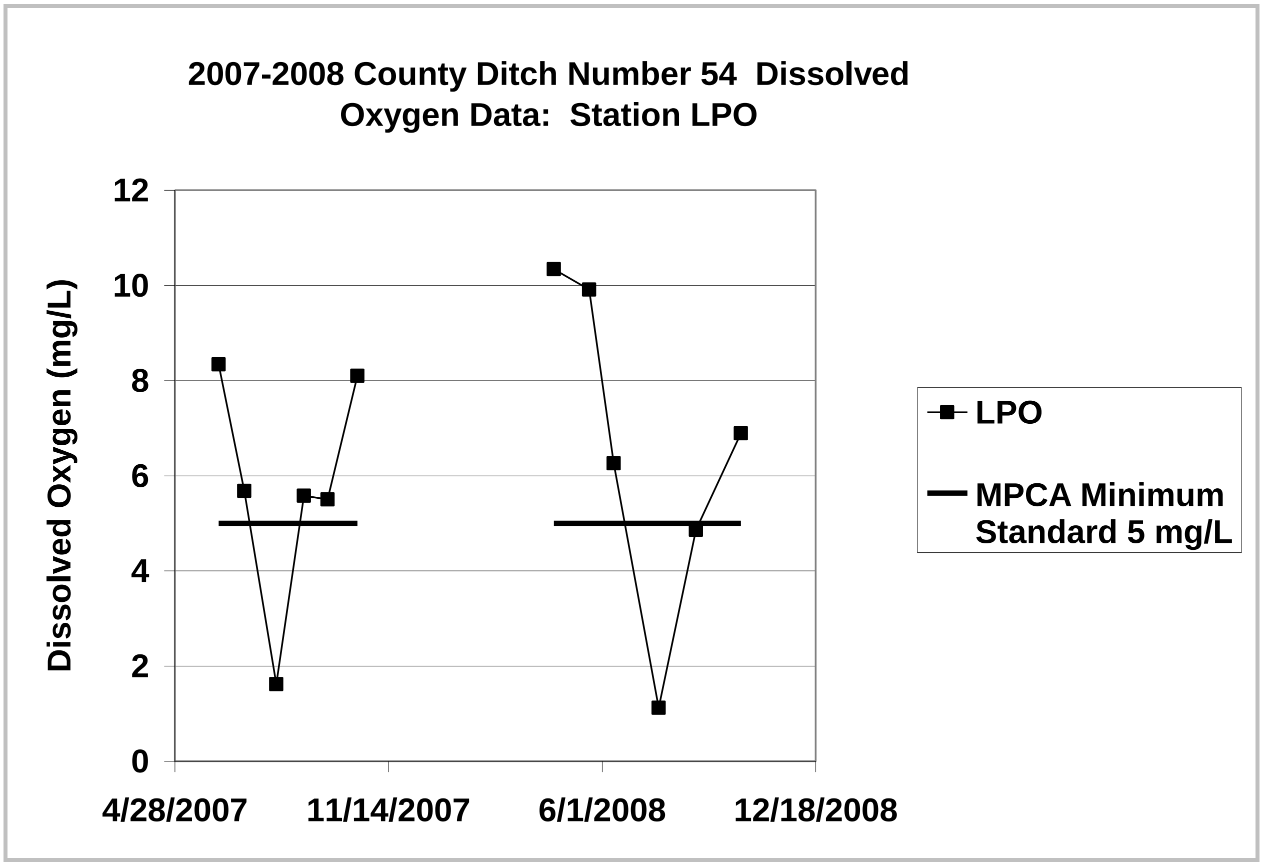

Figure 83. 2007-2008 Le Sueur County Ditch Number 54 Dissolved Oxygen Data: Stations LPI and LPO

During periods in which Le Sueur County Ditch Number 54 had low oxygen values, the Minneapolis St. Paul International Airport reports precipitation of:

- 9.32 inches during August 2007 which was 5.27 inches above normal

- 2.13 inches during July of 2008 which was 1.91 inches below normal
- 3.35 inches during August of 2008 which was 0.70 inches below normal

Below normal precipitation during July of 2008 was accompanied by low flow conditions in Le Sueur County Ditch Number 54. Flow at LPO on July 24, 2008 was 0.5 cfs (Scott WMO 2008). Low flow conditions in 2008 were similar to the low flows observed when fish were collected in 2003 (i.e., 0.08 cfs).

Because 2008 and 2003 were both dry years, low dissolved oxygen is considered a candidate stressor for Le Sueur County Ditch Number 54. Precipitation at the Minneapolis St. Paul International Airport was 6.68 inches below normal during 2003 and was 7.50 inches below normal in 2008. July precipitation was 1.98 inches below normal in 2003 and was 1.91 inches below normal in 2008. Low dissolved oxygen concentrations were associated with low flows during 2007 and 2008. Similar low flows were observed in 2003. Because 2003 and 2008 were both dry years and low dissolved oxygen occurred in 2008, low dissolved oxygen is a candidate stressor for the stream's 2003 impaired fish MRAP IBI score.

Macroinvertebrate samples collected at Station 03MN077 on July 22, 2003 indicate low oxygen conditions stressful to fish occurred in Le Sueur County Ditch Number 54 prior to the collection of 2003 fish samples. 2003 macroinvertebrate data indicate Chironomidae was dominant comprising 77.8 percent of the sample and the dominant two taxa comprised 93.1 percent of the sample. The stream had a Hilsenhoff Biotic Index (HBI) value of 5.8, indicating oxygen conditions were fair (EDA Data for 03MN077, Retrieved 2009). Data from Le Sueur County Ditch 54 were compared to results of a Nine Mile Creek study that indicated HBI values greater than 5.5 were associated with an impaired fish assemblage due to stressful oxygen conditions. 2003 through 2008 Nine Mile Creek fish and invertebrate data indicated fish MRAP IBI scores exceeded the MRAP IBI impairment threshold of 30 or greater when HBI scores were 5.5 or less (i.e., within the good category) during 2006 and 2008. Conversely, fish MRAP IBI scores were below the impairment threshold of 30 or greater when HBI scores were greater than 5.5 during 2003 through 2005 and 2007. In the Nine Mile study, the fish community was not impaired when invertebrate data indicated good oxygen conditions were present and was impaired when the invertebrate data indicated fair to fairly poor oxygen conditions were present (Barr 2009).

A conceptual model of candidate cause 3, low dissolved oxygen, is shown in Figure 84. The model shows that drought conditions reduce oxygen in Le Sueur County Ditch Number 54 by reducing

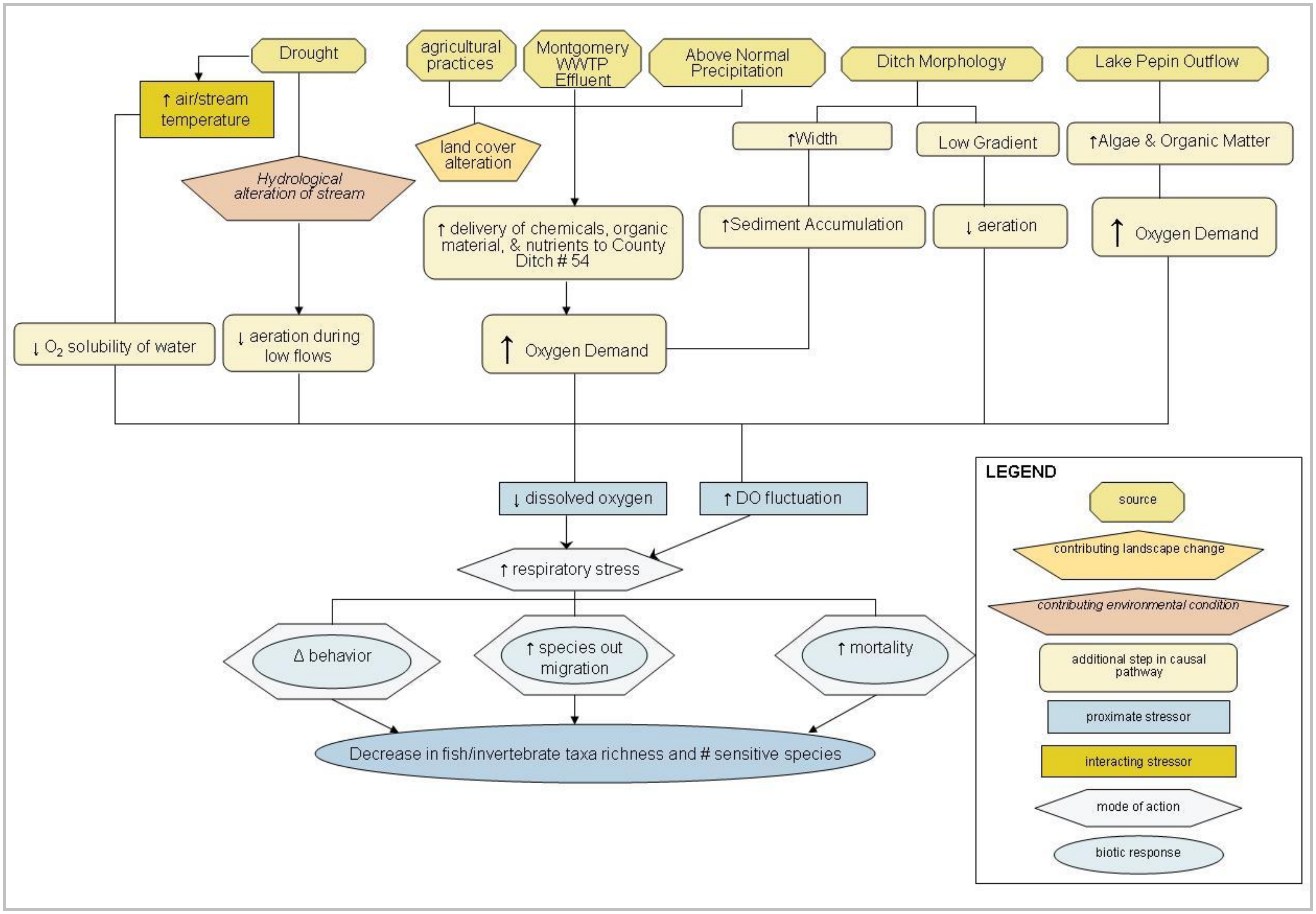

Figure 84. Conceptual Model of Low Dissolved Oxygen Concentrations in Le Sueur County Ditch Number 54

flows which reduce stream aeration. Increased stream temperatures occurring during drought conditions reduce oxygen solubility of water and cause a reduction in dissolved oxygen. Above normal precipitation, land cover alteration from agricultural practices, and effluent from the Montgomery wastewater treatment facility increase delivery of chemicals, organic material, and nutrients to Le Sueur County Ditch 54 which increase oxygen demand and reduce dissolved oxygen. Reduced dissolved oxygen increases respiratory stress which changes behavior, increases species migration out, and increases mortality. The end result of these changes is a decrease in fish and invertebrate taxa richness and number of sensitive species, resulting in fish MRAP IBI impairment.

4.3.3.4 Habitat

Habitat is considered a possible stressor because deeper depths of fine sediment were observed at County Ditch Number 54 (11.38 centimeters on July 22, 2003) than at an unimpaired location on Sand Creek (9.31 centimeters on August 2, 2007) and a tributary to Raven Stream (4.69 centimeters on July 3, 2003) (MPCA Data, 2009). In addition, County Ditch Number 54 observed a slightly higher percent fines (52 percent) and percent embeddedness (56 percent) than an unimpaired location on Sand Creek (50 percent fines and 43 percent embeddedness) and a tributary to Raven Stream (46 percent fines and 54 percent embeddedness). Per personal communication with Scott County staff, backwater conditions have been observed in County Ditch Number 54 as well as a significant of accumulated muck or sediment (Nelson, 2009). With the backwater effect and widened ditch condition, staff thought that water moves very slowly in the ditch, and there is sediment deposition in lower flows, that might be resuspended during higher flows (Nelson, 2009).

4.3.4 Porter Creek

4.3.4.1 Habitat Fragmentation

Habitat fragmentation is considered a possible stressor because two dams and two natural migration barriers (i.e., low gradient and low dissolved oxygen) prevent passage of fish between upstream and downstream segments of Porter Creek. Two grade control structures or small dams located 2 miles and 4 miles from the mouth of Porter Creek interrupt the stream's connectivity. A migration barrier occurs downstream from Bradshaw Lake WMA where the natural occurrence of a lack of stream gradient and wetlands in the watershed has the potential to have an effect on the dissolved oxygen dynamics of Porter Creek. Under low flow conditions, the low gradient downstream from the Bradshaw Lake WMA (i.e., a series of wetlands) and low dissolved oxygen in the stream are migration barriers.

Scott Watershed Management Organization (WMO) staff measured dissolved oxygen at Station NEW (Figure 29) on 13 occasions during 2007 and 2008. Twelve of the thirteen measurements (92 percent) failed to meet the MPCA standard (Figure 85). In addition, Scott County staff noted that flows on the dates of observations were very low, almost zero in most cases. The data indicate that flow and dissolved oxygen in the stream segment downstream from the Bradshaw Lake WMA are natural migration barriers under certain parts of the flow regime. We recommend future monitoring of flow and dissolved oxygen concentrations in Porter Creek upstream and downstream from Bradshaw Lake WMA as well as within Bradshaw Lake WMA. We also recommend fish monitoring at the same locations where flow and oxygen data are collected. The data will indicate impacts of flow and oxygen on fish migration and fish IBI.

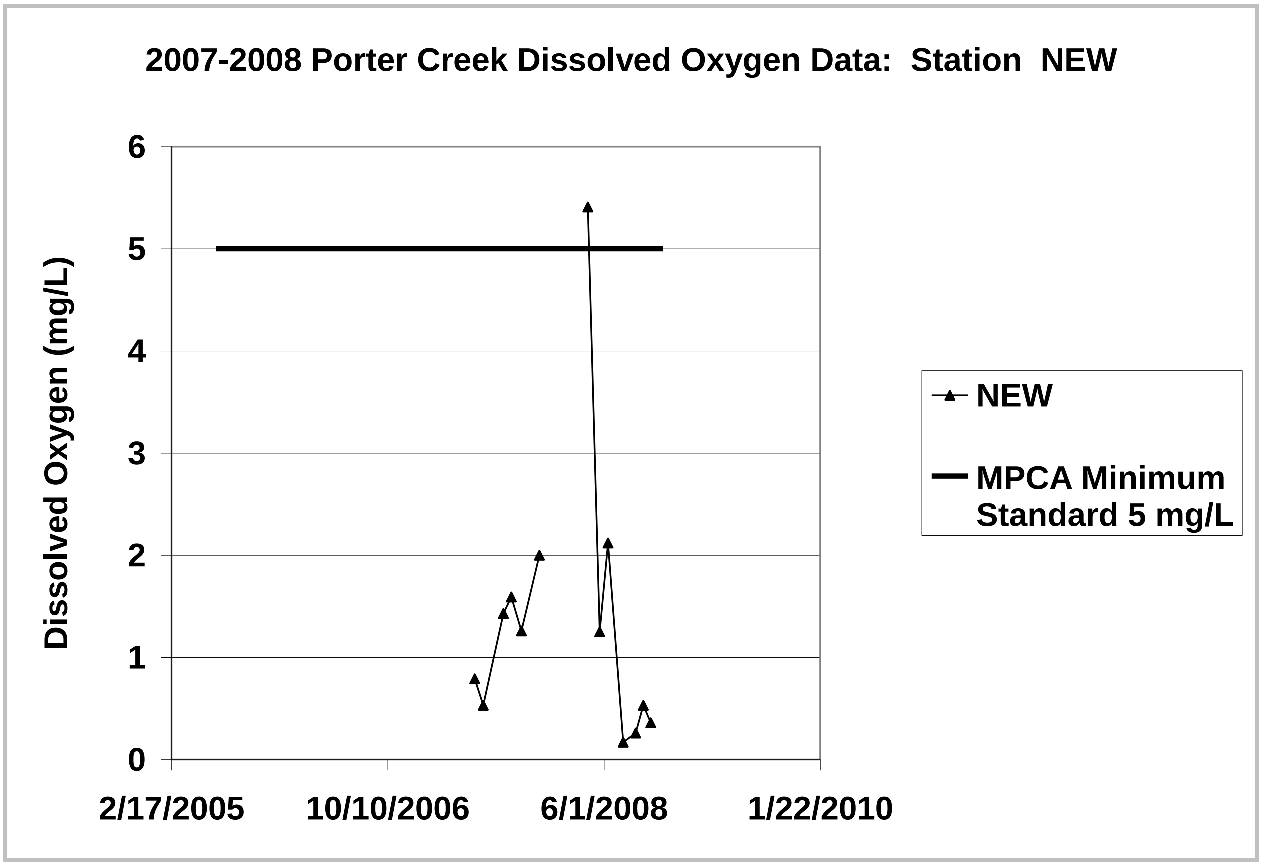

Figure 85. 2007-2008 Porter Creek Dissolved Oxygen Data: Station NEW

As discussed in Section 4.3.1.1, dams adversely impact warmwater fish and macroinvertebrate communities by fragmenting streams and degrading both habitat and water quality. Even small dams have reduced species richness, harvestable-sized sport fish abundance, number of sucker species, percentage of insectivorous minnows, and number of intolerant species while concurrently increasing predominance of tolerant and omnivorous species ((Santucci, V.J. et al., 2005).

Study results indicate negative impacts of habitat fragmentation have occurred for a considerable distance upstream from dams. Even low-head dams with relatively small impoundments can have profound detrimental effects on the biotic integrity of warmwater rivers (Santucci, B.J. et al., 2005).

Evaluation of Porter Creek fish MRAP IBI scores from sample locations upstream and downstream from two small dams indicates biological Station 99MN004, located downstream from the first dam was unimpaired (i.e., MRAP IBI score of 34)and biological Station 99MN003, located upstream from the second dam as well as being located upstream from the natural migration barriers, was impaired (MRAP IBI score of 29). The data indicate habitat fragmentation has adversely impacted the Porter Creek fishery and has resulted in impairment of Porter Creek upstream from the second dam and natural migration barriers. No data were collected from the reach between the two dams.

