Bluff Creek TMDL

Biological Stressor Identification

Prepared for
City of Chanhassen and
Minnesota Pollution Control Agency

March 2010

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1.0 Introduction

In 2004, Bluff 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).

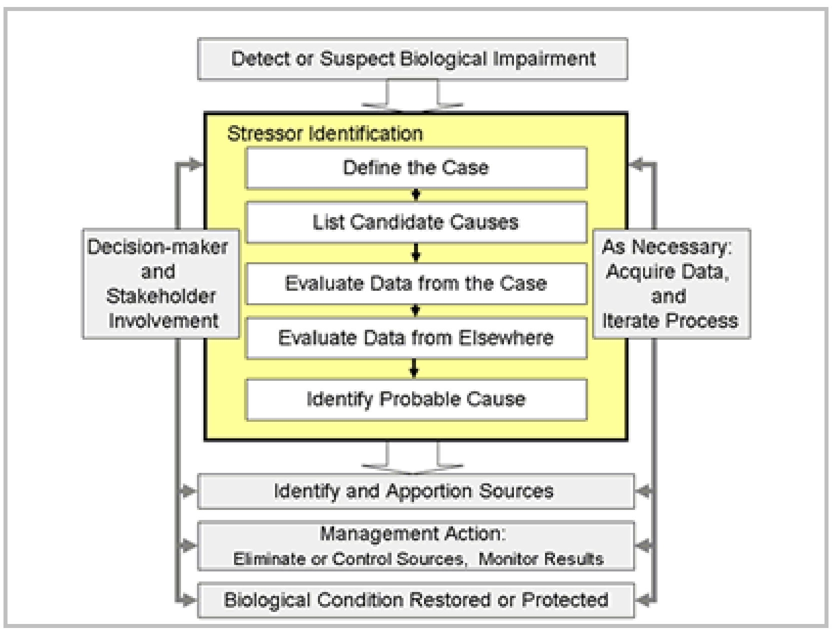

Figure 1 Stressor Identification Process

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 Bluff Creek.

2.0 Background

Bluff Creek is a small tributary of the Lower Minnesota River. The stream begins at the headwaters located near Trunk Highway 41 on the north and discharges into the Minnesota River Floodplain (Figure 2). The catchment area at the outlet of Bluff Creek in Rice Lake is 6.4 square miles, the total length of the main stem is 7.5 miles, the mean streamwise slope varies between 0.08 percent and 0.70 percent, and the creek is moderate to fully entrenched for most of its course (Riley-Purgatory-Bluff Creek Watershed District, 1996). The watershed land use of the upper reaches is comprised of a mix of forested upland and meadow. The middle reach notes a mix of land uses and is rapidly urbanizing. The lower reach notes steep valley walls, is highly sinuous, and lined with trees. About 85 percent of the catchment is covered by high-relief, hummocky glacial deposits of loamy till, with some localized organic deposits of muck. It is worth mentioning that Lusardi (1997) delineated discontinuous scarps along the relatively flat middle reach referred to above. These scarps could be tracking a former (in geologic time scale), relatively wide fluvial channel, which presumably has been filled with sediment from the adjacent highly-erodible upland areas that the creek has not had the capacity to transport downstream. The remaining lower 15 percent of the catchment is covered by low-relief glacial deposits of loamy till in the upland areas, where the stream corridor is covered by more recent slopewash deposits of sand and gravel material (Barr, 2006c).

Three historic periods can be distinguished based on land use in the Bluff Creek watershed. The first corresponds to pre-European settlement, until the 1850s. Big woods of maple-basswood forest and oak savanna extended across the watershed, and native prairie plants composed the understory vegetation. Magner and Steffen (2001) argue that some stable degree of morphologic equilibrium had been reached in the Minnesota River and tributaries prior to plowing of the prairie. The second period was dominated by the introduction and intensification of agricultural practices, beginning in the 1900s. Consistent with Zimmerman et al. (1993), it is reasonable to hypothesize that as more water and sediment reached the stream, the channel morphology evolved toward a new equilibrium configuration, which may or may not have been attained; cultivation patterns have been switching from field to row crops. The last period corresponds to urban sprawl, beginning in the 1980s. A preliminary analysis of LandSat imagery indicates that the mean percent imperviousness in the Bluff Creek watershed has jumped from 3 percent in 1986 to 15 percent in 2002, with the highest percentage increase between 1991 and 1998. This urban development, which is expected to continue progressing at a rapid pace in the next twenty years, has likely generated another change in the

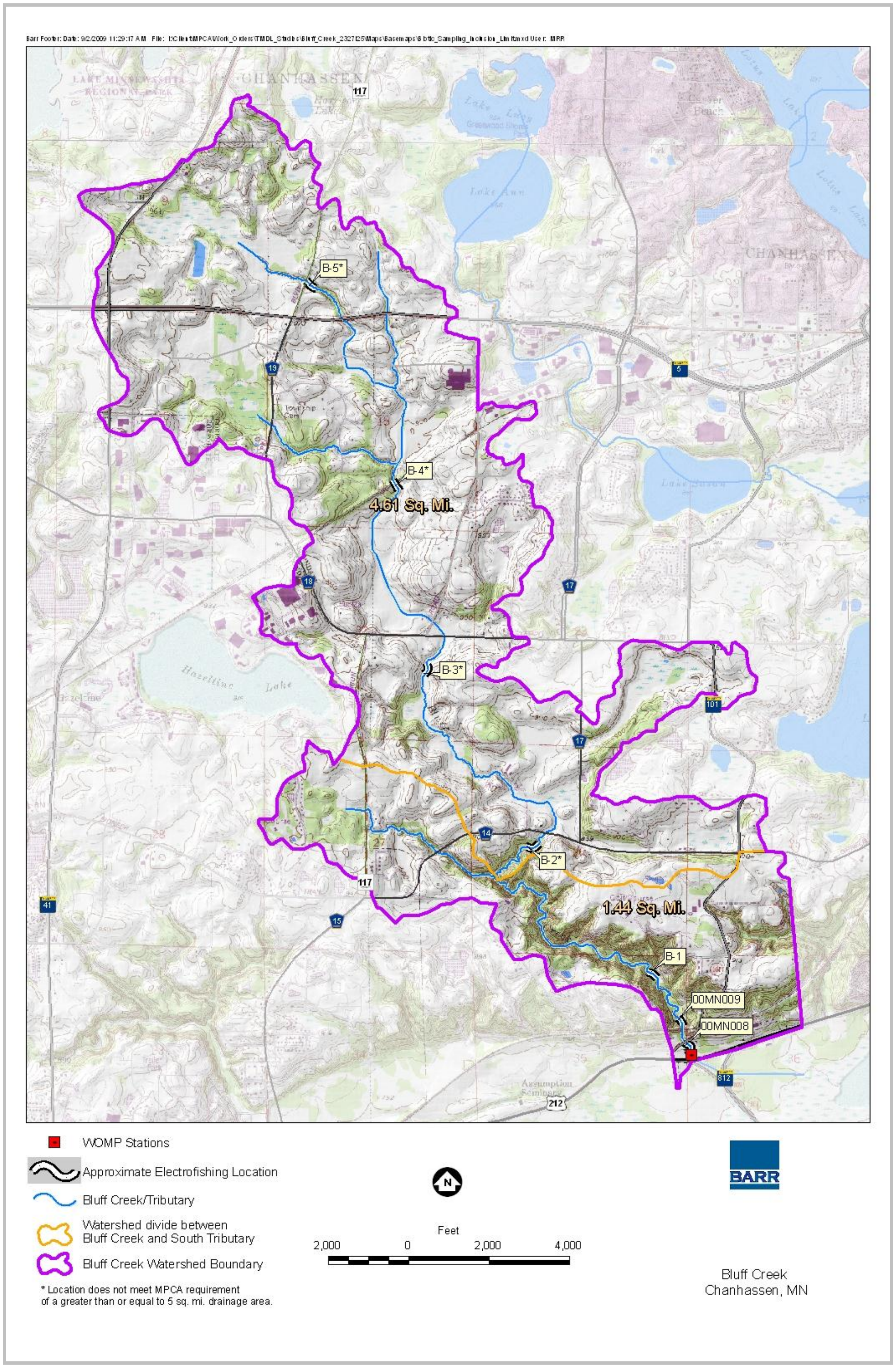

Figure 2 Biological Sample Locations—Bluff Creek TMDL Study

hydrologic and sediment supply boundary conditions of the stream, hence the channel has again begun working toward a new morphologic equilibrium.

With the introduction of agricultural practices at the turn of the last century and later intensification in the Bluff Creek watershed, more sediment and more water reached the stream. The United States Army Corps of Engineers (2004) point out that the prairie and forest vegetation helped to hold soils in place. Moreover, larger evapotranspiration losses and a lower drainage density predicts less volume runoff and smaller peak flows before than after plowing of the prairie. The increase in sediment supply from the upland areas to the stream must have been particularly important after row crop cultivation became more dominant in the watershed, beginning in the 1950s. It is not clear whether the longitudinal profile of Bluff Creek was subject to overall bed aggradation; the increase in sediment supply may or may not have been compensated by the increase in frequency, magnitude, and duration of water discharges above the threshold for fluvial motion of bed material. It is reasonable to expect, however, that the increase in sediment supply caused localized bed aggradation, probably more pronounced in the middle reaches of the creek where the streamwise bed slope is less steep and therefore the sediment transport capacity is smaller, as well as an increase in stream sinuosity, especially in the downstream reach of the creek (Barr, 2006c).

It can be assumed that urban development has produced an even bigger increase in frequency, magnitude, and duration of competent flows, so the positive trend continues. But contrary to what happened until the 1980s, the amount of sediment delivered from the upland areas of the watershed to the stream must have decreased; there is less surface area in the watershed that can be eroded. Put simply, urban sprawl generates more water and less sediment. Nonetheless, ravine erosion in the highly erodible watershed has increased causing the conveyance of substantial loads of sediment to the stream. The anticipated morphodynamic response to the additional water from urbanization is the overall promotion of channel incision combined with a bigger probability of streambank erosion due to mass-wasting failures, rather than increased fluvial erosion of the channel banks or greater channel migration rates; the ratio of floodprone width to bankfull width is about two for most of the water course. It is not clear whether this in-stream sediment contribution results in an increased sediment transport conveyance along the creek, or if the sediment is deposited within a few feet downstream from its source. Lauer et al. (2006) indicate that eroding banks usually do not contribute sediment such that a net increase in sediment results from the eroding banks on most single-thread rivers, because the channel usually rebuilds a new bank on the opposite side of the channel from the eroding bank. In this regard, point bars are observed in Bluff Creek (Barr, 2006c).

A 2007 inventory of Bluff Creek indicated ravine erosion contributes significant quantities of sediment to Bluff Creek annually. Ravine erosion, for the most part, is occurring independently of Bluff Creek, and is due to overland stormwater runoff and/or groundwater seepage. The majority of the ravines with severe or moderate erosion are located between Stations B-1 and B-2 (Figure 2). Much of the stream itself was observed to be stable, although some reaches of downcutting and bank erosion were observed. Nonetheless, ravine erosion within the watershed results in sediment delivery to Bluff Creek and a corresponding degradation of biological habitat.

Ravine erosion in the Bluff Creek watershed, pictured above, delivers sediment to the stream which degrades biological habitat.

3.0 Define the Impairment

3.1 The Biological Impairment and Its Basis

In 2002, Bluff Creek was listed on the 303(d) list of impaired waters for elevated turbidity levels measured at the Metropolitan Council Environmental Services (MCES) Watershed Outlet Monitoring Program (WOMP) station located on the main stem of the creek downstream of Highway 212. In 2004, Bluff 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 Biological Integrity (IBI) scores. For the Minnesota River Basin, biological impairment for fish is defined as failing to meet the MRAP IBI impairment threshold score of 30 or greater out of a possible score of 60. Only streams with a watershed area of at least 5 square miles are obligated to meet the MRAP IBI impairment threshold.

Bluff Creek fish data collected by the Minnesota Department of Natural Resources (MDNR) and the Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) were evaluated to determine the reaches of Bluff Creek that are considered to have impaired fish assemblages (Appendix A). Data were collected by the Minnesota Department of Natural Resources (MDNR) from two locations on July 22, 2000 as a part of a survey to characterize Twin Cities Metro Area streams. Both locations noted a tributary watershed area greater than 5 square miles and, hence, both locations are obligated to meet the state IBI impairment threshold of 30 or greater. Station 00MN009 (Figure 2) noted an IBI score of 21.6, which is below the impairment threshold of 30 or greater, and Station 00MN008 (Figure 2) noted an IBI score of 31.2, which is above the impairment threshold of 30 or greater (MDNR, 2000). The data (Figure 3) indicate the stream was impaired at the upstream location (00MN009), but was not impaired at the downstream location (00MN008).

When the differences in data between the upstream and downstream locations are compared with results of a recent study completed by the University of Minnesota (Dolph et al. 2010), the significance of the differences becomes questionable. Dolph et al. (2010) found swings in IBI scores of small streams in the St. Croix basin to be roughly 20 points and slightly more for small streams in the Upper Mississippi River basin. They (Dolph et al. 2010) also note that greater variability of IBI scores are found at sites that fail to capture more than 500 fish. Because Bluff Creek is a small stream and less than 500 fish were captured in surveys, the differences found in the 2000 survey may not be consistently repeated in future surveys due to variability. Although the data indicate the downstream site was impaired and the upstream site was not impaired, the possibility that the score differences may not be significant is also acknowledged.

Data were annually collected by RPBCWD from Station B-1 (Figure 2) during 1997 through 2006 to determine the stream's fish assemblage and also to determine whether the District's ecological use goals for the stream had been attained. Because Station B-1 notes a tributary watershed area greater than 5 square miles, this location is obligated to meet the state IBI impairment criteria. No fish were observed or collected during the 1997 and 1998 monitoring events, indicating severe impairment. During 1999 through 2006, IBI scores at B-1 were consistently 16.8 (Figure 3) and were below the impairment threshold during all 8 sampling years (Barr, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006a, and 2006b).

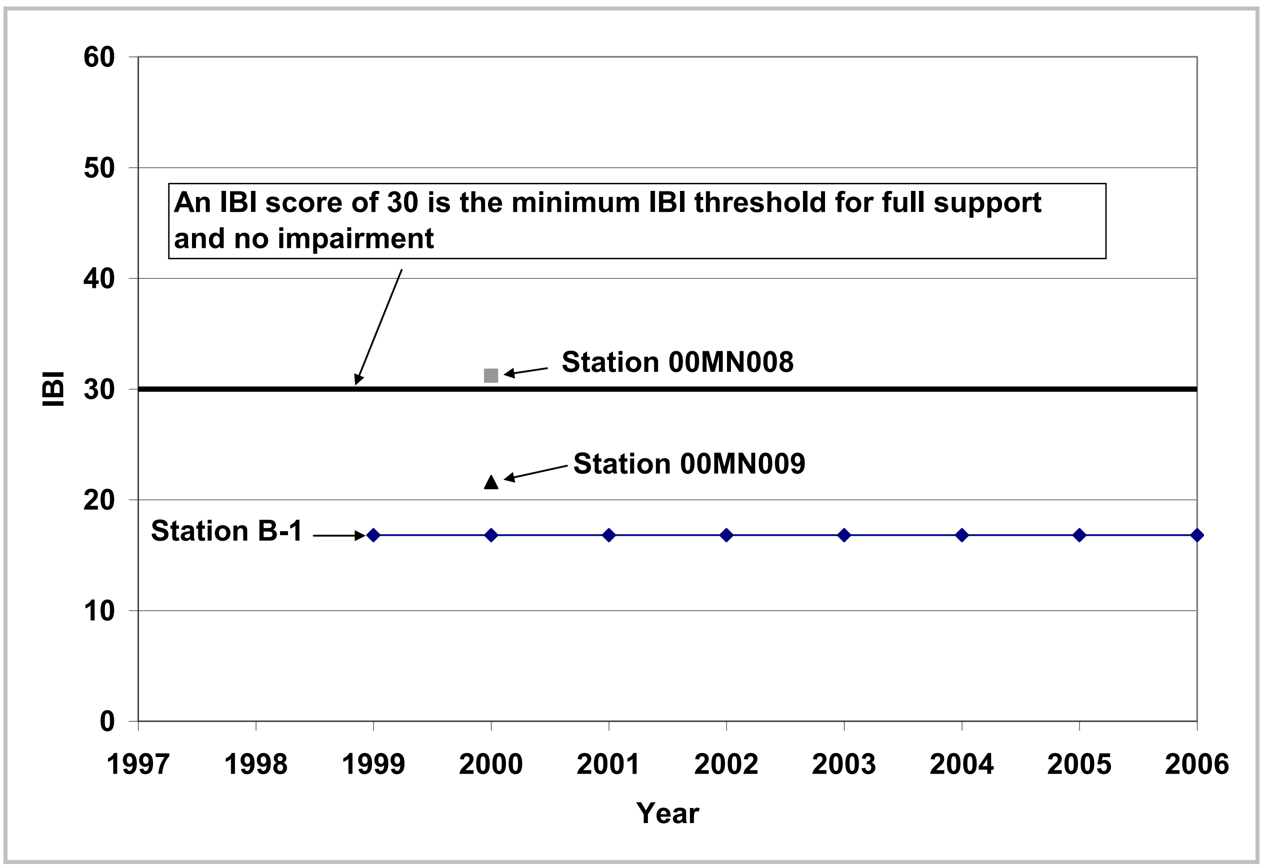

Figure 3 1999-2006 Bluff Creek IBI Summary—Stations B-1, 00MN008, and 00MN009

The consistent scores occurred at B-1 because only one or two species of fish were present each year. Brook stickleback was consistently present and northern fathead minnow co-occurred during about half of the events. B-1 noted a score of 16.8 and 00MN009 noted a score of 21.6 during 2000—both were impaired.

Data collected by RPBCWD at additional upstream locations aid in the understanding of the stream's impairment and the stressors causing the biological impairment. RPBCWD annually collected data from four stations upstream of Station B-1 to determine the stream's fish assemblage and to determine whether the District's ecological use goals for the stream had been attained. Since the watershed tributary to these locations is less than 5 square miles, they are neither expected nor obligated to attain the fish IBI impairment threshold of 30 or greater. However, data from these locations are considered in the Stressor Identification to help attain an understanding of the Bluff Creek fish community and to identify stressors preventing attainment of the IBI impairment threshold score of 30 or greater in downstream stream reaches. Data collected from upstream Stations B-2 through B-5 (Figure 2) during 1997 through 2006 noted IBI scores ranging from 12 through 38.4 (Figure 4) (Barr, 1998, 1999, 2001, 2002, 2003, 2004, 2005, 2006a). Stations with IBI scores greater than 30 noted more native species, more minnow species, and more intolerant species as well as fewer tolerant species than locations with IBI scores less than 30.

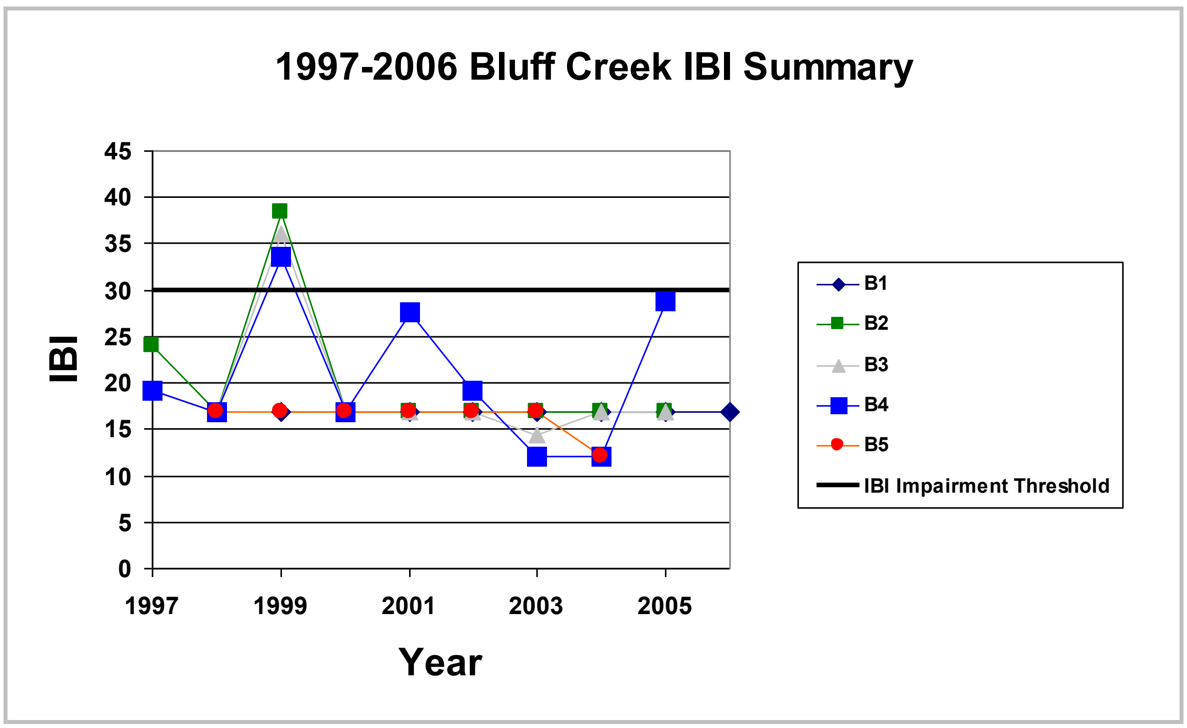

Figure 4 1997-2006 Bluff Creek IBI Summary—Stations B1-B5

Flow and IBI scores during 1997 through 2005 were evaluated to determine whether changing IBI scores were associated with changing flows. The absence of fish at B-1 and reduced IBI scores at other Bluff Creek locations during 1997 through 1998 were associated with increased flows while improved IBI scores at all Bluff Creek locations during 1999 were associated with decreased flows (Figures 4 and 5). 1999 flows were, on average, lower than flows during other years (Figure 5). The association of poorer IBI scores with increased flows and improved IBI scores with reduced flows may be associated with changes in sediment loads to Bluff Creek. During years when increased precipitation resulted in increased flows (e.g., 2002, See Figure 6), increased ravine erosion in the watershed and increased sediment delivery to Bluff Creek are expected to occur. Conversely, during years when reduced precipitation results in lower flows (e.g., 1999, See Figure 6), reduced ravine erosion in the watershed and reduced sediment delivery to Bluff Creek are expected to occur. Habitat fragmentation (i.e, the large drop at the downstream end of the regional trail culvert) further exacerbates the impact of high flows on the fish at B-1 and is believed to play a role in the absence of fish observed during 1997 and 1998. Discharge at the WOMP Station (Figure 2) reached 2,476 cfs on April 13, 1997. It appears that when the high flows of 1997 moved fish downstream, habitat fragmentation prevented the replenishing of the B-1 fish community and fish were absent from this location.

3.2 Specific Effects

The IBI was disaggregated and macroinvertebrate data were assessed to identify more specific effects that appeared to indicate distinctive impairment mechanisms (See Tables 1 through 3; Fish data in Appendix A; Invertebrate data in Appendix E). Specific effects associated with the impairment observed at Stations B-1 and 00MN009 include a low number of native fish species, a high relative abundance of the two most dominant invertebrate taxa, an absence of intolerant invertebrates, and an absence of darters, insectivores, and simple lithophilic spawners. The data indicate environmental degradation has occurred in the impaired reach. The absence of darters and simple lithophilic spawners indicate the impaired stream reach may have habitat deficiencies due to siltation of coarse substrates and excessive sedimentation or due to cold water temperatures. The absence of darters may also indicate a loss of channel complexity from channelization. Because the downstream unimpaired location noted darters, the data either indicate siltation of coarse substrates is not problematic at the downstream location, the downstream channel is more complex, or that another stressor (e.g., habitat fragmentation between the two locations) is the driving force in the fish assemblage.

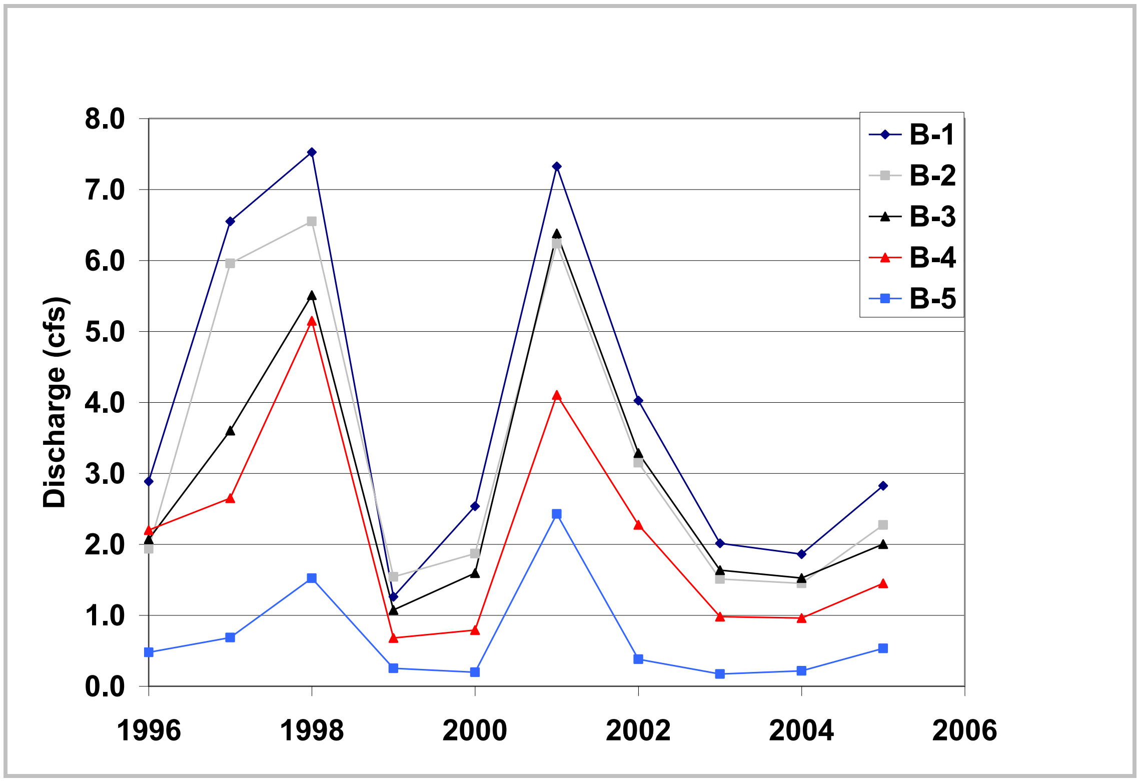

Figure 5 1996-2005 Bluff Creek Average Discharge at Stations B-1, B-2, B-3, B-4, and B-5

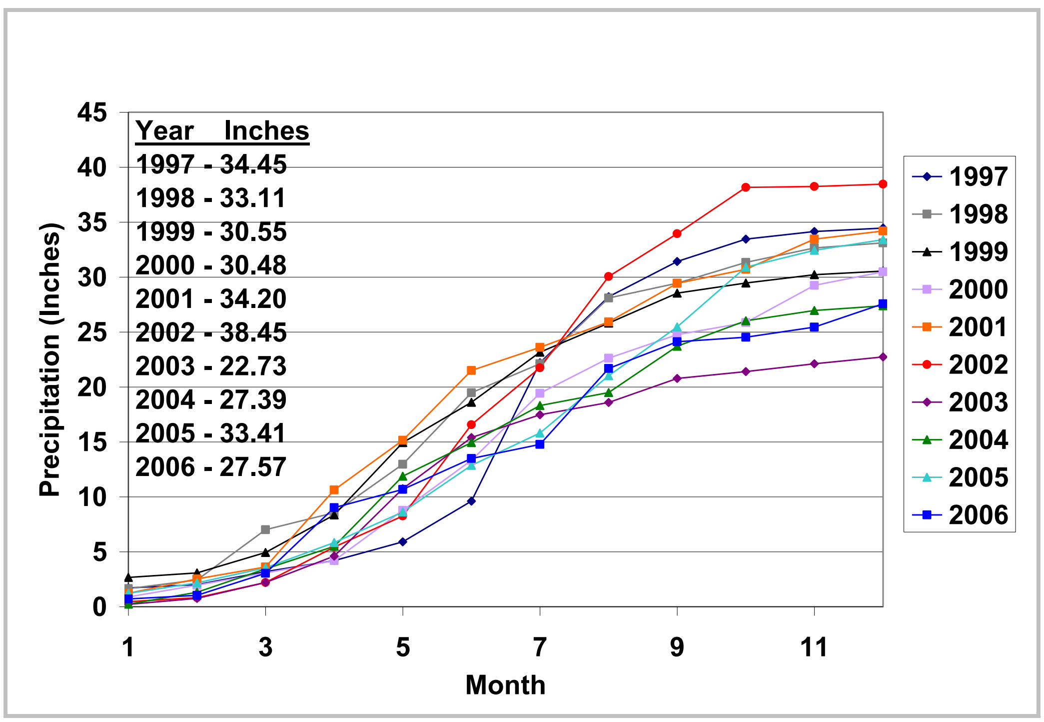

Figure 6 1997-2006 Minneapolis/St. Paul Cumulative Precipitation (Monthly Time Step)

Table 1 1999-2006 Evaluation of Bluff Creek Biological Attributes: B-1

Parameter	1999	2000	2001	2002	2003	2004	2005	2006
Species Richness and Composition								
# of Native Fish Species	1	1	2	2	1	2	1	2
# of Darter Fish Species	0	0	0	0	0	0	0	0
% Dominant 2 Invertebrate Taxa	72	91	96	73	82	85	85	--
# of Ephemeroptera, Plecoptera, and Trichoptera (EPT) Taxa	5	3	5	10	8	6	6	--
Trophic Composition and Reproductive Function								
% Simple Lithophils (Fish)	0	0	0	0	0	0	0	0
% Omnivores (Fish)	0	0	33	14	0	6	0	30
Number of Filterer Invertebrate Taxa*	3	2	1	7	4	2	3	--
Abundance and Condition								
% Deformities, Eroded Fins, Lesions, and Tumors (DELT) Fish	0	0	0	0	0	0	0	0
Tolerance Measures								
Number of Intolerant Invertebrate Taxa	0	0	0	0	0	0	0	--
Percent Tolerant Invertebrate Taxa	0.2	0	0.2	0.5	0	0	1.7	--
Habitat Measures								
# of Clinger Invertebrate Taxa**	4	3	4	10	9	7	8	--

*Blackflies and net spinning caddisflies

**Heptageniid mayflies, blackflies, craneflies, net spinning caddisflies, case building caddisflies, and Elmidae beetles

Table 2 2000 Evaluation of Bluff Creek Biological Attributes: 00MN008 and 00MN009

Parameter	00MN008	00MN009
Species Richness and Composition		
# of Native Fish Species	4	2
# of Darter Fish Species	1	0
% Dominant 2 Invertebrate Taxa	NA	NA
# of Ephemeroptera, Plecoptera, and Trichoptera, (EPT) Taxa	NA	NA
Trophic Composition and Reproductive Function		
% Simple Lithophils (Fish)	0	0
% Omnivores (Fish)	28	8
Number of Filterer Invertebrate Taxa	NA	NA
Abundance and Condition		
% Deformities, Eroded Fins, Lesions, and Tumors (DELT) Fish	0	0
Tolerance Measures		
Number of Intolerant Invertebrate Taxa	NA	NA
Percent Tolerant Invertebrate Taxa	NA	NA
Habitat Measures		
# of Clinger Invertebrate Taxa	NA	NA

Table 3 Bluff Creek Average IBI Metric Scores

Site Metric	Site Metric Description	Score B-1 1999-2006 Averages	Score MN00MN008 2000	Score 00MN009 2000
1	*Total # of native species*	1	3	1
2	*# of darter species*	1	3	1
3	*# of sunfish species**			
4	*# of minnow species***	1	3	1
5	*# of intolerant species*	1	3	1
6	*% of tolerant individuals*	1	3	5
7	*% of individuals omnivores*	1	3	5
8	*% of individuals insectivores*	1	1	1
9	*% of top carnivores**			
10	*Catch per unit effort by gear type*	1	5	1
11	*% of individuals simple lithophils*	1	1	1
12	*% of individuals w/ DELT*	5	1	1
SITE IBI AVG. TOTAL	raw	14	26	18
	adjusted**	16.8	31.2	21.6

*excluded as per Bailey, et al (1992) for sites < 100 square miles
**IBI score adjusted for exclusion of 2 metrics. Score x 1.2 = total site score

3.3 The Investigation's Purpose

The purpose of the investigation is to identify the stressors causing the stream's biological impairment. The investigation results will be used in the TMDL study to identify measures to attain resolution to the impairment.

3.4 The Geographic Area Under Investigation

Bluff Creek is located in Carver County near Chanhassen. The stream is tributary to the Minnesota River. The investigation will be limited to identifying the probable cause of the biological impairment from Station B-1 to 00MN008 (See Figure 2). Upstream sites B-2 through B-5 will be evaluated during the investigation to help understand the Bluff Creek fish assemblage and to aid in identifying stressors in the impaired downstream reach. However, this upstream portion of the stream is not obligated to meet the IBI impairment threshold due to the small size of the tributary watershed. The stream reach from 00MN008 to Rice Lake does not appear to be impaired per the 2000 MDNR data, but additional data collection is recommended to confirm this reach currently meets the IBI impairment threshold.

4.0 Candidate Causes of Biological Impairment

This section begins by looking at possible candidate causes of the biological impairment of Bluff Creek. Initially, we looked at all common candidate causes listed in CADDIS. Data were then used to either validate or eliminate candidate causes. Candidate causes that were eliminated are discussed followed by a discussion of candidate causes that were validated by the data.

4.1 Eliminated Candidate Causes

4.1.1 Presence of Toxics

Presence of toxics was eliminated as a stressor because data indicate it is unlikely that toxics are present in Bluff Creek. A component (metric) of the fish IBI can be used as an indicator of acute toxicity. Decreases in the DELT (Deformities, Eroded Fins, Lesions, and Tumors) component of the IBI are often associated with environmental degradation due to industrial pollutants. In the Bluff Creek watershed, the seven monitoring sites (Figure 2) generally received a DELT score of 5 out of 5 throughout the monitoring period, indicating little possibility of the presence of toxic chemicals (Barr, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006a, 2006b).

The invertebrate community provides a second indicator of the presence of toxics. A comparison of invertebrate metric values that indicate the presence of toxic chemicals with Bluff Creek values for these metrics indicates little possibility of the presence of toxic chemicals in Bluff Creek (Table 4).

Table 4 Invertebrate Metrics Indicating Presence of Toxic Chemicals and 1999-2005 Bluff Creek Values—B-1

Invertebrate Metric	Values That Indicate Presence of Toxic Chemicals*	1999-2005 Bluff Creek Values—B-1
ICI** Median and 75th Percentile Values	<14 to 18	23.4 to 31.2
EPT*** Median and 75th Percentile Values	<2 to 4	6 to 7.5

*Yoder et al., 1995

**ICI is the Invertebrate Community Index

***EPT is Ephemeroptera, Plecoptera, and Trichoptera

4.1.2 Low Dissolved Oxygen

Low dissolved oxygen was eliminated as a stressor because water quality and biological data indicate it is unlikely that low oxygen levels are present in Bluff Creek. Dissolved oxygen measurements were collected from Station B-1 during 1991 through 2005 by the RPBCWD and from the WOMP Station during 2003 through 2008 by MCES. The data consistently met the MPCA impairment threshold of 5 mg/L and indicate that adequate oxygen was consistently present in the stream to fully support all forms of aquatic life (Figure 7).

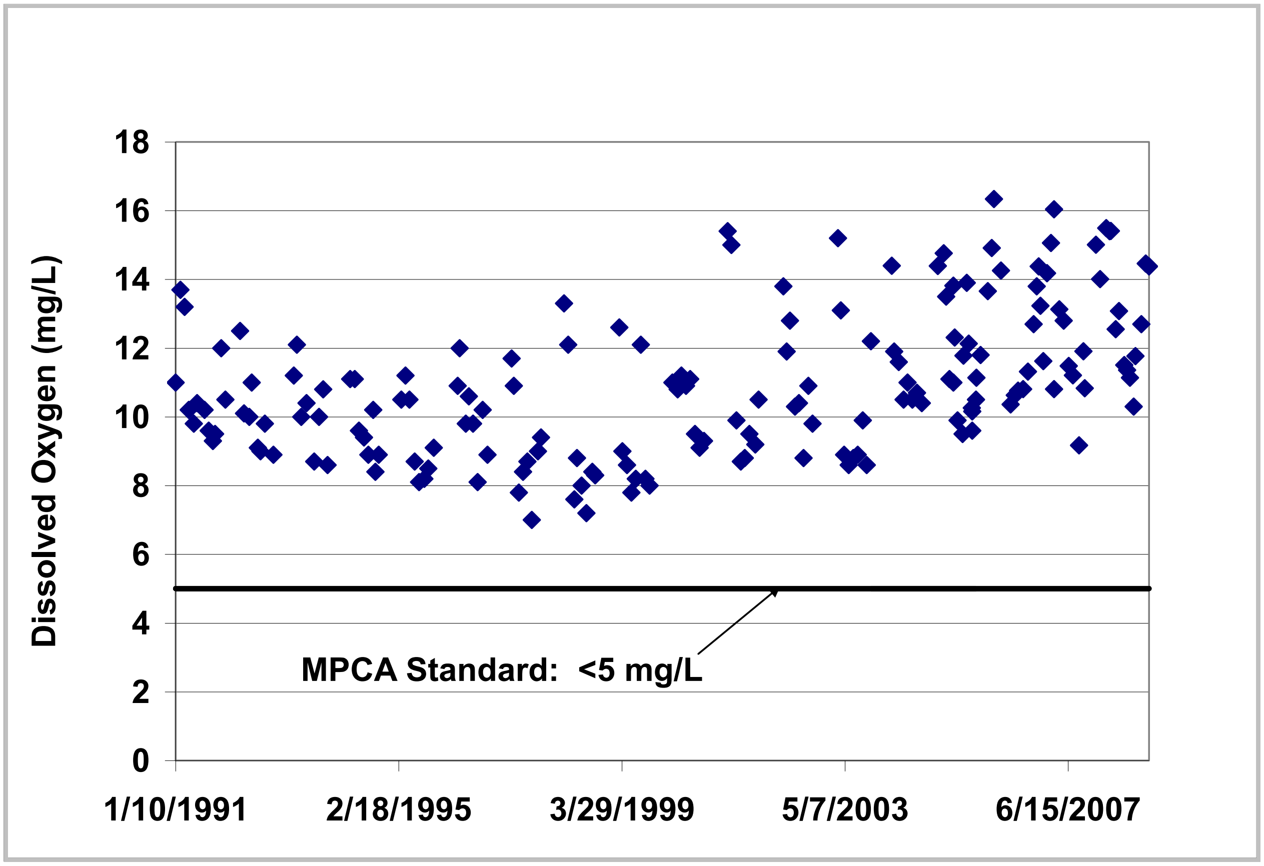

Figure 7 1991-2008 Bluff Creek Dissolved Oxygen Data: B-1 and WOMP Stations

Dissolved oxygen was measured continuously (i.e., at 15-minute intervals) at the WOMP station (Location shown in Figure 2) during September 9 through September 29, 2008. Daily maximum, average, and minimum values shown in Figure 8 were consistently higher than the MPCA standard of at least 5 mg/L. The data indicate adequate dissolved oxygen was consistently present in the stream to fully support all forms of aquatic life.

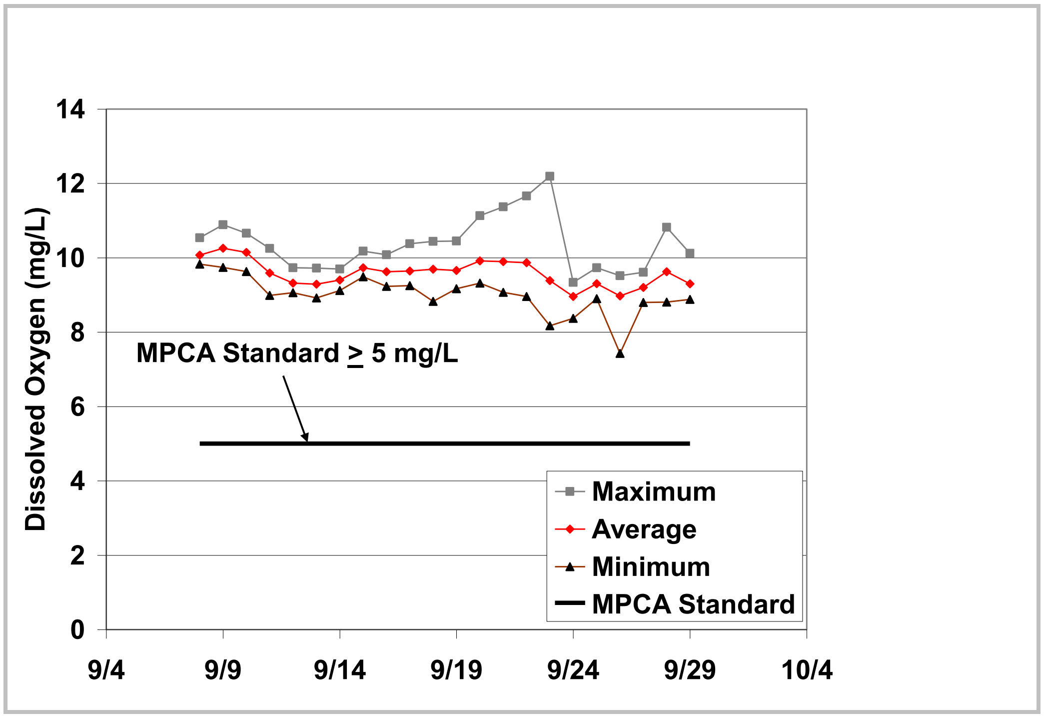

Figure 8 2008 Bluff Creek Daily Maximum, Average, and Minimum Dissolved Oxygen Concentrations at the Highway 212 WOMP Station

Continuous dissolved oxygen measurements were made at an upstream location, Pioneer Trail, during July 18 through November 17, 2008. Dissolved oxygen concentrations at Pioneer Trail were generally greater than 5 mg/L, but approximately 2 percent of the measurements were less than 5 mg/l due to diel changes (Figure 9). Plants in Bluff 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 changes in Bluff Creek depressed the stream's oxygen level below 5 mg/L approximately 2 percent of the time and depressed the stream's oxygen level below 4 mg/L approximately 0.2 percent of the time. The data do not indicate impairment to the stream based upon criteria currently under consideration by the MPCA for assessing/listing waters impairment due to depressed dissolved oxygen:

> *"A stream is considered impaired if 1) more than 10 percent of the "suitable" (taken before 9 am) May through September measurements, or more than 10 percent of the total May through September measurements, or more than 10 percent of the October through April measurements violate the standard and 2) there are at least 3 total violations. A designation of "full support" requires at least 20 "suitable" measurements from a set of monitoring data that adequately represents at least two overall monitoring seasons"* (MPCA, 2009a).

Concentrations at the downstream Highway 212 location were consistently higher than concentrations at Pioneer Trail during the September 9 through September 29 period (Figure 9). The data indicate the stream becomes more oxygenated as it flows downstream.

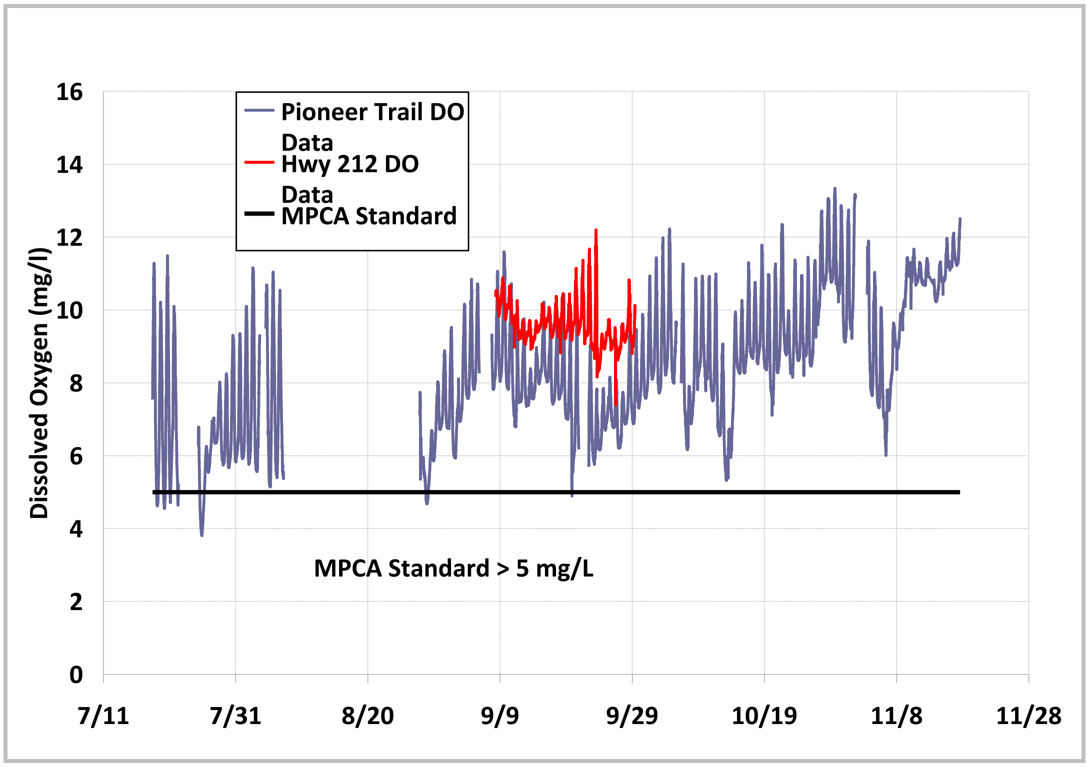

Figure 9 2008 Bluff Creek Continuous Dissolved Oxygen Concentrations at Pioneer Trail and Highway 212

Macroinvertebrate data provide further confirming evidence that adequate levels of oxygen have consistently occurred in Bluff Creek. The macroinvertebrate community is exposed to the temporal variations in stream water quality and "integrate" the quality of passing water. As such, they provide evidence of long-term impacts of the stream's water quality. Biotic indices, such as Hilsenhoff's Biotic Index (HBI) identify problems with low dissolved oxygen in streams. The HBI was used to evaluate macroinvertebrate data collected from Station B-1 (Figure 2) during 1992 through 2005. The HBI is a measure of organic and nutrient pollution, which causes lower dissolved oxygen levels, especially at night, during the summer, and after a heavy rain (Hilsenhoff, 1982). Lower levels of dissolved oxygen in turn affect the ability of each species of arthropod (i.e., aquatic insects, amphipods, and isopods) to survive in a particular stream. As shown in Figure 10, HBI values during 1995 through 2005 were relatively consistent and ranged from 4.1 to 4.5 on a scale of 1 to 10 (1 indicates organisms with lowest tolerance to low oxygen conditions and 10 indicates organisms with highest tolerance to low oxygen conditions) (Barr, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006). On average, the invertebrate species living within Bluff Creek are very sensitive to reductions in dissolved oxygen concentrations and would be eliminated if low oxygen conditions were to occur in the stream. The data indicate little possibility that low oxygen concentrations have been present in Bluff Creek during the period of record.

