Nine Mile Creek

Biological Stressor Identification

Prepared for
Minnesota Pollution Control Agency

November 2010

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Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

In 2003 Nine Mile 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 impaired biota due to low fish Index of Biotic Integrity (IBI) scores. Once water bodies are listed as impaired, stressors causing impairment must be identified, and remediation efforts, including development of total maximum daily loads (TMDL) for identified pollutants, need to be initiated. The Stressor Identification process is a formal method developed by the Environmental Protection Agency (EPA) by which the causes of biological impairment may be identified 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).

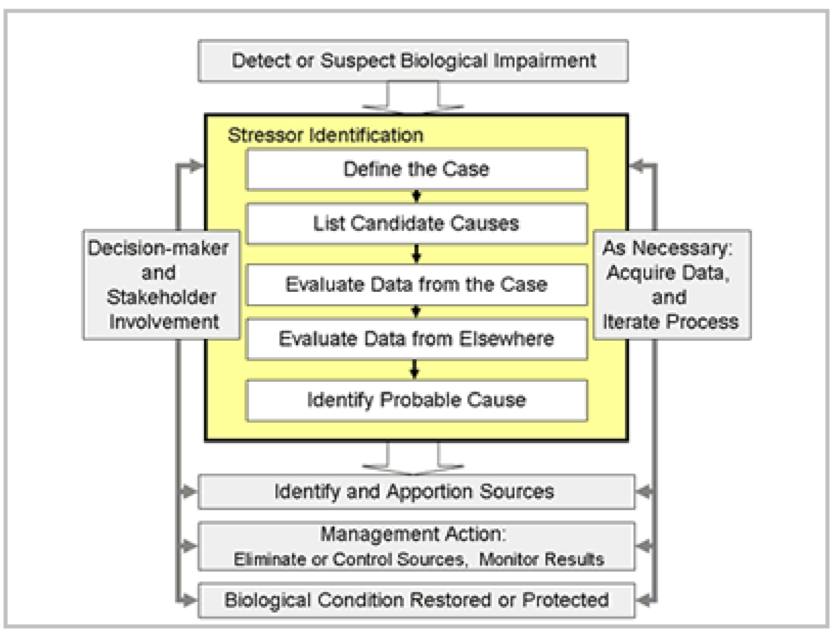


Figure 1. Stressor Identification Process

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 Nine Mile Creek.

2.0 Define the Impairment

2.1 The Biological Impairment and Its Basis

In 2003 Nine Mile Creek was listed on the 303(d) list of impaired waters for elevated chloride and turbidity levels measured at the Metropolitan Council Environmental Services (MCES) Watershed Outlet Monitoring Program (WOMP) station located on the Main Stem of the creek at 106th Street. In 2003 Nine Mile Creek was also placed on the Minnesota Pollution Control Agency's (MPCA) list of impaired waters in need of a Total Maximum Daily Load (TMDL) study for impaired biota due to low fish Index of Biological Integrity (IBI) scores. In Minnesota, biological impairment for fish in the Minnesota River Basin is defined as failing to meet the Minnesota River Assessment Project (MRAP) IBI impairment threshold score of 30 or greater out of a possible score of 60. Only streams with a watershed area of at least 5 square miles are obligated to meet the IBI impairment threshold. Reaches of Nine Mile Creek that are obligated to meet the IBI impairment threshold are shown in Figure 2.

Nine Mile Creek fish data collected by the United States Geological Survey (USGS), the Minnesota Department of Natural Resources (MDNR), the Minnesota Pollution Control Agency (MPCA), and the Nine Mile Creek Watershed District (NMCWD) were evaluated to determine the reaches of Nine Mile Creek that are considered to have impaired fish assemblages. Table 1 summarizes the data collection locations and years as well as collecting organization. Sample locations are shown in Figure 3. IBI scores are presented in Tables 2 and 3.

Seven Nine Mile Creek sample locations noted impairment during the period of record. Impaired fish assemblages were observed at three locations on the North Branch of Nine Mile Creek during 2003 through 2008. IBI scores less than the impairment threshold of 30 or greater were observed at 03MN058 in 2003, at EUC-2 in 2003, 2004, and 2008, and at EUC-2A in 2004, 2005, and 2007. One location on the South Branch, EUC-5A, noted impaired fish assemblages during 2003 through 2005 and during 2007. Three Main Stem locations observed impaired fish assemblages during 1997 through 2007. IBI scores less than 30 were observed at 96MN004 during 1997, at EUC-7A in 2003 through 2005 and 2007, and EUC-7B in 2003, 2004, and 2007.

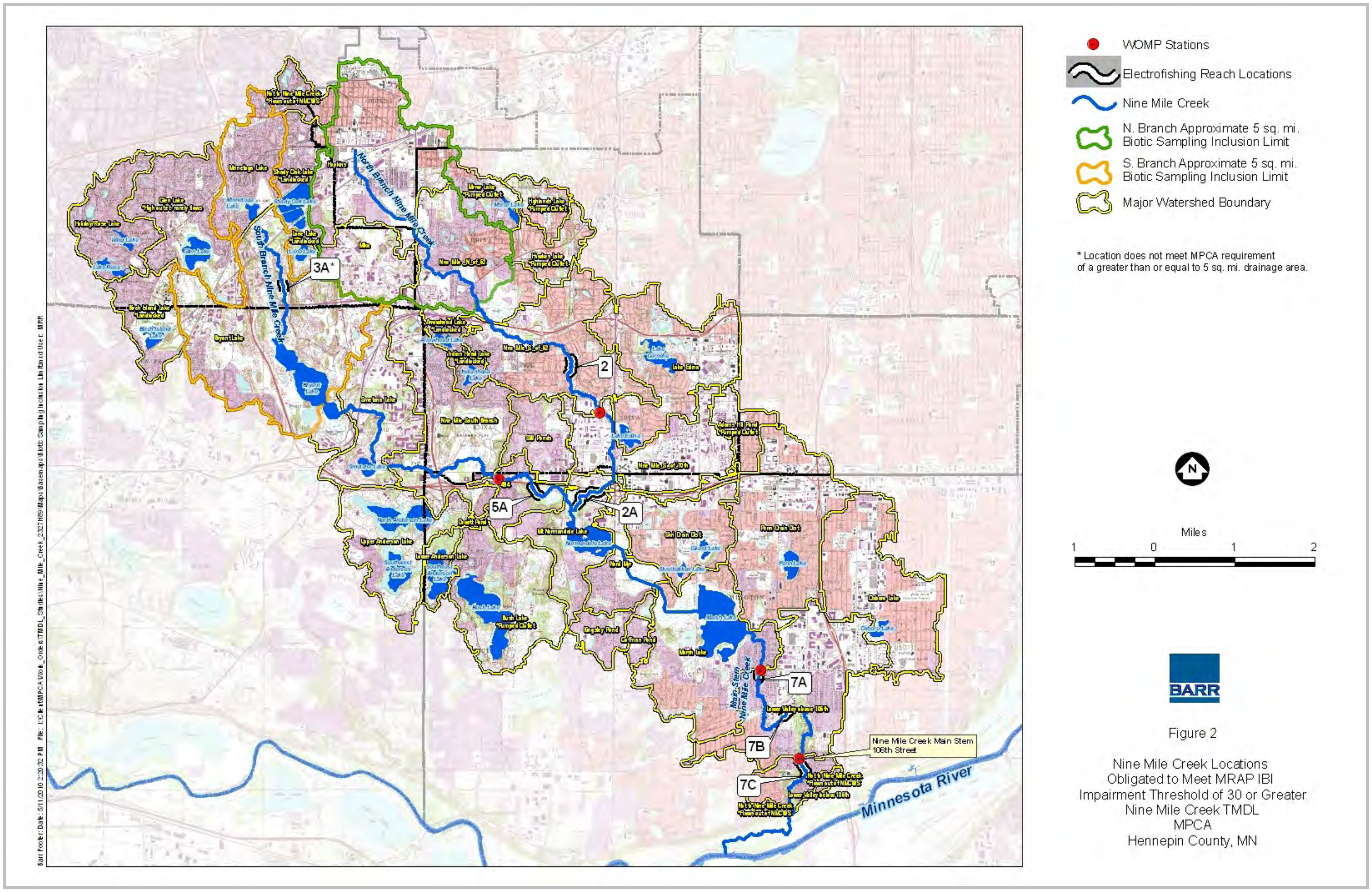


Figure 2. Nine Mile Creek Locations Obligated to Meet MRAP IBI Impairment Threshold of 30 or Greater

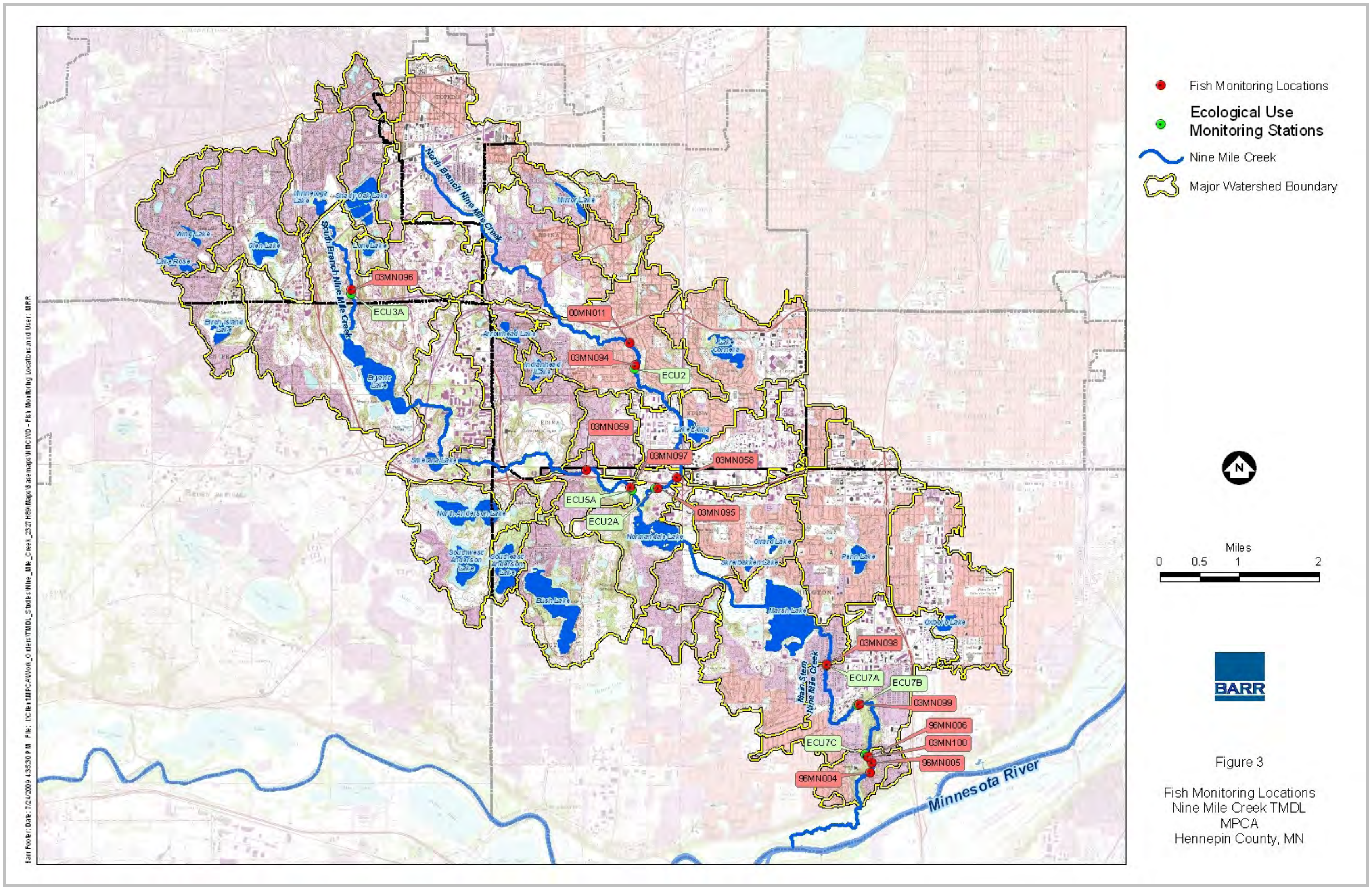


Figure 3. Fish Monitoring Locations

Table 1. Nine Mile Creek Fish Data Details – Collection Dates, Locations, and Collecting Organization

Station	Collecting Organization	Year of Collection
96MN004	USGS	1996-1998
96MN005	USGS	1996
96MN006	USGS	1996
00MN011	MDNR	2000
03MN058	MPCA	2003
03MN059	MPCA	2003
EUC-2/03MN094	Nine Mile Creek Watershed District	2003-2008
EUC-2A/03MN095	Nine Mile Creek Watershed District	2003-2008
EUC-5A/03MN097	Nine Mile Creek Watershed District	2003-2008
EUC-7A/03MN098	Nine Mile Creek Watershed District	2003-2008
EUC-7B/03MN099	Nine Mile Creek Watershed District	2003-2008
EUC-7C/03MN100	Nine Mile Creek Watershed District	2003-2008

Fish data were collected from Nine Mile Creek, pictured above.

Table 2. Nine Mile Creek IBI Data Summary – USGS, MPCA, and MDNR Data

Year	96MN004	96MN005	96MN006	00MN011	03MN058	03MN059
1996 (USGS)	48	43.2	45.6			
1997 (USGS)	28.8					
1998 (USGS)	36					
2000 (MDNR)				38.4		
2003 (MPCA)					26.4	33.6
	Impaired Sites					
An IBI score of 30 is the minimum IBI threshold for full support and no impairment.						

Table 3. Nine Mile Creek IBI Data Summary – Nine Mile Creek Watershed District Data

Year	EUC-2	EUC-2A	EUC-5A	EUC-7A	EUC-7B	EUC-7C	Annual Mean IBI*
2003	19.2	33.6	19.2	16.8	28.8	38.4	26.0
2004	26.4	24.0	16.8	28.8	28.8	31.2	26.0
2005	31.2	26.4	26.4	28.8	33.6	38.4	30.8
2006	40.8	33.6	33.6	31.2	33.6	36.0	34.8
2007	36.0	28.8	28.8	26.4	26.4	36.0	30.4
2008	28.8	31.2	33.6	36.0	38.4	38.4	34.4
*Annual average for all sites with a watershed area > 5 square miles							
	Impaired Sites						
An IBI score of 30 is the minimum IBI threshold for full support and no impairment.							

2.2 Specific Effects

The IBI was disaggregated and assessed to identify more specific effects that appeared to indicate distinctive impairment mechanisms (See Table 4). On average, Nine Mile Creek noted low scores for number of intolerant species, catch per unit effort, and percent of individuals that are simple lithophils. The low scores for number of intolerant species indicate fish species sensitive to environmental degradation were absent from Nine Mile Creek. Lack of intolerant species and the lower scores for catch per unit effort indicate the stream was degraded. The low scores for percent of individuals that are simple lithophils indicates Nine Mile Creek either lacks the clean gravel or boulder size substrate required for reproduction or that siltation has occurred in the stream's riffle areas.

2.3 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 TMDL study to identify measures to attain resolution to the impairment.

2.4 The Geographic Area Under Investigation

The Nine Mile Creek watershed is located in southern Hennepin County and includes portions of Bloomington, Eden Prairie, Edina, Hopkins, and Richfield. The stream is tributary to the Minnesota River.

Nine Mile Creek, pictured above, is located in southern Hennepin County.

Table 4. Nine Mile Creek 2003-2008 Average IBI Metric Scores

Site Metric	2003-2008 Averages	Score ECU-2	Score ECU-2A	Score ECU-5A	Score ECU-7A	Score ECU-7B	Score ECU-7C	All Sites
1	*Total # of native species*	4.3	4.3	2.7	4.0	4.0	5.0	4.1
2	*# of darter species*	3.0	3.3	1.3	2.7	2.0	2.3	2.4
3	*# of sunfish species**							
4	*# of minnow species***	3.0	1.3	1.7	3.3	2.7	3.7	2.6
5	*# of intolerant species*	1.0	1.0	1.3	1.0	1.0	1.0	1.1
6	*% of tolerant individuals*	1.7	3.0	1.7	1.7	1.0	1.3	1.7
7	*% of individuals omnivores*	3.3	5.0	3.3	3.7	4.3	5.0	4.1
8	*% of individuals insectivores*	2.3	3.0	2.3	2.3	3.7	4.7	3.1
9	*% of top carnivores**							
10	*Catch per unit effort by gear type*	1.0	1.0	1.0	1.0	1.0	1.0	1.0
11	*% of individuals simple lithophils*	1.3	1.0	1.0	1.0	2.0	2.7	1.5
12	*% of individuals w/ DELT*	4.3	1.7	5.0	2.3	4.3	3.7	3.6
SITE IBI AVG. TOTAL	Raw	25.3	24.7	21.3	23.0	26.0	30.3	25.1
	Adjusted	32.6	28.8	26.9	29.8	31.7	36.0	30.4

3.0 Background

Nine Mile Creek is approximately 15 miles in length from its headwater, where it crosses County Road 3 in Hopkins, to its mouth at the Minnesota River. The stream's watershed is approximately 50 square miles.

The contributing watershed to Nine Mile Creek has changed over time from a natural condition to agricultural land use, and finally to urban land use. Historical aerial photos of the Nine Mile Creek watershed were reviewed for years beginning with 1935 to gain a better understanding of the history of the creek and associated watershed, particularly with regard to land use. The Nine Mile Creek watershed was primarily agricultural until the 1950's, when rapid urbanization occurred. The creek was straightened prior to 1935 to provide better drainage for farming in the area that is now Normandale Lake, Nord Myr Marsh, and Marsh Lake Park. This portion of the creek was formerly County Ditch No. 1. Portions of the North Fork and South Fork were also straightened, particularly along the North Fork near T.H. 100 and in the Bredesen Park area.

The change in land use from agricultural to residential has probably improved much of the riparian vegetation, as grazing and farming practices ceased. Because vegetation is a very strong influence on stream stability, the overall condition of the streams may have improved as a result of the change in land use from farming to residential. The frequency and duration of flood flows has increased with urbanization, offsetting some of the benefits of improved vegetation.

The creek is divided into three reaches, North Branch, South Branch, and Main Stem.

The South Branch begins at Minnetonka Lake in Minnetonka, and then flows to Bryant Lake and Smetana Lake before continuing east toward Normandale Lake. A secondary branch, County Ditch 34, originates at Birch Island Lake, combines with the Glen Lake outlet in the Eden Prairie Industrial Park area and flows into Bryant Lake on the West side of the Lake. The South Branch flows through relatively flat topography.

The North Branch begins in Hopkins near Excelsior Boulevard (County Road 3) and West of 11th Avenue. It flows southerly through Bredesen Park, continues south and joins with the south branch upstream of Normandale Lake. The North Fork flows through relatively flat topography.

The Main Stem begins just upstream of Normandale Lake (i.e., where the north and south branches join) and ends at the Minnesota River. From Normandale Lake the creek flows through Nord Myr

Marsh and Marsh Lake. The outflow from Marsh Lake is controlled by the Marsh Lake dam. From here, the creek flows through a residential area, with yards abutting the creek for much of its length. After crossing Old Shakopee Road, the creek steepens as it descends into the lower valley.

The stream's riparian corridor extends 23 miles, from Eden Prairie, Minnetonka, and Hopkins to Edina and Bloomington. Riparian corridors extend from the water level of the stream, up to and including the transition from hydrophytic (wet) to mesic (moist) plant communities. The riparian corridor was assessed during 1998 and again during 2003. The assessment included all areas within the corridor, including sites with paved surfaces. The assessment results indicate the riparian corridor is comprised of the following components. Herbaceous plant communities comprise 37 percent of the corridor, while forest communities make up 21 percent, impervious surface areas are 19 percent, open water areas are 12 percent, shrub communities occur in 7.6 percent, and planted or cultivated areas comprise 4 percent of the corridor.

The riparian corridor of Nine Mile Creek, pictured above, extends 23 miles from Eden Prairie, Minnetonka, and Hopkins to Edina and Bloomington.

4.0 Candidate Causes of Biological Impairment

This section looks at possible candidate causes of the biological impairment of Nine Mile Creek. Initially, all common candidate causes listed in CADDIS were evaluated. Data were then used to either validate or eliminate candidate causes. Candidate causes that were eliminated are not discussed because the addition of this discussion would cause the report to become excessively long due to the large volume of data considered in their elimination. One exception is a brief discussion of habitat fragmentation.

Despite the occurrence of two dams on Nine Mile Creek, habitat fragmentation was eliminated as a candidate stressor. Dams occur at the outlet of Normandale Lake and at the outlet of Marsh Lake. The dams interrupt the connectivity of Nine Mile Creek and prevent the passage of fish between upstream and downstream locations. This interruption of connectivity can adversely impact a stream's fish assemblage and cause impairment (Santucci, V.J. et al., 2005). Because the interruption of connectivity consistently occurs due to the constancy of the dams, impairment resulting from habitat fragmentation is typically consistent. In Biological Stressor Identification studies of Bluff Creek (Carver County, MN) and Sand Creek (Scott, Rice, and LeSueur counties, MN), habitat fragmentation was identified as a stressor and impairment consistently occurred within reaches impacted by habitat fragmentation (Barr, 2009A and Barr, 2009B). If habitat fragmentation was a candidate cause of impairment on Nine Mile Creek, the impairment in reaches impacted by the dams would be expected to be consistent. However, Nine Mile Creek's impairment in reaches impacted by the dams was intermittent rather than consistent. All Nine Mile Creek sample locations were unimpaired during 2006, most locations were unimpaired during 2008, and some locations were unimpaired during other years – North Branch EUC 2A during 2003, North Branch EUC-2 during 2005 and 2007, and Main Stem EUC-7B in 2005. Because Nine Mile Creek's impairment was intermittent rather than consistent, habitat fragmentation was eliminated as a candidate stressor.

A second reason for elimination of habitat fragmentation as a stressor is the opportunity for replenishment of the stream's fishery both upstream and downstream from the dams. The presence of a reservoir (Normandale Lake) and two natural lakes (Smetana and Bryant) upstream from the Normandale Lake outlet provides a supply of fish for replenishment of the stream's fishery when needed. The Minnesota River downstream from the Marsh Lake outlet provides a supply of fish for replenishment of the fishery within the Main Stem of Nine Mile Creek when needed. The intermittent rather than constant impairment of Nine Mile Creek is evidence that replenishment of fish from lakes and streams connected to Nine Mile Creek prevents habitat fragmentation from causing impairment of Nine Mile Creek.

The possible candidate causes of the biological impairment of each of the three reaches of Nine Mile Creek; South Branch, North Branch, and Main Stem, are discussed separately.

4.1 South Branch

Four possible stressors were identified for the South Branch:

- Inadequate Baseflow
- Dissolved Oxygen
- Sediment
- Ionic Strength

4.1.1 Candidate Cause 1: Inadequate Baseflow

The South Branch of Nine Mile Creek, pictured above, frequently experiences flows below 0.1 cfs and sometimes dries up during periods of reduced precipitation, such as during 2007.

Inadequate baseflow is considered a possible stressor because the South Branch of Nine Mile Creek frequently experiences flows less than 0.1 cfs and sometimes dries up during periods of reduced precipitation (Figures 5 through 9). The South Branch flows into and out of several lakes, beginning as the outflow to Minnetoga Lake and then flowing into and out of Bryant Lake and Smetana Lake before flowing into Normandale Lake (Figure 3). Stream flow in each reach of the South Branch is dependent upon outflow from an upstream lake. During periods of reduced precipitation when no lake outflow occurs, baseflow is inadequate to support the stream's biological community. Continuous flow data were collected by Nine Mile Creek Watershed District from the 78th Street WOMP station during 2004 through 2008 (Figure 4). The data indicate baseflow was frequently less than 0.1 cfs. Specifically, flow was less than 0.1 cfs for 18 days in 2004, 1 day in 2005, 16 days in 2006, 11 days in 2007, and 13 days in 2008. Low flows have generally occurred during July and August (Figures 5-9).

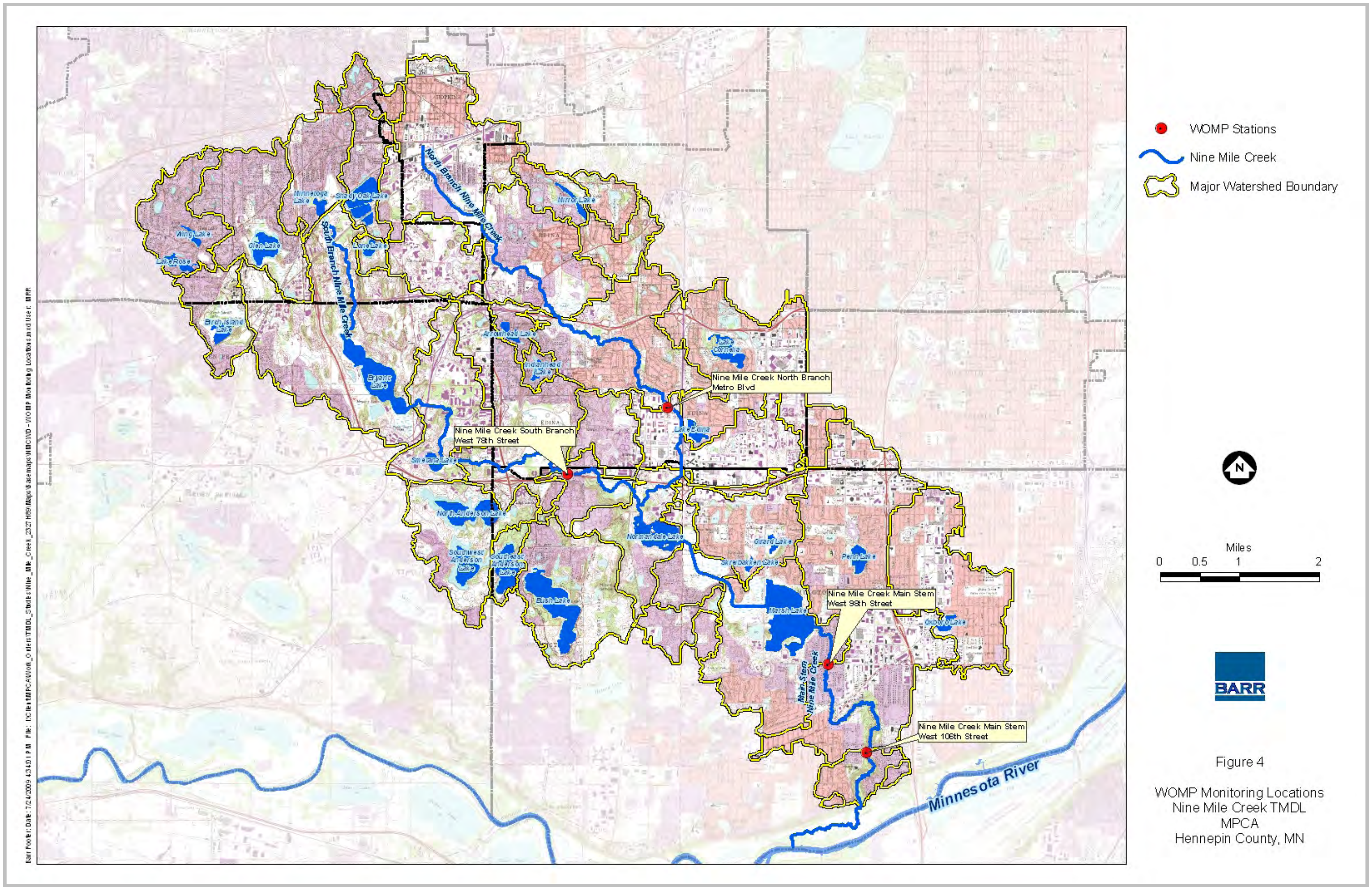


Figure 4. WOMP Monitoring Locations

As shown in Figures 5 through 9, the South Branch at EUC-5A (Location shown in Figure 3) noted IBI scores below the impairment threshold of 30 or greater during 2004 through 2005 and during 2007. During 2004 and 2007, fish samples were collected following a low flow period (i.e., flows were less than 0.1 cfs). During 2006 and 2008, IBI scores were above the impairment threshold where fish sampling occurred prior to the periods of low flow (i.e., flows less than 0.1 cfs) that stressed the biological community (Figures 7 and 9). An impaired fish IBI score was observed, during 2005 even though low flows (i.e., flows less than 0.1 cfs) were not observed prior to the collection of fish samples. The data from 2004, 2006, 2007, and 2008 indicate that low flows could have caused some stress for the biological community, while another stressor could explain the impaired condition in 2005.

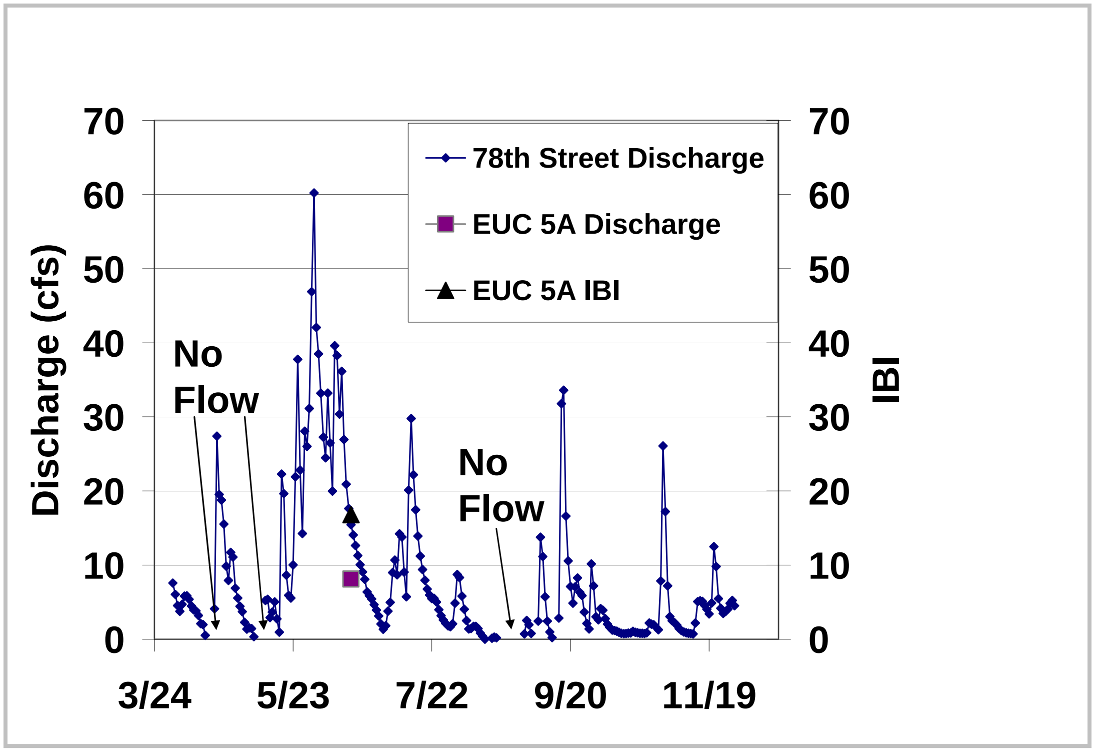


Figure 5. 2004 Nine Mile Creek South Branch Discharge and IBI

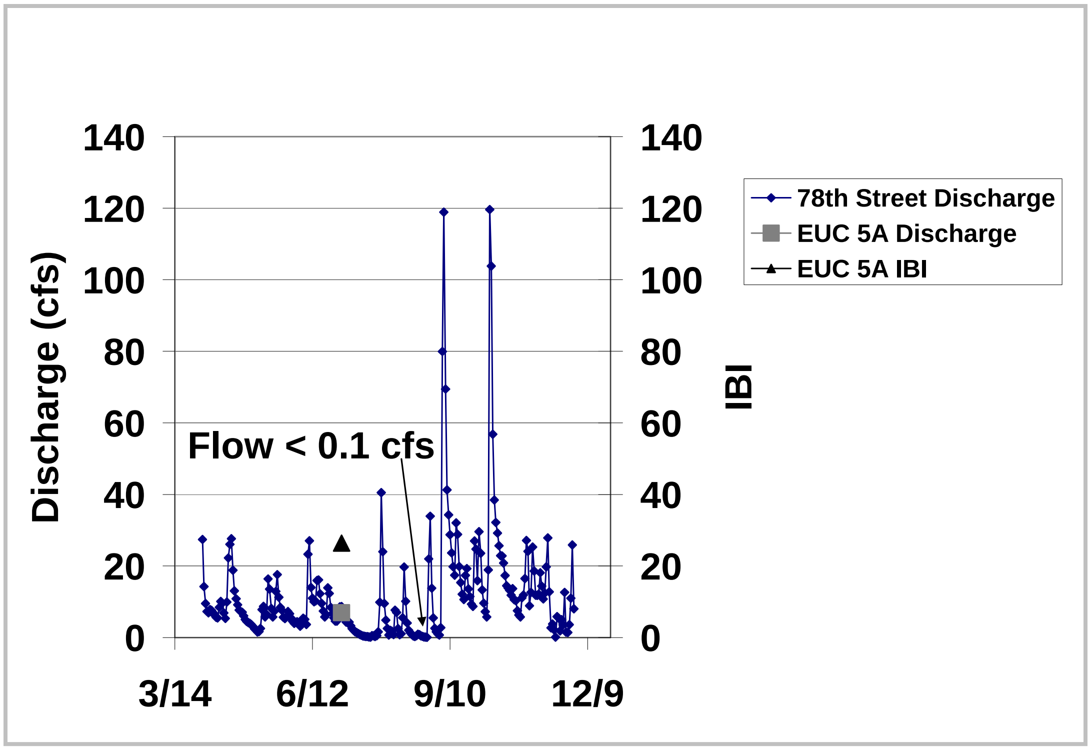


Figure 6. 2005 Nine Mile Creek South Branch Discharge and IBI

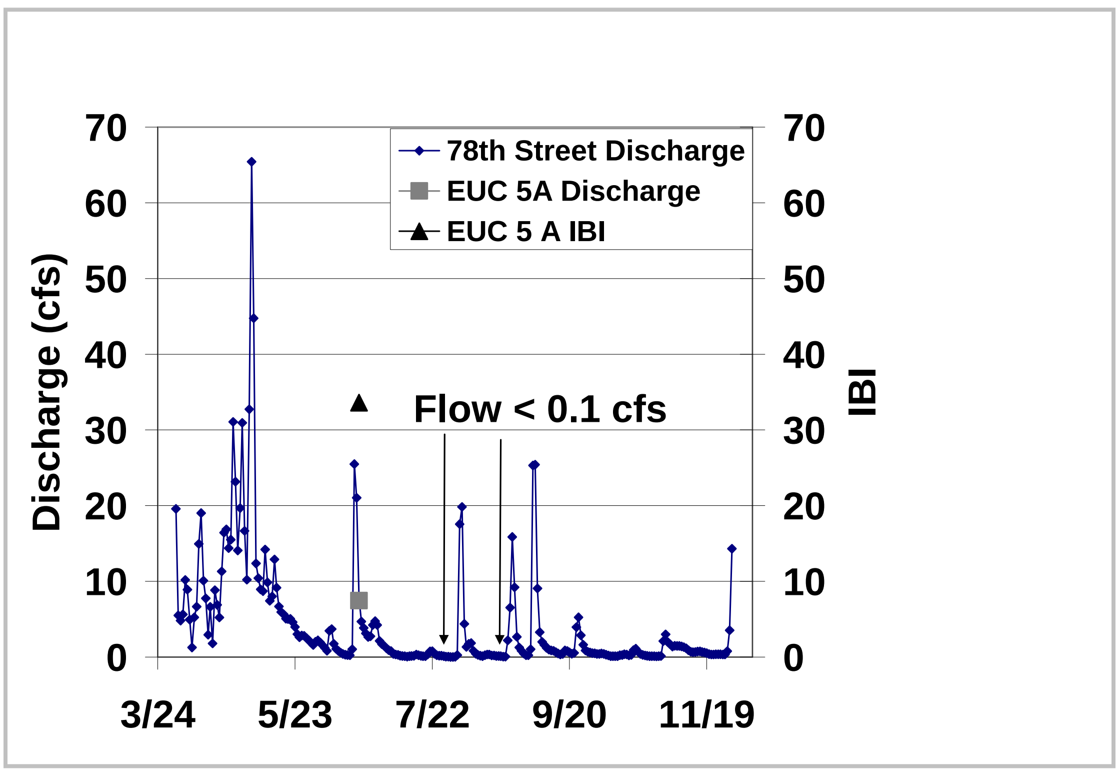


Figure 7. 2006 Nine Mile Creek South Branch Discharge and IBI

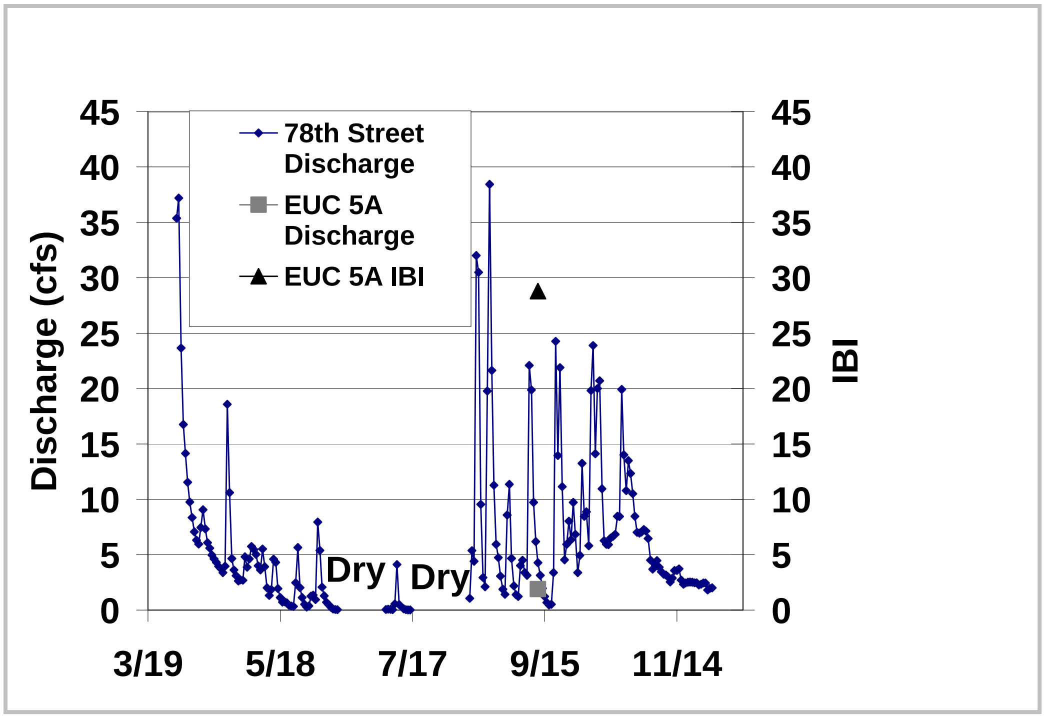


Figure 8. 2007 Nine Mile Creek South Branch Discharge

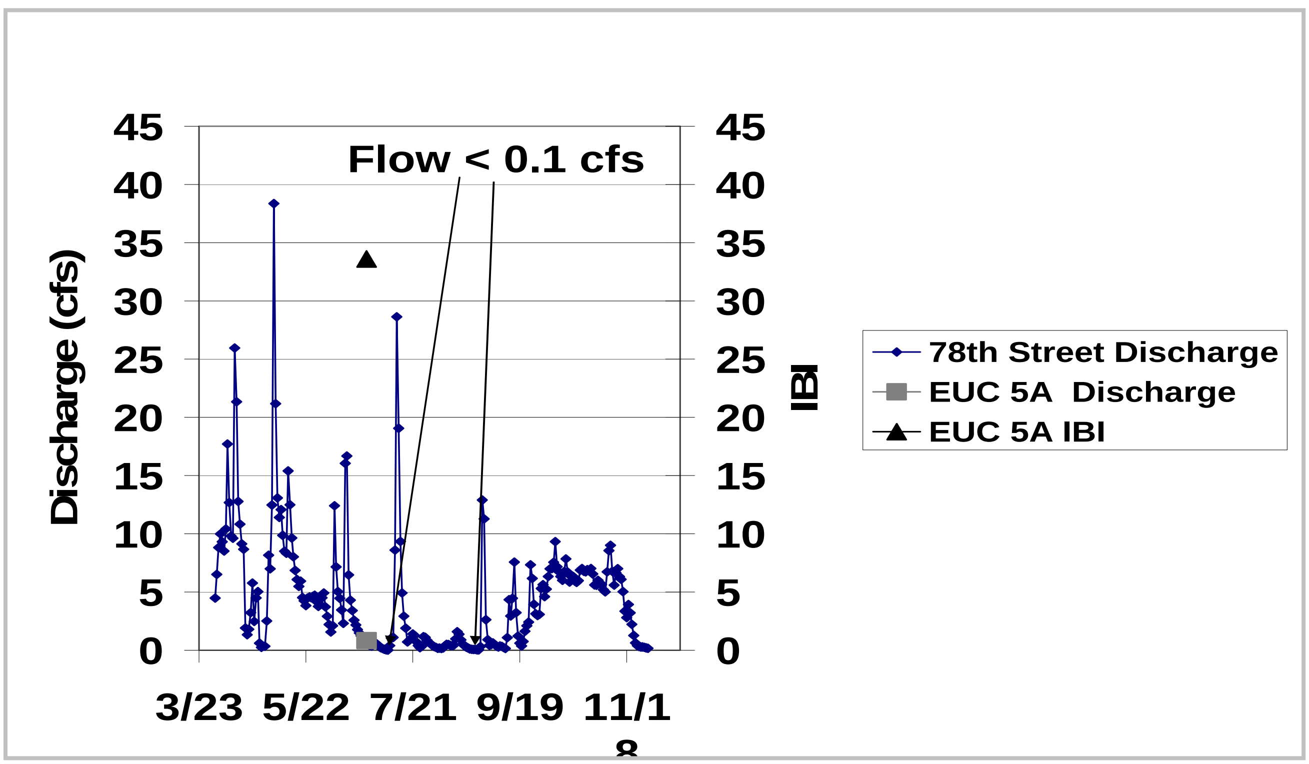


Figure 9. 2008 Nine Mile Creek South Branch Discharge

A conceptual model of candidate cause 1, inadequate baseflow, is shown in Figure 10. The model shows that reduced precipitation causes a change in lake water surface elevation in upstream lakes and reduces discharge from upstream sources. Conversion to higher intensity land use and imperviousness has reduced infiltration and caused a decrease in baseflow. The reduced discharge from upstream lakes and the decrease in summer and winter 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 IBI impairment threshold of 30 or greater.