An assessment of Porter Creek fish communities upstream and downstream from the dams and natural migration barriers indicates a higher number of species, minnow species, and intolerant species as well as a higher percentage of omnivores, insectivores, and simple lithophils were found downstream from the dams and natural migration barriers. A higher percentage of tolerant species occurred upstream from the dams and natural migration barriers. Of the 17 Porter Creek fish species, 8 species occurred both upstream and downstream from the dams and natural migration barriers, 7 species only occurred downstream from the dams and natural migration barriers, and 2 species only occurred upstream from the dams and natural migration barriers (Table 13).

A comparison of Porter Creek fish data with the results of a study following dam removal in the Baraboo River, Wisconsin provides further evidence that habitat fragmentation has adversely impacted Porter Creek's fishery. A study of changes in fish assemblage following dam removal in the Baraboo River, Wisconsin indicated biotic integrity scores (possible range = 0-100) increased by 35 to 50 points at three of the four impoundments as a result of decreases in percent tolerant species, increases in the number of intolerant species, and in some cases, increases in species richness. After dam removal, 10 species that were found below, but not above the most downstream dam before removal, were collected at new sites upstream from the dam (Catalano et al., 2007). Porter Creek fish data indicate a lower species richness, fewer omnivores, insectivores, and simple lithophils as well as a higher percentage of tolerant species occurred upstream from the dams and natural migration barriers. The fish MRAP IBI score was lower upstream from the dams and natural migration barriers (Table 13).

Table 13 Comparison of Porter Creek Fish Species Upstream and Downstream From Two Small Dams and Two Natural Fish Migration Barriers

Species Scientific Name	Species Common Name	Downstream From Dams and Natural Migration Barriers	Upstream From Dams and Natural Migration Barriers	Fish Present		
		99MN004	99MN003	Only DS	Only UPS	Both UPS and DS
Catostomus commersonii	White sucker	20	14			X
Lepomis cyanellus	Green sunfish	38	25			X
Lepomis machrochirus	Bluegill sunfish	4	0	X		
Micropterus salmoides	Largemouth bass	1	0	X		
Pomoxis nigromaculatus	Black crappie	0	1		X	
Campostoma anomalum	Central stoneroller	8	3			X
Cyprinus carpio	Common carp	2	0	X		
Hybognathus hankinsoni	Brassy minnow	0	3		X	
Notropus cornutus	Common shiner	2	0	X		
Notropis dorsalis	Bigmouth shiner	14		X		
Pimephales promelas	Fathead minnow	8	25			X
Rhinichthys atratulus	Blacknose dace	11		X		
Semotilus atromaculatus	Creek chub	28	76			X
Ictalurus melas	Black bullhead	1	9			X
Noturus flavus	Stonecat	1		X		
Etheostoma nigrum	Johnny darter	4	1			X
Umbra limi	Central mudminnow	4	79			X
	Total	146	236			

Because Porter Creek stream reaches downstream from the dams and natural migration barriers had a higher number of species, a higher percentage of insectivores, and a lower percentage of tolerant species, the Porter Creek data indicate habitat fragmentation is a candidate cause of the stream's impaired fish assemblage in the reach upstream from the dams and natural migration barriers. A conceptual model of candidate cause 1, habitat fragmentation, is shown in Figure 74. The model shows that habitat fragmentation from the dams and natural migration barriers causes a loss of connectivity that reduces fish refuge and migration as well as the number of sensitive species and insectivores. The resultant reduction in species richness and number of fish causes impairment.

4.3.4.2 Inadequate Baseflow

Biological Station 99MN003, pictured above, dries up during periods of reduced precipitation, such as occurred during 2007 when the above picture was taken (Photo from Interfluve 2008).

Inadequate baseflow is considered a candidate stressor because Porter Creek frequently experiences periods of no flow and sometimes dries up during periods of reduced precipitation. Scott Watershed Management Organization (WMO) measured flow continuously during 2005 through 2008 at two locations. Station XAN monitored unimpaired biological station 99MN004 and Station JON monitored a location downstream from impaired biological station 99MN003 (Figure 29). Daily average flow measurements from the two locations are shown in Figure 86.

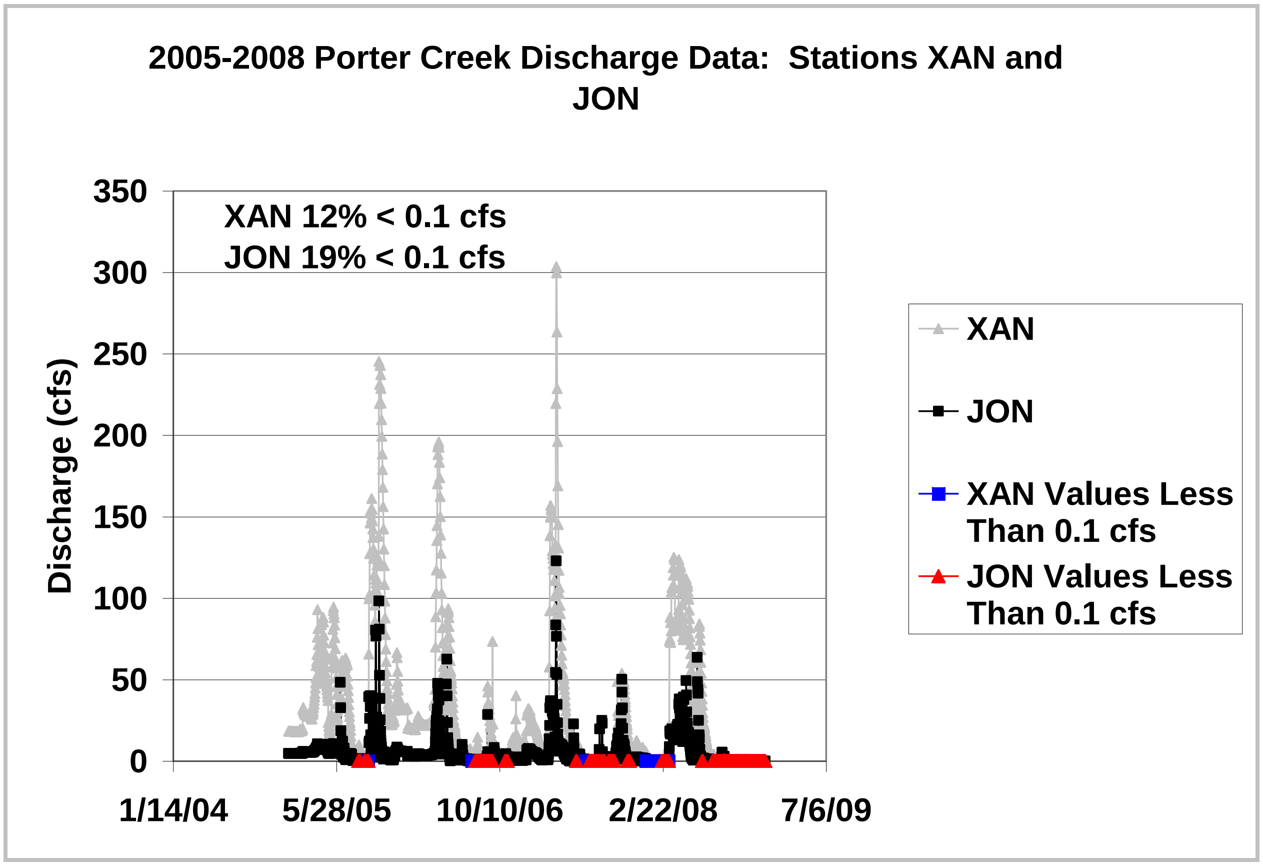

Figure 86. 2005-2008 Porter Creek Discharge Data: Stations XAN and JON

The impaired upstream reach of Porter Creek consistently had inadequate baseflow at a higher frequency than the unimpaired downstream reach. During 2005 through 2008, flow was less than 0.1 cfs, the threshold for support of fish (Ball 1982), at a frequency of 12 percent at unimpaired downstream Station XAN and at a frequency of 19 percent at upstream impaired Station JON. During the individual years, Station XAN had flows less than 0.1 cfs at a frequency of 0.3 percent in 2005, 4.7 percent in 2006, 11.2 percent in 2007, and 32.1 percent in 2008. Station JON consistently had flows that were less than 0.1 cfs at a higher frequency than downstream Station XAN. Specifically, Station JON had flows less than 0.1 cfs at a frequency of 3.8 percent in 2005, 12.3 percent in 2006, 15.3 percent in 2007, and 47.4 percent in 2008 (Figure 86). The data indicate that downstream reaches of Porter Creek consistently had higher flows than upstream reaches and had inadequate baseflow less often than upstream reaches.

During the 2005 through 2008 period, baseflow was consistently adequate for full support of aquatic life at downstream unimpaired Station XAN during the spring through early summer period and inadequate baseflow during the summer first occurred during the July through September period.

Upstream Station JON annually had inadequate baseflow sooner than Station XAN. During the 2005 through 2008 growing seasons, inadequate baseflow first occurred at Station JON during the June through August period. The data indicate the impaired upstream reaches annually experience inadequate baseflow sooner and more frequently than the downstream unimpaired reaches of Porter Creek. The data further indicate it is unlikely that inadequate baseflow occurred at unimpaired downstream Station XAN either prior to or during the collection of fish samples in June of 1999 since inadequate baseflow first occurred during July at this location during the 2005 through 2008 monitoring period.

Because the January through June period of 1999 was wetter than the January through June period of 2005 through 2008, it appears unlikely that upstream impaired Station JON had inadequate baseflow during the 1999 growing season prior to or during fish sample collection in June of 1999. Precipitation data from the Minneapolis St. Paul International Airport indicate approximately 19 inches of precipitation occurred during January through June of 1999 compared with 8 to 13 inches of precipitation during this same period (January through June) of 2005 through 2008. Although inadequate baseflow likely did not occur during the April through June period of 1999, previous occurrences of inadequate baseflow in combination with habitat fragmentation has stressed the biological communities at locations upstream from the Porter Creek dams (See discussion in Section 4.3.4.1. for details regarding dam locations and natural migration barriers causing habitat fragmentation).

While the data indicate inadequate baseflow is a candidate stressor, the respective roles of natural and anthropogenic causes are unknown. Future monitoring of flow is recommended to determine the respective roles of natural and anthropogenic causes of inadequate baseflow to Porter Creek.

The co-occurrence of inadequate baseflow and habitat fragmentation has concurrently stressed the fish assemblage of upstream impaired reaches of Porter Creek and prevented replenishment of extirpated species at locations upstream from Porter Creek dams and natural migration barriers. Habitat fragmentation has caused the impacts of inadequate baseflow to upstream impaired Station 99MN003 to be more severe and longer lasting than impacts of inadequate baseflow on unimpaired downstream Station 99MN004. Because the downstream location has connectivity with Sand Creek, fish from Sand Creek can easily replenish the stream’s fish assemblage following periods of inadequate baseflow. In contrast, the upstream impaired location is separated from Sand Creek by two dams and two natural migration barriers. Hence, this location has no opportunity for a similar replenishment. Inadequate baseflow has stressed the biological community of Station 99MN003 and downstream dams have prevented a replenishment of fish extirpated by this stress.

A conceptual model of candidate cause 1, inadequate baseflow, is shown in Figure 87. The model shows that no stream gradient downstream of the Bradshaw Lake WMA reduces baseflow. In addition, land alteration has reduced infiltration due to increased runoff. Reduced infiltration in combination with reduced precipitation diminishes discharge to the stream from upstream sources resulting in a decrease of both summer and winter baseflows. The reduction in baseflows changes the physical and chemical properties of the water and the structural habitat of the stream. The resultant loss of pool and riffle habitat causes a decrease in fish and invertebrate taxa richness. The loss of fish taxa richness causes a low fish IBI score that fails to meet the MRAP IBI impairment threshold of 30 or greater.

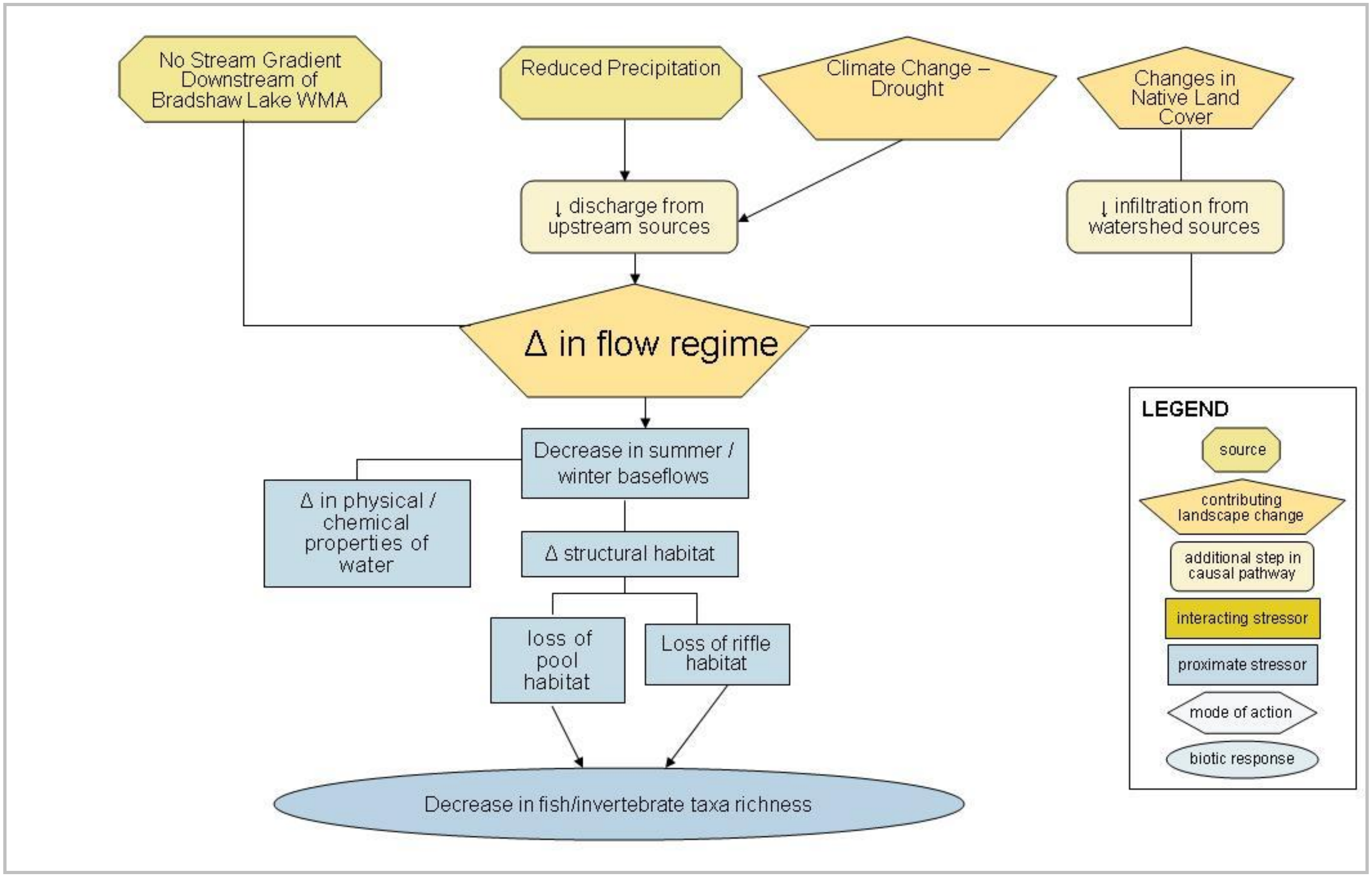

Figure 87. Conceptual Model of Inadequate Baseflow in Porter Creek

4.3.4.3 Low Dissolved Oxygen

Even though low dissolved oxygen levels did not occur when fish samples were collected in 1999, low dissolved oxygen is considered a candidate stressor because oxygen concentrations below 5 mg/L, the threshold for full support of aquatic life (Minnesota Rule Chapter 7050.0222, subpart 4), occurred more frequently in the upstream impaired reaches than the downstream unimpaired reach of Porter Creek during 2007 through 2008.

On June 25, 1999, dissolved oxygen concentrations at biological Stations 99MN003 and 99MN004 were 7.82 and 7.85, respectively. These concentrations fully supported aquatic life.

Scott Watershed Management Organization (WMO) staff measured dissolved oxygen at Stations JON, CR2P, NEW, XAN, and XEO (Figure 29) on approximately 12 occasions during 2007 and 2008. The following stations had measurements below 5 mg/L (Figure 88):

- NEW – 92 percent of sample events
- CR2P – 50 percent of sample events
- XEO – 22 percent of sample events
- XAN – 4 percent of sample events

The data indicate impaired upstream reaches of Porter Creek (NEW, CR2P, and XEO) had oxygen concentrations that did not support aquatic life more frequently than the unimpaired downstream reach (XAN). Station JON, the site located closest to the impaired fish sampling site, did not observe low dissolved oxygen concentrations during 2007 and 2008.

Scott Watershed Management Organization (WMO) staff measured oxygen continuously at Station XAN (Figure 29) during July of 2008. Dissolved oxygen was below 5 mg/L for half an hour on July 25 (i.e., from 5:45 to 6:15 A.M.) due to diel oxygen changes (Figure 89). Station XAN had a maximum dissolved oxygen concentration of 7.29 mg/L and an average dissolved oxygen concentration of 6.2 mg/L on July 25. All other July 2008 dissolved oxygen measurements were greater than 5 mg/L. The data indicate oxygen concentrations generally supported aquatic life at the unimpaired downstream station, XAN.