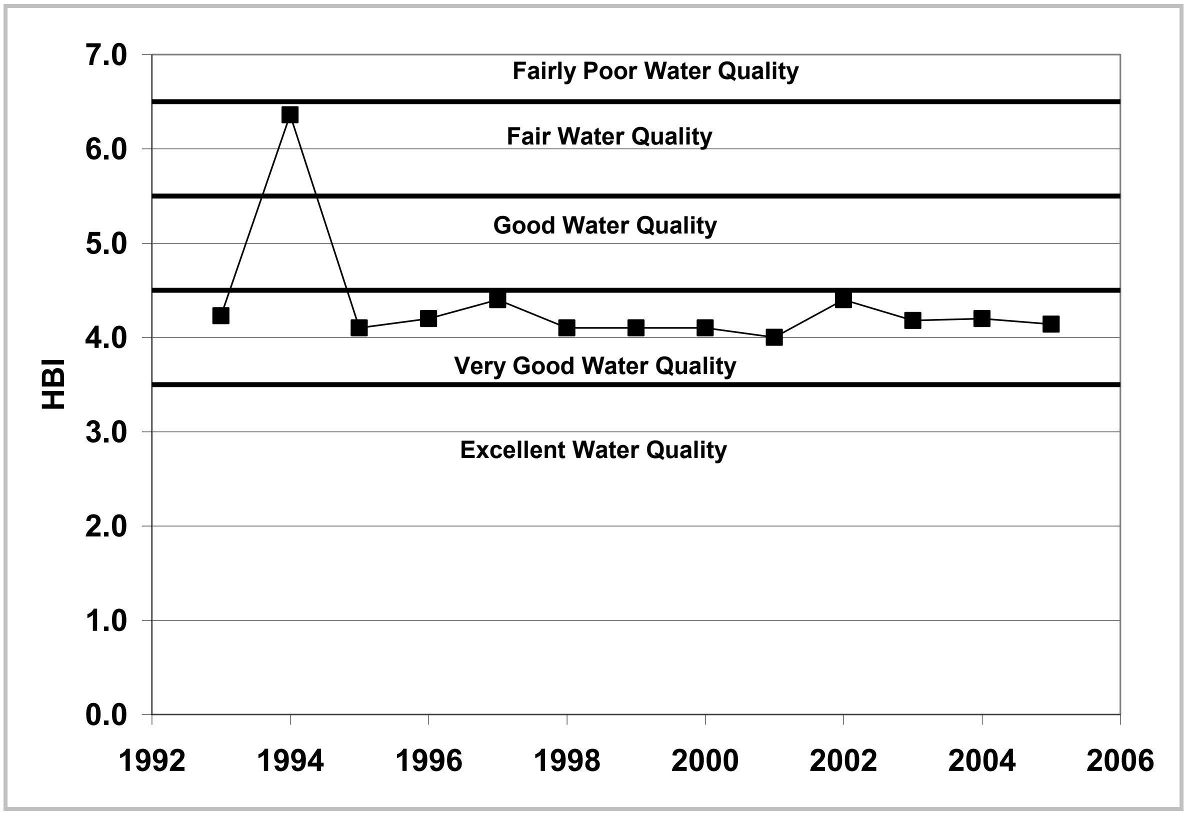

Figure 10 1992-2005 Bluff Creek Macroinvertebrates: HBI Summary of B-1

4.1.3 pH

pH was eliminated as a candidate stressor because data indicate the pH range observed in Bluff Creek consistently supports all aquatic life. Metropolitan Council Environmental Services (MCES) measured pH at the WOMP station (Figure 2) during 1993 through 2008. Mean pH during the period of record was 8.0. Measurements during the period of record were within the MPCA standard which protects all aquatic life (Figure 11).

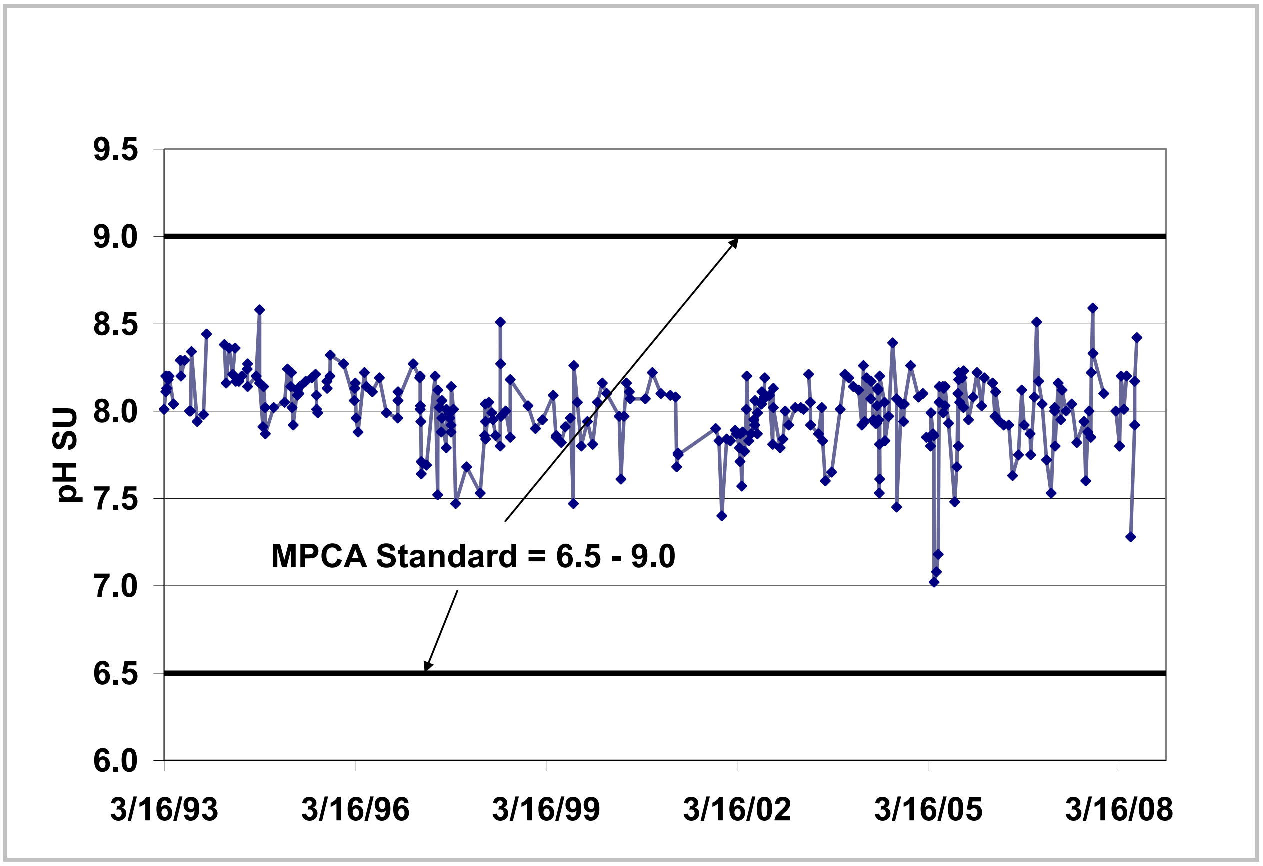

Figure 11 1993-2008 Bluff Creek pH Data: WOMP Station

4.1.4 Nutrients

Although high nutrient concentrations have been observed in Bluff Creek, nutrients are eliminated as a stressor because the data indicate their presence in the stream has not stressed the biological community. High nutrient loadings entering a stream can accelerate primary production and increase biological activities. When excess plants and algae result from the high nutrients, oxygen depletion problems may result when the plants and algae die. Bacteria decomposing the plant tissue deplete dissolved oxygen and at the same time release nutrients into the water column resulting in oxygen poor conditions for aquatic life and a nutrient rich environment which fuels additional plant and algae growth. Since excess plant growth and depleted oxygen levels have not been observed in Bluff Creek (Figures 7 through 9), the data indicate high nutrient concentrations have not caused biological impairment. The invertebrates inhabiting Bluff Creek are sensitive to low oxygen levels (Figure 10) and would be eliminated by depleted oxygen levels. Invertebrate data provide further evidence that excess nutrient loading to Bluff Creek has not caused stressful low oxygen levels.

Although high nutrient concentrations in Bluff Creek have not stressed the biological community, their presence is an indication of anthropogenic impacts upon the stream. Phosphorus (total and total dissolved) and nitrogen (total Kjeldahl, ammonia, nitrate, and nitrite) concentrations were measured in Bluff Creek by MCES at the WOMP station (Figure 2) during 1993 through 2008. The data indicate that high nutrient concentrations have been observed in Bluff Creek. Likely sources of the high phosphorus and nitrogen concentrations observed in the stream are snowmelt and stormwater runoff (Figures 12 through 17). High nutrient concentrations included both dissolved and particulate nutrients and were generally accompanied by high total suspended solids and turbidity levels. Although the nutrients have not stressed the biological community, the sediment concurrently added to Bluff Creek with the nutrients is a stressor discussed in a later section.

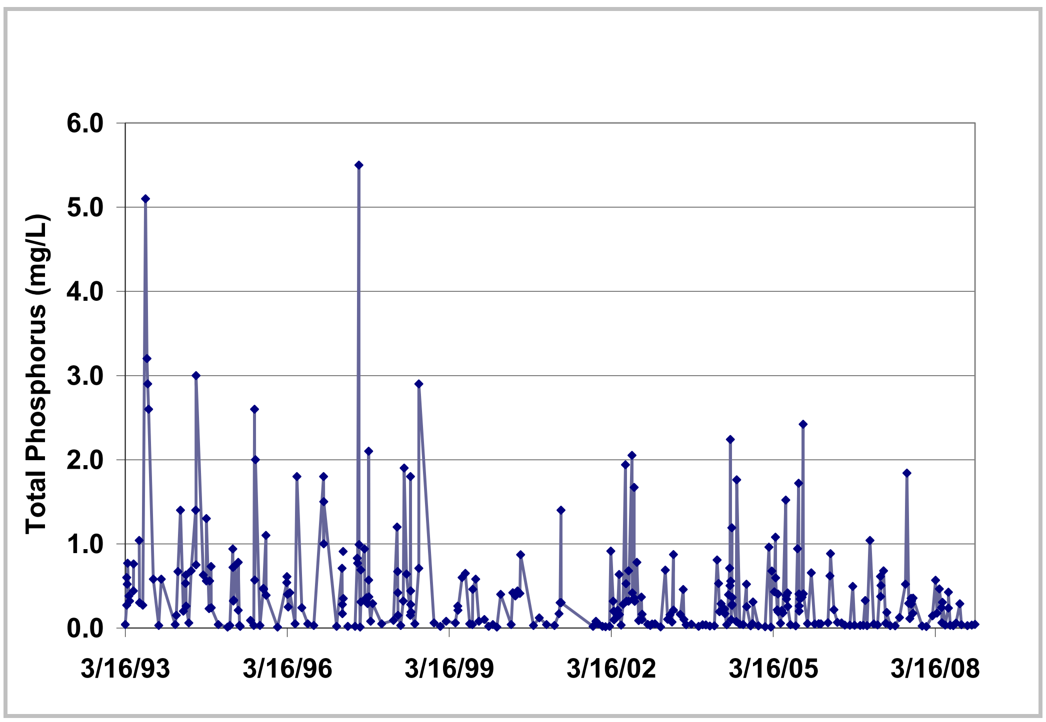

Figure 12 1993-2008 Bluff Creek Total Phosphorus: WOMP Station

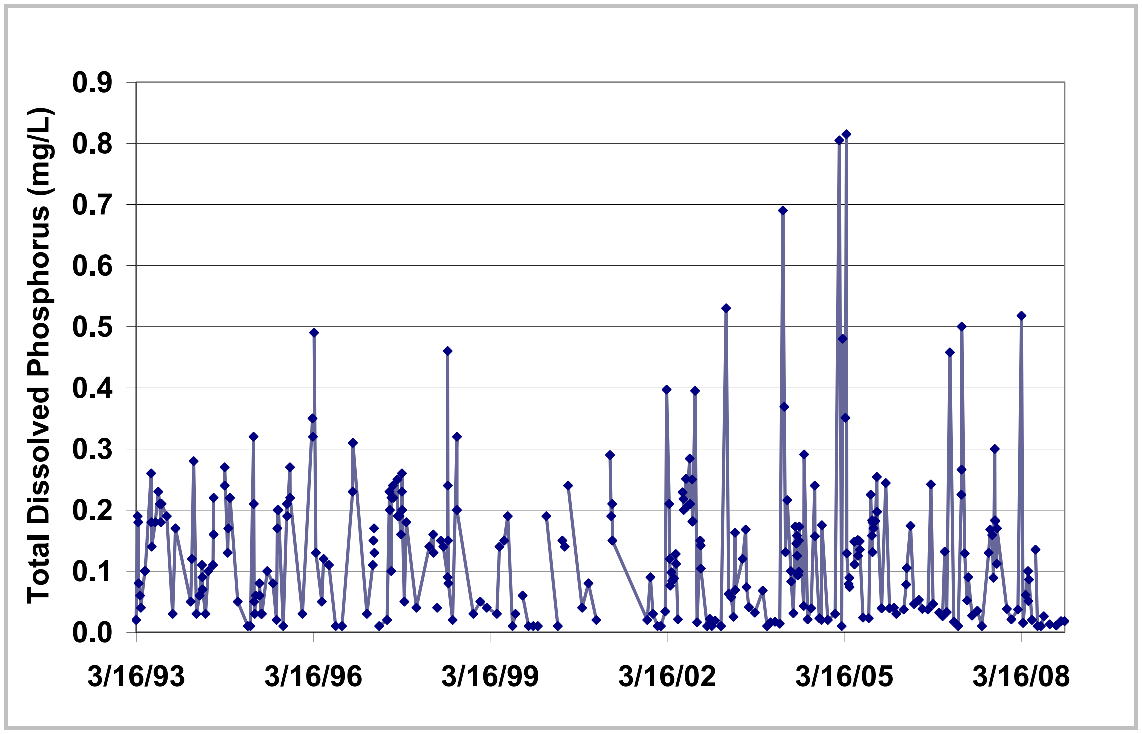

Figure 13 1993-2008 Bluff Creek Total Dissolved Phosphorus: WOMP Station

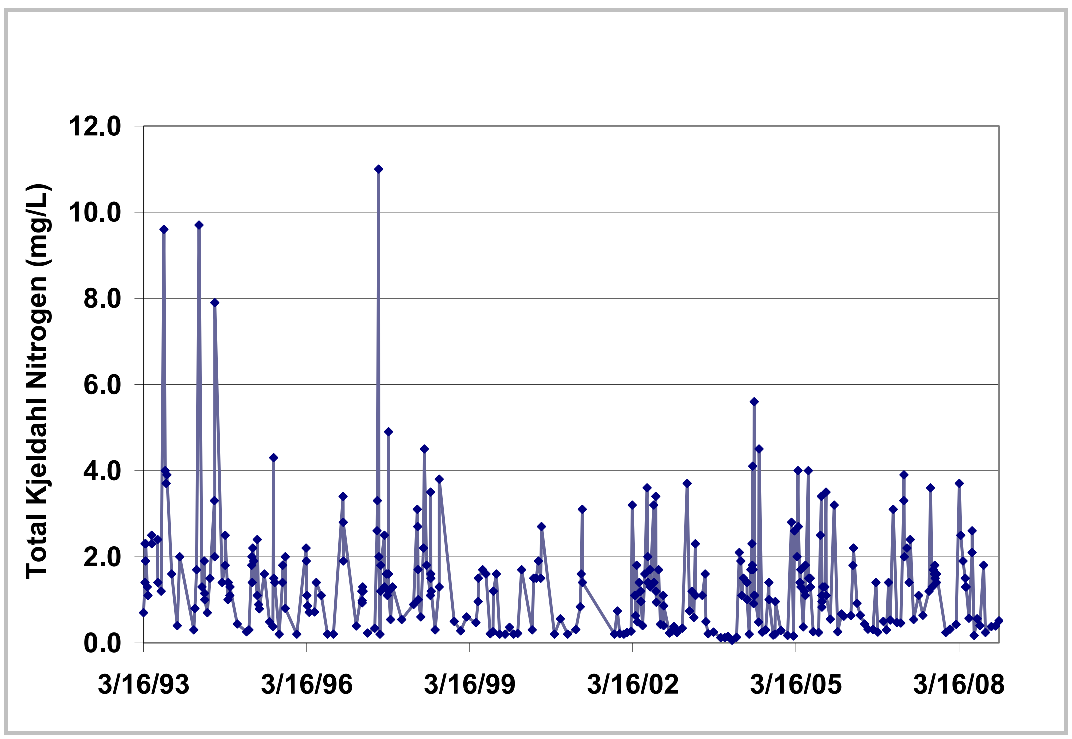

Figure 14 1993-2008 Bluff Creek Total Kjeldahl Nitrogen: WOMP Station

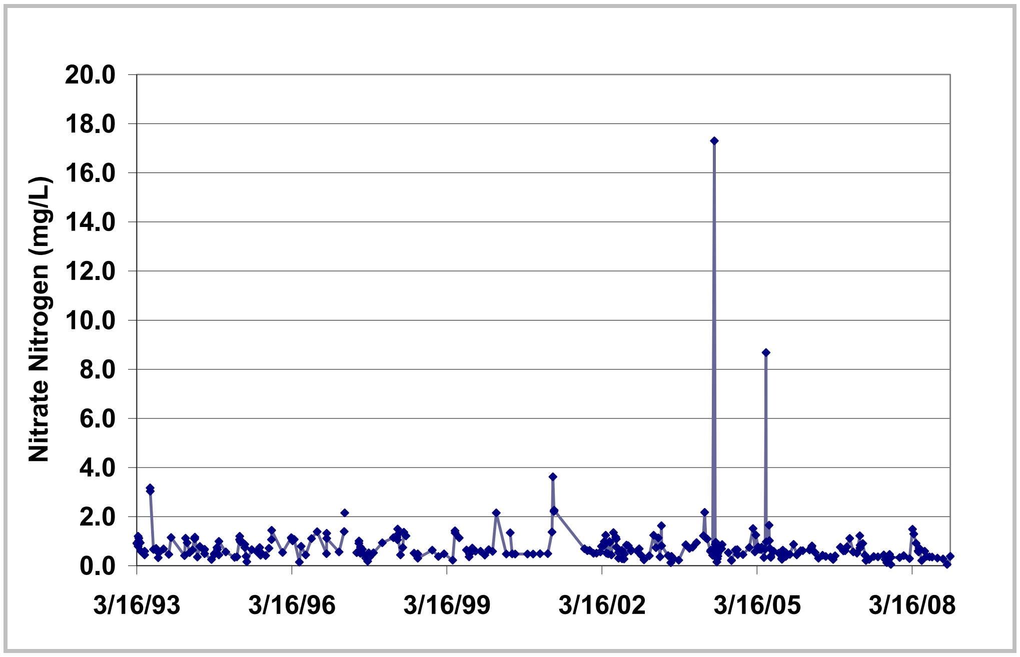

Figure 15 1993-2008 Bluff Creek Nitrate Nitrogen: WOMP Station

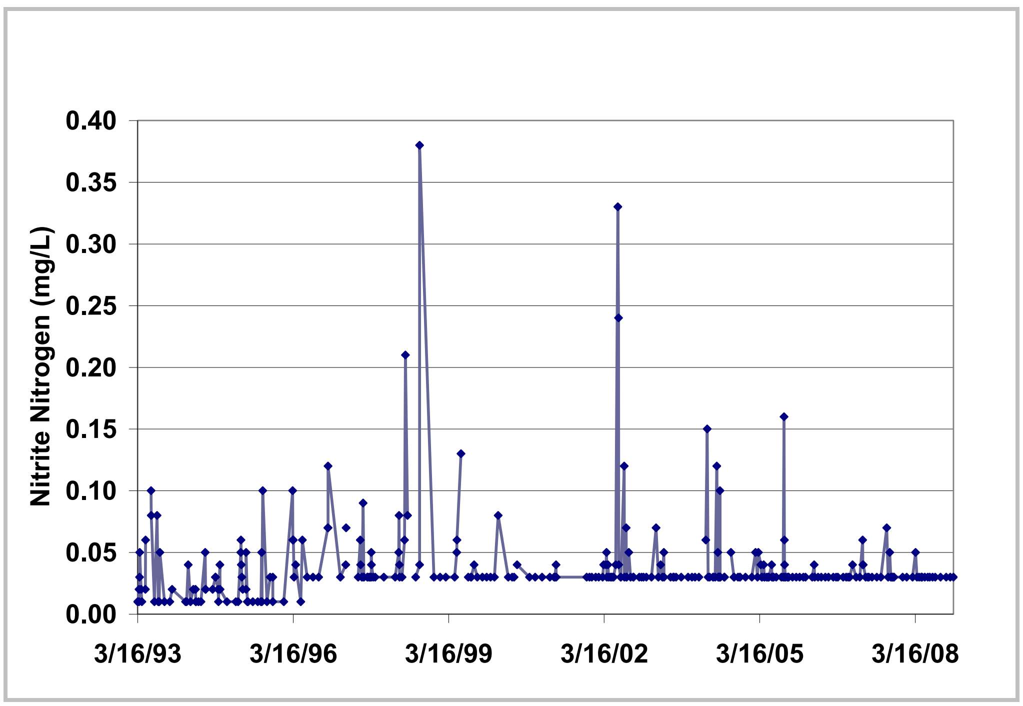

Figure 16 1993-2008 Bluff Creek Nitrite Nitrogen: WOMP Station

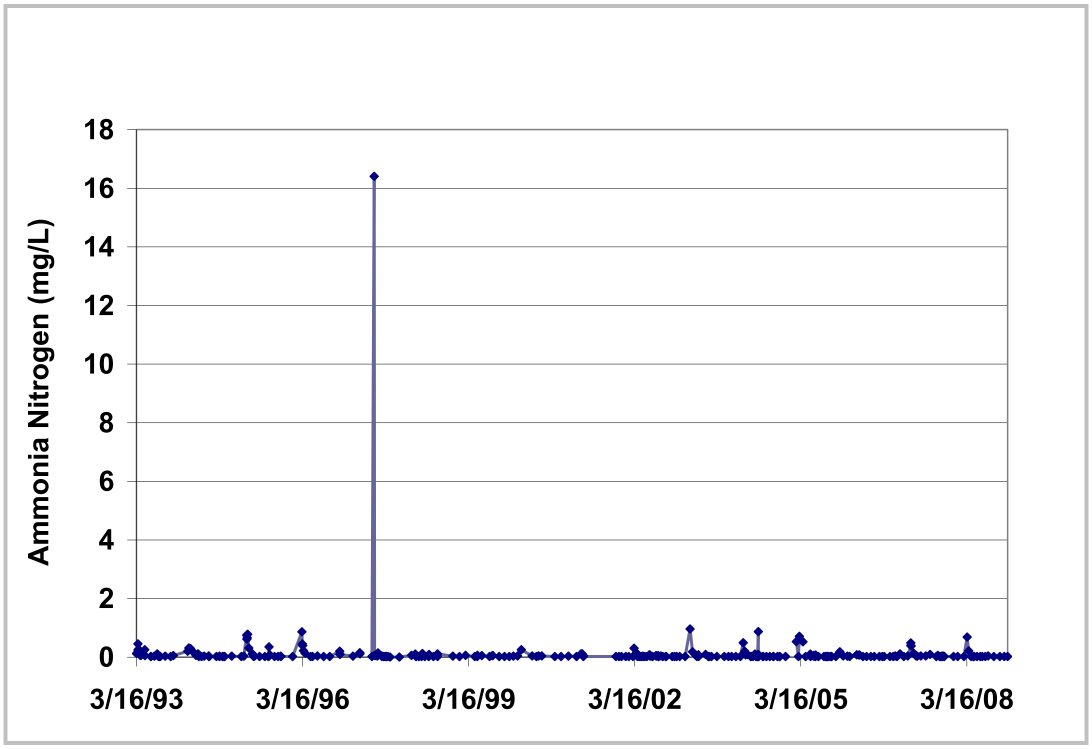

Figure 17 1993-2008 Bluff Creek Ammonia Nitrogen: WOMP Station

A periphyton growth study provides evidence that high nutrients in Bluff Creek are not causing excessive plant growth. Study results indicate periods of high nutrients in Bluff Creek are associated with storm events and a net decline of stream productivity due to scouring of periphyton from stream substrates during periods of high flow. A periphyton growth study of Bluff Creek by RPBCWD during 1998 documents growth and loss patterns in Bluff Creek. Periphyton growth and nutrient levels were measured at Station B-1 (Figure 2) at weekly intervals during June 1 through June 29, 1998 (Table 5 and Figure 18). Normal periphyton growth was observed when stream flows were normal and nutrient levels were relatively low. Periphyton growth increased aerial chlorophyll *a* on the periphytometer sampling units from 0 on June 1 to a 9.68 $\mu g/m^2$ on June 22 (Figure 18). However, stream energy and sediment conveyed to the stream by stormwater runoff scoured periphyton from Bluff Creek substrates resulting in a net loss of plant material following a 1.35-inch rainstorm on June 27 through 28. Stormwater runoff conveyed to Bluff Creek during the storm increased total phosphorus concentrations from 0.056 mg/L on June 22 to 1.8 mg/L on June 27 and dissolved phosphorus from 0.024 mg/L on June 22 to 0.217 on June 28 (Table 5). Stormwater runoff on June 27 also caused high levels of total Kjeldahl nitrogen (1.8 mg/L), total suspended solids (1,300 mg/L), volatile suspended solids (124 mg/L), and turbidity (350 NTU) (Table 5). Flows increased from 16.6 cfs on June 26 to 94.3 cfs on June 27 and then declined to 18.7 cfs on June 29 and 7.4 cfs on June 30 (Figure 19). The increased stream energy and sediment levels following the rainstorm caused scour of periphyton within the stream as evidenced by a 40 percent decline in aerial chlorophyll *a* from 9.68 µg/m^2 on June 22 to 5.80 µg/m^2 on June 29 (Figure 18). The data indicate that although high nutrient concentrations accompanied by high sediment loads are found in Bluff Creek for a brief period of time following storm events, accelerated plant growth does not occur. In addition, scouring reduces stream periphyton resulting in a net loss of plant material following storm events.

Table 5 Bluff Creek Water Quality Data Summary for June 1-29, 1998: B-1

Parameter	6/1	6/8	6/15	6/22	6/27	6/28	6/29
Total Phosphorus (mg/L)	0.089	0.040	0.049	0.056	1.80	0.44	--
Total Dissolved Phosphorus (mg/L)					0.46		
Total Ortho Phosphorus (mg/L)					--	0.217	
Soluble Reactive Phosphorus (mg/L)	--	0.035	0.037	0.024	--	--	0.145
Total Kjeldahl Nitrogen (mg/L)					3.50		
Ammonia Nitrogen (mg/L)					0.05	0.09	
Total Suspended Solids (mg/L)					1,300	307	
Volatile Suspended Solids (mg/L)					124	22	
Turbidity (NTU)					350	55	

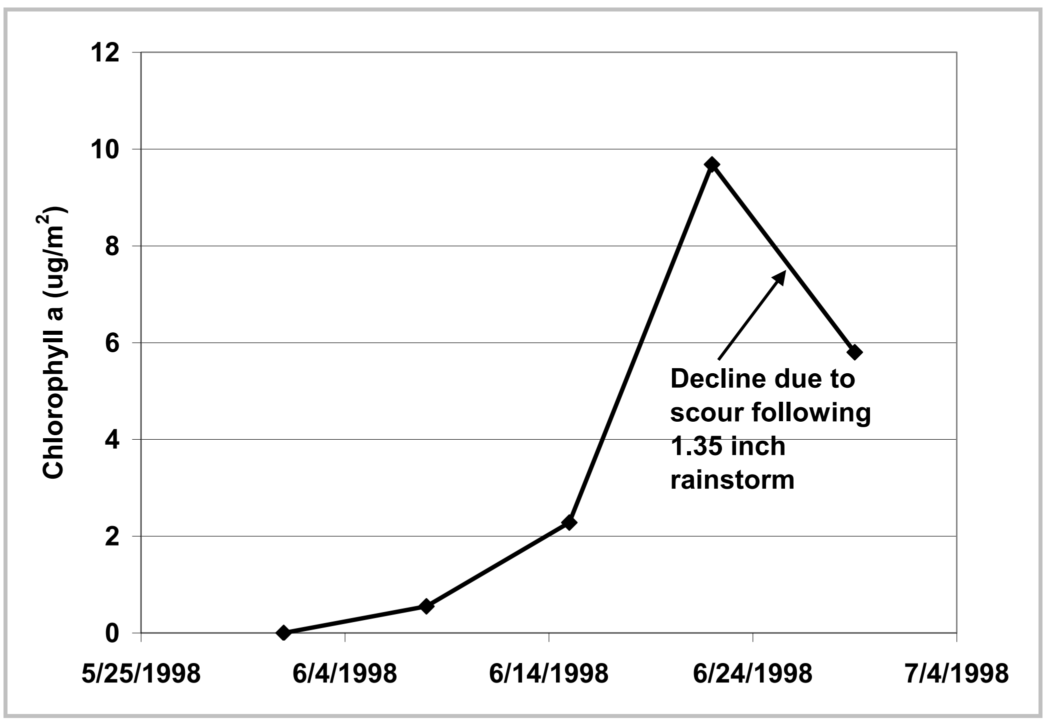

Figure 18 1998 Bluff Creek Periphyton Growth Study: B-1

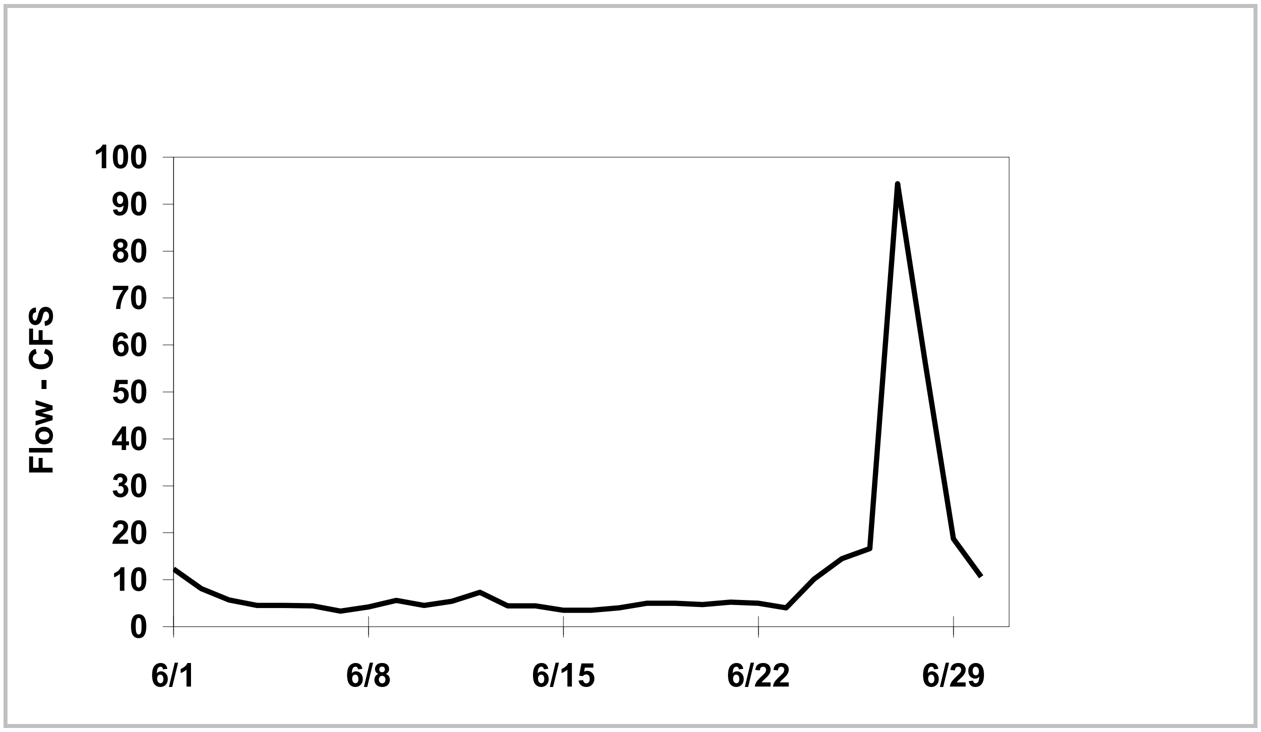

Figure 19 1998 Bluff Creek June Flow Values

The presence of high nutrients in a stream can stress a biological community when unionized ammonia concentrations reach toxic levels. Ammonia occurs in two forms, ionized and unionized. Stream temperature and pH determine the partitioning of ammonia into the two forms. Ammonia concentrations, pH, and temperature in Bluff Creek were measured by MCES at the WOMP station during 1993 through 2008. Unionized ammonia concentrations were computed to determine whether toxic concentrations of unionized ammonia have occurred in Bluff Creek during the period of record. Only one instance of ammonia toxicity occurred during the 15-year data collection period. On July 2, 1997, unionized ammonia reached 46.1 µg/L which exceeded the MPCA standard of 40 µg/L (Figure 20). The high concentration occurred immediately after a storm event. Stormwater runoff conveyed large quantities of sediment to the stream which not only caused the high unionized ammonia concentration, but also caused high suspended solids concentrations (640 mg/L). Because unionized ammonia has been below toxic levels since 1997, this parameter is not considered a stressor to the stream's biological community.

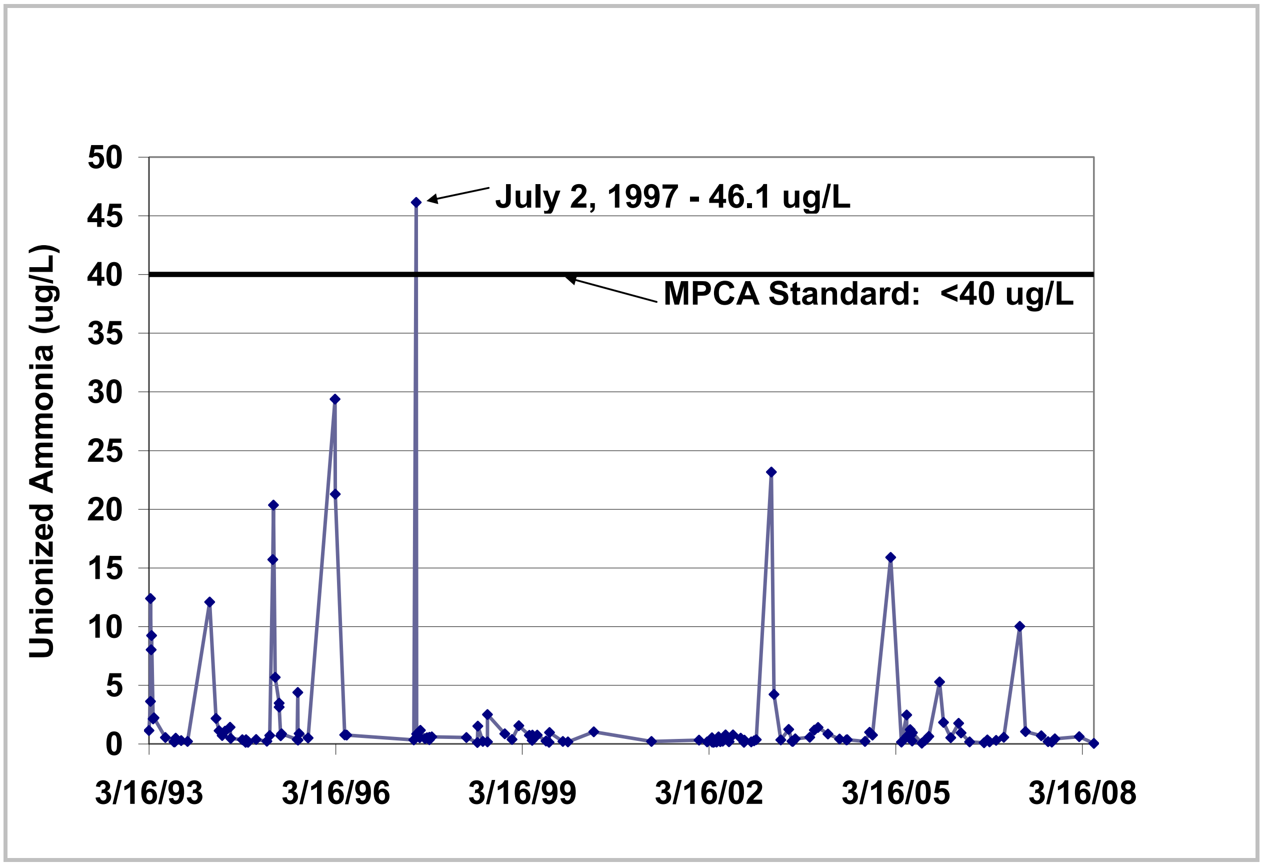

Figure 20 1993-2008 Bluff Creek Unionized Ammonia: WOMP Station

The data indicate nutrients have not caused biological impairment. Neither excess plant growth nor depleted oxygen levels have been observed in Bluff Creek. The invertebrates inhabiting Bluff Creek are sensitive to low oxygen levels and would be eliminated by depleted oxygen levels. Data collected from Bluff Creek indicate that although high nutrient concentrations accompanied by high sediment loads are found in Bluff Creek for a brief period of time following storm events, accelerated plant growth does not occur. In addition, scouring reduces stream periphyton resulting in a net loss of plant material following storm events. Unionized ammonia has been below toxic levels since 1997 and is not considered a stressor to the biological community. Hence, nutrients are eliminated as a candidate stressor to Bluff Creek.

4.1.5 Temperature

Temperature was eliminated as a candidate cause of impairment because Bluff Creek temperature data indicate warmer temperatures that can stress aquatic life are not found in Bluff Creek. The stream's mean summer maximum temperatures are within the range of reference streams within the

Minnesota River Basin. Bluff Creek temperature data indicate it is a stream with coldwater temperature conditions.

Although temperature is eliminated as a candidate cause of stream impairment, temperature is, and will be, an important consideration in impairment evaluation of Bluff Creek. Bluff Creek's impairment was determined by evaluating the stream's fishery with the Minnesota River Basin IBI. This IBI was developed from a mixture of streams with warmwater, coolwater, and coldwater temperature conditions in the Minnesota River Basin. Mundahl et al. (1998) have indicated a coldwater IBI is the appropriate tool to evaluate a stream with coldwater temperature conditions and advised against using an IBI developed from a mixture of stream types (Mundahl et al., 1998).

Streams are classified into one of three categories based upon temperature. Coolwater streams have a mean maximum daily temperature between 22 and 24°C during a normal summer, coldwater streams normally have summer maximum daily means below 22°C, and warmwater streams exceed 24°C (Lyons, 1992). During 1998, continuous temperature measurements by RPBCWD at Station B-1 occurred from June 1 through October 16. Bluff Creek's 1998 summer (June 15 through August 31) maximum daily mean temperature was 16.6°C (Figure 21) which is less than the coldwater stream temperature threshold (Lyons, 1992). During 2008, continuous temperature measurements by MCES at the WOMP Station (Figure 2) occurred from March 19 through year's end. Bluff Creek's 2008 summer (June 15 through August 31) maximum daily mean temperature was 16.4°C (Figure 22). These data indicate Bluff Creek is a stream with coldwater temperature conditions.

Monthly temperature measurements by RPBCWD during March through October of 1996 through 2005 were below the coldwater threshold and provide further evidence that Bluff Creek is a stream with coldwater temperature conditions. Station B-1 (Figure 2) noted a temperature range of 0.7 to 18.3°C during this period (Figure 23), which is below the coldwater threshold of 22°C. Upstream Stations B-2 through B-5 (Figure 2) noted temperatures ranging from 0 to 22.5 °C during the period of record:

- B-2: 0 to 22.5° C
- B-3: 0 to 21.6° C
- B-4: 0 to 22.5° C
- B-5: 0 to 21.9° C

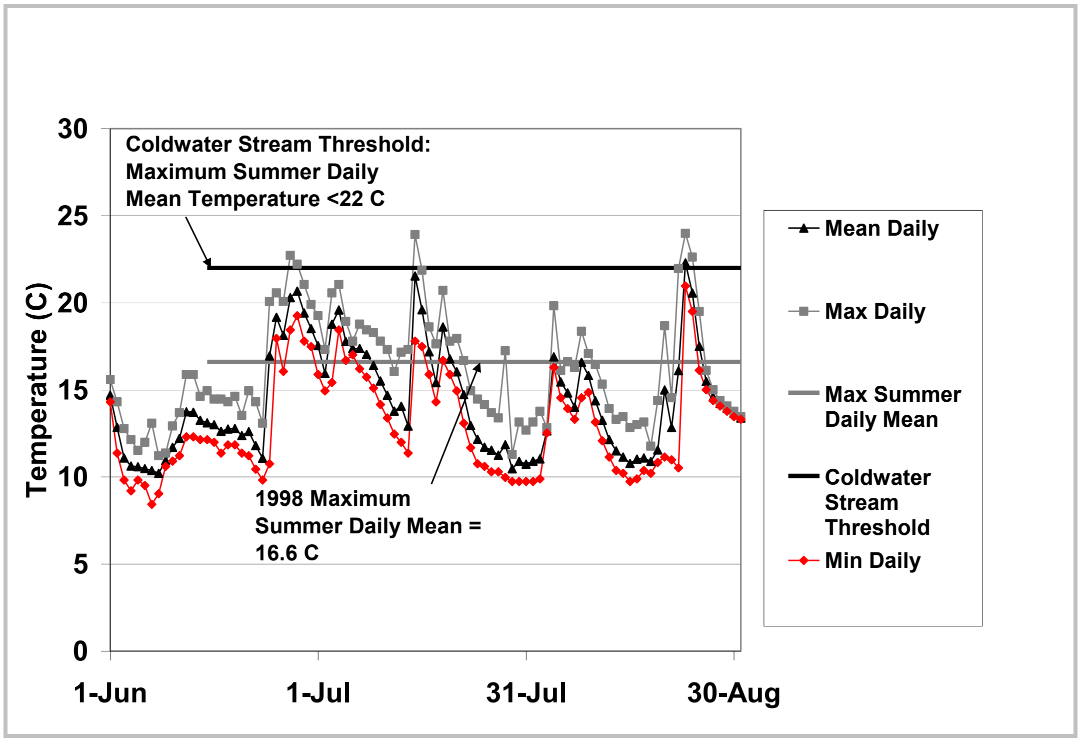

Figure 21 1998 Bluff Creek Minimum, Average, and Maximum Daily Temperature Measurements

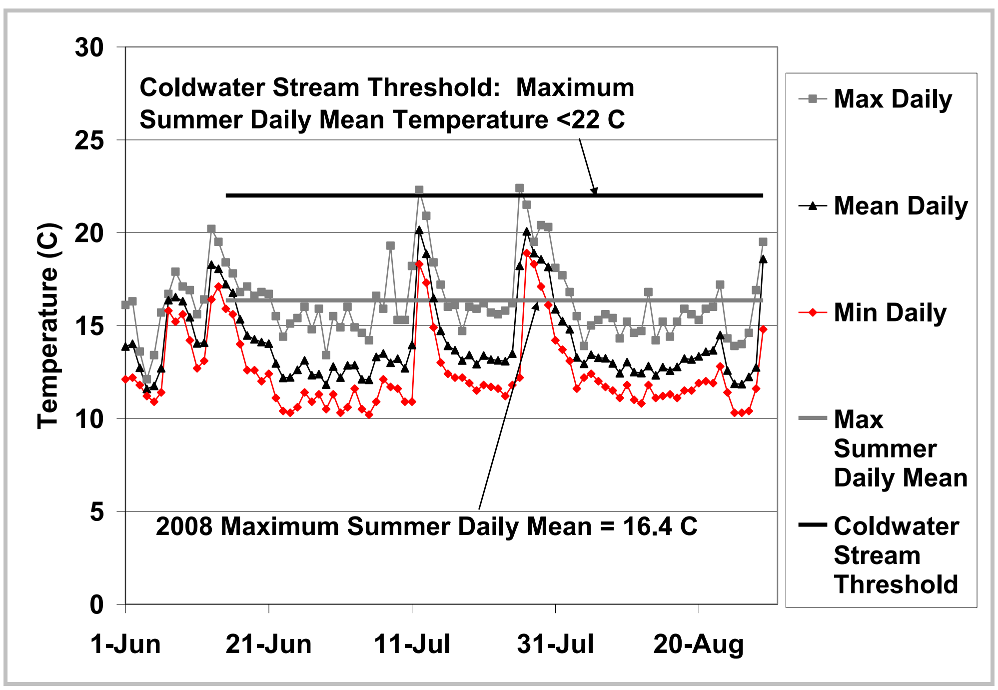

Figure 22 2008 Bluff Creek Minimum, Average, and Maximum Daily Temperature Measurements

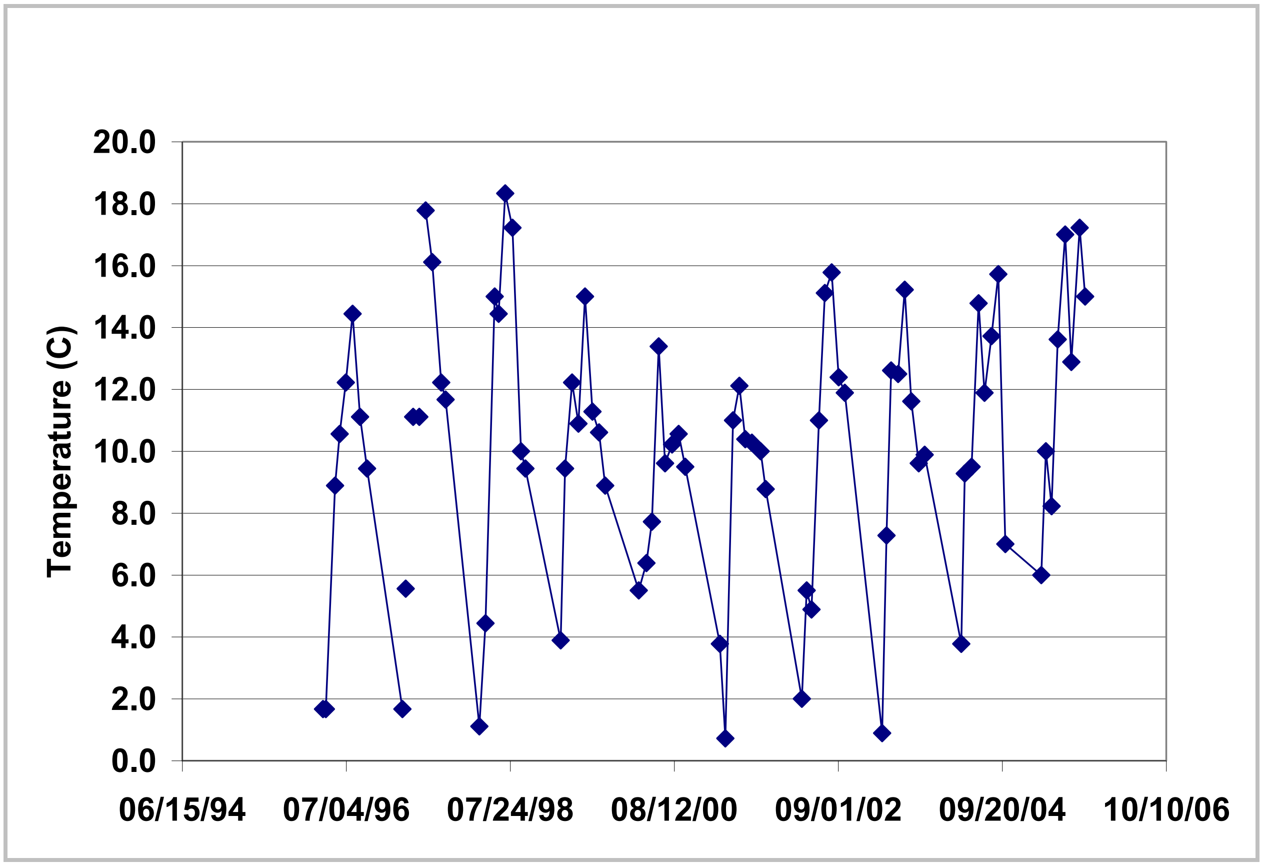

Figure 23 1996-2005 Bluff Creek Temperature Data: B-1

The mean summer maximum temperature in Bluff Creek was nearly the same during 1998 (16.6°C) and 2008 (16.4°C) despite flow differences during the two years (Figure 24). During 1998, the mean summer daily flow was 8.6 cfs and during 2008 the mean summer daily flow was 1.3 cfs. The data indicate that stream temperature is primarily determined by groundwater rather than surface flows. Hence, during the period of record, the stream does not show evidence of anthropogenic temperature alteration resulting from stormwater runoff.