Inadequate baseflow at the South Branch of Nine Mile Creek, pictured above, causes a decrease in fish and invertebrate taxa richness and low fish IBI scores.

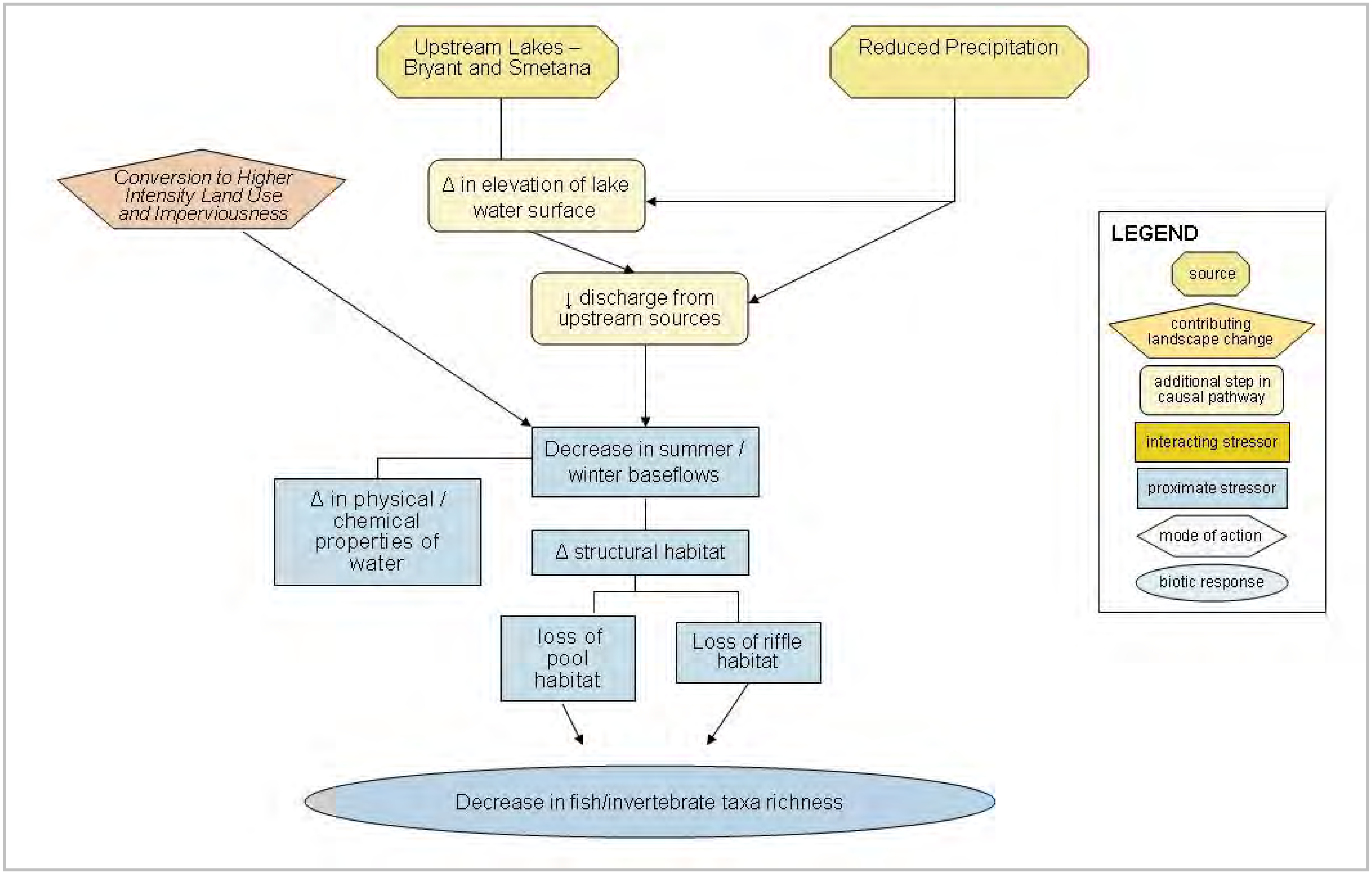


Figure 10. South Branch Nine Mile Creek: Conceptual Model of Flow Alteration Due to Reduced Precipitation

4.1.2 Candidate Cause 2: Dissolved Oxygen

Dissolved oxygen is considered a possible stressor because diel oxygen changes in the stream have resulted in oxygen concentrations below 5 mg/L, the threshold for full support of aquatic life specified in Minnesota Rule Chapter 7050. Nine Mile Creek has been classified under Minn. R. Pt. 7050.0220 as fisheries and recreational streams-Class 2B waters. The dissolved oxygen standard for Class 2B streams is:

"5.0 mg/L as a daily minimum. This dissolved oxygen standard may be modified on a site specific basis according to Part 7050.0220, subpart 7, except that no site-specific standard shall be less than 5 mg/L as a daily average and 4 mg/L as a daily minimum. Compliance with this standard is required 50 percent of the days at which flow of the receiving waters is equal to the $7Q_{10}$" (Minnesota Rule Chapter 7050.0222, subpart 4).

Plants in the South Branch of Nine Mile Creek add oxygen to the stream during the day (photosynthesis) and deplete the stream of oxygen during the night (respiration).

The Nine Mile Creek Watershed District measured dissolved oxygen continuously at the 78th Street WOMP Station (Figure 4) during July 3 through August 7 of 2009. The stream was dry from July 12 through 20. The data indicate dissolved oxygen concentrations ranged from a high of 1.38 to 15.99 mg/L during the daylight hours to a low of 0.035 to 3.165 mg/L during the night (Figure 11). Plants in the South Branch of Nine Mile Creek added oxygen to the stream during the daylight hours when they were photosynthesizing. However, during the night, the stream biota, both plants and animals, depleted the stream of oxygen as they respired. The diel oxygen changes in the South Branch of Nine Mile Creek depressed the stream's oxygen levels below the impairment threshold of 5 mg/L as a daily minimum for Class 2B streams (Minnesota Rule Chapter 7050.0222, subpart 4). The variations represent a stressor to the stream's biological community. The average daily dissolved oxygen concentration was 4.8 mg/L which is below the 5.0 mg/L daily average specified in the MPCA standard for Class 2B waters (Minnesota Rule Chapter 7050.0222, subpart 4).

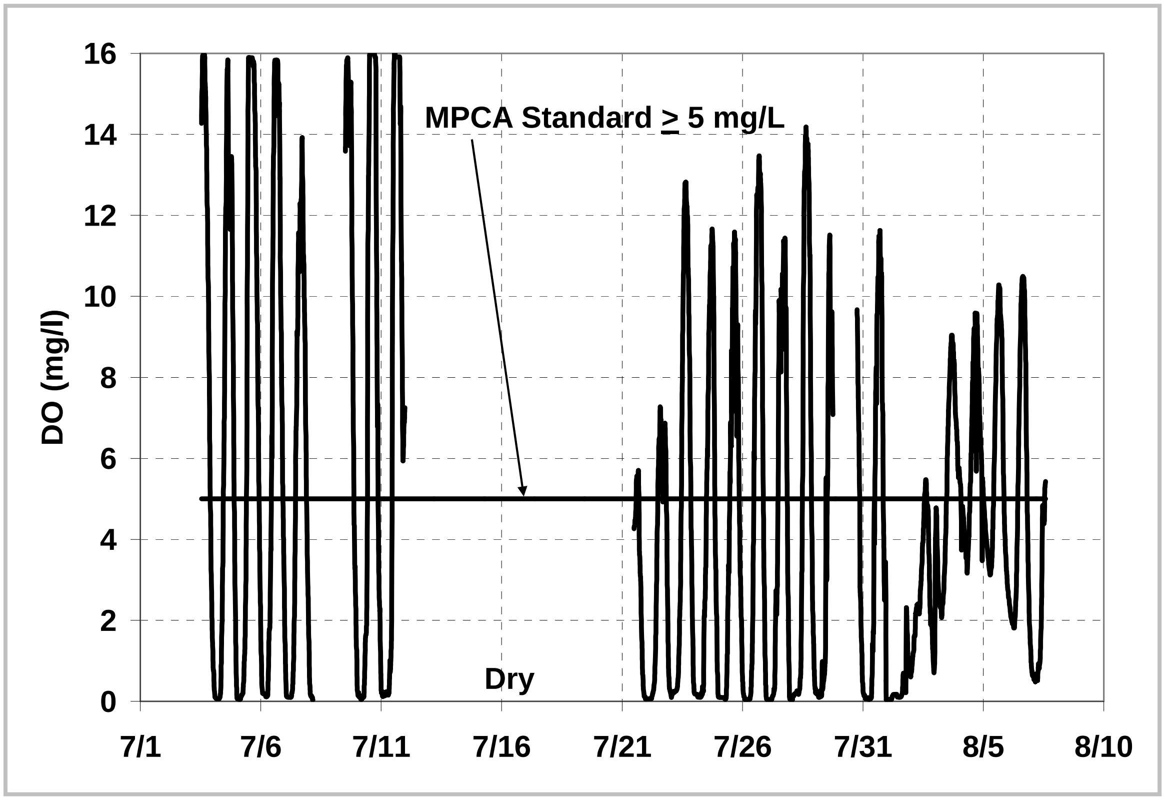


Figure 11. July - August 2009 Nine Mile Creek Dissolved Oxygen: South Branch at 78th Street

On July 23, 2009, a synoptic longitudinal dissolved oxygen survey was completed on the South Branch of Nine Mile Creek. A total of 9 locations (Figure 12) were surveyed between 5:45 and 7:45 A.M. Low flow conditions were observed throughout the South Branch. No outflow occurred from Bryant Lake and the stream reach at Bryant Lake Drive was dry. With the exception of the two most downstream locations (N2 WOMP Station and E. Bush Lake Rd), sample locations were either a stagnant pool or just a trickle of water.

The two survey locations upstream of Bryant Lake experienced oxygen concentrations greater than 5 mg/L (7.8 and 8.8 mg/L) and met the dissolved oxygen standard for a Class 2B stream (Minnesota Rule Chapter 7050.0222, subpart 4). Hence, this stream reach showed no evidence of oxygen levels that would cause biological stress. All 7 survey locations downstream from Bryant Lake experienced oxygen concentrations less than 5 mg/L (i.e., from 1.3 to 4.8 mg/L) and did not meet the 5 mg/L dissolved oxygen standard for a Class 2B stream (Minnesota Rule Chapter 7050.0222, subpart 4). Hence, this stream reach showed evidence of oxygen conditions that would stress aquatic life.

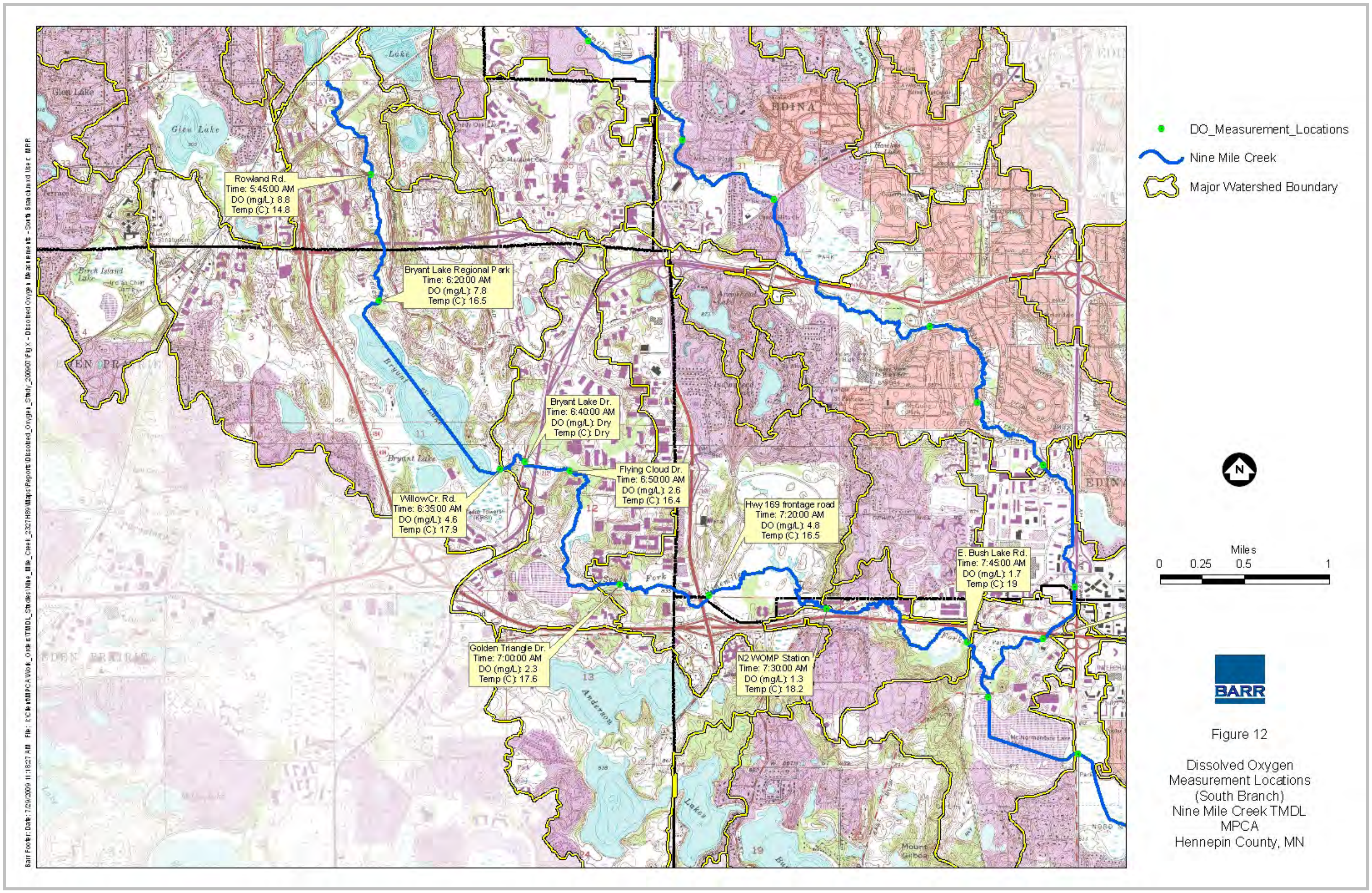


Figure 12. Dissolved Oxygen Measurement Locations (South Branch)

The continuous oxygen measurements at 78th Street indicate diel oxygen changes would cause stress on the biological community on a daily basis. The synoptic longitudinal survey measurements indicate oxygen levels that would cause biological stress are widespread, occurring throughout the South Branch from Bryant Lake to the confluence of the South Branch with the North Branch just upstream from Normandale Lake.

A conceptual model of candidate cause 2, dissolved oxygen reduction due to anaerobic sediment in natural wetlands, reduced precipitation and respiration, is shown in Figure 13. The model shows that stagnant flow conditions result in anaerobic sediment developing within the natural wetlands that are tributary to this branch of the creek. Reduced precipitation increases hydraulic residence time and evapotranspiration in upstream lakes and causes hydrological alteration of flow to Nine Mile Creek. These changes reduce discharge to Nine Mile Creek which reduces aeration causing reduced oxygen in discharge waters. Increased air and stream temperatures reduce oxygen solubility of water. No photosynthesis at night in combination with respiration by the biological community within the stream reduces oxygen in the stream. Reduced dissolved oxygen increases respiratory stress and causes changes in behavior, increased species out migration, and increased mortality. The end result is a decrease in fish and invertebrate taxa richness and the number of sensitive species, which were not observed in the South Branch of Nine Mile Creek.

Macroinvertebrate data collected from EUC-5A on the South Branch of Nine Mile Creek during 1997 through 2008 were analyzed using Hilsenhoff's Biotic Index (HBI) to assess stream oxygen levels. The HBI is an aggregate measure of the type of macroinvertebrates in a stream. Macroinvertebrates in the index are ranked according to their tolerance to low dissolved oxygen levels. Hence, the HBI can be used as another measure of oxygen changes in a stream. For the purpose of calculating the biotic index, every species or genus has been assigned index values from 0-10; with 0 assigned to species most intolerant of organic pollution and resultant low oxygen levels and 10 assigned to the most tolerant species. Intermediate values were assigned to species intermediate in their tolerance of organic pollution and resultant low oxygen levels. The HBI is an average of tolerance values for all individuals collected from a site. The water quality/oxygen level of each station was then determined from the biotic index value as illustrated in Table 5.

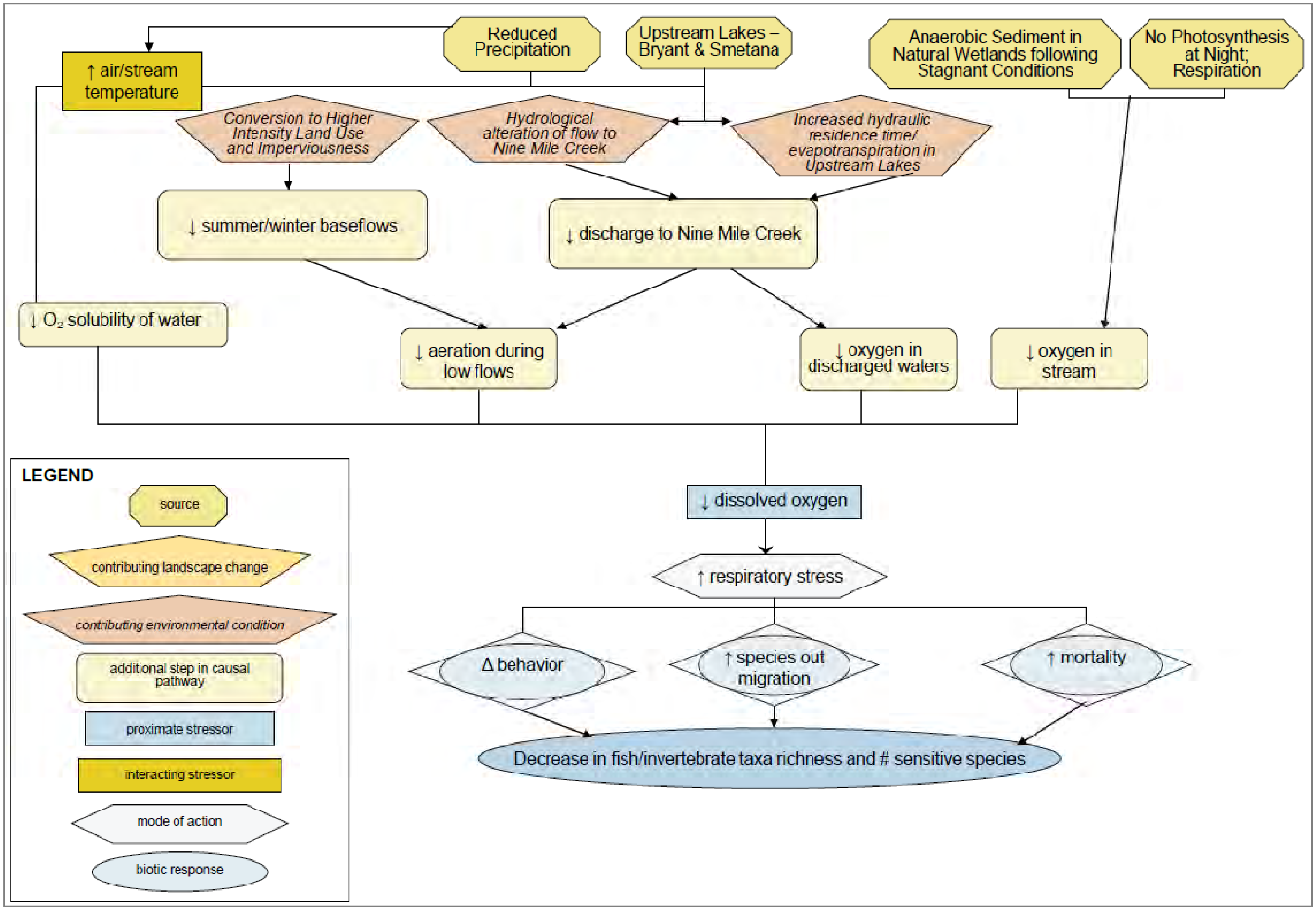


Figure 13. South Branch Nine Mile Creek: Conceptual Model of Dissolved Oxygen Reduction Due to Anaerobic Sediment in Natural Wetlands, Reduced Precipitation and Respiration

Table 5. Water Quality/Oxygen Levels and Degree of Organic Pollution Associated With HBI Values

Biotic Index	Water Quality/Oxygen Level	Degree of Organic Pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very Good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

HBI values measured at EUC-5A located on the South Fork of Nine Mile Creek (Figure 3) have generally been in the poor category (73 percent), although a few values (27 percent) were in the fairly poor category (Figure 14). The data confirm that stressful oxygen conditions have consistently occurred in the South Branch of Nine Mile Creek for at least a decade.

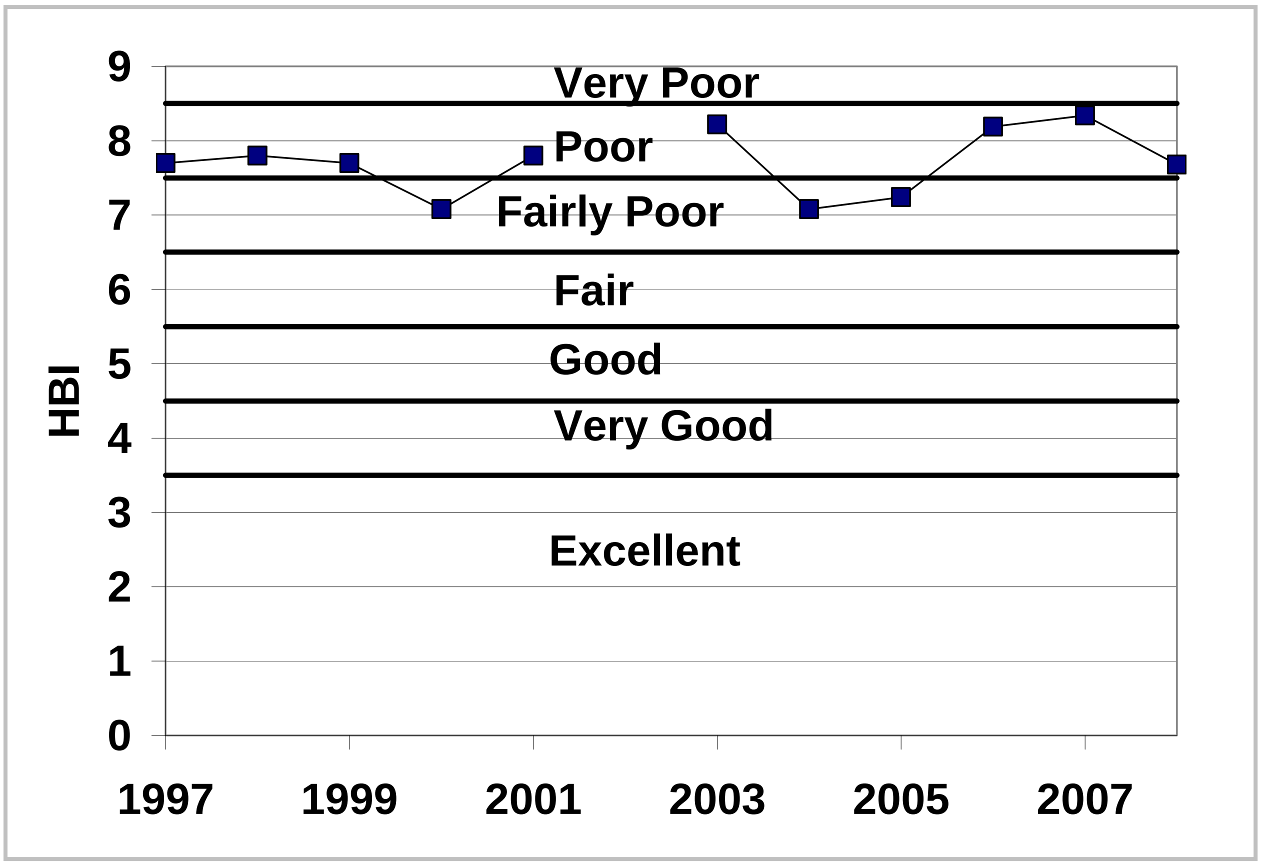


Figure 14. 1997-2008 Nine Mile Creek South Fork (EUC-5A) HBI

4.1.3 Candidate Cause 3: Sediment

Sediment was considered as a candidate stressor because deeper depths of fine sediment have been associated with IBI scores below the impairment threshold of 30 or greater on the South Branch of Nine Mile Creek. Nine Mile Creek Watershed District collected habitat data at EUC-5A during 2003 through 2006. Thirteen transects and five sample locations along each transect were sampled within the fish sampling reach of EUC-5A. All habitat sample locations contained fine sediment during all sample years. The maximum depth of fine sediment was highest during 2003 and decreased annually through 2006 (Figure 15).

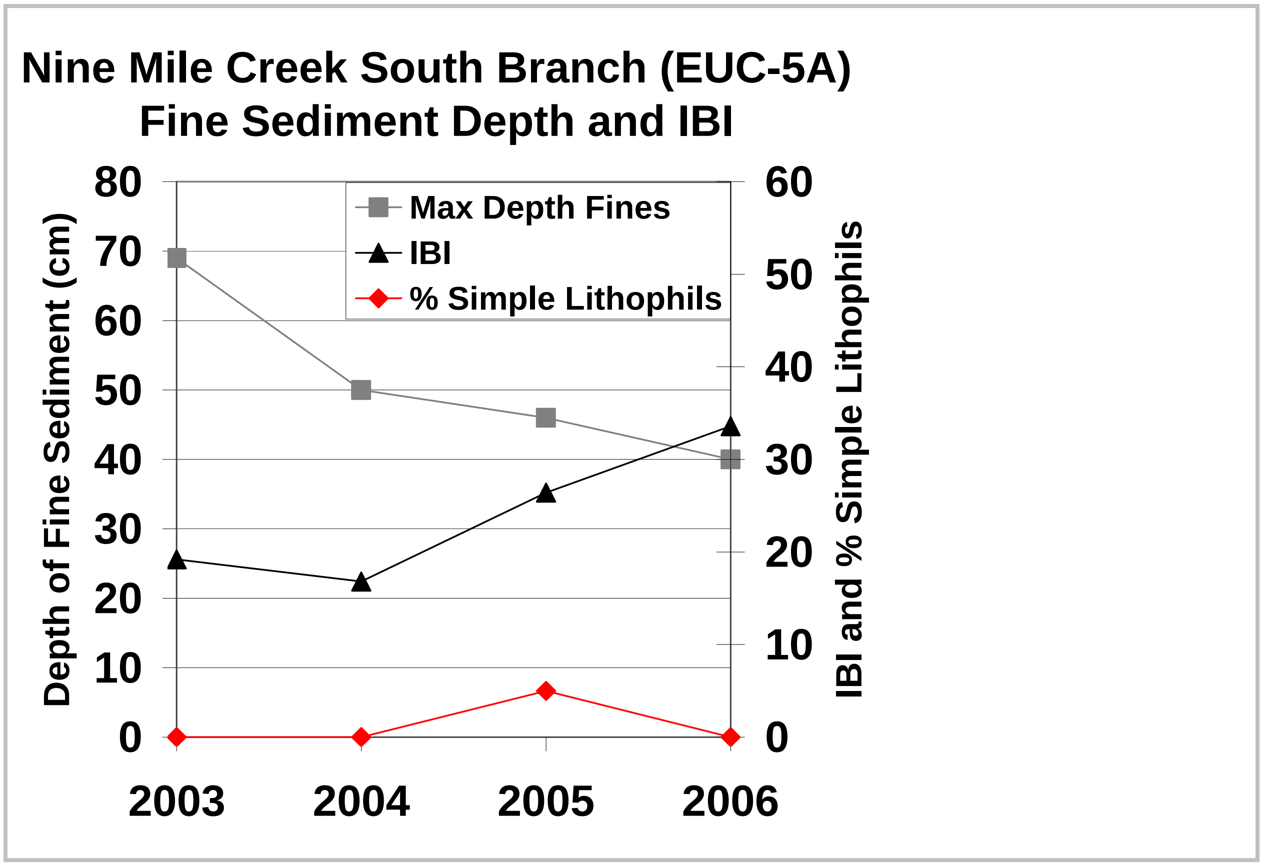


Figure 15. Nine Mile Creek South Branch (EUC-5A) Fine Sediment Depth, IBI, and % Simple Lithophils

Historical accumulation of fine sediment at EUC-5A may be due in part to impacts of upstream beaver dam construction. During 1978 through 1992, reduced flow to this stream reach created ideal conditions for fine sediments to settle out and accumulate.

Additional sediment was added to this location in 2003 when six-lane expansion on I-494 occurred from Highway 5 to France Avenue and runoff from the construction site conveyed sediment to the stream. Replacement of the culvert immediately downstream from EUC-5A during 2003 as a part of the construction project, however, caused a change in flow characteristics through this stream reach that decreased fine sediment depths at this location annually during 2004 through 2006 (Figure 15).

Replacement of the culvert immediately downstream from EUC-5A in 2003 with the culvert pictured above caused a change in flow characteristics through this stream reach that decreased fine sediment depths at this location annually during 2004 through 2006.

As fine sediment depths decreased at EUC-5A during 2004 through 2006, IBI scores increased. Although IBI scores during 2003 through 2005 were below the impairment threshold of 30 or greater, the 2006 IBI score exceeded the impairment threshold and the reach was not impaired in 2006 (Figure 15).

Simple lithophils are fish, such as white sucker, that require clean gravel or boulders for reproduction and are adversely impacted by sediment. Simple lithophils were absent from this location during 2003, 2004, and 2006. In 2005, five percent of the fish community was comprised of simple lithophils. The substrate at this location has consistently been comprised of sand and silt which are unsuitable for lithophil reproduction. The absence or low numbers of lithophils at this location are due to lack of suitable habitat for reproduction.

A Rosgen stream assessment was conducted on the South Branch of Nine Mile Creek during 1997 to better understand the physical characteristics of the stream. The survey was repeated in 2003 to assess stream changes over time. In 1997, the EUC-5 stream reach was a Type E channel characterized by a narrow, deep channel and a broad floodplain. The floodplain consisted almost entirely of grasses, with a few interspersed willow trees. The banks were quite stable, with only a few raw areas. The sinuosity of the channel was on the low end of that expected for an E channel.

The survey was repeated in 2003 and the results indicated the survey reach had aggraded since the 1997 survey. The changes indicated excessive sediment loading to the channel had occurred since 1997. Possible sources of sediment could include stormwater runoff conveyed to the stream by a large storm sewer pipe constructed upstream of the surveyed reach since the 1997 survey or stormwater runoff from construction on Interstate I-494 occurring during 2003. Survey results indicated the channel in this reach was still classified as a Type E, but also indicated the channel cross-section was widening. If the bed aggradation and channel widening were to continue, the stream would probably revert to a Type C. The banks continued to be quite stable, with only a few exposed areas.

Habitat survey results shown in Figure 15 indicate a reduction in sediment depth occurred after completion of the Interstate I-494 construction project. The data suggest the construction project was the primary source of sediment loading to the stream and the primary cause of degradation during the 1997 through 2003 period. Annual sediment reduction during the 2003 through 2006 period suggest the stream was returning to sediment levels present before the onset of the construction project.

Because sediment depth was associated with impaired IBI scores during 2003 through 2005, sediment is considered a possible candidate stressor. The results of the Rosgen stream assessments provide further evidence supporting sediment as a candidate stressor to the stream's fish community. A conceptual model of candidate cause 3, sediment, is shown in Figure 16. The model shows that stormwater runoff from watershed sources and streambank erosion add sediment to the stream. Sediment deposition increases coverage by fine sediment, burial, fine substrate habitats, and pool-filling. Interstitial spaces and substrate size decline as well as substrate diversity and stability. These declines cause a decline in habitat and spawning areas for simple lithophils. The habitat changes caused by increased coverage by fine sediment cause biologically impaired fish and invertebrates.