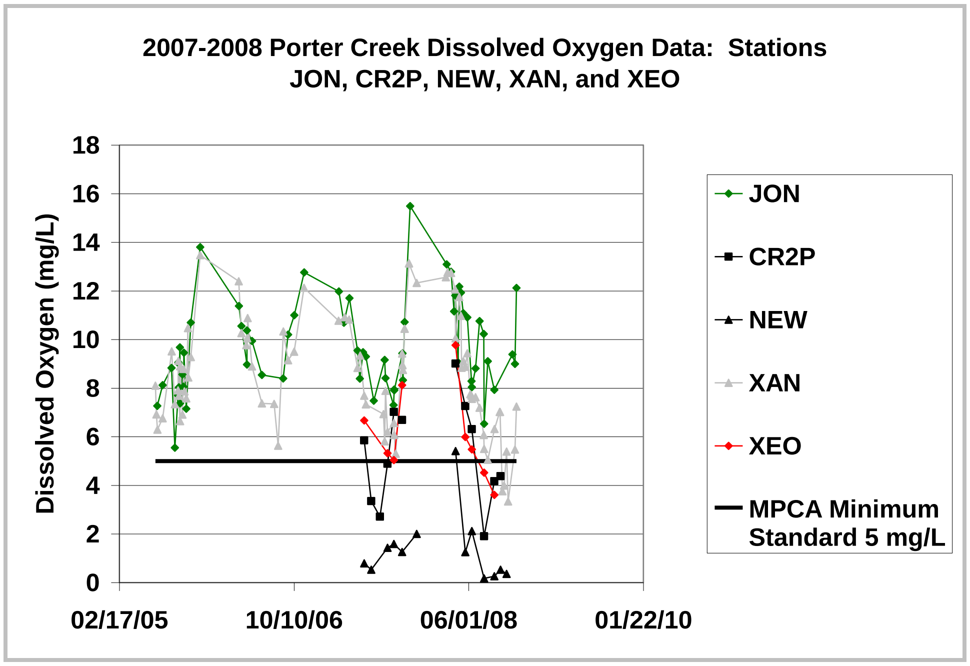

Figure 88. 2007-2008 Porter Creek Dissolved Oxygen Data: Stations JON, CR2P, NEW, XAN, and XEO

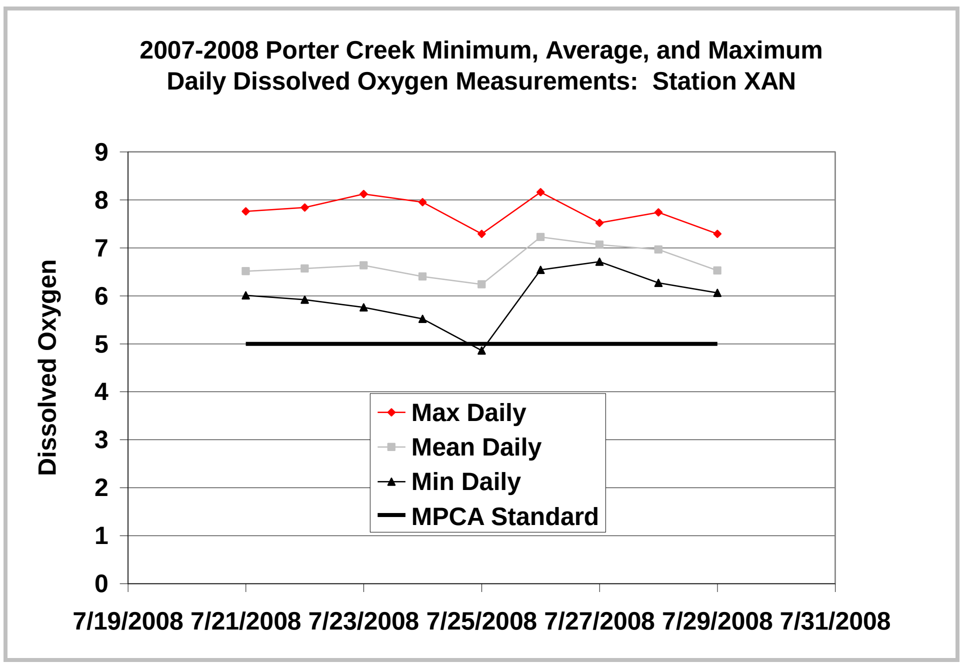

Figure 89. 2007-2008 Porter Creek Minimum, Average, and Maximum Daily Dissolved Oxygen Measurements: Station XAN

The co-occurrence of low oxygen levels and habitat fragmentation has concurrently stressed the fish assemblage of upstream impaired reaches of Porter Creek and prevented replenishment of extirpated species. Habitat fragmentation has caused the impact of low oxygen concentrations to upstream impaired reaches of Porter Creek (i.e., Station 99MN003) to be more severe and longer lasting than impacts of low dissolved oxygen concentrations on unimpaired downstream reaches (i.e., Station 99MN00). Because the downstream location has connectivity with Sand Creek, fish from Sand Creek can easily replenish the stream's fish assemblage when low dissolved oxygen concentrations stress or extirpate species of fish. In contrast, the upstream impaired location is separated from Sand Creek by two dams as well as two natural migration barriers (i.e., lack of gradient and low dissolved oxygen concentrations downstream from Bradshaw Lake WMA under low flow conditions) and, hence, has no opportunity for a similar replenishment. Low dissolved oxygen concentrations have stressed the biological community of Station 99MN003 and migration barriers have prevented a replenishment of fish extirpated by this stress.

A conceptual model of candidate cause 3, low dissolved oxygen, is shown in Figure 90. The model shows that drought conditions depress oxygen concentrations in Porter Creek by diminishing flows which reduce stream aeration. Increased stream temperatures occurring during drought conditions lessen oxygen solubility of water and reduce dissolved oxygen concentrations. Above normal precipitation and land cover alteration from agricultural practices increase delivery of chemicals, organic material, and nutrients to Porter Creek which increase oxygen demand and reduce dissolved oxygen. Lower dissolved oxygen concentrations increase respiratory stress which changes behavior, increases species migration out, and increases mortality. Fish and invertebrate taxa richness and number of sensitive species decrease resulting in fish IBI impairment.

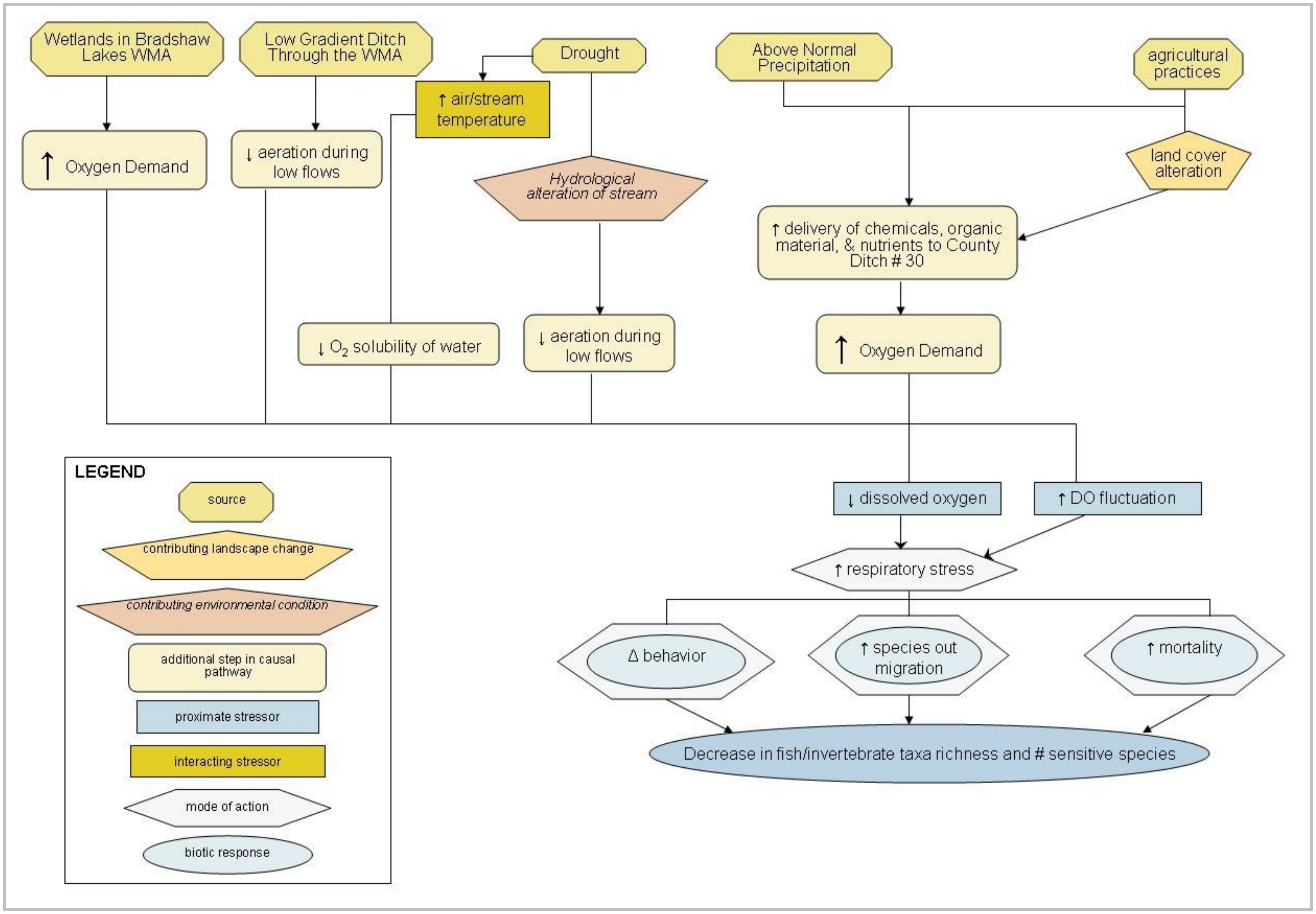

Figure 90. Conceptual Model of Low Dissolved Oxygen Concentrations in Porter Creek

4.3.4.4 Sediment

Sediment is a candidate stressor of Porter Creek because highest sediment concentrations were consistently found in the impaired upstream reach. Scott Watershed Management Organization (WMO) staff collected total suspended solids and volatile suspended solids samples from two locations on Porter Creek during 2005 through 2008. Downstream Station XAN is the same location as unimpaired biological station 99MN004. Upstream Station JON is located downstream from impaired biological Station 99MN003.

Failing bluffs along upstream reaches of Porter Creek, pictured above and below, add sediment to the stream. The sites pictured above and below are located immediately downstream from the biomonitoring site (Pictures from Inter-Fluve 2008).

FLUX modeling results of total suspended solids and volatile suspended solids data collected from Stations XAN and JON during 2005 through 2008 indicate both total and volatile suspended solids loads consistently increased between upstream and downstream reaches of Porter Creek due to flow increases (Table 14). Unimpaired Station XAN consistently had highest loads (Table 14). However, highest flow weighted mean total and volatile suspended solids concentrations were consistently found in the impaired upstream reach monitored by Station JON. Because highest sediment concentrations consistently occurred in the impaired reach of the stream, sediment is a candidate stressor for the impaired fish community of Porter Creek. The data indicate the fish in impaired upstream reaches of Porter Creek were consistently exposed to higher concentrations of sediment than fish in unimpaired downstream reaches.

Table 14. Porter Creek Total and Volatile Suspended Solids Annual Loads, Total and Volatile Suspended Solids Flow Weighted Mean Concentrations, and Annual Flow Volume: Stations SA 8.2, CR2, and 145

Station	TSS Annual Load (kg)			
	2005	2006	2007	2008
JON	589,833	311,528	638,879	402,663
XAN	3,630,499	1,662,550	1,871,810	1,679,689

Station	TSS Flow-weighted Mean Concentration (ppb)			
	2005	2006	2007	2008
JON	92,552	89,263	118,844	97,870
XAN	84,163	77,263	83,052	84,156

Station	VSS Annual Load (kg)			
	2005	2006	2007	2008
JON	63,680	35,468	67,411	44,896
XAN	579,774	272,000	293,882	270,765

Station	VSS Flow-weighted Mean Concentration (ppb)			
	2005	2006	2007	2008
JON	9,992	10,163	12,540	10,912
XAN	13,441	12,640	13,039	13,566

Station	Annual Flow Volume (ft^3)			
	2005	2006	2007	2008
JON	92,552	89,263	118,844	97,870
XAN	84,163	77,263	83,052	84,156

Habitat survey results provide additional evidence that sediment is a candidate stressor. Habitat survey results from Porter Creek Station 99MN003 indicate this stream location had more embeddedness than the unimpaired downstream location. According to the SVAP assessment, riffle embeddedness of the impaired upstream reach was from 40 to 90 percent as compared with 20 to 30 percent at the unimpaired downstream reach 1 (Inter-Fluve 2008). The MSHA assessment also indicated more embeddedness occurred at the impaired upstream reach than the unimpaired downstream reach (Inter-Fluve 2008).

A conceptual model of candidate cause 5, sediment, is shown in Figure 91. The model shows that runoff from crop farming and ravines draining to Porter Creek increase sediment delivery to the stream and sediment deposition within the stream. In addition, crop farming has resulted in vegetation removal, a reduction in sediment buffering capacity, and increased sediment delivery to

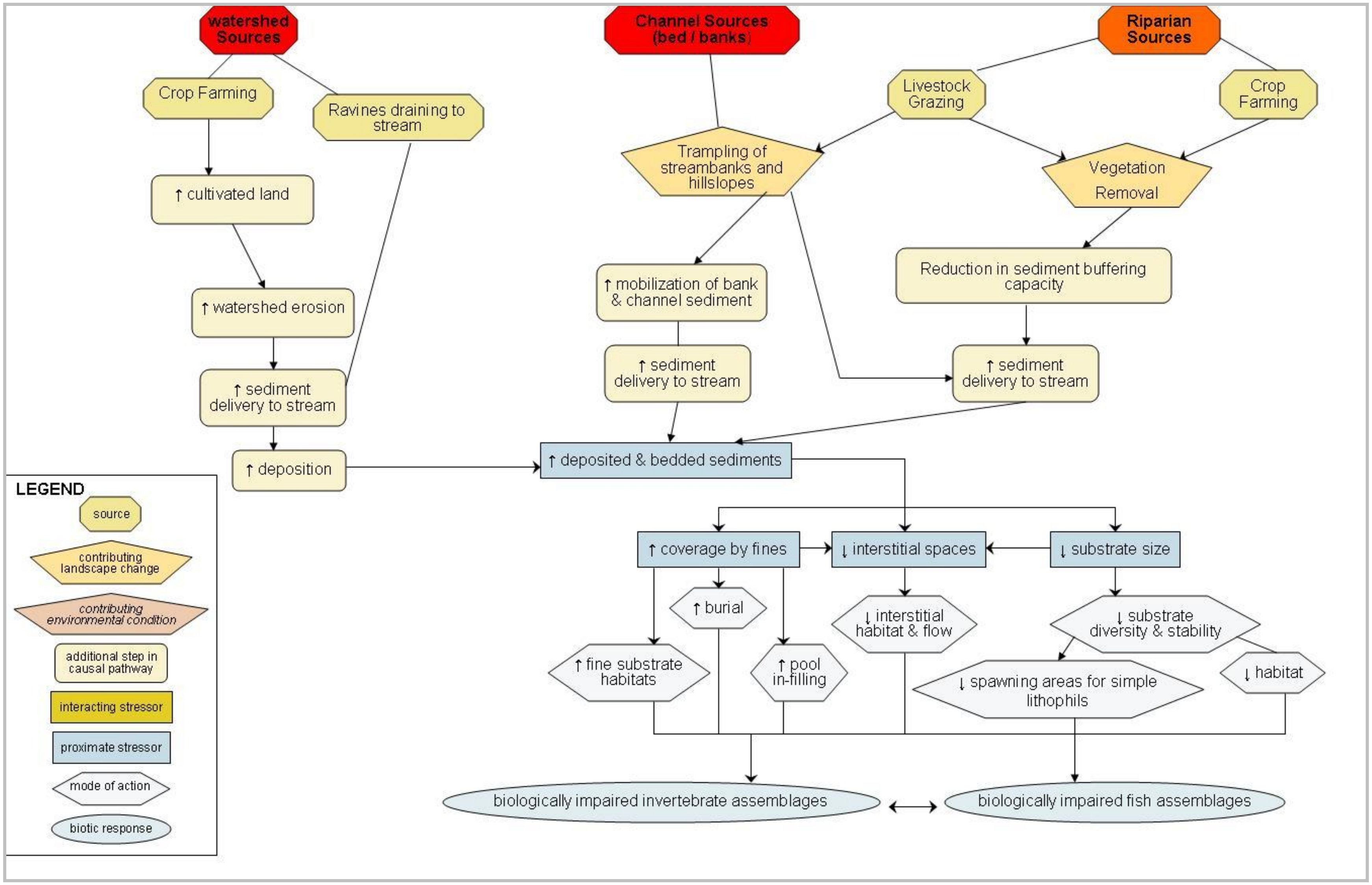

Figure 91. Conceptual Model of Sediment in Porter Creek

the stream. Livestock in reach 13, downstream from biological Station 99MN003, have trampled streambanks, reduced bank stability, and increased sediment delivery to the stream. Increased sediment delivery to the stream has resulted in increased concentrations of sediment as well as an increase in deposited and bedded sediments. Increased coverage by fines, reduced interstitial spaces, and reduced substrate size from deposited and bedded sediments has reduced substrate diversity and stability, reduced spawning areas for simple lithophils, degraded habitat, increased pool in-filling, burial, and fine substrate habitats. Habitat changes resulting from increased sediment delivery to the stream have caused a biologically impaired fish assemblage.

4.3.4.5 Habitat

Habitat is considered a candidate stressor of Porter Creek because the impaired upstream reach had poorer habitat than the unimpaired downstream reach. In addition, the unimpaired downstream reach of Porter Creek had better habitat than both impaired and unimpaired Sand Creek biological locations (Figure 29) while the impaired upstream reach of Porter Creek had habitat that was either similar to or poorer than Sand Creek biological locations (Figure 29).

Cattle wandering freely through the stream channel at Reach 13, pictured above, created problems with bed and 2008). Reach 13 is immediately downstream from impaired Station 99MN003 (Picture from Interfluve 2008).