Although on average, the stream temperature has remained stable over the period of record, reduced stream flow in 2008 resulted in a slight increase in daily temperature variability. The summer average daily temperature variation during 1998 was 3.2°C compared with 4.0 °C during 2008 (Figure 25). In 2008, solar radiation had a greater influence over daily temperature variability than occurred in 1998 when streamflow, on average, was higher. However, the summer average daily temperature variation in Bluff Creek (3.2 to 4.0 °C) is within the range observed for 6 coldwater reference streams within the Minnesota River Basin (Table 6). The average daily temperature variation for these 6 reference streams was 3.8 °C (Table 6).

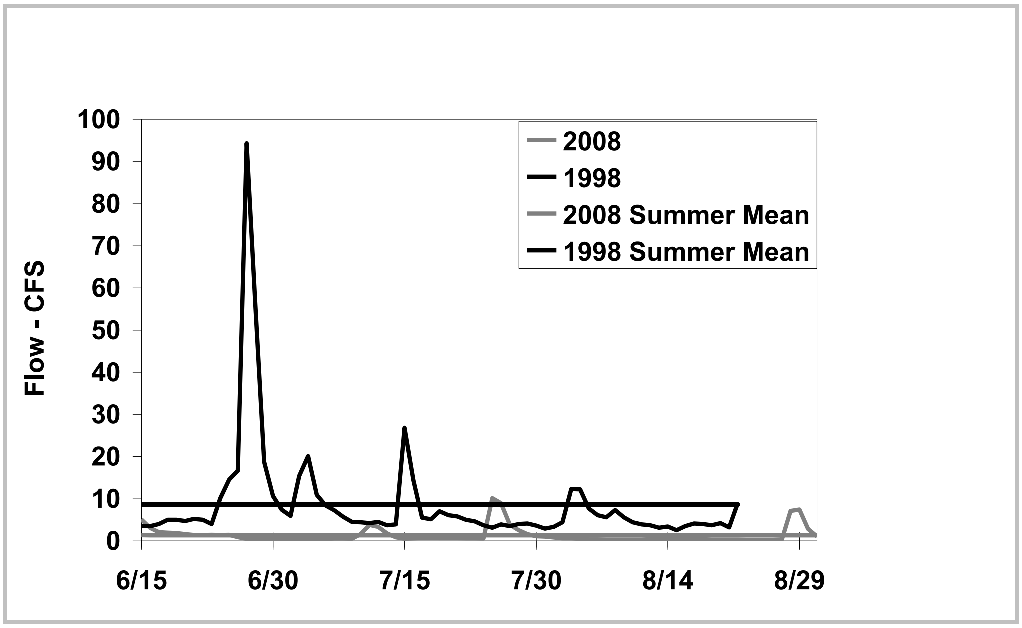

Figure 24 Comparison of 1998 and 2008 Bluff Creek Average Daily Flows During June 15 Through August 31 Period

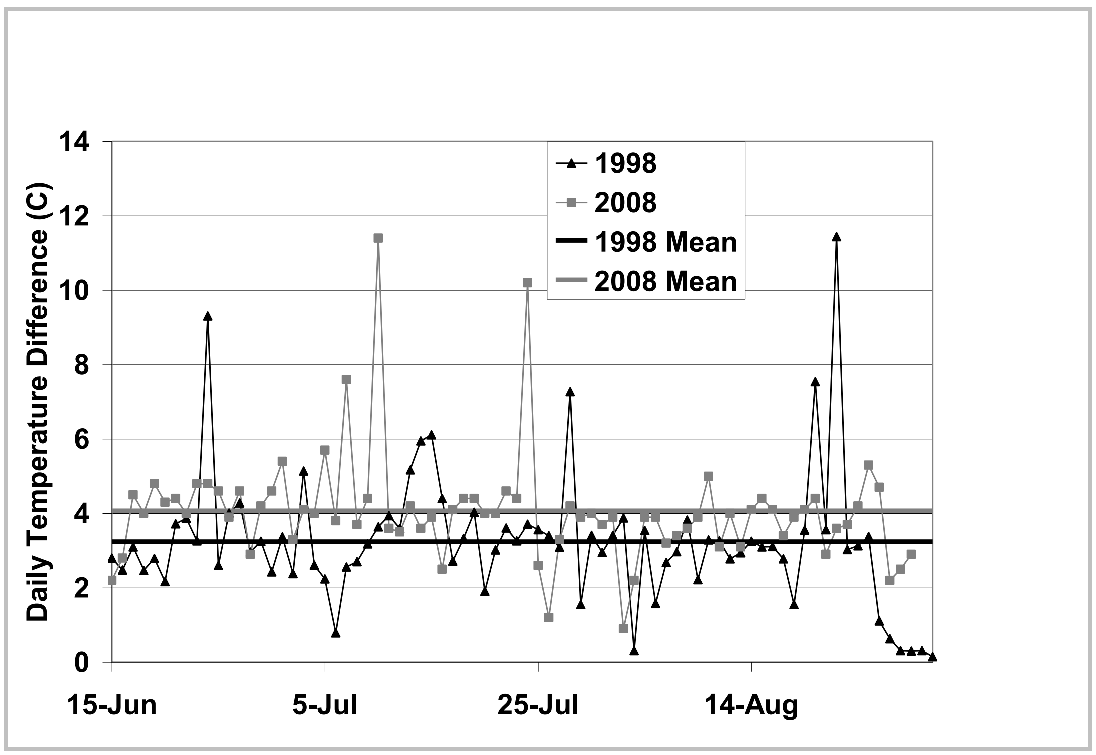

Figure 25 Comparison of 1998 and 2008 Bluff Creek Summer Daily Temperature Differences Between Maximum and Minimum Temperatures

Table 6 Summer Average Maximum and Average Daily Variation For 6 Reference Streams With Coldwater Temperatures Within the Minnesota River Basin (MPCA 2008a)

Stream Name	Stream Field Number	Mean Summer Maximum Temperature	Summer Average Daily Variation
Little Chippewa River	03MN004	21.99	2.89
Dutch Charley Creek	03MN035	21.92	4.49
Lazarus Creek	03MN046	21.98	3.94
Tributary to Chippewa River	03MN056	11.85	2.32
Tributary to Perch Creek	03MN064	21.84	5.69
Nicollet Creek	03MN069	21.56	3.43

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

Bluff Creek's biological impairment was based upon an evaluation using the Minnesota River Basin IBI which was developed from streams with a combination of coldwater, coolwater, and warmwater temperatures. Reference reaches used to develop the IBI included 5 streams with coldwater temperature conditions, 6 streams with coolwater temperature conditions, and 17 streams with warmwater temperature conditions (MPCA, 2008c).

High quality streams with coldwater temperatures are too cold to support the full complement of species found in warmwater streams (Lyons et al., 1996). Most fish species are not adapted to thrive in the cold summer water temperatures that characterize high quality streams with coldwater temperature conditions (Becker, 1983; Lyons 1992). Streams with coldwater temperatures are harsh environments where only a handful of species can live. Species-rich families such as the catostomids, centrarchids, and percids have few or no members adapted for the bioenergetic and reproductive thermal challenges of streams with coldwater temperatures (Hynes, 1970). As a result, streams with coldwater temperatures have a depauperate fish fauna and lack many of the taxonomic groups that are important in the much more species-rich warmwater streams.

Because the stream's fishery is comprised of few species and brook stickleback, a stenothermal (narrow temperature range) coolwater species, has been the dominant species in Bluff Creek during the period of record, the data suggest possible temperature impacts on the stream's fish assemblage. As shown in Figures 26 and 27, brook stickleback comprised from 50 to 100 percent of the total number of fish species and from 67 to 100 percent of the total number of individuals during the period of record.

Currently, Bluff Creek is designated in as a Class 2B to protect aquatic life. Due to the temperatures found in Bluff Creek, a Use Attainability Analysis is recommended to evaluate whether the current Use Class or a different Use Class more reflective of the cold temperatures is suitable. Tiered Aquatic Life Use should address stream Use Classes when developed for Minnesota. This work may help guide future management of appropriate Bluff Creek fish populations. Until that time, the recommendations in this document and in the forthcoming TMDL are based from the 2B status. Similar to all TMDL Projects, the TMDL Report and Implementation Plan for Bluff Creek can be reevaluated and revised as needed to reflect new policies, standards, classifications, and additional monitoring.

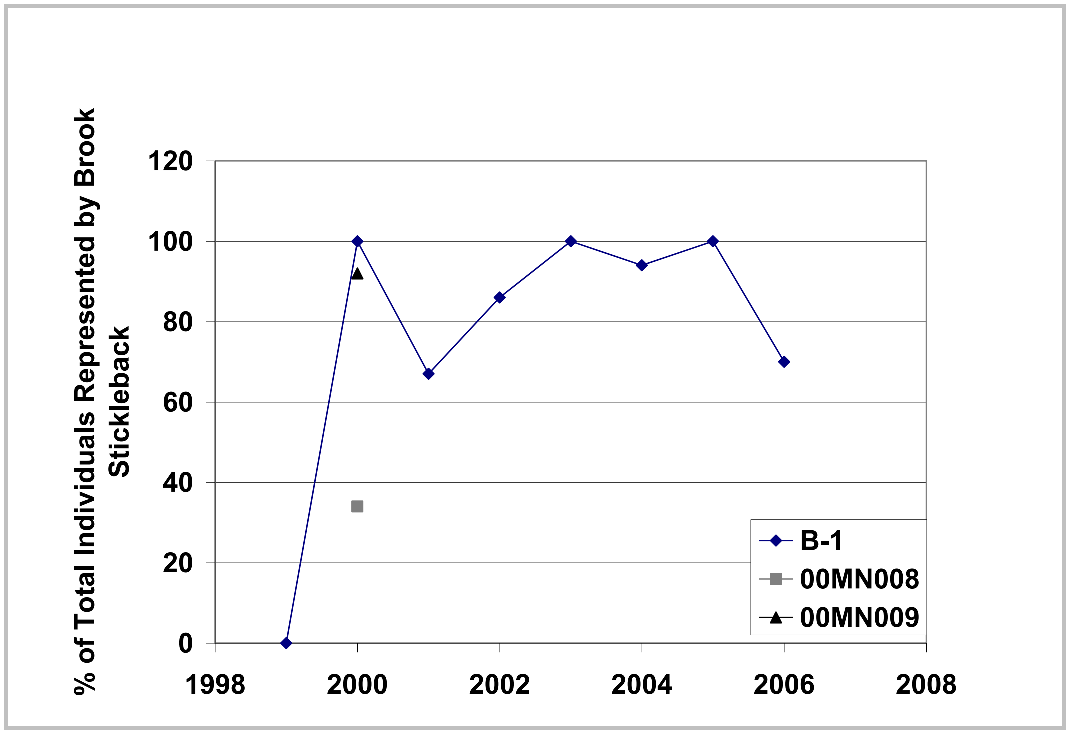

Figure 26 Percent of Total Individuals Represented by Brook Stickleback in Bluff Creek During 1999-2006

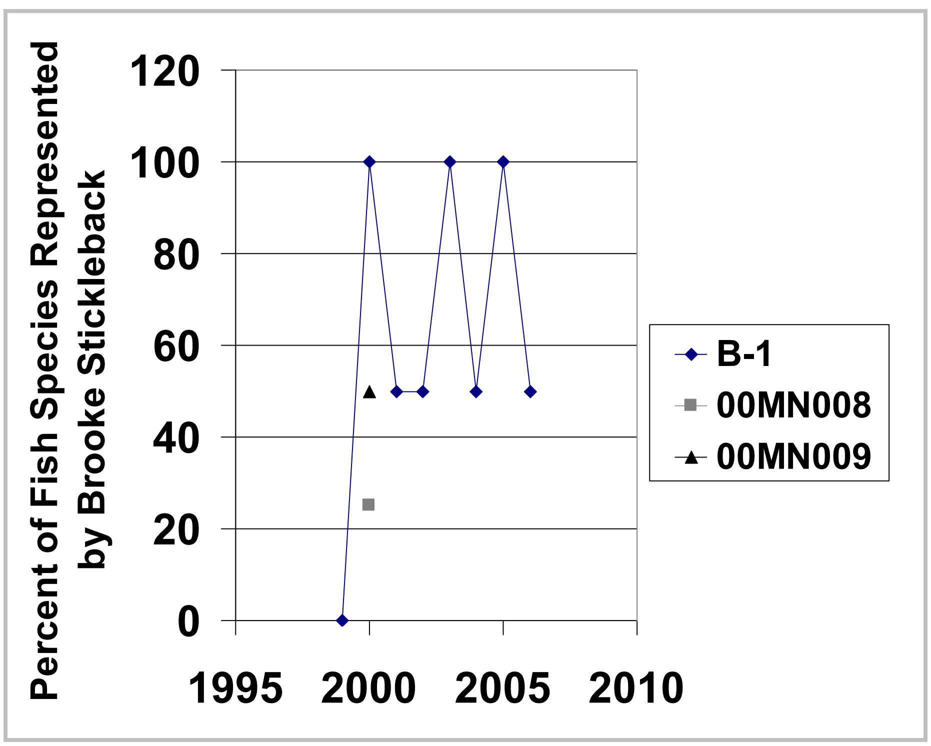

Figure 27 Percent of Fish Species Represented by Brook Stickleback in Bluff Creek During 1999-2006

4.2 Candidate Causes

4.2.1 Candidate Cause 1: Habitat Fragmentation

Habitat Fragmentation is considered a possible stressor because a large drop at the downstream end of the regional trail culvert (Figure 28) interrupts the connectivity of Bluff Creek. This interruption of connectivity prevents passage of fish between upstream and downstream reaches of Bluff Creek. Such isolation may increase mortality due to isolation from food sources and prevent replenishment of the species when disease or other stressors eliminate individual fish or species. Isolation may lead to the demise of a fishery, including extinction (Letcher et al., 2007). Evaluation of Bluff Creek stream reaches upstream and downstream of the culvert indicates upstream reaches (Stations B-1 and 00MN009 in Figure 2) were impaired while a downstream reach (Station 00MN008 in Figure 2) was not impaired. During 2000, upstream reaches observed IBI scores of 16.8 at B-1 and 21.6 at 00MN009 while the downstream reach, 00MN008, noted an IBI score of 31.2 which is above the impairment threshold of 30 or greater. The data indicate habitat fragmentation has adversely impacted Bluff Creek's fishery and has resulted in impairment of stream reaches located upstream of the culvert.

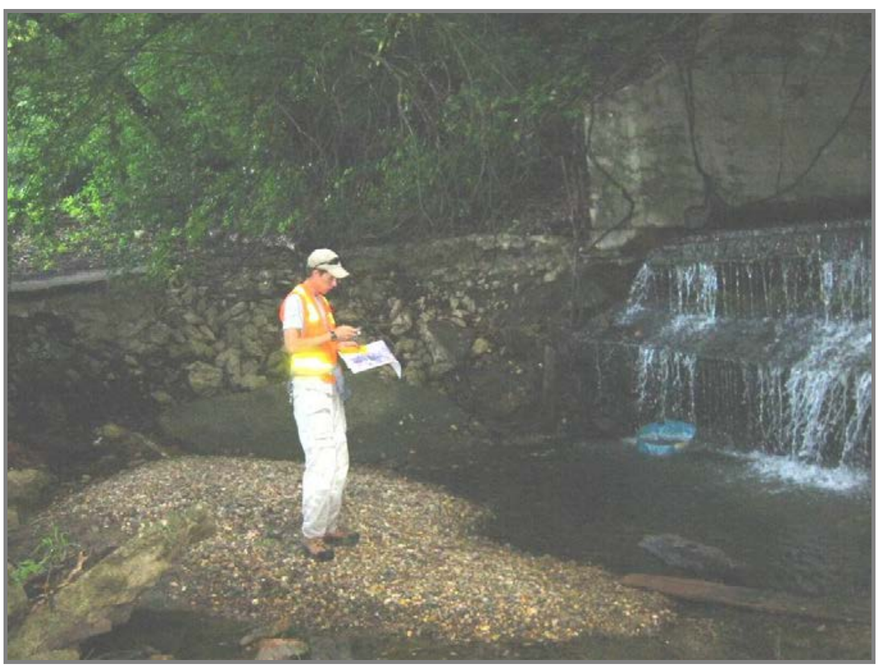

Figure 28 Large drop at downstream end of regional trail culvert

The Bluff Creek fish assemblage during 2000 provides evidence of the impact of habitat fragmentation on the stream's fishery. During 2000, brook stickleback, a coolwater fish species, comprised 25 percent of the fish species and 34 percent of the number of individuals collected from

00MN008, a station downstream from the culvert. In contrast, brook stickleback comprised from 50 to 100 percent of the number of fish species and from 92 to 100 percent of the number of individuals collected from upstream locations B-1 and 00MN009 during 2000 (Figures 26 and 27). These data indicate a more diverse fish assemblage was able to inhabit stream reaches downstream from the culvert. The downstream reach included several eurythermal (inhabit a large temperature range) species in addition to a stenothermal (inhabit a narrow temperature range) coolwater species. In contrast, the isolated reaches upstream from the culvert observed fewer species than the downstream reach and were dominated by a single stenothermal coolwater species. A conceptual model of candidate Cause 1, habitat fragmentation, is shown in Figure 29. The model shows that the large drop at the end of the regional trail culvert causes a loss of connectivity which reduces fish migration, results in a reduced refuge for fish, and reduces sensitive species. Habitat fragmentation reduces replenishment of species when climate changes, either wet or dry weather, cause changes in the stream's flow regime and species reductions due to either high or low flow conditions. The reduction in fish taxa richness and reduction in number of fish resulting from habitat fragmentation causes impairment.

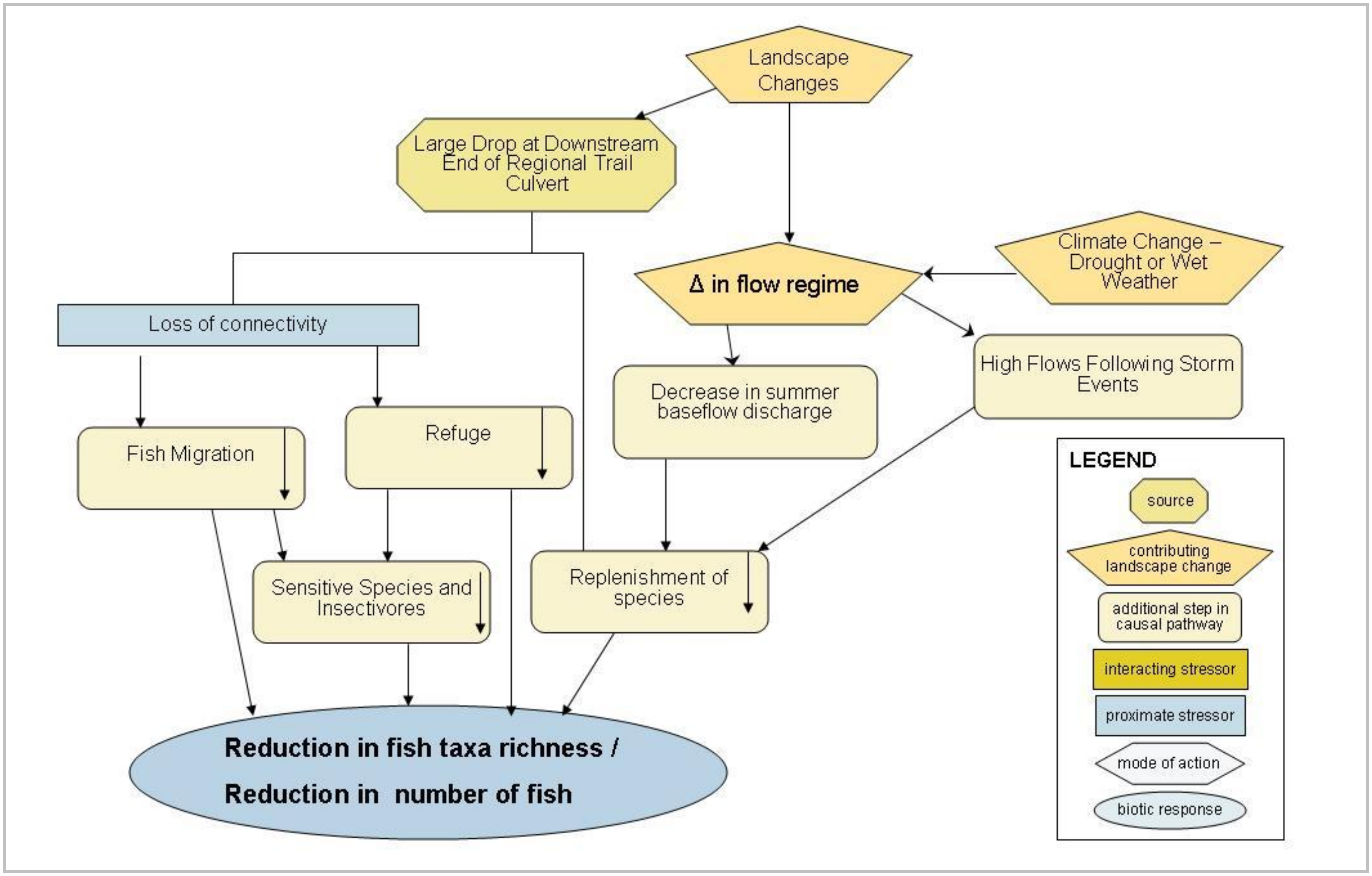

Figure 29 Conceptual Model of Candidate Cause 1: Habitat Fragmentation

4.2.2 Candidate Cause 2: Sediment

Sediment is considered a candidate stressor because high sediment loads and turbidity levels have been consistently observed in Bluff Creek. As shown in Figure 30, total suspended solids concentrations in excess of 1,000 mg/L have frequently occurred during the period of record. Volatile suspended solids concentrations have consistently exceeded 100 mg/L (Figure 31). Turbidity values have consistently exceeded the MPCA standard (25 NTU) throughout the period of record (Figure 32). High sediment concentrations have been associated with snowmelt and precipitation events. As shown in the conceptual model of candidate Cause 2, sediment is conveyed to the stream from the watershed as well as from in-channel sources (Figure 33).

To further evaluate in-channel sediment contributions to Bluff Creek, RPBCWD prepared an order of magnitude estimate of total in-channel sediment contribution to Bluff Creek in 2006. The estimate is 570,000 pounds per year (260 ton/year). For a total catchment area of 6.4 miles, the estimate of 570,000 pounds/year is equivalent to a sediment yield of 140 pounds per acre. This estimate indicates the in-channel sediment contribution would represent almost 25 percent of the total suspended solids yield measured in Bluff Creek between 1990 and 1996 (Barr, 2006c).

Results of a Bluff Creek inventory indicate the primary sources of sediment to Bluff Creek are ravines and escarpments in the lower valley, primarily between Stations B-1 and B-2 (Figure 2). RPBCWD performed a detailed inventory of stream erosion in the lower valley of Bluff Creek during 2007. The inventory consisted of a reconnaissance walk of the stream channel and visits to all of the contributing ravines. During the visits, erosion sites were photographed, soil and vegetation conditions were noted, storm sewer inlets documented, and erosion dimensions estimated.

2007 Bluff Creek inventory results indicated significant stream bank erosion as well as erosion in contributing ravines and large slope failures in the valley that were not necessarily associated with a ravine. An overview map of survey results is shown in Figure 34. Detailed results of the investigation are presented in Appendix C.

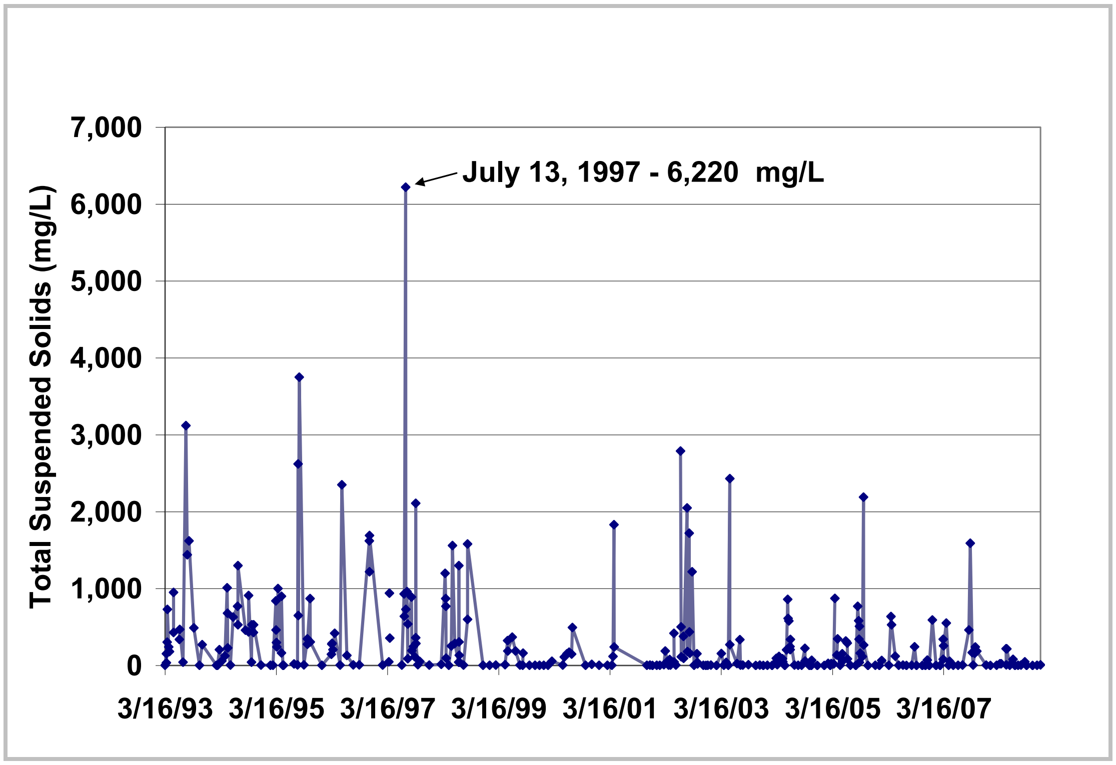

Figure 30 1993-2008 Bluff Creek Total Suspended Solids: WOMP Station

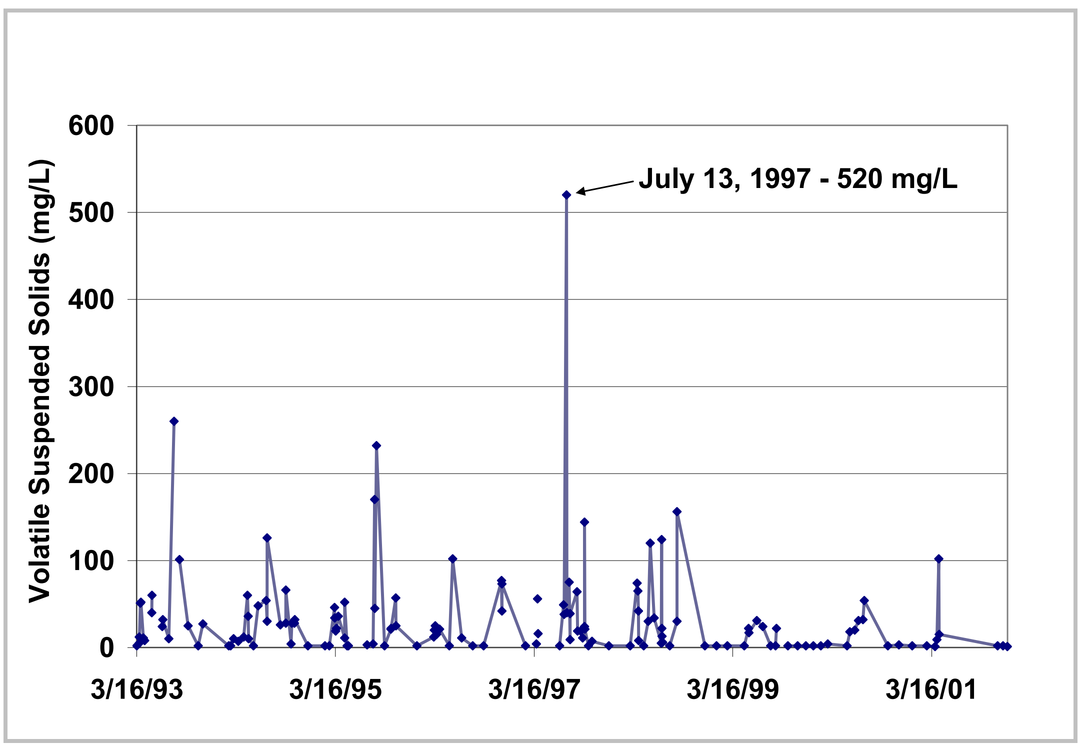

Figure 31 1993-2008 Bluff Creek Volatile Suspended Solids: WOMP Station

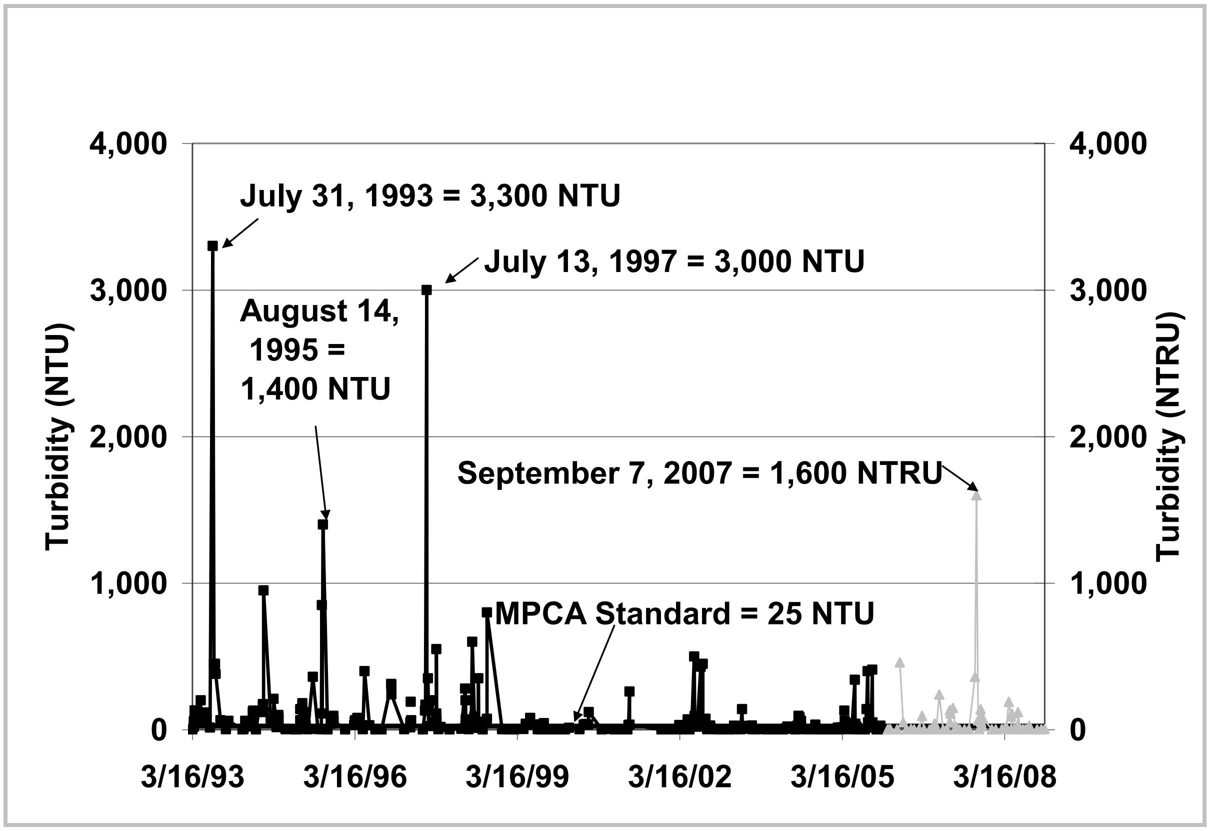

Figure 32 1993-2008 Bluff Creek Turbidity: WOMP Station

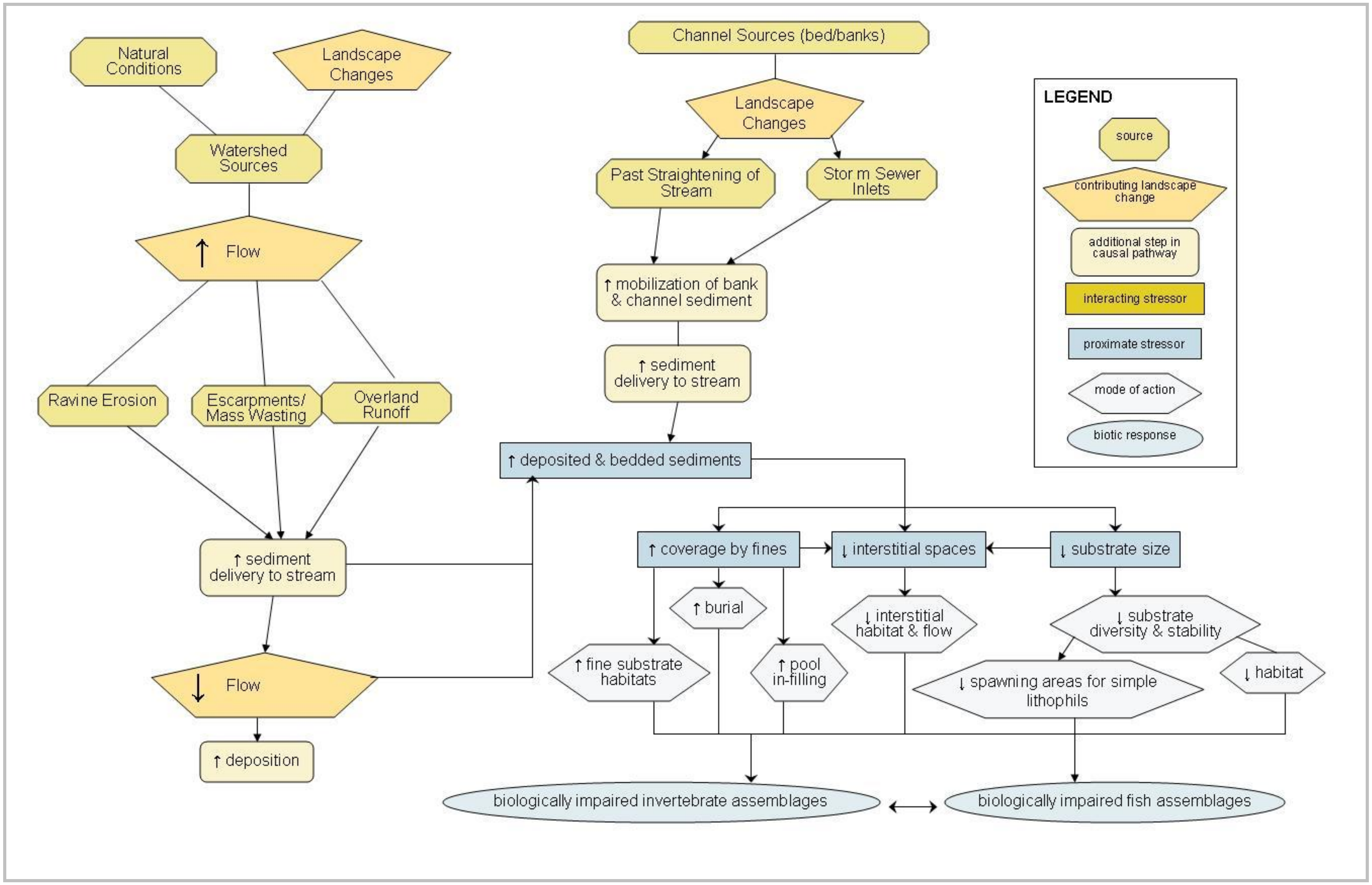

Figure 33 Conceptual Model of Candidate Cause 2: Sediment

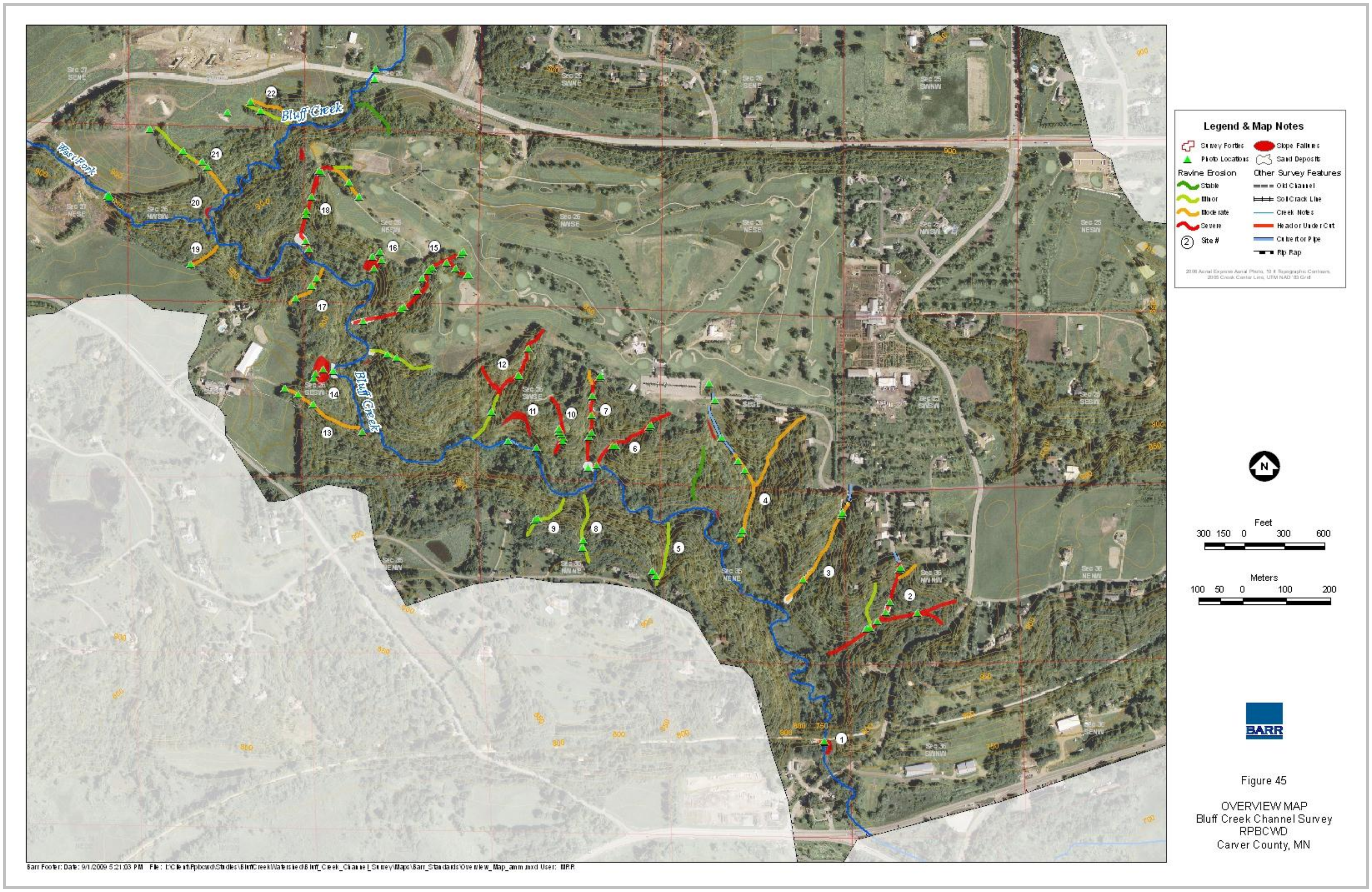

Figure 34 Overview Map: Bluff Creek Channel Survey

The inventory results indicate much of the stream itself was stable, although downcutting and bank erosion were observed in some reaches. Ravine erosion, for the most part, is occurring in the Bluff Creek watershed rather than within Bluff Creek, and is due to overland runoff/or groundwater seepage. The majority of the ravines with severe or moderate erosion are located between Stations B-1 and B-2 and are upstream from the WOMP station (Figure 2). Streambank and ravine erosion appear to be the primary sources of the suspended solids (Figures 30 and 31) and turbidity (Figure 32) measured at the WOMP station (Figure 2).

Although erosion in ravines in the lower valley of Bluff Creek is the primary source of sediment to the stream, streambank erosion also delivers sediment to the stream (Figure 35). A Rosgen stream assessment was conducted on Bluff Creek to better understand the physical characteristics of the stream. Bluff Creek is primarily a Type C and E stream (Figure 36). These stream types are highly sensitive to disturbance; they have moderate (E) to very high (C) sediment supply, high (E) to very high (C) streambank erosion potential, and very high vegetation controlling influence (RPBCWD, 1996).

Bluff Creek is a C stream type from Pioneer Trail downstream to T.H. 101, where the floodplain is more confined by the valley walls (Figure 36). The C stream is typified by a somewhat wider and shallower channel than the type E channel, with a narrower floodplain. Reaches B-1 and B-2 are Type C channels (Figure 36). The lower valley, with primarily C stream type, is very vulnerable to bank erosion problems. A 2007 survey of Bluff Creek identified three streambank erosions sites. Site 1 (Figure 35 and pictured to the right) is an eroded bank immediately downstream of the regional trail culvert pictured in Figure 28. The stream channel has downcut significantly below the culvert, and the culvert is being undermined.

Figure 35 Streambank erosion is undermining this culvert at Site 1.

