# Shell Rock River Watershed Biotic Stressor Identification Report

A study of local stressors limiting the biotic communities

Minnesota Pollution Control Agency

April 2014

## Legislative charge

*Minn. Statutes § 116.011 Annual Pollution Report*
*A goal of the Pollution Control Agency is to reduce the amount of pollution that is emitted in the state. By April 1 of each year, the MPCA shall report the best estimate of the agency of the total volume of water and air pollution that was emitted in the state the previous calendar year for which data are available. The agency shall report its findings for both water and air pollution, etc, etc.*
*HIST: 1995 c 247 art 1 s 36; 2001 c 187 s 3*


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# Acronyms

AUID – Assessment Unit ID
BOD – Biological Oxygen Demand
CADDIS – Causal Analysis/Diagnosis Decision Information System
DELT – Deformities, Eroded fins, Lesions, and Tumors
DO – Dissolved Oxygen
EDA – Environmental Data Access
EPA – U.S. Environmental Protection Agency
EPT – Ephemeroptera, Plecoptera, and Trichoptera
FWC – Flow weighted concentration
HUC – Hydrologic Unit Code
IBI – Index of Biotic Integrity
MDNR – Minnesota Department of Natural Resources
mg/L – milligrams per Liter
MPCA – Minnesota Pollution Control Agency
MSHA – MPCA Stream Habitat Assessment
MSUM – Minnesota State University Mankato
SID – Stressor Identification
SOE – Strength of Evidence
TIV – Tolerance Indicator Value
TMDL – Total Maximum Daily Load
TP – Total Phosphorus
TSS – Total Suspended Solids
TSVS – Total Suspended Volatile Solids
USGS – United States Geological Survey
WET – Whole Effluent Toxicity Test
WRAPS – Watershed Restoration and Protection Strategies
WWTP – Wastewater Treatment Plant

# Executive summary

The Minnesota Pollution Control Agency (MPCA) has substantially increased the use of biological monitoring and assessment as a means to determine and report the condition of rivers and streams. The basic approach is to evaluate fish and aquatic macroinvertebrates (mostly insects), and related habitat conditions at sites throughout a major watershed. The resulting information is used to produce an index of biological integrity (IBI). Segments of streams and rivers with low IBI scores are deemed impaired.

The objective of this report was to evaluate the environmental data available for the Shell Rock River watershed to diagnose the probable causes of biological impairments on the Shell Rock River. Numerous candidate causes for impairment were evaluated using the U.S. Environmental Protection Agency's (EPA's) Causal Analysis/Diagnosis Decision Information System (CADDIS), and weight of evidence analysis. Stressor identification (SID) is defined by the EPA as a formal step by step approach that identifies stressors causing biological impairment of aquatic ecosystems, and provides a structure for organizing the scientific evidence supporting the conclusions. In simpler terms, it is the process of identifying the major factors causing harm to fish, macroinvertebrates, and other stream life. Stressor identification is a key component of the major watershed restoration and protection strategies (WRAPS) being carried out under Minnesota's Clean Water Land and Legacy Amendment. After an analysis of biological, chemical, and physical data, a list of probable stressors were identified. These include:

- Loss of habitat due to excess deposited and bedded sediment (DBS)
- Temperature
- Dissolved oxygen
- Nitrogen
- Phosphorus
- pH
- Low flow
- Ion strength
- Pesticides

These nine stressors and their connections to biological impairments in the Shell Rock River watershed will be evaluated in this report. The initial list of candidate causes was reduced after additional data analysis leaving seven candidate causes for final analysis in this report. The initial list can be seen in Appendix B. The stressors with strong evidence of their impacts on the biological communities were found to be the main stressors. The main stressors to the Shell Rock River are nutrients (phosphorus and nitrite+nitrate nitrogen), dissolved oxygen (DO), and lack of habitat due to excess deposited and bedded sediment. Ionic strength, flow, pH, temperature, and suspended sediments appear to be contributing stressors to different degrees. The effect of pesticides is unclear.

Eutrophication and the resulting DO fluctuations are the primary stressors to the Shell Rock River. Both nitrate and phosphorus concentrations are highest just downstream of the Albert Lea Wastewater Treatment Plant (WWTP), while chlorophyll-a values are highest just downstream of Albert Lea Lake. Phosphorus values were recorded at 5.4 mg/L and nitrate values at 12 mg/L below the Albert Lea WWTP. Continuous DO concentrations routinely fall below 5 mg/L and daily fluctuations average 13.33 mg/L, with the highest reported at 20.36 mg/L. While nutrients are driving the DO fluctuations, high water temperatures and low flows during dry conditions are also playing a role in elevated DO values. DO fluctuations occur when an overabundance of nutrients increase the number of aquatic plants. These plants then produce oxygen through photosynthesis during the day, and consume the oxygen during the night through respiration. An overabundance of aquatic plants and algae can use oxygen faster than it is replenished; leading to large drops in DO levels. As these plants die off, bacteria that decompose plant material also use up large amounts of oxygen. Average nitrate values are highest in the Bancroft Creek and Peter Lund Creek systems, with the highest average at CD 32 (trib. to Peter Lund). Average phosphorus values are highest on the Shell Rock River, followed by Goose Creek and Shoff Creek. Nutrient management of both phosphorus and nitrogen is needed throughout the watershed.

The lack of habitat due to deposited and bedded sediment is also a main stressor to the system. This sediment deposition affects fish species dependent on coarse substrates for feeding and reproduction. Lack of diversity in channel morphology is also affecting the available habitat. The high width to depth ratio leads to few refuge areas for fish, particularly during dry years. The stream has few riffles, and pools and runs are covered with fine sediment due to deposition. The low gradient nature of the stream creates low stream power, and the flow is not enough to move the fine sediments once they are deposited. Prevention of stream bank erosion is important to limit further deposition of fine sediments to the stream bed.

# Introduction

## Organization framework of stressor identification

The SID is prompted by biological assessment data indicating that a biological impairment has occurred. Through a review of available data, stressor scenarios are developed that may accurately characterize the impairment, the cause, and the sources/pathways of the various stressors. Confidence in the results often depends on the quality of data available to the SID process. In some cases, additional data collection may be necessary to accurately identify the stressors (Figure 1).

SID draws upon a broad variety of disciplines, such as aquatic ecology, geology, geomorphology, chemistry, land-use analysis, and toxicology. Strength of evidence (SOE) analysis is used to develop cases in support of, or against various candidate causes. Typically, the majority of the information used in the SOE analysis is from the study watershed, although evidence from other case studies or scientific literature can also be drawn upon in the SID process.

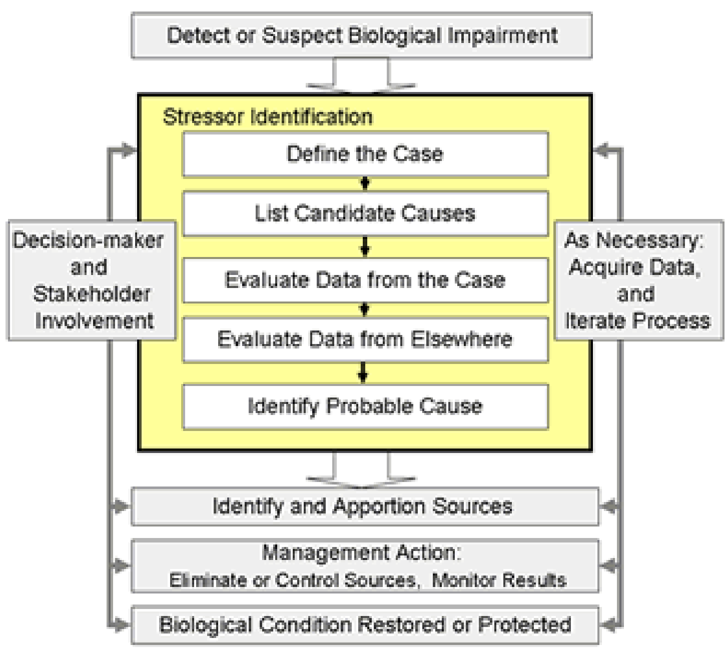



**Figure 1: Conceptual model of SID process**

Completion of the SID process does not result in a finished Total Maximum Daily Load (TMDL) study. The product of the SID process is the identification of the stressor(s) for which the TMDL allocation will be developed. In other words, the SID process may help investigators nail down excess fine sediment as the cause of biological impairment, but a separate effort is then required to determine the TMDL and implementation goals needed to restore the impaired condition.

# Elements of stream health

The elements of a healthy stream consist of five main components (Figure 2): stream connections, hydrology, stream channel assessment, water chemistry, and stream biology. The following flowchart shows the five components of a healthy stream. If one or more of the components are unbalanced the stream ecosystem fails to function properly and is listed as an impaired water body.

**The Elements of Stream Health**

Stream Health is linked to the 5 main categories below. The MPCA and local partners examine many interrelated factors to identify stressors

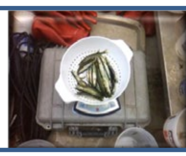
**Stream Connections**
Examples: dams, culverts and drainage tiles

**Hydrology**
Examples: stream flow and runoff

**Stream Channel Assessment**
Example: Bank erosion and Channel Stability

**Water Chemistry**
Example: Dissolved oxygen, nutrients and temperature

**Stream Biology**
Example: fish and macroinvertebrates



**What conditions stress our streams?**

Several factors can stress the biological condition within streams.

**Too much sediment**
Soil and other particles in water can make it difficult for fish and invert to breathe, feed and reproduce. Sediment can fill pools and smoother gravel and rock habitat

**Low Oxygen**
Fish and macroinvertebrates need dissolved oxygen in the water to breathe and survive.

**Temperature**
Stream temperature affects metabolism of fish, especially cold water fish species and also influences oxygen content in water.

**Lack or Loss of Habitat**
Habitat affects all aspects of survival for fish and macro invertebrates. Habitat encompasses places to live, food to eat, places to reproduce and means of protection.

**Increased nutrients**
Excess nutrients, such as phosphorus and nitrogen, cause excessive algal blooms which can lead to high daily fluctuations in dissolved oxygen concentrations. High amounts of nitrogen can be toxic to fish and macro invertebrates.