Porter Creek habitat was assessed in the spring of 2007. Information was collected on soils, streamflow, stream bed grain size, had aquatic biota, fish passage barriers, infrastructure, land use, and vegetation. This information was compiled on three forms: a customized reconnaissance form, a Minnesota Stream Habitat Assessment form (MSHA), and a Stream Visual Assessment Protocol (SVAP) form.

The habitat of Porter Creek as assessed by MSHA is poorer in the upstream impaired reach than the downstream unimpaired reach. Impaired upstream biological Station 99MN003 (also Reach 14 shown in Figure 3) had a MSHA score of 54.6, which is less than the MSHA score of 70 at downstream unimpaired biological Station 99MN004 (also Reach 1 shown in Figure 3). The MSHA score in the impaired upstream reach of Porter Creek is lower than scores from biological stations located on Sand Creek (Table 15). The MSHA score in the unimpaired downstream reach of Porter Creek is higher than scores at biological stations located on Sand Creek (Table 16). The data indicate poor habitat is a plausible stressor of the fish assemblage in the upstream reach of Porter Creek. The data further indicate good habitat supports the unimpaired fish assemblage of the downstream reach of Porter Creek.

Table 15. Porter and Sand Creek Fish MRAP IBI and MSHA Scores*

Fish Site	Fish MRAP IBI		MSHA Scores						
			MSHA Reach	Total	Surrounding Land Use	Riparian Zone	Substrate	Cover	Channel Morphology
Porter Creek									
99MN003	29		14	54.6	0	13.0	19.6	11.0	11.0
99MN004	34		1	70.0	0	14.0	22.0	12.0	22.0
Sand Creek									
03MN077	29		NA	NA	NA	NA	NA	NA	NA
07MN056	31		12	63.9	2.5	6.0	18.4	8.0	29.0
07MN055	24								
90MN116	20		10	62.8	2.5	6.0	16.8	7.0	30.5
01MN044	22	[1]							
01MN044	26	[2]	8a	63.5	2.5	7.0	19.0	6.0	29.0
00MN006	26		7b	63.0	2.0	7.0	17.0	6.0	31.0
07MN033	48		6a	59.4	2.0	7.0	19.4	5.0	26.0
07MN034	38		4b	60.4	5.0	5.0	16.4	11.0	23.0

[1]Sampled July 24, 2001
[2]Sampled July 25, 2007
*Inter-Fluve (2008)

The habitat of Porter Creek as assessed by SVAP is also poorer in the impaired upstream reach than the unimpaired downstream reach. As shown in Table 16, impaired upstream biological Station 99MN003 (also Reach 14 shown in Figure 3) had a SVAP score of 81 compared with a score of 90 for downstream unimpaired biological Station 99MN004 (also Reach 1 shown in Figure 3). The unimpaired downstream reach of Porter Creek had a higher SVAP score (90) than the biological stations of Sand Creek (SVAP scores of 64 to 83). The impaired upstream reach had a SVAP score within the range of scores occurring at Sand Creek biological stations

Table 16. Porter and Sand Creek Fish MRAP IBI and SVAP Scores*

	Fish MRAP IBI Sites								
	Sand Creek							Porter Creek	
	03MN077	07MN056	07MN055 & 90MN116	01MN044	00MN006	07MN033	07MN034	99MN003	99MN004
	Fish MRAP IBI Scores								
	29	31	20 & 20	22 & 26	26	48	34	29	34
	SVAP Scores								
	Sand Creek							Porter Creek	
Assessment Metric	**Not Assessed**	**SVAP Reach 12**	**SVAP Reach 10**	**SVAP Reach 8**	**SVAP Reach 7**	**SVAP Reach 6**	**SVAP Reach 4**	**SVAP Reach 14**	**SVAP Reach 1**
Channel Condition	NA	8	7	5	3	3	3	9	10
Hydrologic Alteration	NA	8	8	8	5	5	5	8	8
Riparian Zone	NA	7	9	9	6	6	10	8	10
Bank Stability	NA	7	6	6	8	8	1	8	8
Water Appearance	NA	3	7	7	8	8	7	3	4
Nutrient Enrichment	NA	3	6	6	6	6	8	5	7
Barriers to Fish Movement	NA	10	10	10	1	3	10	10	10
Instream Fish Cover	NA	5	5	5	3	3	5	5	5
Pools	NA	7	7	7	7	7	4	4	7
Insect/Invertebrate Habitat	NA	6	6	6	4	4	3	5	4
Canopy cover	NA	1	1	1	10	1	1	10	7
Riffle Embeddedness	NA	8	9	9	8	8	5	4	8
Macro-invertebrates Had	NA	2	2	2	4	4	2	2	2
Total SVAP	NA	75	83	81	73	66	64	81	90
Overall Score (Total/13)	NA	5.8	6.4	6.2	5.6	5.1	4.9	6.2	6.9

*Inter-Fluve 2008

Impaired upstream biological Station 99MN003 (also Reach 14 shown in Figure 3) had poorer channel morphology and poorer substrate than unimpaired downstream biological Station 99MN004 (also Reach 1 shown in Figure 3). According to the SVAP assessment, riffle embeddedness of the impaired upstream reach was from 40 to 90 percent as compared with 20 to 30 percent at the unimpaired downstream reach 1 (Inter-Fluve 2008). According to the MSHA assessment, channel morphology issues in the impaired upstream reach included lower sinuosity, a less stable channel, and a poorer score for channel development than the unimpaired downstream reach (Inter-Fluve 2008). The MSHA assessment also indicated more embeddedness occurred at the impaired upstream reach than the unimpaired downstream reach (Inter-Fluve 2008).

Habitat is considered a candidate stressor because the habitat in the impaired upstream reach of Porter Creek was poorer than habitat in the unimpaired downstream reach. Increased embeddedness, together with other habitat issues, in the impaired reach has stressed the stream's fish assemblage. The habitat assessment of Porter Creek found that a number of early stage ravines drain to the stream and input sediment to the impaired reach. The ravines are located approximately 24 miles from the mouth of Porter Creek. The channel bed of impaired biological Station 99MN003 (also Reach 14 shown in Figure 3) was composed of a mix of cobble, gravel, sand, and fine-grained material. Sand and fines made up most of the depositional features of this reach, whereas gravel and cobble were found in the thalweg sections of the channel. In the channel, residual pools were nearly absent from the reach and fish habitat was minimal.

Stream reaches immediately downstream from biological Station 99MN003 had cattle wandering freely through the stream channel as well as failing bluffs during the 2007 habitat assessment. The cattle created problems with bed and bank stability and the failing bluffs added sediment to the stream (Inter-Fluve 2008).

A conceptual model of candidate cause 6, habitat, is shown in Figure 92. The model shows that row crops necessitated a watershed land cover alteration that resulted in increased sediment delivery to Porter Creek. Ravine drainage inputs increased channel incision. Failing bluffs added sediment to the stream. Cattle grazing decreased streambank stability and increased sediment delivery. Collectively, cattle grazing, row crops, failing bluffs, and ravine drainage inputs caused a change in channel morphology as well as a change in structural habitat, sediment transport efficiency, and water chemistry. An impaired fish community resulted from the habitat degradation resulting from cattle grazing, row crops, failing bluffs, and ravine drainage inputs.

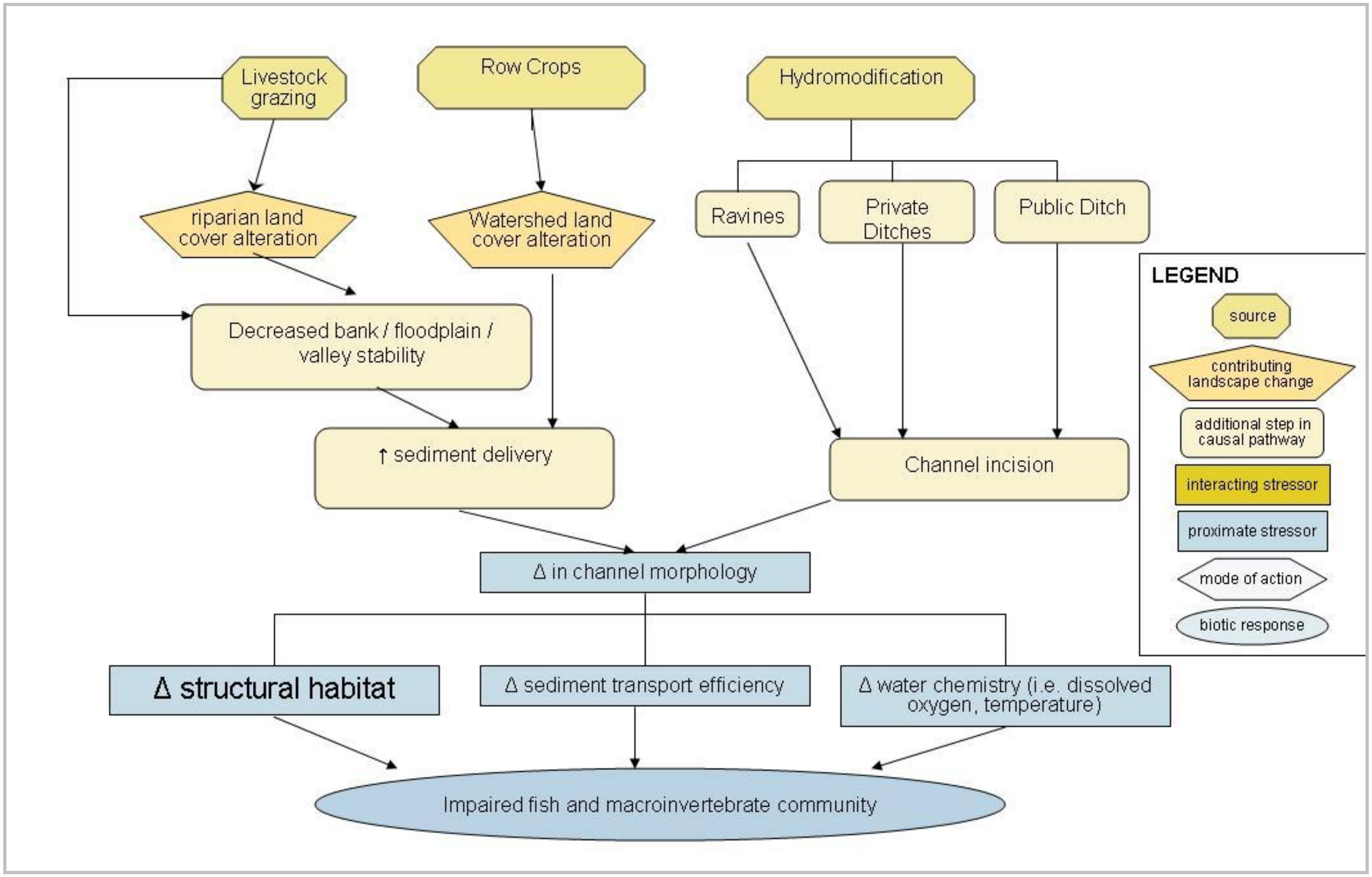

Figure 92. Conceptual Model of Habitat in Porter Creek

5.0 Evaluate Data From the Case

Physical and water quality data as well as biological data from Sand Creek, Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek were evaluated to determine the strength of evidence for the candidate causes of the streams' impairment. The types of evidence used in the evaluation were:

- **Spatial/Temporal Co-occurrence—**Biological effect occurred where (spatial co-occurrence) and when (temporal co-occurrence) the cause occurred and did not occur where and when the cause was absent.
- **Evidence of Exposure or Biological Mechanism—**Measurements of the biota show that relevant exposure to the cause has occurred, or that other biological mechanisms linking the cause to the effect have occurred
- **Causal Pathway—**Steps in the pathways linking sources to the cause can serve as supplementary or surrogate indicators that the cause and the biological effect are likely to have co-occurred
- **Stressor-Response Relationships from the Field—**As exposure to the cause increases, intensity or frequency of the biological effect increases; as exposure to the cause decreases, intensity or frequency of the biological effect decreases
- **Manipulation of Exposure—**Field experiments or management actions that increase or decrease exposure to a cause must increase or decrease the biological effect
- **Laboratory Tests of Site Media—**Controlled exposure in laboratory tests to causes (usually toxic substances) present in site media should induce biological effects consistent with the effects had in the field.
- **Temporal Sequence—**The cause must precede the effect.
- **Verified Predictions—**Knowledge of a cause's mode of action permits prediction and subsequent confirmation of previously unobserved effects.
- **Symptoms—**Biological measurements (often at lower levels of biological organization than the effect) can be characteristic of one or a few specific causes.

The CADDIS system for scoring types of evidence (Appendix B) was used to evaluate the evidence from the case. The symbols used in the scoring and their meanings are:

- **D** – This finding is sufficient to diagnose the candidate cause as the cause of impairment
- **+++** – This finding convincingly supports the case for the candidate cause
- **++** – This finding strongly supports the case for the candidate cause
- **+** – This finding somewhat supports the case for the candidate cause, but is not strongly supportive because the association could be coincidental
- **0** – This finding neither supports nor weakens the case for the candidate cause, because the evidence is ambiguous.
- **-** – This finding somewhat weakens the case for the candidate cause, but is not strongly weakening due to potential confounding or random error.
- **--** – This finding strongly weakens the case for the candidate cause
- **---** – This finding convincingly weakens the case for the candidate cause
- **NA** – Cannot be scored because the data required for scoring are not available.

Evaluation results follow for parameters supported by evidence.

5.1 Candidate Cause 1: Habitat Fragmentation

5.1.1 Spatial/Temporal Co-occurrence — Habitat fragmentation and an impaired biological community co-occurred in Sand Creek, Picha Creek, and Porter Creek. Four locations upstream of a Sand Creek natural waterfalls noted an impaired fish community and two downstream locations did not. Picha Creek Station 01MN058, located immediately upstream from a culvert/fish barrier, was impaired. One location upstream of two Porter Creek dams as well as two natural migration barriers (i.e., low gradient and low dissolved oxygen) noted an impaired fish community and one downstream location did not. The evidence was compatible with spatial and temporal co-occurrence and a score of + was given (Table 17).

Table 17 Sand Creek, Picha Creek, and Porter Creek Evidence Table for Habitat Fragmentation: Evidence Using Data From Sand Creek, Picha Creek, and Porter Creek

Types of Evidence, Habitat Fragmentation	Sand Creek	Picha Creek	Porter Creek
Spatial/temporal co-occurrence	+	+	+
Temporal Sequence	+	+	+
Evidence of Exposure or Biological Mechanism	++	++	++
Causal Pathway	++	++	++
Symptoms	D	+	D

5.1.2 Temporal Sequence — Habitat fragmentation preceded fisheries impairment in Sand Creek, Picha Creek, and Porter Creek during each year in which data were collected. Hence a score of + was given for temporal sequence (Table 17).

5.1.3 Evidence of Exposure or Biological Mechanism — Two Sand Creek biological stations (07MN033 and 07MN034) were downstream from a natural waterfalls and one Porter Creek biological station (99MN004) was downstream from two small dams as well as natural migration barriers in free-flowing reaches and had unimpaired fish communities. The stream reaches that were not exposed to habitat fragmentation were not impaired. Four Sand Creek biological stations (90MN116, 00MN006, 01MN044, and 07MN055), one Picha Creek station (01MN058), and one Porter Creek biological station (99MN003) were exposed to habitat fragmentation at the same time as the streams had an impaired fish community. Because impaired fish communities occurred in Sand Creek, Picha Creek, and Porter Creek locations exposed to habitat fragmentation, a score of ++ was given for evidence of biological mechanism. The score indicates the biological mechanism, habitat fragmentation, is consistently present in impaired stream reaches (Table 17).

5.1.4 Causal Pathway — All steps in the causal pathway of habitat fragmentation and fish community impairment were present in Sand Creek, Picha Creek, and Porter Creek when either a natural waterfalls, dams, natural migration barrier, or a culvert/fish barrier were present and an impaired fish community was present. Because the data show that all steps in at least one causal pathway are present, a score of ++ was given (Table 17).

5.1.5 Symptoms — The differences in symptoms or species occurrences observed upstream and downstream from The Falls on Sand Creek and small dams as well as natural migration barriers on Porter Creek are diagnostic of the candidate cause, habitat fragmentation. Stream reaches downstream from The Falls, dams, or natural migration barriers had a higher number of species, a higher percentage of insectivores, and a lower percentage of tolerant species (Tables 9 and 13) than upstream locations. This difference in species assemblage in upstream and downstream locations is diagnostic of habitat fragmentation impacts. A score of D was given for symptoms (Table 17).

Sand Creek upstream and locations had additional species evidence diagnostic of the candidate cause, habitat fragmentation. Seven fish species found downstream, but not upstream of The Falls on Sand Creek, are diagnostic of habitat fragmentation. Shorthead redhorse, golden redhorse, hornyhead chub, blackside darter, pumpkinseed, logperch, and emerald shiner were found downstream from The Falls on Sand Creek, but were not found upstream from The Falls. The difference in species assemblage in upstream and downstream locations is diagnostic of habitat fragmentation. The data provide further evidence that a score of D is appropriate for Sand Creek symptoms (Table 17).

The high percentage of tolerant species (i.e., 42 to 43 percent) and the absence of intolerant and insectivore species at Station 01MN058 on Picha Creek characterize the candidate cause, habitat fragmentation. However, other stressors, such as inadequate baseflow, poor habitat, and sediment could also eliminate intolerant and insectivore species as well as increase the proportion of tolerant individuals. Because the species occurring in Picha Creek characterize habitat fragmentation and a few other stressors, a score of + was given for symptoms (Table 17) because the symptoms are indicative of multiple possible causes.

5.2 Candidate Cause 2: Inadequate Baseflow

5.2.1 Spatial Co-occurrence — Inadequate baseflow and an impaired biological community co-occurred in Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek. Picha Creek and Le Sueur County Ditch 54 had a discharge of less than 0.1 cfs when fish samples were collected to determine stream impairment. When the MPCA attempted to collect fish samples from Picha Creek in 2007, it was dry. Hence, impaired fish MRAP IBI and inadequate baseflow co-occurred. The evidence was compatible with spatial co-occurrence and a score of + was given (Table 18).