4.1.4 Candidate Cause 4: Ionic Strength

Ionic strength was considered as a candidate stressor because relatively high (>1,000 µmhos/cm @ 25° C) specific conductance values have been measured in the stream. Minnesota Rule Chapter 7050 (Minn. R. 7050) specifies standards applicable to Minnesota streams to protect aquatic life. Nine Mile 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 Nine Mile Creek is the standard specified for

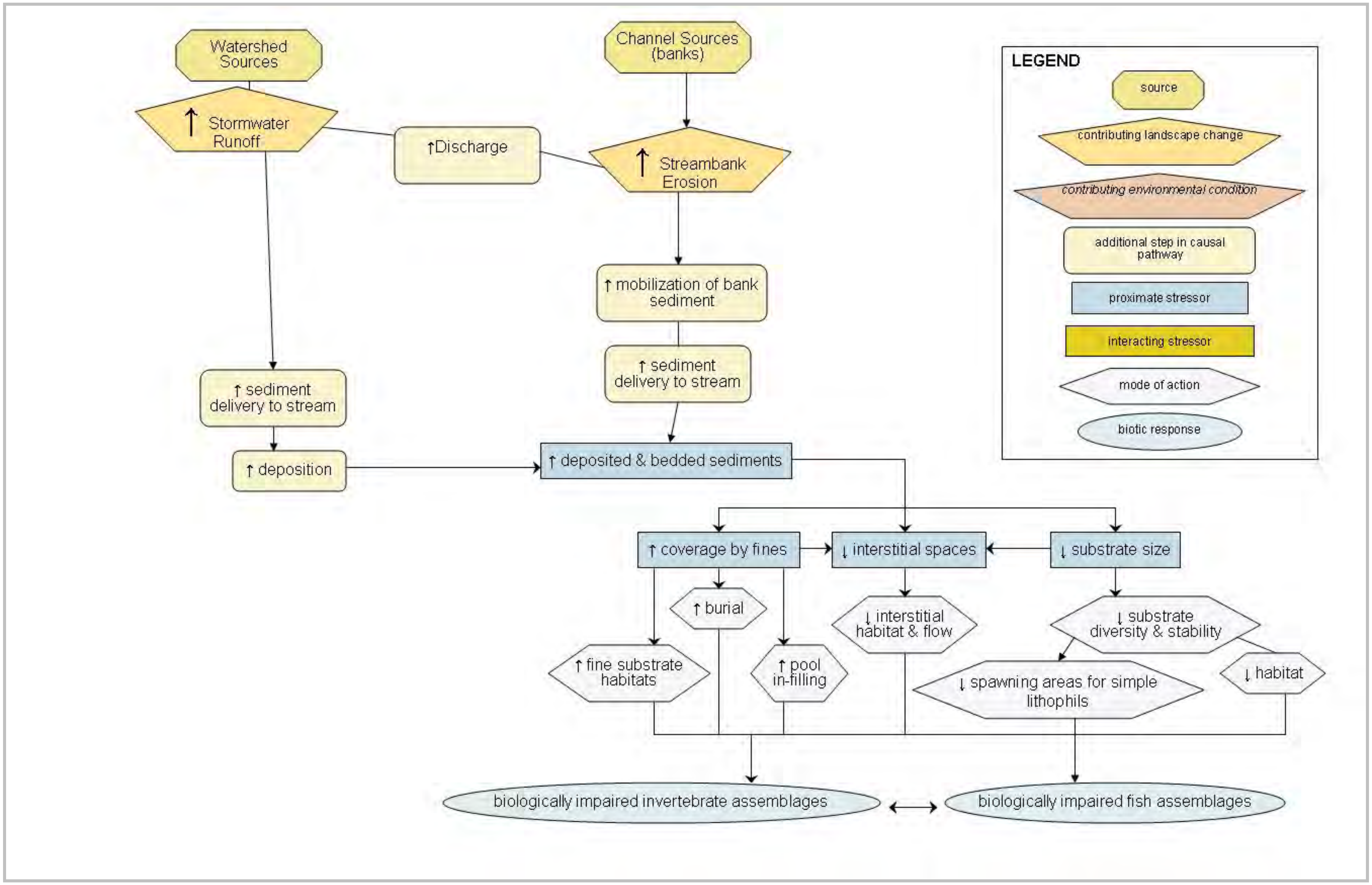


Figure 16. South Branch, North Branch, and Main Stem Nine Mile Creek: Conceptual Model of Sediment

Class 4A waters – values are not to exceed 1,000 µmhos/cm @ 25° C (Minnesota Rule Chapter 7050.0224 Subpart 2).

The NMCWD has continuously measured specific conductance at the 78th Street WOMP Station since late 2003 (Figure 4). Data from the 78th Street WOMP Station indicate specific conductance annually exceeded the 7050 standard during the December through March period (Figure 17).

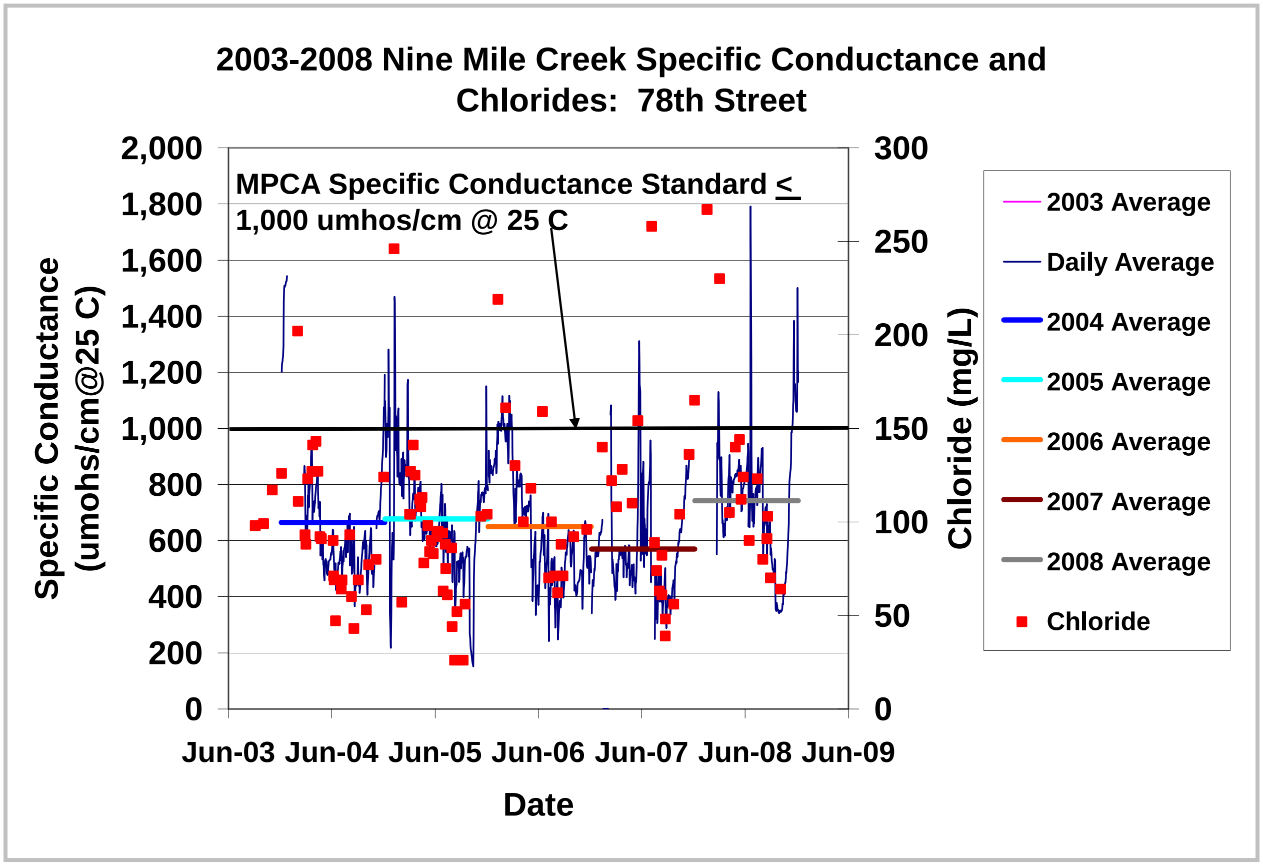


Figure 17. 2003-2008 Nine Mile Creek Specific Conductance and Chloride: 78th Street

A comparison of specific conductance values and chloride concentrations indicates chloride is the ion causing the high specific conductance measurements at the 78th Street WOMP Station. Changes in specific conductance measurements consistently coincided with changes in chloride concentrations during the period of record (Figure 17).

The MCES measured specific conductance continuously at the 106th Street WOMP location during this same period (Figure 4). Although data from the 78th Street and 106th Street WOMP Stations indicate specific conductance annually exceeded the 7050 standard during the December through March period (Figure. 18) at both locations, specific conductance values from 78th Street on the

South Branch have consistently been lower than values from the 106th Street location on the Main Stem (Figure 18). Fish IBI scores from EUC-7C (i.e., 106th Street, Figure 3) have consistently met the MPCA standard and, hence, high specific conductance levels have not caused biological impairment at this location (Table 3).

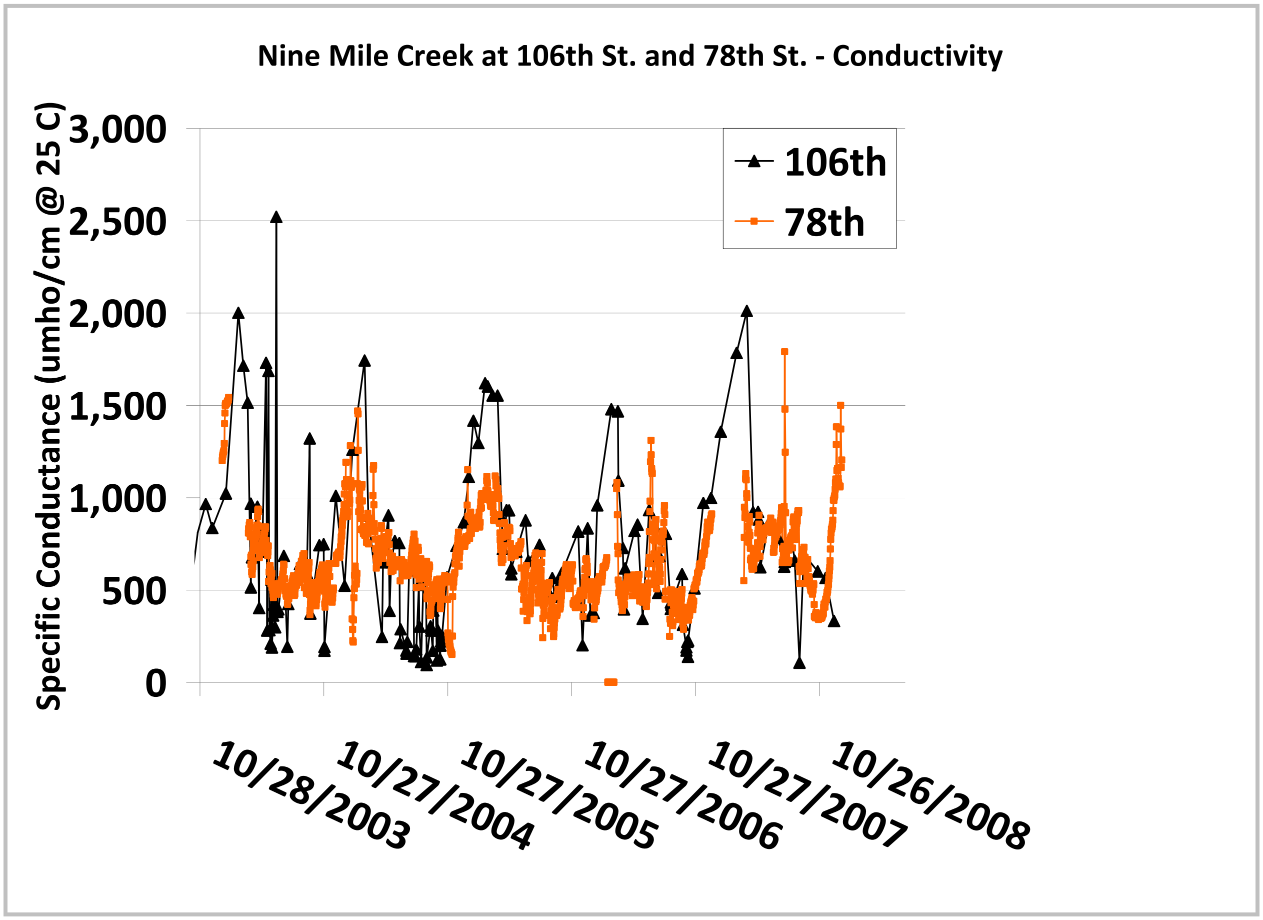


Figure 18. Nine Mile Creek Specific Conductance: Compare South Branch at 78th Street With Main Stem at 106th Street

High specific conductance levels at the 78th Street location occurred concurrently with impaired IBI scores during 2004, 2005, and 2007. High specific conductance levels at 78th Street during 2006 and 2008 occurred concurrently with unimpaired IBI scores, although levels in excess of the MPCA standard were lower during 2006 and 2008 than levels observed during 2004, 2005, and 2007 (Figure 17). High specific conductance levels at downstream 106th Street occurred concurrently with unimpaired IBI scores during 2004 through 2008. The conflicting data do not provide strong support for the hypothesis that ionic strength is a candidate stressor for the fish community.

A conceptual model of candidate cause 4, ionic strength is shown in Figure 19. The model shows that road salt and deicers used on highways, residential, industrial, and commercial areas are conveyed to the stream via stormwater drainage. Increased ions in discharge waters and soil cause a change in the ion content of the stream. This change 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 due to chlorides cause biologically impaired fish assemblages, biologically impaired invertebrate assemblages, and other biological impairments.

4.2 North Branch

Three possible stressors were identified for the North Branch:

- Dissolved Oxygen
- Ionic Strength
- Sediment

4.2.1 Candidate Cause 1: Dissolved Oxygen

Dissolved oxygen is considered a possible stressor because diel oxygen changes in the stream have resulted in oxygen concentrations below 5 mg/L, the threshold for full support of aquatic life (Minnesota Rule Chapter 7050.0222, subpart 4). The NMCWD continuously measured dissolved oxygen at the Metro Boulevard WOMP Station (Figure 4) during July 3 through August 7 of 2009. The 2009 data indicate diel oxygen changes cause stressful conditions for the biological community on a daily basis. The data indicate dissolved oxygen concentrations were consistently greater than 5 mg/L during the daylight hours and were consistently less than 5 mg/L during the night (Figure 20). Minimum daily oxygen concentrations ranged from 0.039 to 7.66 mg/L and maximum daily oxygen concentrations ranged from 4.17 to 10.47 mg/L.

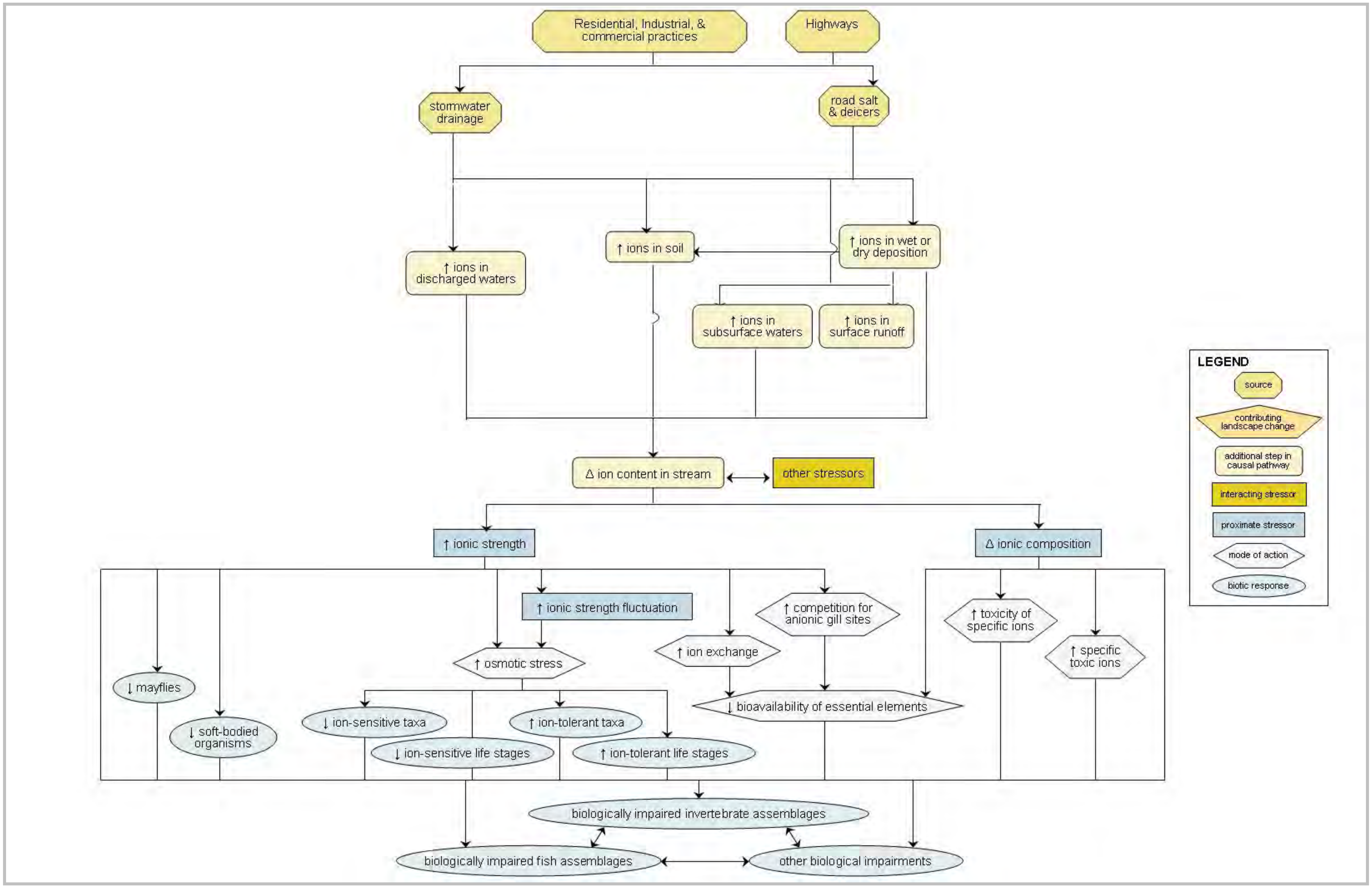


Figure 19. South Branch Nine Mile Creek: Conceptual Model of Ionic Strength

Average daily dissolved oxygen concentrations during the period of measurement ranged from 1.80 to 8.18 mg/L (Figure 20). The average daily dissolved oxygen concentration for the period was 4.5 mg/L which is below the 5.0 mg/L daily average specified in the MPCA standard for Class 2B waters (Minnesota Rule Chapter 7050.0222, subpart 4). The data indicate low dissolved oxygen concentrations are a cause of the stream's biological impairment.

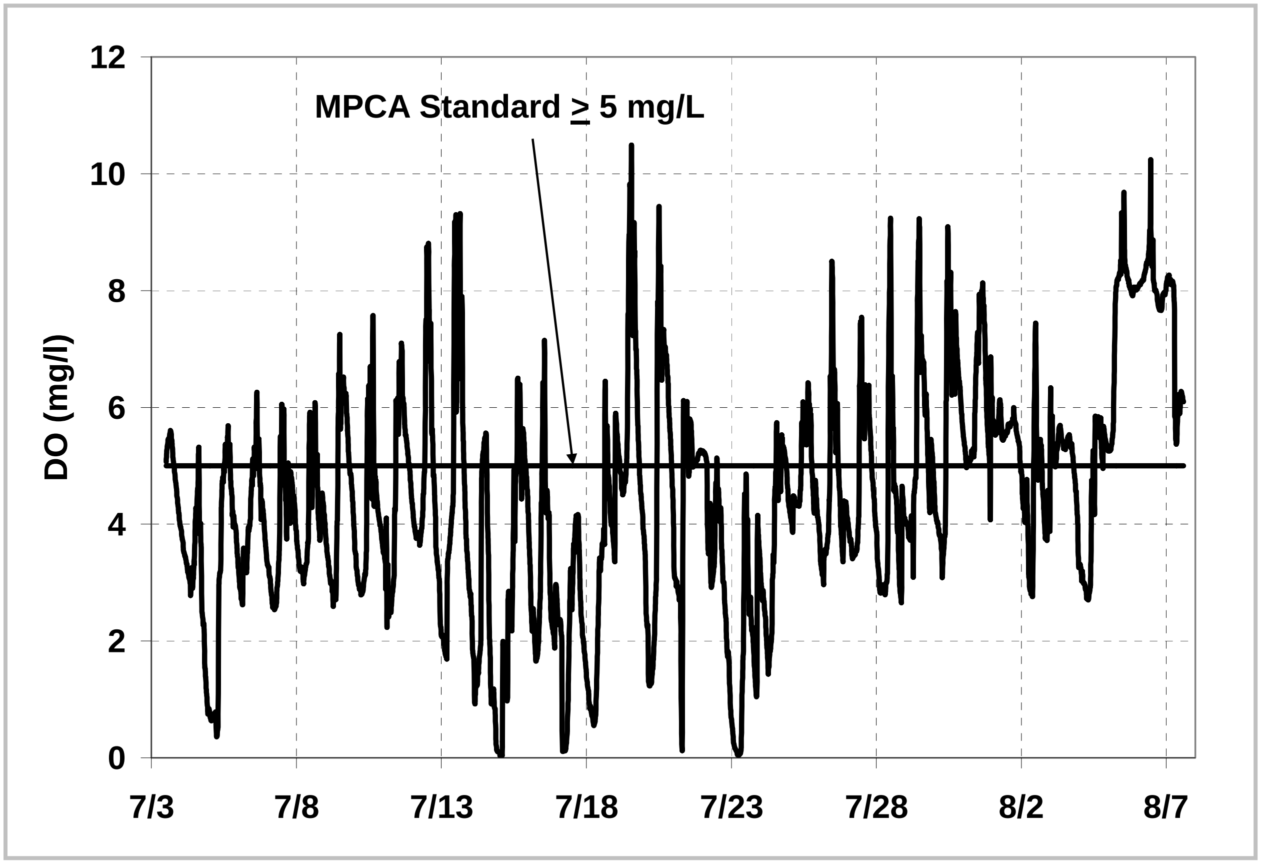


Figure 20. July - August 2009 Nine Mile Creek Dissolved Oxygen: North Branch at Metro Boulevard

On July 23, 2009, a synoptic longitudinal dissolved oxygen survey was completed on the North Branch of Nine Mile Creek. A total of 9 locations (Figure 21) were surveyed between 5:00 and 6:45 AM. Four locations (Dovre Dr., Valley Ln., Brook Dr., and American Blvd. shown on Figure 21) observed dissolved oxygen concentrations less than 5 mg/L. Five locations observed dissolved oxygen concentrations greater than 5 mg/L. The dissolved oxygen concentration at 72nd St W (Figure 21), near the WOMP station (Figure 4), was 5.89 mg/L. The data indicate portions of the North Branch showed evidence of oxygen conditions that would stress aquatic life. However, the stream reaches with lower oxygen conditions were near stream reaches with sufficient oxygen to support

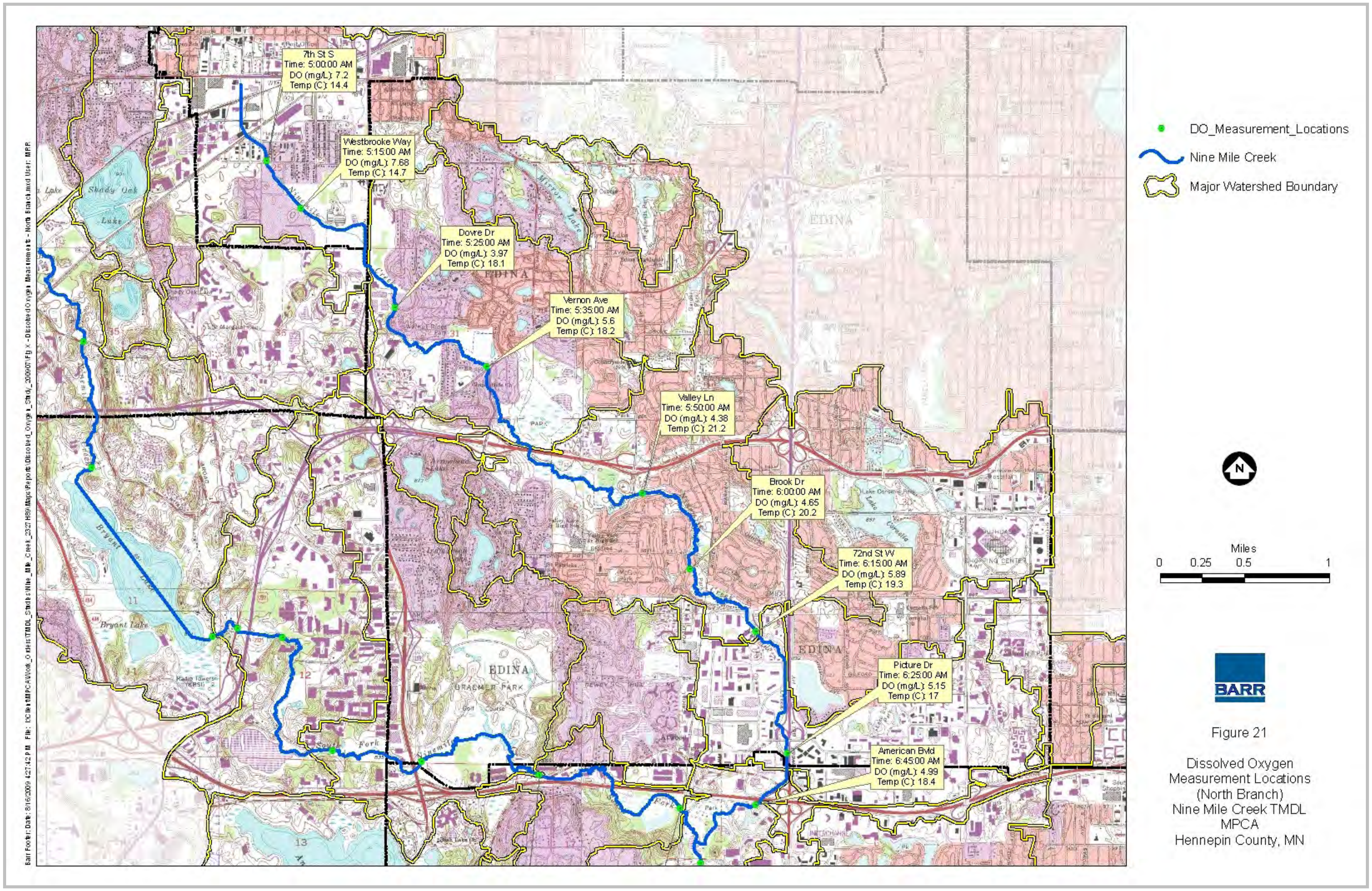


Figure 21. Dissolved Oxygen Measurement Locations (North Branch)

aquatic life. For example, Dovre Drive with a dissolved oxygen concentration of 3.97 mg/L was downstream from Westbrooke Way with a dissolved oxygen concentration of 7.68 mg/L and upstream from Vernon Avenue with a dissolved oxygen concentration of 5.6 mg/L. The data indicate diel oxygen fluctuations, expected to cause stress to aquatic life, occurred at intermittent locations on the North Branch from Dovre Drive to American Boulevard.

Significant diel oxygen fluctuations were measured in the North Branch of Nine Mile Creek, pictured above, during July and August of 2009.

HBI data from the North Branch provide additional evidence that dissolved oxygen may be a stressor causing biological impairment. Macroinvertebrate data collected from EUC-2 on the North Branch of Nine Mile Creek during 1976 through 2008 were analyzed using Hilsenhoff's Biotic Index (HBI) to assess stream oxygen levels. HBI levels measured at EUC-2 have generally been in the fair category (78 percent), but have occasionally been in the good (16 percent), very good (3 percent) or fairly poor (2006) category (Figure 22).

HBI levels measured at EUC-2A during 1997 through 2008 were in the fairly poor category 55 percent, of the time, were borderline fair to fairly poor 18 percent of the time, and were fair 27 percent of the time (Figure 23). EUC-2 and EUC-2A are both located within North Branch reaches noting dissolved oxygen concentrations less than 5 mg/L during the July 23, 2009 longitudinal survey. The presence of aquatic organisms tolerant to fair to fairly poor oxygen conditions at these locations is consistent with the observation of stressful oxygen conditions in the stream reaches. HBI values from EUC-2A were generally higher than values measured at EUC-2 during 1997 through

2008 (Figures 22 and 23). The data indicate poorer oxygen conditions generally occurred at the downstream location, EUC-2A, than the upstream location, EUC-2.

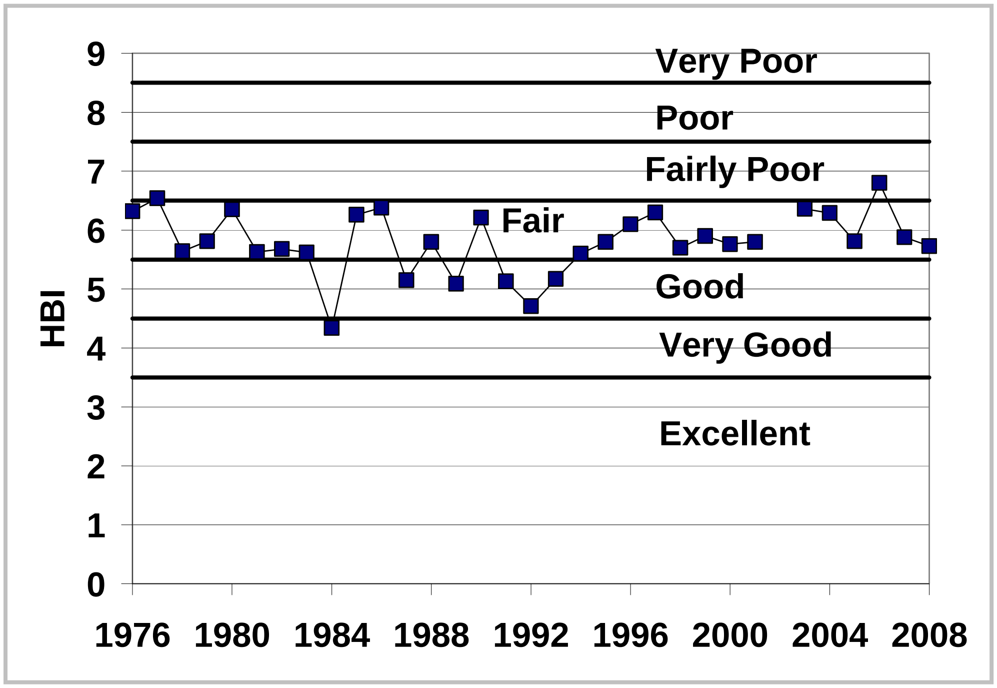


Figure 22. 1976-2008 Nine Mile Creek North Fork (EUC-2) HBI.

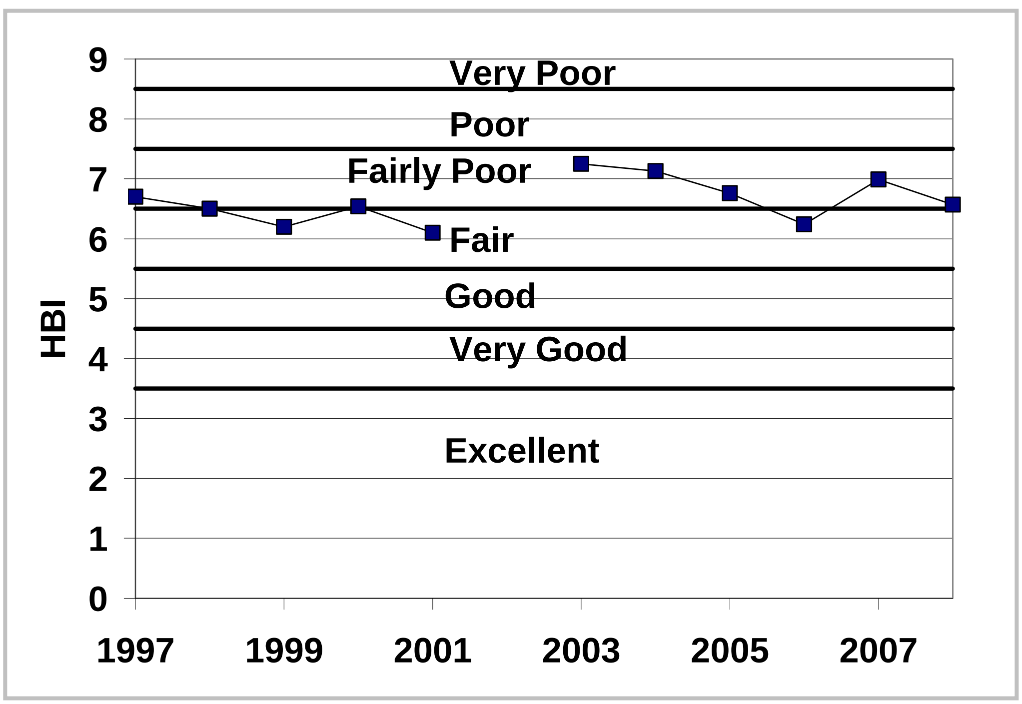


Figure 23. 1997-2008 Nine Mile Creek North Fork (EUC-2A) HBI

A conceptual model of candidate cause 1, dissolved oxygen reduction due to anaerobic sediment in natural wetlands, reduced precipitation and respiration, is shown in Figure 24. The model shows that stagnant flow conditions result in anaerobic sediment developing within the natural wetlands that are tributary to this branch of the creek. Reduced precipitation causes hydrological alteration of flow to Nine Mile Creek. The reduced discharge to Nine Mile Creek reduces aeration causing reduced oxygen in discharge waters. Increased air and stream temperatures reduce oxygen solubility of water. Conversion to higher intensity land use and imperviousness causes a decrease in summer and winter baseflows and a resultant reduction in aeration during low flows. No photosynthesis at night in combination with respiration by the biological community within the stream reduces oxygen in the stream. Reduced dissolved oxygen increases respiratory stress and causes changes in behavior, increased species out migration, and increased mortality. The end result is a decrease in fish and invertebrate taxa richness and the number of sensitive species, which were not found in the North Branch of Nine Mile Creek.

4.2.2 Candidate Cause 2: Ionic Strength

Ionic strength was considered a candidate stressor because relatively high (>1,000 µmhos/cm@ 25°C) specific conductance values have been consistently measured in the stream (Figure 25). The NMCWD continuously measured specific conductance at the Metro Boulevard WOMP Station during late 2003 through early 2007 when measurements generally exceeded the MPCA standard of 1,000 µmhos/cm @ 25°C (Minnesota Rule Chapter 7050.0224 Subpart 2). In addition, annual average specific conductance measurements were consistently greater than the MPCA standard (Figure 25). The higher specific conductance measurements indicate ionic strength is a potential stressor to the fish community.

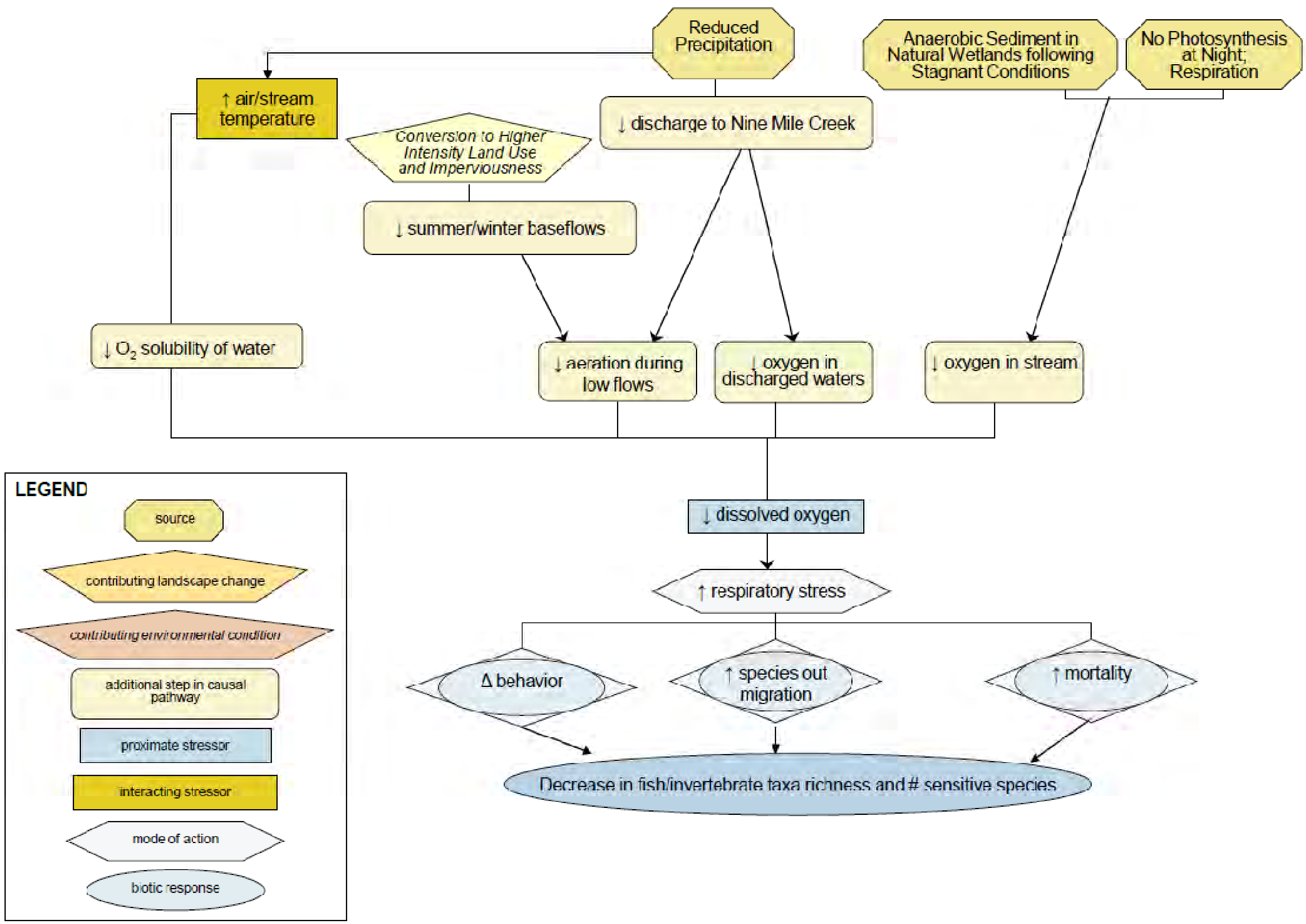


Figure 24. North Branch Nine Mile Creek: Conceptual Model of Dissolved Oxygen Reduction Due to Anaerobic Sediment in Natural Wetlands, Reduced Precipitation and Respiration

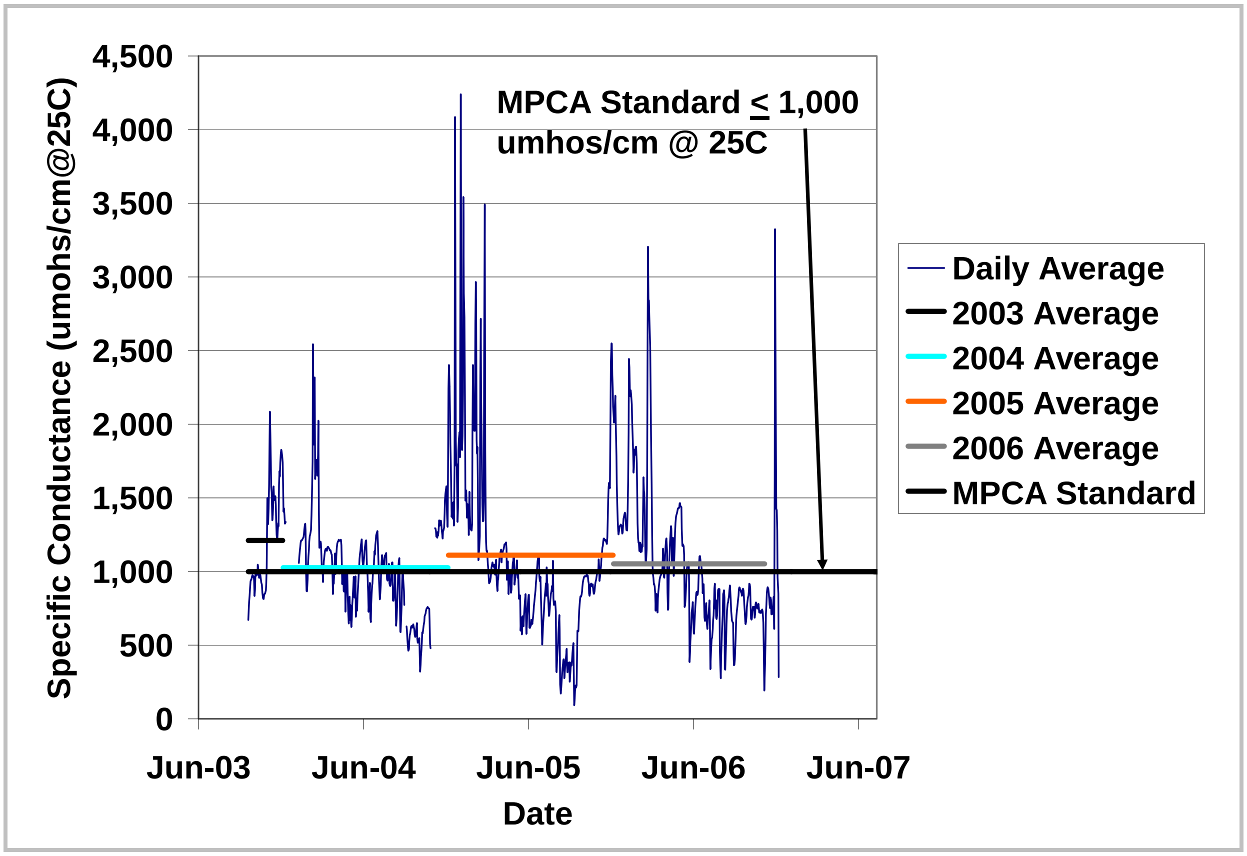


Figure 25. 2003-2008 Nine Mile Creek Specific Conductance: Metro Boulevard

Stormwater drainage adds chlorides from road salts and deicing to the North Branch of Nine Mile Creek. Chlorides increase ionic strength and may stress the biological community.