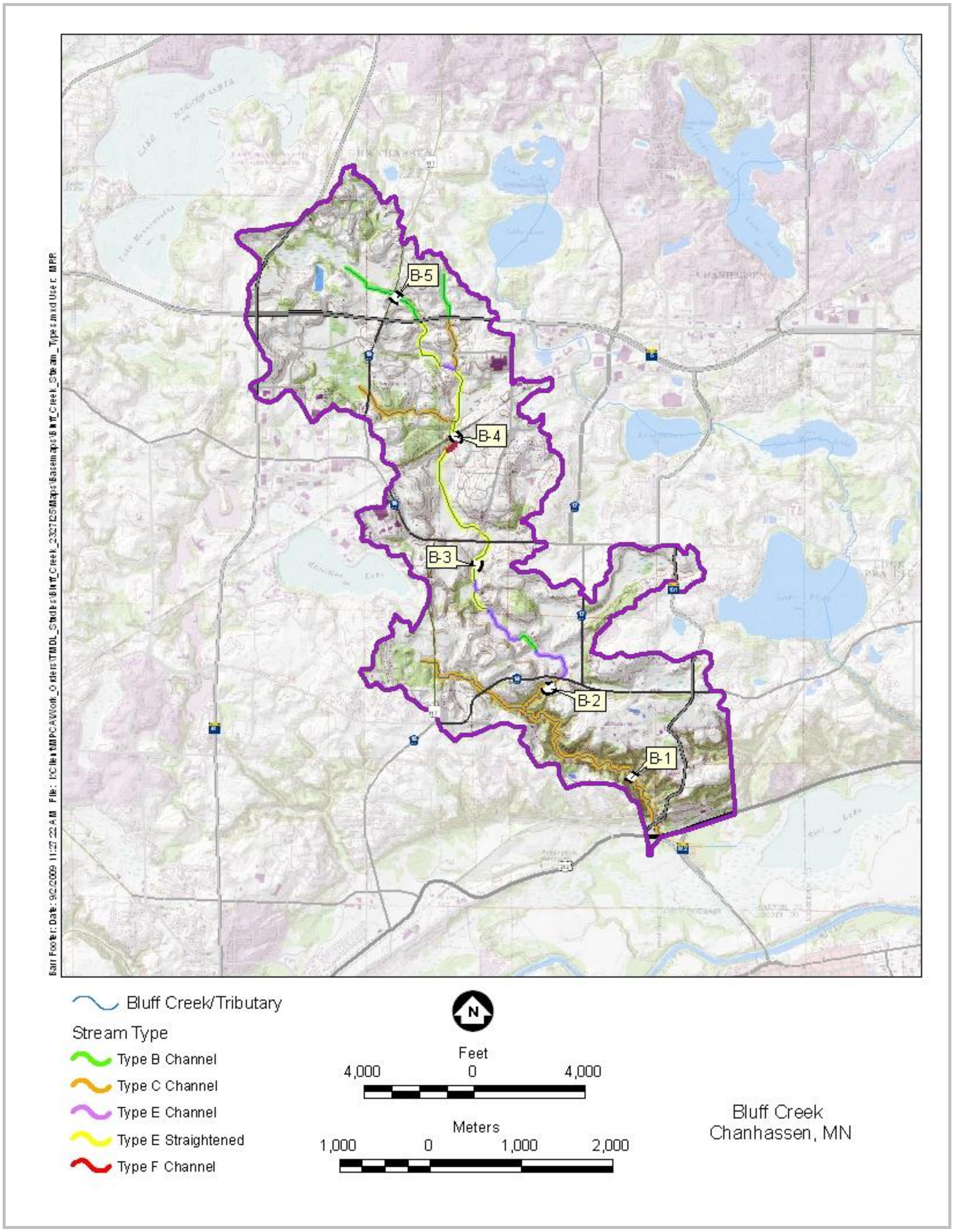

Figure 36 Bluff Creek Stream Types: Bluff Creek TMDL Study

The second streambank erosion site, Site 11 [shown on Figure 34 and pictured to the right (Figure 37)], is located in the lower valley of Bluff Creek. This location notes a slope failure immediately adjacent to the stream. The third site, Site 20 [shown on Figure 37 and pictured below (Figure 38)], consists of an approximately 400-foot long reach of Bluff Creek having severe bank erosion.

Figure 37 Site 11 noted slope failure immediately adjacent to the stream

Past straightening of stream reaches has contributed to the degradation of stream reaches and added to the stream's sediment problem. As shown in Figure 36, several sections of the stream are Type E straightened stream reaches. Reach B-3 notes a loss of meandering due to straightening (Figure 36). Channel straightening downstream of Reach B-4 (Figure 36) together with an upstream railroad culvert have resulted in degradation at this Type C reach.

Figure 38 Severe bank erosion is found in the 400-foot reach of Bluff Creek at Site 20. Flow causes and determines the degree of streambank erosion in Bluff Creek.

The impact of sediment on the fish community in Bluff Creek is evident from IBI scores from stream stations upstream and downstream from the primary sediment sources to Bluff Creek. As noted previously, the primary sources of sediment to the stream are ravines with severe or moderate erosion that are located between Stations B-1 and B-2. IBI scores from B-1 and B-2 were compared during the years in which the highest and lowest mean annual total suspended solids (TSS) concentrations were observed in Bluff Creek. The highest mean annual TSS was observed in 1997 (715 mg/L) and the lowest mean annual TSS was observed in 1999 (97 mg/L). During 1997, no fish were observed or caught at Station B-1 while Station B-2 noted an IBI score of 24 which is below the impairment threshold. During 1999, Station

B-1 noted an IBI score of 16.8, which is below the impairment threshold while Station B-2 noted an IBI score of 38.4 which is above the impairment threshold. While both stations noted improved IBI scores during the year in which lower TSS was measured, Station B-2 met the impairment standard during 1999 while Station B-1 failed to meet the impairment standard. The data indicate sediment from ravine erosion downstream of B-2 is a candidate cause of the stream impairment observed at Station B-1.

Habitat data collected by the RPBCWD from B-1 during 2003 through 2006 provide evidence that sediment is a stressor for the fish community. The number of locations with fine sediment was divided by the total number of stations sampled to determine the percent of locations with fine sediment. Fine sediment was found at 79 to 96 percent of sample locations (Table 7). The number of locations with embeddedness was divided by the number of locations with coarse substrate (i.e., boulder, rubble, and gravel) to determine the percent of eligible locations with embeddedness. From 91 to 100 percent of locations observed sediment embeddedness and the percent embeddedness observed at these locations ranged from 39 to 63 percent (Table 7).

Table 7 Habitat Summary of EUC-B1.

Year	Mean Water Depth	Mean Depth of Fines	Max Depth of Fines	% of Locations With Fines	# Locations With Embed-dedness	% of Eligible locations with Embed-dedness	Mean % Embed-dedness	IBI
	cm	cm	cm	%	#	%	%	Score
2003	21	3	13	80	46	100	43	16.8
2004	13	4	16	79	30	91	54	16.8
2005	9	5	17	96	39	100	39	16.8
2006	10	4	12	77	40	100	63	16.8

Lithophils are fish, such as white sucker, that require clean gravel or boulders for reproduction and are adversely impacted by sediment deposits. Lithophils were not observed at B-1 during the period of record. The lack of lithophils at B-1 (Table 3) was associated with the presence of fine and bedded sediment (Table 7). The data indicate sediment is a stressor to the B-1 biological community.

As shown in Figure 33, suspended, deposited, and bedded sediment cause harm to the biological community. Suspended sediment decreases visibility, decreases feeding efficiency, and increases gill damage in fish. Abrasion reduces periphyton growth thereby reducing food availability. Sediment causes a reduction in taxa with exposed gills, visual feeders, and herbivores and omnivores.

Invertebrates are also harmed by sediment, particularly sensitive invertebrates with exposed gills, such as stoneflies. Invertebrate data collected from Bluff Creek indicates high concentrations of TSS caused the disappearance of stoneflies while declining concentrations resulted in their reappearance (Figure 39). Stonefly sampling during 1998 through 2004 consistently occurred during October. Because the stonefly life cycle generally ranges from a few months to one year, changes in numbers of stonefly nymphs in Bluff Creek over a seven year period cannot be explained by emergence of adults from the stream. The data indicate changes in numbers of stonefly nymphs at B-1 during 1998 through 2004 are due to changes in sediment in Bluff Creek (Figure 39).

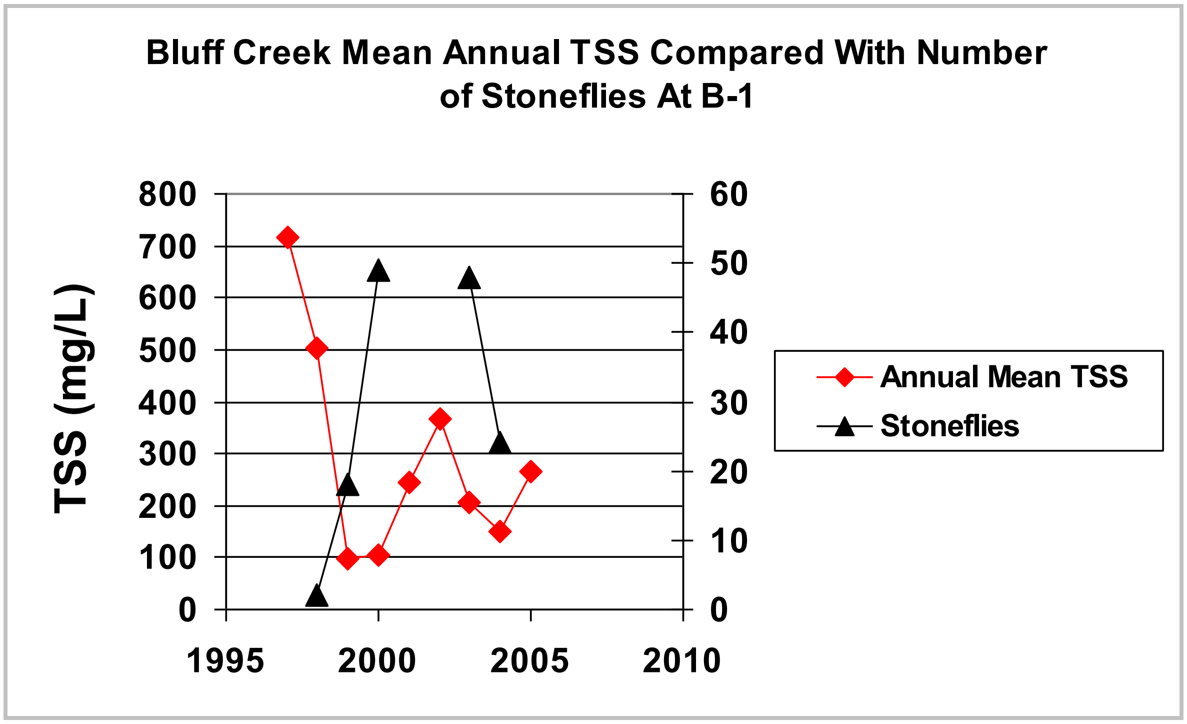

Figure 39 Bluff Creek Mean Annual TSS Compared With Number of Stoneflies at B-1

Turbidity and total suspended solids data from Bluff Creek have measured the amount of fine sediment plus organic material suspended in the water column (Figures 32 and 30, respectively). A periphyton growth study has documented the role of sediments to scour periphyton from substrates and thereby reduce available food for the stream's biological community (Figure 18). A stream survey has identified sediment sources to the stream (Figure 34). A habitat survey has documented the presence of fine and bedded sediment in Bluff Creek (Table 7). Fish (Figure 3) and invertebrate (Figure 39) data have documented the impact of sediment on the stream's biological community. These pieces of evidence indicate sediment is a candidate cause of the stream's impairment.

4.2.3 Candidate Cause 3: Flow

High flows are a problem for Bluff Creek because sediment input from bank and ravine erosion is evident at high flows (Appendix C). Reduced IBI scores during 1997 through 1998 were associated with increased flows while improved IBI scores during 1999 was associated with decreased flows (Figure 5). Hence, flow is a candidate stressor. Management of flow should be included in management measures to address the stream's sediment problem.

To prevent the current problem from worsening with future development, management measures to prevent anthropogenic flow increases should be employed now and in the future. Currently, there is no long-term record of anthropogenic flow increases in Bluff Creek. Bankfull flow is the primary parameter used to determine whether watershed development has resulted in the addition of increased volumes of surface runoff. Bankfull flow is the maximum amount of discharge that a stream channel can carry without overflowing. As a watershed urbanizes and surface runoff volume increases, the frequency of bankfull flow increases. This increase causes an increase in streambank erosion. An evaluation of Bluff Creek flow during 2002 through 2008 indicates bankfull discharge occurred twice during the period and both occurrences were in 2005 [(i.e., 85 cfs on September 5 and 175 cfs on October 5 (Figure 41)]. This is a frequency of once every 4 years, which is less than the average return interval of 1.5 years (Leopold, 1994; Dunne and Leopold, 1978). To prevent the current bankfull discharge frequency from increasing, management measures to prevent anthropogenic flow increases should be employed now and in the future.

Figure 40 Increased overland flow increases ravine erosion, pictured above, and increases sediment deposited and bedded in Bluff Creek.

Although there is no long-term record of anthropogenic flow increases, higher flows have been associated with declining IBI scores while lower flows have been associated with improving IBI scores (Figures 4 and 5). As shown in Figure 42, wet weather, as well as watershed land cover alteration, increase surface water inputs to Bluff Creek. Increased surface runoff increases sediment input from ravines as well as sediment input from streambank erosion. These increases in deposited and bedded sediment to Bluff Creek cause stress to the biological community as shown in Figure 33.

Hence, Figure 42 shows that flow interacts with sediment to cause impairment of the biological community.

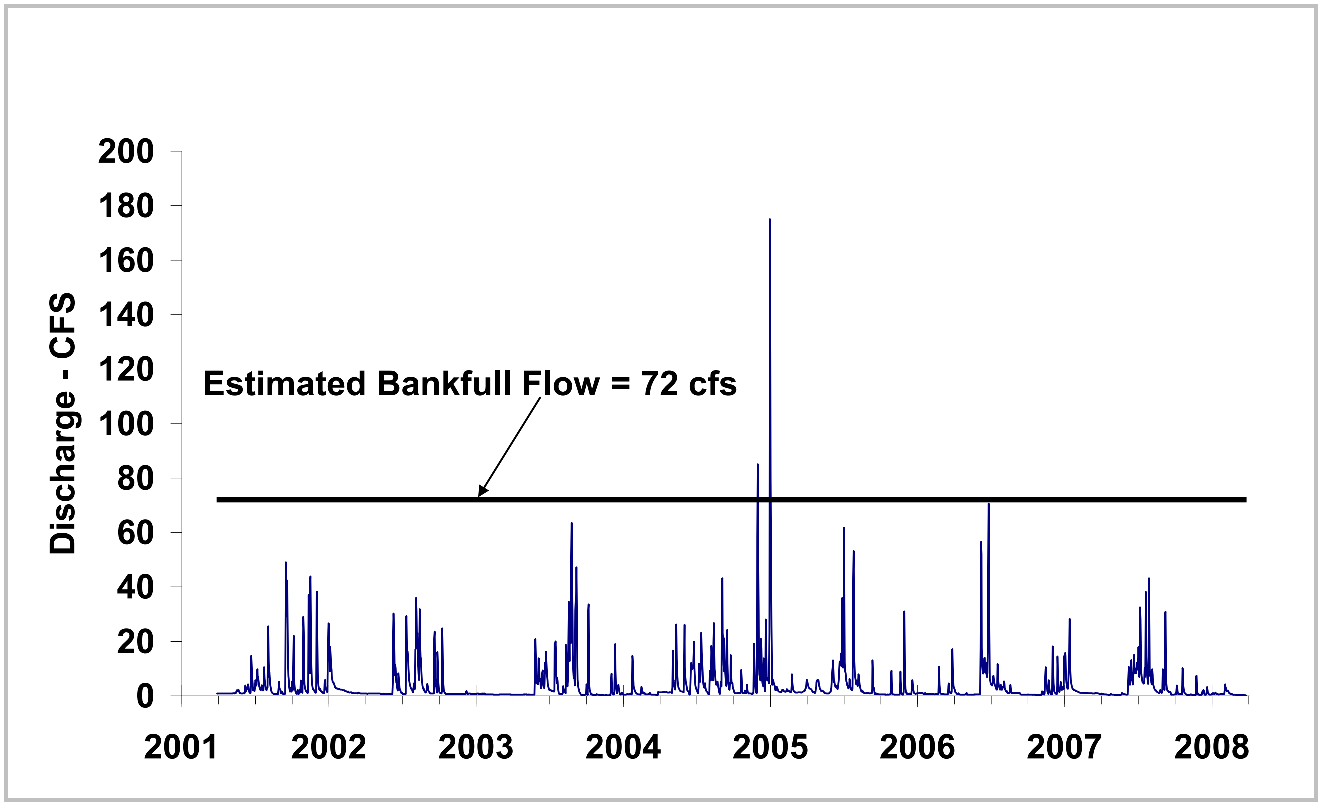

Figure 41 2002-2008 Bluff Creek Average Daily Flows Compared With Bankfull Flow: WOMP Station

Bluff Creek has consistently observed adequate baseflow to support the stream's biological community during the period of record. As shown in Figure 43, Bluff Creek mean daily flows at the WOMP Station (Figure 2) were at least 0.2 cfs during 1998 through 2008. Periods in which flow is not shown on the graph were periods in which equipment problems occurred and flow was not measured. According to Ball (1982), a discharge of at least 0.1 is required to support tolerant or very tolerant forage fish or tolerant macroinvertebrates and a discharge of at least 0.2 cfs is required to support intolerant forage fish, intolerant macroinvertebrates, or a valuable population of tolerant forage fish. Mean daily flows were consistently above the threshold required for the support of both tolerant and intolerant fish and invertebrates. Flow measurements at the WOMP Station and B-1 during 1998 indicate the two locations note nearly identical flows (Figure 44). Hence, flow data from the WOMP station appear to be representative of flows at B-1. The data indicate Bluff Creek at and downstream from B-1 has consistently observed adequate baseflow during the 1998 through

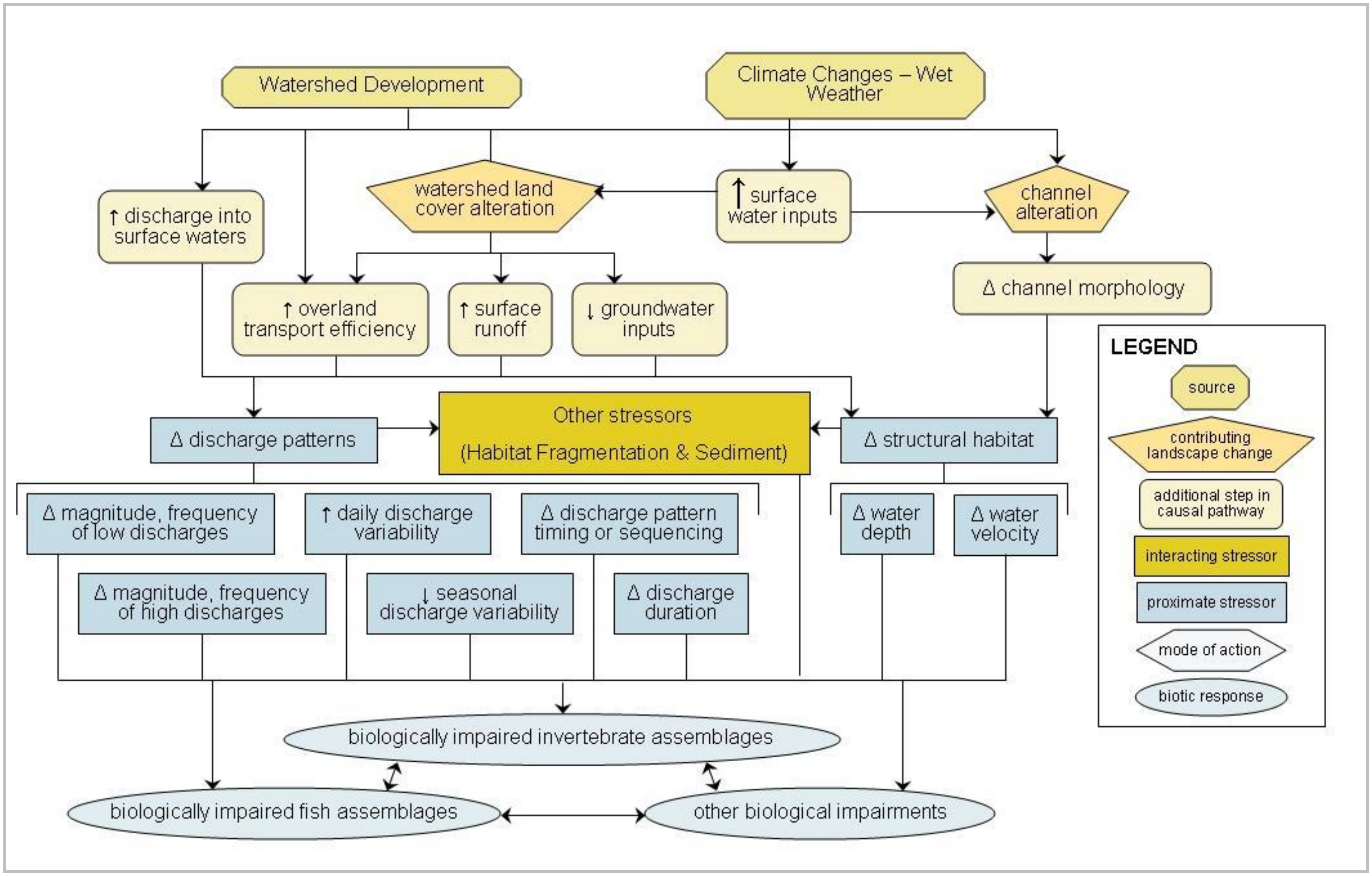

Figure 42 Conceptual Model of Candidate Cause 3: Flow

2008 period of record. The stream has not observed problematic low flow conditions and, therefore, only high flows appear to be a stressor to the stream's biological community.

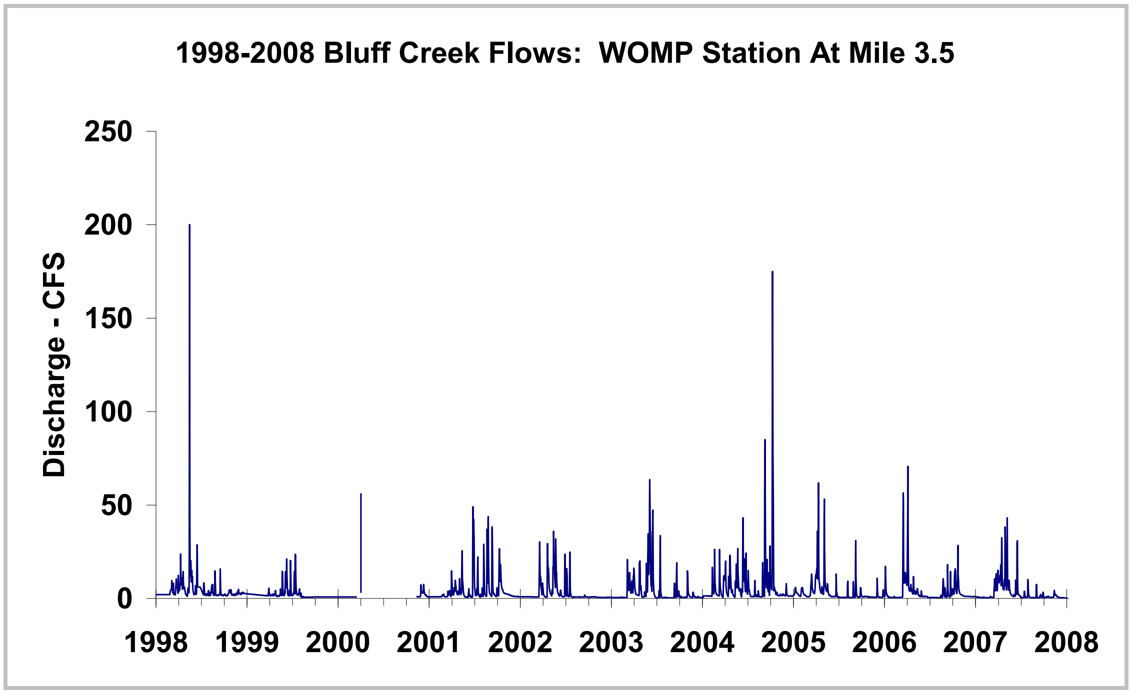

Figure 43 1998-2008 Bluff Creek Average Daily Flows: WOMP Station

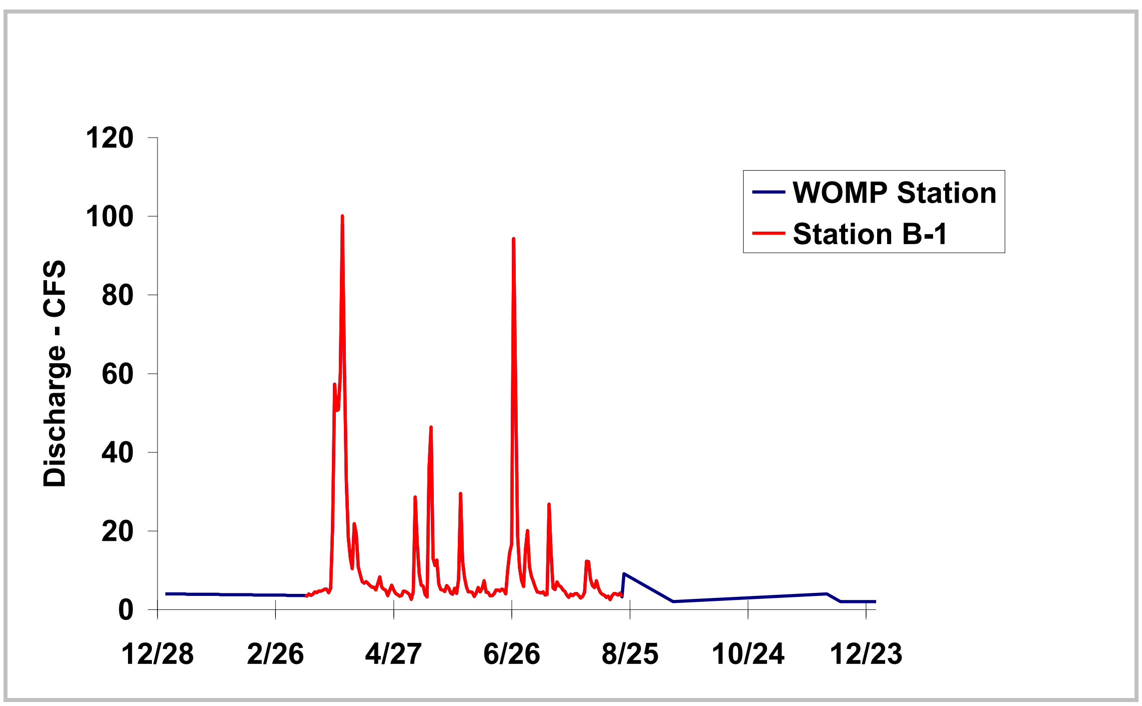

Figure 44 1998 Bluff Creek Discharge Data: B-1 and WOMP Station at Mile 3.5

High flows not only increase sediment loading to Bluff Creek, but also exacerbate the stress to the biological community caused by habitat fragmentation. The impact of extremely high flows on the biological community is evident from data collected during 1997 and 1998. Discharge at the WOMP Station (Figure 2) reached 2,476 cfs on April 13, 1997 (Figure 45) and generally ranged from 25 to 100 cfs during May through December of 1997 (Figure 46). No fish were observed or collected at B-1 during 1997 (Figure 4). Although flows were lower in 1998 (Figure 47) than 1997 (Figures 45 and 46), no fish were collected from B-1 during 1998 (Figure 4). It appears that when the high flows of 1997 moved fish downstream from the regional trail culvert, the habitat fragmentation prevented the fish from returning to the upstream location and replenishing the fish community. During 1999, flows were lower than 1997 through 1998 and fish were once again observed at B-1 (Figures 47, 4, and 5) due to replenishment of the fish community. Hence, Figure 42 shows that flow interacts with habitat fragmentation to cause impairment of the biological community.

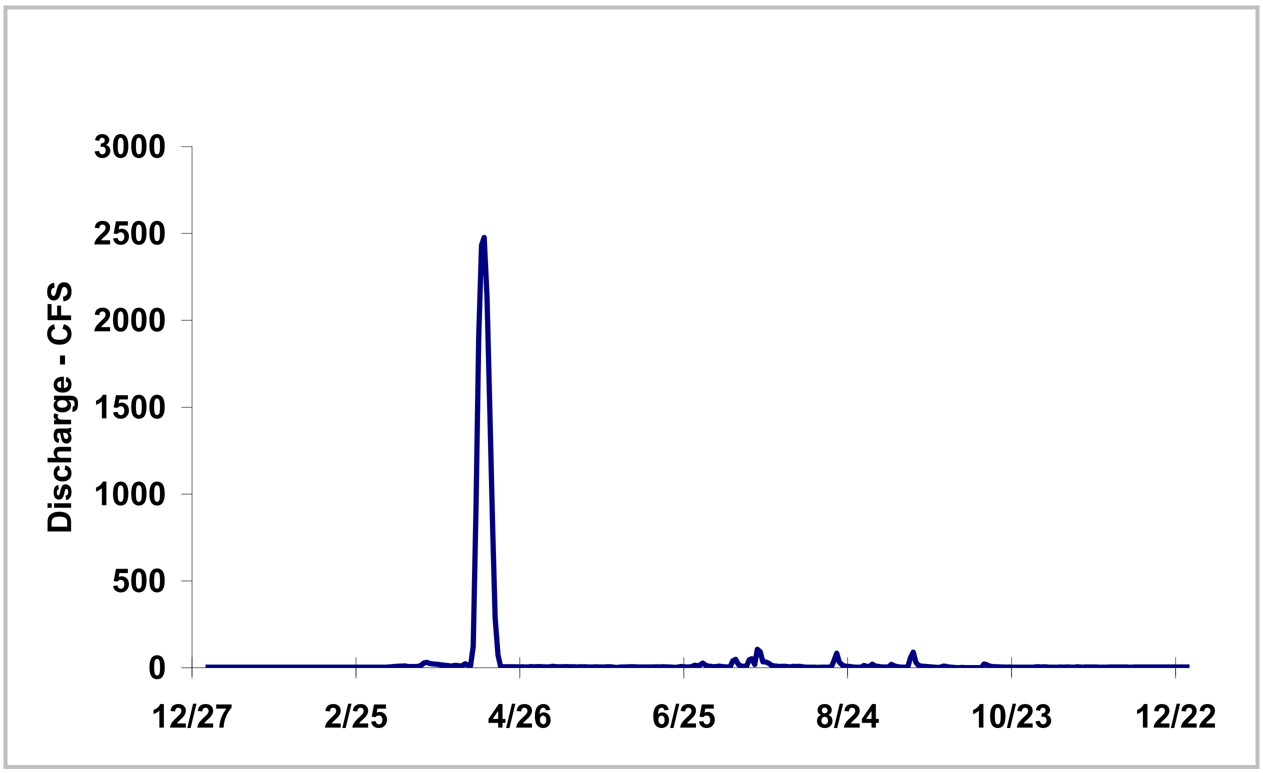

Figure 45 1997 Bluff Creek Flows: WOMP Station

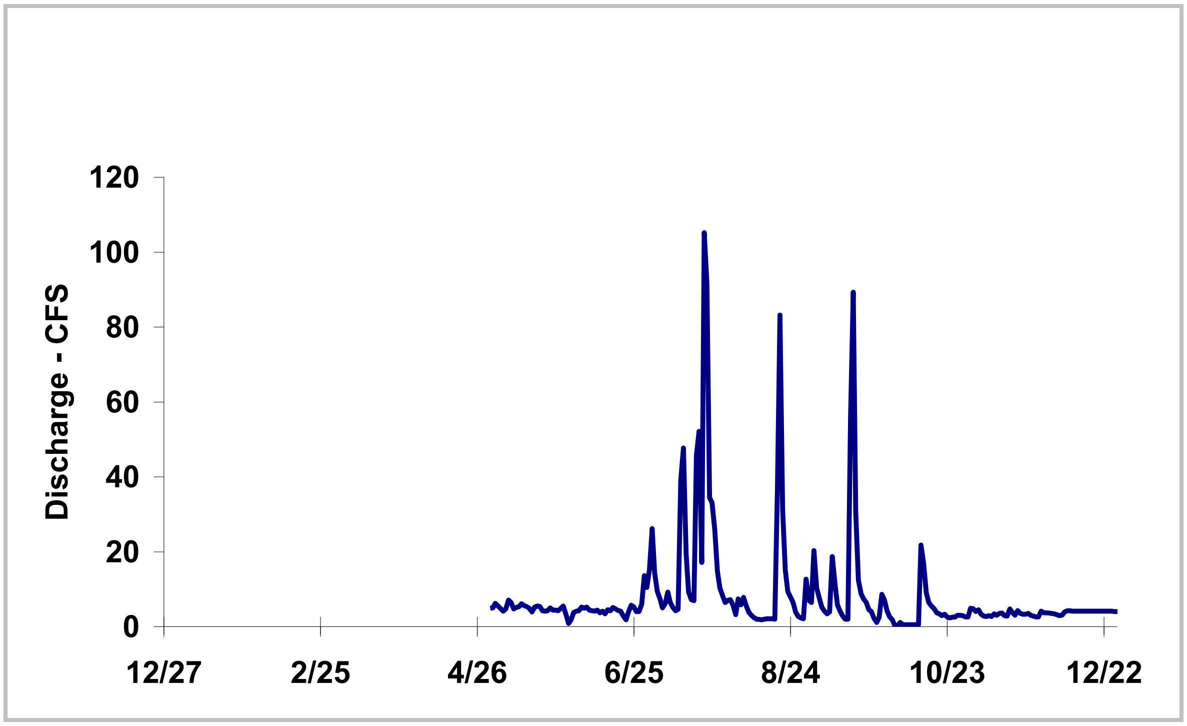

Figure 46 May Through December, 1997 Bluff Creek Flows: WOMP Station

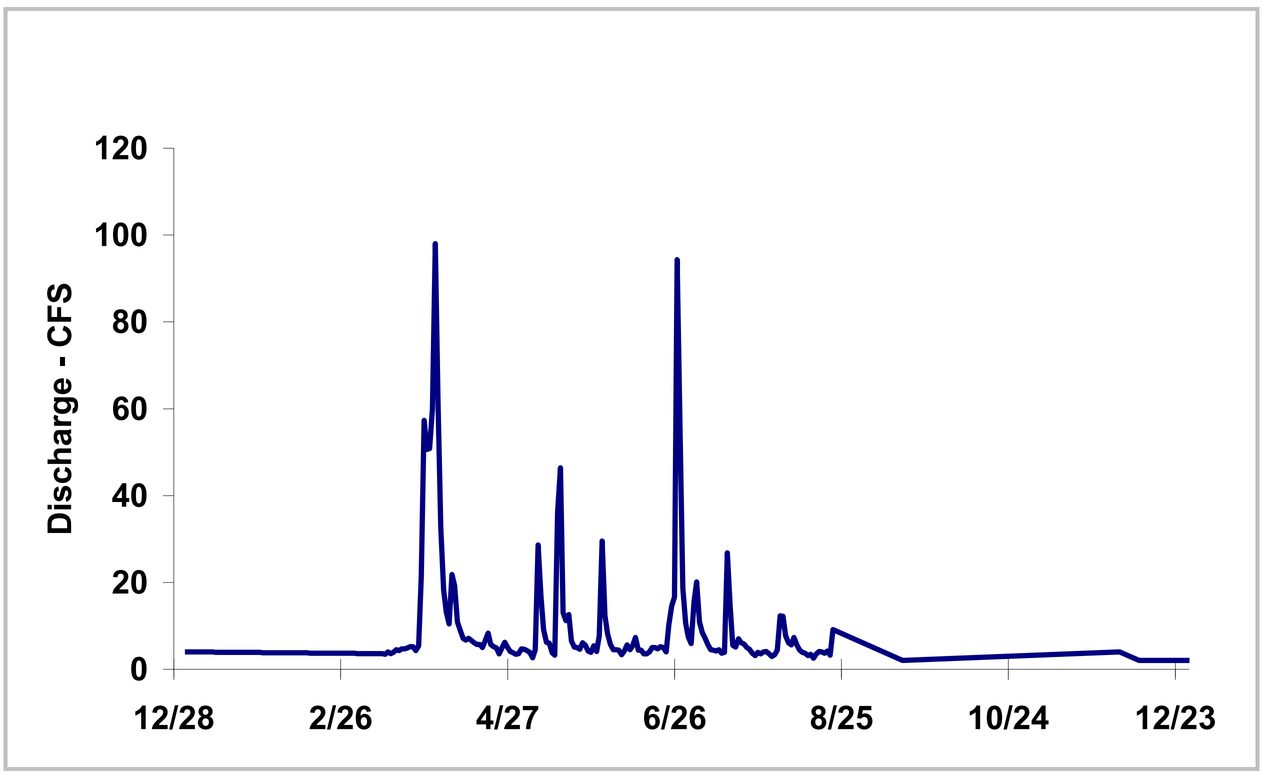

Figure 47 1998 Bluff Creek Flows: WOMP Station

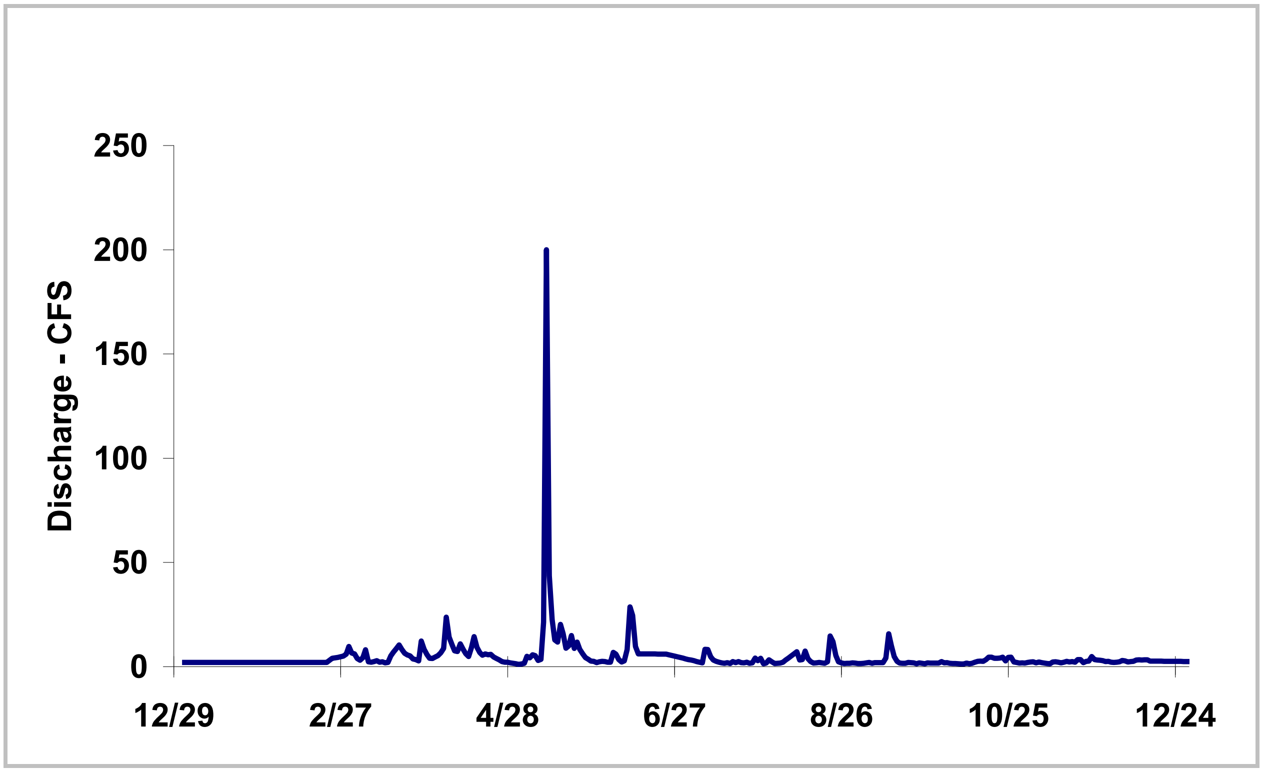

Figure 48 1999 Bluff Creek Flows: WOMP Station

4.2.4 Candidate Cause 4: Metals Contamination

Metals contamination is considered a candidate stressor because lead, copper, and zinc have failed to meet MPCA standards for Bluff Creek. However, because MCES sample collection methods (MCES 2003) and analyses methods did not include the EPA "clean hands/dirty hands" method, the rigorous ultra clean protocols of this method were not employed in sample collection and analysis. Hence, there is the possibility that some level of contamination occurred and the high values are a result of contamination rather than the addition of pollutants to the stream. Additional monitoring using the "clean hands/dirty hands" method for both sample collection and analysis is recommended to confirm that lead, copper, and zinc are candidate stressors of Bluff Creek.

Metals data collected from the MCES WOMP station during 1993 through 2008 were analyzed and the analyses results depicted in Figures 49 through 72 which show analyses results for each of the six metals species: lead, copper, zinc, cadmium, chromium, nickel. Four types of graphs are shown for each of the six metals species.

- Concentrations of metals plotted on the y-axis and sample collection date plotted on the x-axis for each metals species. The Class 2B chronic standard is also shown for each metals species. The chronic standard is the highest concentration of a toxicant to which aquatic organisms can be exposed indefinitely with no harmful effects, or to which humans or wildlife consumers of aquatic organisms can be exposed for a lifetime with no harmful effects. Because the standard varies with total hardness, the chronic standard values for Bluff Creek were calculated from equations provided for each metals species in Minn. R. Pt. 7050.0222, subpart 4 (Figures 49, 53, 57, 61, 65, 69).

- Concentrations of metals plotted on the y-axis and hardness on the x-axis with three Class 2B standards - chronic, maximum, and final acute values (FAV) – shown for each metals species. **Chronic standard (CS)** is the highest concentration of a toxicant to which aquatic organisms can be exposed indefinitely with no harmful effects, or to which humans or wildlife consumers of aquatic organisms can be exposed for a lifetime with no harmful effects. **Maximum standard (MS)** is a concentration that protects aquatic organisms from potential lethal effects of a short-term "spike" in toxicant concentrations. The MS is always equal to one half the final acute value. **Final acute value (FAV)** is the concentration that would kill about half of the exposed individuals of a very sensitive aquatic species. The FAV is most often used as an "end-of-pipe" effluent limit to prevent an acutely toxic condition in the effluent or the mixing zone (Figures 50, 54, 58, 62, 66, 70).
- Relationship between metals concentrations and total suspended solids (TSS) for each metals species– this graph indicates whether or not metals are conveyed to Bluff Creek via total suspended solids (Figures 51, 55, 59, 63, 67, and 71).
- Relationship between metals concentrations and flow duration interval for each metals species – this graph indicates the flow range in which the highest concentrations are observed (Figures 52, 56, 60, 64, 68, 72).