**Figure 2. The five components of stream health and conditions that stress streams**

# Common stream stressors to biology (fish, macroinvertebrates)

**Table 1. The stream health component along with the associated stressor(s) and their link to biological health**

| Stream Health | Stressor(s) | Link to Biology |
|---|---|---|
| **Stream Connections** | **Loss of Connectivity**<br>· Dams and culverts<br>· Lack of wooded riparian cover<br>· Lack of naturally connected habitats/ causing fragmented habitats | Fish and macroinvertebrates cannot freely move throughout system. Stream temperatures also become elevated due to lack of shade. |
| **Hydrology** | **Flow Alteration**<br>· Channelization<br>· Peak discharge (flashy)<br>· Lack of baseflow<br>· Transport of chemicals | Unstable flow regime within the stream can cause a lack of habitat, unstable stream banks, filling of pools and riffle habitat, and affect the fate and transport of chemicals. |
| **Stream Channel Assessment** | **Lack of Physical Habitat**<br>**Sediment (suspended or bedded)**<br>· Loss of dimension/pattern/profile<br>· Bank erosion from instability<br>· Loss of riffles due to accumulation of fine sediment<br>· Increased turbidity and or TSS | Habitat is degraded due to excess sediment in the water column and streambed. There is a loss of clean rock substrate from embeddedness of fine material and a loss of intolerant species. |
| **Water Chemistry** | **Low Dissolved Oxygen Concentrations**<br>**Elevated levels of nutrients**<br>· Increased nonpoint pollution from urban and agricultural practices<br>· Increased point source pollution from urban treatment facilities<br>Ø Increased algal and or periphyton growth in stream<br>Ø Widely variable DO levels during the daily cycle | There is a loss of intolerant species and a loss of diversity of species, which tends to favor species that can breathe air or survive under low DO conditions. Biology tends to be dominated by a few tolerant species. |
| **Stream Biology** | Fish and macroinvertebrate communities are affected by all of the above listed stressors | If one or more of the above stressors are affecting the fish and macroinvertebrate community, the IBI scores will not meet expectations and the stream will be listed as impaired. |

# Shell Rock River watershed

The Shell Rock River is a warm-water (Class 2B) tributary to the Cedar River, and begins at the outlet of Albert Lea Lake southeast of the city of Albert Lea. The small tributaries and larger agricultural drainage systems upstream of Albert Lea Lake include Peter Lund, Wedge Creek, Shoff Creek, and Bancroft Creek. Goose Creek and County Ditch 16 flow into the Shell Rock River downstream of Glenville. Land use in the watershed is predominantly comprised of corn and soybean row crops, with most depressional areas drained for agricultural uses. There is a good buffer along portions of the river, particularly along the upper stretches of the Shell Rock River with both prairie grasses and forested areas present (Figure 3). The river is low gradient and sinuous, with numerous riparian wetlands alongside the river. The gradient of the Shell Rock River below Albert Lea Lake is less than 1 foot/mile. The city of Albert Lea (2012 population of 17,900) is located between Fountain and Albert Lea Lakes, and the city's drainage area is about 10.4 square miles. The entire Shell Rock River watershed includes 254 square miles of drainage area to the Iowa border (including a small portion in Iowa that drains north to Minnesota).

**Figure 3. Shell Rock River**

Watershed wide biological sampling occurred in 2009. As described in the [Shell Rock River Monitoring and Assessment Report](MPCA 2012) (MPCA 2012), all data collected during a 10-year window was used for assessment with impairments occurring only on the Shell Rock River. The remainder of the watershed was not able to be assessed due to channelization or being categorized as limited resource waters. Two impairments were deferred due to predominantly channelized reaches: Bancroft Creek for macroinvertebrates and County Ditch 16 for DO. Additional information on Bancroft Creek, which is a major tributary to Fountain Lake, has been included to provide information for future planning.

The fish and macroinvertebrate thresholds and confidence intervals are shown in Table 2. The fish IBI scores were all calculated using the southern streams IBI (class 2), and the macroinvertebrate scores were calculated using the southern forest streams glide pool IBI (class 6). The water quality standards call for the maintenance of a healthy community of aquatic life. IBI scores provide a measurement tool to assess the health of the aquatic communities. IBI scores for the Shell Rock River are in Table 3. IBI scores higher than the impairment threshold indicate that the stream reach supports aquatic life.

Contrarily, scores below the impairment threshold indicate that the stream reach does not support aquatic life. Confidence limits around the impairment threshold help to ascertain where additional information may be considered to help inform the impairment decision. When IBI scores fall within the confidence interval, interpretation and assessment of waterbody condition involves consideration of potential stressors, and draws upon additional information regarding water chemistry, physical habitat, land use activities, etc. Other metrics besides just those used in the IBI will also be discussed in this report, as they are often more closely tied to individual stressors.

**Table 2. Fish and macroinvertebrate thresholds and confidence intervals**

| Class | Class Name | Fish IBI Thresholds | Upper CL | Lower CL |
|---|---|---|---|---|
| 2 | Southern Streams | 45 | 54 | 36 |
| 6 | Southern Forest Streams GP | 46.8 | 66 | 38.8 |

**Table 3. Shell Rock River sites fish and macroinvertebrate IBI scores**

| Field Number | Location | Fish IBI | Invert IBI |
|---|---|---|---|
| 04CD037 | 1 mile downstream of Albert Lea Lake | 42 | 33 |
| 09CD087 | Upstream of 170th St, 1.5 mile S of Albert Lea | 48 | 36.2 |
| 04CD017 | At Hwy 13 bridge in Glenville | 40 | 29.5 |
| 09CD088 | Downstream of Hwy 65, 2 mi. SE of Glenville | 51 | 38 |
| 11CD001 | Downstream of 130th St, 2 mi. S of Glenville | 61 | 27.9 |
| 04CD015 | Downstream of Hwy 7, 2 mi. S of Glenville | 33 | 49 |
| 09CD089 | Upstream of CSAH 1, 1 mi. W of Gordonsville | 34 | 43 |

**At or Below Lower Confidence Limit** **At or Below Threshold, Above Lower Confidence Limit** **At or Below Upper Confidence Limit, Above Threshold** **Above Upper Confidence Limit**

# Summary of biological impairments

The Shell Rock River reach from Albert Lea Lake to Goose Creek is listed for fish, macroinvertebrate, DO, pH, fecal coliform, and turbidity impairments (Figure 4). The biological impairments are new to the 2012 TMDL list. The stream reach (AUID 07080202-501) is 12 miles in length. Impairments exist on Bancroft and Wedge Creeks for E. coli, and Shoff Creek is impaired for turbidity. This report will focus on stressors to the biological community impairments. The DO, pH, and turbidity impairments will be addressed as to how they affect the biological impairments. The TMDLs will focus more intensively on these chemical impairments, in addition to the fecal coliform and E. coli impairments which will not be addressed in this report.

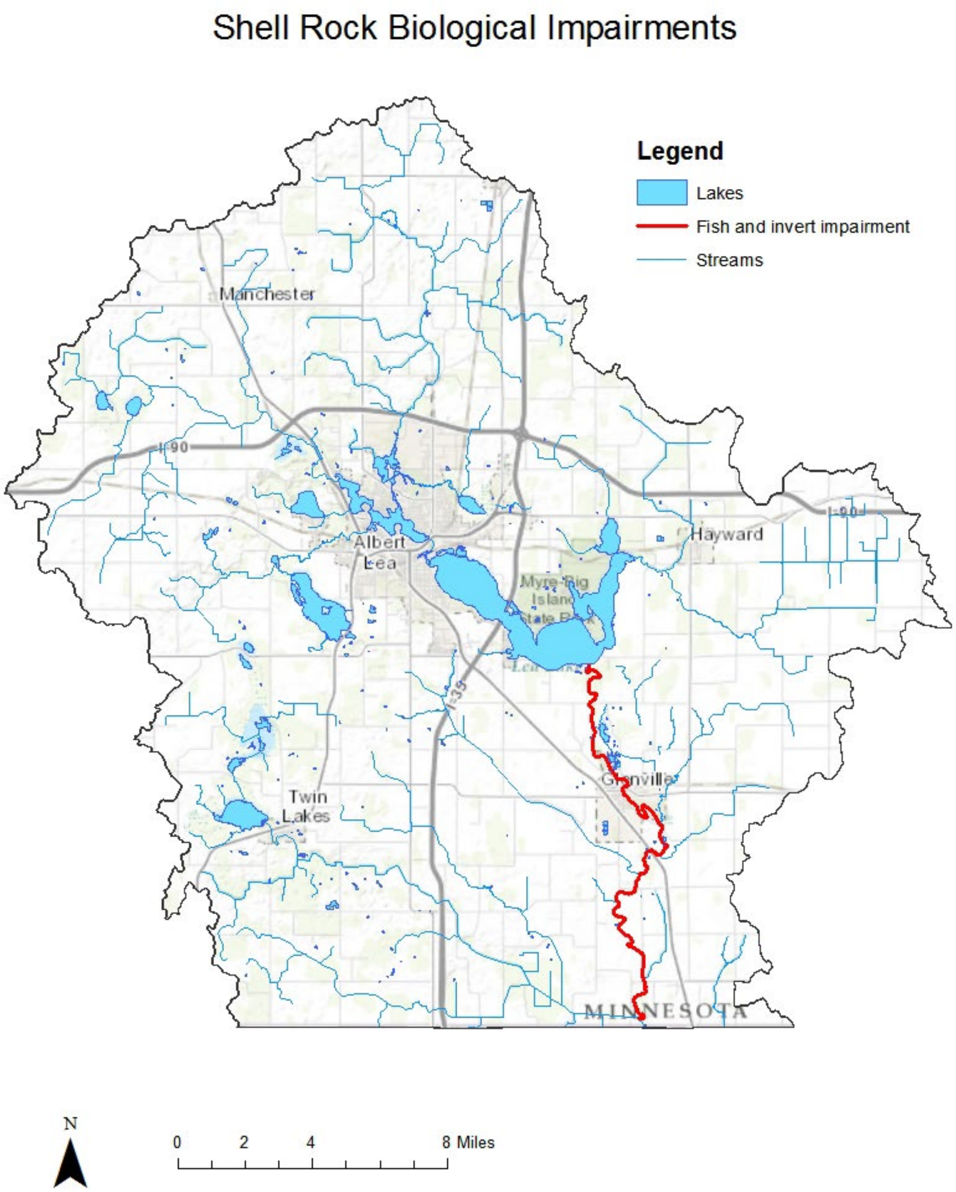



**Figure 4. Biological impairments in the Shell Rock River watershed**

Chemical and biological information is available throughout the watershed through sampling done by the Minnesota Pollution Control Agency (MPCA), the Minnesota Department of Natural Resources (MDNR), the Shell Rock River watershed district, local counties, and citizens. A comprehensive review of biological, chemical, and physical data was performed; the locations of the chemical and biological sampling stations are located in Figures 5 and 6.