Flow data are not available during 1999 when fish data were collected at Porter Creek. However, dry climatic conditions occurred during the month in which 1999 fish data were collected. In addition, the impaired reach of Porter Creek frequently had inadequate baseflow when climatic conditions were dry during 2005 through 2008. The upstream impaired Porter Creek reach monitored by Station JON had flows less than 0.1 cfs at a frequency of 3.8 percent in 2005, 12.3 percent in 2006, 15.3 percent in 2007, and 47.4 percent in 2008. The evidence was compatible with spatial co-occurrence and a score of + was given (Table 18).

Table 18 Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek Evidence Table for Inaequate Baseflow: Evidence Using Data From Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek			
Types of Evidence, Inadequate Baseflow	**Picha Creek**	**Le Sueur County Ditch Number 54**	**Porter Creek**
Spatial Co-occurrence	+	+	+
Temporal Sequence	+	+	+
Evidence of Exposure or Biological Mechanism	++	++	++
Causal Pathway	++	++	++

5.2.2 Temporal Sequence — Inadequate baseflow preceded fish IBI impairment at Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek. Dry climatic conditions and a discharge of less than 0.1 cfs preceded fish IBI impairment at Picha Creek and Le Sueur County Ditch Number 54. The evidence was compatible with temporal sequence and a score of + was given (Table 18).

Dry climatic conditions preceded fish IBI impairment at Porter Creek Station 99MN003. Although flow data are not available for 1999 when fish impairment occurred, dry climatic conditions occurred whenever inadequate baseflow occurred at Station 99MN003 during 2005 through 2008. Because dry climatic conditions occurred when fish samples were collected from Station 99MN003 in June of 1999, a score of + was given for temporal sequence (Table 18).

5.2.3 Evidence of Exposure or Biological Mechanism — Because discharge was less than 0.1 cfs when fish samples were collected from Picha Creek and Le Sueur County Ditch Number 54, the fish assemblage was exposed to inadequate baseflow and the biological mechanism for impairment. A score of ++ was given for exposure or biological mechanism (Table 18).

During June of 1999 when Porter Creek Station 99MN003 had fish IBI impairment, the stream was exposed to dry climatic conditions. During 2005 through 2008 inadequate baseflow was detected in Porter Creek Station 99MN003 during dry climatic conditions. The evidence was compatible with exposure or biological mechanism and a score of ++ was given (Table 18).

5.2.4 Causal Pathway — All steps in the causal pathway of inadequate baseflow and fish community impairment were present when fish impairment occurred in Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek. Discharge was less than 0.1 cfs at Picha Creek and Le Sueur County Ditch Number 54. A score of ++ was given for causal pathway (Table 18).

Below normal precipitation occurred during June of 1999 when Porter Creek Station 99MN003 had impaired fish MRAP IBI and below normal precipitation occurred when Porter Creek Station 99MN003 had inadequate baseflow during 2005 through 2008. Because the data shows that all steps in at least one causal pathway are present, a score of ++ was given (Table 18).

5.3 Candidate Cause 3: Low Dissolved Oxygen

5.3.1 Spatial Co-occurrence — Although Le Sueur County Ditch Number 54 and Porter Creek had low dissolved oxygen concentrations during 2007 and 2008, neither stream had low dissolved oxygen concentrations on the day that fish samples were collected that indicated impairment due to low fish IBI. Hence, it is uncertain whether low dissolved oxygen concentrations co-occurred with impaired fish MRAP IBI and caused the impairment.

Le Sueur County Ditch Number 54 Station LPO had low dissolved oxygen concentrations on one occasion in 2007 (i.e., 1.62 mg/L on August 1) and two occasions during 2008 (i.e., 1.12 mg/L on July 24 and 4.86 mg/L on August 28).

During 2007 and 2008, four Porter Creek stations had low dissolved oxygen concentrations at the following locations and frequencies:

- NEW – 92 percent of sample events
- CR2P – 50 percent of sample events
- XEO – 22 percent of sample events
- XAN – 4 percent of sample events

Station JON, the site located closest to the impaired fish sampling site did not observe low dissolved oxygen concentrations during 2007 and 2008.

Le Sueur County Ditch Number 54 Station 03MN077 had a dissolved oxygen concentration of 7.80 mg/L on July 22, 2003, when fish samples were collected that determined impairment. Impaired Porter Creek Station 99MN003 had a dissolved oxygen concentration of 7.82 mg/L on June 25, 1999 when fish samples were collected that determined impairment.

Because low oxygen concentrations did not occur on the day fish samples were collected that determined impairment at Stations 03MN077 and 99MN003, it is uncertain whether the candidate cause, low dissolved oxygen, and the effect, impaired fish, co-occur. Hence, a score of 0 was given (Table 19).

Table 19. Le Sueur County Ditch Number 54 and Porter Creek Evidence Table for Low Dissolved Oxygen: Evidence Using Data From LeSueur County Ditch Number 54 and Porter Creek

Types of Evidence, Low Dissolved Oxygen	County Ditch Number 54	Porter Creek
Spatial co-occurrence	0	0
Temporal Sequence	0	0
Evidence of Exposure or Biological Mechanism	0	0
Causal Pathway	0	0
Symptoms	+	NA*

*Data not available to score symptoms for Porter Creek.

5.3.2 Temporal Sequence — Although dissolved oxygen concentrations fully supported aquatic life at Le Sueur County Ditch Number 54 Station 03MN077 and Porter Creek Station 99 MN003 when fish sampling indicated impairment, both streams observed low dissolved oxygen concentrations during 2007 and 2008 during periods of reduced precipitation. However, because the candidate cause was not present when fish sampling indicated impairment, the temporal relationship between the candidate cause and the effect is uncertain. A score of 0 was given (Table 19).

5.3.3 Evidence of Exposure or Biological Mechanism — Although the fish assemblage of Le Sueur County Ditch Number 54 Station 03MN077 and Porter Creek 99MN003 were not exposed to low dissolved oxygen when fish sampling indicated impairment, both streams had low dissolved oxygen concentrations during 2007 and 2008 during periods of reduced precipitation. However, because the candidate cause was not present when fish sampling indicated impairment, exposure or the biologic mechanism is uncertain and a score of 0 was given (Table 19).

5.3.4 Causal Pathway — Although the fish assemblage of Le Sueur County Ditch Number 54 Station 03MN077 and Porter Creek 99MN003 were not exposed to low dissolved oxygen when fish sampling indicated impairment, both streams had low dissolved oxygen concentrations during 2007 and 2008 during periods of reduced precipitation. However, because the candidate cause was not present when fish sampling indicated impairment, the presence of all steps in the causal pathway is uncertain and a score of 0 was given (Table 19).

5.3.5 Symptoms

Macroinvertebrate data collected at Le Sueur County Ditch 54 Station 03MN077 is diagnostic of low dissolved oxygen stressing the biological community. The stream had a HBI value of 5.8 indicating oxygen conditions were fair. Since symptoms or species occurrences observed at the site include some but not all of a diagnostic set, a score of + was given (Table 19).

Macroinvertebrate data were not available for Porter Creek. Hence, symptoms could not be scored due to lack of data.

5.4 Candidate Cause 4: Ionic Strength

5.4.1 Spatial Co-occurrence — Although Le Sueur County Ditch Number 54 had high specific conductance levels during 2007 and 2008, the stream did not have high specific conductance levels on the day that fish samples were collected that indicated impairment due to low fish MRAP IBI. Hence, it is uncertain whether ionic strength co-occurred with impaired fish MRAP IBI and caused the impairment.

During 2007 through 2008, specific conductance exceeded the MPCA standard of 1,000 µmhos/cm at 25° C (Minnesota Rule Chapter 7050.0224, Subpart 2) at Station LPO on July 2, 2007 (5,899 µmhos/cm at 25° C), August 1, 2007 (3,527 µmhos/cm at 25° C), September 18, 2007 (1,919 µmhos/cm at 25° C), and July 24, 2008 (4,118 µmhos/cm at 25° C).

Le Sueur County Ditch Number 54 Station 03MN077 had a specific conductance level of 708 µmhos/cm at 25° C on July 22, 2003 when fish samples were collected that determined the stream was impaired for low fish MRAP IBI.

Because a high specific conductance level did not occur on the day fish samples were collected that determined fish impairment of Le Sueur County Ditch Number 54 Station 03MN077, it is uncertain whether the candidate cause, ionic strength, and the effect, impaired fish MRAP IBI, co-occur. Hence, a score of 0 was given (Table 20).

Table 20. Le Sueur County Ditch Number 54 Evidence Table for Ionic Strength: Evidence Using Data From Le Sueur County Ditch Number 54	
Types of Evidence, Ionic Strength	**County Ditch Number 54**
Spatial co-occurrence	0
Temporal Sequence	0
Evidence of Exposure or Biological Mechanism	0
Causal Pathway	0

5.4.2 Temporal Sequence — Ionic strength levels fully supported aquatic life at Le Sueur County Ditch Number 54 Station 03MN077 when 2003 fish sampling indicated impairment. Le Sueur County Ditch Number 54 had high specific conductance levels that did not fully support aquatic life during 2007 and 2008. However, because the candidate cause was not present when fish sampling indicated impairment, the temporal relationship between the candidate cause and the effect is uncertain. A score of 0 was given (Table 20).

5.4.3 Evidence of Exposure or Biological Mechanism — The fish assemblage of Le Sueur County Ditch Number 54 Station 03MN077 was not exposed to high levels of ionic strength when fish sampling indicated impairment. Specific conductance at Station 03MN077 when fish samples were collected on July 22, 2003 was 708 µmhos/cm at 25° C and fully supported aquatic life. 2007 and 2008 specific conductance measurements from Le Sueur County Ditch Number 54 indicate high levels of ionic strength have occurred and provide evidence that the fish assemblage has been exposed to ionic strength levels that do not support aquatic life. However, because the stream did not have high ionic strength levels when fish sampling indicated impairment, the data show that exposure or the biologic mechanism is uncertain. A score of 0 was given (Table 20).

5.3.4 Causal Pathway — Data show that high ionic strength levels were missing in the causal pathway of high ionic strength levels and fish impairment when 2003 fish sampling determined impairment for Le Sueur County Ditch Number 54. The stream had high ionic strength levels in 2007 and 2008. However, because specific conductance levels at the stream fully supported aquatic life when fish sampling indicated impairment, the data show that the presence of all steps in the causal pathway is uncertain. A score of 0 was given (Table 20).

5.5 Candidate Cause 5: Habitat

5.5.1 Spatial Co-occurrence — Poor habitat and an impaired biological community co-occurred in County Ditch Number 54, Picha Creek, and Porter Creek. County Ditch Number 54 Station 03MN077 observed deeper depths of fine sediment and higher percent fines (2003 survey) than an unimpaired Sand Creek location (2007 survey). The impaired upstream reach of Porter Creek (i.e., Station 99MN003) observed poorer habitat than the unimpaired downstream reach (2007 survey). Picha Creek Station 01MN058 observed poorer habitat than Sand Creek (2007 survey). Fish survey results indicate both stations are impaired with low fish IBI scores. The evidence was compatible with spatial co-occurrence and a score of + was given (Table 21).

Table 21. County Ditch Number 54, Picha Creek, and Porter Creek Evidence Table for Habitat: Evidence Using Data From County Ditch Number 54, Picha Creek, and Porter Creek

Types of Evidence, Habitat	County Ditch Number 54	Picha Creek	Porter Creek
Spatial co-occurrence	+	+	+
Temporal Sequence	+	0	0
Evidence of Exposure or Biological Mechanism	++	+	+
Causal Pathway	++	+	+

5.5.2 Temporal Sequence — Because the fish and habitat surveys of Picha Creek and Porter Creek were completed at different times, the temporal sequence is uncertain. The fish surveys were completed in 2001 at Picha Creek and in 1999 at Porter Creek. The habitat surveys were completed in 2007. Because the temporal relationship between the candidate cause, habitat, and the effect, fish impairment, is uncertain, a score of 0 was given (Table 21).

The fish and habitat surveys on County Ditch Number 54 were performed at the same time and the data indicate poor habitat preceded fish IBI impairment. The evidence was compatible with temporal sequence and a score of + was given (Table 21).

5.5.3 Evidence of Exposure or Biological Mechanism — Habitat data are not available from Picha Creek Station 01MN058 for 2001 and from Porter Creek Station 99MN003 for 1999 when fish sampling indicated impairment. Both locations had poor habitat during 2007. The data show that exposure or the biological mechanism is weak or inconsistently present. Hence, a score of + was given (Table 21).

The fish and habitat surveys on County Ditch Number 54 were performed at the same time and the data indicate poor habitat occurred at the same time as fish IBI impairment. The evidence is compatible with exposure or biological mechanism and a score of ++ was given (Table 21).

5.5.4 Causal Pathway — Habitat data are not available from Picha Creek Station 01MN058 for 2001 and from Porter Creek Station 99MN003 for 1999 when fish sampling indicated impairment. Both locations had poor habitat during 2007. The data show that some steps in the causal pathway of habitat and impaired fish MRAP IBI are present. Hence, a score of + was given (Table 21).

The fish and habitat surveys on County Ditch Number 54 were performed at the same time and the data indicate poor habitat and impaired fish IBI co-occurred. The evidence is compatible with poor habitat causing impaired fish IBI. Hence, a score of ++ was given (Table 21).

5.6 Candidate Cause 7: Sediment

5.6.1 Spatial Co-occurrence — Sediment and fish MRAP IBI impairment co-occurred at Picha Creek Station 01MN058 and Porter Creek Station 99MN003. Data from a 2007 habitat survey indicated Station 01MN058 had higher sediment embeddedness than both impaired and unimpaired Sand Creek biological stations. Picha Creek had 40 to 90 percent embeddedness and Sand Creek biological stations had embeddedness ranging from less than 20 percent to 40 percent.

2007 habitat data indicate impaired Porter Creek Station 99MN003 had higher flow weighted mean total suspended solids concentrations as well as higher embeddedness than unimpaired Station 99MN004. During 2005 through 2008, impaired Station 99MN003 had total suspended solids flow weighted mean concentrations ranging from 89,263 to 118,844 parts per billion (ppb) compared with concentrations ranging from 77,263 to 84,163 at unimpaired Station 99MN004. In 2007, impaired Station 99MN003 had embeddedness ranging from 40 to 90 percent compared with 20 to 30 percent at unimpaired Station 99MN004. The evidence was compatible with spatial co-occurrence and a score of + was given (Table 22).

Table 22. Picha Creek and Porter Creek Evidence Table for Sediment: Evidence Using Data From Picha Creek and Porter Creek

Types of Evidence, Sediment	Picha Creek	Porter Creek
Spatial co-occurrence	+	+
Temporal Sequence	0	0
Evidence of Exposure or Biological Mechanism	+	+
Causal Pathway	+	+

5.6.2 Temporal Sequence — Embeddedness data were not collected when fish sampling indicated impairment at Picha Creek Station 01MN058 and Porter Creek Station 99MN003. In addition, total suspended solids data were not collected from Porter Creek Stations in 1999 when fish sampling indicated impairment at Station 99MN003. However, 2007 habitat data indicated sediment embeddedness stressed the fish communities at Stations 01MN058 and 99MN003. 2005 through 2008 data indicated higher flow weighted mean total suspended solids concentrations occurred at impaired Station 99MN003 than unimpaired Station 99MN004. However, because sediment data were not collected when fish sampling indicated impairment, the temporal relationship between the candidate cause and fish impairment is uncertain and a score of 0 was given (Table 22).

5.6.3 Evidence of Exposure or Biological Mechanism — Embeddedness data are not available from Stations 01MN058 and 99MN003 when fish sampling indicated impairment. Total suspended solids data are not available from 99MN003 when fish sampling indicated impairment. However, 2007 data indicate the fish at 01MN058 and 99MN003 were exposed to high sediment embeddedness (i.e., 40 to 90 percent). The fish at impaired Station 99MN003 were exposed to higher flow weighted mean total suspended solids concentrations and higher embeddedness than unimpaired Station 99MN004. The data show that exposure or the biological mechanism is weak or inconsistently present. Hence, a score of + was given (Table 22).

5.6.4 Causal Pathway — Embedded sediment data are not available from Picha Creek Station 01MN058 for 2001 and from Porter Creek Station 99MN003 for 1999 when fish sampling indicated impairment. Suspended sediment data are not available from Porter Creek Station 99MN003 for 1999 when fish sampling indicated impairment. Both locations had high sediment embeddedness (i.e., 40 to 90 percent) during 2007. Porter Creek Station 99MN003 had higher flow weighted mean total suspended solids concentrations and higher embeddedness than unimpaired Station 99MN004. The fish at Stations 01MN058 and 99MN003 were exposed to sediment. The data show that some steps in the causal pathway of habitat and impaired fish MRAP IBI are present. Hence, a score of + was given (Table 22).

6.0 Evaluate Data From Elsewhere

Data from other studies were evaluated to determine whether a plausible mechanism and stressor response could be identified for seven candidate causes: habitat fragmentation, inadequate baseflow, low dissolved oxygen, ionic strength, habitat, metals contamination, and sediment.

6.1 Candidate Cause 1: Habitat Fragmentation

6.1.1 Plausible Mechanism

Results of numerous studies indicate habitat fragmentation is a plausible stressor for fish impairment. Barriers prevent movement between habitat patches (Porto et al., 1999). Barriers prevent connectivity to neighboring populations and, hence, have influenced fish distribution patterns (Reid et al., 2008). Within watersheds, natural waterfalls and dams are considered responsible for extirpations of fish populations (Winston et al., 1991; Lutterall et al., 1999). Extirpation mechanisms include: (1) restricted access to, and/or alteration of spawning habitats; (2) increased numbers of predators due to the creation of lentic habitats; (3) the creation of small isolated populations that are more vulnerable to extinction events; and, (4) the prevention of re-colonization from other populations after local extinction events due to barriers, such as a natural waterfalls, dam, or a culvert/fish barrier (Winston et al, 1991; Rieman and Dunham, 2000; Schrank et al., 2001; Hill et al., 2002). Dams adversely affect warmwater stream fish and macroinvertebrate communities by degrading habitat and water quality and fragmenting streams (Santucci, V.J. et al., 2005). These data indicate habitat fragmentation in Sand Creek, Picha Creek, and Porter Creek is a plausible mechanism for the streams' impaired fish assemblage. Hence a score of + was given for plausible mechanism (Table 23).