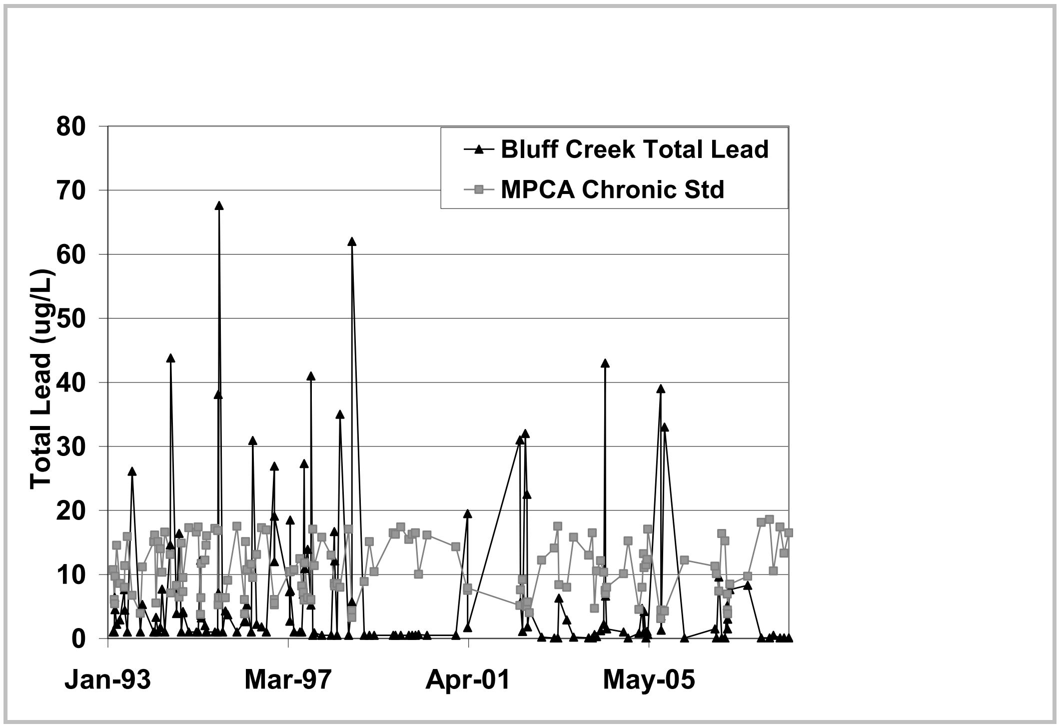

Figure 49 1993-2008 Bluff Creek Total Lead Compared With Chronic Standard: WOMP Station

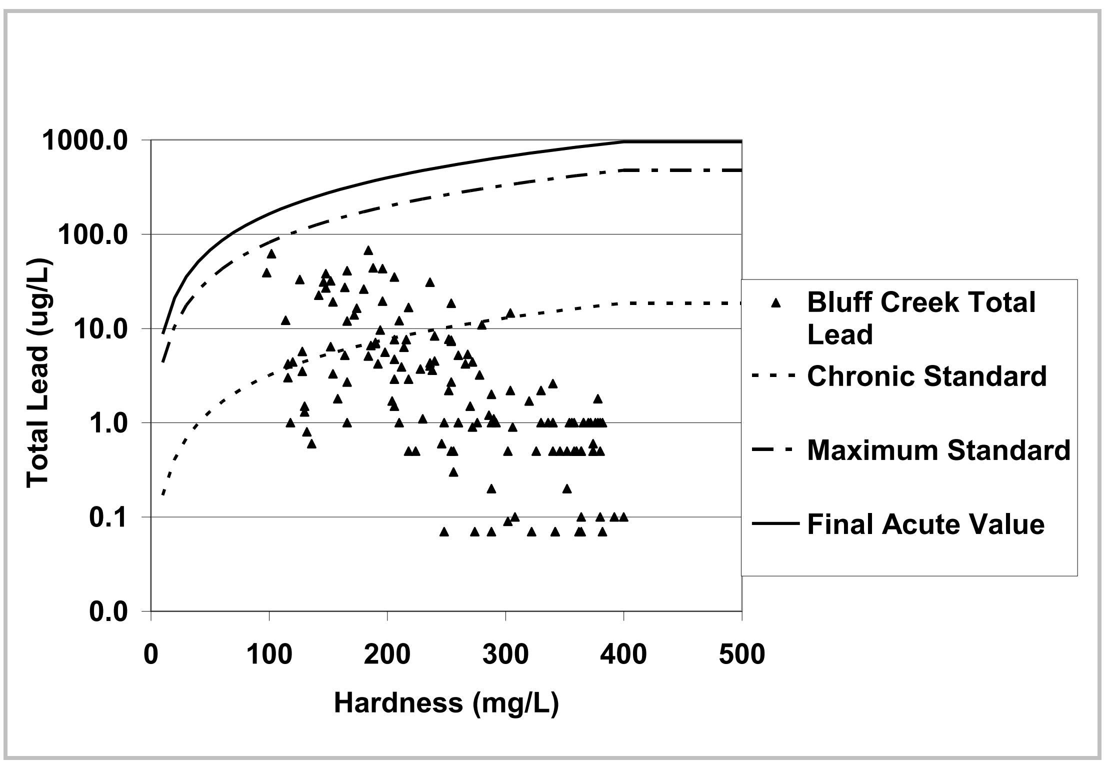

Figure 50. 1993-2008 Bluff Creek Total Lead: WOMP Station

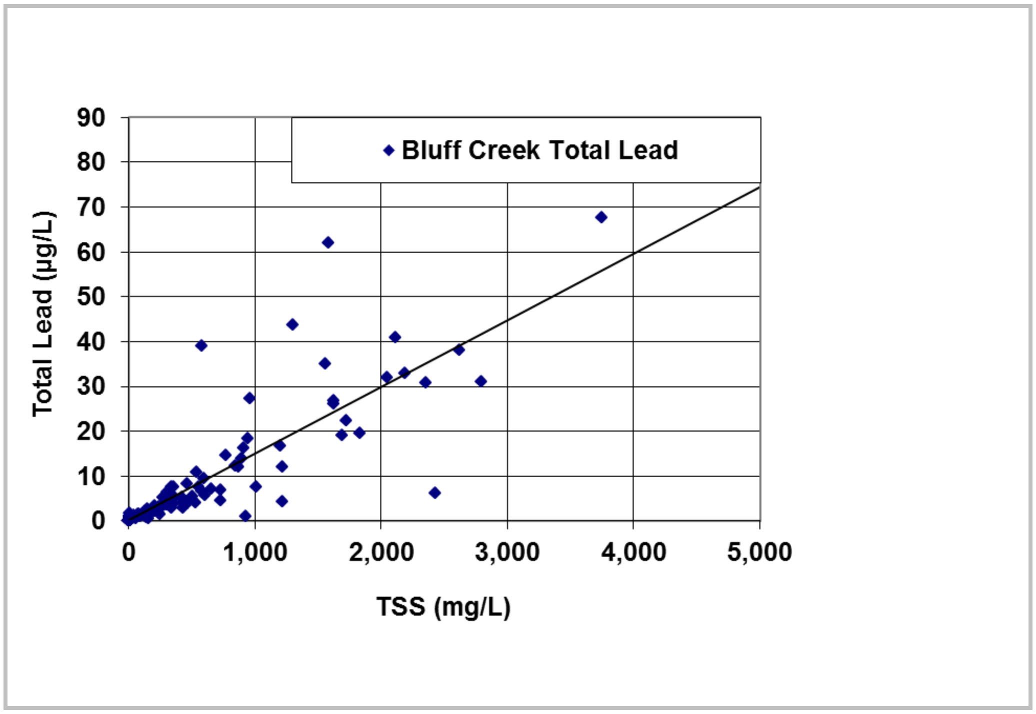

Figure 51. Lead versus Suspended Solids for Bluff Creek WOMP Site

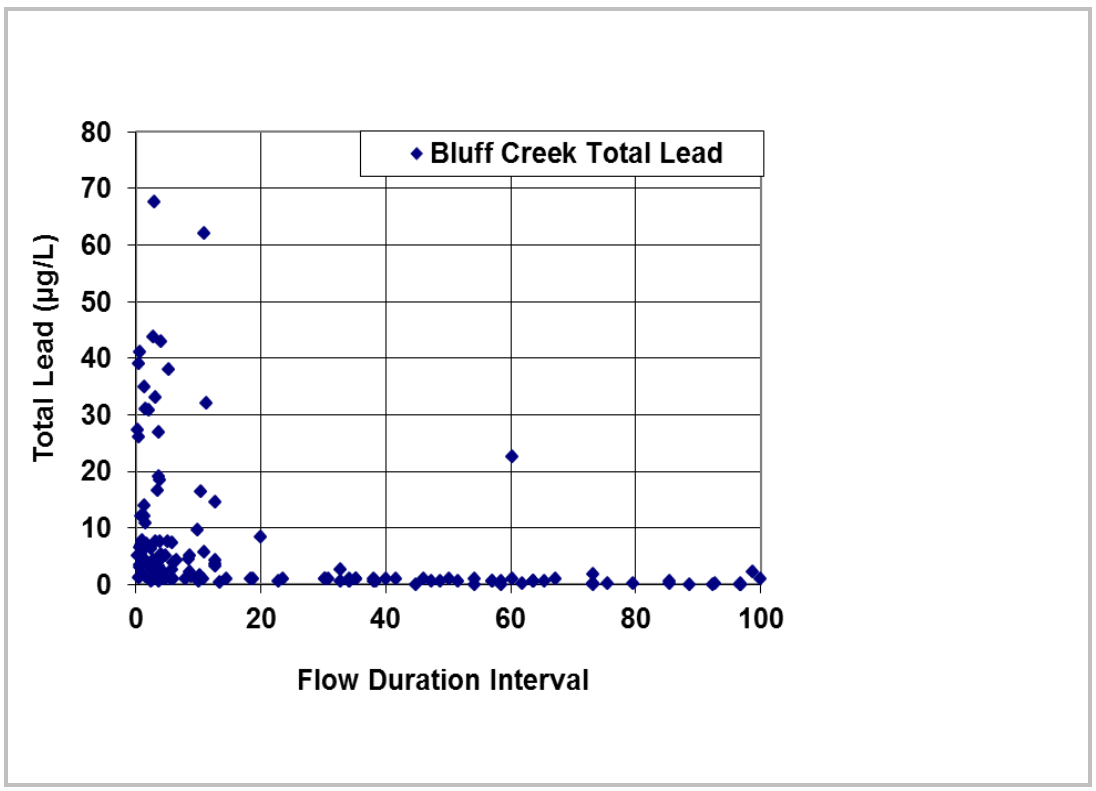

Figure 52. Lead Water Quality Duration Curve for Bluff Creek WOMP Site

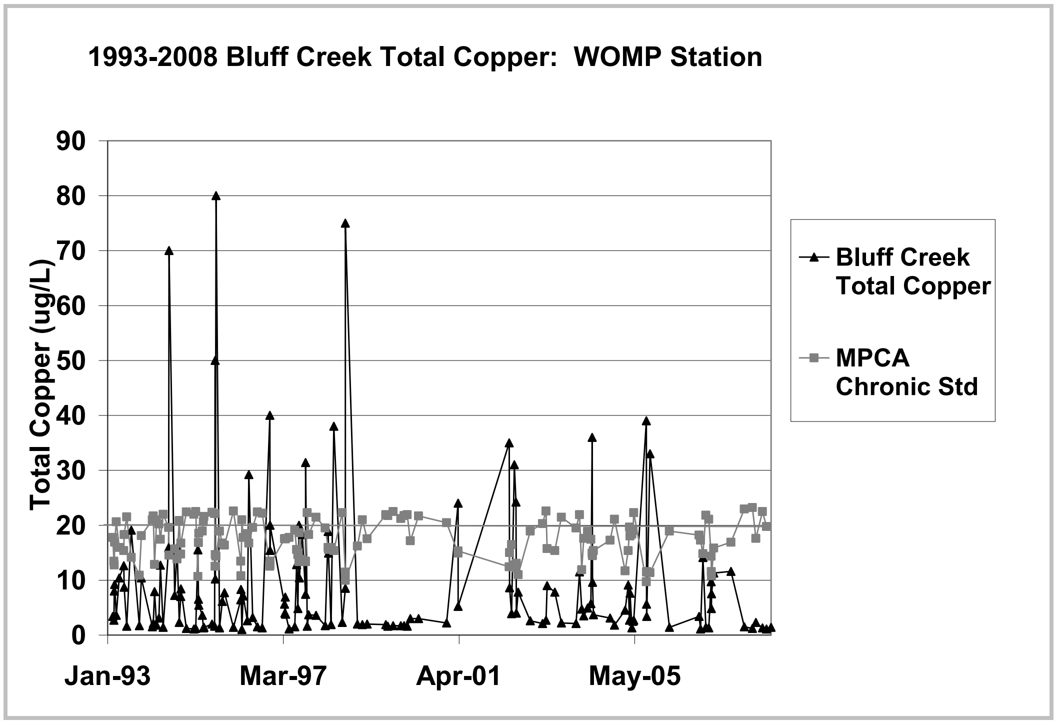

Figure 53 1993-2008 Bluff Creek Total Copper Compared With Chronic Standard: WOMP Station

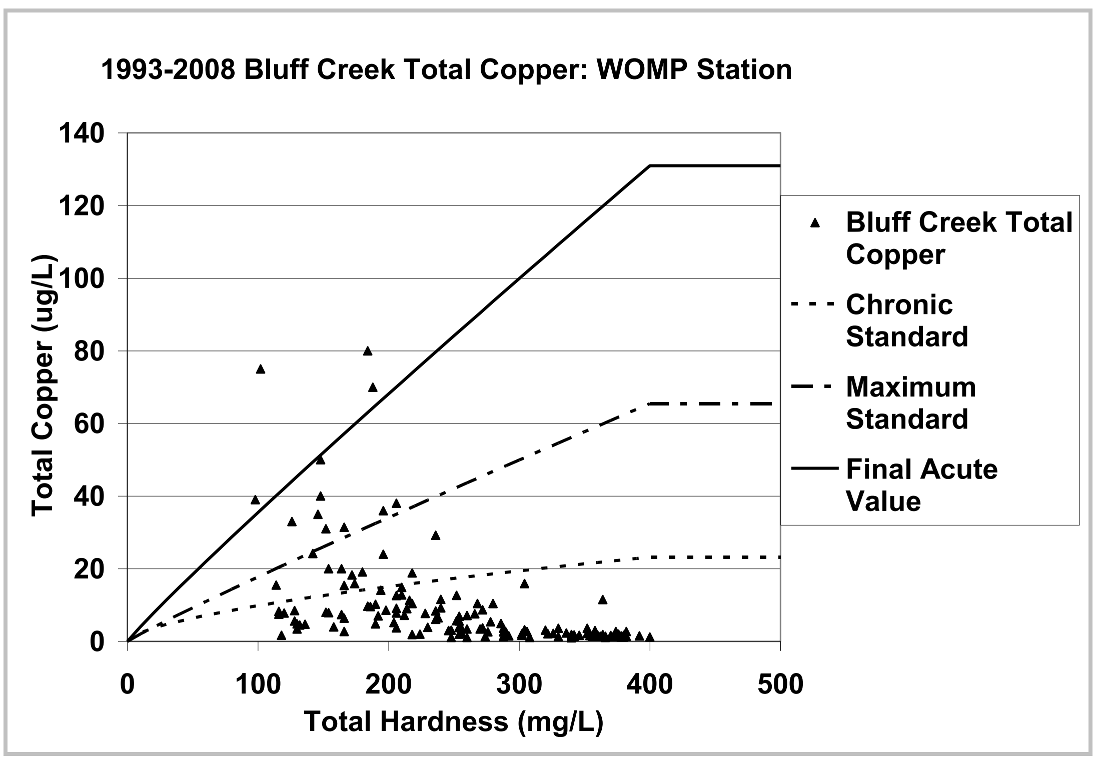

Figure 54. 1993-2008 Bluff Creek Total Copper: WOMP Station

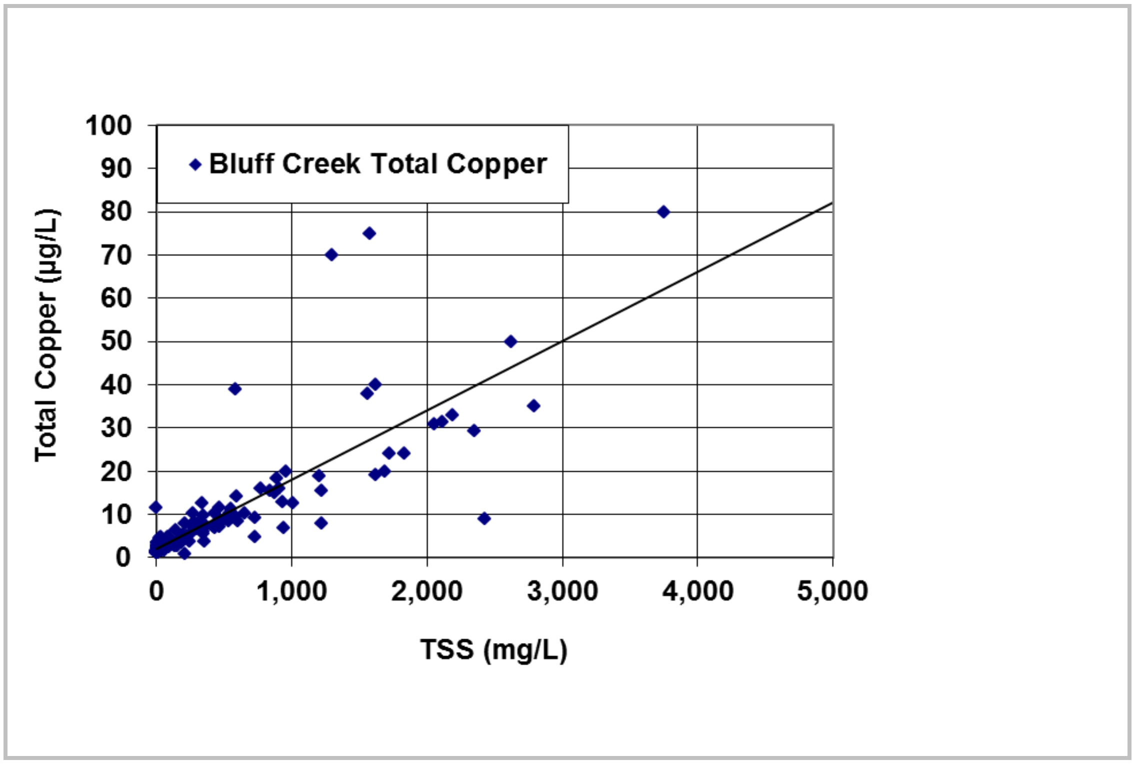

Figure 55. Copper versus Suspended Solids for Bluff Creek WOMP Site

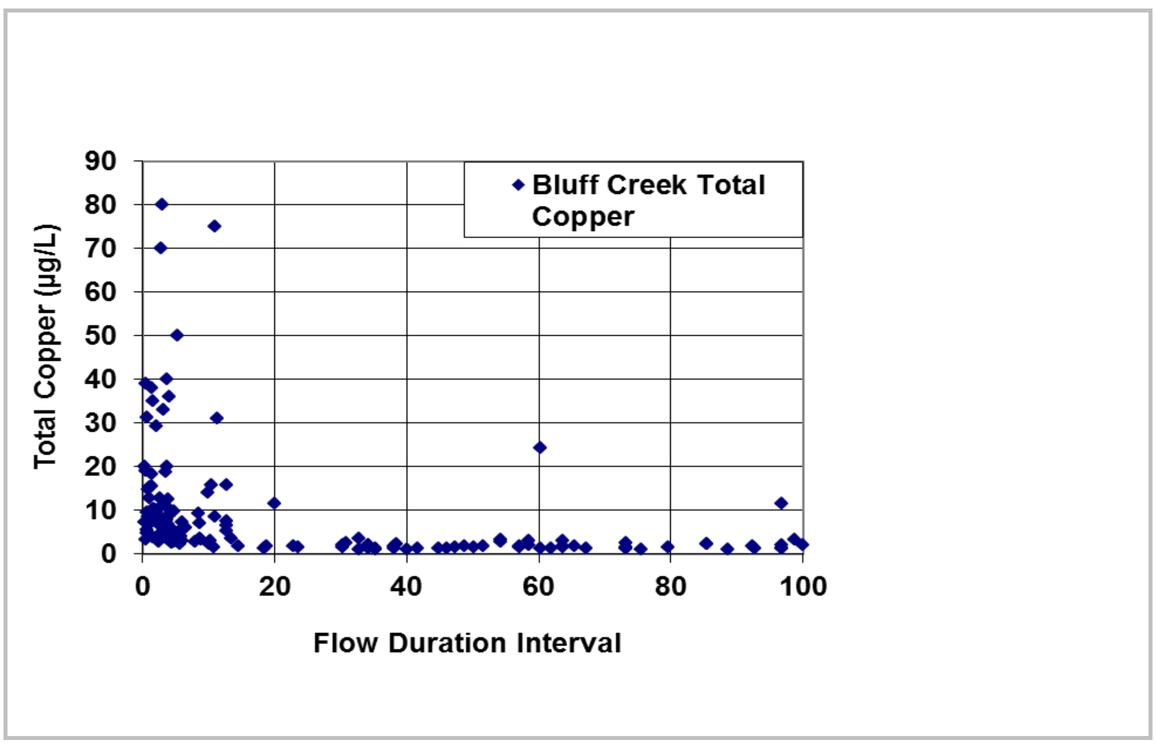

Figure 56. Copper Water Quality Duration Curve for Bluff Creek WOMP Site

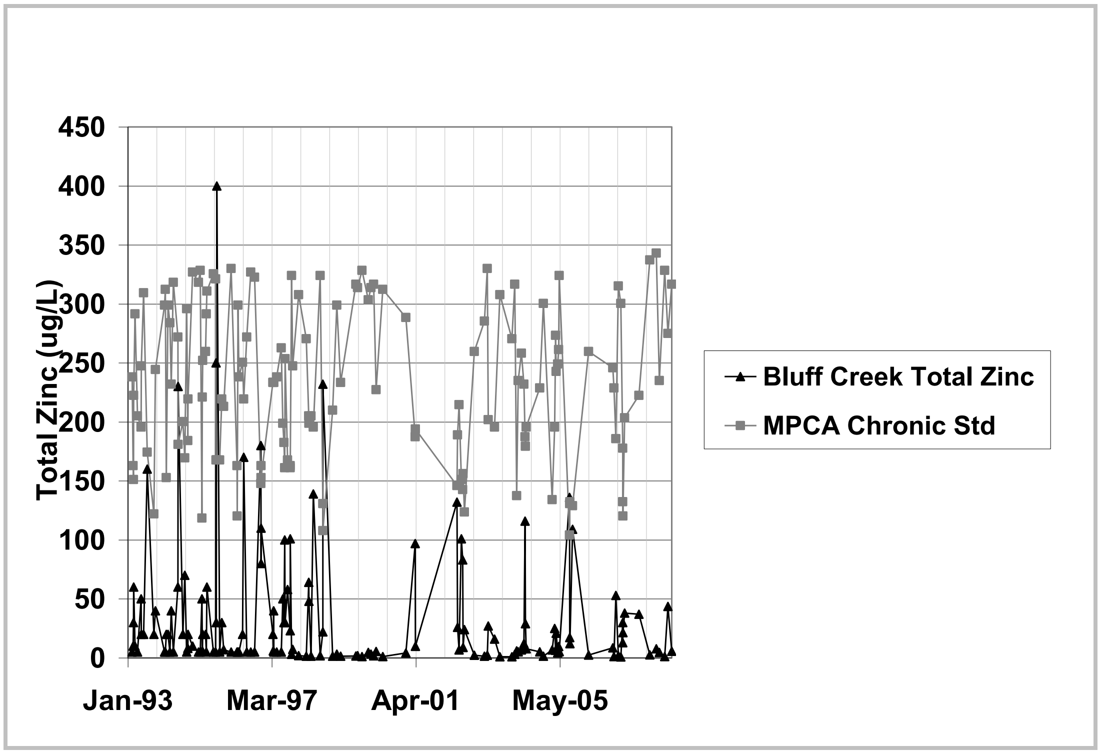

Figure 57 1993-2008 Bluff Creek Total Zinc Compared With Chronic Standard: WOMP Station

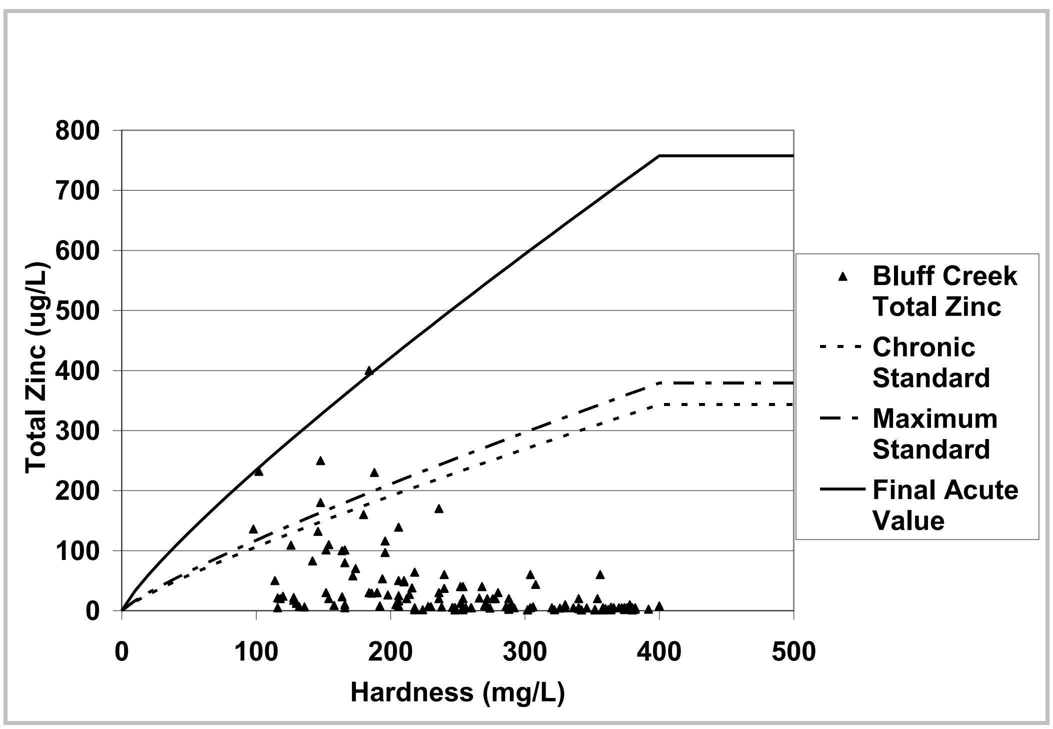

Figure 58. 1993-2008 Bluff Creek Total Zinc: WOMP Station

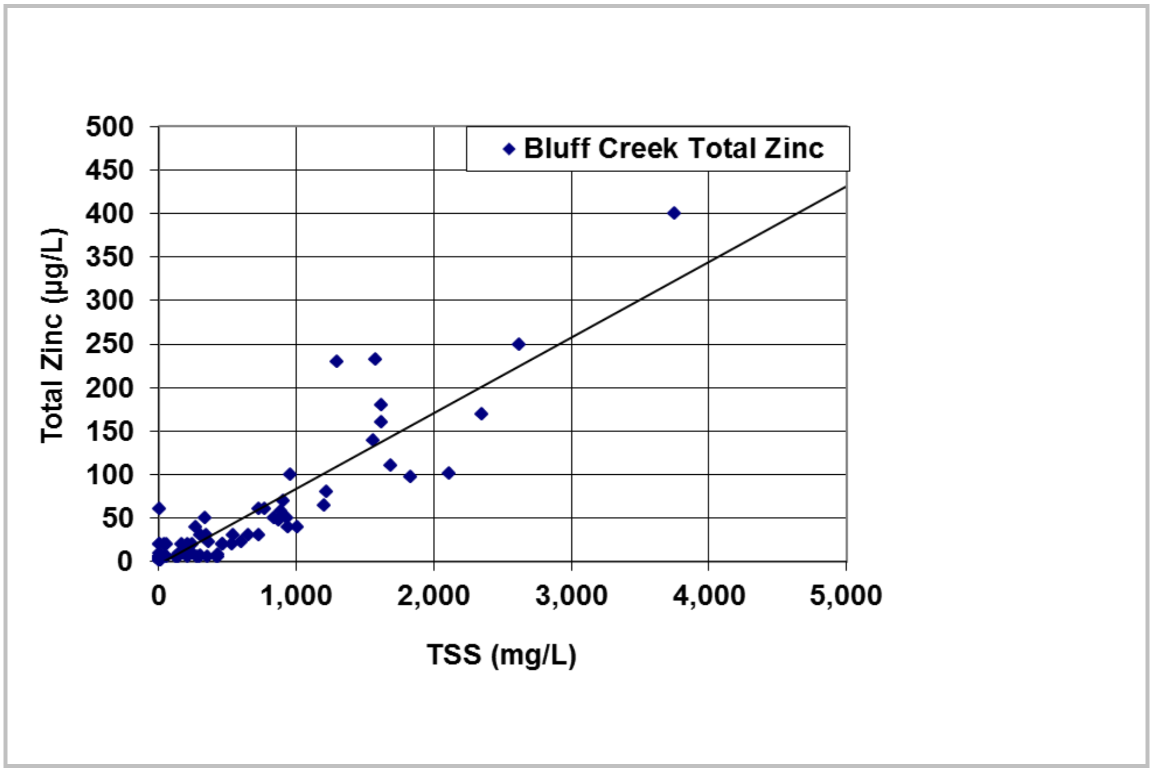

Figure 59. Zinc versus Suspended Solids for Bluff Creek WOMP Site

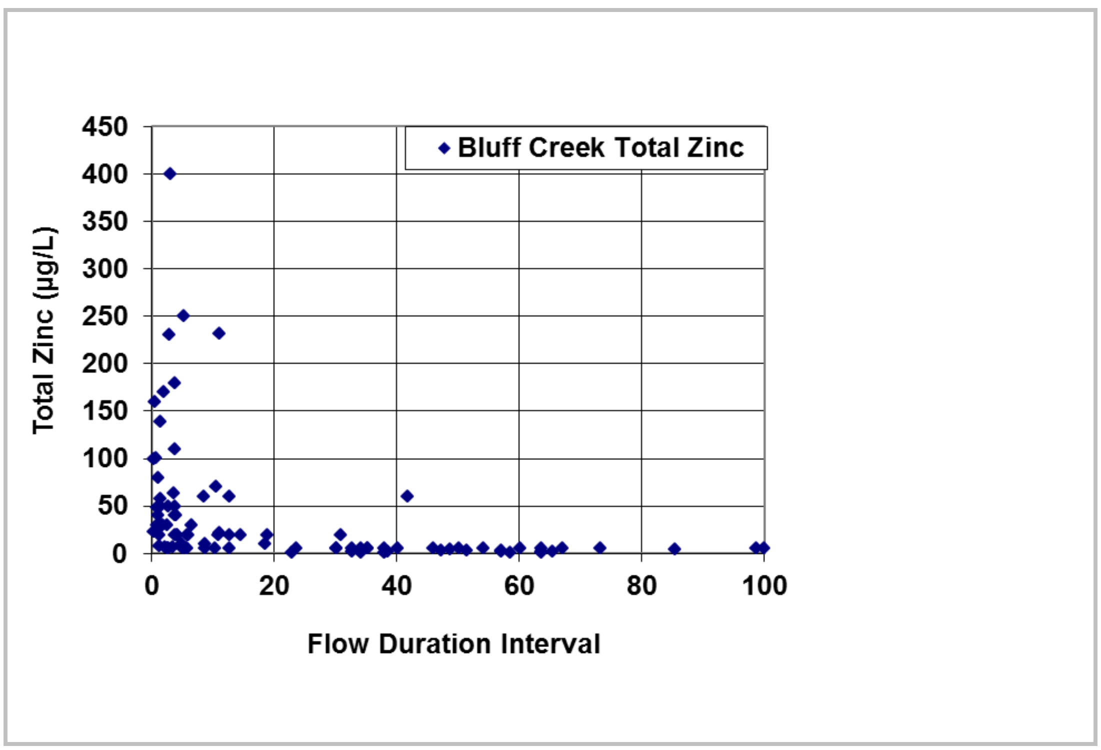

Figure 60. Zinc Water Quality Duration Curve for Bluff Creek WOMP Site

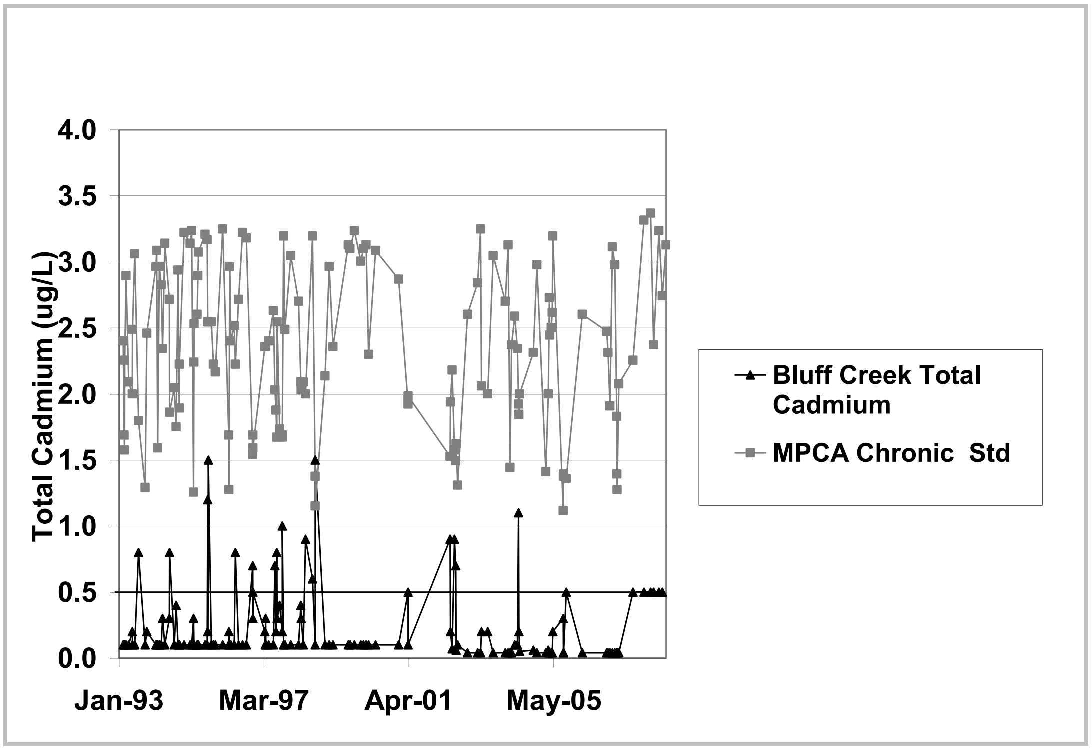

Figure 61 1993-2008 Bluff Creek Total Cadmium Compared With Chronic Standard: WOMP Station

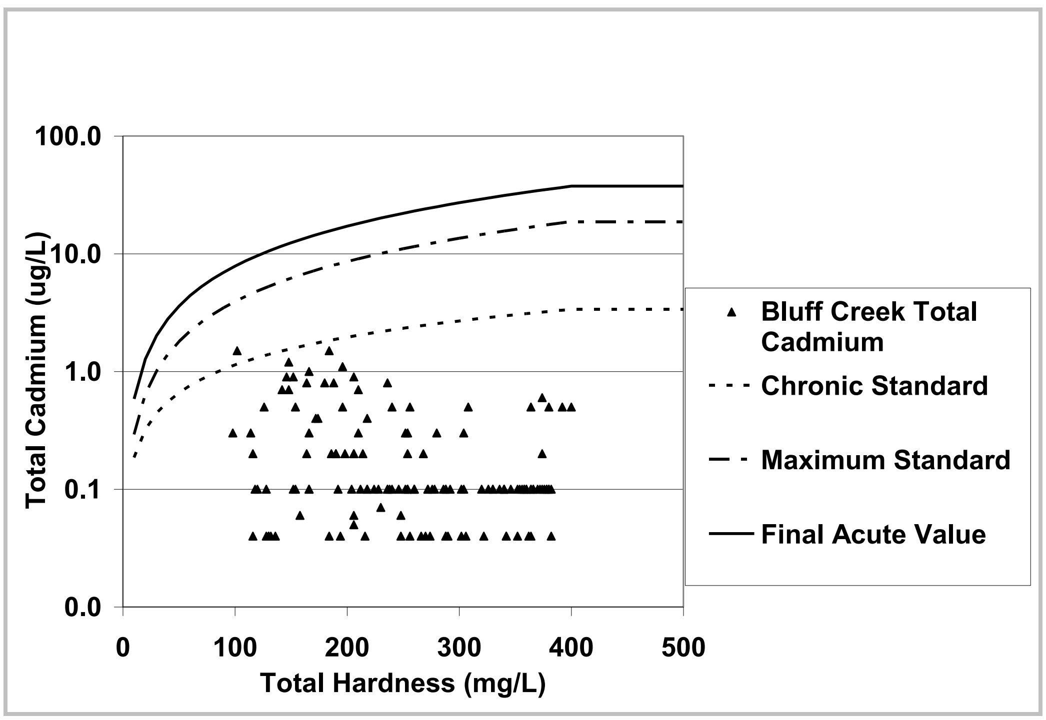

Figure 62. 1993-2008 Bluff Creek Total Cadmium: WOMP Station

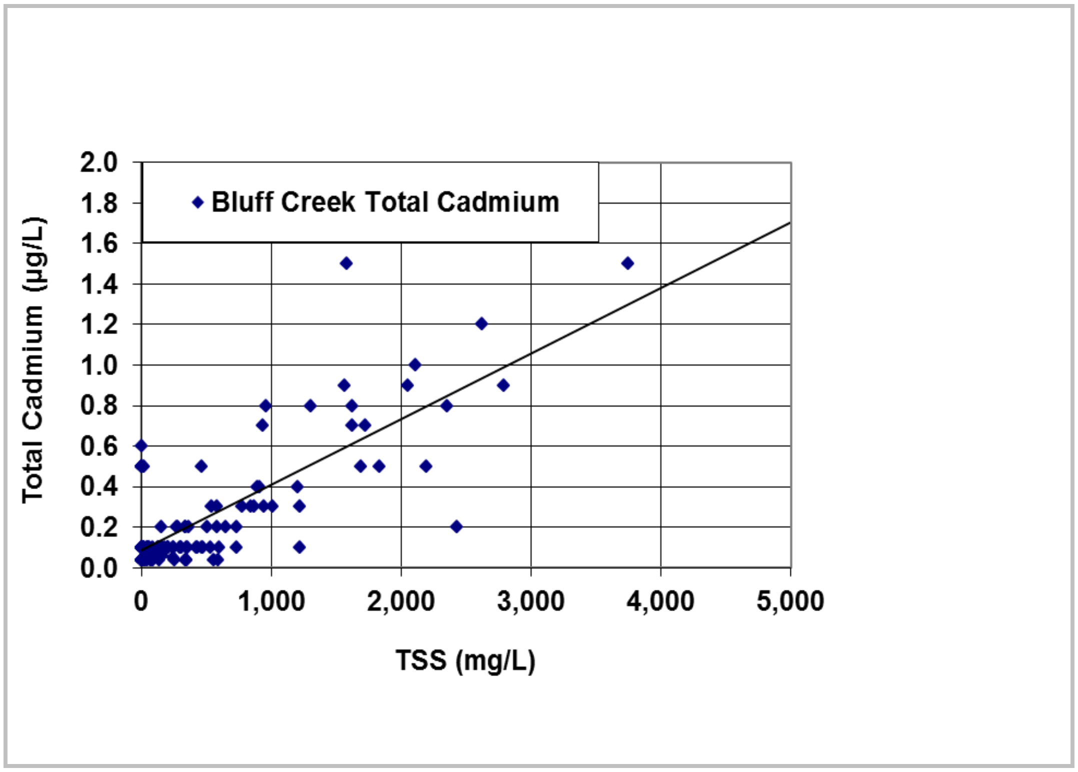

Figure 63. Cadmium versus Suspended Solids for Bluff Creek WOMP Site

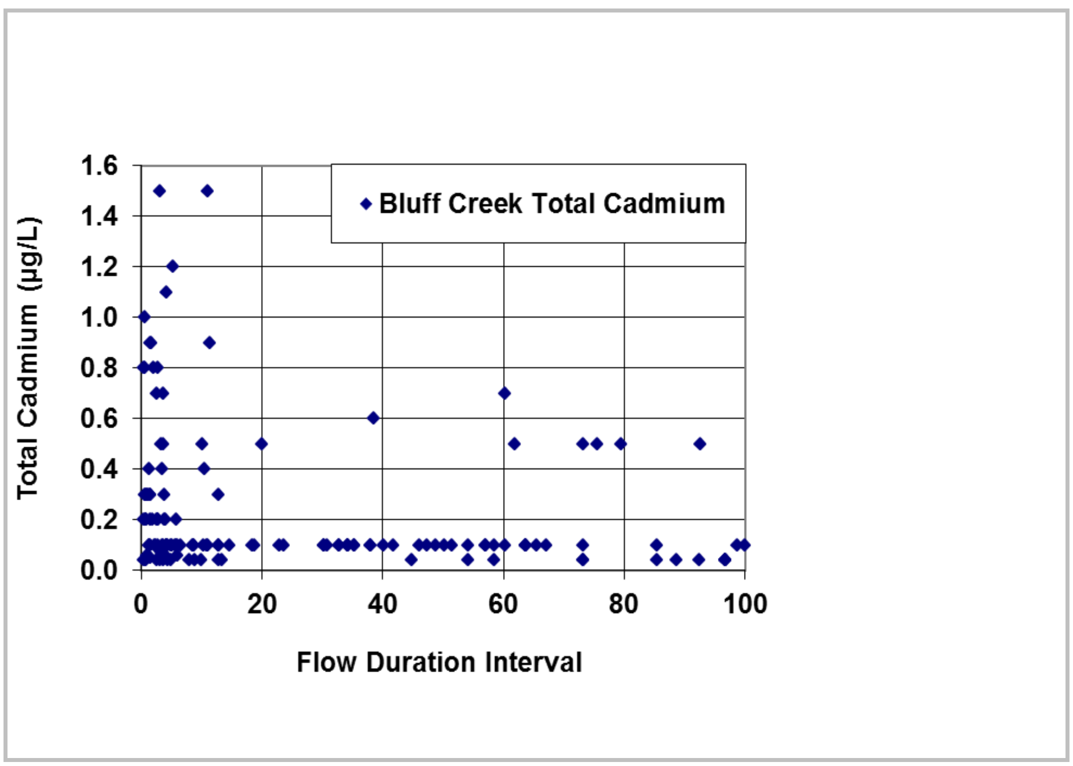

Figure 64. Cadmium Water Quality Duration Curve for Bluff Creek WOMP Site

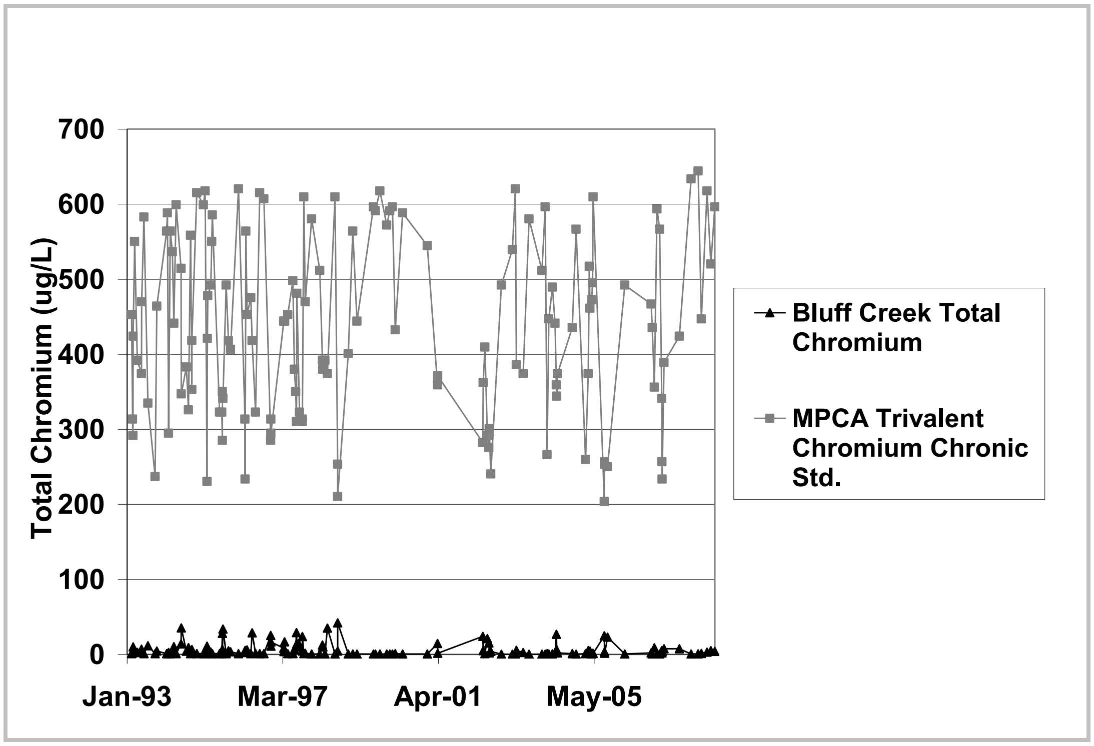

Figure 65 1993-2000 Bluff Creek Total Chromium Compared With Chronic Standard: WOMP Station