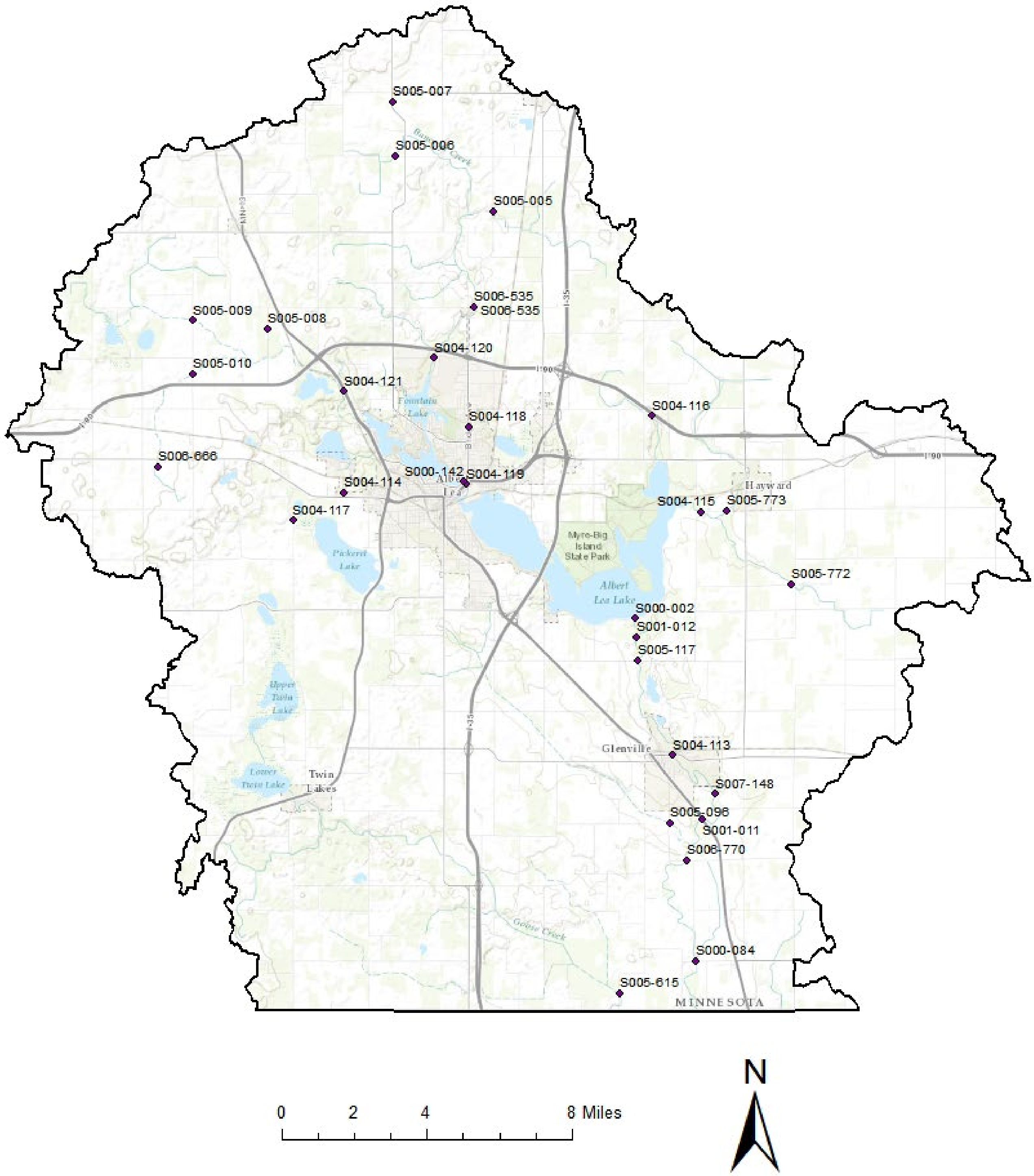



**Figure 5. Chemistry sampling locations in the Shell Rock River watershed**

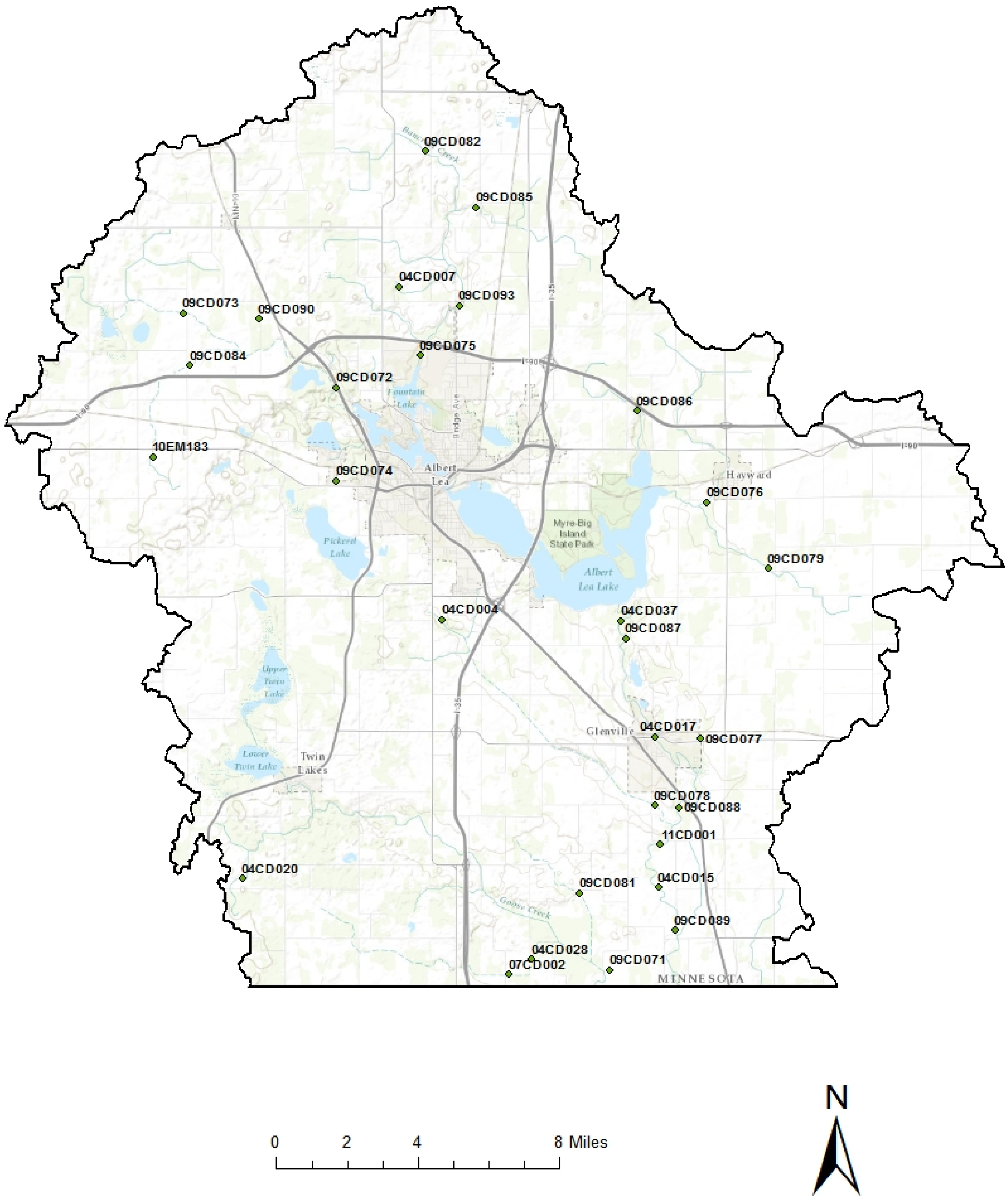



**Figure 6. Biological monitoring stations in the Shell Rock River watershed**

# Candidate cause: Dissolved oxygen

Dissolved oxygen measures the concentration of oxygen in milligrams (mg) per volume, one Liter (L). DO concentrations and fluctuations are affected by shifts in ambient air and water temperature, precipitation, stream flow, atmospheric pressure, plant/algal growth and decomposition, salinity, and ammonia concentrations. Low concentrations or highly fluctuating concentrations of DO can have detrimental effects on many fish and macroinvertebrate species (Davis, 1975; Nebeker et al., 1991).

Fish require oxygen for respiration. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995). Some macroinvertebrates that are intolerant to low levels of DO include mayflies, stoneflies and caddisflies (Marcy, 2007). Many species of fish avoid areas where DO concentrations are below 5.0 mg/L (Raleigh et al., 1986). Additionally, fish growth rates can be significantly affected by low DO levels (Doudoroff and Warren, 1965).

In most streams and rivers, the critical conditions for stream DO usually occur during the late summer season when water temperatures are high and stream flows are reduced to baseflow. As temperatures increase, the saturation levels of DO decrease. Increased water temperature also raises the DO needs for many species of fish (Raleigh et al., 1986). Low DO can be an issue in streams with slow currents, excessive temperatures, high biological oxygen demand, and/or high groundwater seepage (Hansen, 1975). Heiskary et al. (2013) observed several strong negative relationships between fish and macroinvertebrate metrics and DO flux.

## Water quality standards

The standard for Class 2B (warm-water) streams in the state of Minnesota for DO is 5.0 mg/L as a daily minimum (Minn. Stat. 7050.0222 subp. 4).

## Dissolved oxygen in the Shell Rock River watershed

Instantaneous (i.e. one single measurement) DO readings are available throughout the watershed and were used as an initial screening tool. DO was measured at 17.7 mg/L during the fish sample collection in Glenville in 2004, indicating DO as a possible stressor in the Shell Rock River. While cold-water streams can often have elevated DO readings due to colder water holding more DO, values over 14 mg/L are often tied to nutrients and daily DO fluctuations. In 2012, large daily fluxes (up to 20.94 mg/L) were recorded throughout the stream along with many daily minimum values below the 5.0 mg/L standard for Class 2B waters. The proposed stream water quality standard for the south region of the state for daily DO fluctuations (max-min) is 4.5 mg/L. In the Shell Rock River, daily DO fluctuations are more than four times the proposed standard.

## Sources and causal pathways for dissolved oxygen

Dissolved oxygen concentrations in lotic environments are driven by a combination of natural and anthropogenic factors. Natural background characteristics of a watershed, such as topography, hydrology, climate, and biological productivity define the DO regime of a waterbody. Agricultural and urban land-uses, impoundments (dams), and point-source discharges are just some of the anthropogenic factors that can cause unnaturally high, low, or volatile DO concentrations. The conceptual model for low DO as a candidate stressor is modeled at EPA's CADDIS Dissolved Oxygen webpage.