Table 23. Sand Creek, Picha Creek, and Porter Creek Evidence Table for Habitat Fragmentation: Evidence From Other Systems

Types of Evidence, Habitat Fragmentation	Sand Creek	Picha Creek	Porter Creek
Plausible Mechanism	+	+	+
Plausible Stressor Response	+	+	+

6.1.2 Plausible Stressor Response

Study results indicate impairment is a plausible stressor response to habitat fragmentation. A study of changes in fish assemblage following dam removal in the Baraboo River Wisconsin indicated biotic integrity scores (possible range = 0-100) increased by 35 to 50 points at three of the four impoundments as a result of decreases in percent tolerant species, increases in the number of intolerant species, and in some cases, increases in species richness. After dam removal, 10 species that were found below, but not above the most downstream dam before removal, were collected at new sites upstream from the dam (Catalano et al., 2007).

In a study of impacts of low head dams on the fish community of the Fox River of Illinois, data indicated free-flowing areas downstream from dams had higher species richness, substantially higher overall and harvestable-sized sport fish abundance, and more sucker species and intolerant fish species. Samples from free-flowing areas also contained a higher percentage of insectivorous minnows, such as spotfin shiners and sand shiners. In contrast, stations upstream from dams had a predominance of tolerant and omnivorous species (Santucci, V.J. et al., 2005).

Studies have shown that seven Sand Creek fish species were found downstream from dams but not upstream. They include redhorse species (Reid et al., 2008), hornyhead chub (Miller et al., 2005), blackside darter (Santucci et al., 2005), pumpkinseed (Santucci et al., 2005), logperch (Hester et al., 2007), and emerald shiner (Catalano et al., 2007). These seven species were found downstream from The Falls on Sand Creek, but not upstream.

Because evidence from Catalano et al. (2007), Santucci et al., (2005), Reid et al., (2008), Miller et al., (2005), and Hester et al., (2007) indicate impairment is a plausible response to habitat fragmentation, a score of + was given for plausible stressor response (Table 23).

6.2 Candidate Cause 2: Inadequate Baseflow

6.2.1 Plausible Mechanism

Several studies provide evidence that inadequate baseflow is a plausible mechanism for fish impairment. James (2009) described the results of inadequate baseflow in the following quote:

"Low flows are a common bottleneck to fish production in streams. Low flows in summer may limit rearing habitat, concentrate fish in shrinking pools with declining water quality and dry up portions of the channel inhabited not only by fish but by mussels, crayfish and other invertebrates that are important in fish and wildlife food chains."

Bradford and Heinonen (2008) indicated low flows can cause a reduction in habitat availability, food production, and water quality and can accentuate the effects of river ice during the winter.

Davies (2005) indicated there are close relationships between the physical habitat used by fish and flow, both directly in terms of the relationship between the energetics of swimming and feeding and hydraulics, and indirectly by determining the distribution and composition of stream substrate, food resources, cover, etc. Davies (2005) found that key flow requirements for fish survival include:

- Presence of sufficient baseflow to allow occupancy of habitat for rearing, cover and shelter, and to sustain food production;
- Presence of sufficient flow during low flow periods to maintain refuges (e.g., in pools) and water quality;
- Full connectivity of flow to allow passage of fish during various stages of a species' life history;

Because evidence from James 2009, Bradford and Heinonen 2008, and Davies 2005 indicate inadequate baseflow is a plausible mechanism for fish impairment in Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek, a score of + is given for plausible mechanism (Table 24).

Table 24. Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek Evidence Table for Inadequate Baseflow: Evidence From Other Systems

Types of Evidence, Inadequate Baseflow	Picha Creek	Le Sueur County Ditch Number 54	Porter Creek
Plausible Mechanism	+	+	+
Plausible Stressor Response	+	+	+

6.2.2 Plausible Stressor Response

Ball (1982) describes the fish response to inadequate baseflow in the following quote:

"*The flow or quantity of water available to support aquatic organisms is of primary importance. It is an obvious fact that large fish species require a higher level of flow than small fish species to survive in a stream. Without adequate flow, large fish would not have room to move, feed or reproduce. Stream flow is directly correlated to the classes of organisms, or uses, a stream is capable of supporting. Flow stability or frequency also becomes an important factor in some streams.*"

Ball (1982) found that flows greater than 0.1 cubic feet per second are required to support fish and flows greater than 0.2 cubic feet per second are required to support intolerant forage fish.

Because evidence from Ball (1982) indicates fisheries impairment is a plausible stressor response to inadequate baseflow in Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek, a score of + was given for plausible stressor response (Table 24).

6.3 Candidate Cause 3: Low Dissolved Oxygen

6.3.1 Plausible Mechanism

Data from other studies indicate low oxygen level is a plausible mechanism for biological impairment. Studies have demonstrated that low oxygen levels have the following impacts on fish:

Death - Oxygen levels below a critical threshold are lethal (Douderoff and Shumway 1970; Casselman 1978; EIFAC 1973); USEPA 1986). Mortality and loss of equilibrium occurred between 1 and 3 mg/L (Canadian Council of Ministers of the Environment 1999).

Behavior Changes - Studies have documented that fish compensate for low dissolved oxygen concentrations by several behavioral responses: increased use of air breathing or aquatic surface respiration (ASR), changes in activity level or habitat, and avoidance behavior. Birtwell (1989) reported that much of a chum salmon run was prevented as a result of low dissolved oxygen. Migrating salmon avoided dissolved oxygen levels of 3.5 to 5 mg/L (Birtwell and Kruzynski 1989).

Reduced Growth - Studies have documented that reduced growth in fish results from exposure to low dissolved oxygen concentrations – coho salmon (Mason 1969), mountain whitefish (Siefert et al. 1974), smallmouth bass (Siefert et al. 1974), lake trout (Carlson and Siefert 1974), and lake herring (Brooke and Colby 1980).

Delayed Embryo Development - Douderoff and Shumway indicated that low dissolved oxygen during embryonic development resulted in delayed development and increased mortality as embryos aged. At low dissolved oxygen concentrations, hatching of fathead minnows (Brungs 1971), walleye (Oseid and Smith 1971), mountain whitefish (Siefert et al. 1974), white suckers (Siefart and Spoor 1974), lake trout (Carlson and Siefert 1974), scale carp (Kaur and Toor 1978), lake herring (Brooke and Colby 1980), and burbot (Giles et al. 1966) was delayed.

Embryo Deformities - Low dissolved oxygen during embryonic development could result in structural deformities (Douderoff and Shumway 1970) including shortening of the vertebral column and abnormal alevins in chum salmon (Alderice et al. 1958), irreversible locked lower jaw of largemouth bass larvae, making the fish unable to swim up and feed (Spoor 1977), deformed fails and spines and abnormal nervous systems and brain development in steelhead trout (Silver et al.

1963), deformed heads, jaws that did not articulate, and irregular-shaped eyes in lake herring (Brooke and Colby 1980).

Because evidence from several studies indicates dissolved oxygen is a plausible mechanism for Le Sueur County Ditch Number 54 and Porter Creek's impaired fishery, a score of + is given for plausible mechanism (Table 25).

Table 25. Le Sueur County Ditch Number 54 and Porter Creek Evidence Table for Low Dissolved Oxygen: Evidence From Other Systems

Types of Evidence, Low Dissolved Oxygen	County Ditch Number 54	Porter Creek
Plausible Mechanism	+	+
Plausible Stressor Response	+	+

6.3.2 Plausible Stressor Response

Results of a study of Hardwood Creek Minnesota indicate fish impairment occurred in areas with low dissolved oxygen (EOR, 2009).

Responses of Atlantic cod to low oxygen levels in a study completed by Herbert and Steffenson (2005) provide additional evidence that fisheries impairment is a plausible stressor response to low oxygen levels. The study found that Atlantic cod initially increased swimming speed by 18 percent when oxygen was reduced and was interpreted as an initial avoidance response to the low oxygen levels. However swimming speed was reduced 21 percent at a moderate level of steady and continued drop of oxygen and continued to drop by 41 percent under progressively deep hypoxia. At the critical oxygen tension of Atlantic cod, major physiological stress was documented including elevations in plasma cortisol and blood lactate. The responses to prolonged exposure were adaptive for the survival of the cod.

Alabaster and Lloyd (1982) concluded that a minimum value of 5 mg/L would be satisfactory for most stages and activities in the life cycle of fish.

A study of Nine Mile Creek indicated an impaired fish assemblage occurred whenever the HBI was greater than 5.5 in the Main Stem of Nine Mile Creek. The data further indicated that an unimpaired fish assemblage occurred whenever the HBI was less than 5.5 in the Main Stem of Nine Mile Creek. The study showed that a HBI score greater than 5.5 was symptomatic of stressful low dissolved oxygen concentrations that caused an impaired fish assemblage (Barr 2009).

Because evidence from EOR (2009), Herbert and Steffenson (2005), Alabaster and Lloyd (1982),and Barr (2009) indicate impairment is a plausible response of Le Sueur County Ditch Number 54 and Porter Creek's fishery to low dissolve oxygen a score of + is given for plausible stressor response (Table 25).

6.4 Candidate Cause 4: Ionic Strength

6.4.1 Plausible Mechanism

Data from other studies indicate ionic strength is a plausible mechanism for biological impairment. Wichard et al (1973), McCulloch (1993) and Ziegler (2007) documented that elevated conductivity can be toxic to biological organisms through effects on osmoregulation.

Because evidence from Wichard et al (1973), McCulloch (1993), and Ziegler (2007) indicates ionic strength is a plausible mechanism for impaired fish in Le Sueur County Ditch Number 54, a score of + is given for plausible mechanism (Table 26).

Table 26. Le Sueur County Ditch Number 54 Evidence Table for Ionic Strength: Evidence From Other Systems

Types of Evidence, Ionic Strength	County Ditch Number 54
Plausible Mechanism	+
Plausible Stressor Response	+

6.4.2 Plausible Stressor Response

Kimmel and Argent (2009) studied the response of fish to a gradient of specific conductance. Study results indicated losses of species richness, density, and coefficient of community (I) at two stations directly below discharges from a coal mine that noted high specific conductance levels. Species richness declined from 28 at the reference site to 7 at the site directly below the treated effluents. Kominoski et al (2007) indicated biotic index scores indicating higher water quality were associated with lower dissolved ion concentration.

Because evidence from several studies indicates biological impairment is a plausible response of fish to ionic strength, a score of + is given for plausible stressor response (Table 26).

6.5 Candidate Cause 5: Habitat

6.5.1 Plausible Mechanism

Studies indicate habitat is a plausible mechanism for County Ditch Number 54, Picha Creek, and Porter Creek fish impairment. Sediment embeddedness affects both the density and diversity of invertebrates, which represent the main food supply for many fish species (Cordone et al., 1961; Chutters, 1969; and Waters, 1995). In several studies, an embedded substratum reduced fish populations by increasing fish emigration and mortality (McCrimmon, 1954; Saunders et al., 1965; Elwood et al., 1969; Barton, 1977; Bjornn et al., 1977; and Hillman et al., 1987). Bolliet et al. (2005) found embeddedness significantly decreased mean body weight and increased heterogeneity in fish size in a study with brown trout. Because evidence from several studies indicates habitat is a plausible mechanism for impaired fish in County Ditch Number 54, Picha Creek, and Porter Creek, a score of + is given for plausible mechanism (Table 27).

Table 27. Picha Creek and Porter Creek Evidence Table for Habitat: Evidence From Other Systems

Types of Evidence, Habitat	County Ditch Number 54	Picha Creek	Porter Creek
Plausible Mechanism	+	+	+
Plausible Response	+	+	+

6.5.2 Plausible Stressor Response

Studies indicate fish impairment is a plausible response for County Ditch Number 54, Picha Creek, and Porter Creek fish impairment. Studies have indicated fish response to sediment embeddedness includes emigration and mortality, which reduce populations (McCrimmon, 1954; Saunders et al., 1965; Elwood et al., 1969; Barton, 1977; Bjornn et al., 1977; and Hillman et al., 1987). Because evidence from several studies indicates impairment is a plausible response of fish to habitat, a score of + was given for plausible stressor (Table 27).

6.6 Candidate Cause 7: Sediment

6.6.1 Plausible Mechanism

Data from several studies indicate sediment is a plausible mechanism for biological impairment of Picha Creek and Porter Creek.

- Reproduction: Caux et al. (1997) and Rowe et al. (2003) noted changes in salmonid community composition associated with increased turbidity, such as cascading trophic effects affecting fish community composition, high mortality of eggs from decreased gas exchange, and physiological and behavioral changes in juvenile and adult fish. A high percentage of fine sediment is also inversely related to embryos and fry (U.S. EPA 1998).

- Prey Availability: Fine sediments also disrupted trophic interactions, due to smothering, scour, and lack of habitat (Caux et al 1997). Highly embedded substrates, low abundance of boulders and gravel affect fish through decreased integrated flow (decreasing prey abundance) and decreased cover (Rowe et al. 2003).

Because the results of studies completed by Caux et al. (1997), Rowe et al. (2003) and U.S. EPA (1998) indicate sediment is a plausible mechanism for fish impairment in Picha Creek and Porter Creek, a score of + is given for plausible mechanism (Table 28).

Table 28. Picha Creek and Porter Creek Evidence Table for Sediment: Evidence From Other Systems

Types of Evidence, Sediment	Picha Creek	Porter Creek
Plausible Mechanism	+	+
Plausible Stressor Response	+	+

6.6.2 Plausible Stressor Response

Results from several studies indicate fisheries impairment is a plausible stressor response to sediment. Rabeni et al. (1995) and Rashleigh et al. (2003) found that sediment impacted the fish assemblage found in streams. Specifically they found that herbivores, benthic insectivores and simple lithophilous spawners were most sensitive to siltation while other guilds were not. These results were repeatable in both intraregional comparisons among sites of similar size and character, and in interregional comparisons of streams which varied in characteristics beside siltation. Rashleigh et al. (2003) found that the number of benthic invertivore, cyprinid, and lithophilic species appeared to be negatively associated with many substrate characteristics that are indicative of sedimentation.

Caux et al. (1997) recommend substrate not exceed 10% fine material (<2mm) for Canadian salmonids. U.S. EPA (1998) set in-stream summer criteria for percent fines (<6.5mm) of <30% for viable salmonid fry emergence. The D50 (Knopp 1993) values of at least 37mm and ideally 69 mm are ideal targets for mean particle size diameter for western mountain streams. Fisheries impairment was the biological response to sediment found in the Groundhouse River. Specifically, Site 3 in the

Groundhouse River had almost 60% fines (vs. 15% for site 2, located upstream from the sediment source), greater than 50% embedded substrates, and a D50 value of 1 mm. Site 3 noted fisheries impairment (MPCA, 2008b).

Because evidence from Caux et al. (1997), U.S. EPA (1998), Knopp 1993), MPCA (2008), Rabeni et al. (1995), and Rashleigh et al. (2003) indicate impairment is a plausible response of Picha Creek and Porter Creek's fishery to sediment, a score of + is given for plausible stressor response (Table 28).

7.0 Identify Probable Cause

The strength of evidence for the six candidate causes – habitat fragmentation, inadequate baseflow, low dissolved oxygen, ionic strength, habitat, and sediment - are summarized in Tables 29 through 34.

Table 29. Sand Creek, Picha Creek, and Porter Creek Evidence Table for Habitat Fragmentation

Types of Evidence, Habitat Fragmentation	Sand Creek	Picha Creek	Porter Creek
Evidence Using Data From Sand Creek, Picha Creek, and Porter Creek			
Spatial/temporal co-occurrence	+	+	+
Temporal Sequence	+	+	+
Evidence of Exposure or Biological Mechanism	++	++	++
Causal Pathway	++	++	++
Symptoms	D	+	D
Evidence Using Data From Other Systems			
Plausible Mechanism	+	+	+
Plausible Stressor Response	+	+	+
Multiple Lines of Evidence			
Consistency of Evidence	+++	+++	+++
Explanatory Power of Evidence	++	++	++

Table 30. Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek Evidence Table for Inadequate Baseflow

Types of Evidence, Inadequate Baseflow	Picha Creek	Le Sueur County Ditch Number 54	Porter Creek
Evidence Using Data From Picha Creek, Le Sueur County Ditch Number 54, and Porter Creek			
Spatial Co-occurrence	+	+	+
Temporal Sequence	+	+	+
Evidence of Exposure or Biological Mechanism	++	++	++
Causal Pathway	++	++	++
Evidence Using Data From Other Systems			
Plausible Mechanism	+	+	+
Plausible Stressor Response	+	+	+
Multiple Lines of Evidence			
Consistency of Evidence	+++	+++	+++
Explanatory Power of Evidence	++	++	++

Table 31. Le Sueur County Ditch Number 54 and Porter Creek Evidence Table for Low Dissolved Oxygen

Types of Evidence, Low Dissolved Oxygen	County Ditch Number 54	Porter Creek
Evidence Using Data From Le Sueur County Ditch Number 54 and Porter Creek		
Spatial co-occurrence	0	0
Temporal Sequence	0	0
Evidence of Exposure or Biological Mechanism	0	0
Causal Pathway	0	0
Symptoms	+	NA*
Evidence Using Data From Other Systems		
Plausible Mechanism	+	+
Plausible Stressor Response	+	+
Multiple Lines of Evidence		
Consistency of Evidence	0	0
Explanatory Power of Evidence	0	0

*Data not available to score symptoms for Porter Creek.