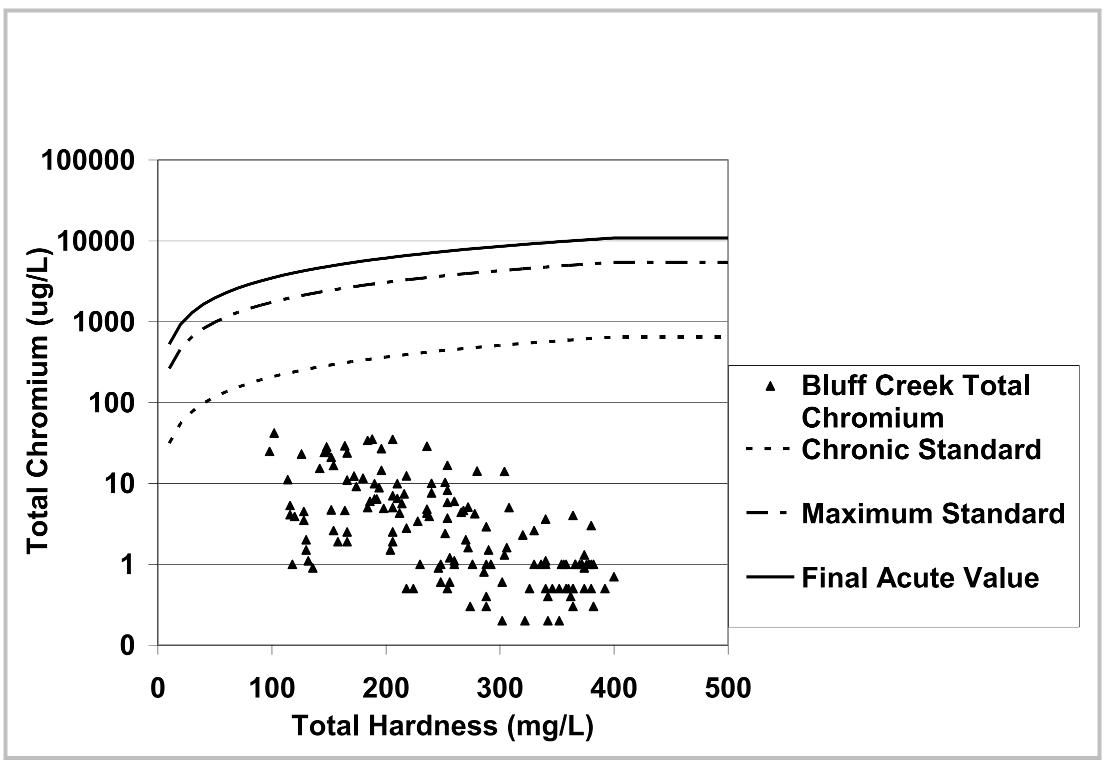

Figure 66. 1993-2008 Bluff Creek Total Chromium: WOMP Station

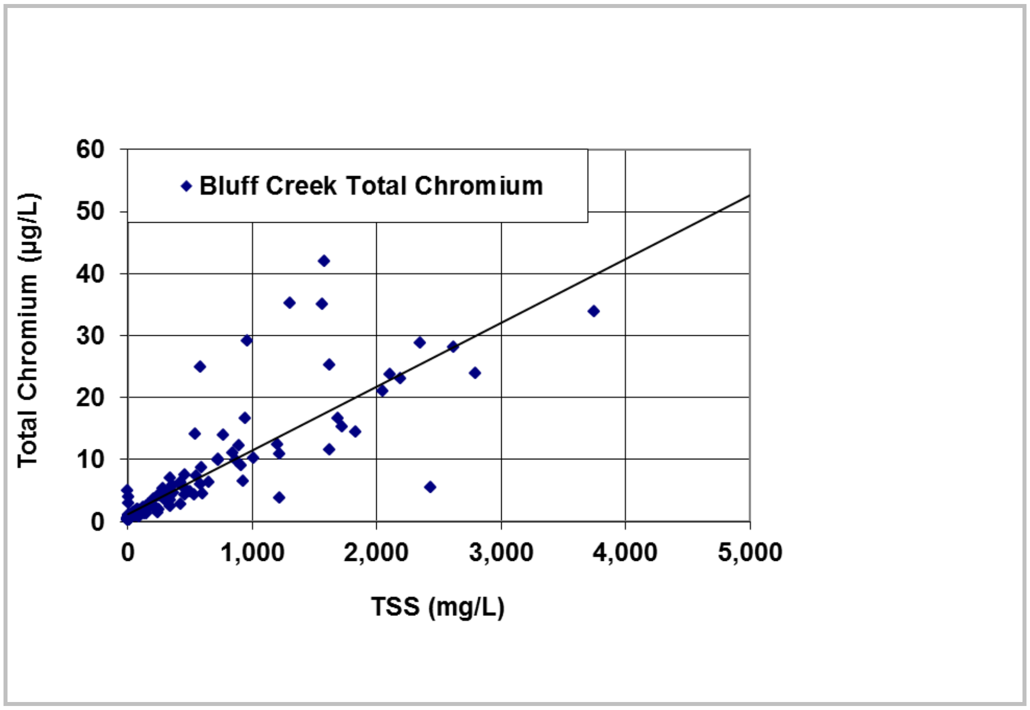

Figure 67. Chromium versus Suspended Solids for Bluff Creek WOMP Site

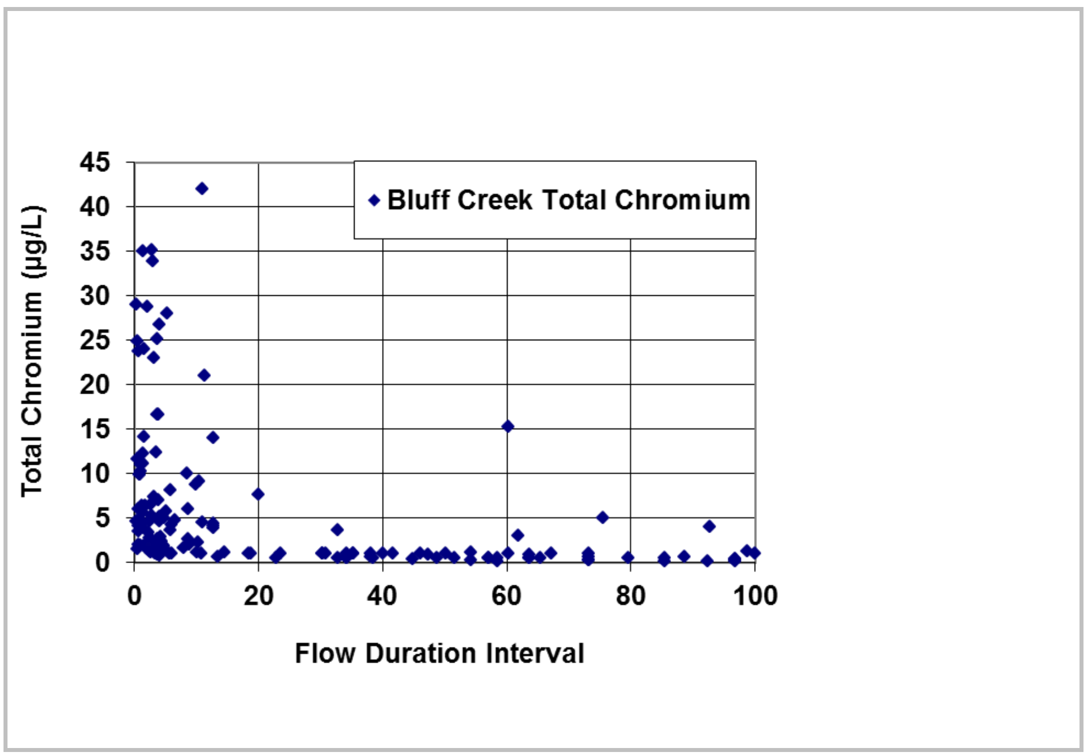

Figure 68. Chromium Water Quality Duration Curve for Bluff Creek WOMP Site

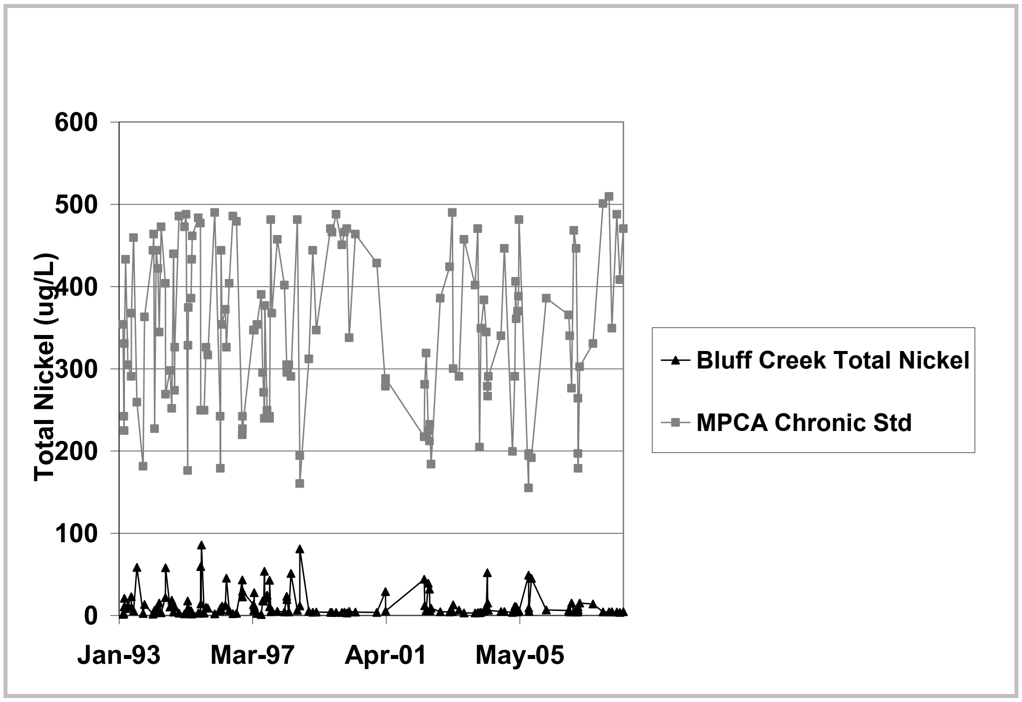

Figure 69 1993-2008 Bluff Creek Total Nickel Compared With Chronic Standard: WOMP Station

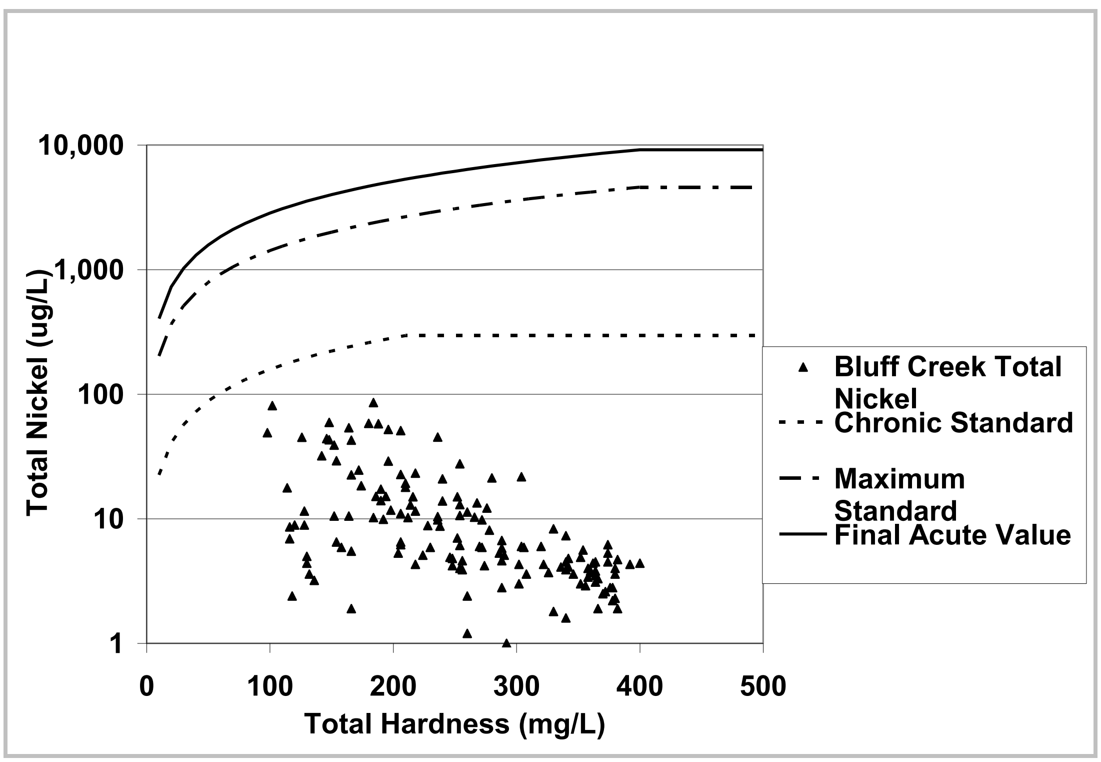

Figure 70. 1993-2008 Bluff Creek Total Nickel: WOMP Station

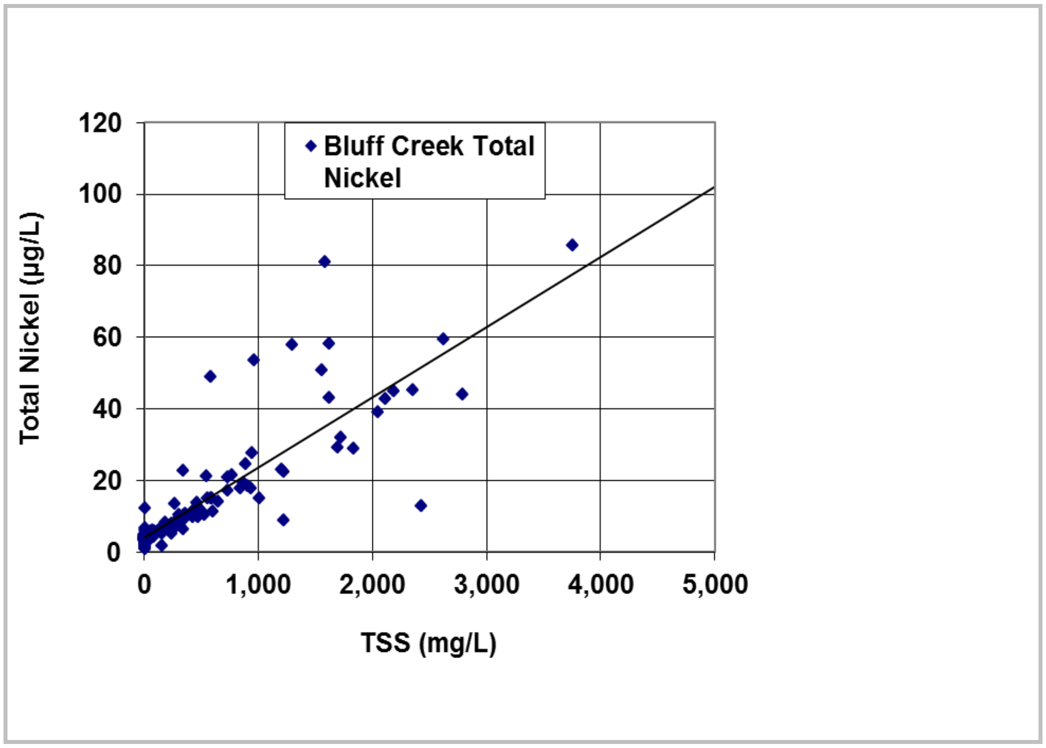

Figure 71. Nickel versus Suspended Solids for Bluff Creek WOMP Site

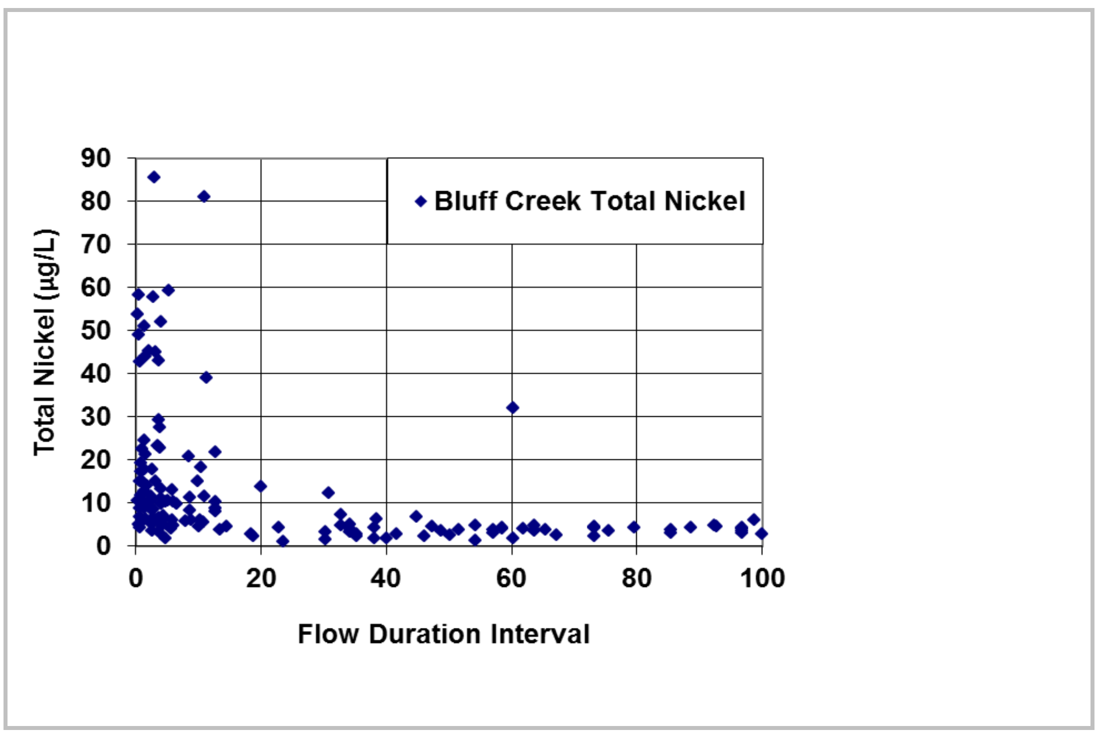

Figure 72. Nickel Water Quality Duration Curve for Bluff Creek WOMP Site

Water quality data collected by the MCES at the WOMP Station (Figure 2) during 1993 through 2008 indicate nickel and chromium have consistently met all three MPCA standards, but lead, copper, zinc, and cadmium failed to meet one or more standards:

- Lead—failed to meet the chronic standard at a frequency of 10 percent but always met the maximum standard and FAV (Figures 49 through 50)

- Copper—failed to meet the chronic standard at a frequency of 7 percent, failed to meet the maximum standard at a frequency of 2 percent, and failed to meet the FAV at a frequency of 1 percent (Figures 53 and 54).

- Zinc—failed to meet the chronic standard at a frequency of 2 percent, failed to meet the maximum standard at a frequency of 2 percent, and failed to meet the FAV at a frequency of 1 percent (Figures 57 and 58)

- Cadmium—failed to meet the chronic standard at a frequency of 0.3 percent but always met the maximum standard and FAV (Figures 61 and 62).

The data indicate lead, copper, and zinc are candidate stressors of Bluff Creek. Research studies have shown that high concentrations of these metals species have the following adverse impacts on fish:

- **Lead**—Fish exposed to high levels of lead have exhibited muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis (Eisler, 1988).

- **Copper—**High concentrations of copper have been toxic to fish (Owen, 1981).

- **Zinc**—Growth, survival, and reproduction can all be adversely affected by elevated zinc levels (Eisler, 1993).

An analysis of the relationship between flow duration intervals and metals concentrations (i.e., lead, copper, and zinc) indicates highest metals concentrations consistently occurred during high flows [(i.e., flows occurring at a frequency of less than 20 percent (Figures 52, 56, 60, and 64)]. An analysis of the relationship between total suspended solids and metals concentrations (i.e. lead, copper, and zinc) indicates metals concentrations in Bluff Creek are related to total suspended solids (Figures 51, 55, 59, and 63). The data indicate metals are entering Bluff Creek with sediment during periods of high flow. Because “clean hands/dirty hands” methodology was not employed during collection and analyses of metals samples, the potential for contamination is acknowledged. For this reason, paired biological and metals monitoring using “clean hands/dirty hands” methodology for sampling and analysis is recommended to confirm metals contamination as well as adverse impacts of metals contamination on Bluff Creek biota.

As shown in Figure 73, metals harm the biological community by increasing mortality, increasing susceptibility to other stressors, reducing reproductive success, and increasing deformities and disease. Harm occurs whether metals occur as particulate metals (i.e., sorbed to particles and bound to abiotic ligands) or dissolved metals (i.e., are found in membrane permeable organometallic compounds). Particulate metals are ingested and absorbed in the gut, increasing the tissue concentration of metals. As tissue concentration of metals increases, protein damage increases, membrane destabilization occurs, and bioaccumulation may occur. Free metal ions enter organisms through passive diffusion through the gill epithelium or through increased binding and uptake at the gill epithelium. Once ingested, free metals ions reduce the uptake of nutrients, impair blood ion regulation, and increase tissue concentrations of metals. As tissue concentrations of metals increase, protein damage and membrane destabilization occurs. The end result of exposure to high metals concentrations is a biologically impaired fish and invertebrate community.

A comparison of metals concentrations and mayfly numbers in Bluff Creek during 1999 through 2005 provides evidence of the harm that high metals concentrations may be causing to the mayfly community of Bluff Creek. Numbers of *Baetis brunneicolor* from Station B-1 consistently increased when metals concentrations declined and decreased when metals concentrations increased during 1999 through 2005 (Figure 74). The direct response of this mayfly species to changing metals concentrations provides evidence that metals contamination is a candidate cause of the stream’s biological impairment. Studies by Clements et al. (1990), Newman et al. (1991), and Cain et al. (2000) confirm that species of mayflies, including *Baetis brunneicolor*, are highly sensitive to metals. A 100 percent reduction in *Baetis brunneicolor* was observed after 10 days of exposure to 25 µg/L copper (Newman et al., 1991). Collection of additional paired biological metals and monitoring data is recommended. The additional paired biological and metals monitoring data will best guide implementation efforts.

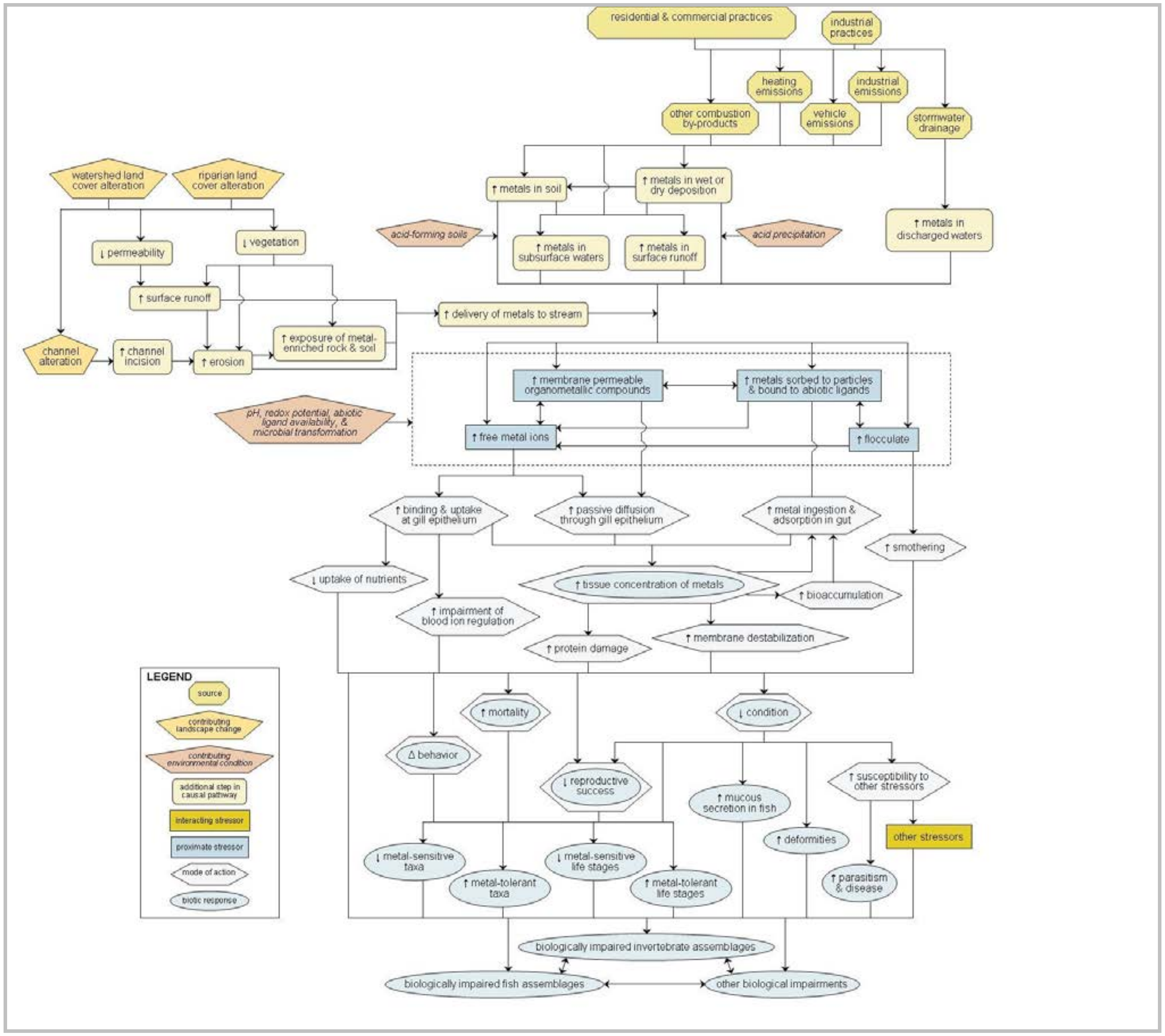

Figure 73 Conceptual Model of Candidate Cause 4: Metals Contamination

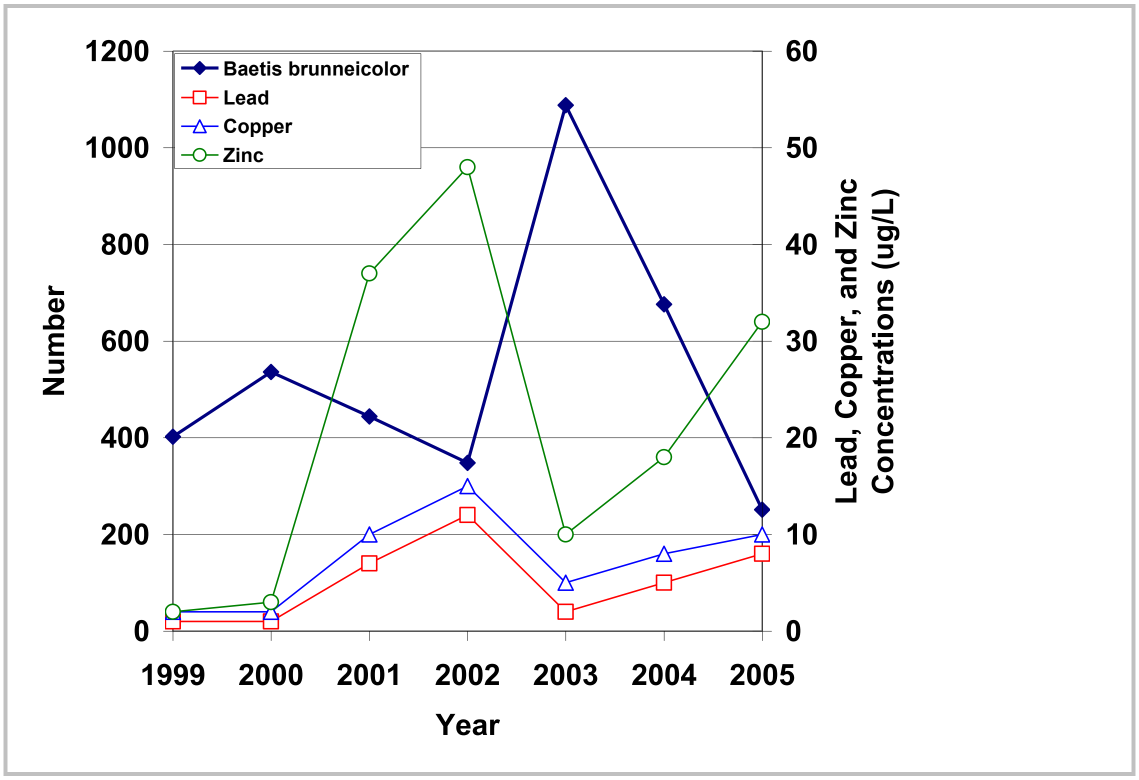

Figure 74 Number of *Baetis brunneicolor* Mayflies Observed at Bluff Creek Station B-1 and Mean Annual Concentrations of Lead, Copper, and Zinc During 1999-2005

4.2.5 Candidate Cause 5: Ionic Strength

Ionic strength is considered a candidate stressor because relatively high (>1,000 µmhos/cm @ 25° C) specific conductance levels have been measured in Bluff Creek. Minnesota Rule Chapter 7050 (Minn. R. 7050) specifies standards applicable to Minnesota streams to protect aquatic life. Bluff 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 Bluff Creek is the standard specified for Class 4A waters – values are not to exceed 1,000 µmhos/cm @ 25° C (Minnesota Rule Chapter 7050.0224 Subpart 2). RPBCWD measured specific conductance at Station B-1 (Figure 2) monthly during March through October of 1996 through 2005. Although nearly all measurements were less than the MPCA Class 4A standard of 1,000 µmhos/cm @ 25°C, a couple of measurements exceeded this standard—1,104 µmhos/cm @ 25°C on March 18, 1997 and 1,251 µmhos/cm @ 25°C on March 19, 2002 (Figure 75). MCES measured specific conductance at the WOMP station (Figure 2) during 1993 through 2008. Although nearly all measurements met the MPCA Class 4A standard, three measurements exceeded the standard—1,090 µmhos/cm @ 25°C on March 21, 2006, 1,040 µmhos/cm @ 25°C on March 19, 2008, and 1,017 µmhos/cm @ 25°C on March 28, 2008. As shown in Figure 76, concentrations of specific conductance and chloride appear to vary concurrently and as shown in Figure 77, specific conductance levels increased with increasing chloride concentrations. The relationship between chloride concentrations and specific conductance levels indicate that road salts are reaching Bluff Creek during snowmelt runoff in sufficient quantity to occasionally elevate specific conductance levels above the MPCA Class 4A standard (Figures 75 through and 77).

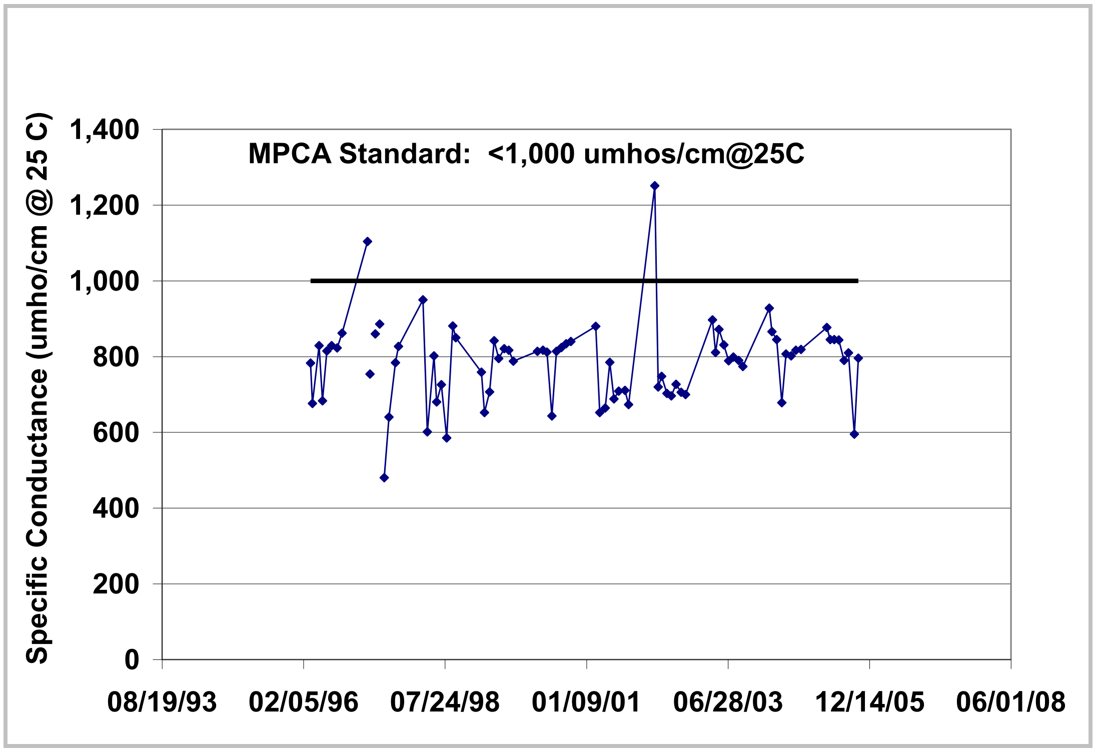

Figure 75 1996-2005 Bluff Creek Specific Conductance Data: B-1

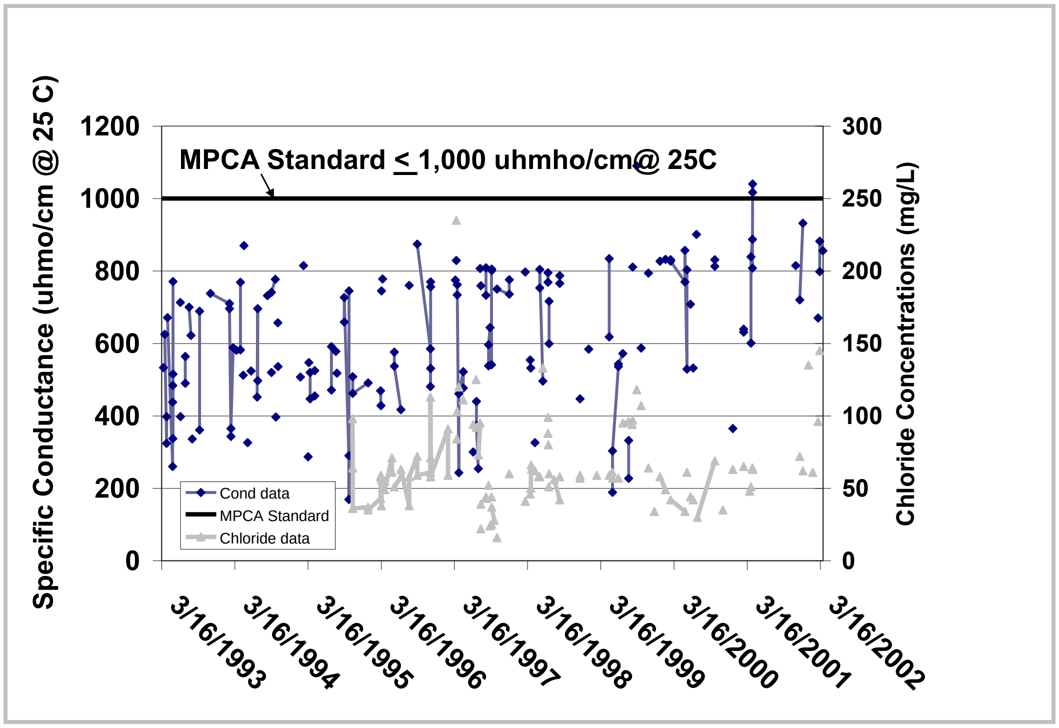

Figure 76 1993-2008 Bluff Creek Specific Conductance Data: WOMP Station

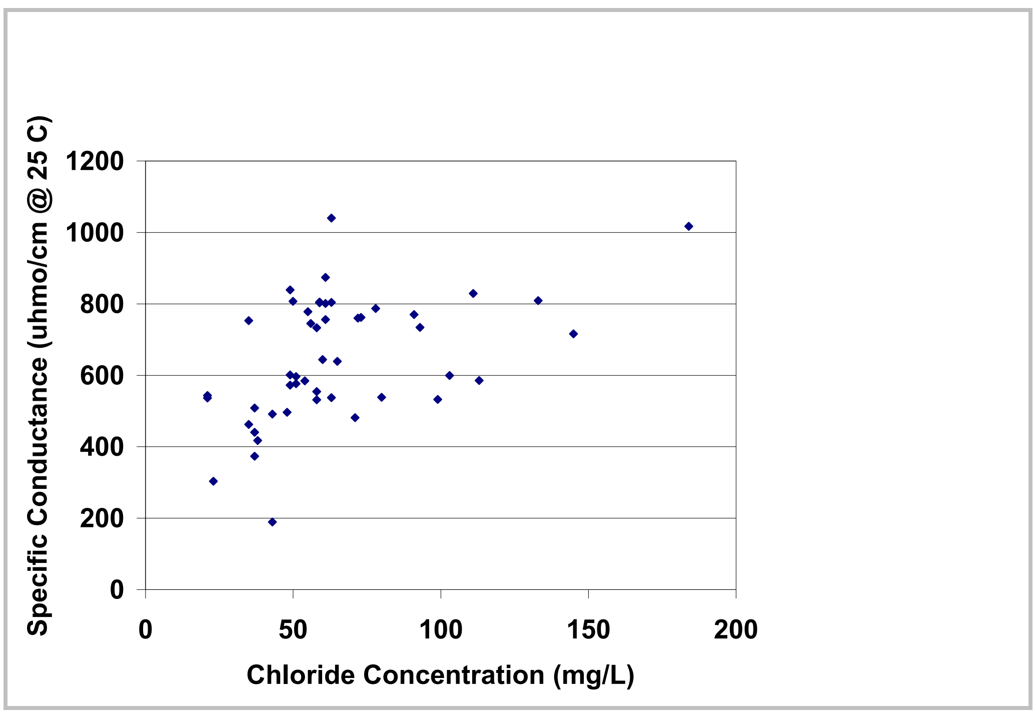

Figure 77. Specific Conductance versus Chloride for Bluff Creek WOMP Station

During 1995 through 2005, specific conductance levels at Station B-1 were consistently higher than levels at the downstream WOMP station. In 2000, mean annual specific conductance levels were 800 µmhos/cm @ 25°C at Station B-1 and 577 µmhos/cm @ 25°C at the downstream WOMP station (Figure 78). As noted previously, in 2000 the IBI at B-1 failed to meet the impairment threshold while a downstream station, 00MN008 located near the WOMP station, met the IBI impairment threshold (Figure 3).

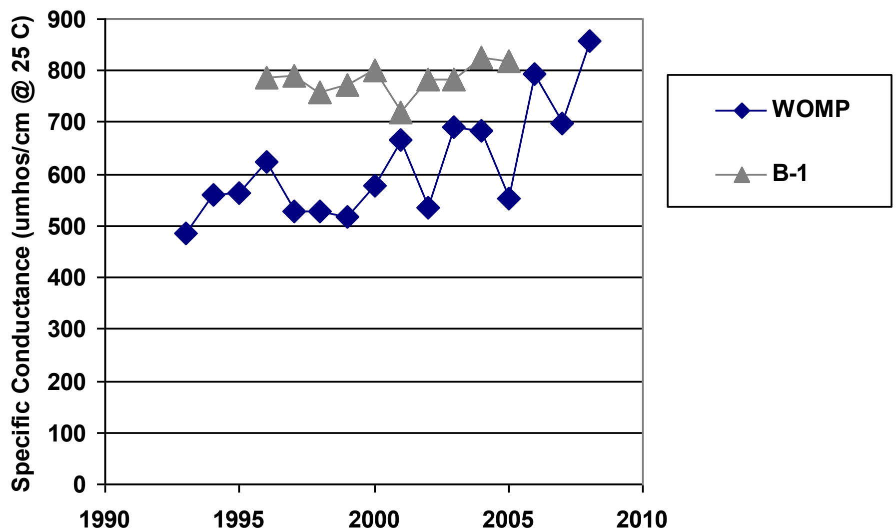

Figure 78 Comparison of Bluff Creek Mean Annual Specific Conductance Values at B-1 and WOMP Stations

The chloride standards applicable to Bluff Creek are the standards specified for Class 2B waters (Minnesota Rule Chapter 7050.022 Subpart 2). Chloride data collected from the MCES WOMP station (Figure 2) during 1999 through 2008 indicate chloride concentrations in Bluff Creek exceeded the MPCA chronic standard for a Class 2B stream on only one occasion (March 12, 2002, see Figure 79) during the period of record and all values met the MPCA maximum and final acute value (FAV) standards. Hence, despite the relationship between chloride and specific conductance shown in Figure 77, chloride does not appear to be the ion causing the stream's high specific conductance values, except for one occasion during 2002.

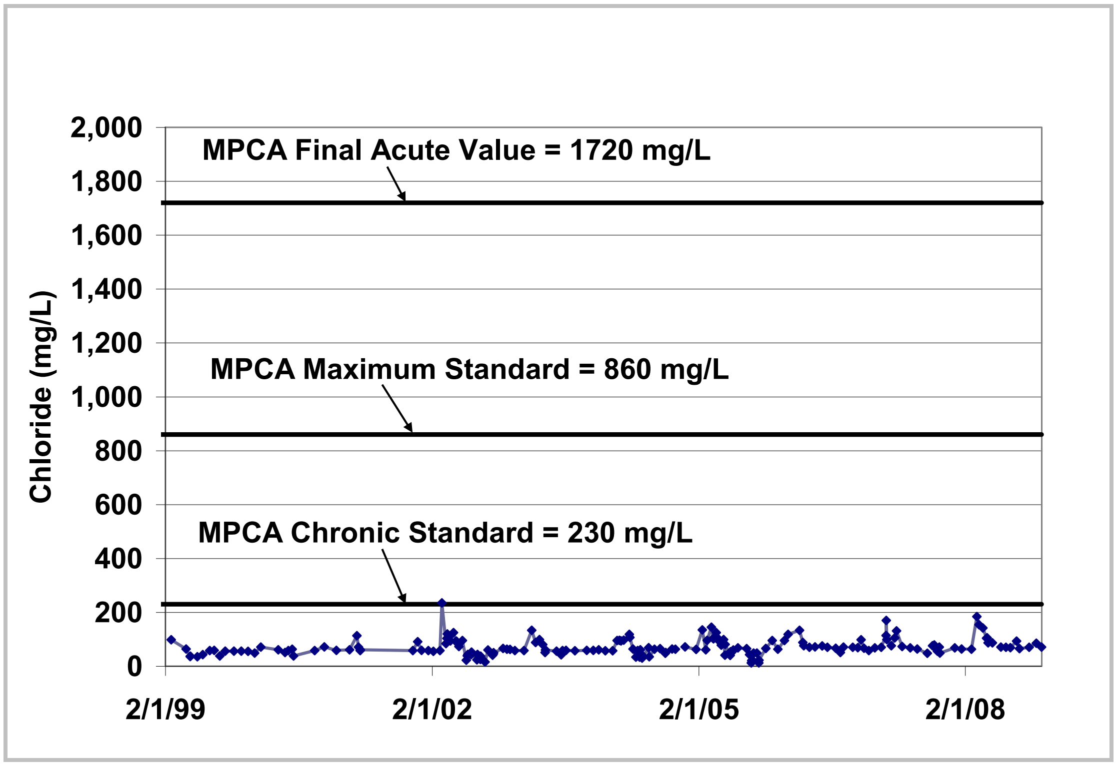

Figure 79 1993-2008 Bluff Creek Chloride Data: WOMP Station

Specific conductance, or electrical conductivity, is an indication of the amount of dissolved minerals or total dissolved solids in water. Elevated conductivity can be toxic to biological organisms through effects on osmoregulation (Wichard et al, 1973; McCulloch et al, 1993; and Ziegler et al, 2007). Aquatic insects, such as mayflies (Ephemeroptera), have relatively high cuticular permeability and regulate ion uptake and efflux using specialized external chloride cells on their gills and integument and internally via Malpighian tubules (Komnick, 1977, Gaino and Rebora, 2000). Large increases in certain ions can disrupt water balance and ion exchange processes and cause organism stress or death. Impacts of elevated conductivity vary with species. *Heptagenia* (Figure 80) is a more sensitive mayfly species than *Baetis* and mayflies are more sensitive than caddisflies, such as *Ceratopsyche* and *Hydropsyche* (Figure 81) (EPA, 2008).

Figure 80 Pictured above is *Heptagenia*, a mayfly species sensitive to ionic strength. *Heptagenia* was found in Bluff Creek during 2002, 2004, and 2005.

A linear regression of average annual specific conductance values and IBI scores at Station B-1 during 1999 through 2005 indicates the two variables are related, but the relationship does not support the hypothesis that ionic strength is a candidate stressor (Figure 82). Increasing IBI scores were observed with increasing specific conductance levels (R^2 of 0.79 and p-value of 0.02). The relationship indicates increasing specific conductance levels resulted in increasing IBI scores, the opposite effect expected from a candidate cause of impairment.