The large daily fluctuations in DO levels in the Shell Rock River are tied to the high phosphorus loads coming into the stream. The nutrient inputs from Albert Lea Lake, agricultural runoff, the Albert Lea WWTP, and other point sources are upsetting the natural dynamics by increasing algae and macrophyte production, which in turn increases photosynthesis, respiration, and decomposition. This cycle creates large fluctuations in DO levels, which in the Shell Rock River span from less than 1.0 mg/L, which is not enough oxygen for many aquatic organisms, to greater than 24.0 mg/L, which is supersaturated water. Both of those values are stressful, and wide fluctuations like this in one day are also stressful to aquatic communities. This stress results in a shift from functional assemblages of aquatic communities to tolerant or generalist species (Heiskary et al. 2013).

# Candidate cause: Nitrogen

Nitrate toxicity to freshwater aquatic life is dependent on concentration and exposure time, as well as the overall sensitivity of the organism(s) in question. Certain species of caddisflies, amphipods, and salmonid fishes seem to be the most sensitive to nitrate toxicity according to Camargo and Alonso (2005). Camargo et al (2005) cited a maximum level of 2.0 mg/L nitrate-N as appropriate for protecting the most sensitive freshwater species and that NO3-N concentrations are under 10.0 mg/L to be protective of several sensitive fish and aquatic invertebrate taxa. The intake of nitrite and nitrate by aquatic organisms has been shown to convert oxygen-carrying pigments into forms that are unable to carry oxygen, thus inducing a toxic effect on fish and macroinvertebrates (Grabda et al, 1974; Kroupova et al, 2005).

## Water quality standards

Streams classified as Class 1 waters of the state, designated for domestic consumption in Minnesota, have a nitrate water quality standard of 10.0 mg/L (Minn. Stat. 7050.0222 subp. 3). At this time, none of the Assessment Unit ID (AUIDs) in the Shell Rock River watershed that are impaired for biota are classified as Class 1 streams. Minnesota currently does not have a nitrate standard for other waters of the state except for Class 1; however an aquatic life nitrate standard is being drafted.

## Nitrogen in the Shell Rock River watershed

Water chemistry samples have been taken throughout the watershed, and total nitrate (Nitrate + Nitrite) values on the main-stem Shell Rock River range from less than 0.05 up to 12.0 mg/L, indicating nitrate is a potential stressor. Concentrations of nitrate as high as 15.0 mg/L were collected from tile lines after rain events. Unionized ammonia is another form of nitrogen, and all concentrations were all well below the water quality standard of 0.04 mg/L.

## Sources and causal pathways for nitrogen

The conceptual model for nitrogen as a candidate stressor is modeled at EPA's CADDIS Nitrogen webpage. Lefebvre et al. (2007) determined that fertilizer application and land-cover were the two major determinants of nitrate signatures observed in surface water and that nitrate signatures in surface waters increased with fertilization intensity. Nitrogen is commonly applied as a crop fertilizer, predominantly for corn. Since the watershed is largely comprised of cropland planted in corn, it is likely that various forms of nitrogen including nitrate and ammonia are being applied throughout the watershed. This is reinforced by the high nitrate concentrations collected out of tile drains. A statewide nitrogen study found that cropland commercial fertilizers make up 47% of nitrogen added to the landscape, 21% occurs through cropland legume fixation, 16% from manure application, and 15% from atmospheric deposition (MPCA, 2013). These land applications can reach waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013).

# Candidate cause: Phosphorus

Phosphorus is an essential nutrient for all aquatic life, but elevated phosphorus concentrations can result in an imbalance which can impact stream organisms. Excess phosphorus results in indirect impacts to fish and macroinvertebrates, and direct impacts to aquatic communities from response variables such as DO flux, chlorophyll-a, and biological oxygen demand (BOD) (Heiskary et al., 2013). Elevated phosphorus levels increase algae and aquatic plant growth and decomposition; resulting in changes in DO and pH concentrations, water clarity, and available food resources and habitat.

## Water quality standards

There is currently no water quality standard for total phosphorus (TP); however, there is a draft nutrient standard for rivers of Minnesota (Heiskary et al., 2013). The current draft standard for the southern region of the state is a maximum concentration of 0.15 mg/L with at least one response variable out of desired range (BOD, DO flux, chlorophyll-a, and/or pH).

## Phosphorus in the Shell Rock River watershed

Over 90% of recent available water chemistry data values in the watershed are over the proposed water quality standard for phosphorus (0.150 mg/L). A phosphorus value of 1.75 mg/L was collected on the Shell Rock River during biological sampling in 2009, and follow-up sampling found values up to 5.4 mg/L.

## Sources and causal pathways for excess phosphorus

Phosphorus is closely tied to the DO fluxes that are occurring on the Shell Rock River. Increased phosphorus levels lead to increased algal and macrophyte growth which in turn leads to increased decomposition and respiration rates. Increased plant and algal growth causes increased oxygen production through photosynthesis during the day. The excess plant material eventually dies, and bacterial activity during decomposition strips oxygen from the water. This leads to low early morning DO readings in streams, and high readings in the afternoon. Streams dominated with submerged macrophytes experience the largest swings in DO and pH (Wilcox and Nagels 2001). Phosphorus is delivered to streams by wastewater treatment facilities, urban stormwater, agricultural runoff, and direct discharges of sewage. Phosphorus bound to sediments in the river channel could be contributing to concentrations; however there is no data available. Orthophosphorus is the form of phosphorus that is readily available for plant and algal uptake, and can influence excess algae growth. While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from waste water treatment plants, noncompliant septic systems, and fertilizers in urban and agricultural runoff. The causes and potential sources for excess phosphorus are modeled at EPA's CADDIS Phosphorus webpage. The majority of the watershed is agricultural and the Albert Lea WWTP is inputting high levels of phosphorous to the Shell Rock River.

# Candidate cause: pH

The term pH is a measure of acidity or basicity, with a scale ranging from 0 to 14. As described by the EPA, pH values are considered high when they are above 9.0 for a prolonged amount of time or frequency (CADDIS 2013). Photosynthesis from elevated rates of eutrophication creates an increase in pH values. High pH values also influence elevated ionic strength and the toxicity of other chemicals such as ammonia. As pH increases, unionized ammonia becomes the predominant form, which can lead to ammonia toxicity (CADDIS 2013). Values of pH outside the range of 6.5-9.0 or highly fluctuating values are stressful to aquatic life.

### Water quality standards

The standard for Class 2B (warm-water) streams in the state of Minnesota for pH is range of 6.5 as a daily minimum and 9.0 as a daily maximum (Minn. Stat. 7050.0222 subp. 4).

### pH in the Shell Rock River watershed

Values of pH on the Shell Rock River range from 6.37 to 9.6. The highest values in the watershed are on the Shell Rock River. Values of pH over 9.0 have been found throughout the main-stem Shell Rock River.

### Sources and causal pathways for pH

The conceptual model for pH as a candidate stressor is modelled at EPA's CADDIS pH webpage. Human effects on pH values can result from agricultural runoff, urbanization, and industrial discharges. Some geology has naturally high hydrogen ions that can leach into surface water, but it would be rare for this to be the only cause. Photosynthesis of overabundant macrophytes and algae can remove carbon dioxide from the water, causing a higher pH. Effects on biology include decreased growth and reproduction, decreased biodiversity, and damage to skin, gills, eyes, and organs. Concentrations of nutrients (especially nitrogen) also play a significant part in pH dynamics, as nitrification and respiration both produce hydrogen ions (CADDIS 2013).

## Candidate cause: Temperature

Stream temperature naturally varies due to air temperature, geology, shading, and the inputs from tributaries and springs. Different organisms are adapted to and prefer different temperature regimes. Water temperature regulates the ability of organisms to survive and reproduce (EPA, 1986). Thermal pollution can increase stream temperatures through loss of riparian shading, urban and agricultural runoff, and direct discharges to the stream. Warmer water holds less DO, and higher water temperatures also affects the toxicity of numerous chemicals in the aquatic environment. Algal blooms often occur with temperature increases (EPA, 1986).

### Water quality standards

The standard for Class 2B (warm-water) waters of the state is not to exceed 5 degrees Fahrenheit (°F) above the monthly average of maximum daily temperature (Minn. Stat. 7050.0222 subp. 4). In no case shall it exceed the daily average temperature of 86 degrees Fahrenheit (30 degrees Celsius).

### Temperature in the Shell Rock River watershed

Temperatures in the Shell Rock River have been recorded up to 30.77 degrees Celsius (°C) (87.4 °F). The short- term maximum temperature for survival of northern pike is 30 °C (86 °F) (EPA, 1986). Northern pike have only been found in the Shell Rock River in small numbers. The average July temperature (the warmest month) from 2007 to 2012 is 25 °C (77 °F).

### Sources and causal pathways for elevated temperature

Riparian land cover alteration and increasing channel width are both occurring in the Shell Rock River, contributing to higher water temperatures. Increased temperatures can influence predator-prey dynamics, but this is hard to quantify. The causes and potential sources for excess temperature are modeled at EPA's CADDIS Temperature webpage.

# Candidate cause: Specific conductance and ionic strength

Specific conductance refers to the collective amount of ions in the water. In general, the higher the level of dissolved minerals in a volume of water, the more electrical current (or conductance) can be transmitted through that water. Aquatic organisms maintain a careful water and ion balance, and can become stressed by an increase in ion concentrations (SETAC, 2004). Calcium, sodium, and magnesium are all necessary for aquatic health, and occur naturally, but imbalances can be toxic (SETAC, 2004).

## Water quality standards

A standard of 1,000 µmhos/cm at 25 °C exists for Class 4 waters of the state (Minn. Stat. 7050.0224 subp. 2) that is protective of agricultural and irrigation uses, but is a not an aquatic life standard.

## Specific conductance and ionic strength in the Shell Rock River Watershed

Conductivity values differ widely along the Shell Rock River, and range from 275 to 1,512 uS/cm. The lowest values have been recorded downstream of the Albert Lea Lake dam. The highest values have been recorded downstream of CR 84 and the Albert Lea WWTP.

## Sources and causal pathways for specific conductance and ionic strength

The presence of dissolved salts and minerals in surface waters does occur naturally, and biota are adapted to a natural range of ionic strengths. However, industry runoff and discharges, road salt, urban stormwater drainage, agricultural drainage, WWTP effluent, and other point sources can increase ions in downstream waters. The causes and potential sources for ionic strength are modeled at EPA's CADDIS Ionic strength webpage.