A comparison of specific conductance measurements at the North Branch Metro Boulevard Station and Main Stem 106th Street Station provides further evidence that ionic strength is a stressor to the fish community. Higher specific conductance measurements were consistently observed at the Metro Boulevard station than the 106th

Street Station (Figure 26). Fish IBI scores from EUC-7C (i.e., 106th Street, Figure 3) have consistently met the MPCA standard and, hence, biological impairment has not been observed at this location (Table 3). Fish IBI scores from the North Branch locations (EUC-2 and EUC-2A) failed to meet the MPCA standard about half of the time during 2003 through 2008 (Table 3). Higher specific conductance values together with lower IBI scores on the North Branch indicate ionic strength is a potential stressor to the fish community.

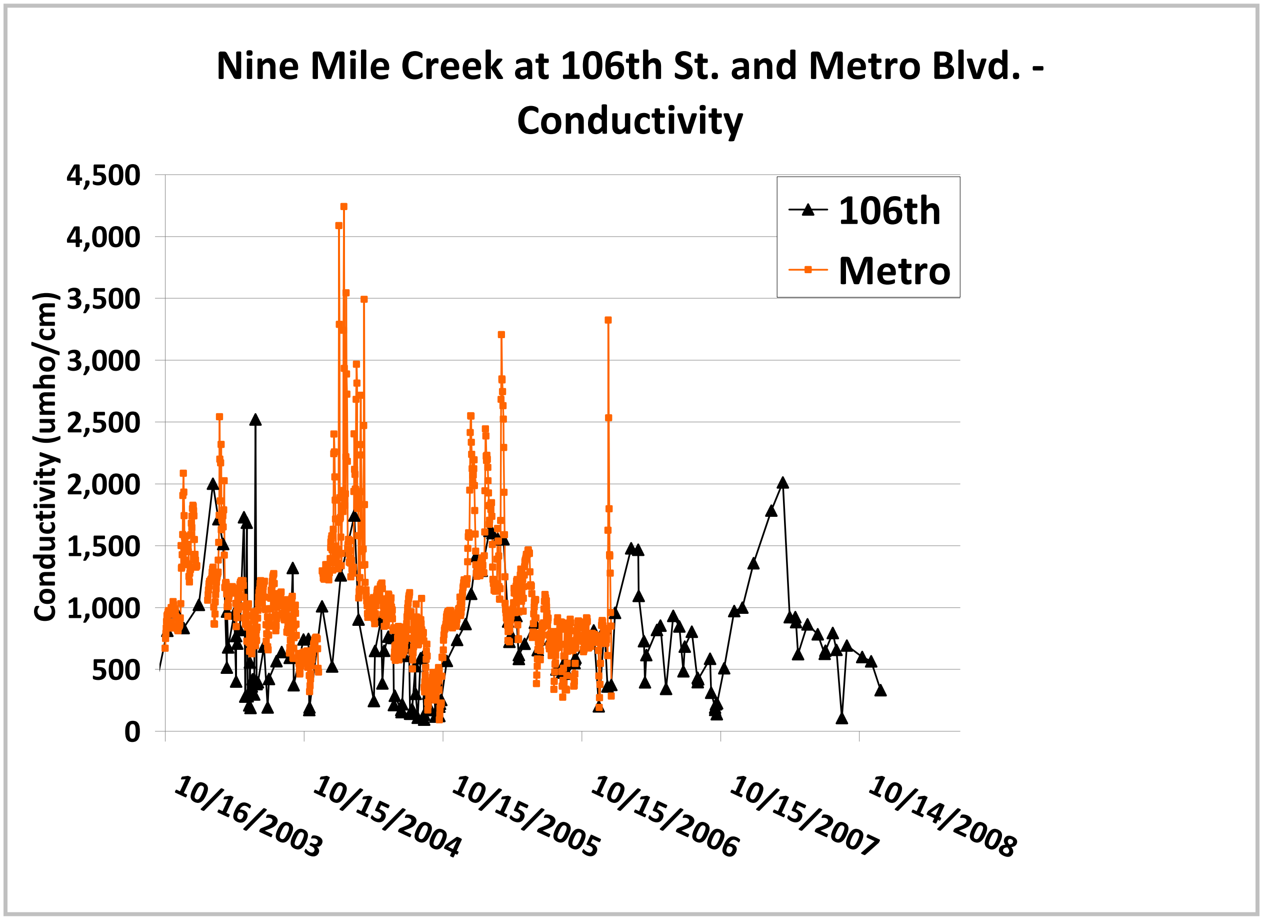


Figure 26. Nine Mile Creek Specific Conductance: Compare North Branch at Metro Boulevard With Main Stem at 106th Street

High chloride concentrations observed on the North Branch indicate chloride is the ion causing stress to the biological community. The NMCWD collected chloride samples from the Metro Boulevard WOMP Station during 2004 through 2008. Concentrations exceeded the MPCA standard of 230 mg/L (Minnesota Rule Chapter 7050.0222 Subpart 2) on five occasions during a 2-year period and on 8 occasions during the monitoring period Figure (27).

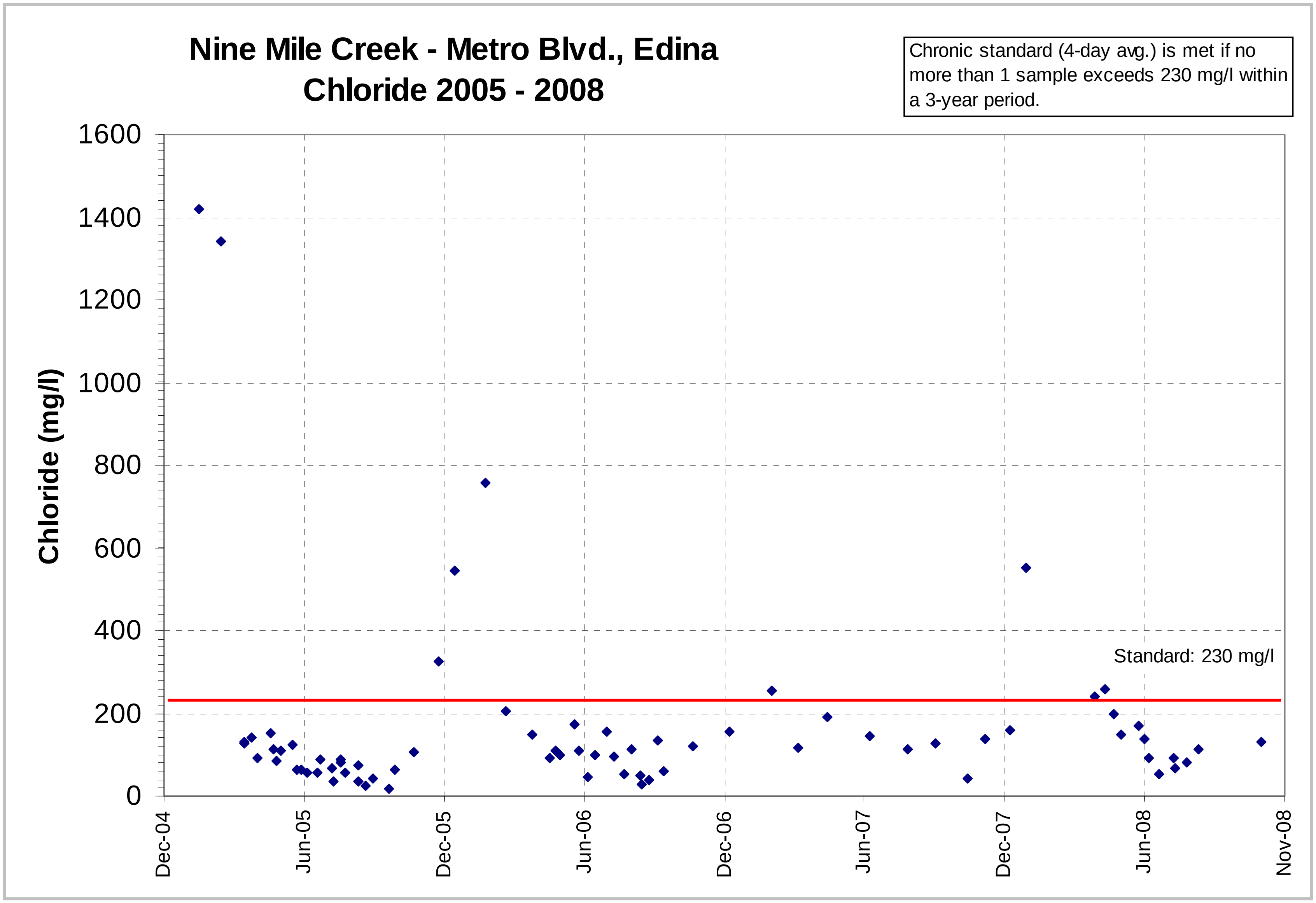


Figure 27. Nine Mile Creek – Metro Blvd., Edina Chloride 2005-2008

High chloride concentrations estimated from specific conductance measured during 2007 provide further evidence that ionic strength consistently causes stress to the biological community. A relationship between chloride and specific conductance data was determined from data collected at the Metro Boulevard WOMP station (R^2=0.91) and this relationship was used to estimate chloride concentrations from continuous specific conductance measurements from the Metro Boulevard WOMP Station during December of 2006 through 2007 (Figure 28). The estimated continuous chloride concentrations exceeded the MPCA chronic standard at least monthly during December of 2006 through February of 2007. Observed concentrations during February were approximately five times higher than the MPCA chronic standard.

A conceptual model of candidate cause 2, ionic strength due to chlorides, is shown in Figure 19 and discussed in Section 4.1.4.

Ionic strength due to chlorides is a candidate cause of biological impairment of the North Branch of Nine Mile Creek pictured to the left and right.

Station EUC-2

Station EUC-2A

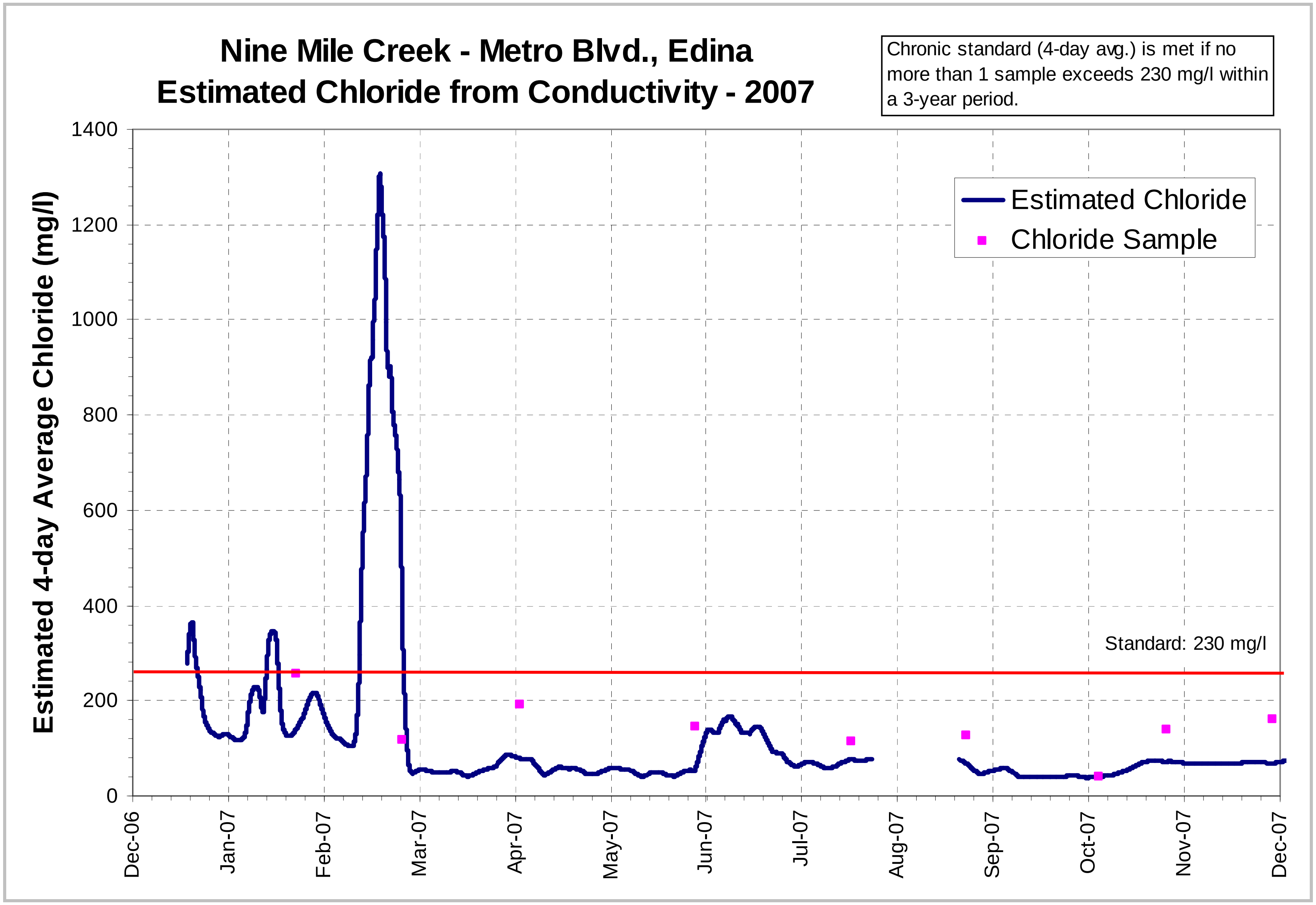


Figure 28. Nine Mile Creek – Metro Blvd., Edina Estimated Chloride from Conductivity - 2007

4.2.3 Candidate Cause 3: Sediment

Sediment was considered as a candidate stressor because deeper depths of fine sediment have been associated with IBI scores below the impairment threshold of 30 or greater on the North Branch of Nine Mile Creek. The NMCWD collected habitat data at EUC-2 and EUC-2A during 2003 through 2006. Thirteen transects and five sample locations along each transect were sampled at each location. All habitat sample locations contained fine sediment during all sample years.

Changes in fine sediment depth at EUC-2 corresponded with changes in IBI scores during 2003 through 2006. The maximum depth of sediment occurred in 2003 and decreased annually through 2006 (Figure 29). IBI scores increased annually during 2003 through 2006 (Figure 29). IBI scores failed to meet the MPCA standard during 2003 and 2004, but met the standard during 2005 and 2006 (Figure 29). The data indicate fine sediment was a candidate cause of the stream's impairment during 2003 through 2004, but did not cause impairment during 2005 through 2006.

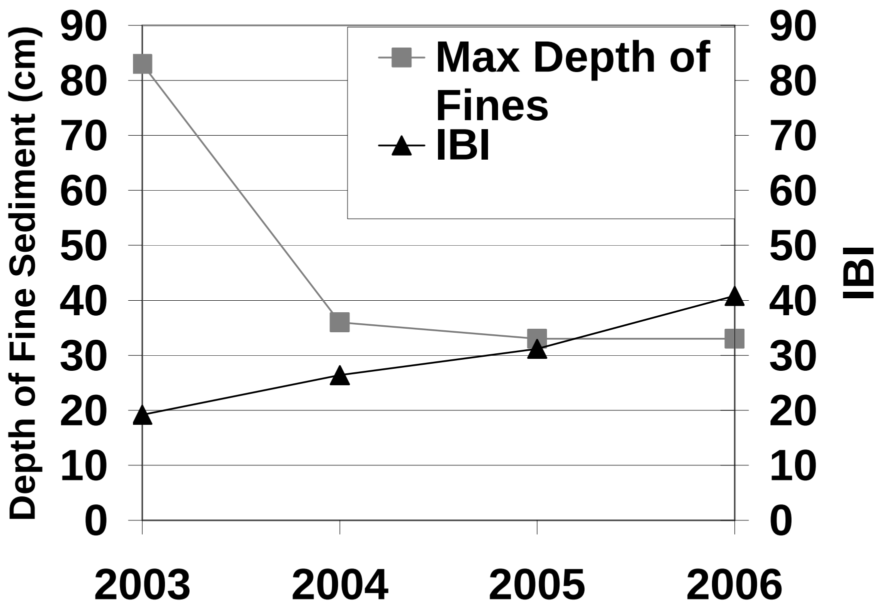


Figure 29. Nine Mile Creek North Branch (EUC-2) Fine Sediment Depth and IBI

Lithophils are fish, such as white sucker, that require clean gravel or boulders for reproduction and are adversely impacted by sediment deposits. A comparison of changes in percent lithophils and changes in sediment at EUC-2 indicates lithophils were adversely impacted by sediment deposited on the stream's substrate. The percent simple lithophils increased concurrently with a decrease in sediment during 2003 through 2004 (Figure 30). Conversely, the percent lithophils decreased with an increase in percent embeddedness during 2004 through 2005. During 2005 through 2006, an increase in percent lithophils was associated with a decrease in percent embeddedness. The data indicate sediment is a stressor to the biological community of EUC-2.

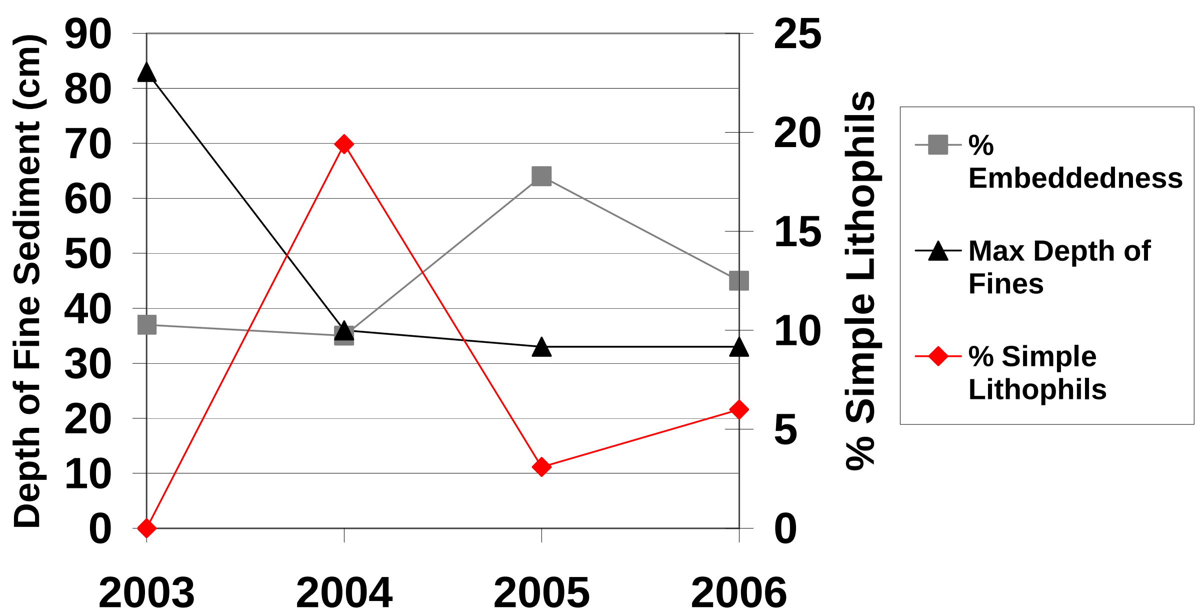


Figure 30. Nine Mile Creek North Branch (EUC-2) Fine Sediment Depth, Percent Embeddedness, and Percent Simple Lithophils

Changes in fine sediment also corresponded with changes in IBI scores at EUC-2A during 2003 through 2006. The maximum depth of fine sediment at EUC-2A occurred in 2004 (Figure 31). IBI scores decreased from 2003 through 2004 as fine sediment maximum depth increased and increased during 2004 through 2006 when fine sediment depths decreased (Figure 31). IBI scores failed to meet MPCA criteria during 2004 and 2005, but met MPCA criteria during 2003 and 2006 (Figure 31.)

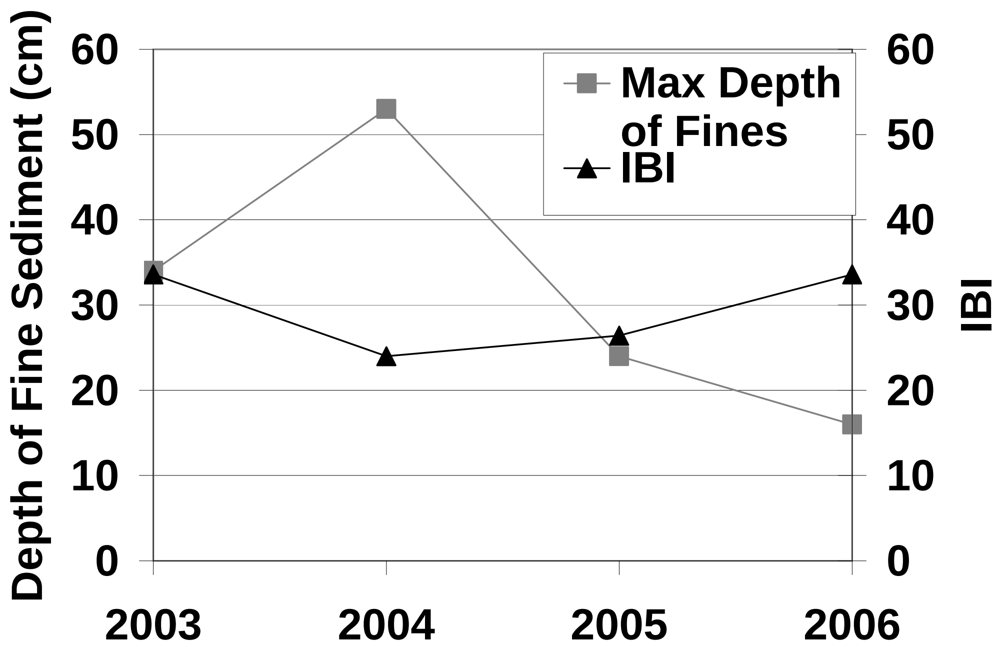


Figure 31. Nine Mile Creek North Branch (EUC-2A) Fine Sediment Depth and IBI

A comparison of changes in percent lithophils and changes in percent embeddedness by sediment deposited on the substrate at EUC-2A indicates lithophils were adversely impacted by sediment. The percent simple lithophils increased concurrently with a decrease in sediment during 2003 through 2004 (Figure 32). Conversely, the percent lithophils decreased with an increase in percent embeddedness during 2004 through 2005. The data indicate sediment is a stressor to the biological community of EUC-2A.

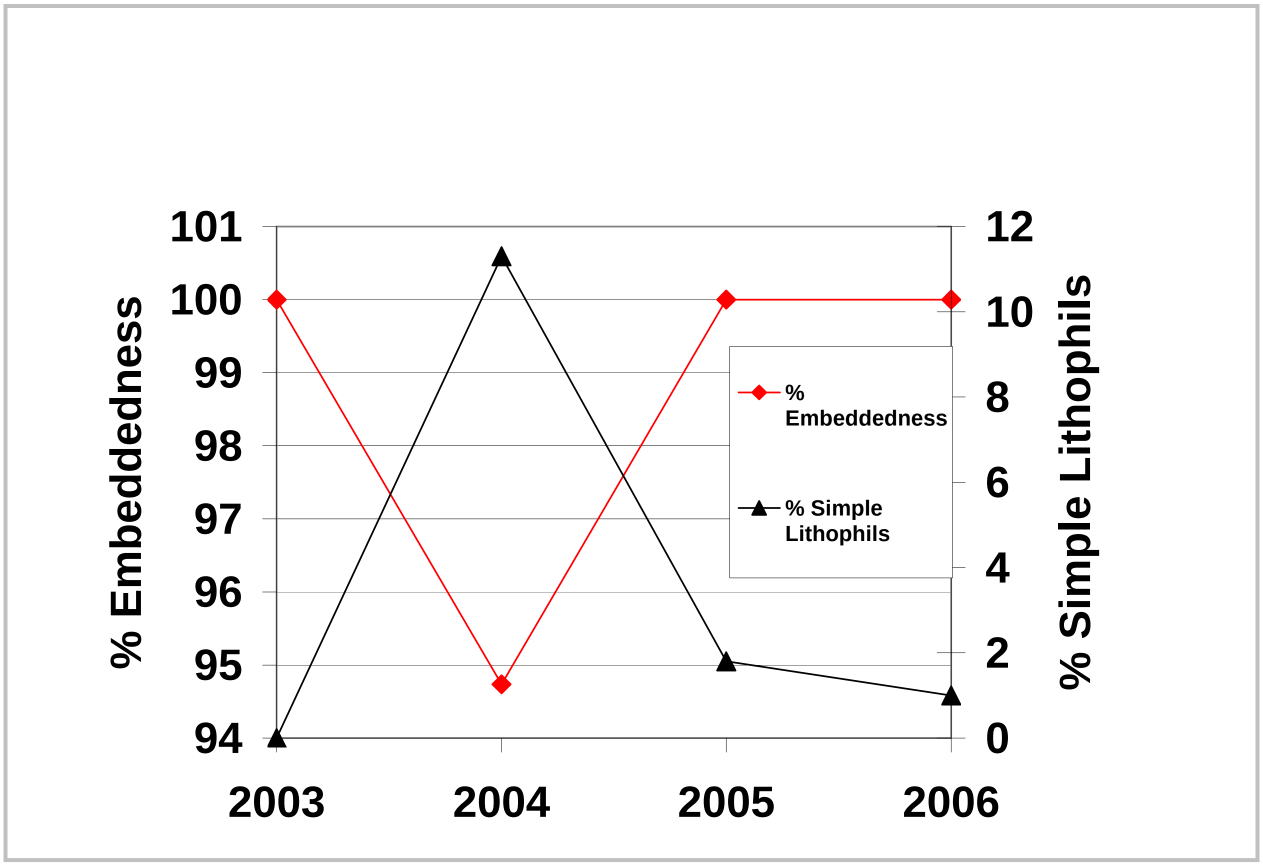


Figure 32. Nine Mile Creek North Branch (EUC-2A): % Embeddedness and % Simple Lithophils

A Rosgen stream assessment was conducted on the North Branch of Nine Mile Creek between West 70th Street and CSAH 62, west of T.H. 100 during 1997 and again in 2003. The stream was a Type E with a relatively narrow and deep channel during both surveys. As is typical of this stream type, the floodplain is quite wide and marshy, with vegetation consisting primarily of grasses, willow, and dogwood. During 1997, this reach was in fairly good condition, with good vegetative cover on the banks and therefore little bank erosion. The exception to this occurred where the channel abuts the residential properties, where manicured lawns exist up to the streambank. Bank erosion was a problem in this area, with vertical cut banks slumping into the creek.

Results of the 2003 survey indicate this reach had degraded since the 1997 survey. As noted in 1997, there was little bank erosion evident where the banks were well vegetated with reed canary grass. However, bank erosion was evident where the channel abuts residential properties with turf lawn adjacent to the stream. Also, there was a large amount of debris clogging the channel at the downstream end of this reach.

Because fluctuations in fine sediment depth during 2003 through 2006 were correlated with changes in the stream's fish community, sediment is considered a possible candidate stressor. A conceptual model of candidate cause 3, sediment is shown in Figure 16 and discussed in Section 4.1.3.

4.3 Main Stem

Four possible stressors were identified for the Main Stem:

- Inadequate Baseflow
- Dissolved Oxygen
- Sediment
- Ionic Strength

4.3.1 Candidate Cause 1: Inadequate Baseflow

The Main Stem of Nine Mile Creek at EUC-7A, pictured above, has experienced flows less than 0.1 cfs and sometimes dries up during periods of reduced precipitation.

Inadequate baseflow is considered a possible stressor because the Main Stem of Nine Mile Creek at 98th Street observed flows of 0.1 cfs or less during 2006 through 2008. The Main Stem of Nine Mile Creek flows into and out of Marsh Lake, located immediately upstream from 98th Street. Stream flow in reaches of the Main Stem of Nine Mile Creek downstream from Marsh Lake is dependent upon outflow from Marsh Lake. During periods of reduced precipitation when no outflow occurs, baseflow is inadequate to support the stream's biological community.

Continuous flow data were collected by Nine Mile Creek Watershed District from the 98th Street WOMP station during 2003 through 2008 (Figure 4). The data indicate baseflow was 0.1 cfs or less for periods of time during 2006 through 2008. Periods of low flow generally have occurred during July and August (Figures 33 through 35). During 2007, fish samples were collected following a period when the stream was dry and IBI scores were below the impairment threshold (Figure 34). During 2006 and 2008, IBI scores were above the impairment threshold where fish sampling occurred prior to the periods of low flow (i.e., flows less than 0.1 cfs) that stressed the biological community (Figures 33 and 35). Data collected during 2006 through 2008 support the hypothesis that inadequate baseflow is a stressor to the biological community.

Flow data for the summer period of 2003 and 2005 are not available and data collected during 2004 indicate another stressor caused impairment of the biological community. IBI scores were below the impairment threshold during 2004 despite no observed periods of low flow (i.e., flows less than 0.1 cfs).

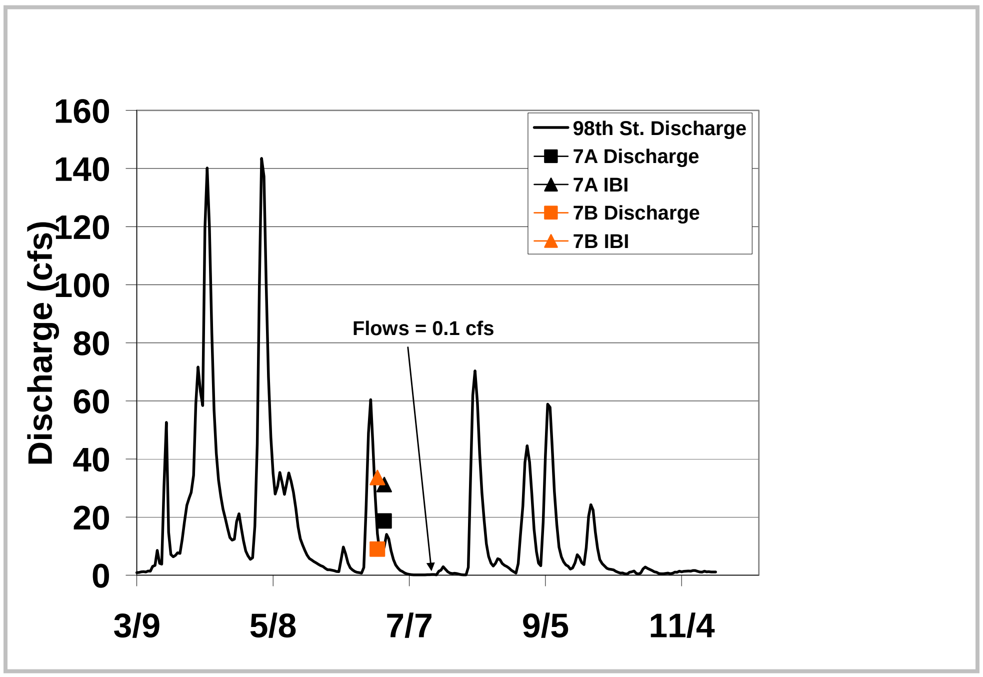


Figure 33. 2006 Nine Mile Creek Main Stem Discharge and IBI at EUC 7A and 7B

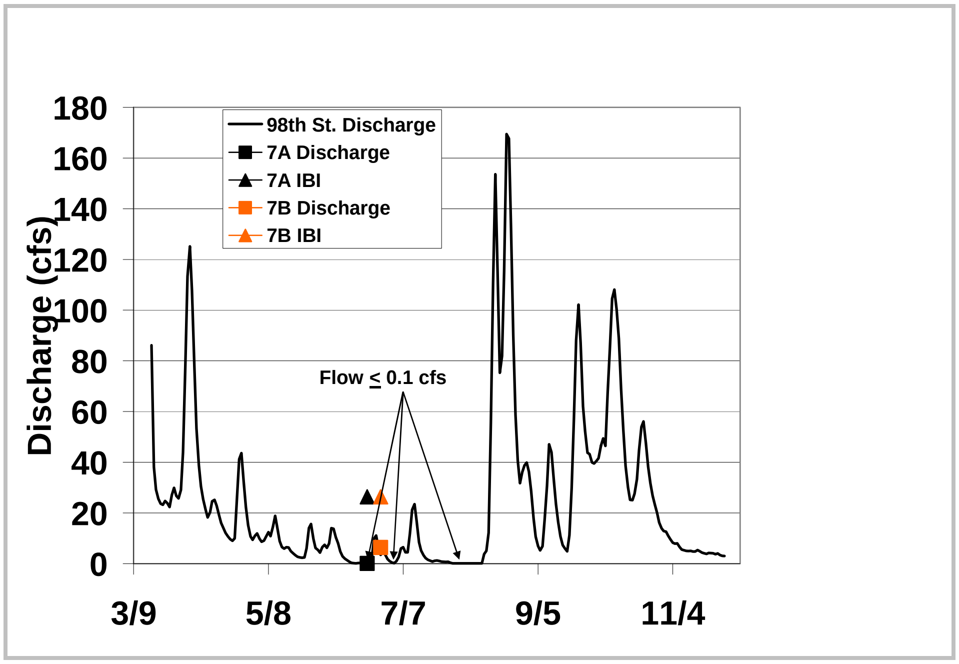


Figure 34. 2007 Nine Mile Creek Main Stem Discharge and IBI at EUC 7A and 7B

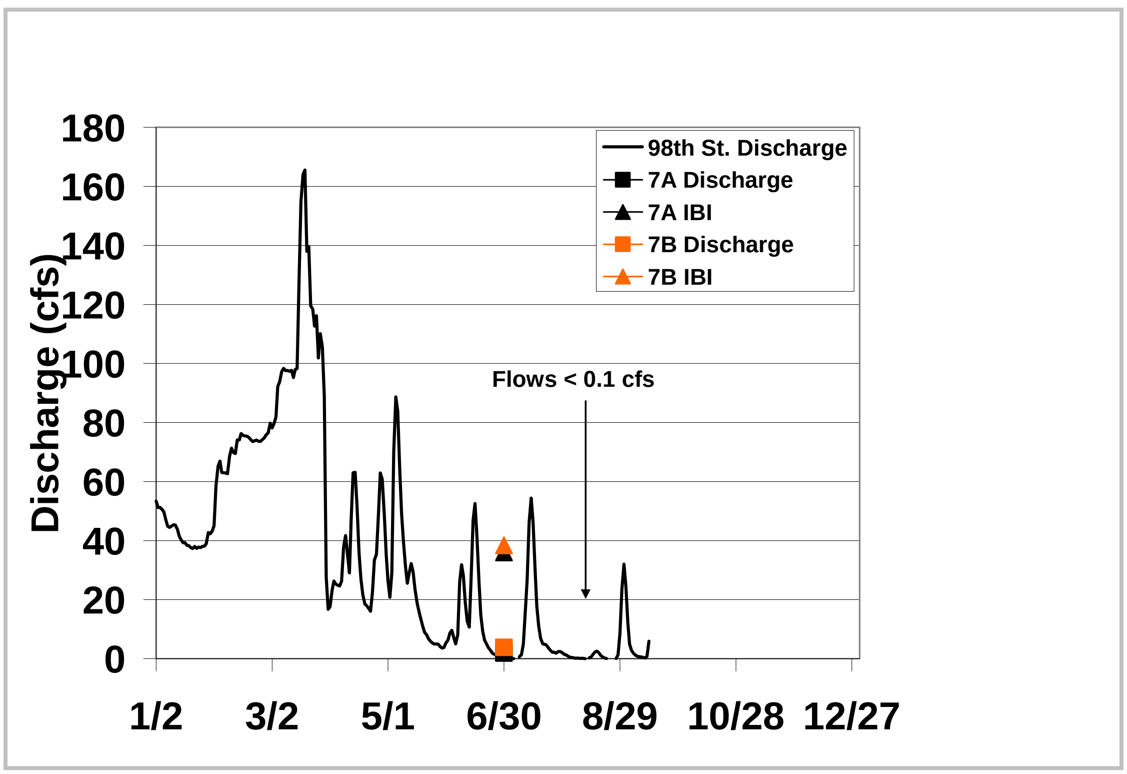


Figure 35. 2008 Nine Mile Creek Main Stem Discharge and IBI at EUC 7A and 7B

A conceptual model of candidate cause 1, inadequate baseflow, is shown in Figure 36. The model shows that reduced precipitation causes a change in Marsh Lake surface elevation and reduces discharge from Marsh Lake. Land use changes that result in a conversion to higher intensity land use and imperviousness reduce infiltration. The resultant decrease in summer and winter baseflows, as well as reduced discharge from Marsh Lake, changes the physical and chemical properties of the water and the structural habitat of the stream. The 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 IBI impairment threshold of 30 or greater.