Table 32. Le Sueur County Ditch Number 54 Evidence Table for Ionic Strength

Types of Evidence, Ionic Strength	County Ditch Number 54
Evidence Using Data From County Ditch Number 54	
Spatial co-occurrence	0
Temporal Sequence	0
Evidence of Exposure or Biological Mechanism	0
Causal Pathway	0
Evidence Using Data From Other Systems	
Plausible Mechanism	+
Plausible Stressor Response	+
Multiple Lines of Evidence	
Consistency of Evidence	0
Explanatory Power of Evidence	0

Table 33. County Ditch Number 54, Picha Creek, and Porter Creek Evidence Table for Habitat

Types of Evidence, Habitat	County Ditch Number 54	Picha Creek	Porter Creek
Evidence Using Data From County Ditch Number 54, Picha Creek, and Porter Creek			
Spatial co-occurrence	+	+	+
Temporal Sequence	+	0	0
Evidence of Exposure or Biological Mechanism	++	+	+
Causal Pathway	++	+	+
Evidence Using Data From Other Systems			
Plausible Mechanism	+	+	+
Plausible Response	+	+	+
Multiple Lines of Evidence			
Consistency of Evidence	+++	+++	+++
Explanatory Power of Evidence	++	++	++

Table 34. Picha Creek and Porter Creek Evidence Table for Sediment

Types of Evidence, Sediment	Picha Creek	Porter Creek
Evidence Using Data From Picha Creek and Porter Creek		
Spatial co-occurrence	+	+
Temporal Sequence	0	0
Evidence of Exposure or Biological Mechanism	+	+
Causal Pathway	+	+
Evidence Using Data From Other Systems		
Plausible Mechanism	+	+
Plausible Stressor Response	+	+
Multiple Lines of Evidence		
Consistency of Evidence	+++	+++
Explanatory Power of Evidence	++	++

The evidence tables indicate the probable causes for impairment are:

- **Sand Creek** – The probable cause of impairment is habitat fragmentation. Collection of additional data is needed to determine whether sediment and ionic strength are co-stressors with habitat fragmentation. All other candidate causes were eliminated

- **Le Sueur County Ditch Number 54** – The probable causes of impairment are inadequate baseflow and habitat**.** The evidence for inadequate baseflow and habitat are strongest followed by low dissolved oxygen and ionic strength. Collection of metals and sediment data is needed to determine whether metals and sediment are candidate causes. Collection of additional dissolved oxygen, specific conductance, and chloride data are recommended to determine whether current oxygen and ionic strength levels are stressing the stream's fish community. Concurrent collection of fish data is recommended to determine whether the stream is currently impaired for low fish IBI as well as to determine whether dissolved oxygen concentrations and ionic strength levels are impacting the fish assemblage. Flow monitoring is recommended to discern the respective roles of natural limitation and anthropogenic land use changes as causes of inadequate baseflow in County Ditch 54.

- **Picha Creek** – The overriding probable cause of impairment is inadequate baseflow followed by habitat fragmentation, then habitat and sediment. Multiple lines of evidence indicate Picha Creek is naturally intermittent and incapable of supporting an unimpaired fish assemblage due to natural causes. Evidence for inadequate baseflow is strongest followed by habitat fragmentation which is stronger than the evidence for habitat and sediment. Collection of additional metals and dissolved oxygen data is needed to determine whether metals and dissolved oxygen are candidate causes. Fish monitoring at additional Picha Creek locations is recommended to determine areas of Picha Creek impaired due to poor habitat as well as provide data that are representative of the Picha Creek fishery.

- **Porter Creek** – The probable cause of impairment is habitat fragmentation followed by inadequate baseflow, then habitat and sediment (equally strong), and low dissolved oxygen. The evidence for habitat fragmentation is strongest followed by inadequate baseflow. Habitat and sediment are equally strong, but not as strong as habitat fragmentation and inadequate baseflow. Lack of data for low dissolved oxygen weakens this candidate cause. Collection of additional dissolved oxygen data is recommended to determine whether current levels are stressing the stream's fish community. Collection of dissolved oxygen, flow, and fish data are recommended to determine the role of low stream gradient and low dissolved oxygen in causing a natural barrier to fish passage downstream of Bradshaw Lake WMA during low flow conditions. Flow data collection will also discern the respective roles of natural limitations and anthropogenic land use changes as causes of inadequate baseflow.

Volume 2 Feasibility Study and Implementation of this project presents a program for addressing habitat fragmentation, sediment, habitat, and recharge. Other probable stressors identified such as chlorides, ionic strength, and low dissolved oxygen will require additional investigation.

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Appendix A

Fish Data

Table A-1. Fish Data From Sample Locations Within Sand Creek Watershed

FieldNum	WB Name	VisitDate	Project	Data Source	VisitNum	tsn	Name1	Name2	Common Name	CN Code	Number	Weight	Length Min	Length Max	DELT Num	ID Det	Voucher	Anomalies	Taxa Count	Date Entered	Year
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	162153	Umbra	limi	central mudminnow	CNM	3				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	163363	Hybognathus	hankinsoni	brassy minnow	BRM	1				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	163376	Semotilus	atromaculatus	creek chub	CRC	68				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	163382	Rhinichthys	atratulus	blacknose dace	BND	14				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	163439	Notropis	dorsalis	bigmouth shiner	BMS	15				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	163508	Campostoma	anomalum	central stoneroller	CSR	51				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	163517	Pimephales	promelas	fathead minnow	FHM	43				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	163836	Luxilus	cornutus	common shiner	CSH	23				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	164013	Noturus	flavus	stonecat	STC	1				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	164039	Ameiurus	melas	black bullhead	BLB	1				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	168132	Lepomis	cyanellus	green sunfish	GSF	14				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	168369	Etheostoma	nigrum	johnny darter	JND	9				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
90MN116	Sand Creek	23-Aug-90	mrap	MPCA	19900066	553273	Catostomus	commersonii	white sucker	WTS	21				0	Schmidt etc.	FALSE		TRUE	20-Sep-01	1990
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	163363	Hybognathus	hankinsoni	brassy minnow	BRM	2	9	71	80	0	Schmidt	TRUE		TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	163376	Semotilus	atromaculatus	creek chub	CRC	59	782	72	250	0	Schmidt	TRUE	1A	TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	163382	Rhinichthys	atratulus	blacknose dace	BND	33	214	32	98	0	Schmidt	TRUE		TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	163439	Notropis	dorsalis	bigmouth shiner	BMS	9	18	34	86	0	Schmidt	TRUE		TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	163508	Campostoma	anomalum	central stoneroller	CSR	15	222	66	138	0	Schmidt	TRUE		TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	163517	Pimephales	promelas	fathead minnow	FHM	32	24	31	50	0	Schmidt	TRUE		TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	164013	Noturus	flavus	stonecat	STC	6	167	69	164	0	Schmidt	TRUE		TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	164039	Ameiurus	melas	black bullhead	BLB	1	70	170	170	0	Schmidt	TRUE		TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	168132	Lepomis	cyanellus	green sunfish	GSF	124	1612	48	131	0	Schmidt	TRUE		TRUE	21-Sep-01	2000

Table A-1 (Continued). Fish Data From Sample Locations Within Sand Creek Watershed

FieldNum	WB Name	VisitDate	Project	Data Source	VisitNum	tsn	Name1	Name2	Common Name	CN Code	Number	Weight	Length Min	Length Max	DELT Num	ID Det	Voucher	Anomalies	Taxa Count	Date Entered	Year
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	168369	Etheostoma	nigrum	johnny darter	JND	5	15	61	75	0	Schmidt	TRUE		TRUE	21-Sep-01	2000
00MN006	Sand Creek	21-Sep-00	metro surveys	Schmidt	20000133	553273	Catostomus	commersonii	white sucker	WTS	11	1717	113	295	0	Schmidt	FALSE		TRUE	21-Sep-01	2000
01MN058	unnamed trib. To Sand Creek (Picha Creek)	08-Aug-01	EMAP	MPCA	20010046	162153	Umbra	limi	central mudminnow	CNM	3	26.5	31	49	0	Schmidt	TRUE		TRUE	10-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	08-Aug-01	EMAP	MPCA	20010046	163376	Semotilus	atromaculatus	creek chub	CRC	56	74	38	65	0	Schmidt	TRUE		TRUE	10-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	08-Aug-01	EMAP	MPCA	20010046	163382	Rhinichthys	atratulus	blacknose dace	BND	26	92	40	79	0	Schmidt	TRUE		TRUE	10-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	08-Aug-01	EMAP	MPCA	20010046	163517	Pimephales	promelas	fathead minnow	FHM	1	3	60	60	0	Schmidt	TRUE		TRUE	10-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	08-Aug-01	EMAP	MPCA	20010046	166399	Culaea	inconstans	brook stickleback	BST	47	39	34	55	0	Schmidt	TRUE		TRUE	10-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	162153	Umbra	limi	central mudminnow	CNM	2	3.5	49	53	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	163363	Hybognathus	hankinsoni	brassy minnow	BRM	9	12.5	36	54	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	163376	Semotilus	atromaculatus	creek chub	CRC	65	303.5	32	204	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	163382	Rhinichthys	atratulus	blacknose dace	BND	35	252	26	103	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	163419	Notropis	stramineus	sand shiner	SDS	1	3	67	67	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	163439	Notropis	dorsalis	bigmouth shiner	BMS	2	7	67	72	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	163508	Campostoma	anomalum	central stoneroller	CSR	10	51	48	98	0	Niemela	TRUE		TRUE	16-Aug-01	2001

Table A-1 (Continued). Fish Data From Sample Locations Within Sand Creek Watershed

FieldNum	WB Name	VisitDate	Project	Data Source	VisitNum	tsn	Name1	Name2	Common Name	CN Code	Number	Weight	Length Min	Length Max	DELT Num	ID Det	Voucher	Anomalies	Taxa Count	Date Entered	Year
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	163517	Pimephales	promelas	fathead minnow	FHM	2	2.5	42	62	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	164013	Noturus	flavus	stonecat	STC	6	165	117	145	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	166399	Culaea	inconstans	brook stickleback	BST	1	0.5	40	40	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	168369	Etheostoma	nigrum	johnny darter	JND	5	11.5	42	68	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN044	Sand Creek	24-Jul-01	EMAP	MPCA	20010048	553273	Catostomus	commersonii	white sucker	WTS	3	6.5	51	62	0	Niemela	TRUE		TRUE	16-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	24-Jul-01	EMAP	MPCA	20010060	162153	Umbra	limi	central mudminnow	CNM	17	14	29	46	0	Niemela	TRUE		TRUE	30-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	24-Jul-01	EMAP	MPCA	20010060	163376	Semotilus	atromaculatus	creek chub	CRC	158	275	34	125	0	Niemela	TRUE		TRUE	30-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	24-Jul-01	EMAP	MPCA	20010060	163382	Rhinichthys	atratulus	blacknose dace	BND	60	186.5	26	78	0	Niemela	TRUE		TRUE	30-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	24-Jul-01	EMAP	MPCA	20010060	163517	Pimephales	promelas	fathead minnow	FHM	2	3	45	47	0	Niemela	TRUE		TRUE	30-Aug-01	2001
01MN058	unnamed trib. To Sand Creek (Picha Creek)	24-Jul-01	EMAP	MPCA	20010060	166399	Culaea	inconstans	brook stickleback	BST	144	96	31	61	1	Niemela	TRUE	1D	TRUE	30-Aug-01	2001
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	162153	Umbra	limi	central mudminnow	CNM	5	45	59	103	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	163363	Hybognathus	hankinsoni	brassy minnow	BRM	2	11	78	86	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	163376	Semotilus	atromaculatus	creek chub	CRC	229	1984	27	235	0	Kramschuster	TRUE	229-B	TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	163382	Rhinichthys	atratulus	blacknose dace	BND	79	77	25	75	0	Kramschuster	TRUE	55-B	TRUE		2007

Table A-1 (Continued). Fish Data From Sample Locations Within Sand Creek Watershed

FieldNum	WB Name	VisitDate	Project	Data Source	VisitNum	tsn	Name1	Name2	Common Name	CN Code	Number	Weight	Length Min	Length Max	DELT Num	ID Det	Voucher	Anomalies	Taxa Count	Date Entered	Year
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	163439	Notropis	dorsalis	bigmouth shiner	BMS	171	249	25	77	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	163508	Campostoma	anomalum	central stoneroller	CSR	18	179	52	133	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	163517	Pimephales	promelas	fathead minnow	FHM	17	7	28	39	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	164003	Noturus	gyrinus	tadpole madtom	TPM	1	0.5	25	25	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	164013	Noturus	flavus	stonecat	STC	3	83	132	156	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	164039	Ameiurus	melas	black bullhead	BLB	12	897	124	213	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	168132	Lepomis	cyanellus	green sunfish	GSF	27	45	73	125	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	168141	Lepomis	macrochirus	bluegill	BLG	6	42	66	79	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	168167	Pomoxis	nigromaculatus	black crappie	BLC	6	468	158	188	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	168369	Etheostoma	nigrum	johnny darter	JND	112	58	25	64	0	Kramschuster	TRUE		TRUE		2007
07MN056	Sand Creek	02-Aug-07	TMDL	MPCA	20070049	553273	Catostomus	commersonii	white sucker	WTS	25	2162	52	264	0	Kramschuster	TRUE	2-W, 1-S	TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	162153	Umbra	limi	central mudminnow	CNM	1	4	79	79	0	Butterfield	TRUE		TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	163363	Hybognathus	hankinsoni	brassy minnow	BRM	3	9	69	74	0	Butterfield	TRUE		TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	163376	Semotilus	atromaculatus	creek chub	CRC	341	785	30	182	0	Butterfield	TRUE	1-Y,250-B	TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	163382	Rhinichthys	atratulus	blacknose dace	BND	169	468	25	86	0	Butterfield	TRUE	10-B	TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	163439	Notropis	dorsalis	bigmouth shiner	BMS	22	60	31	80	0	Butterfield	TRUE		TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	163508	Campostoma	anomalum	central stoneroller	CSR	187	236	44	99	0	Butterfield	TRUE	93-LB	TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	163517	Pimephales	promelas	fathead minnow	FHM	1	2	59	59	0	Butterfield	TRUE		TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	164013	Noturus	flavus	stonecat	STC	8	50	40	135	0	Butterfield	TRUE		TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	164039	Ameiurus	melas	black bullhead	BLB	1	11	98	98	0	Butterfield	TRUE		TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	168132	Lepomis	cyanellus	green sunfish	GSF	5	107.5	33	126	0	Butterfield	TRUE		TRUE		2007
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	168369	Etheostoma	nigrum	johnny darter	JND	49	64	37	57	0	Butterfield	TRUE		TRUE		2007

Table A-1 (Continued). Fish Data From Sample Locations Within Sand Creek Watershed

FieldNum	WB Name	VisitDate	Project	Data Source	VisitNum	tsn	Name1	Name2	Common Name	CN Code	Number	Weight	Length Min	Length Max	DELT Num	ID Det	Voucher	Anomalies	Taxa Count	Date Entered	Year
07MN055	Sand Creek	02-Aug-07	TMDL	MPCA	20070149	553273	Catostomus	commersonii	white sucker	WTS	6	168	65	211	0	Butterfield	TRUE		TRUE		2007
01MN044	Sand Creek	25-Jul-07	TMDL	MPCA	20070253	163376	Semotilus	atromaculatus	creek chub	CRC	1064	2004	25	154	0	Butterfield	TRUE	75-B	TRUE		2007
01MN044	Sand Creek	25-Jul-07	TMDL	MPCA	20070253	163382	Rhinichthys	atratulus	blacknose dace	BND	389	1261	36	110	0	Butterfield	TRUE	10-B	TRUE		2007
01MN044	Sand Creek	25-Jul-07	TMDL	MPCA	20070253	163439	Notropis	dorsalis	bigmouth shiner	BMS	30	87	34	79	0	Butterfield	TRUE	0	TRUE		2007
01MN044	Sand Creek	25-Jul-07	TMDL	MPCA	20070253	163508	Campostoma	anomalum	central stoneroller	CSR	836	1754	45	109	0	Butterfield	TRUE	125-B	TRUE		2007
01MN044	Sand Creek	25-Jul-07	TMDL	MPCA	20070253	163517	Pimephales	promelas	fathead minnow	FHM	1	56	1	56	0	Butterfield	TRUE	0	TRUE		2007
01MN044	Sand Creek	25-Jul-07	TMDL	MPCA	20070253	164013	Noturus	flavus	stonecat	STC	24	18	25	54	0	Butterfield	TRUE	0	TRUE		2007
01MN044	Sand Creek	25-Jul-07	TMDL	MPCA	20070253	168369	Etheostoma	nigrum	johnny darter	JND	147	218	48	81	0	Butterfield	TRUE	0	TRUE		2007
01MN044	Sand Creek	25-Jul-07	TMDL	MPCA	20070253	553273	Catostomus	commersonii	white sucker	WTS	141	338	47	72	0	Butterfield	TRUE	0	TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	162153	Umbra	limi	central mudminnow	CNM	2	9	63	81	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163344	Cyprinus	carpio	common carp	CAP	2	1261	325	445	0	Butterfield	FALSE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163363	Hybognathus	hankinsoni	brassy minnow	BRM	27	94	56	86	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163376	Semotilus	atromaculatus	creek chub	CRC	353	2159	25	186	0	Butterfield	TRUE	200-B	TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163382	Rhinichthys	atratulus	blacknose dace	BND	172	605	37	85	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163395	Nocomis	biguttatus	hornyhead chub	HHC	11	29	70	137	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163412	Notropis	atherinoides	emerald shiner	EMS	1671	2532	51	79	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163419	Notropis	stramineus	sand shiner	SDS	86	350	40	71	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163439	Notropis	dorsalis	bigmouth shiner	BMS	103	238	58	74	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163508	Campostoma	anomalum	central stoneroller	CSR	370	1517	39	116	0	Butterfield	TRUE	150-B	TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163516	Pimephales	notatus	bluntnose minnow	BNM	151	311	25	80	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163517	Pimephales	promelas	fathead minnow	FHM	479	725	44	57	0	Butterfield	TRUE	450-G, 280-B	TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	163803	Cyprinella	spiloptera	spotfin shiner	SFS	131	145	42	64	0	Butterfield	TRUE		TRUE		2007

Table A-1 (Continued). Fish Data From Sample Locations Within Sand Creek Watershed