# Candidate cause: Turbidity/total suspended solids

Reduced transparency can increase due to suspended particles such as sediment, algae and organic matter. Increases in suspended solids and turbidity within aquatic systems are now considered one of the greatest causes of water quality and biological impairment in the United States (U.S. EPA, 2003). Although sediment delivery and transport are an important natural process for all stream systems, sediment imbalance (either excess sediment or lack of sediment) can result in the loss of habitat and/or direct harm to aquatic organisms. As described in a literature review by Waters (1995), excess suspended sediments cause harm to aquatic life through two major pathways: (1) direct, physical effects on biota (i.e. abrasion of gills, suppression of photosynthesis, avoidance behaviors); and (2) indirect effects (i.e. loss of visibility, increase in sediment oxygen demand). Elevated turbidity levels and total suspended solids (TSS) concentrations can reduce the penetration of sunlight and can thwart photosynthetic activity and limit primary production (Munawar et al., 1991; Murphy et al., 1981). Sediment can also cause increases in water temperature through particles trapping heat.

The presence of algae and other volatile solids, such as detritus in the water column can contribute to elevated TSS concentrations and high turbidity. Total suspended volatile solids (TSVS) can provide a rough estimation of the amount of organic matter present in suspension in the water column. Elevated TSVS concentrations can impact aquatic life in a similar manner as suspended sediment-with the suspended particles reducing water clarity, but unusually high concentrations of TSVS can also be indicative of nutrient imbalance and an unstable DO regime.

## Water quality standards

The water quality standard for turbidity is 25 Nephelometric Turbidity Units (NTUs) for Class 2B waters for protection of aquatic life (Minn. Stat. 7050.0222 subp. 4). Total suspended solids and transparency tube measurements can be used as surrogate standards. A strong correlation exists between the measurements of TSS concentration and turbidity. In 2010, MPCA released draft TSS standards for public comment (Markus, 2010). The new TSS criteria are stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The draft TSS standard for the Shell Rock River has been set at 65.0 mg/L. There is currently no standard for TSVS.

## Turbidity in the Shell Rock River watershed

The Shell Rock River and Shoff Creek are both currently impaired for turbidity, and have the highest average TSS values in the watershed. Values of TSS range from 1.0 to 304.0 mg/L in the Shell Rock River watershed. The highest TSS values recorded on the Shell Rock River were located at station S000-084 along the Iowa border.

## Sources and causal pathways for turbidity/total suspended solids

High turbidity occurs when heavy rains fall on unprotected soils, dislodging the soil particles which are transported by surface runoff into rivers and streams (MPCA and MSUM, 2009). The soil may be unprotected for a variety of reasons, such as construction, mining, agriculture, or insufficiently vegetated pastures. Bank erosion also plays a role in stream turbidity. The causes and potential sources for sediment are modeled at EPA's CADDIS Sediments webpage. Additionally, a large number of bottom feeders (such as carp), which stir up bottom sediments can be a source of turbidity. Common carp are commonly found in the Shell Rock River with stations ranging in their abundance from 2 to 134 fish, and averaging 43.

Sources of organic matter include the breakdown and decay of plants and algae. High nutrient loads increase the amount of plants and algae present in the stream. Nutrients are delivered to streams by wastewater treatment facilities, urban stormwater, agricultural runoff, and direct discharges of sewage.

# Candidate cause: Deposited and bedded sediment

Excess fine sediment deposition on benthic habitat has been proven to adversely impact fish and macroinvertebrate species that depend on clean, coarse stream substrates for feeding, refugia, and/or reproduction (Newcombe et al., 1991). Aquatic macroinvertebrates are generally affected in several ways: (1) loss of certain taxa due to changes in substrate composition (Erman and Ligon, 1988); (2) increase in drift (avoidance by movement with current) due to sediment deposition or substrate instability (Rosenberg and Wiens 1978); and (3) changes in the quality and abundance of food sources such as periphyton and other prey items (Pekarsky 1984). Fish communities are typically influenced through: (1) a reduction in spawning habitat or egg survival (Chapman, 1988) and (2) a reduction in prey items as a result of decreases in primary production and benthic productivity (Bruton, 1985; Gray and Ward, 1982). Fish species that are simple lithophilic spawners require clean, coarse substrate for reproduction. These fish do not construct nests for depositing eggs, but rather broadcast them over the substrate. Eggs often find their way into interstitial spaces among gravel and other coarse particles in the stream bed. Increased sedimentation can reduce reproductive success for simple lithophilic spawning fish, as eggs become smothered by sediment and become oxygen deprived. The sediments primarily responsible for causing an embedded condition in southern Minnesota streams are sand and silt particles, which can be transported in the water column under higher flows, or as a bedload component. When stream velocities decrease, these sediments can "settle out" into a coarser bottom substrate area, thus causing an embedded condition.

### Water quality standards

There currently is no applicable standard for lack of habitat due to deposited and bedded sediment for biotic communities.

### Deposited and bedded sediment in the Shell Rock River watershed

Sand and silt are the dominant substrates in the Shell Rock River, with greater than 70% of fines recorded at all sites where intensive habitat data was collected. Where coarse substrates are present in the river, they are embedded with fine sediments. Fine sediments are a natural part of stream substrate; they become a problem when they cover and fill in the gaps between coarse substrate, limiting the habitat availability for fish and macroinvertebrates. This situation is occurring in the Shell Rock River, making embeddedness of coarse substrate with fine sediment a stressor to the aquatic communities.

### Sources and causal pathways for deposited and bedded sediments

Bedded and deposited sediments are closely related to suspended sediments. Due to the low gradient nature of the Shell Rock River, suspended sediment is dropping out of the water column and depositing on the bed of the river. Decreases in bank stability lead to sediment loss from the stream-banks, causing sediment loads in the water column. Bank instability is often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, and increases in impervious surfaces.

## Candidate cause: Flow alteration

Across the conterminous United States, Carlisle et al. (2010) found that there is a strong correlation between diminished streamflow and impaired biological communities. Habitat availability can be scarce when flows are interrupted, low for a prolonged duration, or extremely low, leading to a decreased wetted width, cross sectional area, and water volume. Aquatic organisms require adequate living space and when flows are reduced beyond normal baseflow, competition for resources increases. Pollutant concentrations can increase when flows are lower than normal, making it more difficult for populations to maintain a healthy diversity. Often tolerant organisms that can out-compete others in such limiting situations will thrive. Low flows of prolonged duration lead to macroinvertebrate and fish communities comprised of generalist species or that have preference for standing water (CADDIS, 2012).

Flow conditions can have an effect on the type of fish species that are present. Active swimmers, such as the green sunfish, contend better under low velocity conditions (Carlisle et al., 2010). EPA's CADDIS lists the response of low flow alteration with reduced total stream productivity, elimination of large fish, changes in taxonomic composition of fish communities, fewer species of migratory fish, fewer fish per unit area, and a greater concentration of some aquatic organisms (potentially benefiting predators).

The Shell Rock River watershed has transitioned from perennial to agricultural land cover, with loss of wetlands and increases in channelization and surface and subsurface drainage. There is a high percentage of channel alteration in the tributaries to Albert Lea Lake and the Shell Rock River (Figure 7). This level of channelization suggests that the flow regime of the watershed is such that spring and event flows are higher than normal and base flow levels much lower than normal.

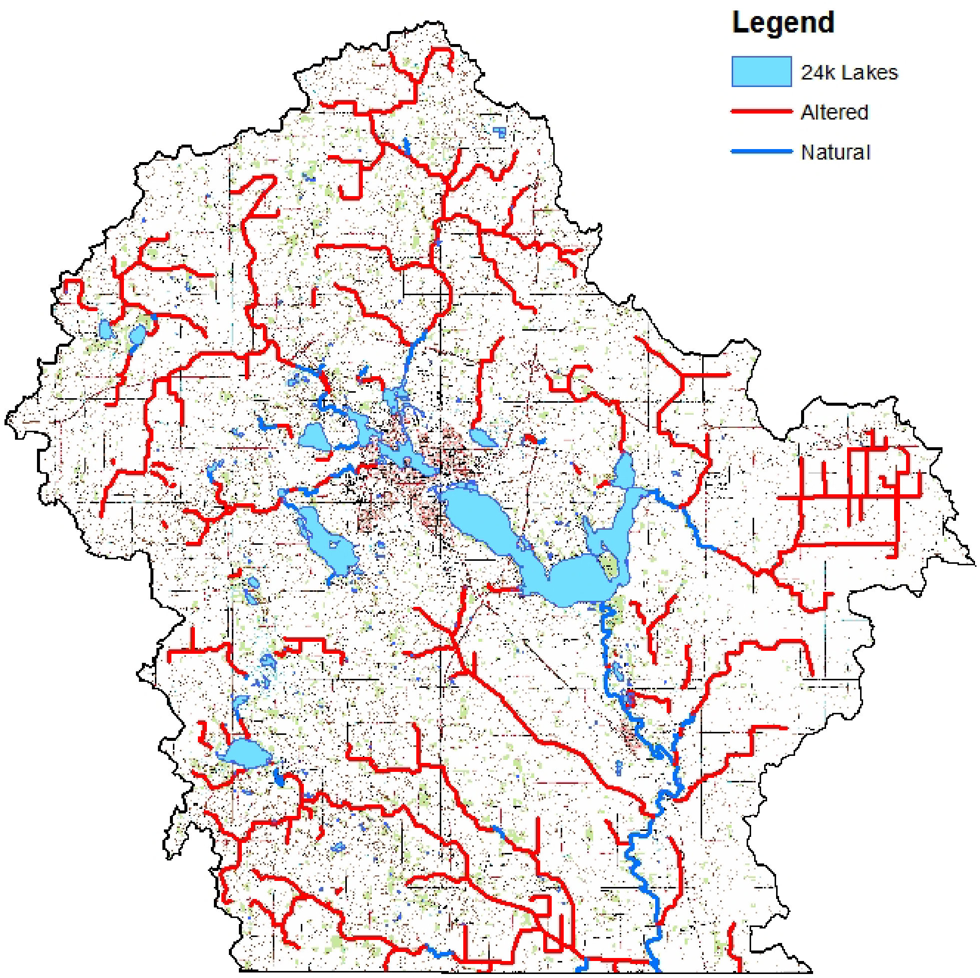



**Figure 7. Altered and natural channels in the Shell Rock River watershed**

The combination of these landscape altering modifications has led to alteration of the river's hydrologic regime. The significant loss of upland storage through wetland drainage, channelization, ditching and tiling has increased peak flow rates and shortened the duration of the runoff hydrograph for both spring and summer discharge events. The channelized reaches and subsurface tiling serve to route water quickly off the landscape which alters the natural hydrologic regime of the system.