Reduced precipitation causes a change in Marsh Lake surface elevation and reduces discharge from Marsh Lake, pictured above.

4.3.2 Candidate Cause 2: Dissolved Oxygen

Dissolved oxygen is considered a possible stressor because diel oxygen changes in the stream have resulted in oxygen concentrations below 5 mg/L, the threshold for full support of aquatic life (Minnesota Rule Chapter 7050.0222, subpart 4). The NMCWD continuously measured dissolved oxygen at the 98th Street WOMP Station (Figure 4) during July through December of 2008 and during July 3 through August 7 of 2009. The data during July through August of 2008 indicate diel oxygen fluctuations could stress the biological community on a daily basis. The data indicate dissolved oxygen concentrations were consistently greater than 5 mg/L during the daylight hours and were consistently less than 5 mg/L during the night (Figure 37). During July and August, minimum daily oxygen concentrations ranged from 2.1 to 5.0 mg/L and maximum daily oxygen concentrations ranged from 8.0 to 8.6 mg/L (Figure 37). Average daily dissolved oxygen concentrations during July and August ranged from 4.8 to 6.3 mg/L (Figure 37). The data indicate low dissolved oxygen concentrations are likely a cause of the stream’s biological impairment.

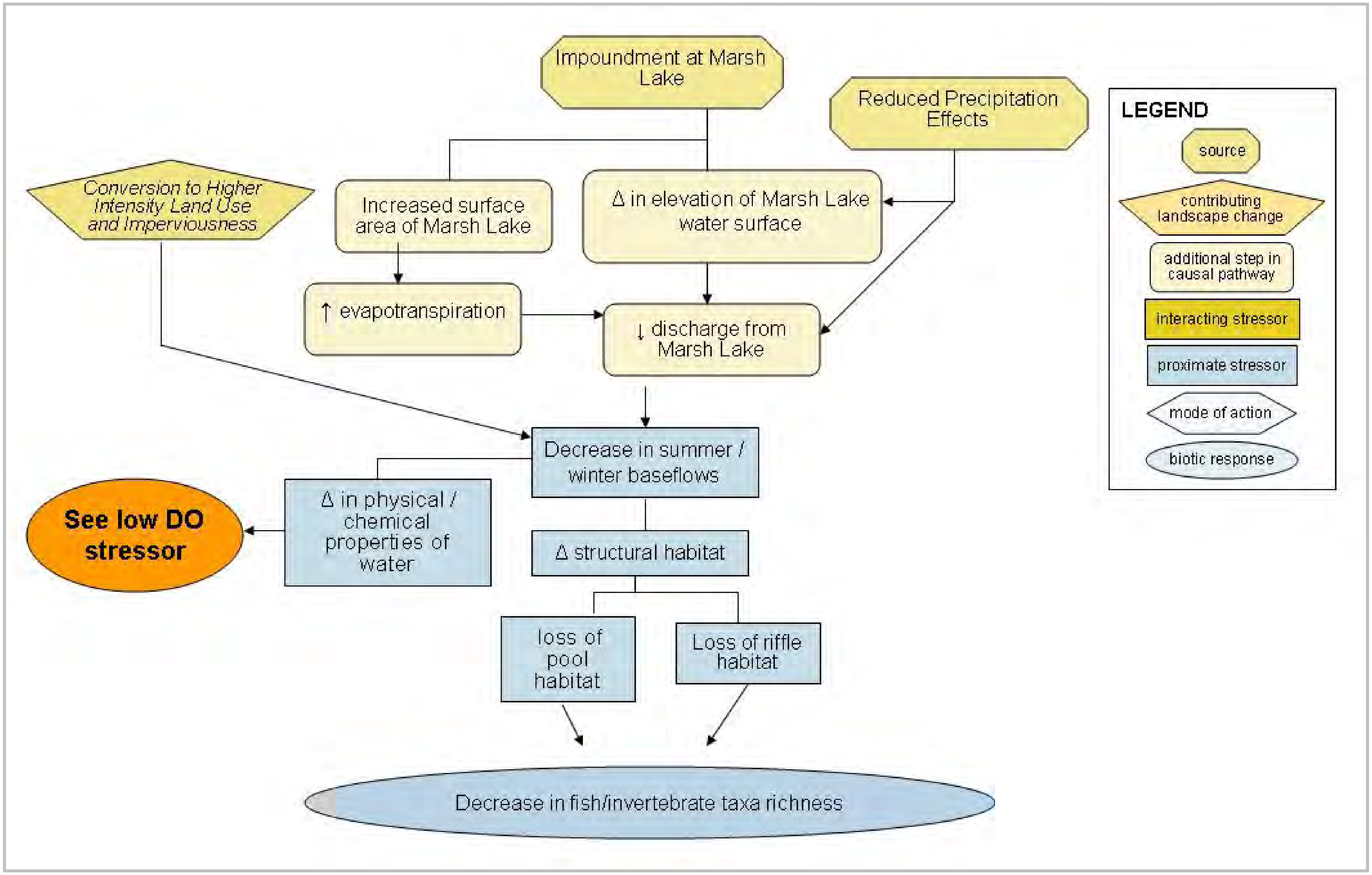


Figure 36. Nine Mile Creek Main Stem (EUC-7A and EUC-7B): Conceptual Model of Flow Alteration Due to Reduced Precipitation

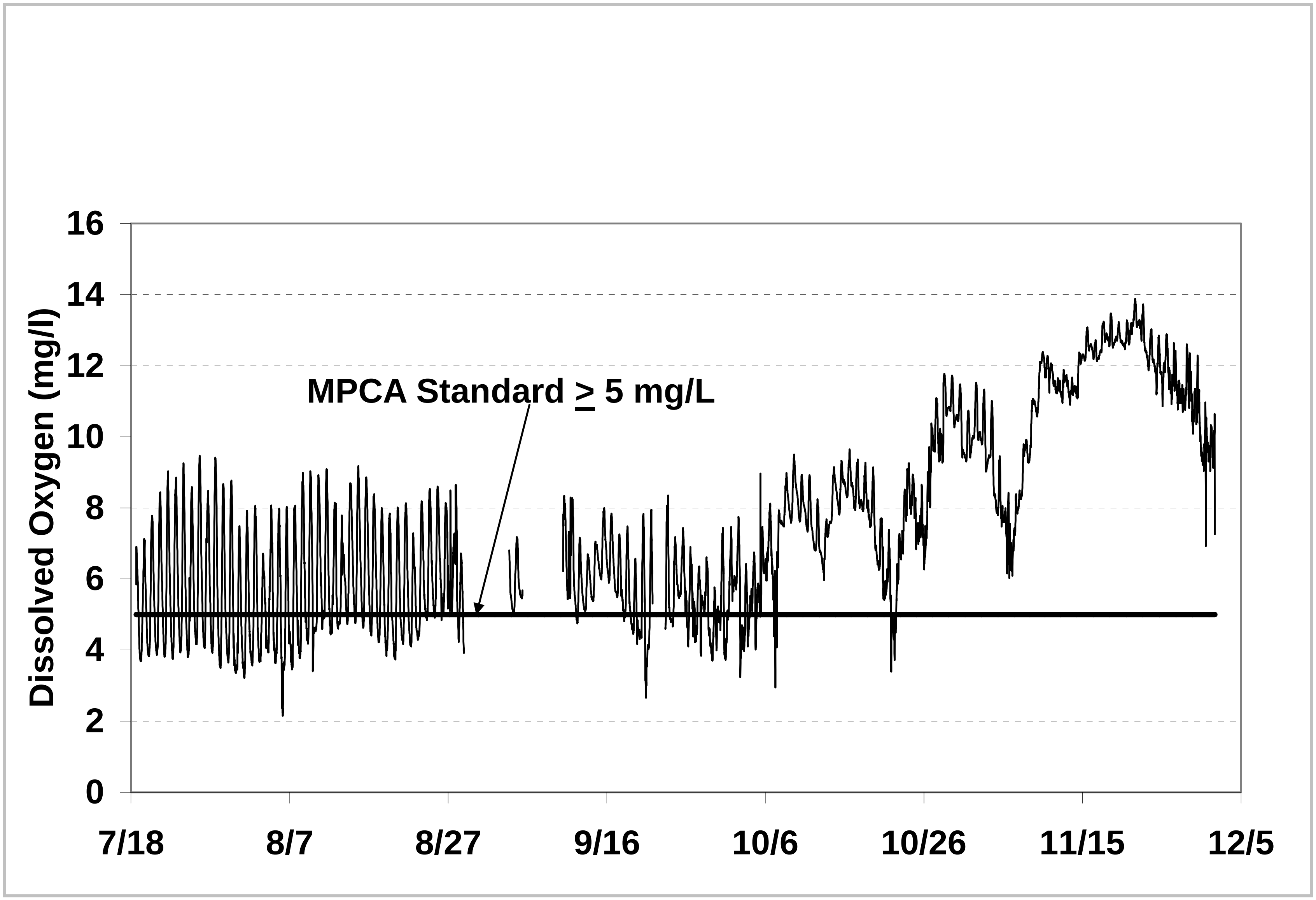


Figure 37. July-November 2008 Nine Mile Creek Dissolved Oxygen: Main Stem at 98th Street

Fall oxygen concentrations provide further evidence of the stream's impairment. Dissolved oxygen concentrations were higher during September through December than July through August of 2008, but low dissolved oxygen concentrations were occasionally present during September through October. Minimum daily oxygen concentrations during September through October ranged from 2.7 to 10.3 mg/L, maximum daily oxygen concentrations ranged from 7.8 to 11.7 mg/L, and average daily oxygen concentrations ranged from 5.2 to 10.9 mg/L (Figure 37). Minimum daily dissolved oxygen concentrations were less than 5 mg/L during 21 days or 34 percent of the period (Figure 37). The data provide further evidence that dissolved oxygen is a cause of the stream's impairment.

The 2009 summer dissolved oxygen data indicated diel oxygen fluctuations could stress the stream's biological community and provided additional evidence that dissolved oxygen is a likely cause of the stream's impairment. The NMCWD continuously measured dissolved oxygen at the 98th Street WOMP Station (Figure 4) during July 3 through August 7 of 2009. Dissolved oxygen concentrations were continuously below 5 mg/L during July 13 through July 17. During July 3 through 12 and July 14 through August 7, dissolved oxygen concentrations were consistently greater than 5 mg/L during the daylight hours and were consistently less than 5 mg/L during the night (Figure 38). During the 2009 period of measurement, minimum daily oxygen concentrations ranged from 0.40 to 6.7 mg/L, maximum daily dissolved oxygen concentrations ranged from 0.84 to 10.6 mg/L, and mean daily dissolved oxygen concentrations ranged from 0.58 to 8.7 mg/L (Figure 38). The average daily

The NMCWD continuously measured dissolved oxygen at the 98th Street WOMP Station, pictured above. Plant respiration in Nine Mile Creek, pictured above and below, caused low oxygen concentrations at night.

dissolved oxygen concentration for the period was 4.8 mg/L which is below the 5.0 mg/L daily average specified in the MPCA standard for Class 2B waters (Minnesota Rule Chapter 7050.0222, subpart 4).

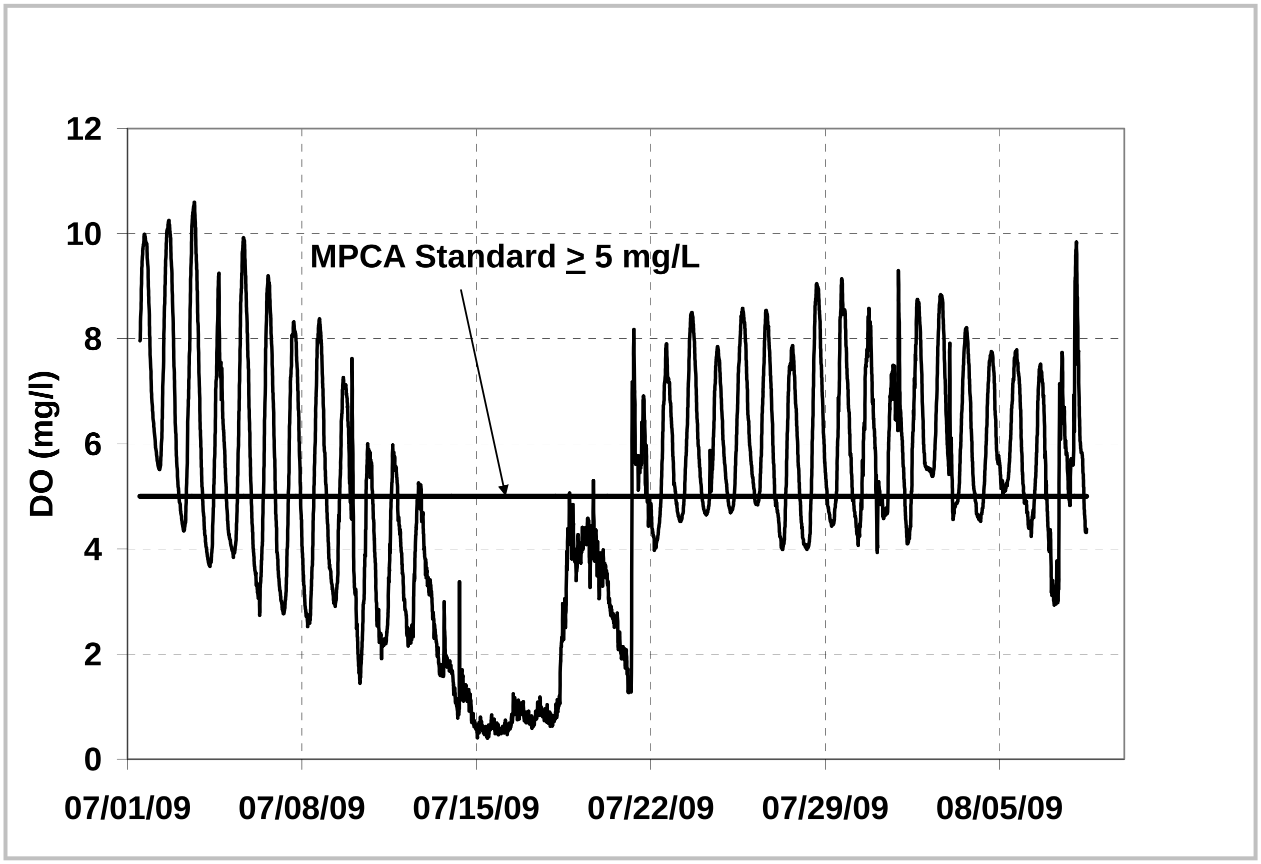
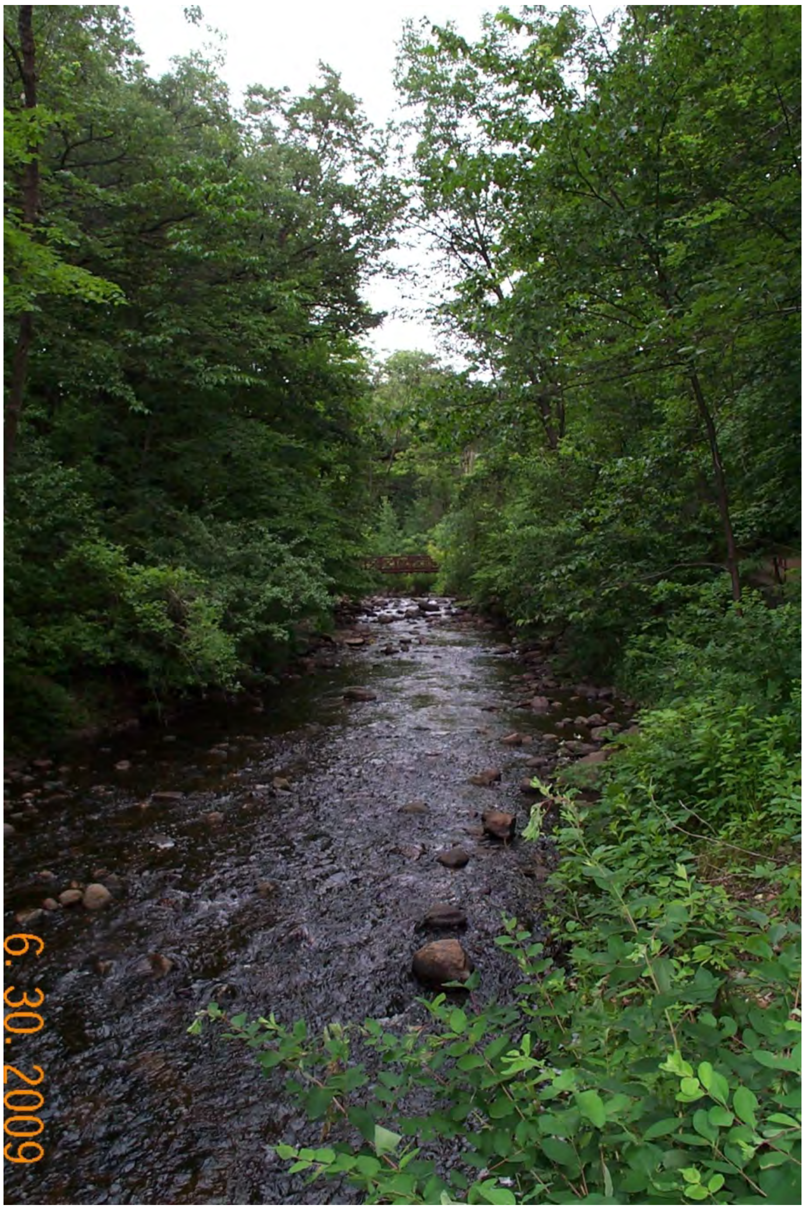


Figure 38. July 2009 Nine Mile Creek Dissolved Oxygen: Main Stem at 98th Street

Results from a July 23, 2009 synoptic longitudinal dissolved oxygen survey completed on the Main Stem of Nine Mile Creek provided additional evidence that dissolved oxygen is causing the stream's impairment. A total of 8 locations (Figure 39) were surveyed between 5:08 and 6:35 AM. Four locations (84th St. West, 90th St. West, France Ave., and 98th St. West shown on Figure 39 observed dissolved oxygen concentrations less than 5 mg/L. The data indicate portions of the Main Stem of Nine Mile Creek showed evidence of oxygen conditions that would stress aquatic life. Specifically, the inflow to

A dissolved oxygen concentration greater than 5 mg/L was observed at the Main Stem of Nine Mile Creek immediately downstream from Normandale lake, pictured above.

Normandale Lake, immediately downstream from the confluence of the North and South Branches of Nine Mile Creek, and stream reaches from 90th Street to 98th Street observed dissolved oxygen concentrations less than 5 mg/L (Figure 39). Main Stem reaches with dissolved oxygen concentrations greater than 5 mg/L included a location immediately downstream from the outflow of Normandale Lake and stream reaches from 102nd Street through 106th Street (Figure 39). The data provide further evidence that dissolved oxygen likely is a cause of the stream's biological impairment.



During a longitudinal synoptic survey on July 23, 2009, Nine Mile Creek stream reaches from 102nd Street through 106th Street, pictured above, dissolved oxygen observations were greater than 5 mg/L.

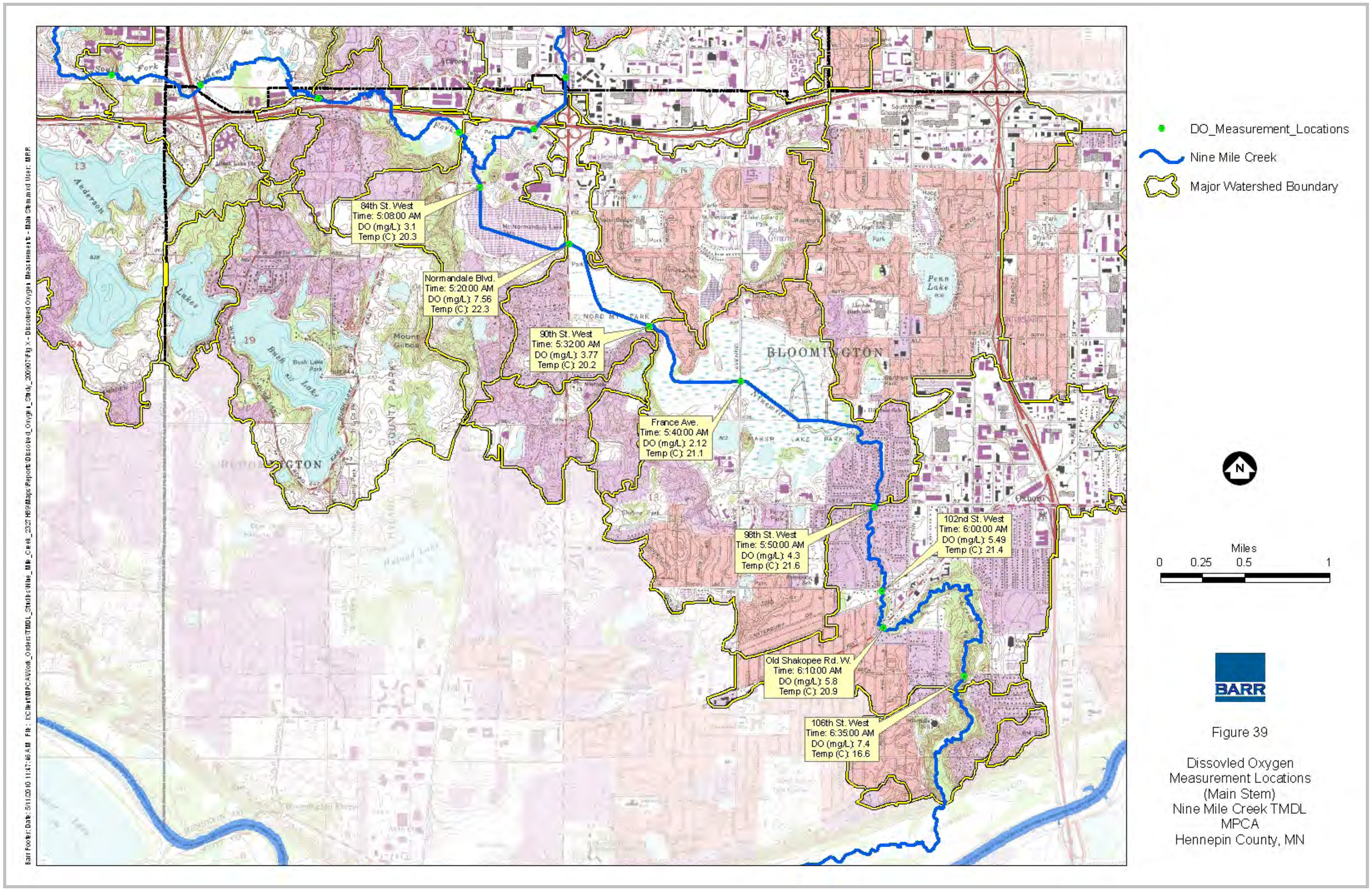


Figure 39. Dissolved Oxygen Measurements Locations (Main Stem)

HBI data from the Main Stem provide additional evidence that dissolved oxygen is a stressor causing biological impairment. Macroinvertebrate data collected from EUC-7A, located at 98th Street on the Main Stem of Nine Mile Creek (location shown on Figure 3) during 1976 through 2008 were analyzed using Hilsenhoff's Biotic Index (HBI) to assess stream oxygen levels. HBI levels measured at EUC-7A were in the fairly poor category during half of the years and in the fair category 31 percent of the years (Figure 40). HBI levels at EUC-7A were occasionally poor (6 percent), borderline poor/fairly poor (3 percent), borderline fair/good (3 percent), or good (6 percent) (Figure 40).

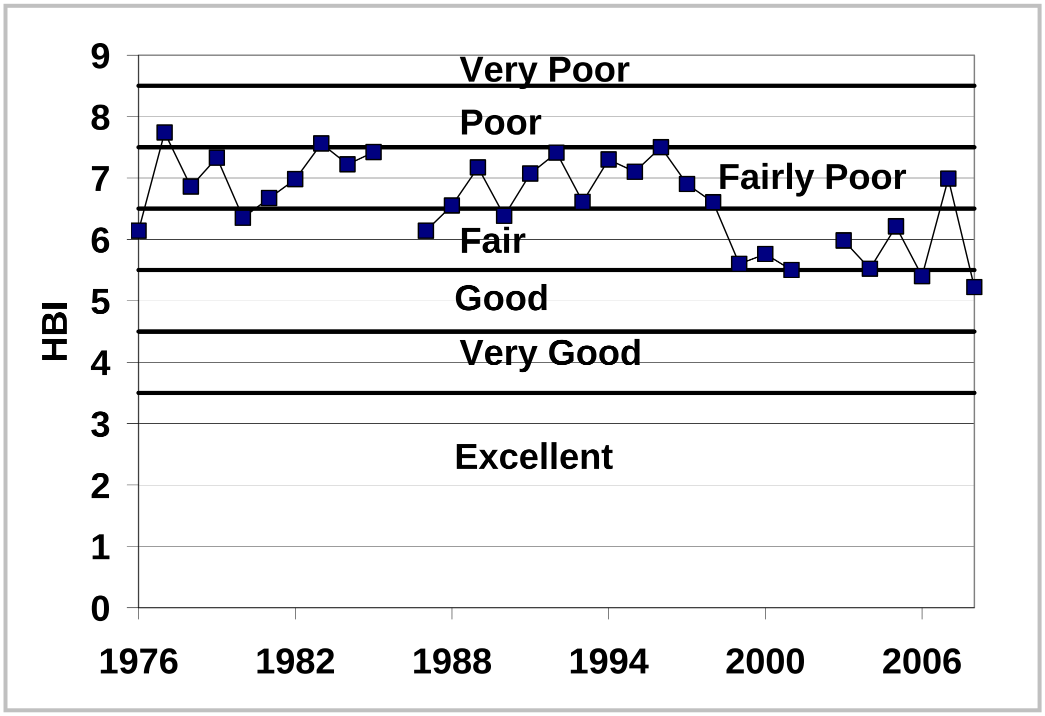


Figure 40. 1976-2008 Nine Mile Creek Main Stem (EUC-7A) HBI

Dissolved oxygen as a cause of impairment is evident from a comparison of IBI and HBI scores from EUC-7A during 2003 through 2008. The comparison shows the relationship between stream oxygen conditions (HBI) and fish impairment (IBI). The IBI scores exceeded the impairment threshold of 30 or greater when HBI scores were within the good category during 2006 and 2008 (Figure 40 and Table 3). Conversely, the IBI scores were below the impairment threshold of 30 or greater when HBI scores were within the fair or fairly poor categories during 2003 through 2005 and 2007 (Figure 40 and Table 3). When the invertebrate data indicated good oxygen conditions were present, the fish community was not impaired. When the invertebrate data indicated fair to fairly poor oxygen conditions were present, the fish community was impaired.

Increased oxygenation of Nine Mile Creek as it has flowed downstream from 98th Street has reduced the frequency of fish impairment and has resulted in an invertebrate community that is more sensitive to low oxygen conditions in downstream reaches. HBI values from EUC-7B, located in Moir Park downstream of Old Shakopee Road on the Main Stem of Nine Mile Creek (location shown on Figure 3) during 1997 through 2008 were within the good or very good categories during the period of record (Figure 41). As noted previously, upstream EUC-7A generally noted HBI values within the fairly poor or fair categories during this period. The data are consistent with dissolved oxygen measurements that indicate dissolved oxygen has generally increased from upstream to downstream locations along Nine Mile Creek. An annual average of monthly dissolved oxygen measurements during March through October of 1997 through 2008 was 7.1 mg/L at EUC-7A, 8.4 mg/L at EUC-7B, and 9.8 mg/L at EUC-7C (Barr, 2008). The data indicate dissolved oxygen concentration increased as the stream flowed downstream from 98th Street and through the Lower Valley reach of Nine Mile Creek. Increased dissolved oxygen levels were correlated with a reduced frequency of biological impairment. EUC-7A noted impairment during two thirds of the 2003 through 2008 sample period, EUC-7B noted impairment during half of the sample period, and EUC-7C was not impaired during the sample period.

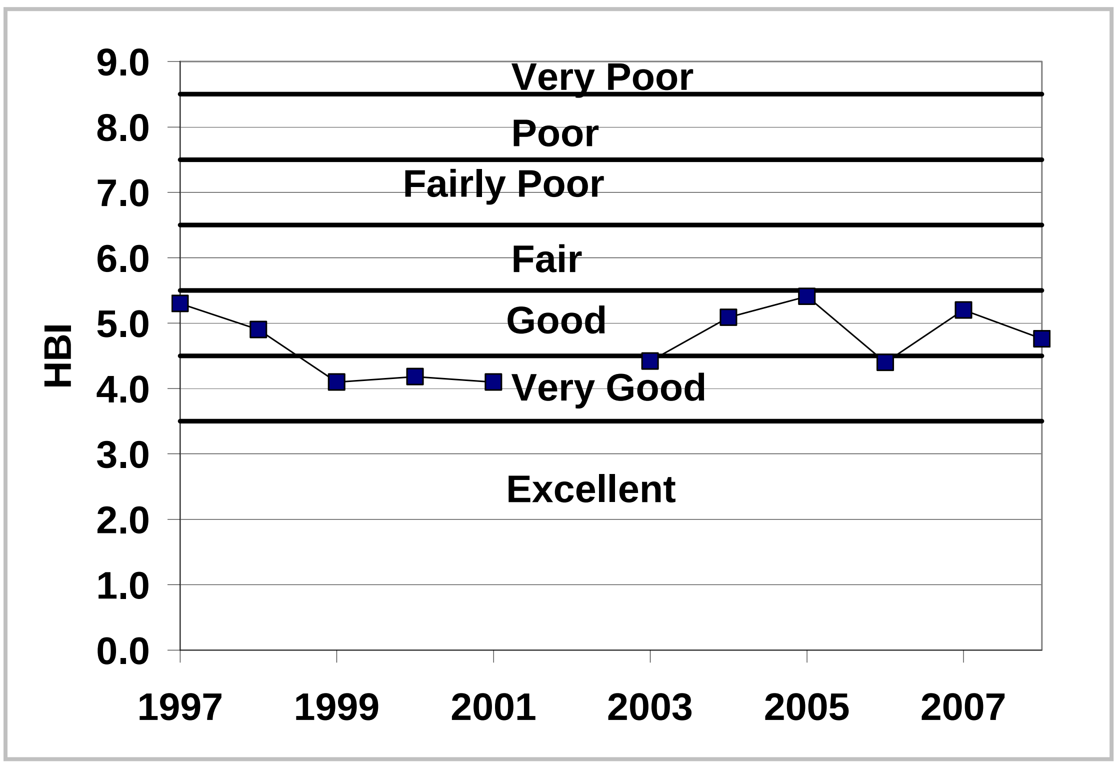


Figure 41. 1976-2008 Nine Mile Creek Main Stem (EUC-7B) HBI

A conceptual model of candidate cause 2, dissolved oxygen reduction due to anaerobic sediment in natural wetlands, precipitation and respiration, is shown in Figure 42. The model shows that stagnant flow conditions result in anaerobic sediment developing within the Marsh Lake wetland complex that is tributary to the main stem of the creek. Reduced precipitation causes hydrological alteration of upstream Marsh Lake and reduced discharge to Nine Mile Creek. The reduced discharge to Nine Mile Creek reduces aeration causing reduced oxygen in discharge waters. Increased air and stream temperatures reduce oxygen solubility of water. Land use changes result in conversion to higher intensity land use and imperviousness. The resultant reduction in infiltration causes reduced summer and winter baseflows. Reduced aeration during low flows cause reductions in dissolved oxygen. No photosynthesis at night in combination with respiration by the biological community within the stream reduces oxygen in the stream and in Marsh Lake. Reduced dissolved oxygen increases respiratory stress and causes changes in behavior, increased species out migration, and increased mortality. The end result is a decrease in fish and invertebrate taxa richness and the number of sensitive species, which were not found in the Main Stem of Nine Mile Creek. As noted previously, the Main Stem of Nine Mile Creek at 106th Street is not impaired. Hence the model is solely applicable to reaches upstream from 106th Street.

Reduced precipitation reduces discharge to Nine Mile Creek from Marsh Lake, pictured above. The reduced discharge reduces aeration which causes reduced oxygen levels in the stream.

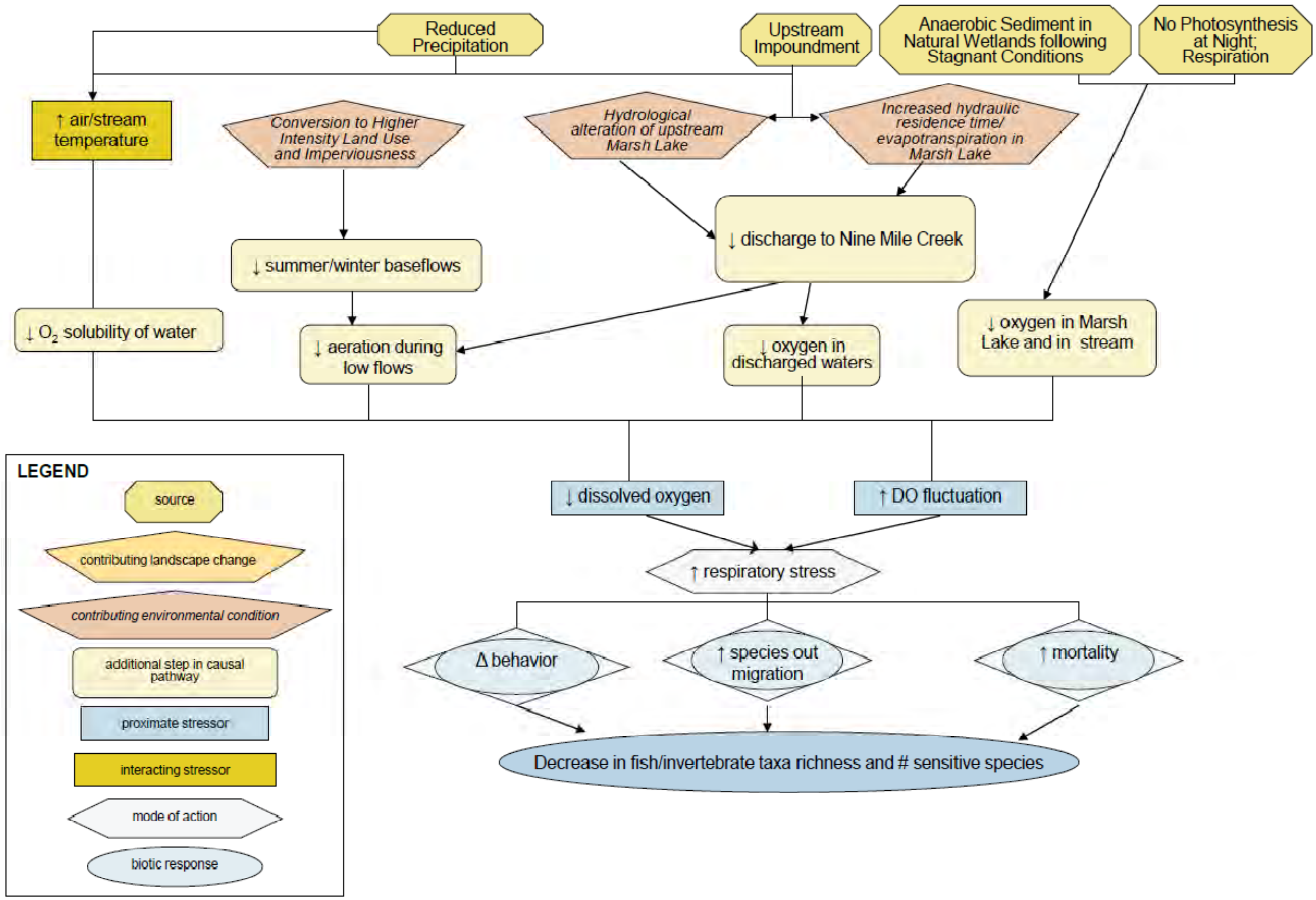


Figure 42. Conceptual Model for Candidate Cause 2: Dissolved Oxygen Reduction Due to Anaerobic Sediment in Natural Wetlands, Reduced Precipitation and Respiration –– Main Stem Nine Mile Creek

4.3.3 Candidate Cause 3: Ionic Strength

Ionic strength was considered as a candidate stressor because relatively high (>1,000 µmhos/cm @ 25° C) specific conductance values have been measured in the stream and chloride estimated from specific conductance has annually exceeded the MPCA standard during the period of record. Minnesota Rule Chapter 7050 (Minn. R. 7050) specifies standards applicable to Minnesota streams to protect aquatic life. The specific conductance standard applicable to Nine Mile Creek is not to exceed 1,000 µmhos/cm @ 25° C (Minnesota Rule Chapter 7050.0224 Subpart 2). The chronic chloride standard applicable to Nine Mile Creek is for a 4-day average not to exceed 230 mg/L more than once in three years (Minnesota Rule Chapter 7050.0222, subpart 4)

The NMCWD has continuously measured specific conductance at the 98th Street WOMP Station since late 2003 (Figure 4). Data from the 98th Street WOMP Station indicate specific conductance annually exceeded the 7050 standard and all exceedances occurred during the November through April period (Figure 43).