Figure 81 ***Hydropsyche*** **caddisflies pictured above are more tolerant to high conductivity levels than mayflies. Hydropsyche were observed nearly annually in Bluff Creek since 1997.**

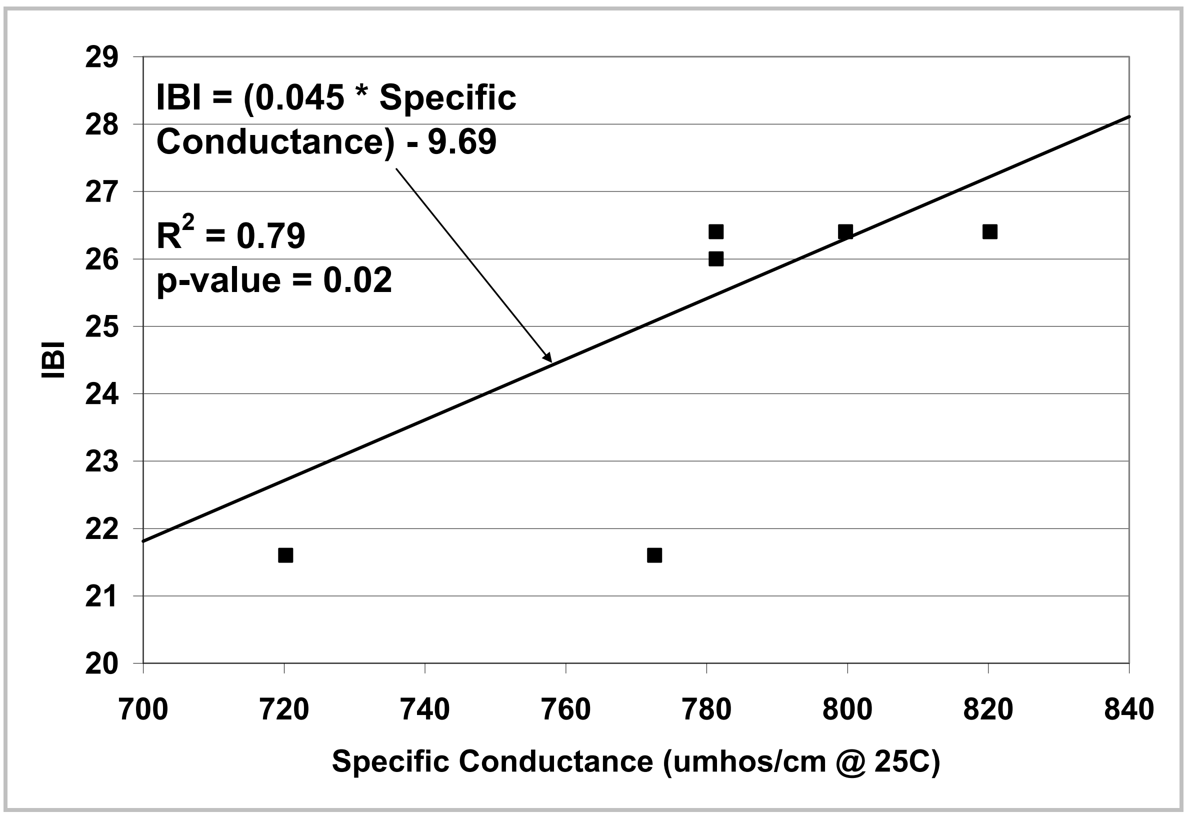

Figure 82. 1999-2005 IBI versus Specific Conductance: B1

As shown in Figure 83, increased ionic strength (i.e., increased specific conductance levels) causes increased osmotic stress, increased ion exchange, increased competition for anionic gill sites,

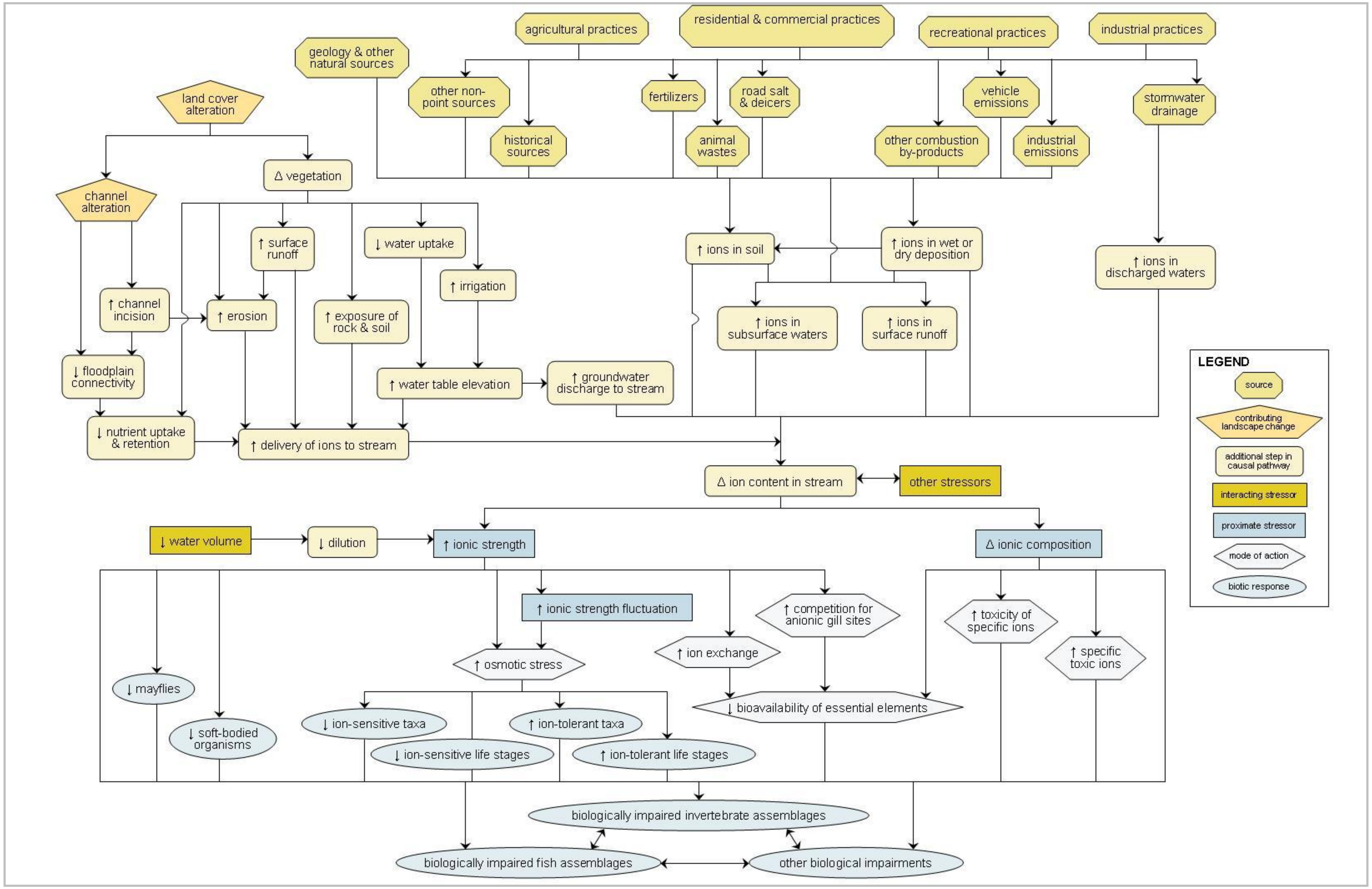

Figure 83 Conceptual Model of Candidate Cause 5: Ionic Strength

increased toxicity of specific ions, and decreased bioavailability of essential elements. Biologically impaired fish and invertebrate assemblages may result from increased ionic strength.

Specific conductance is a candidate cause because specific conductance values have occasionally exceeded MPCA criteria. In addition, concurrent changes in chloride and specific conductance values and an apparent relationship between the two constituents indicate a plausible mechanism for the high levels of ionic strength observed in the stream – the addition of salt during highway deicing events. However, several pieces of evidence weaken the case for specific conductance as a candidate cause. Most specific conductance values have met MPCA criteria. All but one chloride value met MPCA criteria. Impacts from occasional ionic strength increases in Bluff Creek are not shown by invertebrate data because Bluff Creek has consistently noted the presence of several macroinvertebrates that are sensitive to increased ionic stress. The presence of *Heptagenia,* a mayfly species particularly sensitive to increased ionic strength, indicates ionic strength increases have not adversely impacted the biological community (Figure 84). Changes in *Baetis brunneicolor* numbers do not appear to be associated with changes in ionic strength (Figure 84). However, confounding stressors such as metals contamination make it difficult to determine the impacts of ionic strength from *Baetis brunneicolor* numbers.

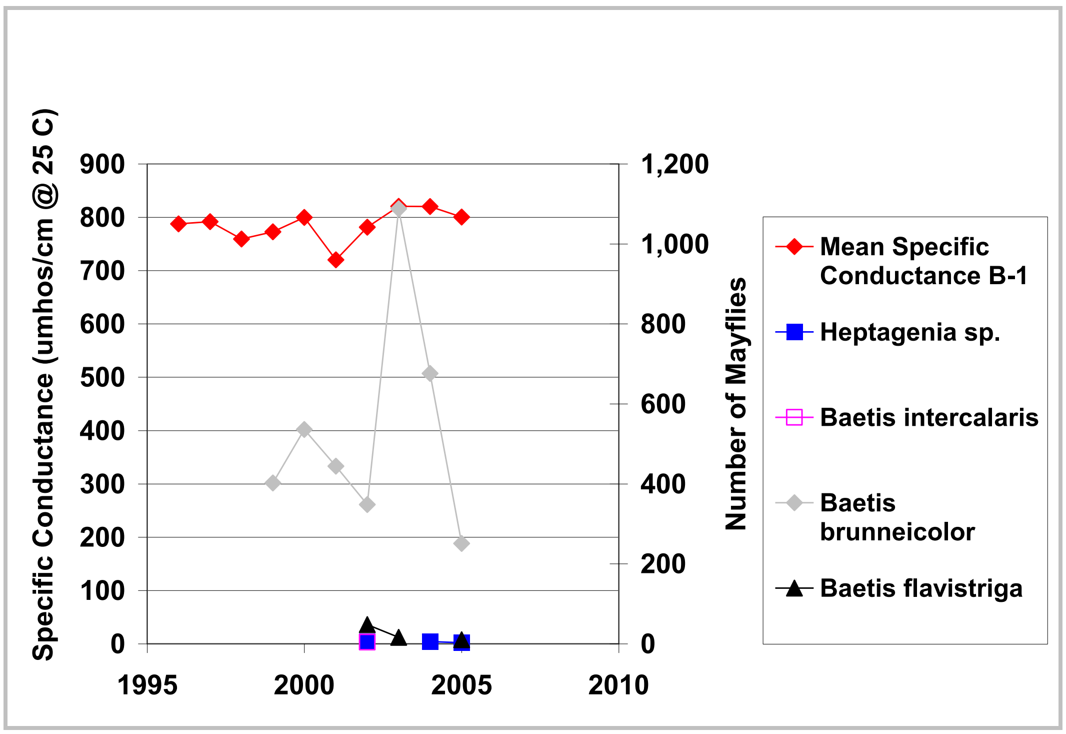

Figure 84 Comparison of Bluff Creek Mean Annual Specific Conductance Values and Mayfly Numbers at Station B-1

5.0 Evaluate Data From the Case

Physical and water quality data as well as biological data from Bluff Creek were evaluated to determine the strength of evidence for the candidate causes of Bluff 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 B) was used to evaluate the evidence from the case. Evaluation results follow for parameters supported by evidence.

5.1 Candidate Cause 1: Habitat Fragmentation

5.1.1 Spatial Co-occurrence – In 2000, two locations upstream of the regional trail culvert noted an impaired fish community and the downstream location did not. Impairment at the upstream location co-occurred with habitat fragmentation. An unimpaired fishery at the downstream location co-occurred with no habitat fragmentation. The evidence was compatible with spatial co-occurrence and a score of + was given (Table 8).

Table 8 Bluff Creek Evidence Table for Habitat Fragmentation: Evidence Using Data From Bluff Creek

Parameter	Candidate Cause 1 Habitat Fragmentation	
	Score	Score Interpretation
Spatial 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.
Evidence of Exposure or Biological Mechanism	++	Data show that exposure or the biological mechanism is clear and consistently present.
Symptoms	D	Symptoms or species occurrences observed at the site are diagnostic of the candidate cause.
Causal Pathway	++	Data show that all steps in at least one causal pathway are present.
Temporal Sequence	+	The candidate cause occurred prior to the effect.

5.1.2 Evidence of Exposure or Biological Mechanism – In 2000, the fish species richness and composition upstream from the regional trail culvert was poor in comparison to the downstream location. The upstream location was exposed to habitat fragmentation while the downstream location was not. The upstream location was impaired and the downstream location was not impaired. The evidence is compatible with exposure or biological mechanism (i.e., fish exposed to habitat fragmentation were negatively impacted, resulting in impairment). A score of ++ was given for evidence of exposure or biological mechanism (Table 8).

5.1.3 Symptoms – As shown in Figures 26 and 27, stream reaches upstream from the regional trail culvert (i.e., Stations B-1 and 00MN009) observed fewer species than a downstream location (i.e., 00MN008) not exposed to habitat fragmentation. A single species, brooke stickleback, comprised from 50 to 100 percent of species collected from locations upstream from the regional trail culvert, but only 25 percent of species collected from a downstream location. Brooke stickleback, comprised from 92 to 100 percent of individuals collected from locations upstream from the regional trail culvert, but only 34 percent of individuals collected from a downstream location. A score of D was given for symptoms because the difference in number of species at locations upstream and downstream from the regional trail culvert is diagnostic of impairment due to habitat fragmentation (Table 8).

5.1.4 Causal Pathway

All steps in the causal pathway of habitat fragmentation and fish impairment were present throughout the period of record (i.e., 1997 through 2006). Habitat fragmentation occurred throughout this period and fisheries impairment was annually observed. Because the data show that all steps of the causal pathway of habitat fragmentation causing fish impairment, a score of ++ was given (Table 8).

5.1.5 Temporal Sequence

Habitat fragmentation annually preceded fisheries impairment during the period of record (i.e., 1997 through 2006). Hence, a score of + was given for temporal sequence (Table 8).

5.2 Candidate Cause 2: Sediment

5.2.1 Spatial/Temporal Co-occurrence

High sediment loads and an impaired biological community consistently co-occurred in Bluff Creek Station B-1 during the period of record (i.e., 1997 through 2006). The evidence supports temporal co-occurrence of sediment and an impaired biological community (Table 9).

A comparison of IBI scores of Station B-2, located upstream from the predominant sediment sources to the stream, and IBI scores of Station B-1, located downstream from the predominant sediment sources, indicated B-2 was unimpaired while B-1 was impaired. The evidence supports spatial co-occurrence of sediment and impairment of the stream's fishery. A score of + was given for temporal/spatial co-occurrence (Table 9).

Table 9 Bluff Creek Evidence Table for Sediment: Evidence Using Data From Bluff Creek

Parameter	Candidate Cause 2 Sediment	
	Score	Score Interpretation
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.
Evidence of Exposure or Biological Mechanism	++	Data show that exposure or the biological mechanism is clear and consistently present.
Symptoms	D	Symptoms or species occurrences observed at the site are diagnostic of the candidate cause.
Causal Pathway	++	Data show that all steps in at least one causal pathway are present.
Temporal Sequence	+	The candidate cause occurred prior to the effect.

5.2.2 Evidence of Exposure or Biological Mechanism

The Bluff Creek biological community was consistently exposed to high sediment during the period of record (i.e., 1997 through 2006) and an impaired biological community consistently occurred. Suspended solids and turbidity data (Figures 30 and 32, respectively) show that sediment plus organic material has consistently been suspended in the water column. A habitat survey has documented the consistent presence of fine and bedded sediment in the stream (Table 7). Fish (Figure 3) and invertebrate (Figure 39) data have documented the adverse impact of the sediment on the stream's biological community. The evidence is compatible with exposure or biological mechanism (i.e., fish exposed to sediment were negatively impacted resulting in impairment). A score of ++ was given for evidence of exposure or biological mechanism (Table 9).

5.2.3 Symptoms

The presence of stoneflies in Bluff Creek when sediment concentrations have declined and the disappearance of stoneflies when sediment concentrations have increased is a symptom of the adverse impact of sediment on the stream's biological community. As shown in Figure 39, declines in mean annual TSS at B-1 were accompanied by the presence of stoneflies, while increases in mean TSS were accompanied by the absence of stoneflies. Stoneflies are sensitive to water quality and are eliminated when high concentrations of sediment are present. A score of D was given for symptoms because the direct response of stoneflies to sediment changes in the stream is diagnostic of impairment due to sediment (Table 9).

5.2.4 Causal Pathway

All steps in the causal pathway of sediment and fish impairment were present throughout the period of record (i.e., 1997 through 2006). Suspended sediment was consistently measured in the water column (Figures 30 through 32), fine and bedded sediment was consistently measured at B-1 (Table 7), and fish impairment consistently occurred (Figure 3). Because the data show that all steps of the causal pathway of sediment causing fish impairment, a score of ++ was given (Table 9).

5.2.5 Temporal Sequence

Sediment (suspended, deposited, and/or bedded) was annually present in the stream prior to the measurement of fisheries impairment during the period of record (i.e., 1997 through 2006). Hence, a score of + was given for temporal sequence (Table 9).

5.3 Candidate Cause 3: Flow

5.3.1 Temporal Co-occurrence

Increased flows during 1997 and 1998 were associated with the absence of fish at B-1 and reduced flows during 1999 were associated with the presence of fish at B-1. Discharge at the WOMP Station (Figure 2) reached 2,476 cfs on April 13, 1997 (Figure 44). Average discharge during 1997 and 1998 was higher than average discharge during 1999 (Figure 5). Although average discharge during 1999 was lower than 1997 and 1998, a significant flow event occurred on May 12 when discharge reached 200 cfs (Figure 46). Although fish were observed at B-1 in 1999, it appears that the high flow event in May caused impairment (Figure 5). The flow and fish data from 1997 through 1999 are compatible with temporal co-occurrence of flow and biological impairment. Hence, a score of + was given for temporal co-occurrence (Table 10).

Table 10 Bluff Creek Evidence Table for Flow: Evidence Using Data From Bluff Creek

Parameter	Candidate Cause 3 Flow	
	Score	**Score Interpretation**
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.
Evidence of Exposure or Biological Mechanism	+	Data show that exposure or the biological mechanism is weak or inconsistently present.
Causal Pathway	++	Data show that all steps in at least one causal pathway are present.
Temporal Sequence	+	The candidate cause occurred prior to the effect.
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.

5.3.2 Evidence of Exposure or Biological Mechanism

A comparison of flow measurements and IBI scores during 1997 through 1999 (Figures 4 and 5) indicates the fish community was exposed to higher flows during 1997 and 1998 than 1999. High flows during 1997 and 1998 were associated with the absence of fish at B-1. Although fish were observed in 1999, a high flow event during May caused impairment (Figure 4). The data indicate exposure to high flows have adversely impacted the biological community and that high flows are a biological mechanism causing impairment.

While changes in flow were associated with changes in IBI scores during 1997 through 1999, changes in flow were not associated with changes in IBI scores during 2000 through 2005. The IBI score at B-1 remained constant during this period despite changes in flow. Although the 1997 through 1999 data indicate high flows adversely impacted the fish community, the flow threshold at which no adverse impact to the fish occurs is not known. Hence, it is not known whether flows occurring during the 2000 through 2005 period are the cause of the observed impairment of the fish community. This unknown aspect of flow as a stressor (i.e., impairment flow threshold) and the lack of change in IBI scores with changing flows during 2000 through 2005 indicate that exposure (i.e., to high flows) or biological mechanism is weak or inconsistently present. Hence, a score of + was given for evidence of exposure or biological mechanism for flow (Table 10).

5.3.3 Causal Pathway

All steps in the causal pathway of high flows and impairment were present during the 1997 through 1999 period. Increased flows during 1997 and 1998 were associated with the absence of fish at B-1 and reduced flows during 1999 were associated with the presence of fish at B-1. Although flows were lower during 1999 than 1997 and 1998, a significant flow event occurred on May 12 when discharge reached 200 cfs. Although fish were observed, it appears that the high flow event in May caused impairment during 1999. Because the data show that all steps of the causal pathway of high flows causing fish impairment were present, a score of ++ was given (Table 9).

5.3.4 Temporal Sequence

As shown in Figures 4 and 5, increased flows during 1997 and 1998 preceded reduced IBI scores. Decreased flows during 1999 preceded improved IBI scores. As shown in Figures 44 through 47, high flow events preceded the impaired fishery annually during 1997 through 1999. The evidence was compatible and a score of + was given for temporal sequence (Table 10).

5.3.5 Manipulation of Exposure

Flow data from 1997 through 1999 show that a reduction in flow results in a reduction of adverse impacts to the fish community. Average discharge during 1997 and 1998 was higher than 1999 and no fish were observed at B-1 during 1997 and 1998. Average discharge was lower in 1999 and fish were observed at B-1. Although a high flow event during May adversely impacted the fish community and impairment occurred, the effect (impairment) was reduced in 1999 as compared with 1997 and 1998. The evidence was compatible and a score of +++ was given for manipulation of exposure (Table 10).

5.4 Candidate Cause 4: Metals Contamination

5.4.1 Temporal Co-occurrence

High concentrations of lead, copper, and zinc observed at the WOMP station co-occurred with an impaired biological community in Bluff Creek Station B-1:

- Lead—failed to meet the chronic standard at a frequency of 10 percent (Figures 49 through 50). An evaluation of lead concentrations during years in which fish data were collected indicates lead failed to meet the chronic standard during 1997, 1998, 2001, 2004, and 2005 (Figures 49 and 50)

- Copper—failed to meet the chronic standard at a frequency of 7 percent, failed to meet the maximum standard at a frequency of 2 percent, and failed to meet the FAV at a frequency of 1 percent (Figures 53 and 54). An evaluation of copper concentrations during years in which fish samples were collected as well as within 3 years of sample collection indicates copper concentrations exceeded the chronic standard during 1994, 1995, 1997, 1998, 2001, 2002, 2004, and 2005; exceeded the maximum standard during 1994, 1995, 1997, 1998, 2002, 2004, and 2005; and exceeded the FAV standard during 1994, 1995, and 1998 (Figures 53 and 54).

- Zinc—failed to meet the chronic standard at a frequency of 2 percent, failed to meet the maximum standard at a frequency of 2 percent, and failed to meet the FAV at a frequency of 1 percent (Figures 57 and 58). An evaluation of zinc concentrations during years in which fish data were collected as well as within 3 years of sample collection indicates zinc concentrations exceeded the chronic standard during 1994, 1995, 1996, 1998 and 2005; exceeded the maximum standard during 1994, 1995, 1996, and 1998; and exceeded the FAV standard during 1995 (Figures 57 and 58)

Because high metals concentrations can adversely impact fish for up to 3 years, it appears that high metals concentrations potentially impacted the fish community during the 1997 through 2006 period in which fish data were collected. The evidence supports temporal co-occurrence of metals and an impaired biological community. Hence, a score of + was given for temporal co-occurrence (Table 11).

5.4.2 Evidence of Exposure or Biological Mechanism

A comparison of metals concentrations and IBI scores during 1997 through 2006 (Figures 3, 49, 50, 53, 54, 57, 58) indicates the fish community was exposed to metals contamination during 1997 through 2006 and was impaired. The data indicate exposure to metals contamination has adversely impacted the biological community and that metals contamination is a biological mechanism causing impairment. Hence, a score of ++ was given for evidence of exposure or biological mechanism for metals contamination causing impairment (Table 11).

Table 11 Bluff Creek Evidence Table for Metals: Evidence Using Data From Bluff Creek

Parameter	Candidate Cause 4 Metals Contamination	
	Score	Score Interpretation
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.
Evidence of Exposure or Biological Mechanism	++	Data show that exposure or the biological mechanism is clear and consistently present.
Symptoms	D	Symptoms or species occurrences observed at the site are diagnostic of the candidate cause.
Causal Pathway	++	Data show that all steps in at least one causal pathway are present.
Temporal Sequence	+	The candidate cause occurred prior to the effect.

5.4.3 Symptoms

The direct response of *Baetis brunneicolor* to changing concentrations of three types of metals – lead, copper, and zinc – during 1999 through 2005 is symptomatic of harm from metals contamination. During 1999 through 2005, numbers of *Baetis brunneicolor* from Station B-1 consistently increased when metals concentrations declined and decreased when metals concentrations increased (Figure 74). *Baetis brunneicolor*, a mayfly, is adversely impacted by metals contamination. The direct response by *Baetis brunneicolor* to changing metals concentrations is diagnostic of metals contamination as a candidate cause of impairment. A score of D was given for symptoms (Table 11).

5.4.4 Causal Pathway

Throughout the period of record, high metals concentrations were associated with high flows and high concentrations of total suspended solids (Figures 51, 52, 55, 56, 59, and 60). Hence, it appears that metals contamination resulted from the conveyance of metals to Bluff Creek by sediment during periods of high flow. When the fish community was impacted by metals contamination, fish impairment was observed. All steps in the causal pathway of metals contamination and fish impairment occurred during the period of record for fish data (i.e., 1997 through 2006). Because the data show that all steps of the causal pathway of metals contamination causing fish impairment were present during 1998 and 2005, a score of ++ was given (Table 11).

5.4.5 Temporal Sequence

Metals contamination was present in Bluff Creek prior to impairment of the fish community during 1997 through 2006 (Figures 3, 49, 50, 53, 54, 57, 58). Hence, a score of + was given for temporal sequence (Table 11).

5.5 Candidate Cause 5: Ionic Strength

5.5.1 Temporal Co-occurrence

Specific conductance measurements exceeded MPCA standards on few occasions during the period of record. Impairment in the fisheries community has been noted during both periods when ionic strength could potentially be a stressor due to high specific conductance levels which may impact a biological community for up to 3 years. High specific conductance levels were observed on March 18, 1997 and March 19, 2002. Impaired fisheries communities were observed during 1997 through 1999 and during 2002 through 2005. However, fisheries impairment has also been observed during years in which ionic strength is not a potential stressor because high specific conductance values were not observed within 3 years of the impaired fisheries community (i.e., 2000, 2001, 2005, and 2006). Because the effect and impaired fisheries community occurred during years in which the candidate cause, ionic strength, did not occur (i.e., 2000, 2001, 2005, and 2006), a score of --- was given (Table 12).

Table 12 Bluff Creek Evidence Table for Ionic Strength: Evidence Using Data From Bluff Creek

Parameter	Candidate Cause 4 Metals Contamination	
	Score	**Score Interpretation**
Spatial/Temporal Co-Occurrence	---	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.
Temporal Sequence	0	The temporal relationship between the candidate cause and the effect is uncertain.
Causal Pathway	++	Data show that all steps in at least one causal pathway are present.
Stressor Response Relationships From the Field	--	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.
Symptoms	R	Symptoms or species occurrences observed at the site are contrary to the candidate cause.

5.5.2 Temporal Sequence

During periods of time when ionic strength could potentially be a stressor due to high specific conductance levels within 3 years of the observance of an impaired fisheries community, the candidate cause, ionic strength, preceded the effect, impaired fisheries community. However, during periods of time when ionic strength could not potentially be a stressor due to a lack of high specific conductance levels within 3 years of the observance of an impaired fisheries community, the candidate cause, ionic strength, did not precede the effect, impaired fisheries. Hence, a score of 0 was given for temporal sequence (Table 12).

5.5.3 Causal Pathway

A temporal comparison of specific conductance and chloride indicates their levels vary concurrently (i.e., increasing chloride levels occur concurrently with increasing specific conductance levels). The data show that all steps in a causal pathway are present (i.e., application of salts during highway deicing causes increased specific conductance levels in Bluff Creek). A score of ++ was given for causal pathway (Table 12).

5.5.4 Stressor Response Relationships From the Field

A regression analysis of specific conductance and IBI scores from Station B-1 during 1999 through 2005 indicate a positive relationship between increasing specific conductance and increasing IBI score. The R^2 of the regression was 0.79 and the p-value was 0.02. Because this evidence refutes the hypothesis that ionic strength is a candidate cause, a score of -- is given for stressor response relationships from the field (Table 12). This finding strongly weakens the case for ionic strength as a candidate cause.

5.5.5 Symptoms

Heptagenia sp., a mayfly species sensitive to ionic strength, was found in Bluff Creek during 2002, 2004, and 2005. This species occurrence is contrary to the candidate cause. Hence, this finding refutes the case for the candidate cause and a score of R is given for symptoms. The score of R eliminates ionic strength from further consideration as a candidate stressor.

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—habitat fragmentation, sediment, flow, and metals contamination.

6.1 Habitat Fragmentation

6.1.1 Plausible Mechanism

Results of a study of impacts of low-head dams on species richness in Wisconsin first order streams indicate habitat fragmentation is a plausible mechanism for biological impairment. Study results indicate downstream dams have a significant effect on species richness (Cumming, 2004). These data indicate habitat fragmentation in Bluff Creek is a plausible mechanism for the stream's impaired fish assemblage. Hence, a score of + was given for plausible mechanism (Table 13).

Table 13 Bluff Creek Evidence Table for Habitat Fragmentation: Evidence Using Data From Elsewhere

Parameter	Candidate Cause 1 Habitat Fragmentation	
	Score	Score Interpretation
Plausible Mechanism	+	A plausible mechanism exists.
Plausible Stressor Response	+	The stressor-response relationship in the case agrees qualitatively with stressor-response relationships from other field, laboratory, and or modeling studies.

6.1.2 Plausible Stressor Response

Results of a study by Letcher et al. indicate impairment is a plausible response to habitat fragmentation in Bluff Creek. Study results indicate the isolation of a stream's fish assemblage that results from habitat fragmentation may lead to the demise of a fishery, including extinction (Letcher et al., 2007). Hence, a score of + was given for plausible stressor response (Table 13).

6.2 Sediment

6.2.1 Plausible Mechanism

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

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

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

Because the results of studies completed by Caux et al. (1997), Rowe et al. (2003) and U.S. EPA (1998) indicate sediment is a plausible mechanism for Bluff Creek's impaired fishery, a score of + is given for plausible mechanism (Table 14).

Table 14 Bluff Creek Evidence Table for Sediment: Evidence Using Data From Elsewhere

	Candidate Cause 2 Sediment	
Parameter	**Score**	**Score Interpretation**
Plausible Mechanism	+	A plausible mechanism exists.
Plausible Stressor Response	+	The stressor-response relationship in the case agrees qualitatively with stressor-response relationships from other field, laboratory, and or modeling studies.

6.2.2 Plausible Stressor Response

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

Caux et al. (1997) recommend substrate not exceed 10% fine material (<2mm) for Canadian salmonids. U.S. EPA (1998) set in-stream summer criteria for percent fines (<6.5mm) of <30% for viable salmonid fry emergence. The D50 (Knopp 1993) values of at least 37 mm and ideally 69 mm are ideal targets for mean particle size diameter for western mountain streams. Fisheries impairment was the biological response to sediment found in the Groundhouse River. Specifically, Site 3 in the Groundhouse River had almost 60% fines (vs. 15% for site 2, located upstream from the sediment source), greater than 50% embedded substrates, and a D50 value of 1 mm. Site 3 noted fisheries impairment (MPCA, 2008b).

Because evidence from Caux et al. (1997), U.S. EPA (1998), Knopp 1993), MPCA (2008), Rabeni et al. (1995), and Rashleigh et al. (2003) indicate impairment is a plausible response of Bluff Creek's fishery to sediment, a score of + is given for plausible stressor response (Table 14).

6.3 Flow

6.3.1 Plausible Mechanism

Results of a study by Cogo et al. (1996) revealed that erosion increased substantially with increased flow rates. Wirtz et al (2009) determined that increasing flow velocity causes higher turbulence and increased sediment concentration. Because evidence from Cogo et al. (1996) and Wirtz et al. (2009) indicate flow is a plausible mechanism for Bluff Creek's impaired fishery, a score of + is given for plausible mechanism (Table 15).

Table 15 Bluff Creek Evidence Table for Flow: Evidence Using Data From Elsewhere

Parameter	Candidate Cause 3 Flow	
	Score	**Score Interpretation**
Plausible Mechanism	+	A plausible mechanism exists.
Plausible Stressor Response	+	The stressor-response relationship in the case agrees qualitatively with stressor-response relationships from other field, laboratory, and or modeling studies.

6.3.2 Plausible Stressor Response

Results of a study by Guenther (1999) indicated adverse changes in native fishes, aquatic insects, and freshwater mussels were related to increased stream flow and associated hydrologic and habitat changes. Habitat fragmentation was found to contribute to the adverse changes to the stream's fish community associated with flow increases. Two darter species and one sculpin species were found to have greater extinction probabilities and reduced colonization probabilities in fragmented streams (Guenther, 1999). A study by Fischer et al. (2000) indicated elevated discharges triggered upstream longitudinal and lateral dispersion of bullheads. Because evidence from Guenther (1999) and Fischer et al. (2000) indicate impairment is a plausible response of Bluff Creek's fishery to increased flows, a score of + is given for plausible stressor response (Table 15).

6.4 Metals Contamination

6.4.1 Plausible Mechanism

Research studies indicate metals contamination is a plausible mechanism for impairment of the Bluff Creek fisheries assemblage. Owen (1981) found that high concentrations of copper have been toxic to fish. Because evidence from Owen (1981) indicates metals contamination is a plausible mechanism for impairment, a score of + is given for plausible stressor mechanism (Table 16).

Table 16 Bluff Creek Evidence Table for Metals: Evidence Using Data From Elsewhere

Parameter	Candidate Cause 4 Metals Contamination	
	Score	**Score Interpretation**
Plausible Mechanism	+	A plausible mechanism exists.
Plausible Stressor Response	+	The stressor-response relationship in the case agrees qualitatively with stressor-response relationships from other field, laboratory, and or modeling studies.

6.4.2 Plausible Stressor Response

A biologically impaired fish assemblage is a plausible response to metals contamination in Bluff Creek. Fish exposed to high levels of lead have exhibited muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis (Eisler, 1988). Growth, survival, and reproduction can all be adversely affected by elevated zinc levels (Eisler, 1993). Because evidence from Eisler (1988 and 1993) indicates an impaired fish assemblage is a plausible response to metals contamination, a score of + is given for plausible stressor response (Table 16).

7.0 Identify Probable Causes

The strength of evidence for the four candidate causes – habitat fragmentation, sediment, flow, and metals contamination - is summarized in Table 17.

Table 17 Bluff Creek Strength of Evidence Summary Table

Parameter	Candidate Cause 1 Habitat Fragmentation	Candidate Cause 2 Sediment	Candidate Cause 3 Flow	Candidate Cause 4 Metals Contamination
Spatial/Temporal Co-Occurrence	+	+	+	+
Evidence of Exposure or Biological Mechanism	++	++	+	++
Symptoms	D	D	NA	D
Causal Pathway	++	++	++	++
Temporal Sequence	+	+	+	+
Manipulation of Exposure	NA	NA	+++	NA
Plausible Mechanism	+	+	+	+
Plausible Stressor Response	+	+	+	+
Consistency of Evidence	+	+	+	+
Coherence of Evidence	+	+	+	+

The probable causes of impairment of Bluff Creek are habitat fragmentation, sediment, flow, and metals contamination. The evidence for habitat fragmentation, sediment, and metals contamination is strongest followed by flow. The probable causes established in this stressor identification process – habitat fragmentation, sediment, flow, and metals – will be addressed in more detail in the Bluff Creek Watershed TMDL and Implementation Plan.

Because "clean hands/dirty hands" methodology was not employed during collection and analyses of metals samples, the potential for contamination is acknowledged. For this reason, paired biological and metals monitoring using "clean hands/dirty hands" methodology for sampling and analysis is recommended to confirm metals contamination as well as adverse impacts of metals contamination on Bluff Creek biota.

Due to the cold temperatures found in Bluff Creek, a Use Attainability Analysis is recommended to evaluate whether the current Use Class or a different Use Class more reflective of the cold temperatures is suitable.

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Appendices

Appendix A

Fish Data

Bluff Creek Fish Data Summary

Location:	Location Description	Stream Status	Gear Type	Total Stream Reach Length (m)	Sample Date	Discharge on sample date (cfs)	Species (Scientific Name)	Species (Common Name)	Number	Length Range (mm)	Weight (g)
ECU-B1	Site B1 is located upstream of Hennepin Cty. Trail (rails to trails), W. of Vogelsberg TR., south end of Bluff Creek Park (Chanhassen)	Perennial	Seine		10/10/1996		No fish observed or caught in the seine				
					10/8/1997		No fish observed or caught in the seine				
					7/29/1998		No fish observed or caught in the seine				
					7/20/1999		*Semotilus atromaculatus*	creek chub	2		
					7/21-24/2000		*Eucalia inconstans*	Brook Stickleback	1		
					7/9-10/2001		*Pimephales promelas*	Northern fathead minnow	2		
							Eucalia inconstans	Brook Stickleback	4		
			Hand Net		7/29-30/2002		*Pimephales promelas*	Northern fathead minnow	1		
							Eucalia inconstans	Brook Stickleback	6		
			Backpack electroshocker	150	7/17/2003	4.6	*Eucalia inconstans*	Brook Stickleback	12	26-55	6
					7/16/2004	2.29	*Eucalia inconstans*	Brook Stickleback	15	26-57	8
							Pimephales promelas	Northern fathead minnow (golden form)	1	30	<1
					8/24/2005	0.67	*Eucalia inconstans*	Brook Stickleback	45	27-75	39
					6/29/2006	0.58	*Eucalia inconstans*	Brook Stickleback	19	25-62	13
							Pimephales promelas	Northern Fathead minnow	8	25-32	3
ECU-B2	Site B2 is located downstream of Pioneer Trail (Chanhassen)	Perennial	Seine		10/10/1996		No fish observed or caught in the seine				
					10/8/1997		*Notropis heterodon*	blackchin shiner	10		
					7/29/1998		*Pimephales promelas*	Northern fathead minnow	1		
							Semotilus atromaculatus	creek chub	6		
					7/20/1999		*Notropis hudsonius*	spottail shiner	4		
							Notropis volucellus	mimic shiner	3		
							Pimephales promelas	Northern fathead minnow	1		
							Semotilus atromaculatus	creek chub	1		
							Eucalia inconstans	Brook Stickleback	26		
					7/21-24/2000		*Semotilus atromaculatus*	creek chub	8		
							Eucalia inconstans	Brook Stickleback	25		
					7/9-10/2001		*Semotilus atromaculatus*	creek chub	2		
							Eucalia inconstans	Brook Stickleback	34		
					7/29-30/2002		*Semotilus atromaculatus*	creek chub	1		
							Eucalia inconstans	Brook Stickleback	84		
			Backpack electroshocker	150	7/17/2003	4.2	*Eucalia inconstans*	Brook Stickleback	24	25-55	12
					7/16/2004	1.86	*Eucalia inconstans*	Brook Stickleback	11	25-48	11
							Pimephales promelas	Northern fathead minnow (golden form)	2	26-28	<1
							Pimephales promelas	Northern fathead minnow	5	29-44	2
					8/24/2005	0.04	*Eucalia inconstans*	Brook Stickleback	30	30-57	29
					8/24/2006	0	Not surveyed in 2006 - standing shallow pools and dry streambed reaches on 7/19 and 7/27				
ECU-B3	Site B3 is located downstream of Lyman Blvd. Creek crosses thru pasture/farm fields. Owner has given permission. (Chanhassen)	Perennial	Seine		10/10/1996		Not surveyed in 1996 - standing water; no flow				
					10/8/1997		*Notropis heterodon*	blackchin shiner	1		
					7/29/1998		*Semotilus atromaculatus*	creek chub	3		
					7/20/1999		*Notropis hudsonius*	spottail shiner	2		
							Notropis volucellus	mimic shiner	1		
							Semotilus atromaculatus	creek chub	10		
							Eucalia inconstans	Brook Stickleback	40		
					7/21-24/2000		*Pimephales promelas*	Northern fathead minnow	13		
							Eucalia inconstans	Brook Stickleback	15		
					7/9-10/2001		*Pimephales promelas*	Northern fathead minnow	15		
							Eucalia inconstans	Brook Stickleback	22		
			Hand Net		7/29-30/2002		*Pimephales promelas*	Northern fathead minnow	1		
							Semotilus atromaculatus	creek chub	108		
							Eucalia inconstans	Brook Stickleback	9		
			Backpack electroshocker	150	6/24/2003	1.7	*Eucalia inconstans*	Brook Stickleback	15	48-62	28

Bluff Creek Fish Data Summary

Location:	Location Description	Stream Status	Gear Type	Total Stream Reach Length (m)	Sample Date	Discharge on sample date (cfs)	Species (Scientific Name)	Species (Common Name)	Number	Length Range (mm)	Weight (g)
							Pimephales promelas	Northern fathead minnow	11	44-55	21
							Phoxinus eos	Northern redbelly dace	1	59	2
					6/25/2004	0.78	*Eucalia inconstans*	Brook Stickleback	77	25-61	40
							Pimephales promelas	Northern fathead minnow	2	33-48	2
					7/18/2005		*Eucalia inconstans*	Brook Stickleback	34	25-60	18
							Pimephales promelas	Northern fathead minnow	2	42-44	7
					7/27/2006	0	Not surveyed in 2006 - dry with stagnant shallow pools				
ECU-B4	Site B4 is located directly west of Lake Drive W. (Dead End) Site is upstream of walking path and downstream of R.R. crossing embankment. (Chanhassen)	Perennial	Seine		10/10/1996		Not surveyed in 1996 - dry				
					10/8/1997		*Notropis heterodon*	blackchin shiner	5		
					7/29/1998		*Semotilus atromaculatus*	creek chub	59		
					7/20/1999		*Notropis hudsonius*	spottail shiner	25		
							Notropis volucellus	mimic shiner	25		
							Semotilus atromaculatus	creek chub	96		
							Eucalia inconstans	Brook Stickleback	83		
					7/21-24/2000		*Lepomis macrochirus*	bluegill	1		
							Semotilus atromaculatus	creek chub	96		
							Eucalia inconstans	Brook Stickleback	43		
					7/9-10/2001		*Rhinichthys atratulus*	blacknose dace	1		
							Pimephales promelas	Northern fathead minnow	7		
							Phoxinus eos	Northern redbelly dace	3		
							Semotilus atromaculatus	creek chub	66		
							Eucalia inconstans	Brook Stickleback	121		
					7/29-30/2002		*Pimephales promelas*	Northern fathead minnow	5		
							Eucalia inconstans	Brook Stickleback	123		
			Backpack electroshocker	150	7/18/2003	2.6	*Eucalia inconstans*	Brook Stickleback	46	25-61	28
							Pimephales promelas	Northern fathead minnow *	28	40-71	61
					6/24/2004	0.44	*Eucalia inconstans*	Brook Stickleback	72	25-62	52
							Pimephales promelas	Northern fathead minnow **	81	35-70	81
					7/15/2005	0.07	*Eucalia inconstans*	Brook Stickleback	57	25-65	33
							Pimephales promelas	Northern fathead minnow	5	60-65	11
							Pimephales promelas	Northern fathead minnow (golden form)	1	62	4
							Lepomis hybrid	Hybrid sunfish	1	65	5
							Ictalurus melas	Black bullhead	1	150	51
					7/15/2006	0	Not surveyed in 2006 - dry in areas with shallow standing pools				
							*Anomalies: eroded fins, black spot, lesions, parasite lesion **Anomilies: lesions				
ECU-B5	Site B5 is located upstream of service road N. of Hwy. 5 and downstream of Galphin Blvd. (Chanhassen)	Intermittent (historically)	Seine		10/10/1996		Not surveyed in 1996 - dry				
					10/8/1997		Standing water or low flow - No fish observed or caught in seine net				
					7/29/1998		Semotilus atromaculatus	creek chub	7		
					7/20/1999		Semotilus atromaculatus	creek chub	10		
					7/21-24/2000		*Pimephales promelas*	Northern fathead minnow	5		
							Eucalia inconstans	Brook Stickleback	3		
					7/9-10/2001		*Pimephales promelas*	Northern fathead minnow	27		
							Eucalia inconstans	Brook Stickleback	7		
			Hand Net		7/29-30/2002		*Pimephales promelas*	Northern fathead minnow	1		
							Eucalia inconstans	Brook Stickleback	2		
			Backpack electroshocker	150	6/30/2003	0.7	*Eucalia inconstans*	Brook Stickleback	4	30-37	4
					6/28/2004	0.01	*Eucalia inconstans*	Brook Stickleback	2	30-35	<1
							Pimephales promelas	Northern fathead minnow ***	21	30-65	37
					7/18/2005		Dry - not surveyed in 2005				

Bluff Creek Fish Data Summary

Location:	Location Description	Stream Status	Gear Type	Total Stream Reach Length (m)	Sample Date	Discharge on sample date (cfs)	Species (Scientific Name)	Species (Common Name)	Number	Length Range (mm)	Weight (g)
					7/19/2006	0	Dry - not surveyed in 2006				

***Anomilies: lesions

FISH SURVEY RECORD MDNR

Field Number: B-2 00MN009

Stream Name: Bluff Creek

Location: 00MN009

43.3 fish per 100m

Species Name	Length Range (mm)	Weight (g)	Number	Anomalies
Brook Stickleback	28-72		60	0
Fathead Minnow	25-45		5	0

Appendix B

Comparison of Bluff Creek Specific Conductance Values and Mayfly Numbers

Table B-1. Comparison of Average Specific Conductance Values and Mayfly Numbers at B-1 During 1999-2005

Average Annual Specific Conductance B-1							
Parameter	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Average Annual Specific Conductance (umhos/cm @ 25 C	773	800	720	781	820	820	800

Mayflies B-1							
Taxa	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Baetis brunneicolor	402	536	444	348	1088	676	251
Baetis flavistriga				48	16		10
Baetis intercalaris				4			
Heptagenia sp.				4		4	2

Appendix C

2007 Inventory and Assessment—Bluff Creek Lower Valley

Figure 45

OVERVIEW MAP
Bluff Creek Channel Survey
RPBCWD
Carver County, MN

Barr Footer: Date: 9/1/2009 5:21:03 PM File: I:\Client\Rpbcwd\Studies\BluffCreekWatershed\Bluff_Creek_Channel_Survey\Maps\Barr_Standards\Overview_Map_amm.mxd User: MRR

2007 Inventory and Assessment - Bluff Creek Lower Valley

Site 1

Site Description:
This site includes the downstream end of the regional trail crossing culvert and an eroded bank immediately downstream of the culvert. The stream channel has downcut significantly below the culvert, and the culvert is being undermined. Left unchecked, the culvert may begin to fail.

Large drop and undermining at downstream end of regional trail culvert

Large bank failure downstream of culvert outlet on left bank

Site 2

Site Description:

Approximately 1,000 foot long main ravine with 600 foot long side ravine on the north side of the valley. Main ravine receives drainage via a corrugated metal pipe from Mandan Circle, with severe erosion below the discharge point. A large sand deposit exists about halfway down the main ravine. The tributary ravine receives drainage from C.R. 101 and has numerous sub-tributary ravines.

Large headcut in main ravine below pipe outlet from Mandan Circle

Tributary ravine has exposed tree roots and many smaller sub-tributary ravines

Site 3

Site Description:

Approximately 850 foot long main ravine on the north side of the valley with moderate erosion. The ravine receives drainage from an 18-inch corrugated metal pipe from Creekwood Drive. The pipe conveys discharge from a pond on the north side of Creekwood Drive. There are several headcuts along the ravine, but no severe slope failures. A sand deposit is present at the bottom of the ravine.

Headcut followed by sand deposit in lower part of ravine

Headcutting in the upper part of the ravine

Site 4

Site Description:

Approximately 750 foot long main ravine with 600 foot secondary ravine on the north side of the valley. Main ravine has moderate erosion, while the secondary ravine requires additional investigation. The main ravine receives drainage from a 24-inch above-ground corrugated metal pipe that originates from the east end of the Bluff Creek Golf Course parking lot. The ravine bottom is well armored and fairly broad, with occasional slope failures along the banks.

Lower part of ravine has well-armored channel bottom with occasional slope failures

Pipe inlet from east end of golf course parking lot is in poor condition

Site 5

Site Description:

Approximately 500 foot long, steep ravine on the south side of the valley with minor erosion. This ravine has a small watershed, with Hesse Valley Road at the head of the ravine.

Looking down into short, steep ravine

Yard waste dumping onto failed slope

Site 6

Site Description:

Approximately 600 foot long ravine on the north side of the valley with severe erosion. The ravine originates from a point approximately 150 feet south of the Bluff Creek golf course parking lot. The ravine is narrow and incised, with a significant headcut approximately 1/3 distance from the bottom. Ravine terminates in a steep gully leading to the creek, with an adjacent failure on the creek bank.

Large headcut in lower part of ravine

Looking up toward the top of the ravine

Site 7

Site Description:

Approximately 700 foot long ravine on the north side of the valley with severe erosion. The mouth of the ravine is near that of Ravine 6, while the head of the ravine is approximately 300 feet west of the Bluff Creek golf course parking lot. The ravine is narrow and incised, with several significant headcuts. A 12-inch pipe drains to this ravine. A trickle of surface water flow was observed, but groundwater seepage may also be a contributing factor. A sand deposit was observed at the bottom of the ravine near the creek.

Large headcut in middle part of ravine

Crack foretells impending slope failure

Site 8

Site Description:

Approximately 500 foot long ravine on the south side of the valley with minor erosion. The ravine originates near Hesse Farm Road and has a small tributary watershed. Although it is steep, there is only minor erosion evident in this ravine.