## Water quality standards

There currently is no applicable standard for flow alteration.

## Flow alteration in the Shell Rock River watershed

During dry years the Shell Rock River has little flow below the Albert Lea Lake dam. Tributaries to the Shell Rock have been channelized to an extent that they were not able to be assessed. While the lake is a buffer between the tributaries and the Shell Rock River, channelization could also be contributing to higher flows in the spring and lower flows in the late summer. Hydrology in the Shell Rock River Watershed has been affected through channel alterations.

Continuous flow data on the Shell Rock River is only available after 2008, which does not provide enough of a data record to develop trend information. There is long term data from the United States Geological Survey (USGS) gage on the Cedar River in Austin. While the Cedar River is part of a separate watershed, it is close to the Shell Rock River and shares similarities. Since 1981 on the Cedar River, the deviation is showing an increasing amount of runoff per value of precipitation (Figure 8). Runoff is trending upwards, while precipitation is not. Recognizing that conditions on the Cedar River in Austin are not the same as on the Shell Rock River, this is intended to provide some information in an area similar to and close to the Shell Rock River, where long-term information is not available.

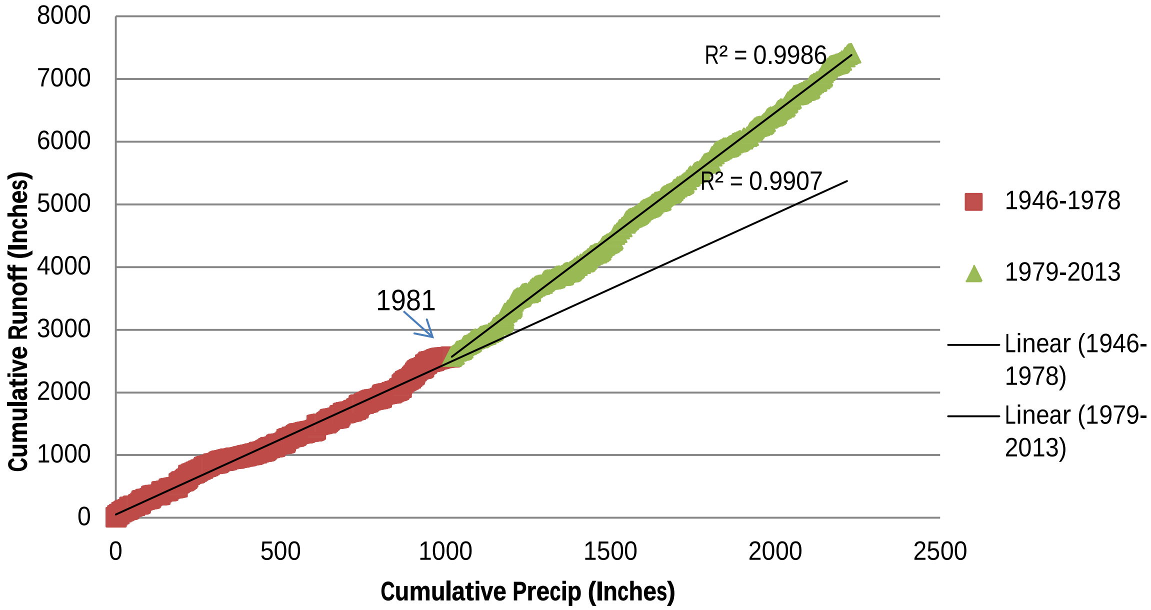



**Figure 8. Runoff versus Precipitation on the Cedar River in Austin**

## Sources and causal pathways for flow

Channelization occurs on ditches serving as first and second order streams that flow to area lakes and the Shell Rock River. The channelized reaches and subsurface tiling serve to route water quickly off the landscape, which alters the natural hydrologic regime of the system. During warm summer conditions with little precipitation, the Shell Rock River loses much of its connection to Albert Lea Lake. The causes and potential sources for altered flow are modeled at EPA's CADDIS Flow Alteration webpage.

## Pesticides

A few pesticide samples have been taken throughout the Shell Rock River watershed. Although pesticides were present in the samples, none was above the state or federal standards. With the limited data available, the effects of pesticides on the biological community within this reach are inconclusive. Currently, the additive effect of pesticides on aquatic organisms at levels below state or federal standards is unknown. More research needs to be developed to characterize this potential effect. Additional monitoring is recommended to further understand the presence of pesticides and their potential impacts to the biological community. Given the current gaps in understanding of the additive effects, it is difficult to rule out pesticide toxicity as a possible stressor or conclude that it may be a stressor.

# Shell Rock River

Eight fish visits and nine macroinvertebrate visits occurred at seven sites along the Shell Rock River from the Albert Lea dam to the Iowa border (Figure 9). This includes visits from sampling years 2004 and 2009 that were used for assessment, and additional sampling that occurred in 2011 to assist with stressor identification. The aerial map shows the locations of the biological and water chemistry sampling stations, major roadways, cities, and the Albert Lea Lake dam.


**Figure 9. Aerial view of the sampling locations on the Shell Rock River**

Metric scores cumulatively made up the IBI score for fish and macroinvertebrates (Figures 10 and 11). Each metric definition is located in Appendix A. There are not individual standards for each metric, but using a target score provides a method of identifying problem metrics for a stream or individual monitoring site. The target of the average score needed to meet the threshold is calculated by taking the IBI impairment threshold and dividing it by the total number of metrics (i.e. all metrics are weighted the same). For fish, this does not take into consideration the deduction that deformities, eroded fins, lesion, and tumors (DELTs) bring to the IBI. The presence of DELTs is a metric that is part of each of the fish classes. If these indicators of poor fish health are present, 5 points are subtracted from the IBI score. If they are not present, the site gets a score of 0. Of the eight fish visits, only one site (09CD087) had a DELT deduction due to lesions and eroded fins present on both carp and black bullheads.

The fish metrics scores for benthic insectivores and sensitive taxa are uniformly low. The percentage of sensitive fish species ranged from 0 to 6, which is very low. Sensitive or pollution intolerant fish species are typically the first to disappear when conditions become increasingly unfavorable. Benthic insectivore species rely on undisturbed benthic habitats to feed and reproduce. Many benthic species require clean coarse substrates, and the degradation of benthic habitats (e.g. channelization, siltation, oxygen depletion) will cause benthic species to decline. The macroinvertebrate metrics scores of clingers taxa, dominant five species, intolerant taxa, and taxa count are uniformly low along the sites on the Shell Rock River. A diverse group of clinger taxa indicate that substrate has not become embedded or covered by fine organic or inorganic material. Station 09CD088 was the only site not to have a score of 0 for intolerant taxa macroinvertebrates, but still only had one intolerant taxa present. Intolerant taxa are very sensitive to environmental degradation.