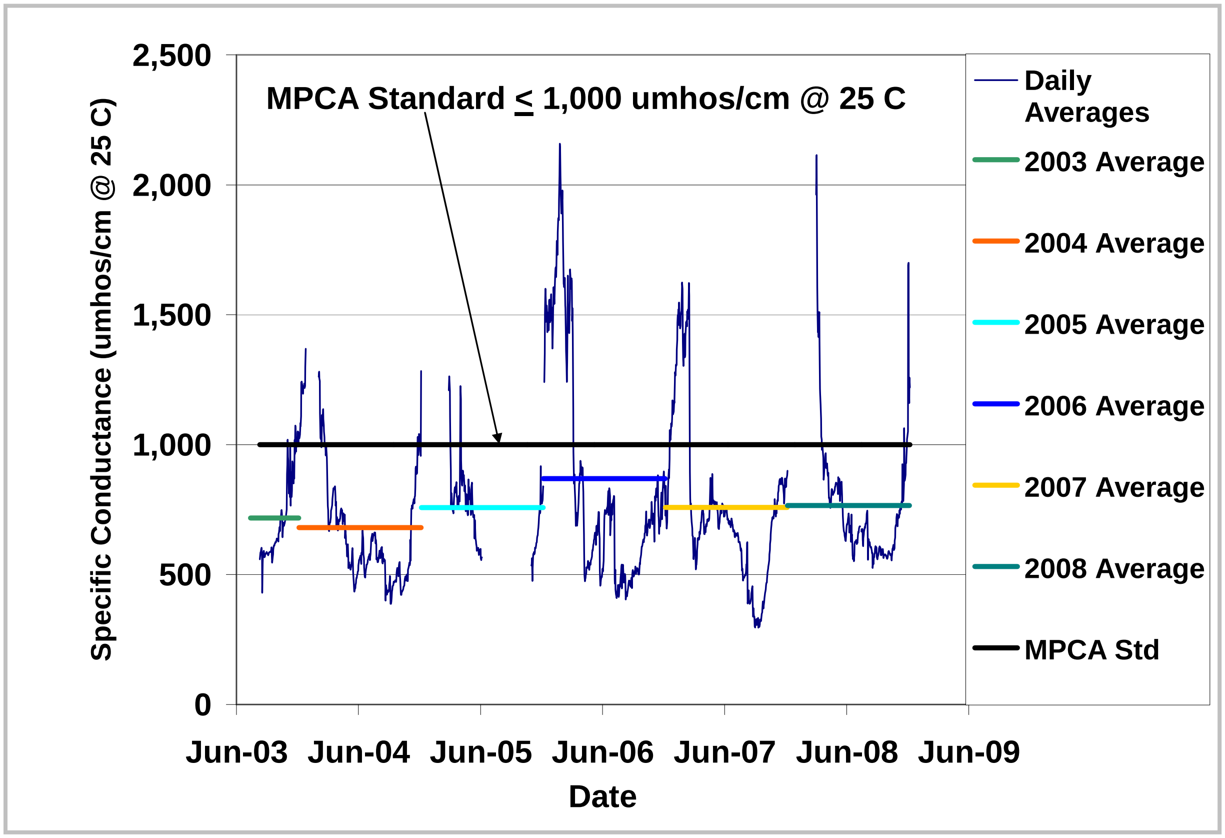


Figure 43. 2003-2008 Nine Mile Creek Specific Conductance: 98th Street

The MCES measured specific conductance continuously at the 106th Street WOMP location during this same period. A comparison of specific conductance data from the 98th Street and 106th Street locations indicates specific conductance annually exceeded the 7050 standard at both the 98th Street and 106th Street locations (Figure 44).

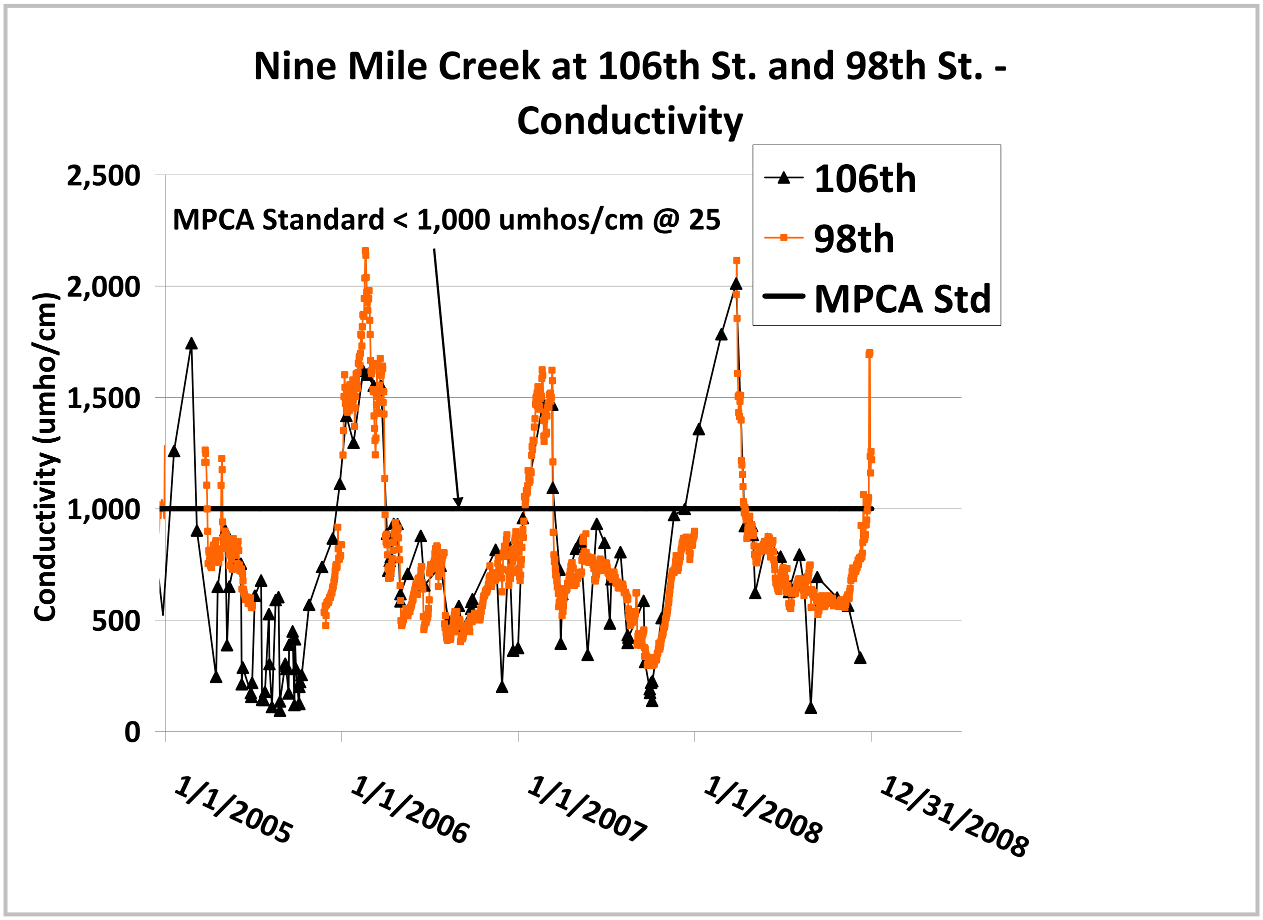


Figure 44. Nine Mile Creek Specific Conductance: Compare Main Stem Locations at 98th Street and 106th Street

Chloride estimated from specific conductance measurements at the 98th Street and 106th Street locations during 2004 through 2008 annually exceeded the chronic standard at both locations during the January through March period. Although higher chloride concentrations were generally estimated for 106th Street during the January through March period, 98th Street sometimes observed higher concentrations than 106th Street (Figures 45 through 49). The data indicate chloride is the ion causing the high specific conductance measurements at both locations.

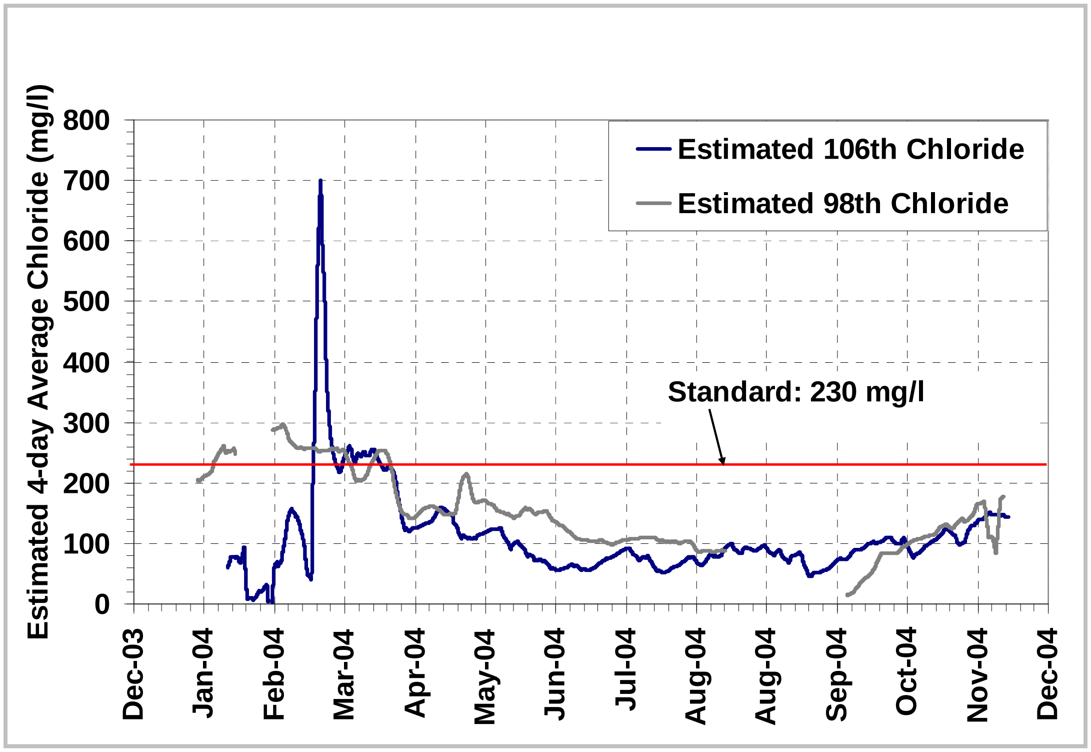


Figure 45. Nine Mile Creek – 98th and 106th St., Bloomington Estimated 4-Day Average Chloride from Conductivity –2004

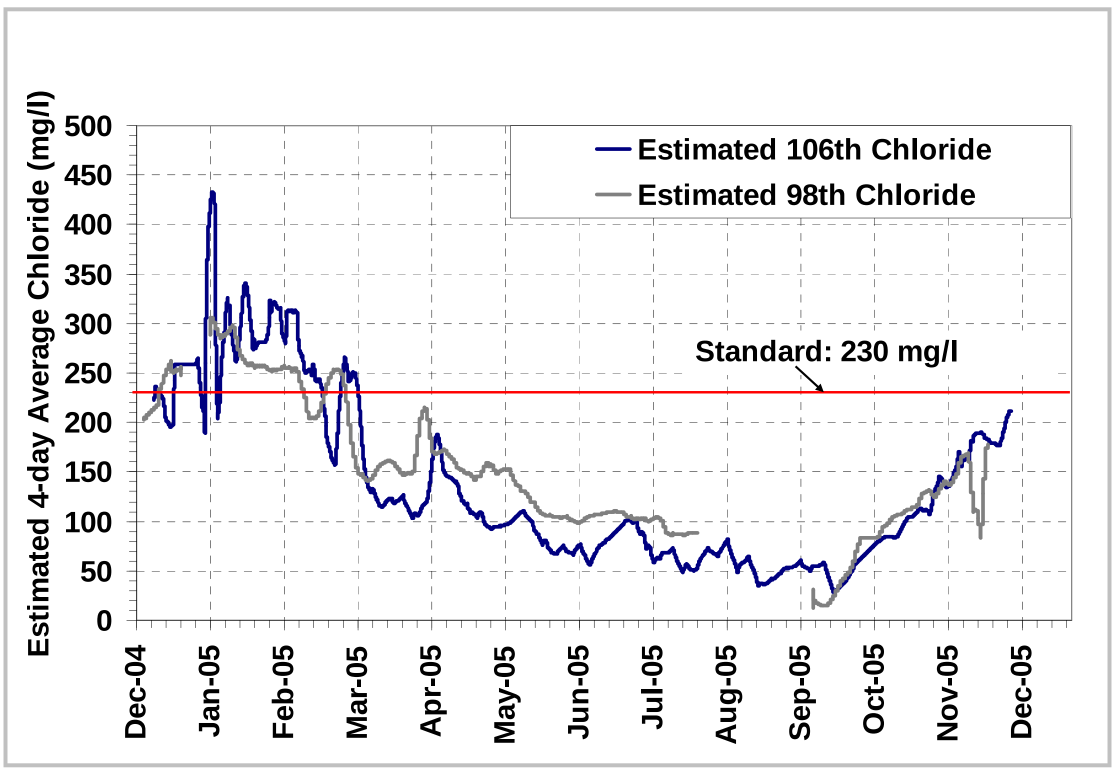


Figure 46. Nine Mile Creek – 98th and 106th St., Bloomington Estimated 4-Day Average Chloride from Conductivity – 2005

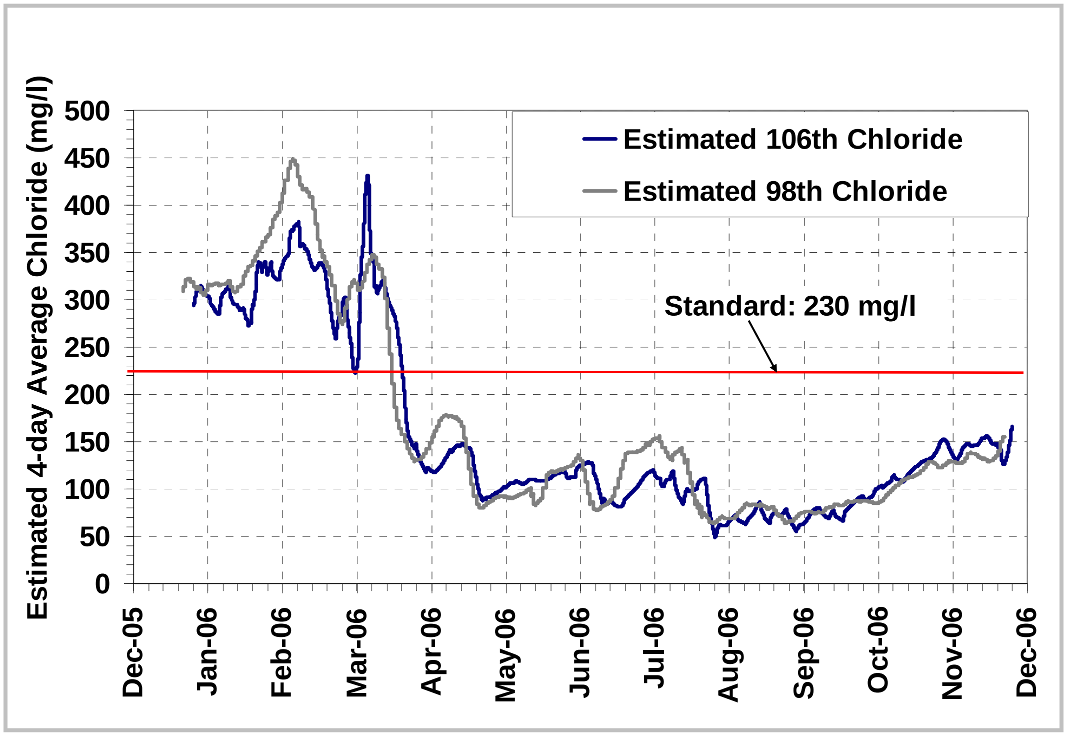


Figure 47. Nine Mile Creek – 98th and 106th St., Bloomington Estimated 4-Day Average Chloride from Conductivity – 2006

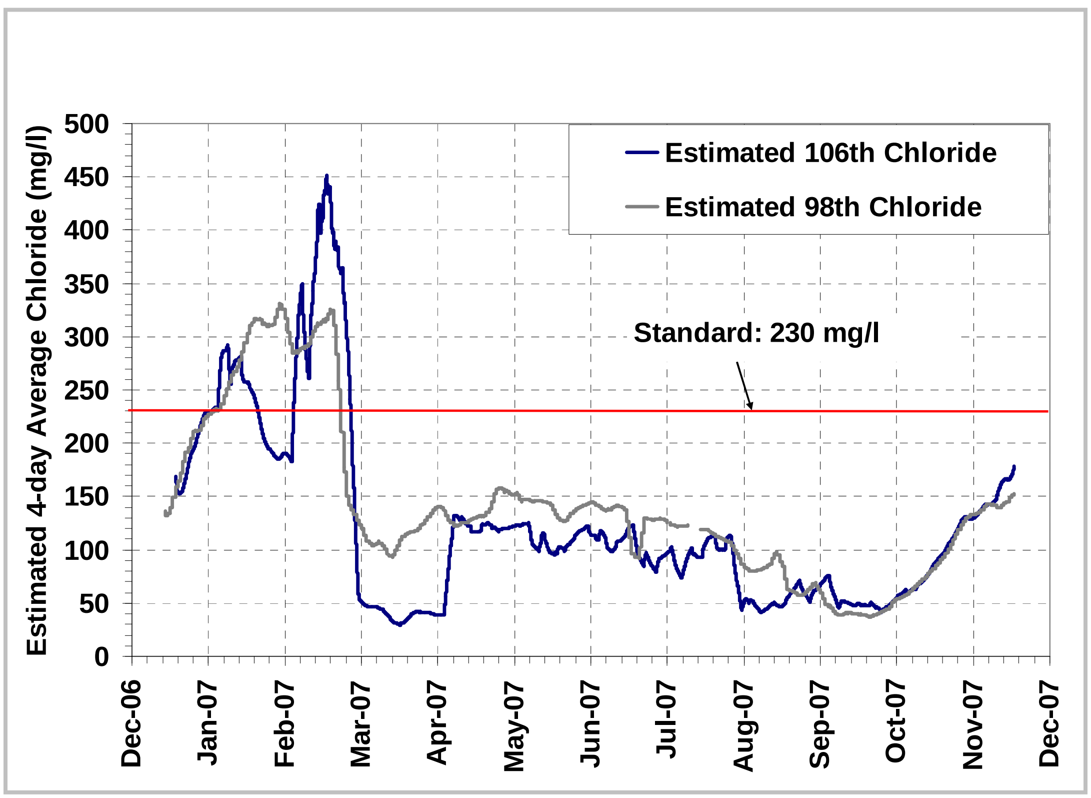


Figure 48. Nine Mile Creek – 98th and 106th St., Bloomington Estimated 4-Day Average Chloride from Conductivity – 2007

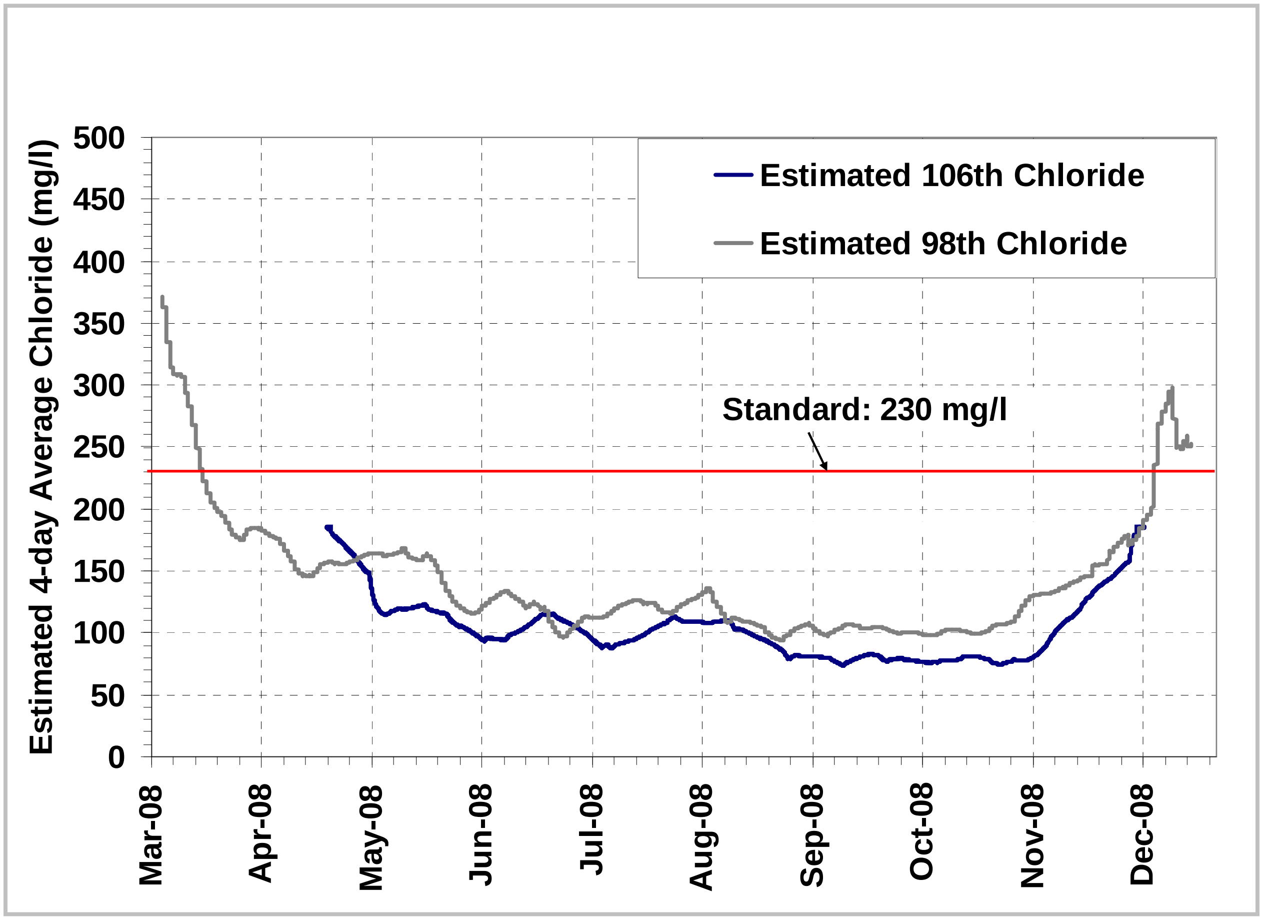


Figure 49. Nine Mile Creek – 98th and 106th St., Bloomington Estimated 4-Day Average Chloride from Conductivity – 2008

High specific conductance levels and chloride concentrations (i.e., estimated from specific conductance) at the 98th Street location occurred concurrently with impaired IBI scores during 2004, 2005, and 2007. However, high specific conductance levels and chloride concentrations at 98th Street during 2006 and 2008 occurred concurrently with unimpaired IBI scores. Furthermore, high specific conductance levels and chloride concentrations at downstream 106th Street occurred concurrently with unimpaired IBI scores during 2004 through 2008. The conflicting data do not provide strong support for the hypothesis that ionic strength is a candidate stressor for the fish community.

A conceptual model of candidate cause 3, ionic strength, is shown in Figure 19. The model details are discussed in Section 4.1.4.

4.3.4 Candidate Cause 4: Sediment

Impairment of the biological community at EUC-7A, pictured above, has been associated with a higher percentage of locations with fine sediment and deeper depths of fine sediment than a downstream unimpaired location, EUC-7C, pictured below.

Sediment was considered as a candidate stressor because deeper depths of fine sediment have been associated with a lower percent of simple lithophils and with impaired IBI scores. The NMCWD collected habitat data at EUC-7A, EUC-7B, and EUC-7C during 2003 through 2006. Thirteen transects and five sample locations along each transect were sampled at each location.

The results of a sediment data comparison at EUC-7A and EUC-7C provide evidence that sediment is a candidate stressor of the biological community at EUC-7A. Fine sediment was observed at a higher percentage of locations at EUC-7A than EUC-7C during 2003 through 2006 (Figure 50). In addition, deeper depths of sediment were observed at EUC-7A than EUC-7C during this period (Figure 51). All IBI scores at EUC-7C were above the impairment threshold, but IBI scores at EUC-7A were below the impairment threshold of 30 or greater during 2003 through 2005.

Simple lithophils are fish, such as white sucker, that require clean gravel or boulder substrate for reproduction and are adversely impacted by sediment deposits on stream substrate. A comparison of percent simple lithophils at EUC-7A, EUC-7B, and EUC-7C indicates the lowest percent simple lithophils consistently occurred at EUC-7A, the location with the highest depth of sediment and highest percent of locations with fine sediment (Figure 52). Sediment appears to be a stressor causing lower IBI scores at EUC-7A, as evidenced by deeper depths of fine sediment, a higher percentage of locations with fine sediment, and lower percent simple lithophils than an unimpaired downstream reach, EUC-7C.

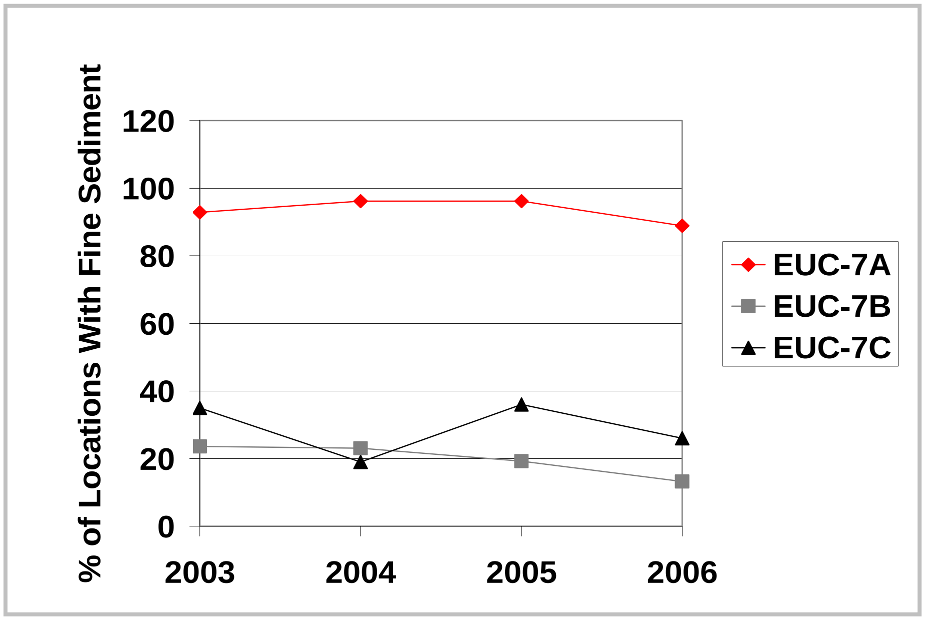


Figure 50. Nine Mile Creek Main Stem % of Locations With Fine Sediment: EUC-7A, EUC-7B, and EUC-7C

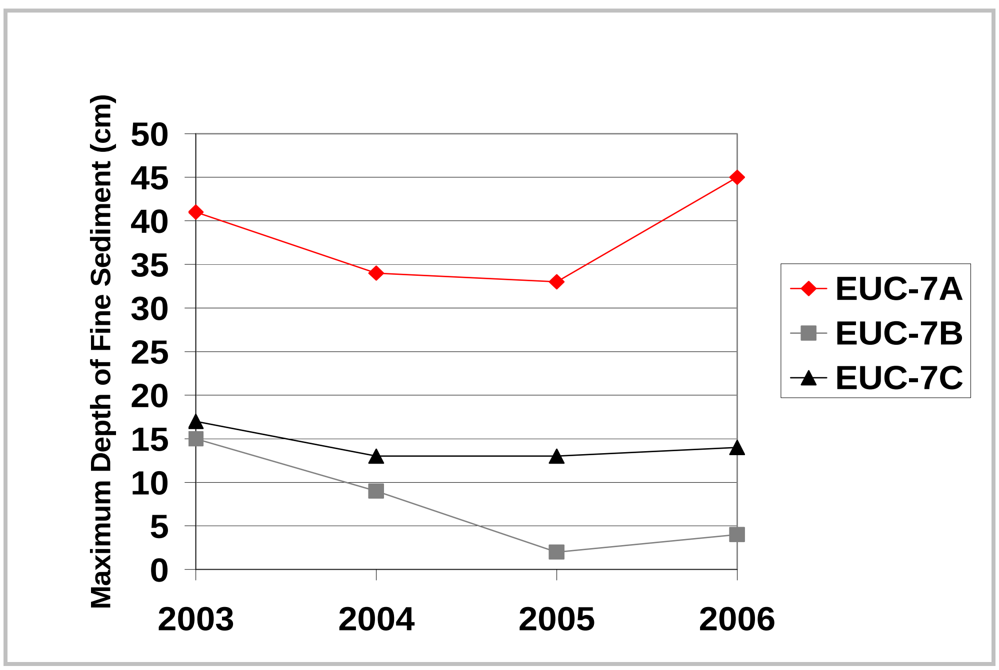


Figure 51. Nine Mile Creek Main Stem Maximum Depth of Fine Sediment: EUC-7A, EUC-7B, and EUC-7C

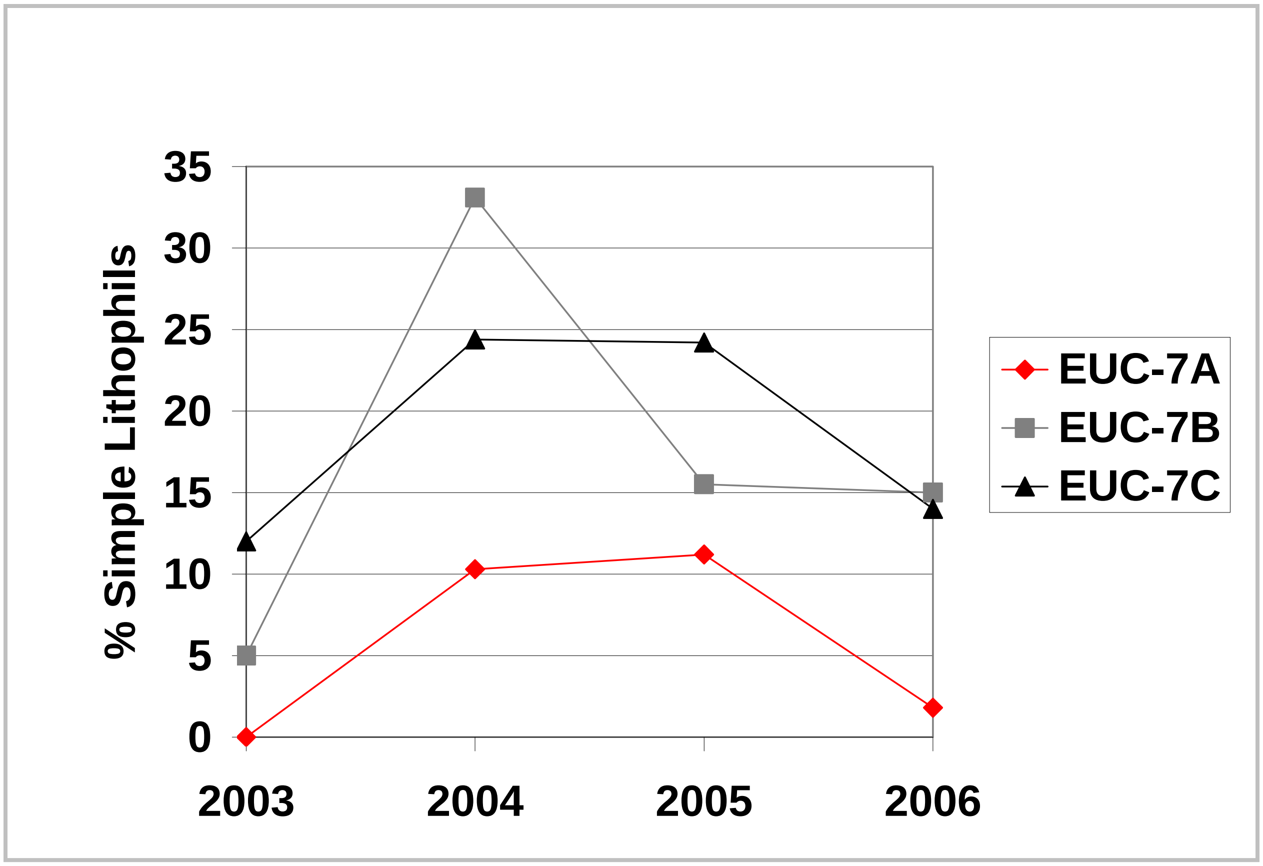


Figure 52. Nine Mile Creek Main Stem % Simple Lithophils: EUC-7A, EUC-7B, and EUC-7C

Further assessment of the relationship between maximum depth of fine sediment and percent simple lithophils indicates changes in percent simple lithophils have consistently varied with changes in maximum depth of fine sediment at EUC-7A, EUC-7B, and EUC-7C throughout the period of record (Figures 53, 54, and 55). These changes demonstrate the impacts of sedimentation on the stream's fish community.