FieldNum	WB Name	VisitDate	Project	Data Source	VisitNum	tsn	Name1	Name2	Common Name	CN Code	Number	Weight	Length Min	Length Max	DELT Num	ID Det	Voucher	Anomalies	Taxa Count	Date Entered	Year
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	164013	Noturus	flavus	stonecat	STC	20	183	35	127	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	164039	Ameiurus	melas	black bullhead	BLB	14	721	110	184	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	168132	Lepomis	cyanellus	green sunfish	GSF	12	450	63	142	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	168144	Lepomis	gibbosus	pumpkinseed	PMK	4	122	97	130	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	168151	Lepomis	humilis	orangespotted sunfish	OSS	29	182	48	84	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	168167	Pomoxis	nigromaculatus	black crappie	BLC	5	420	169	182	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	168369	Etheostoma	nigrum	johnny darter	JND	141	159	33	67	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	168472	Percina	caprodes	logperch	LGP	174	1012	59	109	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	168488	Percina	maculata	blackside darter	BSD	23	103	52	93	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	168494	Percina	phoxocephala	slenderhead darter	SHD	96	321	59	94	0	Butterfield	TRUE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	169364	Aplodinotus	grunniens	freshwater drum	FRD	3	3520	363	545	0	Butterfield	FALSE		TRUE		2007
07MN033	Sand Creek	26-Jul-07	TMDL	MPCA	20070254	553273	Catostomus	commersonii	white sucker	WTS	90	738	50	237	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	162153	Umbra	limi	central mudminnow	CNM	17	69	55	90	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163344	Cyprinus	carpio	common carp	CAP	69	97813	432	692	0	Butterfield	FALSE	2-W	TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163363	Hybognathus	hankinsoni	brassy minnow	BRM	110	422	50	76	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163376	Semotilus	atromaculatus	creek chub	CRC	79	464	44	179	0	Butterfield	TRUE	15-B	TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163382	Rhinichthys	atratulus	blacknose dace	BND	2	5	35	73	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163412	Notropis	atherinoides	emerald shiner	EMS	352	417	47	92	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163419	Notropis	stramineus	sand shiner	SDS	220	288	34	62	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163439	Notropis	dorsalis	bigmouth shiner	BMS	181	387	25	76	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163508	Campostoma	anomalum	central stoneroller	CSR	1	5	78	78	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163516	Pimephales	notatus	bluntnose minnow	BNM	89	145	30	69	0	Butterfield	TRUE		TRUE		2007

Table A-1 (Continued). Fish Data From Sample Locations Within Sand Creek Watershed

FieldNum	WB Name	VisitDate	Project	Data Source	VisitNum	tsn	Name1	Name2	Common Name	CN Code	Number	Weight	Length Min	Length Max	DELT Num	ID Det	Voucher	Anomalies	Taxa Count	Date Entered	Year
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163517	Pimephales	promelas	fathead minnow	FHM	104	248	46	60	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163803	Cyprinella	spiloptera	spotfin shiner	SFS	73	59	36	73	0	Butterfield	TRUE	92-G	TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163917	Carpiodes	cyprinus	quillback	QBS	13	4690	175	455	0	Butterfield	TRUE	1-W	TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163928	Moxostoma	macrolepidotum	shorthead redhorse	SHR	4	364	139	230	0	Butterfield	TRUE	1-W	TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	163939	Moxostoma	erythrurum	golden redhorse	GLR	1	349	328	328	0	Butterfield	FALSE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	164003	Noturus	gyrinus	tadpole madtom	TPM	1	2	33	33	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	164039	Ameiurus	melas	black bullhead	BLB	4	192	125	156	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	167682	Morone	chrysops	white bass	WHB	12	4495	240	370	0	Butterfield	FALSE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168132	Lepomis	cyanellus	green sunfish	GSF	8	223	78	116	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168141	Lepomis	macrochirus	bluegill	BLG	3	263	134	160	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168144	Lepomis	gibbosus	pumpkinseed	PMK	6	91	80	100	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168151	Lepomis	humilis	orangespotted sunfish	OSS	1	2	55	55	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168167	Pomoxis	nigromaculatus	black crappie	BLC	1	87	174	174	0	Butterfield	FALSE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168369	Etheostoma	nigrum	johnny darter	JND	45	55	34	54	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168469	Perca	flavescens	yellow perch	YEP	1	17	125	125	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168472	Percina	caprodes	logperch	LGP	19	38	60	68	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168488	Percina	maculata	blackside darter	BSD	3	4	60	63	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	168494	Percina	phoxocephala	slenderhead darter	SHD	3	11	66	71	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	169364	Aplodinotus	grunniens	freshwater drum	FRD	2	333	243	249	0	Butterfield	FALSE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	553273	Catostomus	commersonii	white sucker	WTS	23	207	49	209	0	Butterfield	TRUE		TRUE		2007
07MN034	Sand Creek	26-Jul-07	TMDL	MPCA	20070255	650173	Sander	vitreus	walleye	WAE	1	3	67	67	0	Butterfield	TRUE		TRUE		2007

Appendix B

Summary Table of System for Scoring Types of Evidence

Table B-1. System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Types of Evidence that Use Data from the Case			
Type of Evidence	**Finding**	**Interpretation**	**Score**
Spatial/Temporal Co-occurrence			
	The effect occurs where or when the candidate cause occurs, **OR** the effect does not occur where or when the candidate cause does not occur.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because the association could be coincidental.	+
	It is uncertain whether the candidate cause and the effect co-occur.	This finding *neither supports nor weakens* the case for the candidate cause, because the evidence is ambiguous.	0
	The effect does not occur where or when the candidate cause occurs, **OR** the effect occurs where or when the candidate cause does not occur.	This finding *convincingly weakens* the case for the candidate cause, because causes must co-occur with their effects.	- - -
	The effect does not occur where and when the candidate cause occurs, **OR** the effect occurs where or when the candidate cause does not occur, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause, because causes must co-occur with their effects.	R

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Temporal Sequence	The candidate cause occurred prior to the effect.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because the association could be coincidental.	+
	The temporal relationship between the candidate cause and the effect is uncertain.	This finding *neither supports nor weakens* the case for the candidate cause, because the evidence is ambiguous.	0
	The candidate cause occurs after the effect.	This finding *convincingly weakens* the case for the candidate cause, because causes cannot precede effects (note that this should be evaluated with caution when multiple sufficient causes are present).	- - -
	The candidate cause occurs after the effect, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause, because effects cannot precede causes.	R
Stressor-Response Relationship from the Field	A strong effect gradient is observed relative to exposure to the candidate cause, at spatially linked sites, and the gradient is in the expected direction.	This finding *strongly supports* the case for the candidate cause, but is not convincing due to potential confounding.	+ +

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Stressor-Response Relationship from the Field	A weak effect gradient is observed relative to exposure to the candidate cause, at spatially linked sites, **OR** a strong effect gradient is observed relative to exposure to the candidate cause, at non-spatially linked sites, and the gradient is in the expected direction.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive due to potential confounding or random error.	+
	An uncertain effect gradient is observed relative to exposure to the candidate cause.	This finding *neither supports nor weakens* the case for the candidate cause, because the evidence is ambiguous.	0
	An inconsistent effect gradient is observed relative to exposure to the candidate cause, at spatially linked sites, **OR** a strong effect gradient is observed relative to exposure to the candidate cause, at non-spatially linked sites, but the gradient is not in the expected direction.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening due to potential confounding or random error.	-
	A strong effect gradient is observed relative to exposure to the candidate cause, at spatially linked sites, but the relationship is not in the expected direction.	This finding *strongly weakens* the case for the candidate cause, but is not convincing due to potential confounding.	- -

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Causal Pathway	Data show that all steps in at least one causal pathway are present.	This finding *strongly supports* the case for the candidate cause, because it is improbable that all steps occurred by chance; it is not convincing because these steps may not be sufficient to generate sufficient levels of the cause.	+ +
	Data show that some steps in at least one causal pathway are present.	This finding *somewhat supports* the case for the candidate cause.	+
	Data show that the presence of all steps in the causal pathway is uncertain.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Data show that there is at least one missing step in each causal pathway.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because it may be due to temporal variability, problems in sampling or analysis, or unidentified alternative pathways.	-
	Data show, with a high degree of certainty, that there is at least one missing step in each causal pathway.	This finding *convincingly weakens* the case for the candidate cause, assuming critical steps in each pathway are known, and are not found at the impaired site after a well-designed, well-performed, and sensitive study.	- - -

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Evidence of Exposure or Biological Mechanism	Data show that exposure or the biological mechanism is clear and consistently present.	This finding *strongly supports* the case for the candidate cause, but is not convincing because it does not establish that the level of exposure or mechanistic action was sufficient to cause the effect.	+ +
	Data show that exposure or the biological mechanism is weak or inconsistently present.	This finding *somewhat supports* the case for the candidate cause.	+
	Data show that exposure or the biological mechanism is uncertain.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Data show that exposure or the biological mechanism is absent.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because the exposure or the mechanism may have been missed.	- -
	Data show that exposure or the biological mechanism is absent, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause.	R

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Manipulation of Exposure	The effect is eliminated or reduced when exposure to the candidate cause is eliminated or reduced, **OR** the effect starts or increases when exposure to the candidate cause starts or increases.	This finding *strongly supports* the case for the candidate cause, but is not convincing because it may result from other factors (e.g., removal of more than one agent or other unintended effects of the manipulation).	+ + +
	Changes in the effect after manipulation of the candidate cause are ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The effect is not eliminated or reduced when exposure to the candidate cause is eliminated or reduced, **OR** the effect does not start or increase when exposure to the candidate cause starts or increases.	This finding *convincingly weakens* the case for the candidate cause, because such manipulations can avoid confounding. However, effects may continue if there are impediments to recolonization or if another sufficient cause is present.	- - -
	The effect is not eliminated or reduced when exposure to the candidate cause is eliminated or reduced, **OR** the effect does not start or increase when exposure to the candidate cause starts or increases, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause, given that data are based on a well-designed and well-performed study.	R

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Laboratory Tests of Site Media	Laboratory tests with site media show clear biological effects that are closely related to the observed impairment.	This finding *convincingly supports* the case for the candidate cause.	+ + +
	Laboratory tests with site media show ambiguous effects, **OR** clear effects that are not closely related to the observed impairment.	This finding *somewhat supports* the case for the candidate cause.	+
	Laboratory tests with site media show uncertain effects.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Laboratory tests with site media show no toxic effects that can be related to the observed impairment.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening, because test species, responses or conditions may be inappropriate relative to field conditions.	-
Verified Predictions	Specific or multiple predictions of other effects of the candidate cause are confirmed.	This finding *convincingly supports* the case for the candidate cause, because predictions confirm a mechanistic understanding of the causal relationship, and verification of a predicted association is stronger evidence than associations explained after the fact.	+ + +

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Verified Predictions	A general prediction of other effects of the candidate cause is confirmed.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because another cause may be responsible.	+
	It is unclear whether predictions of other effects of the candidate cause are confirmed.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	A prediction of other effects of the candidate cause fails to be confirmed.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening, because other factors may mask or interfere with the predicted effect.	-
	Multiple predictions of other effects of the candidate cause fail to be confirmed.	This finding *convincingly weakens* the case for the candidate cause.	- - -
	Specific predictions of other effects of the candidate cause fail to be confirmed, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause.	R
Symptoms	Symptoms or species occurrences observed at the site are diagnostic of the candidate cause.	This finding is sufficient to *diagnose* the candidate cause as the cause of the impairment, even without the support of other types of evidence.	D

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Symptoms	Symptoms or species occurrences observed at the site include some but not all of a diagnostic set, **OR** symptoms or species occurrences observed at the site characterize the candidate cause and a few others.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because symptoms or species are indicative of multiple possible causes.	+
	Symptoms or species occurrences observed at the site are ambiguous or occur with many causes.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Symptoms or species occurrences observed at the site are contrary to the candidate cause.	This finding *convincingly weakens* the case for the candidate cause.	- - -
	Symptoms or species occurrences observed at the site are indisputably contrary to the candidate cause.	This finding *refutes* the case for the candidate cause.	R

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Types of Evidence that Use Data from Elsewhere			
Type of Evidence	**Finding**	**Interpretation**	**Score**
Mechanistically Plausible Cause	A plausible mechanism exists.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because levels of the agent may not be sufficient to cause the observed effect.	+
	No mechanism is known.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The candidate cause is mechanistically implausible.	This finding strongly weakens the case for the candidate cause, but is not convincing because the mechanism could be unknown.	- -
Stressor-Response Relationships from Laboratory Studies	The observed relationship between exposure and effects in the case agrees quantitatively with stressor-response relationships in controlled laboratory experiments.	This finding *strongly supports* the case for the candidate cause, but is not convincing because the correspondence could be coincidental due to confounding or differences in organisms or conditions between the case and the laboratory.	+ +

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Stressor-Response Relationships from Laboratory Studies	The observed relationship between exposure and effects in the case agrees qualitatively with stressor-response relationships in controlled laboratory experiments.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because the correspondence is only qualitative, and the degree of correspondence could be coincidental due to confounding or differences in organisms or conditions between the case and the laboratory.	+
	The agreement between the observed relationship between exposure and effects in the case and stressor-response relationships in controlled laboratory experiments is ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The observed relationship between exposure and effects in the case does not agree with stressor-response relationships in controlled laboratory experiments.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because there may be differences in organisms or conditions between the case and the laboratory.	-
	The observed relationship between exposure and effects in the case does not even qualitatively agree with stressor-response relationships in controlled laboratory experiments, or the quantitative differences are very large.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because there may be substantial and consistent differences in organisms or conditions between the case and the laboratory.	- -

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Stressor-Response Relationships from Other Field Studies	The stressor-response relationship in the case agrees quantitatively with stressor-response relationships from other field studies.	This finding *strongly supports* the case for the candidate cause, but is not convincing because the correspondence could be coincidental due to confounding or differences in organisms or conditions between the case and elsewhere.	+ +
	The stressor-response relationship in the case agrees qualitatively with stressor -response relationships from other field studies.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because the correspondence is only qualitative, and the degree of correspondence could be coincidental due to confounding or differences in organisms or conditions between the case and elsewhere.	+
	The agreement between the stressor-response relationship in the case and stressor-response relationships from other field studies is ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The stressor-response relationship in the case does not agree with stressor-response relationships from other field studies.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because there may be differences in organisms or conditions between the case and elsewhere.	-

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Stressor-Response Relationships from Other Field Studies	There are large quantitative differences or clear qualitative differences between the stressor-response relationship in the case and the stressor-response relationships from other field studies.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because there may be substantial and consistent differences in organisms or conditions between the case and elsewhere.	- -
Stressor-Response Relationships from Ecological Simulation Models	The observed relationship between exposure and effects in the case agrees with the results of a simulation model.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because models may be adjusted to simulate the effects.	+
	The results of simulation modeling are ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The observed relationship between exposure and effects in the case does not agree with the results of simulation modeling.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening, because it may be due to lack of correspondence between the model and site conditions.	-
Manipulation of Exposure at Other Sites	At other sites, the effect is consistently eliminated or reduced when exposure to the candidate cause is eliminated or reduced, **OR** the effect is consistently starts or increases when exposure to the candidate cause starts or increases.	This finding *convincingly supports* the case for the candidate cause, because consistent results of manipulations at many sites are unlikely to be due to chance or irrelevant to the site being investigated.	+ + +

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Manipulation of Exposure at Other Sites	At other sites, the effect is eliminated or reduced at most sites when exposure to the candidate cause is eliminated or reduced, **OR** the effect starts or increases at most sites when exposure to the cause starts or increases.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because consistent results of manipulation at one or a few sites may be coincidental or irrelevant to the site being investigated.	+
	Changes in the effect after manipulation of the candidate cause are ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	At other sites, the effect is not consistently eliminated or reduced when exposure to the cause is eliminated or reduced, **OR** the effect does not consistently start or increase when exposure to the cause starts or increases.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because failure to eliminate or induce effects at one or a few sites may be due to poorly conducted studies, or results may be irrelevant due to differences among sites.	- -
Analogous Stressors	Many similar agents at other sites consistently cause effects similar to the impairment.	This finding *strongly supports* the case for the candidate cause, but is not convincing because of potential differences among the agents or in conditions among the sites.	+ +
	One or a few similar agents at other sites cause effects similar to the impairment.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because of potential differences among the agents or in conditions among the sites.	+

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Analogous Stressors	One or a few similar agents at other sites do not cause effects similar to the impairment.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because of potential differences among the agents or in conditions among the sites.	-
	Many similar agents at other sites do not cause effects similar to the impairment.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because of potential differences among the agents or in conditions among the sites.	- -
Evaluating Multiple Lines of Evidence			
Consistency of Evidence	All available types of evidence support the case for the candidate cause.	This finding *convincingly supports* the case for the candidate cause.	+ + +
	All available types of evidence weaken the case for the candidate cause.	This finding *convincingly weakens* the candidate cause.	- - -
	All available types of evidence support the case for the candidate cause, but few types are available.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because coincidence and errors may be responsible.	+
	All available types of evidence weaken the case for the candidate cause, but few types are available.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because coincidence and errors may be responsible.	-

Table B-1 (Continued). System for Scoring Types of Evidence (From EPA Website - http://cfpub.epa.gov/caddis/step.cfm?step=15)

Type of Evidence	Finding	Interpretation	Score
Consistency of Evidence	The evidence is ambiguous or inadequate.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Some available types of evidence support and some weaken the case for the candidate cause.	This finding *somewhat weakens* the case for the candidate cause, but is not convincing because a few inconsistencies may be explained.	-
Explanation of the Evidence	There is a credible explanation for any negative inconsistencies or ambiguities in an otherwise positive body of evidence that could make the body of evidence consistently supporting.	This finding can save the case for a candidate cause that is weakened by inconsistent evidence; however, without evidence to support the explanation, the cause is barely strengthened.	+ +
	There is no explanation for the inconsistencies or ambiguities in the evidence.	This finding neither strengthens nor weakens the case for a candidate cause.	0
	There is a credible explanation for any positive inconsistencies or ambiguities in an otherwise negative body of evidence that could make the body of evidence consistently weakening.	This finding further weakens an inconsistent case; however, without evidence to support the explanation, the cause is barely weakened.	-