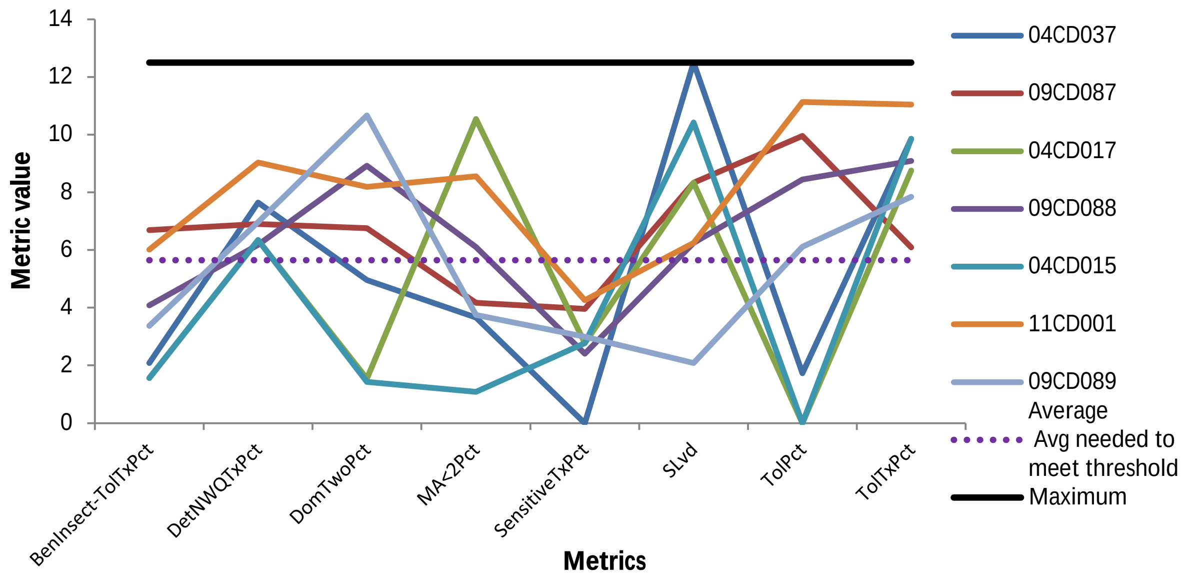



**Figure 10. Shell Rock River fish metric scores**

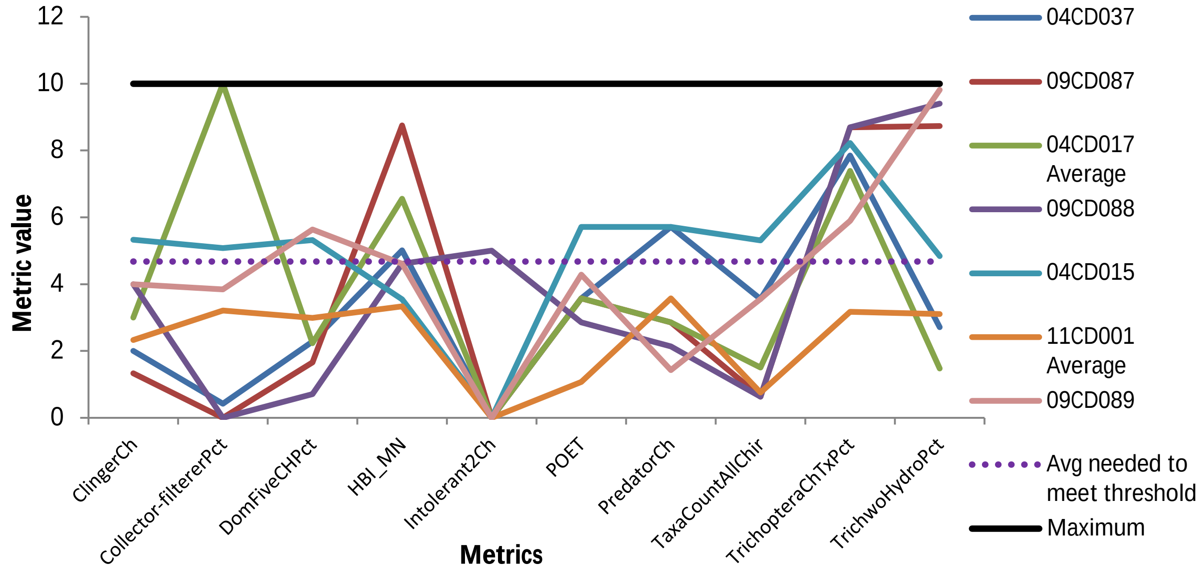



**Figure 11. Shell Rock River macroinvertebrate metric scores**

## Candidate cause: Nitrogen

Nitrate concentrations are high throughout the watershed. Nitrate concentrations in recent years along the Shell Rock River were analyzed by month (Figure 12); these data include all sampling locations on the Shell Rock River in the impaired reach. Some locations have much higher concentrations than others, leading to a wide range of values. The highest nitrate values were collected in August. Nitrate values are highest at CR 84 (S005-117), just downstream of the Albert Lea WWTP (Figure 13). Values drastically increase between the Albert Lea Lake dam and CR 84. Nitrate values of 12.0 mg/L were recorded at station S005-117 during August 2012. In the upstream tributaries to the Shell Rock River, average nitrate values are highest in the Bancroft Creek and Peter Lund Creek systems, with the highest average (11.07 mg/L) at County Ditch 32 (tributary to Peter Lund).

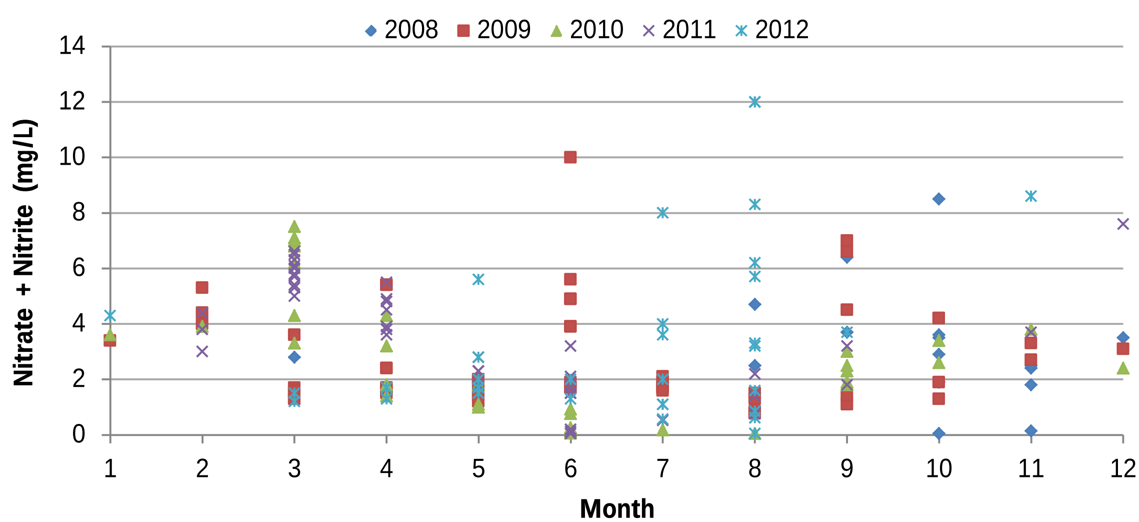



**Figure 12. Nitrate + Nitrite values in the Shell Rock River from 2008-2012**

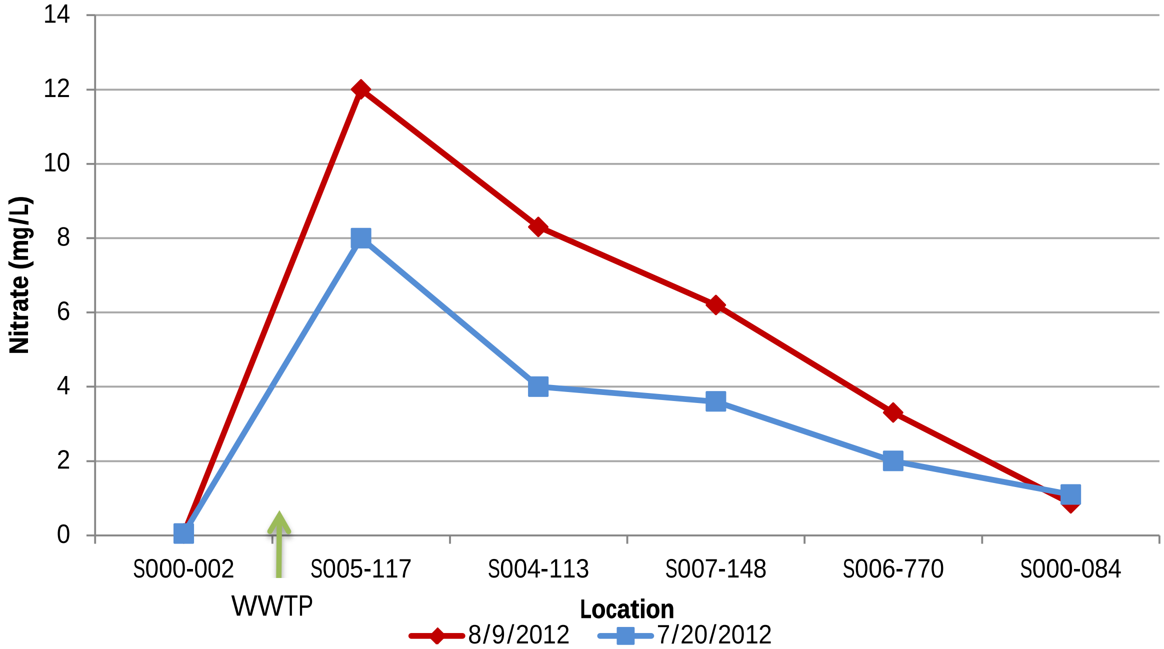



**Figure 13. Longitudinal nitrate data**

## Biotic response

The average nitrate value on the Shell Rock was 2.9 mg/L during biological sampling, values measured during biological visits ranged from 0.17 to 6.3 mg/L. As nitrate concentrations increase, sensitive fish species decrease (Figure 14). The percentage of sensitive individuals in the river ranged from 0 to 6.15%, and averaged 1.41. The percentage of sensitive species in the southern streams class ranged from 0 to 73.71, and averaged 8.34. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (caddisfly) individual percentages. Non-hydropsychid trichoptera are all caddisflies that do not spin nets. The individual percentages on Shell Rock River sites range from 0 to 10%, which is low compared to both the Cedar basin and statewide data (Figure 15). The sensitive fish and non-hydropsychid trichoptera percentages are both low in the Shell Rock River, showing nitrate is a stressor to the biological community.

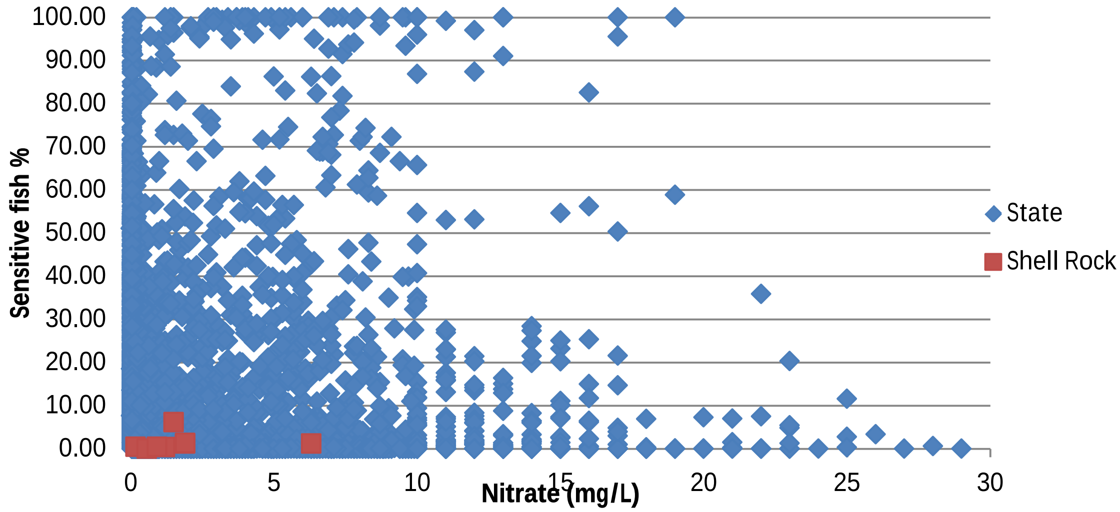



**Figure 14. Nitrate concentrations at the time of fish sampling and percentage of sensitive fish**

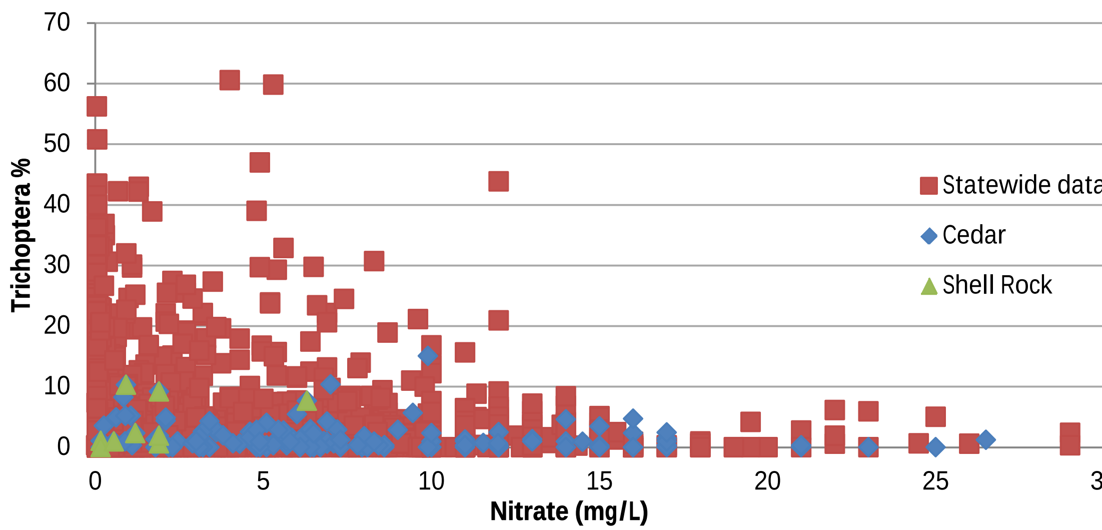



**Figure 15. Nitrate concentrations at the time of fish sampling and percentage of non-hydropsychid Trichoptera**

## Candidate cause: Phosphorus

Albert Lea Lake is impaired for nutrients, as are the lakes that are located upstream of it: Fountain, Pickerel, and White. A draft TMDL report by Barr Engineering shows that Fountain Lake and its contributing watershed was the biggest phosphorus contributor to Albert Lea Lake (43%), followed by internal loading in Albert Lea Lake itself (35%) (Barr 2011). Shoff Creek, which flows into Fountain Lake, had some of the highest phosphorus and TSS concentrations in the watershed, but concentrations were lower in 2010 after reclamation efforts.