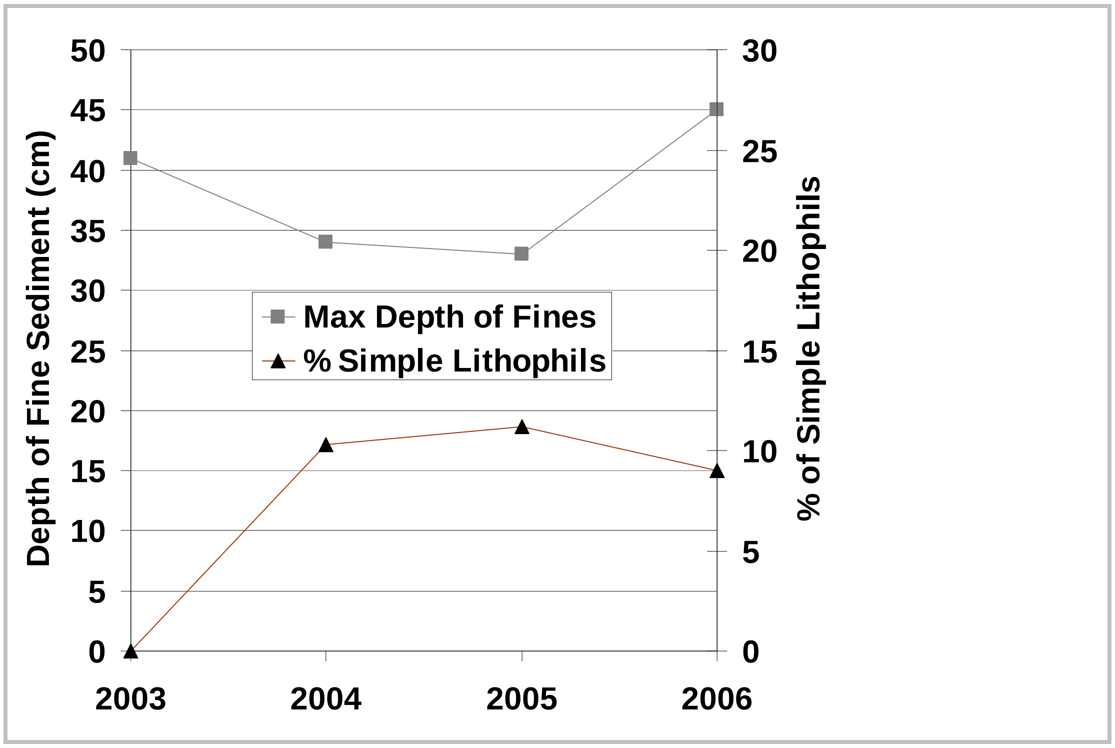


Figure 53. Nine Mile Creek Main Stem (7A) Maximum Depth of Fine Sediment Depth and Simple Lithophils

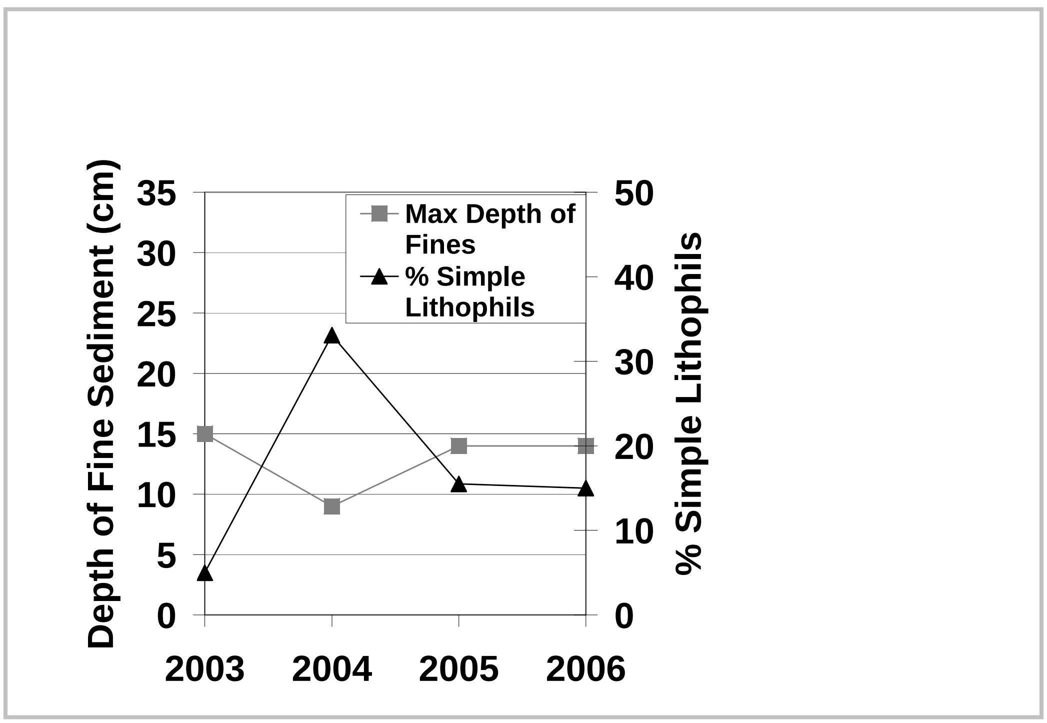


Figure 54. Nine Mile Creek Main Stem (7B) Maximum Depth of Fine Sediment Depth and Simple Lithophils

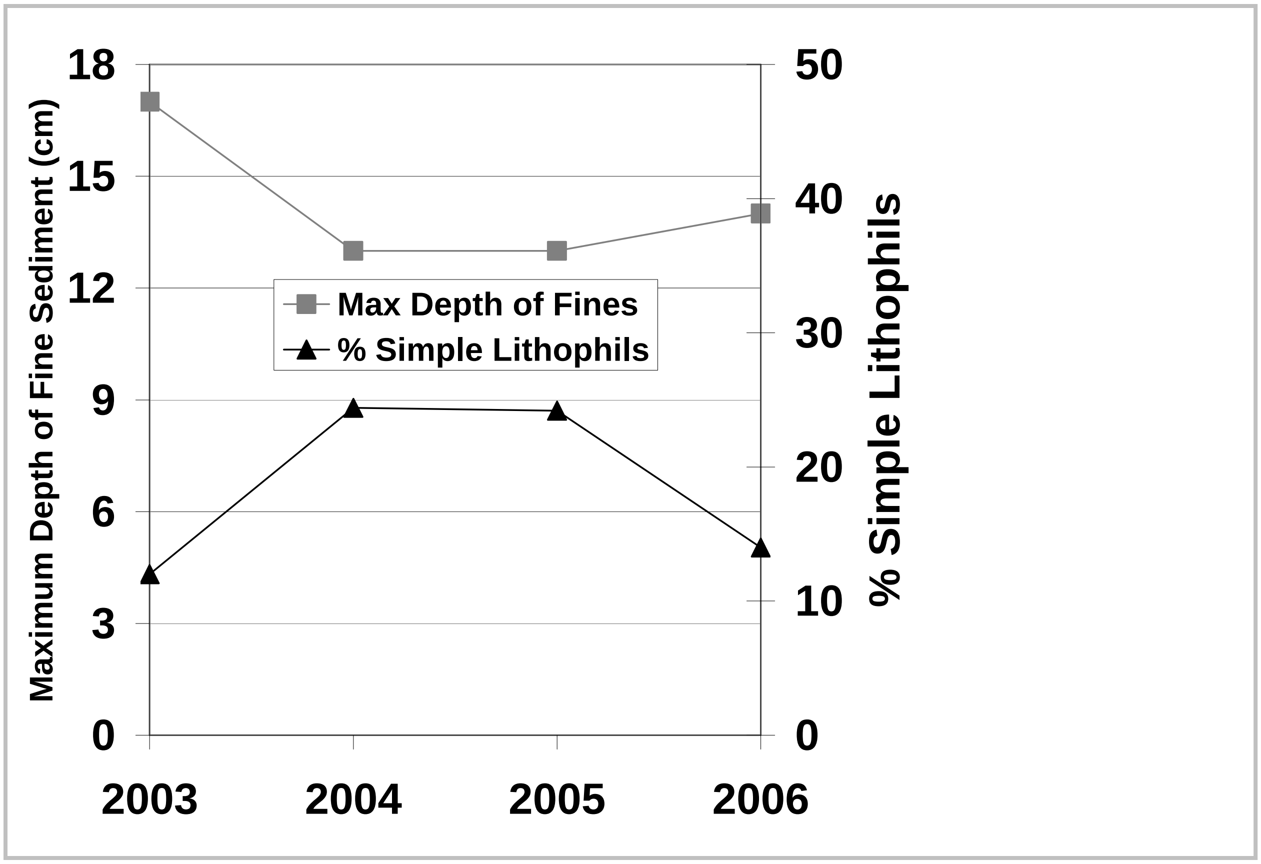


Figure 55. Nine Mile Creek Main Stem (7C) Maximum Depth of Fine Sediment Depth and Simple Lithophils

EUC-7B, located downstream of EUC-7A, consistently observed lower levels of sediment and higher percent lithophils than EUC-7A (Figures 50 through 52). Furthermore, EUC-7B generally observed higher IBI scores than EUC-7A (Table 3). The data indicate improving IBI scores at EUC-7B were correlated with reductions in the percent of locations with fine sediments (Figure 56). The percent of locations with fine sediment declined during 2003 through 2006 and declines in 2005 and 2006 were associated with improving IBI scores that were above the impairment threshold of 30 or greater.

Improving IBI Scores at EUC-7B, pictured above, in 2005 and 2006 were associated with reductions in the percentage of locations with fine sediment.

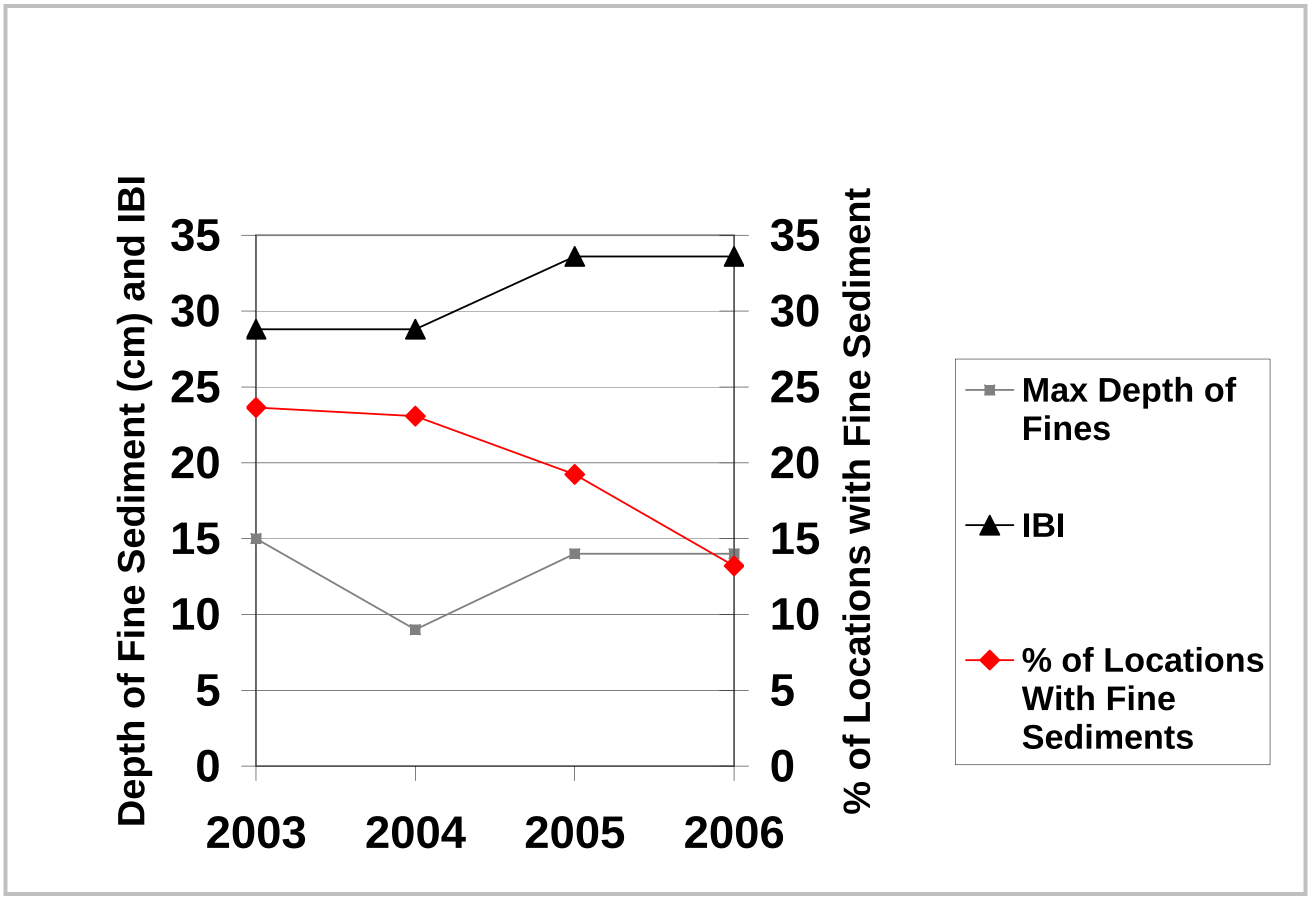


Figure 56. Nine Mile Creek Main Stem (7B) Fine Sediment Depth, Percent of Locations With Fine Sediment, and IBI

A Rosgen stream assessment was conducted on the Main Stem of Nine Mile Creek during 1997 and again in 2003. An assessment of stream reach downstream of Marsh Lake, south of 98th Street and West of Penn Avenue, indicated the stream reach was highly meandering and was a Type C channel. The floodplain of this channel is more confined than with a Type E stream, and the channel dimensions are wider and shallower. This reach is located just prior to where the creek descends into the lower valley. The creek flows through a shallow wooded valley with residential land use on either side.

The 1997 survey results indicated the streambanks were actively eroding, especially where turf lawns abut the channel. 2003 survey results indicated the stream banks continued to actively erode in this reach.

Several factors contribute to the erosion observed in this reach: (1) lack of vegetative root mass due to turf lawn areas and shade from trees; (2) several large storm sewers discharge to the stream in this vicinity, increasing the frequency of bankfull flooding; and (3) the streamflow may be “sediment starved” as it leaves Marsh Lake, and thus have a greater tendency to erode its banks and bed.

An assessment of the frequency of bankfull flooding in this reach indicates discharge from stormsewers has increased the frequency of bankfull flooding at this location as compared with natural conditions. During the 2004 through 2008 period, bankfull flooding occurred at the following frequency at the 98th Street WOMP Station, based upon average daily flow:

- 2004 – 11 days
- 2005 – None
- 2006 – 7 days
- 2007 – 16 days
- 2008 – 25 days

Under natural conditions, bankfull flooding should be between the 1 to 2 year return frequency. With the exception of 2005, bankfull flooding at the 98th Street location occurred more frequently than would be expected for natural conditions. The increased frequency of bankfull flooding contributes to stream erosion and the resultant sediment deposits which adversely impact the stream’s biological community.

A change by homeowners during the 1997 through 2003 period intended for erosion reduction is the addition of rock riprap to the streambanks along their property. However, this only accelerates erosion of the unprotected areas.

This area is worthy of consideration for a coordinated effort to improve stability and erosion-resistance of the channel. Such a project would consist of measures to reduce the flow velocity at susceptible banks, and improve the vegetation of the corridor by selective tree removal and introduction of native plants. Education of homeowners to encourage vegetative buffers between their lawns and the creek would also be beneficial.

A conceptual model of candidate cause 4, sediment, is shown in Figure 16. Model details are discussed in Section 4.1.3.

5.0 Evaluate Data From the Case

Physical and water quality data as well as biological data from Nine Mile Creek were evaluated to determine the strength of evidence for the candidate causes of Nine Mile Creek's impairment. The types of evidence used in the evaluation were:

- **Spatial/Temporal Co-occurrence—**Biological effect observed where and when the cause is observed and not observed where and when the cause is 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 observed 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 A) was used to evaluate the evidence from the case. Evaluation results follow for parameters supported by evidence.

5.1 Candidate Cause 1: Inadequate Baseflow

5.1.1 Spatial/Temporal Co-occurrence – Inadequate baseflow and an impaired biological community co-occurred in Nine Mile Creek during portions of the period of record. During 2007, fish samples were collected following a period when the stream was dry and IBI scores were below the impairment threshold of 30 or greater. During 2006 and 2008, IBI scores were above the impairment threshold where fish sampling occurred prior to the periods of low flow that stressed the biological community. An impaired fish IBI score was observed during 2005 at South Branch location EUC-5A and during 2004 at Main Stem location EUC-7A even though low flows were not observed prior to the collection of fish samples. Another stressor could explain these impaired conditions. The evidence supports spatial/temporal co-occurrence during 2007, but does not support spatial/temporal co-occurrence during 2005 on the South Branch and 2004 on the Main Stem. If only the 2007 data were considered, a score of + would be given for spatial/temporal co-occurrence. However, because the data from 2005 on the South Branch and 2004 on the Main Stem do not support spatial/temporal co-occurrence, a score of 0 was given indicating it is uncertain whether the candidate cause and the effect co-occur (Table 6).

Table 6. Nine Mile Creek Evidence Table for Inadequate Baseflow: Evidence Using Data From Nine Mile Creek

Types of Evidence, Inadequate Baseflow	South Branch	Main Stem at EUC-7A and EUC-7B
Spatial/temporal co-occurrence	0	0
Evidence of Exposure or Biological Mechanism	+	+
Causal Pathway	++	++
Temporal Sequence	+	+

5.1.2 Evidence of Exposure or Biological Mechanism – The South Branch of Nine Mile Creek and the Main Stem at EUC-7A and EUC-7B were exposed to inadequate baseflow at the same time as there was an impaired fish community during 2007. The fish community was exposed to inadequate baseflow when the stream was dry during July and August of 2007. When the stream began flowing again, fish samples were collected from EUC-5A, EUC-7A, and EUC-7B during September and IBI scores were below the impairment threshold. A downstream reach on the Main Stem at 106th Street (EUC-7C) observed adequate baseflow throughout 2007 and IBI scores from this location were above the impairment threshold. If 2007 was the only year of data considered, a score of ++ would be given for evidence of exposure or biological mechanism. However, exposure to inadequate baseflow did not occur prior to collection of fish samples during 2005 on the South Branch or 2004 on the Main Stem of Nine Mile Creek and impaired fish IBI scores were observed. A score of + was given for evidence of exposure or biological mechanism indicating that the data show exposure or the biological mechanism is inconsistently present.

5.1.3 Causal Pathway – All steps in the causal pathway of inadequate baseflow and fish community impairment were present in 2007 when the South Branch of Nine Mile Creek and portions of the Main Stem, including EUC-7A and EUC-7B, were dry and an impaired fish community was observed. Because the data show that all steps in at least one causal pathway are present, a score of ++ was given (Table 6).

5.1.4 Temporal Sequence – A dry stream bed preceded the fish impairment observed at the South Branch of Nine Mile Creek and the Main Stem at EUC-7A and EUC-7B during 2007. Hence, a score of + was given for temporal sequence (Table 6).

5.2 Candidate Cause 2: Dissolved Oxygen

5.2.1 Evidence of Exposure or Biological Mechanism – Continuous oxygen measurements documented daily low oxygen concentrations in the South Branch, North Branch, and Main Stem of Nine Mile Creek during July of 2009 and daily low oxygen concentrations on the Main Stem of Nine Mile Creek during the mid- to late-summer of 2008. A synoptic longitudinal survey in 2009 documented that early morning low oxygen concentrations are widespread, but also documented that Main Stem Station EUC-7C had adequate oxygen to support an unimpaired fish community. Impaired fish communities have been observed in South Branch and North Branch locations as well as Main Stem Stations EUC-7A and EUC-7B. However, downstream Station EUC-7C has consistently observed an unimpaired fish community. The evidence is compatible with exposure of the fish to low dissolved oxygen and low oxygen as the cause of impairment. A score of ++ was given for evidence of exposure or biological mechanism (Table 7).

Table 7. Nine Mile Creek Evidence Table for Dissolved Oxygen: Evidence Using Data From Nine Mile Creek

Types of Evidence, Dissolved Oxygen	South Branch	North Branch	Main Stem at EUC-7A
Evidence of Exposure or Biological Mechanism	++	++	++
Verified or Tested Predictions	+++	+++	+++
Symptoms	D	D	D

5.2.2 Verified Prediction – The following prediction was verified by macroinvertebrate data. It was predicted that if low oxygen levels were stressing the fish community, the macroinvertebrate community would, on average, be comprised of species tolerant to low oxygen conditions. Macroinvertebrate data from the South Branch, North Branch, and Main Stem Station EUC-7A verified this prediction (Figures 14, 22, 23, and 40). A score of +++ was given for verified prediction.

5.2.3 Symptoms – The macroinvertebrate communities at the South Branch, North Branch, and Main Stem Station EUC-7A are diagnostic of the candidate cause, low dissolved oxygen. HBI values observed at these locations are indicative of consistently low levels of dissolved oxygen. A score of D was given for symptoms.

5.3 Candidate Cause 3: Ionic Strength

5.3.1 Spatial/Temporal Co-Occurrence – Ionic strength and biological impairment co-occurred during portions of the period of record.

On the South Branch, specific conductance levels in excess of the MPCA standard (i.e., 1,000 µmhos/cm @ 25° C) co-occurred with impaired fish IBI scores during 2004, 2005, and 2007. Unimpaired fish IBI scores co-occurred with high specific conductance levels during 2006 and 2008, when maximum specific conductance levels were lower than levels observed during 2004, 2005, and 2007. Because changes in chloride and specific conductance levels consistently co-occurred, chloride appears to be the ion causing the high specific conductance levels on the South Branch of Nine Mile Creek.

On the North Branch, high specific conductance co-occurred with impaired fish IBI scores during 2004 at both sample locations (EUC-2 and EUC-2A) and at downstream EUC-2A during 2005 and 2007. During 2006, high specific conductance was observed, but IBI scores were unimpaired at both sample locations. Chloride data and chloride concentrations estimated from specific conductance indicate chloride was the ion causing the high specific conductance levels. The estimated continuous chloride concentrations exceeded the MPCA chronic standard at least monthly during December of 2006 through February of 2007. Observed concentrations during February were approximately five times higher than the MPCA chronic standard and an impaired fish IBI score was observed at EUC-2A during 2007.

On the Main Stem, high specific conductance co-occurred with impaired fish IBI scores at EUC-7A during 2004, 2005, and 2007. Unimpaired fish IBI scores co-occurred with high specific conductance levels during 2006 and 2008. Chloride estimated from specific conductance measurements at the 98th Street and 106th Street locations during 2004 through 2008 annually exceeded the chronic standard at both locations during the January through March period. The data indicate chloride is the ion causing the high specific conductance measurements at both locations. The co-occurrence of high specific conductance and chloride levels and impaired fish IBI scores at EUC-7A during 2004, 2005, and 2007 provides evidence that ionic strength is a stressor for the fish community. The co-occurrence of high specific conductance and chloride levels and unimpaired fish IBI scores at EUC-7A during 2006 and 2008 and at EUC-7C during 2004 through 2007 do not provide conclusive evidence that ionic strength is a significant stressor for the fish community.

Because the effect did not always occur when the cause occurred, a score of --- was given for spatial/temporal co-occurrence of ionic strength and impaired fish IBI on the South Branch, North Branch, and Main Stem of Nine Mile Creek.

Table 8. Nine Mile Creek Evidence Table for Ionic Strength: Evidence Using Data From Nine Mile Creek

Types of Evidence, Ionic Strength	South Branch	North Branch	Main Stem
Spatial/temporal co-occurrence	---	---	---
Evidence of Exposure or Biological Mechanism	+	+	+
Temporal Sequence	+	+	+

5.3.2 Evidence of Exposure or Biological Mechanism –

The South Branch, North Branch, and Main Stem (EUC-7A) of Nine Mile Creek were exposed to high levels of ionic strength due to chlorides at the same time as there was an impaired fish community during 2004, 2005, and 2007. During 2006 and 2008, high levels of ionic strength due to chlorides were observed at the same time as there was an unimpaired fish community at the South Branch and Main Stem of Nine Mile Creek. In 2006, high levels of ionic strength due to chlorides were observed at the North Branch at the same time as there was an unimpaired fish community. In addition, high levels of specific conductance and chlorides were consistently observed at the same time as there was an unimpaired fish community at the downstream Main Stem location (EUC-7C) during 2004 through 2007. Because the data show that exposure or the biological mechanism is inconsistently present, a score of + was given for evidence of exposure or biological mechanism (Table 8).

5.3.3 Temporal Sequence – High levels of ionic strength consistently preceded impaired IBI scores on the South Branch, North Branch, and Main Stem of Nine Mile Creek. High specific conductance and chloride levels were observed during the November through April period when impaired fish IBI scores were observed during the following June through September period. Because high levels of ionic strength consistently preceded impaired IBI scores on the South Branch, North Branch, and Main Stem of Nine Mile Creek, a score of + was given for temporal sequence.

5.4 Candidate Cause 4: Sediment

5.4.1 Spatial/temporal co-occurrence – Sediment exposure generally co-occurred with impairment of the Nine Mile Creek fish community as determined from reductions in percent simple lithophils and impaired fish IBI scores. Because the silt and sand substrate of the South Branch is not suitable for simple lithophil reproduction, reduction in percent simple lithophils was not an appropriate metric to assess sediment impacts on the South Branch of Nine Mile Creek and impaired fish IBI was the metric used to assess sediment impacts.

On the South Branch, fine sediment was present during 2003 through 2006 and co-occurred with impaired fish IBI during 2003 through 2005 (Figure 15). Reductions in fine sediment at this location during 2003 through 2006 resulted in a maximum depth of fine sediment that did not result in impaired fish IBI in 2006. Embeddedness, another measure of sediment impact upon fish, could not be assessed at this location because the substrate was silt and sand, not gravel, cobble or boulder. Because the effect (impaired fish IBI) did not always occur when the cause (sediment) occurred, a score of 0 was given for spatial/temporal co-occurrence of sediment and impaired fish IBI.

Because habitat data have not been collected since 2006, it is not known whether current fine sediment levels are higher or lower than levels measured in 2006. Additional habitat data collection is recommended to determine whether or not fine sediment is currently a stressor to the fish community.

On the North Branch, fine sediment depth decreased annually from 2003 through 2006 at EUC-2 (Figure 30). Impaired fish IBI was observed during 2003 and 2004 while unimpaired fish IBI was observed during 2005 and 2006 (Figure 30). The percent simple lithophils increased with a decrease in depth of fine sediment during 2003 and 2004, decreased with an increase in percent embeddedness during 2004 through 2005, and increased with a decrease in percent embeddedness during 2006 (Figure 31). Sediment (i.e., measured by either depth of fine sediment or percent embeddedness) co-occurred with impairment (i.e., measured by impaired fish IBI scores and/or reduction in percent simple lithophils) at EUC-2.

Sediment also co-occurred with fish impairment at EUC-2A. IBI scores decreased from 2003 through 2004 as fine sediment maximum depth increased and IBI scores increased during 2004 through 2006 when fine sediment depths decreased (Figure 32). The percent lithophils increased concurrently with a decrease in percent embeddedness during 2003 through 2004 and decreased with an increase in percent embeddedness during 2004 through 2005. Percent embeddedness was stable from 2005 through 2006 and percent simple lithophils declined slightly.

A score of + was given for spatial/temporal co-occurrence of sediment and impaired fish IBI for the North Branch of Nine Mile Creek because the effect (impaired fish IBI and/or reductions in percent simple lithophils) consistently co-occurred with the cause (sediment).

A direct relationship between changes in the maximum depth of fine sediment and percent simple lithophils provides evidence of the co-occurrence of sediment and fish impairment on the Main Stem of Nine Mile Creek. As shown in Figures 53 through 55, increases in fine sediment depth consistently resulted in reductions of percent simple lithophils while decreases fine sediment depth consistently resulted in increases in percent simple lithophils. Further evidence of the co-occurrence of sediment and impaired fish IBI scores is shown in Figure 56 where improving IBI scores were associated with reductions in the percent of locations with fine sediments at EUC-7B. Impaired fish IBI scores were observed during 2003 and 2004 while unimpaired fish IBI scores were observed during 2005 and 2006 following a reduction in the percent of locations with fine sediment (Figure 56).

A score of + was given for spatial/temporal co-occurrence of sediment and impaired fish IBI for the Main Stem of Nine Mile Creek because the effect (impaired fish IBI and/or reductions in percent simple lithophils) consistently co-occurred with the cause (sediment).

Table 9. Nine Mile Creek Evidence Table for Sediment: Evidence Using Data From Nine Mile Creek

Types of Evidence, Sediment	South Branch	North Branch	Main Stem
Spatial/temporal co-occurrence	0	+	+
Causal Pathway	++	++	++
Evidence of Exposure or Biological Mechanism	++	++	++
Temporal Sequence	+	+	+
Symptoms	NA	+	+

5.4.2 Evidence of Exposure or Biological Mechanism – The South Branch, North Branch, and Main Stem of Nine Mile Creek were exposed to sediment at the same time there was an impaired fish community. A score of ++ was given because the data show that exposure or the biological mechanism is clear and consistently present.

5.4.3 Causal Pathway – All steps in the causal pathway of sediment and fish community impairment were present during the period of record. Impaired fish IBI scores and reductions in percent lithophils were consistently correlated with sediment at the South Branch, North Branch, and Main Stem of Nine Mile Creek. Because the data show that all steps in at least one causal pathway are present, a score of ++ was given (Table 9).

5.4.4 Temporal Sequence – A score of + was given for temporal sequence because the cause (sediment) occurred prior to the effect (biological impairment).

5.4.5 Symptoms – A score of + was given for symptoms because the species assemblage from the North Branch and Main Stem location EUC-7A was consistently comprised of a low percent of lithophils (Table 9). The low percent lithophils is indicative of a lack of clean gravel or boulder size substrate required for reproduction or that siltation has occurred in the stream's riffle areas. Locations downstream from EUC-7A observed less sediment than EUC-7A and North Branch locations and consistently observed higher percentages of simple lithophils than EUC-7A and North Branch locations. The data indicate the low percentage of simple lithophils at the North Branch and Main Stem EUC-7A locations is due to sediment that adversely impacts lithophil reproduction. The data further indicate the higher percentage of simple lithophils at downstream Main Stem locations EUC-7B and EUC-7C is due to reduced quantities of sediment. An assessment of the data indicates the downstream Main Stem locations observed a larger quantity of suitable lithophil reproduction area in addition to less sediment when compared to North Branch locations and Main Stem location EUC-7A. A score of + was given for symptoms indicating symptoms or species observed at the sites characterize the candidate cause (sediment) and a few others (lack of suitable substrate for lithophil reproduction). Because the sand and silt substrate of the South Branch is unsuitable for lithophils reproduction, the South Branch was not given a score for this metric.

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 four candidate causes: inadequate baseflow, dissolved oxygen, ionic strength, and sediment.

6.1 Inadequate Baseflow

Several studies provide evidence that inadequate baseflow is a plausible stressor for Nine Mile Creek's impaired biota. 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."

Several studies provide evidence that inadequate baseflow is a plausible stressor for Nine Mile Creek's impaired biota. Portions of Nine Mile Creek, including Main Stem location EUC-7B pictured above, dry up during periods of reduced precipitation..

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 Nine Mile Creek's impaired fishery, a score of + is given for plausible mechanism (Table 10).

Table 10. Nine Mile Creek Evidence Table for Inadequate Baseflow: Evidence From Elsewhere

Types of Evidence, Inadequate Baseflow	South Branch	Main Stem at EUC-7A and EUC-7B
Plausible Mechanism	+	+
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 should 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 Nine Mile Creek, a score of + was given for plausible stressor response (Table 10).

6.2 Dissolved Oxygen

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 Nine Mile Creek's impaired fishery, a score of + is given for plausible mechanism (Table 11).

Table 11. Nine Mile Creek Evidence Table for Dissolved Oxygen: Evidence Using Data From Elsewhere

Types of Evidence, Dissolved Oxygen	South Branch	North Branch	Main Stem at EUC-7A
Plausible Mechanism	+	+	+
Plausible Stressor Response	+	+	+

The evidence presented in the Hardwood Creek TMDL indicates fisheries impairment is a plausible stressor response to low oxygen levels. Data from the Hardwood Creek TMDL indicate non-attainment of the fish IBI standard occurred in areas with low dissolved oxygen (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. Oxygen measurements below 5 mg/L in Nine Mile Creek indicate fisheries impairment is a plausible stressor response to these low oxygen levels.

Because evidence from the Hardwood Creek TMDL, Herbert and Steffenson (2005), and Alabaster and Lloyd (1982) indicate impairment is a plausible response of Nine Mile Creek's fishery to low dissolved oxygen, a score of + is given for plausible stressor response (Table 11).

6.3 Ionic Strength

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 Nine Mile Creek's impaired fishery, a score of + is given for plausible mechanism (Table 12).

Table 12. Nine Mile Creek Evidence Table for Ionic Strength: Evidence Using Data From Elsewhere

Types of Evidence, Ionic Strength	South Branch	North Branch	Main Stem
Plausible Mechanism	+	+	+
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. Ometo et al (2000) and Roy et al (2003) showed that lower percent natural land cover or higher urbanization has been shown to increase dissolved ion concentration and decrease density of stream biota associated with good water quality. 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 Nine Mile Creek's fishery to ionic strength, a score of + is given for plausible stressor response (Table 12).

6.4 Sediment

Data from the Groundhouse River TMDL indicate sediment is a plausible mechanism for biological impairment of Nine Mile Creek and an impaired fish assemblage is a plausible response to sediment in Nine Mile Creek.

The Groundhouse River TMDL found that addition of sediment to the Groundhouse River was a plausible cause of the stream's impaired fishery. The following, quoted from the Groundhouse River TMDL, provides evidence of sediment as a plausible mechanism for biological impairment.

- *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 pry abundance) and decreased cover (Rowe et al. 2003).*

Because evidence from the Groundhouse River TMDL indicates sediment is a plausible mechanism for Nine Mile Creek's impaired fishery, a score of + is given for plausible mechanism (Table 13).

Table 13. Nine Mile Creek Evidence Table for Sediment: Evidence Using Data From Elsewhere

Types of evidence, Sediment	South Branch at EUC-5A	North Branch at EUC-2 and EUC-2A	Main Stem at EUC-7A
Plausible Mechanism	+	+	+
Plausible Stressor Response	+	+	+

The evidence presented in the Groundhouse River TMDL also indicates fisheries impairment is a plausible stressor response to sediment. Quoting from the TMDL:

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. 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 (MPCA, 2008).

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.

Because evidence from the Groundhouse River TMDL, Rabeni et al. (1995), and Rashleigh et al. (2003) indicate impairment is a plausible response of Nine Mile Creek's fishery to sediment, a score of + is given for plausible stressor response (Table 13).

7.0 Identify Probable Cause and Factor Evaluation

7.1 Identify Probable Cause

The strength of evidence for the four candidate causes – inadequate baseflow, dissolved oxygen, ionic strength, and sediment - is summarized in Tables 14 through 17. Evidence for the three stream reaches – South Branch, North Branch, and Main Stem – is listed separately in each table.

Table 14. Nine Mile Creek Evidence Table for Inadequate Baseflow

Types of Evidence, Inadequate Baseflow	South Branch	Main Stem at EUC-7A and EUC-7B
Evidence Using Data From Nine Mile Creek		
Spatial/temporal co-occurrence	0	0
Evidence of Exposure or Biological Mechanism	+	+
Causal Pathway	++	++
Temporal Sequence	+	+
Evidence Using Data From Other Systems		
Mechanistically Plausible Cause	+	+
Stressor-Response in Other Field Studies	+	+
Multiple Lines of Evidence		
Consistency of Evidence	-	-
Explanatory Power of evidence	++	++

Table 15. Nine Mile Creek Evidence Table for Dissolved Oxygen

Types of Evidence, Dissolved Oxygen	South Branch	North Branch	Main Stem
Evidence Using Data From Nine Mile Creek			
Evidence of exposure, biological mechanism	++	++	++
Verified or Tested Predictions	+++	+++	+++
Symptoms	D	D	D
Evidence Using Data From Other Systems			
Mechanistically Plausible Cause	+	+	+
Stressor-Response in Other Field Studies	+	+	+
Multiple Lines of Evidence			
Consistency of Evidence	+++	+++	+++
Explanatory Power of evidence	++	++	++

Table 16. Nine Mile Creek Evidence Table for Ionic Strength

Types of Evidence, Ionic Strength	South Branch	North Branch	Main Stem
Evidence Using Data From Nine Mile Creek			
Spatial/temporal co-occurrence	---	---	---
Evidence of exposure, biological mechanism	+	+	+
Temporal Sequence	+	+	+
Evidence Using Data From Other Systems			
Mechanistically Plausible Cause	+	+	+
Stressor-Response in Other Field Studies	+	+	+
Multiple Lines of Evidence			
Consistency of Evidence	-	-	-
Explanatory Power of evidence	0	0	0

Table 17. Nine Mile Creek Evidence Table for Sediment

Types of Evidence, Sediment	South Branch	North Branch	Main Stem
Spatial/temporal co-occurrence	0	+	+
Causal Pathway	++	++	++
Evidence of Exposure or Biological Mechanism	++	++	++
Temporal Sequence	+	+	+
Symptoms	NA	+	+
Evidence Using Data From Other Systems			
Mechanistically Plausible Cause	+	+	+
Stressor-Response in Other Field Studies	+	+	+
Multiple Lines of Evidence			
Consistency of Evidence	0	+++	+++
Explanatory Power of Evidence	++	++	++

Table 18 summarizes the overall conclusions about the candidate causes of biotic impairment in each of the Nine Mile Creek stream reaches. The evidence in Tables 14 through 18 indicate:

- The probable cause of impairment on the South Branch of Nine Mile Creek is dissolved oxygen. The evidence for dissolved oxygen is strongest followed by sediment and then by inadequate baseflow. Ionic strength notes the weakest evidence. Collection of additional habitat data from the South Branch is recommended to determine whether current levels of sediment are similar to 2006 levels or whether changes have occurred. The steady decline in sediment from 2003 through 2006 indicates sediment may no longer be a stressor at this location. Additional data collection is recommended to determine current levels of sediment in the South Branch of Nine Mile Creek and whether those levels are stressing the stream's fish community.

- The probable causes of impairment on the North Branch of Nine Mile Creek are dissolved oxygen and sediment. The evidence for dissolved oxygen is strongest followed by sediment because the symptoms, or poor invertebrate (HBI) scores, were more diagnostic than the symptoms for excess sediment, which was based on the percentage of simple lithophils. Ionic strength notes the weakest evidence.

- The probable causes of impairment on the Main Stem of Nine Mile Creek are dissolved oxygen and sediment. The evidence for dissolved oxygen is strongest followed by sediment and then by inadequate baseflow. Ionic strength notes the weakest evidence.

Table 18. Summary of Candidate Causes for Biotic Impairments in Nine Mile Creek Stream Reaches

Types of Evidence, Dissolved Oxygen	South Branch	North Branch	Main Stem
Inadequate Baseflow	S	NA	S
Dissolved Oxygen	P	P	P
Ionic Strength—Chloride	NA	NA	NA
Sediment	S	S	S

P—Probable Cause
S—Secondary Cause
NA—Not Applicable or Weak Evidence

From a watershed perspective, the 2006 fish IBI scores indicate that all reaches of Nine Mile Creek can fully support the State biological standard. The data further suggest that when dissolved oxygen is not a stressor, the aquatic use of the stream can be fully supporting, without the development of a TMDL for another pollutant. This does not imply that continued watershed management for sediment, flow and chlorides, as well as management and further study of riparian habitat, would not be valuable. In some situations, the data suggests that these efforts would improve biotic integrity, and in other situations it is difficult to distinguish between the effects of the varying co-stressors in the available data.

7.2 Factor Evaluation

Anthropogenic influences (including pollutant loadings and water impoundments) do not contribute to low dissolved oxygen, the probable cause of impairment throughout the Nine Mile Creek watershed, under critical conditions but natural factors exist in the watershed that are likely to account for the low dissolved oxygen condition. Dissolved oxygen depletion is typically caused by biological oxygen demand (BOD) associated with excess organic and/or nutrients, as well as organically-enriched sediments. The conceptual models in Figures 13, 24 and 42 indicate that anaerobic sediment in natural wetlands following stagnant flow or reduced precipitation (drought) conditions, along with excess respiration, are the primary sources of dissolved oxygen depletion in all of the reaches of Nine Mile Creek. This section provides a detailed evaluation of the available monitoring data, along with the characteristics of Nine Mile Creek and its watershed, to determine the relative impacts that natural and/or anthropogenic sources are contributing to the dissolved oxygen/fisheries impairment under the critical conditions.

7.2.1 Dissolved Oxygen and Stream Flow Relationships

The evaluation included comparison of continuous dissolved oxygen measurements and flow to determine whether low oxygen levels were due to low flow conditions during periods of reduced precipitation. The 2009 data from the North Branch and South Branch of Nine Mile Creek indicate low dissolved oxygen levels were related to reduced flow resulting from reduced precipitation. Stream flow and continuous dissolved oxygen data from the South Branch at 78th Street (Figure 57) and the North Branch at Metro Boulevard (Figure 58) indicate minimum dissolved oxygen concentrations generally varied with flow. Flow increases were accompanied by higher minimum dissolved oxygen concentrations while flow decreases were accompanied by lower minimum dissolved oxygen concentrations.