Looking down the ravine

Looking up toward the top of the ravine

Site 9

Site Description:

Approximately 400 foot long ravine on the south side of the valley with minor erosion. The ravine originates about 300 feet north of Hesse Farm Road and has a small tributary watershed. Although it is very steep, there is only minor erosion evident in this ravine.

Looking down the ravine

Yard waste dumping in ravine

Site 10

Site Description:

Approximately 450 foot long ravine on the north side of the valley with severe erosion. . Lower half of ravine is deeply eroded and has been for some time, with vegetation re-established on portions of the eroded slopes. Exposed soils are dense sandy clay, with some strata resembling sandstone.

30 foot deep slope failure area

Typical failed sidewall

Site 11

Site Description:

This site consists of a very large slope failure on the north valley wall. A much smaller slope failure is nearby immediately adjacent to the creek. The larger slope failure has been present for many years, and the lower embankment has largely revegetated with grasses and small trees. The upper, more vertical banks continue to slowly erode. The original failure may have been induced by groundwater seepage or streambank erosion, but the upper vertical bank is probably no longer influenced by these factors.

Large slope failure has revegetated the lower bank

Bank failure on creek

Site 12

Site Description:

Approximately 1000 foot long ravine on the north side of the valley with a 225 foot tributary ravine, both having severe erosion. The lower 350 feet of the ravine is relatively stable, indicating that the ravine may be the result of a headcut that has been slowly migrating up the valley wall.

Severe erosion in upper part of main ravine

Lower extent of ravine is relatively stable with a sandy channel

Site 13

Site Description:

Approximately 650 foot long ravine on the west side of the valley with moderate erosion. The head of the ravine is at a hobby farm and apparently serves as a dumping area for yard waste and building materials. A minor bank failure is present near the mouth of the ravine at Bluff Creek, but does not appear likely to develop into a more severe erosion problem.

Yard waste and building materials at the head of the ravine

Some debris present at midpoint of ravine

Site 14

Site Description:

This site consists of a very large slope failure on the west valley wall, directly north of Site 13. The failure is approximately 300 feet across. Wet soils on the lower part of the failure indicate that groundwater probably plays a role in this failure. The upper vertical bank is comprised of very dense sandy clay. Timber debris and sand from the failure has accumulated at a bend in Bluff Creek.

Large slope failure has wet soils on lower area, very dense sandy clay soils on upper bank.

Timber debris and sand deposit at channel bend

Site 15

Site Description:

Approximately 1,000 foot long ravine on the east side of the valley with severe erosion in the form of slope failures along the ravine. The head of the ravine is split, and each side is advancing. A new 12-inch plastic drain pipe has been installed in the east branch of the split in an attempt to curb the erosion, with fill and geotextile placed in the eroded ravine. A gully has formed in the fill material, however. A path crosses the ravine with a bridge, but the bridge abutments will soon be affected by the erosion. The lower part of the ravine is older and more stable, with a well developed channel carrying flow to Bluff Creek.

Looking down the ravine from golf cart bridge

New pipe outlet from golf course

Site 16

Site Description:

This site consists of a large slope failure on the east valley wall. The failure is approximately 200 feet across and 80 feet high. Groundwater probably plays a role in this failure. The upper vertical bank is comprised of very dense sandy clay. An abandoned drain pipe is evident at the top of the ravine.

Large slope failure has wet soils on lower area, very dense sandy clay soils on upper bank.

Upper vertical bank is very dense clayey sand or soft sandstone

Site 17

Site Description:

Approximately 380 foot long ravine on the east side of the valley with moderate erosion. The head of the ravine originates at the same hobby farm as site 13, with yard waste present. Some headcutting is evident, especially near the top and bottom of the ravine. The middle portion is relatively stable.

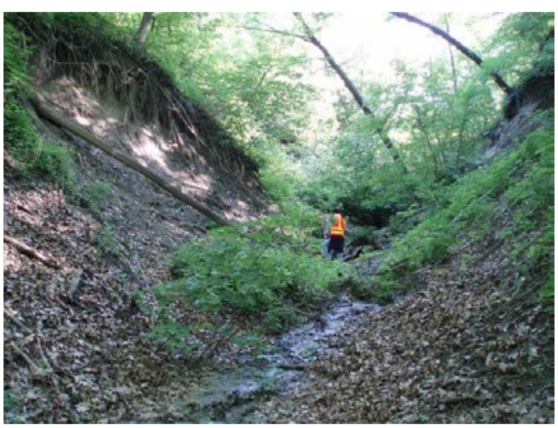
Looking up toward the head of the ravine, some headcutting present

Middle portion of ravine is fairly stable.

Site 18

Site Description:

Approximately 1,000 foot long ravine on the east side of the valley with severe erosion in the form of slope failures and headcutting along the ravine. Portions of the ravine are older, with vegetation present on the bottom and side slopes. Groundwater seepage may play a role in the frequent slope failures, or they may occur following significant flood events. There is another nearby slope failure about 150 feet north of this ravine. Stabilization of this failure could be accomplished at the same time.



Looking down the ravine

Pipe outlet

Site 19

Site Description:

Approximately 250 foot long ravine on the west side of the valley with moderate erosion. The head of the ravine originates at the same hobby farm as site 13, with brushy debris at the head of the ravine. A slope failure also exists near the head of the ravine.

Slope failure near head of ravine

Site 20

Site Description:

This site consists of an approximately 400 foot long reach of Bluff Creek having severe bank erosion. The erosion is occurring primarily on the east side of the valley wall where the stream abuts it. The stream is highly meandering in this reach, with some downed timber which tends to exacerbate the problem.

Bank erosion on outside of bend

Site 21

Site Description:

Approximately 725 foot long ravine on the west side of the valley with minor to moderate erosion. The lower half of the ravine has moderate erosion, while the upper half has minor erosion. Some headcutting and bank erosion is evident throughout the ravine.

Looking up toward the head of the ravine, some headcutting and slope erosion present

Site 22

Site Description:

Site consists of two parallel 350 foot long ravines on the west side of the valley near Highway 212. The southern ravine has minor erosion while the northern ravine has moderate erosion.

Minor erosion present in the southern ravine

Appendix D

Summary Table of System for Scoring Types of Evidence

Causal Analysis/Diagnosis Decision Information System (CADDIS)

Summary Table of Scores

Table S-4. System for Scoring Types of Evidence

Type of Evidence	Finding	Interpretation	Score
Types of Evidence that Use Data from the Case			
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
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.	+ +
	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.	- -
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.	- - -
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
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
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.	+ + +
	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	This finding *convincingly*	

	effects of the candidate cause fail to be confirmed.	*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
	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
Types of Evidence that Use Data from Elsewhere			
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.	
	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.	- -
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	This finding *neither supports nor weakens* the case for the	

	relationship in the case and stressor-response relationships from other field studies is ambiguous.	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.	-
	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.	+ + +
	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.	+
	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.	-
	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	This finding *somewhat weakens* the case for the candidate	

Appendix E

Invertebrate Data Summary

1992 Bluff Creek Invertebrate Data Collected October 2, 1992

Taxa			Station:	14 (B1)
Class	Order	Family	Genus and Species	No. Specimens
INSECTA	Ephemeroptera (mayflies)	Baetidae	*Baetis brunneicolor (nymphs)*	12
			Baetis sp. C	1
	Trichoptera (caddisflies)	Hydropsychidae	*Hydropsyche betteni*	12
		Limnephilidae	*Hesperophylax designatus*	3
	Coleoptera (beetles)	Dryopidae (adults)	*Helichus sp.*	6
		Hydrophilidae (adult)	*Cymbiodyta sp.*	1
CRUSTACEA	Decopoda	Astacidae	*Orconectes virilis*	1
	Amphipoda	Gammaridae	*Gammarus limnaeus*	117
HIRUDINEA				3
			Total Specimens	**156**

1993 Bluff Creek Invertebrate Data Collected September 27, 1993

Taxa			Station:	14 (B1)
Class	Order	Family	Genus and Species	No. Specimens
INSECTA	Coleoptera (beetles)	Dryopidae (adults)	*Helichus sp.*	1
	Diptera (true flies)	Tipulidae	*Tipula sp.* (larvae)	1
	Ephemeroptera (mayflies)	Baetidae	*Baetis brunneicolor* (nymphs)	50
	Trichoptera (caddisflies)	Hydropsychidae	*Cheumatopsyche sp.* (larvae)	1
			Hydropsyche betteni (larvae)	13
CRUSTACEA	Amphipoda	Gammaridae	*Gammarus limnaeus*	57
MALACOSTRACA	Terrestrial Isopoda			1
MOLLUSCA	Gastropoda	Lymnaeidae		1
			Total Specimens	**125**

1994 Bluff Creek Invertebrate Data Collected October 6, 1994

			Station:	**14 (B1)**
Taxa				**No. Specimens**
Class	**Order**	**Family**	**Genus and Species**	
INSECTA	Coleoptera (beetles)	Dytiscidae (adult)		2
		Elmidae	*Dubiraphia sp.* (adults)	5
	Diptera (true flies)	Chironomidae		4
		Tipulidae	*Tipula sp.* (larvae)	1
	Ephemeroptera (mayflies)	Baetidae	*Baetis brunneicolor* (nymphs)	16
			Baetis vagans (nymphs)	2
		Heptageniidae	*Stenacron sp.*	1
	Trichoptera	Hydropsychidae	*Hydropsyche betteni* (larvae)	23
		Lepidostomatidae	*Lepidostoma sp.*	1
CRUSTACEA	Amphipoda	Talitridae	*Hyalella azteca*	42
	Isopoda	Asellidae	*Asellus sp.*	1
MOLLUSCA	Gastropoda	Lymnaeidae	*Lymnaea stagnalis*	1
HIRUDINEA				2
			Total Specimens	**101**

1995 Bluff Creek Invertebrate Data Collected October 11, 1995				
			Station:	**14 (B1)**
Taxa				**No. Specimens**
Class	**Order**	**Family**	**Genus and Species**	
INSECTA	Hemiptera (true bugs)	Gerridae	*Gerris sp.*	1
	Coleoptera (beetles)	Dryopidae (adults)	*Helichus sp.*	4
		Dytiscidae (adult)	*Agabus sp.*	1
		Psephenidae	*Ectopria* (larvae)	1
	Trichoptera (caddisflies)	Hydropsychidae	*Cheumatopsyche sp.* (larvae)	11
			Hydropsyche bettini (larvae)	5
	Diptera (true flies)	Chironomidae (larvae)		3
		Chironomidae (pupa)		1
		Simulidae	*Simulium corbis* (larvae)	2
		Tipulidae	*Tipula sp.* (larvae)	1
CRUSTACEA	Amphipoda	Gammaridae	*Gammarus fasciatus (?)*	836
MALACOSTRACA	Terrestrial Isopoda			2
OLIGOCHAETA				3
			Total Specimens	**871**

1996 Bluff Creek Invertebrate Data collected October 9, 1996

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	**Order**	**Family**	**Genus and Species**					
INSECTA	Ephemeroptera (mayflies)	Baetidae	*Baetis brunneicolor* (nymphs)	50				
			Baetis flavistriga (nymphs)	1				
			Baetis vagans (nymphs)	1				
		Heptageniidae	*Stenacron sp.* (nymphs)	2				
	Coleoptera (beetles)	Dryopidae	*Helichus* (adults)	11	1	14		
		Dytiscidae	*Agabus sp.* (adult)	2		1		
			Laccophilus sp. (adult)			18		
			Laccornis sp. (adults)		1			
			Liodessus sp. (adults)			3		
		Hydrophilidae	*Helophorus sp.* (adults)		1	3		
			Helocombus sp. (adults)			2		
			Tropisternus sp. (adults)		1	4		
		Staphylinidae (adult)	Unable to Identify to Genus/Species			1		
	Trichoptera (caddisflies)	Leptoceridae	*Nectopsyche sp.* (larvae)		2	6		
		Limnophilidae	*Limnephilus sp.* (larvae)	1				
	Diptera (true flies)	Chironomidae	Chironomidae (larvae)	15				
			Chironomidae (pupa)	1				
		Culicidae	*Anopheles sp.* (larvae)			27		
			Culex sp. (larvae)		2	153		
			Culicidae pupae			1		
		Empididae	*Hemerodromia sp.* (larvae)	1				
		Simuliidae	*Simulium corbis* (larvae)		2			
		Stratiomyidae	*Odontomyia sp.* (larvae)		1			
		Tipulidae	*Tipula sp.* (larva)	2				
	Hemiptera (true bugs)	Belostomatidae	*Belostoma sp.* (adults)	1		2		
	Odonata	Coenagrionidae	*Enallagma sp.* (nymphs)			2		
CRUSTACEA	Amphipoda	Gammaridae	*Gammarus sp.*	205	67	167		
	Isopoda	Asellidae	Asellus		8			
ANNELIDA	Hirudinea				2	1		
	Oligochaeta					49		
ENTOGNATHA	Collembola	Isotomidae			1			
MOLLUSCA	Gastropoda	Hydrobiidae	*Amnicola sp.*		1	1		
		Physidae	*Aplexa hypnorum*			2		
			Physa sp.	1	22	106		
		Planorbidae	*Planorbula sp.*			8		
	Pelecypoda	Sphaeriidae	*Sphaerium sp.*		2	89		
			Total Specimens	**294**	**114**	**660**		

1997 Bluff Creek Invertebrate Data collected October 3 and 4, 1997

		Station:		B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	**Order**	**Family**	**Genus and Species**					
INSECTA	Ephemeroptera (mayflies)	Baetidae	*Baetis brunneicolor* (nymphs)	245	94	404	288	2
			Callibaetis spp.				5	
			Unidentifiable Baetis (nymphs)				1	
		Caenidae	*Caenis (* nymphs)			2		
		Heptageniidae	*Heptagenia sp.* (nymphs)	1	1			
			Unidentifiable heptageniids (nymphs)	3				
	Coleoptera (beetles)	Curculionidae (terrestrial?)	Unable to Identify to Genus/Species			2		
		Dryopidae	Unable to Identify to Genus/Species		1			
			Helichus (adults)	19			4	
		Dytiscidae	Laccophilus (adult)	4		68	16	
			Hydroporinae (adults)	5		88	8	
			Colymbetinae (adults)	4				
			Unidentified Dytiscidae (adults,larvae)				1	
		Elmidae	Unable to Identify to Genus/Species		3			
			Optioservus (larvae)		2			
			Optioservus spp.					
		Halipidae	Peltodytes (adults)		1			
			Haliplus (adults)	1		6		
		Hydrophilidae	Unable to Identify to Genus/Species	1		6		
			Tropisternus (adults)			2		
	Trichoptera (caddisflies)	Unable to Identify to Family	Unable to Identify to Genus/Species				1	
		Hydropsychidae	Hydropsyche betteni (larvae)		11		3	1
			Cheumatopsyche (larvae)	3	23		28	2
			Unidentifiable hydropsychidae (larvae)	2	15		1	
		Limnophilidae	Unable to Identify to Genus/Species	1				
	Diptera (true flies)	Athericidae	Unable to Identify to Genus/Species		1			
		Chironomidae	Tanypodinae		3	6	13	1
			Tanytarsini				3	1
			Chironomidae (larvae)			6	6	
			Chironomidae (pupa)	7	6			1
		Culicidae	Unable to Identify to Genus/Species				2	
		Simuliidae	Unable to Identify to Genus/Species	50	19	16	52	1
			Simulium (pupae)	11			1	
		Stratiomyidae	Unable to Identify to Genus/Species				1	
			Unidentifiable stratiomyid (larvae)	2				
		Tabanidae	Unable to Identify to Genus/Species		2			
		Tipulidae	Tipula (larva)	3				
		Higher Diptera (larvae)	Unable to Identify to Genus/Species			2		
		Higher Diptera (pupae)	Unable to Identify to Genus/Species			6	2	

1997 Bluff Creek Invertebrate Data collected October 3 and 4, 1997 (Continued)

		Station:		B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	Order	Family	Genus and Species					
	Hemiptera (true bugs)	Belostomatidae	Belostoma (adults)			22	6	
		Gerridae	Limnoporus (?) (adults)	2				
			Aquarius (adults)	2			14	18
		Pleidae						
			Neoplea (adults)			14	2	
	Odonata							
		Aeshnidae						
			Anax spp.		1	2	12	
			Aeshna spp.				1	
		Corduliidae						
			Somatochlora spp.		1			
		Coenagrionidae			1			
			Argia					
			Enallagma (nymphs)			34	16	
			Probably Ishnura (small)			14	12	
	Plecoptera				3			
	Lepidoptera							
		Pyralidae						
			Acentria spp.					
ARACHNIDA								
		Spiders			2			
CRUSTACEA								
	Malacostraca (crayfish)							
	Amphipoda							
		Gammaridae						
			Gammarus	198	180	700	215	
		Talitridae						
			Hyalella azteca		4	246	101	
	Decapoda							
		Astacidae						
			Orconectes					
	Isopoda			3				
		Terrestrial Porcellio or Cylisticus						2
		Asellidae						
			Asellus		2			16
ANNELIDA								
	Hirudinea					2		2
	Oligochaeta				3	4	4	4

1997 Bluff Creek Invertebrate Data collected October 3 and 4, 1997 (Continued)

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	**Order**	**Family**	**Genus and Species**					
MOLLUSCA								
	Gastropoda							
		Hydrobiidae						
			Amnicola		1	8		
		Lymnaeidae		1				
			Stagnicola					2
		Physidae		2				
			Physa	7	9	140	8	20
		Planorbidae						
		Valvatidae						
		Unidentified slug			2			
		Unidentified snails		1				
	Pelecypoda							
		Sphaeriidae		1	14	14	6	7
			Total Specimens	**579**	**405**	**1,814**	**833**	**80**

1998 Bluff Creek Invertebrate Data collected October, 1998.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				**No. Specimens**	**No. Specimens**	**No. of Specimens**	**No. of specimens**	**No. of specimens**
Class	**Order**	**Family**	**Genus and Species**					
INSECTA								**DRY**
	Ephemeroptera (mayflies)							
		Baetidae						
			Baetis brunneicolor (nymphs)	79	16		8	
			Callibaetis spp.				1	
			Unidentifiable Baetis (nymphs)				1	
		Gerridae						
			Gerris (adults)				1	
		Heptageniidae						
			Stenacron (nymphs)	1				
			Heptagenia		1			
	Coleoptera (beetles)							
		Dryopidae						
			Helichus (adults)	19	10	2	4	
		Dytiscidae						
			Laccophilus (adult)		2		1	
		Elmidae						
			Dubiraphia (larvae)				1	
			Stenelmis (larvae)		4			
			Optioservus (larvae)		5			
		Halipidae						
			Haliplus (adults)				1	
		Hydrophilidae						
			Tropisternus (adults)	2	1			
	Trichoptera (caddisflies)							
		Brachycentridae						
			Brachycentrus occidentalis	1				
		Hydropsychidae						
			Hydropsyche betteni (larvae)	4	32	10	29	
			Ceratopsyche slossonae (larvae)	20		2		
			Cheumatopsyche (larvae)	3	1		4	
			Unidentifiable hydropsychidae (larvae)		8			
	Diptera (true flies)	Chironomidae						
			Chironominae					
			Rheotanytarsus (larvae)			2	1	
			Tanypodinae				5	
			Tanytarsini				2	
			Chironomidae (larvae)				3	
		Culicidae						
			Pupae		1			
		Psychodidae		2				
		Tipulidae						

			Dicranota spp.	1				
			Tipula (larva)	3				

1998 Bluff Creek Invertebrate Data collected October, 1998 (Continued)

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	**Order**	**Family**	**Genus and Species**					
	Diptera (true flies)	Higher Diptera (pupae)				2		
	Hemiptera (true bugs)							
		Belostomatidae						
			Belostoma (adults)	3	9		13	
		Corixidae						
			Sigara (adults)				6	
		Gerridae						
			Limnoporus (?) (adults)	4				
			Aquarius (adults)		2			
		Calopterygidae						
			Calopteryx (nymphs)				1	
	Plecoptera							
			Capniidae		1			
			Filipalpia spp.	2				
DIPLOPODA (MILLIPEDS)				6				
CRUSTACEA								
	Malacostraca (crayfish)							
	Amphipoda							
		Gammaridae						
			Gammarus	307	1500	980	165	
		Talitridae						
			Hyalella azteca				9	
	Cladocera						1	
	Isopoda							
		Asellidae						
			Asellus		1		3	
ANNELIDA								
	Hirudinea			1	2		1	
	Oligochaeta					2	1	
MOLLUSCA								
	Gastropoda							
		Lymnaeidae		1	1	2		
		Physidae						
			Physa	1		4	19	
		Valvatidae						
		Unidentified slug		3	1	4		
	Pelecypoda							
		Sphaeriidae			2	10	4	
			Total Specimens	**463**	**1,600**	**1,020**	**285**	**0**

1999 Bluff Creek Invertebrate Data collected October 4 and 5, 1999.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	**Order**	**Family**	**Genus and Species**					
INSECTA								
x	Ephemeroptera (mayflies)							
		Baetidae						
			Baetis brunneicolor (nymphs)	402	1			
		Gerridae						
			Gerris (adults)		1			
			Aquarius (adults)		2			
x	Coleoptera (beetles)							
		Dryopidae						
			Helichus (adults)		5		5	
		Dytiscidae				2		
			Laccophilus (adult)				1	
			Unidentified Dytiscidae (adults,larvae)				2	
		Elmidae						
			Dubiraphia (adults)			4		
			Stenelmis (adults)		1	2		
			Optioservus (larvae)		13			
		Halipidae						
			Haliplus (adults)				1	
		Hydrophilidae						
			Enochrus (adults)				1	
			Staphylinidae (adults)		1			
			Tropisternus (adults)		1	2	1	
	Trichoptera (caddisflies)							
		Hydropsychidae						
			Hydropsyche betteni (larvae)	20	45		12	
			Ceratopsyche slossonae (larvae)	2	3			
			Cheumatopsyche (larvae)		11		5	
		Phyryganeidae						
			Psilostomis	3			3	
	Diptera (true flies)							
		Chironomidae					4	
			Orthocladinae	36			1	
			Chironominae					
			Diamesa spp.	4				
			Tanypodinae				5	
			Tanytarsini				2	
			Chironomidae (larvae)			2	33	6
			Chironomidae (pupa)		1			
		Culicidae						
			Pupae		1			
		Simuliidae		4				
		Stratiomyidae						

1999 Bluff Creek Invertebrate Data collected October 4 and 5, 1999 (Continued)

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	Order	Family	Genus and Species					
	Diptera (true flies)		Unidentifiable stratiomyid (larvae)				2	
		Tabanidae		1			3	
		Higher Diptera (larvae)					2	
	Hemiptera (true bugs)							
		Belostomatidae						
			Belostoma (adults)		6	6	5	
		Corixidae						
			Sigara (adults)				6	
			Trichocorixa (adults)				4	
		Gerridae						
			Aquarius (adults)				9	
			Gerris (adults)	2				
		Nepidae						
			Ranatra (adults)	1				
	Megaloptera							
		Corydalidae						
			Chauliodes spp.					1
		Sialidae						
	Odonata							
		Aeshnidae						
			Aeshna spp.		1		4	2
		Corduliidae						
			Neurocordulia		1			
		Calopterygidae						
			Calopteryx (nymphs)				1	
	Plecoptera							
			Filipalpia spp.	18				
ARACHNIDA								
		Spiders					3	
		Subclass Acari						
DIPLOPODA (MILLIPEDS)					1			
CRUSTACEA								
	Malacostraca (crayfish)							
	Amphipoda							
		Gammaridae						
			Gammarus	1200	294	296	231	
		Talitridae						
			Hyalella azteca					1
	Cladocera						1	
	Isopoda							
		Terrestrial Porcellio or Cylisticus					2	1
			Asellus					4
ANNELIDA								
	Hirudinea						1	16

1999 Bluff Creek Invertebrate Data collected October 4 and 5, 1999 (Continued)

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	Order	Family	Genus and Species					
	Oligochaeta					12		
HYDROIDEA								
		Hydridae						
			Hydra			1		
MOLLUSCA								
	Gastropoda							
		Lymnaeidae				2		
		Physidae						
			Physa			6	54	8
		Valvatidae						
		Unidentified slug				4		1
	Pelecypoda							
		Sphaeriidae				10	41	1
TURBELLARIA (flatworms)								
		Dugesia" type					9	8
			Total Specimens	**1,693**	**389**	**349**	**454**	**49**

2000 Bluff Creek Invertebrate Data collected October 3 and 4, 2000.

			Station:	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**
Taxa				**No. Specimens**	**No. Specimens**	**No. of Specimens**	**No. of specimens**	**No. of specimens**
Class	**Order**	**Family**	**Genus and Species**					
INSECTA								
x	Ephemeroptera (mayflies)							
		Baetidae						
			Baetis brunneicolor (nymphs)	536				
x	Coleoptera (beetles) unidentified larvae			8				
	Trichoptera (caddisflies)							
		Unidentified larvae		16				
	Diptera (true flies)							
		Chironomidae						
			Chironominae					
			Diamesa spp.	72				
			Tanytarsini					
			Chironomidae (larvae)	32				
		Simuliidae						
			Simulium tuberosum	40				
		Tipulidae		16				
	Plecoptera							
			Undetermined	49				
	Amphipoda							
		Gammaridae						
			Gammarus	2,400				
MOLLUSCA								
	Gastropoda							
		Physidae						
			Physa	64				
			Total Specimens	**3,233**	**0**	**0**	**0**	**0**

2001 Bluff Creek Invertebrate Data collected October 1 and 2, 2001.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	**Order**	**Family**	**Genus and Species**					
INSECTA								
	Ephemeroptera (mayflies)							
		Baetidae						
			Baetis brunneicolor (nymphs)	444	64	8		
		Caenidae						
			Caenis (nymphs)		2			
	Coleoptera (beetles) unidentified larvae							
		Dryopidae						
			Helichus (adults)	16	16	8	24	
		Dytiscidae						
			Agabetes	2	2			
			Laccophilus (adult)	4		16		
		Elmidae						
			Stenelmis (adults)		6			
			Stenelmis (larvae)		4			
			Optioservus (larvae)	4	48			
		Halipidae						
			Haliplus (adults)		4			
		Hydrophilidae						
			Tropisternus (adults)	2		12	8	
	Trichoptera (caddisflies)							
		Hydropsychidae						
			Hydropsyche betteni (larvae)		102	2		
			Ceratopsyche alhedra (?) (larvae)		2			
			Ceratopsyche slossonae (larvae)	12	4			
			Cheumatopsyche (larvae)		82		6	
		Phryganeidae						
			Ptilostomis spp.		2		14	
		Limnophilidae						
			Hesperophylax	4				
			Limnephilus	8				
		Phyryganeidae						
			Psilostomis	4				
	Diptera (true flies)							
		Chironomidae						
			Tanytarsini				8	
			Unidentified chironomidae	16	18			
		Simuliidae						
			Simulium vittatum (larvae)		2			
		Tipulidae					2	
			Tipula (larva)		6			
		Higher Diptera (larvae)		4		4		
	Hemiptera (true bugs)							
		Belostomatidae						

2001 Bluff Creek Invertebrate Data collected October 1 and 2, 2001.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
Class	**Order**	**Family**	**Genus and Species**					
			Belostoma (adults)	2		6		
		Corixidae						
			Sigara (adults)		2	16		
		Gerridae						
			Aquarius (adults)		6	4		
		Pleidae						
			Neoplea (adults)		2		4	
	Odonata							
		Aeshnidae						
			Anax spp.		2	4		
CRUSTACEA								
	Malacostraca (crayfish)				14			
	Amphipoda							
		Gammaridae						
			Gammarus	1820	132	616	396	
		Talitridae						
			Hyalella azteca		2		4	
	Isopoda							
		Terrestrial Porcellio or Cylisticus		2				
	Collembola							
		Undetermined adults			4			
ANNELIDA								
	Hirudinea							
			Erpobella punctata	2	4		4	
MOLLUSCA								
	Gastropoda							
		Hydrobiidae						
			Amnicola		2			
		Physidae						
			Aplexa hypnorum			28		
			Physa	8	40	120	200	
		Planorbidae						
			Helisoma spp.			24		
			Helisoma anthrosa		2			
		Unidentified slug			2			
		Succinea (terrestrial)						
	Pelecypoda							
		Sphaeriidae						
			Pisidium		5	8	8	
			Sphaerium		5	8	8	
TURBELLARIA (flatworms)								
		Dugesia" type		4				
		Tricladida						
			Total Specimens	**2,358**	**588**	**884**	**686**	**0**

2002 Bluff Creek Invertebrate Data collected October 2 through 4, 2002.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
INSECTA								
	Ephemeroptera (mayflies)							
		Baetidae						
			Baetis brunneicolor (larvae)	348	472	48	184	8
			Baetis flavistriga (nymphs)	48				
			Baetis intercalaris	4				
		Heptageniidae						
			Heptagenia	4				
	Coleoptera (beetles) unidentified larvae							2
		Dryopidae						
			Helichus (adults)	22		32	12	
		Dytiscidae						
			Coptotomus (adult)					1
			Laccophilus (adult)			8	4	
			Neobidessus (adults)	2				
		Elmidae						
			Optioservus (larvae)		80	16		
		Halipidae						
			Haliplus (adults)				4	
		Hydrophilidae						
			Tropisternus (adults)	4		8		
	Trichoptera (caddisflies)							
		Hydropsychidae						
			Hydropsyche betteni (larvae)	10	296	56	104	4
			Ceratopsyche alhedra (?) (larvae)	2	64		24	
			Ceratopsyche slossonae (larvae)	2	24			
			Cheumatopsyche (larvae)	2	136		76	
			Unidentifiable hydropsychidae (larvae)	2	32			
		Phryganeidae						
			Ptilostomis spp.	2	8	8		2
		Polycentropodidae						
			Polycentropus sp.				1	
	Diptera (true flies)							
		Athericidae						
			Atherix		8			
		Chironomidae						
			Unidentified chironomidae	8		16	24	18
		Simuliidae						
			Simulium tuberosum	70	64		8	
			Simulium vittatum (larvae)	2	32		20	2
		Tipulidae (undetermined larvae)						
			Tipula (larva)	4	12			1
	Hemiptera (true bugs)							
		Belostomatidae						

2002 Bluff Creek Invertebrate Data collected October 2 through 4, 2002.

			Station:	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**
Taxa				**No. Specimens**	**No. Specimens**	**No. of Specimens**	**No. of specimens**	**No. of specimens**
			Belostoma (adults)	10	40	128	8	
		Corixidae						
			Trichocorixa (adults)				12	
		Gerridae						
			Aquarius (adults)			8	2	1
		Pleidae						
			Neoplea (larvae)		8			
	Odonata							
		Aeshnidae						
			Anax spp.		2		4	
		Coenagrionidae						
			Probably Ishnura (small)		4	8		
DIPLOPODA (MILLIPEDS)					16			
CRUSTACEA								
	Malacostraca (crayfish)							
	Amphipoda							
		Gammaridae						
			Gammarus	260	56	1696	1568	
		Talitridae						
			Hyalella azteca		120	16		6
	Isopoda							
			Asellus	4	8		4	18
	Collembola							
ANNELIDA								
	Hirudinea							
			Erpobella punctata	4	8			6
			Glossophonia complanata	8		8		
	Oligochaeta					16		12
			Earthworms		2		2	2
MOLLUSCA								
	Gastropoda							
		Lymnaeidae						4
		Physidae						
			Physa	14	16	16		24
		Planorbidae						
			Helisoma spp.			48		
		Valvatidae						
		Unidentified slug		2				
	Pelecypoda							
		Sphaeriidae						
			Pisidium		12	8	48	50
			Sphaerium		12	8	48	50
			Total Specimens	**838**	**1,532**	**2,152**	**2,157**	**211**

2003 Bluff Creek Invertebrate Data collected October 6 through 7, 2003.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
INSECTA								
	Ephemeroptera (mayflies)							
		Baetidae						
			Baetis brunneicolor (larvae)	1,088				
			Baetis flavistriga (nymphs)	16				
	Coleoptera (beetles) unidentified larvae							
		Dryopidae						
			Postelichus (adults)	16				
		Dytiscidae						
			Agabetes	2				
		Elmidae						
			Optioservus (adults)	4				
			Optioservus (larvae)	2				
	Trichoptera (caddisflies)							
		Hydropsychidae						
			Hydropsyche betteni (larvae)	12				
			Ceratopsyche slossonae (larvae)	36				
			Unidentifiable hydropsychidae (larvae)	8				
		Phryganeidae						
			Ptilostomis spp.	6				
		Limnophilidae						
			Hesperophylax	2				
	Diptera (true flies)							
		Chironomidae						
			Chironomidae (larvae)	76				
		Simuliidae						
			Simulium tuberosum	16				
		Tipulidae (undetermined larvae)						
			Antocha	2				
			Tipula (larva)	12				
		Higher Diptera (larvae)		2				
	Hemiptera (true bugs)							
		Belostomatidae						
			Belostoma (adults)	10				
		Gerridae						
			Aquarius (adults)	4				
		Pseudoleon						
	Plecoptera							
			Undetermined (probably Capniidae)	48				
DIPLOPODA (MILLIPEDS)				2				
CRUSTACEA								
	Malacostraca (crayfish)							
	Amphipoda							
		Gammaridae						
			Gammarus	688				

2003 Bluff Creek Invertebrate Data collected October 6 through 7, 2003.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				**No. Specimens**	**No. Specimens**	**No. of Specimens**	**No. of specimens**	**No. of specimens**
ANNELIDA								
	Oligochaeta			2				
MOLLUSCA								
	Gastropoda							
		Physidae						
			Physa	112				
		Unidentified slug						
			Limax	2				
			Total Specimens	**1,064**	**0**	**0**	**0**	

2004 Bluff Creek Invertebrate Data collected October 7 through 8, 2004.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				**No. Specimens**	**No. Specimens**	**No. of Specimens**	**No. of specimens**	**No. of specimens**
INSECTA								
	Ephemeroptera (mayflies)							
		Baetidae						
			Baetis brunneicolor (larvae)	676	372	104	24	
			Baetis flavistriga (nymphs)					
			Baetis vagans (nymphs)					
			Baetis intercalaris					
			Baetis fondalis					
			Centroptilium					
			Callibaetis spp.					
			Baetis propinquus group					
			Pseudocloeon spp.					
			Unidentifiable Baetis		8			
		Caenidae						
			Caenis (larvae)					
		Gerridae						
			Gerris (adults)					
			Aquarius (adults)				2	
		Ephemerellidae						
			Ephemerella (nymphs)					
		Heptageniidae						
			Stenacron (larvae))					
			Stenacron (nymphs)					
			Heptagenia	4	32			
			Unidentifiable heptageniids					
	Coleoptera (beetles) unidentified larvae							
		Gyrinidae						
			Gyrinus (adults)					
		Dryopidae						
			Postelichus (adults)	12	12	16	4	
			Helichus (adults)					
		Psephenidae						
			Ectopria (larva)					
		Dytiscidae						
			Agabetes (adults)		4			
			Coptotomus (adult)					
			Ilybius (larva)					
			Laccophilus (larvae)			8		
			Laccophilus (adult)					
			Laccornis (adults)					
			Liodessus (adults)					
			Neobidessus (adults)					
			Hydroporus (adults)					
			Colymbetinae (adults)					

2004 Bluff Creek Invertebrate Data collected October 7 through 8, 2004.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
			Unidentified Dytiscidae (adults,larvae)					
		Elmidae						
			Dubiraphia (adults)					
			Dubiraphia (larvae)					
			Gonielmis (adults)					
			Stenelmis (adults)		4			
			Stenelmis (larvae)					
			Macronychus (larvae)					
			Optioservus (adults)		12	8		
			Optioservus (larvae)	4	104			
			Optioservus spp.					
			Unidentified larvae					
		Halipidae						
			Peltodytes (adults)				2	
			Haliplus (adults)					
		Scirtidae (=Helodidae)						
			Scirtes					
			Elodes (larvae)					
		Hydrophilidae						
			Crinitis (adult)					
			Enochrus (adults)					
			Helocombus (adults)					
			Staphylinidae (adults)					
			Tropisternus (adults)					
		Lampyridae						
			Unidentified larva					
	Trichoptera (caddisflies)							
		Unidentified larvae						
		Brachycentridae						
			Brachycentrus occidentalis					
		Hydropsychidae						
			Hydropsyche betteni (larvae)		128	8	16	
			Ceratopsyche alhedra (?) (larvae)					
			Ceratopsyche bifida group (larvae)					
			Hydropsyche simulans (?)					
			Hydropsyche sparna					
			Hydropsyche morosa					
			Hydropsyche dicantha					
			Ceratopsyche riola (larvae)					
			Hydropsyche slossonae (larvae)		72			
			Ceratopsyche (larvae)					
			Cheumatopsyche (larvae)	4	280		42	
			Unidentifiable hydropsychidae (larvae)					
		Hydroptilidae						
			Hydroptila (larva)					

2004 Bluff Creek Invertebrate Data collected October 7 through 8, 2004.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
			Hydroptilidae (pupa)					
		Leptoceridae						
			Oecetis spp.		4			
			Nectopsyche (larvae)					
		Phryganeidae						
			Ptilostomis spp.		20	64		
		Limnophilidae						
			Hesperophylax	2				
			Limnephilus					
			Undermeterined larvae	4				
		Philopotamidae						
			Chimarra obscura (larvae)					
		Polycentropodidae						
			Polycentropus sp.					
		Phyryganeidae						
			Psilostomis					
		Psychomyiidae						
			Psychomyia (larvae)					
	Diptera (true flies)							
		Athericidae						
			Atherix					
			Atheriz (larvae)					
		Ceratopogonidae						
		Chaobodidae (phantom midges)						
			Eucorethra (pupae)					
		Chironomidae						
			Orthocladinae					
			Thienemanniella					
			Nanocladius					
			Corynoneura (larvae)					
			Chironominae					
			Diamesa spp.				2	
			Glyptotendipes (larvae)					
			Polypedilum (larvae)					
			Rheotanytarsus (larvae)					
			Tanypodinae					
			Procladius (larvae)					
			Tanytarsini					
			Chironomidae (larvae) ,undetermined	48	120	2	38	
			Chironomidae (pupa)					
		Culicidae						
			Anopheles (larvae)					
			Anopheles (pupae)					
			Culex (larvae)					

2004 Bluff Creek Invertebrate Data collected October 7 through 8, 2004.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
			Pupae					
		Dixidae						
			Dixa					
		Psychodidae						
		Empididae						
			Hemerodromia (larvae)					
			Unidentifiable empidid (larva)					
		Simuliidae						
			Simulium tuberosum	36			6	
			Simulium vittatum (larvae)		24	56	16	
			Simulium vittatum (pupae)					
			Simulium corbis (larvae)					
			Simulium jenningsi (larvae)					
			Simulium (pupae)				2	
		Stratiomyidae						
			Odontomyia					
			Unidentifiable stratiomyid (larvae)					
		Tabanidae						
			Chrysops (larvae)					
		Tipulidae (undetermined larvae)						
			Antocha					
			Dicranota spp.					
			Helius (larva)					
			Limnophila (larva)					
			Limonia					
			Tipula (larva)	40	16		2	
		Higher Diptera (larvae)						
		Higher Diptera (pupae)						
	Hemiptera (true bugs)							
		Belostomatidae						
			Belostoma (adults)			24	2	
		Corixidae						
			Hesperocorixa (larvae)					
			Sigara (larvae)			16	12	
			Sigara (adults)					
			Probably Corisella					
			Trichocorixa (adults)					
			Unidentified immatures					
		Gerridae						
			Limnoporus (adults)					
			Aquarius (adults)		4			
			Trepobates (adults)					
			Gerris (adults)					
		Mesoveliidae						
			Mesovelia (adults)					

2004 Bluff Creek Invertebrate Data collected October 7 through 8, 2004.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
		Notonectidae						
			Notoecta (adults)					
		Nepidae						
			Ranatra (adults)					
			Ranatra (larvae)					
		Pleidae						
			Paraplea (adults)					
			Neoplea					
		Veliidae						
			Rhagovelia (adults)					
	Megaloptera							
		Corydalidae						
			Chauliodes spp.					
		Sialidae						
			Sialis (larva)					
	Odonata							
		Aeshnidae						
			Anax spp.					
			Aeshna spp.					
		Corduliidae						
			Neurocordulia					
		Calopterygidae						
			Calopteryx (larvae)					
		Coenagrionidae						
			Argia					
			Enallagma (larvae)					
			Ishnura					
			Probably Ishnura (small)					
			Unidentified					
		Pseudoleon						
	Plecoptera							
			Filipalpia spp.					
			Undetermined (probably Capniidae)	24	8			
	Lepidoptera				4			
		Pyralidae						
			Acentria spp.					
ARACHNIDA								
		Spiders						
		Subclass Acari						
			Limnesia					
			Unionicola					
DIPLOPODA (MILLIPEDS)				2	12			
CRUSTACEA								
	Malacostraca (crayfish)							
	Amphipoda							

2004 Bluff Creek Invertebrate Data collected October 7 through 8, 2004.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
		Cambarus diogenes						
		Gammaridae						
			Gammarus	572	92	400	92	
		Talitridae						
			Hyalella		40	120	22	
	Cladocera							
	Copepoda							
	Decapoda							
		Astacidae						
			Orconectes (crayfish)					
	Isopoda							
		Terrestrial Porcellio or Cylisticus						
			Lirceus					
		Asellidae						
		undertermined terrestrial isopod						
			Asellus		24	16	14	
	Collembola							
		Entomobryidae						
		Undetermined entomobryiid springtail						
ANNELIDA								
	Hirudinea							
			Erpobella punctata		4	8	2	
			Glossophonia complanata					
			Nephalopsis					
			Helobdella stagnalis					
	Oligochaeta			16	4	8	8	
			Undermeterined oligochaetes					
			Earthworms					
HYDROIDEA								
		Hydridae						
			Hydra					
MOLLUSCA								
	Gastropoda							
		Ancylidae						
			Ferrisia					
		Hydrobiidae						
			Amnicola					
		Lymnaeidae					2	
			Fossaria					
			Stagnicola					
		Physidae						
			Aplexa					
			Physa	28	76	40	12	
		Planorbidae						
			Gyraulus					

2004 Bluff Creek Invertebrate Data collected October 7 through 8, 2004.

			Station:	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**
Taxa				**No. Specimens**	**No. Specimens**	**No. of Specimens**	**No. of specimens**	**No. of specimens**
			Lymnaea					
			Helisoma spp.					
			Helisoma anthrosa					
			Helisoma trivolvis					
			Promenetus					
			Planorbula			8		
		Valvatidae						
			Valvata sp.					
			Valvata sincera					
			Valvata tricarinata					
		Unidentified slug						
			Limax	2				
		Succinea (terrestrial)						
	Pelecypoda							
		Sphaeriidae						
			Pisidium			72	28	
			Sphaerium					
			Total Specimens	**1,474**	**1,480**	**978**	**350**	

2005 Bluff Creek Invertebrate Data collected October 10 through 11, 2005.

			Station:	B-1	B-2	B-3	B-4	B-5
Taxa				No. Specimens	No. Specimens	No. of Specimens	No. of specimens	No. of specimens
INSECTA								
	Ephemeroptera (mayflies)							
		Baetidae						
			Baetis brunneicolor (larvae)	251	266	400	72	
			Baetis flavistriga (nymphs)	10				
			Undetermined Baetidae (broken,small,etc)		34	32		
			Unidentifiable Baetis		4			
		Heptageniidae						
			Heptagenia	2	8			
	Coleoptera (beetles) unidentified larvae							
		Dryopidae						
			Helichus (adults)	24	2	8	10	
		Elmidae						
			Dubiraphia (larvae)		2			
			Optioservus (adults)	3	8			
			Optioservus (larvae)	8	42			
		Halipidae						
			Peltodytes (adults)				2	
	Trichoptera (caddisflies)							
		Hydropsychidae						
			Hydropsyche betteni (larvae)	1	60	8	6	
			Hydropsyche slossonae (larvae)		2			
			Cheumatopsyche (larvae)	3	26	4	2	
		Phryganeidae						
			Ptilostomis spp.		18	36		
		Limnophilidae						
			Hesperophylax	1				
		Chironomidae						
			Chironomidae (larvae) ,undetermined		2		12	
		Simuliidae						
			Simulium vittatum (larvae)	3	64	164	12	
		Tipulidae (undetermined larvae)						
			Tipula (larva)	5	22			
	Hemiptera (true bugs)							
		Belostomatidae						
			Belostoma (adults)		4	8	4	
		Corixidae						
			Hesperocorixa (larvae)	1				
			Sigara (larvae)		6		10	
			Corisella		2			
			Trichocorixa (larvae)	2	4	4	24	

2005 Bluff Creek Invertebrate Data collected October 10 through 11, 2005.

			Station:	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**
Taxa				**No. Specimens**	**No. Specimens**	**No. of Specimens**	**No. of specimens**	**No. of specimens**
		Gerridae						
			Aquarius (adults)	1				
		Pleidae						
			Neoplea		2			
	Odonata							
		Aeshnidae						
			Anax spp.				1	
		Coenagrionidae						
			Ishnura	1		4		
DIPLOPODA (MILLIPEDS)				1				
CRUSTACEA								
	Malacostraca (crayfish)							
	Amphipoda							
		Gammaridae						
			Gammarus	190	132	76	86	
		Talitridae						
			Hyalella	7	44	148	34	
	Isopoda							
		Asellidae						
			Asellus	1	6		26	
ANNELIDA								
	Hirudinea							
			Erpobella punctata		6	8	4	
	Oligochaeta (undetermined)			2	4	24	4	
MOLLUSCA								
	Gastropoda (terrestrial snail)					4	12	
		Physidae						
			Aplexa				2	
			Physa		8	56	4	
		Planorbidae						
			Gyraulus				2	
		Unidentified slug			4			
		Terrestrial snail						
	Pelecypoda							
		Sphaeriidae						
			Pisidium	1		28	16	
			Total Specimens	**518**	**782**	**1012**	**345**	