Data from the Main Stem of Nine Mile Creek at 98th Street indicate the relationship between flow and dissolved oxygen concentrations was less clear for this Main Stem location (Figure 59) than the relationships observed for the South Branch (Figure 57) and North Branch (Figure 58) locations. The lack of clarity in the source of the low dissolved oxygen concentrations at the Main Stem 98th Street location is due to the influence of Marsh Lake on the oxygen content of downstream waters. Oxygen levels within Marsh Lake fluctuate due to biological activity within the marsh – plant photosynthesis raises oxygen levels and plant senescence and anaerobic sediment lowers oxygen levels. Hence, water exiting the marsh may have either lower or higher oxygen levels than downstream locations, depending upon natural processes occurring within the marsh and their impact upon the oxygen levels of water exiting the marsh. A comparison of flow and continuous oxygen data from the Main Stem 98th Street location indicate low dissolved oxygen concentrations sometimes resulted from low flows associated with reduced precipitation, and sometimes conveyance of Marsh Lake waters to downstream locations contributed toward reduced oxygen levels (Figure 59).

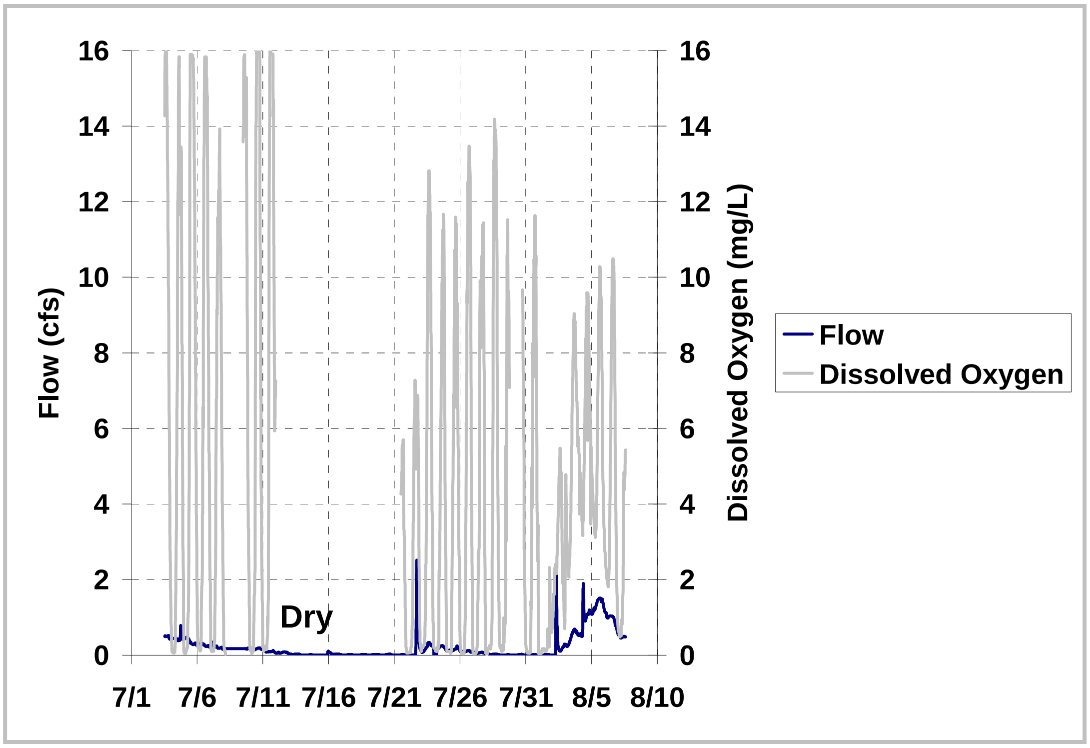


Figure 57. 2009 Nine Mile Creek South Branch Flow and Dissolved Oxygen: West 78th Street

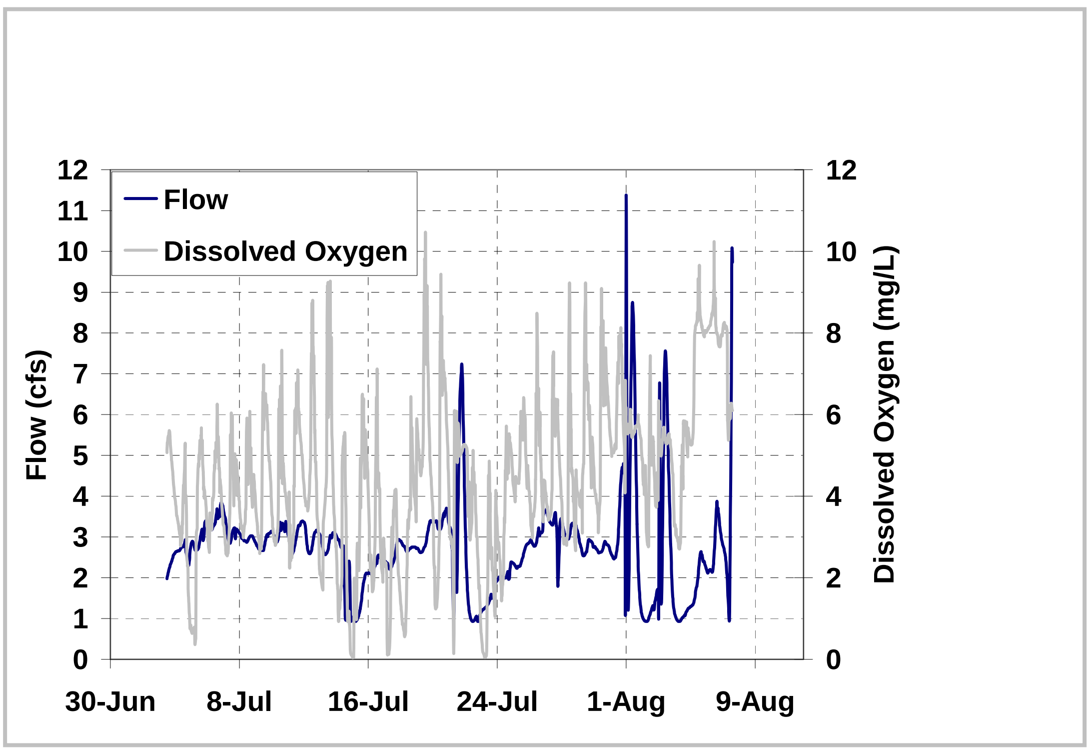


Figure 58. 2009 Nine Mile Creek North Branch Flow and Dissolved Oxygen: Metro Boulevard

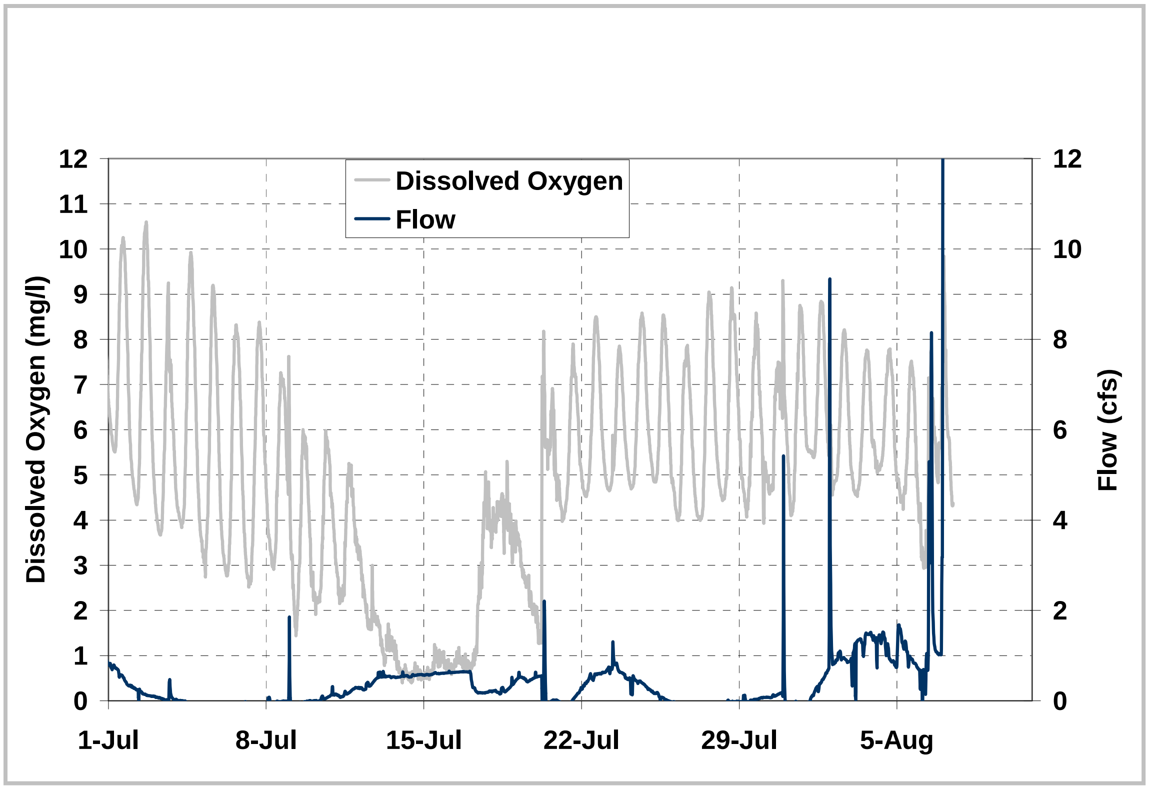


Figure 59. 2009 Nine Mile Creek Main Stem Flow and Dissolved Oxygen: 98th Street

As discussed above, the continuous data from each of the stream monitoring stations indicate that low dissolved oxygen concentrations sometimes resulted from low flows associated with drought-like conditions that occurred during the summer of 2009. Section 7.1 notes that the 2006 fish IBI scores indicate that all reaches of Nine Mile Creek met the State biological standard, indicating that low dissolved oxygen did not represent a significant stressor at that time. As a result, Figure 60 was developed to compare the 2006 and 2009 flow duration data to the long-term flow duration characteristics of the creek, based on average daily flow estimates. Figure 60 shows that the observed flow rates during the 2009 calendar year were consistently lower than the historical flow duration curve, except for the lowest flows, while the 2006 flow data prior to the fish survey was the same or consistently higher throughout the low flow regime. Figure 60 also shows that the lowest average daily flows observed during 2006 and 2009 were comparable, but sustained periods of low flow in 2009 coincided with considerably lower levels of dissolved oxygen throughout the watershed, as previously documented in this section. The 2006 fisheries survey was completed between June 21st and the 26th, and a dissolved oxygen reading of 3.7 mg/L on June 1st at the ECU2 station (shown in Figure 61) was the only watershed observation that did not meet the dissolved oxygen standard prior to the survey. Based on all of the available flow records collected from the MCES WOMP site, a 7Q10 of 0.4 cfs was estimated using the DFLOW program (Version 3.1b from EPA). Limiting the flow records to the growing season (May-September), DFLOW estimated a 7Q10 of 0.8 cfs.

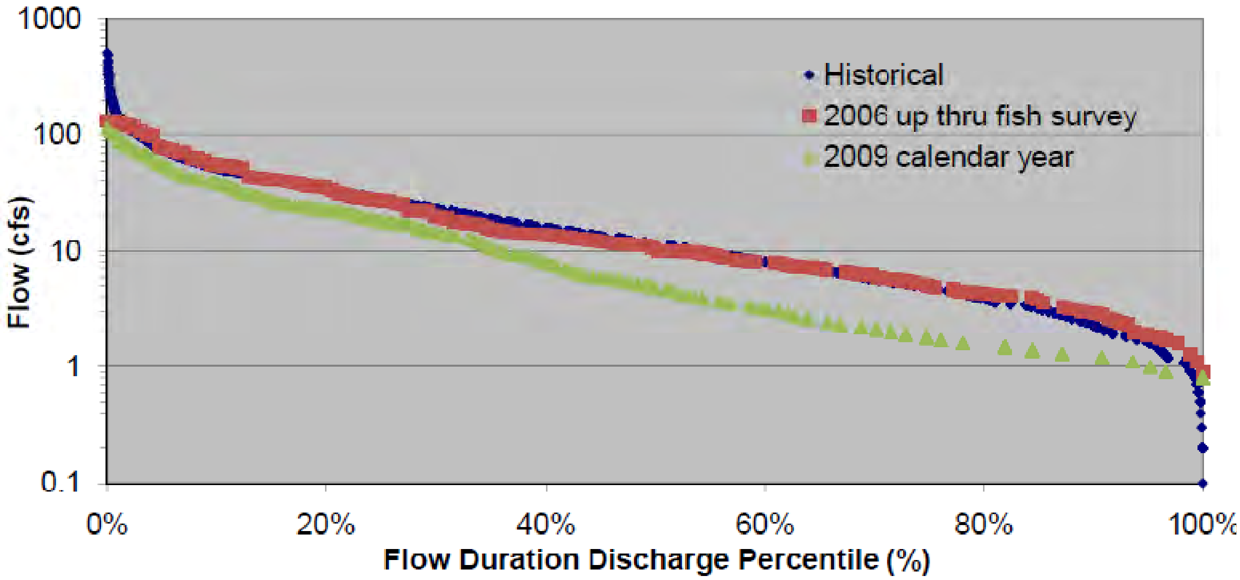


Figure 60. Nine Mile Creek Flow Duration Characteristics: MCES WOMP Site @ 106th Street

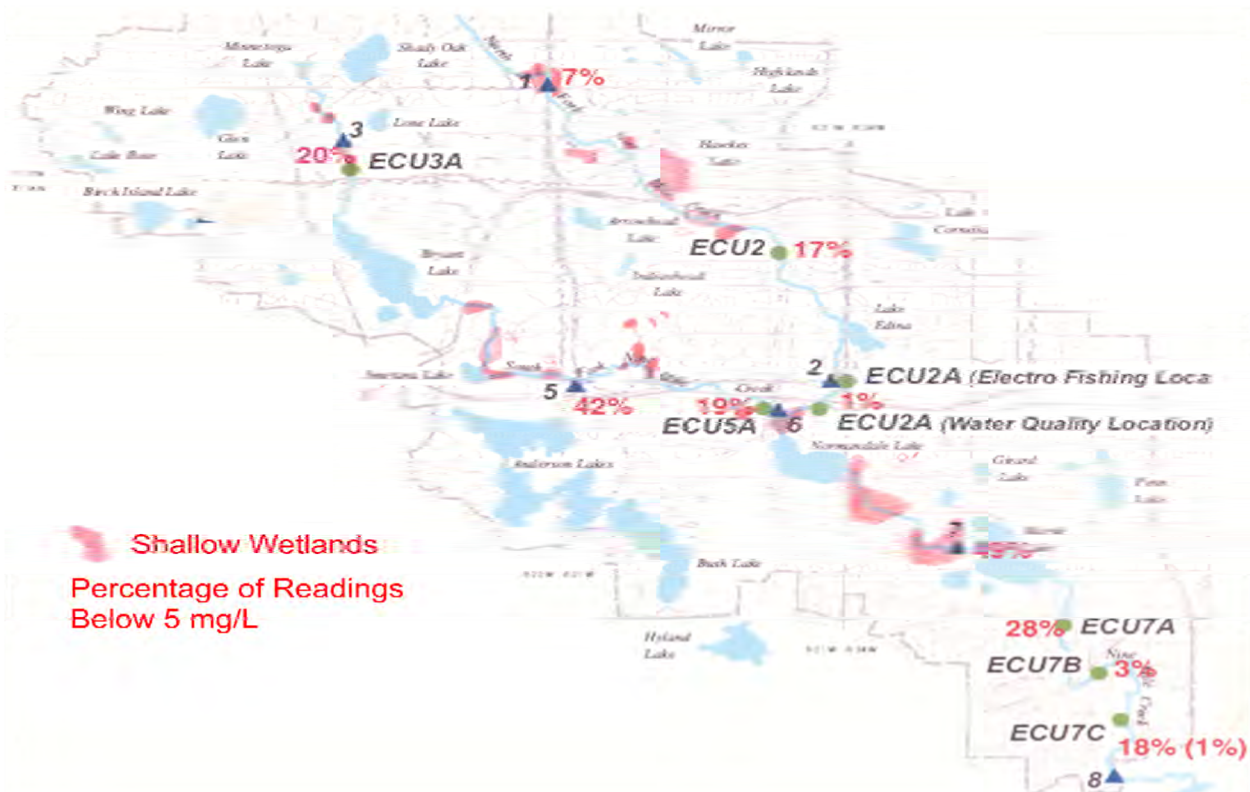


Figure 61. Nine Mile Creek Watershed Dissolved Oxygen Standard Violations Since 1978

Figure 61 shows the locations of the stream water quality (triangles) and ecological use (circles) monitoring stations established for NMCWD. Dissolved oxygen and water quality monitoring data was available for the stream water quality monitoring stations between 1968 and 2001, and since 1997 at the ecological use monitoring stations. Figure 61 shows the frequency with which dissolved oxygen measurements have met the standard at each monitoring station since 1978, when the Normandale Lake impoundment was established. Historical dissolved oxygen impairment occurs most often at Sites 5 and 7 with respective frequencies of standard violations of 42 and 49 percent.

Site 7 is located in the middle of the Marsh Lake complex of shallow riparian wetlands along the main stem of Nine Mile Creek. As discussed in Section 4.3.2, this site experienced low dissolved oxygen during the synoptic survey completed on July 23, 2009, with the data showing progressively lower dissolved oxygen concentrations as flow proceeds from the Normandale Lake dam through the Marsh Lake wetland complex. The dissolved oxygen and coincidental flow measurements (expressed as flow duration discharge percentile) from Site 7 are plotted in Figure 62, which shows that there is no correlation between dissolved oxygen and flow rate. As shown in Figure 59, this may be explained by a build-up of anoxia in the Marsh Lake wetlands under low flow conditions that is subsequently flushed downstream during storm events that produce varying amounts of flow. This effect was most pronounced during July 13-18, 2009 when gradual increases in flow following a period of stagnation resulted in depressed oxygen levels until more flushing at a higher flow rate on July 21st resulted in a return of more oxygen to the system.

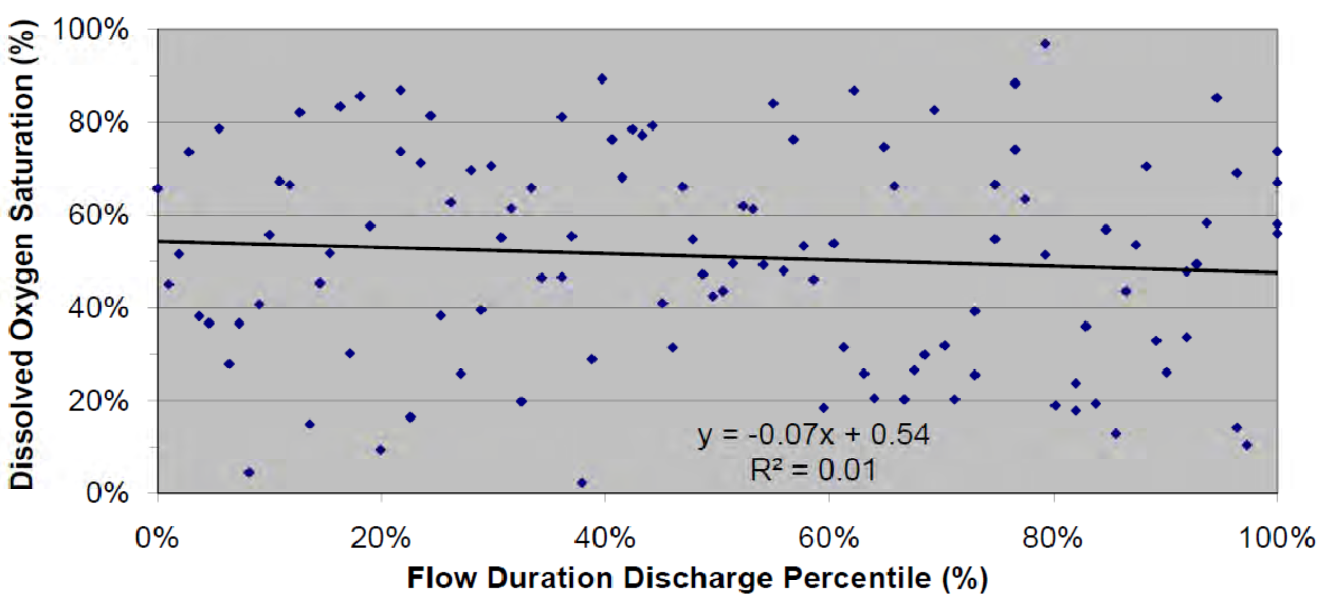


Figure 62. Nine Mile Creek Dissolved Oxygen Saturation Percentage Relationship with Flow Duration Percentile @ Site 7 Since 1978

7.2.2 Spatial Extent of Dissolved Oxygen Impairment

As shown in Figure 63, shallow riparian wetlands were naturally common throughout the Nine Mile Creek watershed. As watershed development has occurred, many of the wetlands areas are not as extensive as they were and some have been subjected to more inundation (such as Lake Edina, Marsh and Normandale Lakes). Figure 61 shows that many of the shallow riparian wetlands that were in existence at the turn of the last century are still present in each of the reaches of Nine Mile Creek.

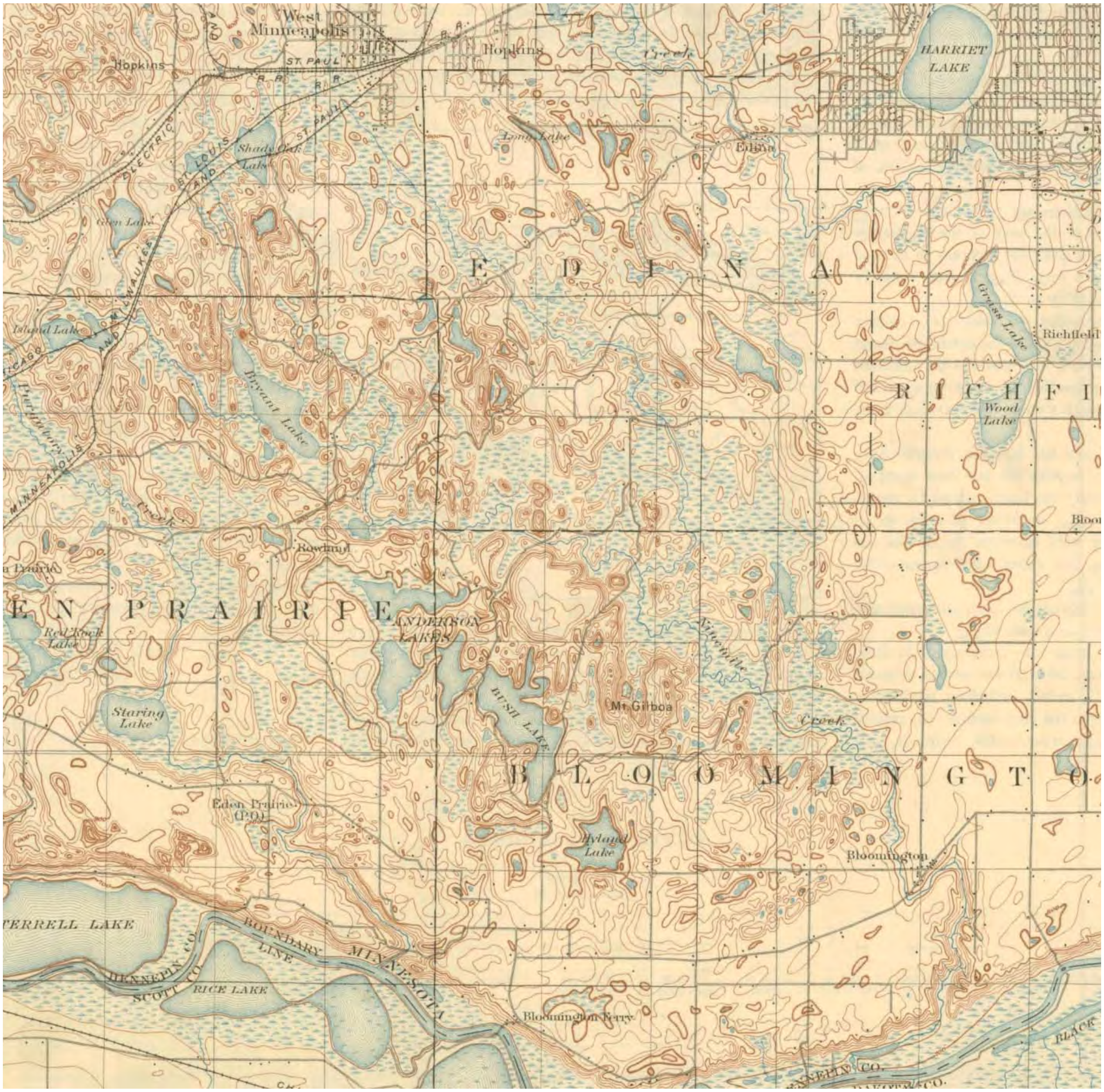


Figure 63. Nine Mile Creek Watershed Features: 1901 Topographic Map

Figure 61 shows that the percentage of dissolved oxygen standard violations is higher immediately downstream of the shallow riparian wetlands in the watershed. The lower valley stream sites (Site 8, ECU7B and ECU7C) possess higher stream gradients and experience more reaeration than the remainder of the stream monitoring sites. Site 2 experiences a disproportionately higher volume of controlled stormwater runoff from industrial/ office developments (located east of Highway 100) during more frequent storm events.

7.2.3 Dissolved Oxygen Impairment Trends

Approximately 2,670 instantaneous dissolved oxygen field measurements have been taken throughout the watershed since 1968. Twenty one percent of the dissolved oxygen readings violated the water quality standard during the period of record. In 1968, approximately two-thirds of the watershed was developed. By 1980, the watershed was 90 percent developed and has essentially been fully developed for the last two decades. Two significant impoundments of the main stem of the creek have been constructed during the period of record. The Marsh Lake dam was constructed in 1970 and Normandale Lake was installed in 1978.

Prior to 1970, 32 percent of the dissolved oxygen readings throughout the watershed violated the water quality standard. Between 1970 and 1977, eighteen percent of the dissolved oxygen readings did not meet the water quality standard, while 21 percent of the watershed readings were violations of the standard since the installation of Normandale Lake. The percentage of dissolved oxygen readings at Site 8 that violated the water quality standard prior to 1970, between 1970 and 1977, and since 1978 were 40%, 33% and 18%, respectively. The percentage of dissolved oxygen standard violations did not differ significantly at all of the monitoring stations upstream of Normandale Lake, before and after the installation of Normandale Lake. Since dissolved oxygen readings throughout the watershed have remained the same or improved over the last 40 years, none of the anthropogenic influences—impoundments and watershed development—on dissolved oxygen dynamics in Nine Mile Creek have had a documented, deteriorating effect.

7.2.4 Dissolved Oxygen and Water Quality Interrelationships

The interrelationships between the historical water quality sample constituent concentrations were examined for each of the monitoring stations using correlation matrices. The water quality constituent data throughout the watershed typically showed a significant positive correlation between nitrate and dissolved oxygen and a significant inverse correlation between phosphorus and dissolved oxygen, suggesting that nitrate was scarce and phosphorus was elevated under low dissolved oxygen conditions. Figure 64 shows an example of how nitrate and total phosphorus sample concentrations were each related to the dissolved oxygen measurements, based on the available data at Site 7.

Since the data at the watershed monitoring stations indicated that the sample nitrate concentrations are considerably lower when dissolved oxygen is low, and nitrate is negatively correlated with total phosphorus, the data doesn't support the premise that excess nutrient loadings are contributing to impairments for dissolved oxygen. Thomann & Mueller (1987) indicate that under low dissolved oxygen, bacteria reduction of nitrate can occur separately from utilization from aquatic plants. Under anaerobic conditions in sediment of shallow wetlands, the following denitrification sequence would occur (Thomann & Mueller, 1987):

- Nitrate is reduced to nitrogen gas and liberated
- Low level of nitrate in sediment sets up gradient with higher nitrate concentrations in water column
- Nitrate in water column diffuses to interstitial water in sediment leading to a loss of nitrate from the water column

As a result, the data indicate that high levels of phosphorus in flow are a by-product of low dissolved oxygen in shallow upstream wetlands, with diffuse flow, and high nutrients do not appear to be the cause of low dissolved oxygen in downstream stream reaches. It is expected that this effect of natural wetlands on dissolved oxygen in Nine Mile Creek is further exacerbated during the warmest portion of the summer by decreased oxygen solubility and an increasing rate of peat decomposition, with an associated release of organics and increased biological oxygen demand.

Figure 64 shows that while the relationship between ammonia and dissolved oxygen is not as strong as nitrate and dissolved oxygen at the MCES WOMP site, the pattern is similar and indicates that there were very few times that the ammonia concentrations exceeded 0.2 mg/L. A more-detailed evaluation of the monitoring data, throughout the watershed WOMP stations, showed that all of the higher ammonia concentrations were associated with samples collected during the winter months. During the growing season, ammonia is typically below 0.07 mg/L and was measured at 0.02 mg/L most of the time. As a result, ammonia levels in the stream are not sufficient to contribute to low dissolved oxygen under critical conditions. There was not enough paired data with either biological oxygen demand or chemical oxygen demand to evaluate the relationships with dissolved oxygen at any of the stream monitoring stations.

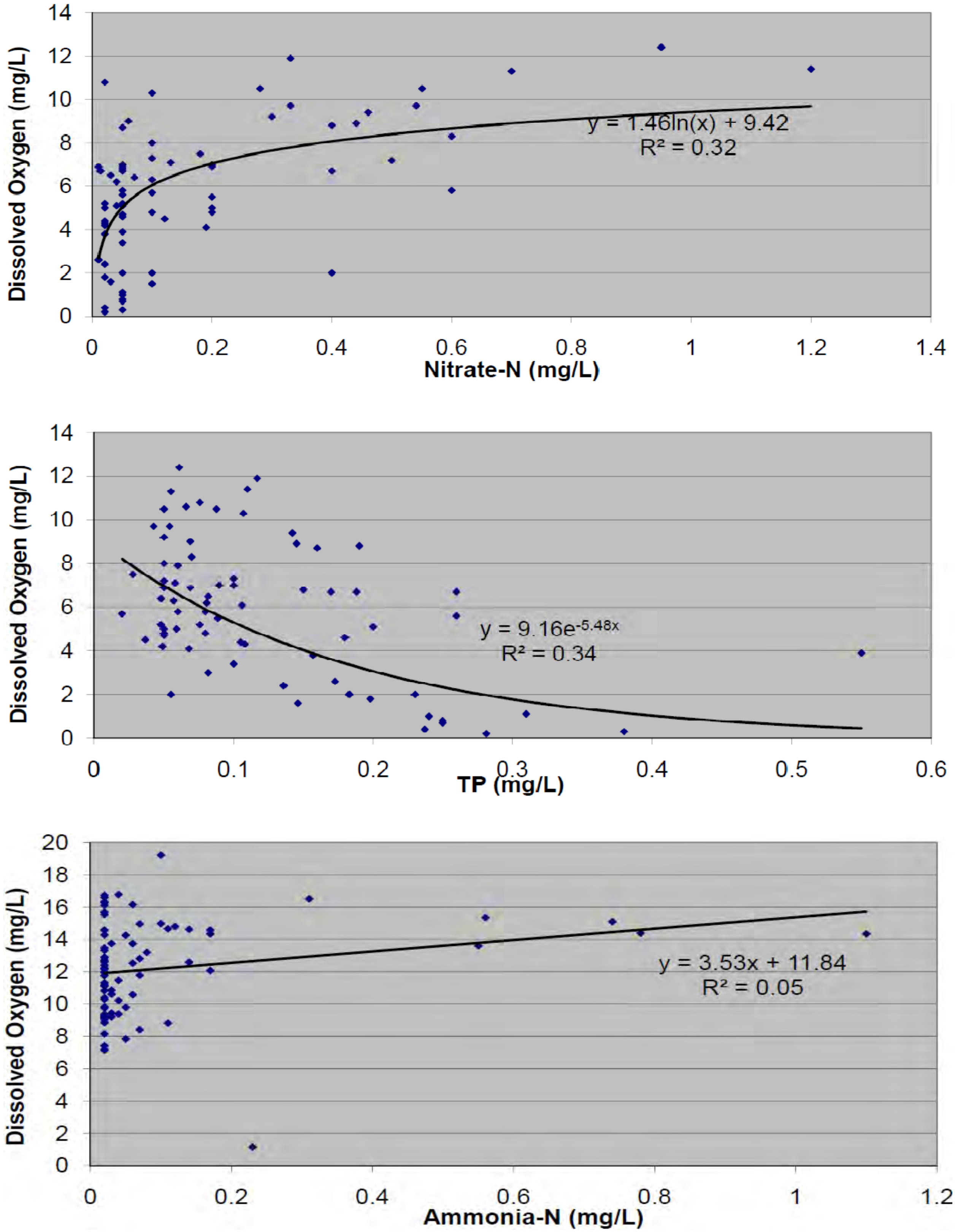


Figure 64. Relationships Between Dissolved Oxygen and Nutrient Concentrations: Nine Mile Creek Main Stem

Figure 65 shows that there is not a statistically significant positive relationship between nutrient loadings and the percentage of dissolved oxygen standard violations observed at the downstream WOMP station. The figure also shows that the flow-weighted mean nutrient concentrations are negatively correlated with the percentage of dissolved oxygen standard violations, which does not support the premise that excess nutrient loadings are contributing to an impairment for dissolved oxygen.

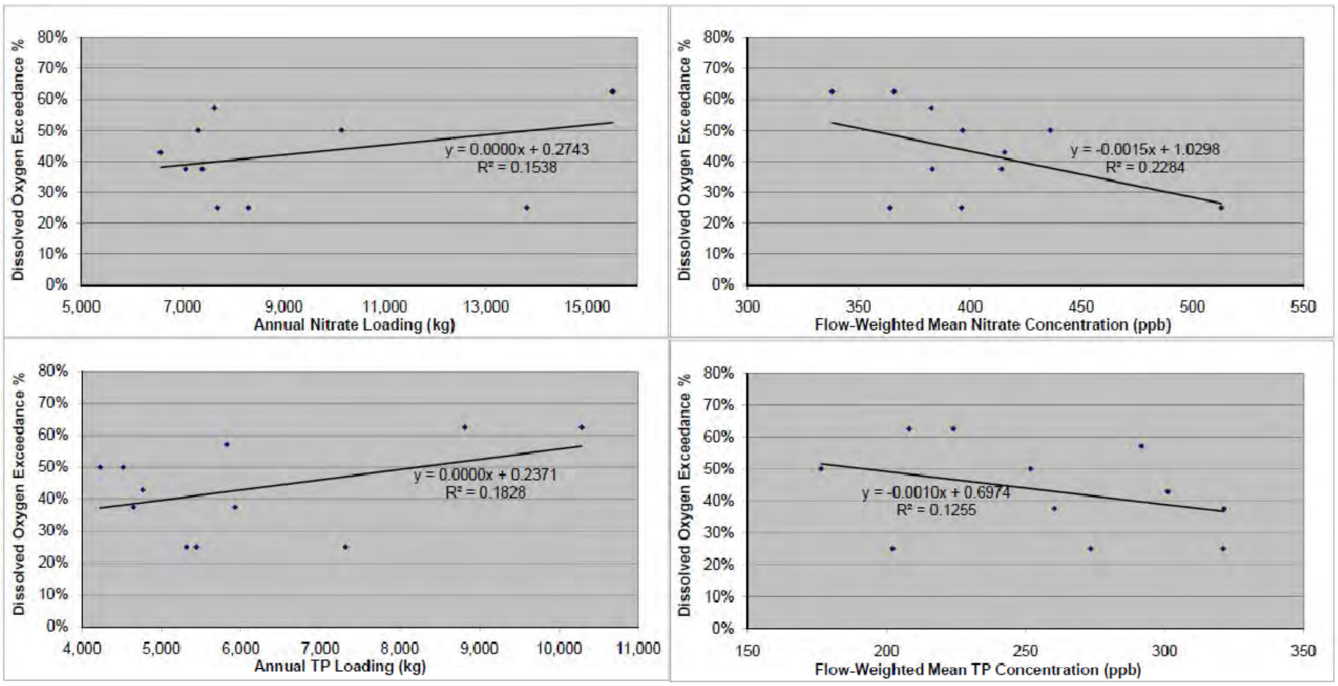


Figure 65. Relationships Between Dissolved Oxygen Standard Violations and Nutrient Loadings/Flow-Weighted Mean Concentrations: Nine Mile Creek Main Stem

7.2.5 Factor Evaluation Conclusions

Based on a detailed evaluation of the available monitoring data, along with the characteristics of Nine Mile Creek and its watershed, it can reasonably be concluded that the anthropogenic influences in the watershed do not contribute to low dissolved oxygen under the critical conditions and that natural factors exist in the watershed that are likely to account for the low dissolved oxygen condition, as indicated by the following determinations:

- Historical dissolved oxygen impairment occurs more frequently at watershed sites that are immediately downstream of shallow riparian wetlands, which naturally exist throughout the watershed

- There was limited or no correlation between dissolved oxygen and flow rate, but gradual increases in flow following a period of stagnation resulted in depressed oxygen levels until subsequent storm events produced more flushing of shallow riparian wetlands
- Since dissolved oxygen readings throughout the watershed have remained the same or improved over the last 40 years, none of the anthropogenic influences—impoundments and watershed development—on dissolved oxygen dynamics in Nine Mile Creek have had a documented, deteriorating effect
- The interrelationships between the water quality constituents at each of the monitoring stations could only be explained by the occurrence of a denitrification sequence (Thomann & Mueller, 1987), under anaerobic conditions in sediment of shallow wetlands, where nitrate in the water column diffuses to interstitial water in sediment causing a loss of nitrate from the water column; and higher levels of phosphorus observed in the flow are a by-product of low dissolved oxygen in upstream wetlands and not a cause of low dissolved oxygen in downstream stream reaches
- Ammonia levels in the stream flow under the critical conditions are not sufficient enough to contribute to low dissolved oxygen
- There is not a strong positive relationship between nutrient loadings or flow-weighted mean concentrations and the percentage of dissolved oxygen standard violations observed at the downstream WOMP station

Based on this evaluation, development of a TMDL for nutrients or oxygen demanding substances would not be appropriate for improving dissolved oxygen conditions in Nine Mile Creek.

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Appendix A

Summary Table of System for Scoring Types of Evidence

Table A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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 A-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.	-