Phosphorus and chlorophyll-a values are both high in the Shell Rock River. Chlorophyll-a values are a proximate measurement of eutrophication and have more direct impacts on biology than phosphorus. Increases in chlorophyll-a are directly related to elevated phosphorus concentrations. Chlorophyll-a concentrations are commonly used to measure algal productivity in surface water. While the Shell Rock Monitoring and Assessment Report (MPCA 2012) shows a decreasing trend in phosphorus concentrations at Station S000-084 since 1961, average phosphorus concentrations in the Shell Rock

River remain 3.5 times the proposed phosphorus standard (0.150 mg/L). Data from 2007 to 2012 shows the average phosphorus values are highest on the Shell Rock River, followed by Goose Creek. The highest individual values recorded were located on Goose Creek (2.83 mg/L), Bancroft Creek (1.1 mg/L), and the Shell Rock River (5.4 mg/L).

Phosphorus in the Shell Rock River from recent years was analyzed by month (Figure 16). These data include all sampling locations on the Shell Rock River on the impaired reach. Similar to nitrate, phosphorus concentrations were highest during the month of August.

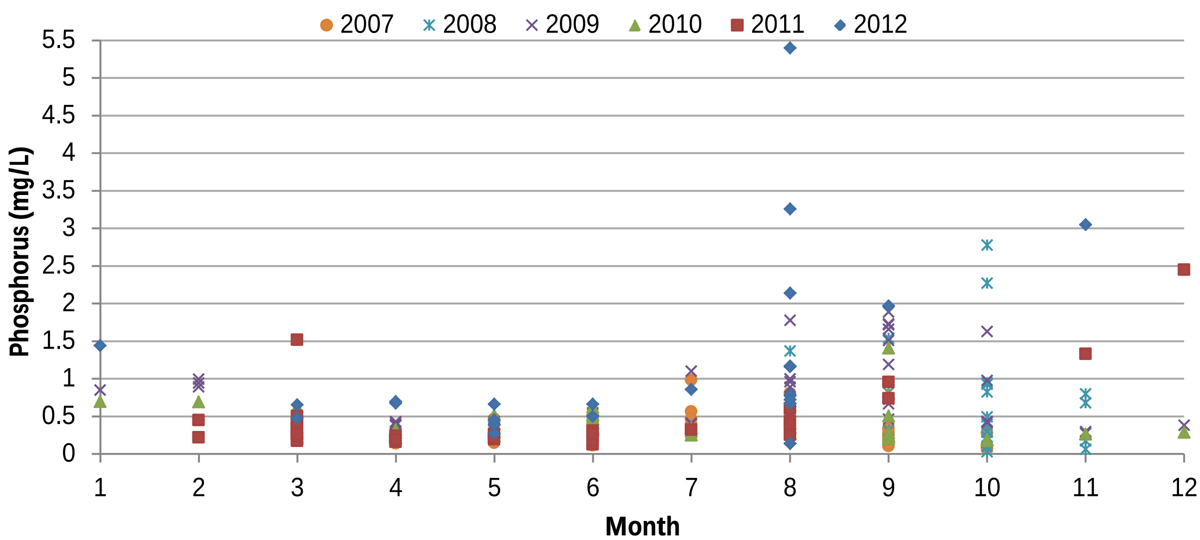



**Figure 16. Phosphorus values in the Shell Rock River from 2007-2012**

The main-stem Shell Rock River has nutrient values that are much higher than the proposed chlorophyll-a and phosphorus standards (35.0 µg/L and 0.150 mg/L respectively). The longitudinal surveys (Figure 17) show that phosphorus values are highest at station S005-117 (at CR 84) just downstream of the Albert Lea WWTP. Recorded values are up to 5.4 mg/L, but values are consistently high throughout the river. During sampling in July and August of 2012, values were all over 0.70 mg/L at five sites along the river (they were all over 1.0 mg/L during the July visit), except for station S000-002, located at the Albert Lea dam (with values of 0.092 mg/L and 0.140 mg/L respectively). Values are highest at station S005-117 and then steadily decrease downstream. The high phosphorus values are reinforced by the presence of high DO flux and elevated chlorophyll-a values. Nutrient loading can create an increase in phytoplankton (measured as sestonic chlorophyll); along with temperature, light, and residence time (Heiskary et al., 2013).

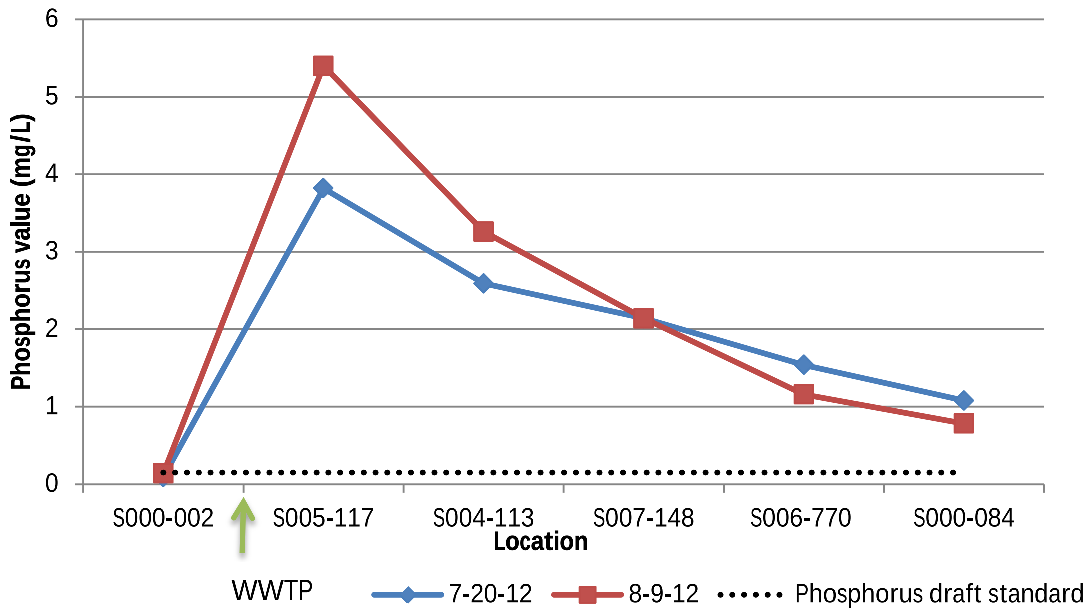



**Figure 17. Longitudinal phosphorus data**

Precipitation was low during the summer of 2012 (Figure 18). The lower than average amount of rain caused the Albert Lea WWTP discharge to become a larger percent of the total river flow. Drier conditions, particularly during late summer have occurred the last few years.

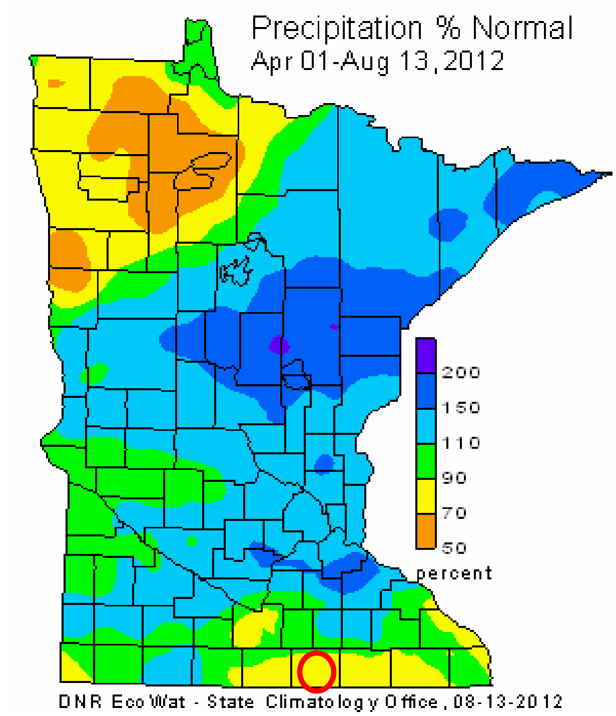



**Figure 18. Percentage of normal precipitation that occurred in 2012**

Orthophosphorus is the form of phosphorus that is readily available for plant and algal uptake, and can influence excess algae growth. The average percentage of orthophosphorus compared to phosphorus concentrations at station S000-002 averaged 19%, and was highest in 2011 at 86%. At station S000-084 the percentage of orthophosphorus to phosphorus averaged 64% and was highest in 2008, 2011, and in 2012 reaching almost 100%. Station S004-113 averaged 57% and was nearly 100% numerous times in 2009.

Chlorophyll-a measures the green pigments in plants that are photosynthesizing, and is used to estimate the amount of algae present. The chlorophyll-a values measured were highest downstream of the Albert Lea Lake, values then decrease and increase again downstream of Glenville (Figures 19 and 20). Chlorophyll-a values at the dam range up to 336.0 ug/L, while the average on the Shell Rock River is 60.0 ug/L. The chlorophyll-a values are predominantly a function of the "wash-out" from Albert Lea Lake at the uppermost river site, but all of the values are well above the proposed standard of 35.0 mg/L throughout the reach. A close relationship between chlorophyll-a and pH values is expected, and was found to be evident during 2012 longitudinal sampling in the Shell Rock River.

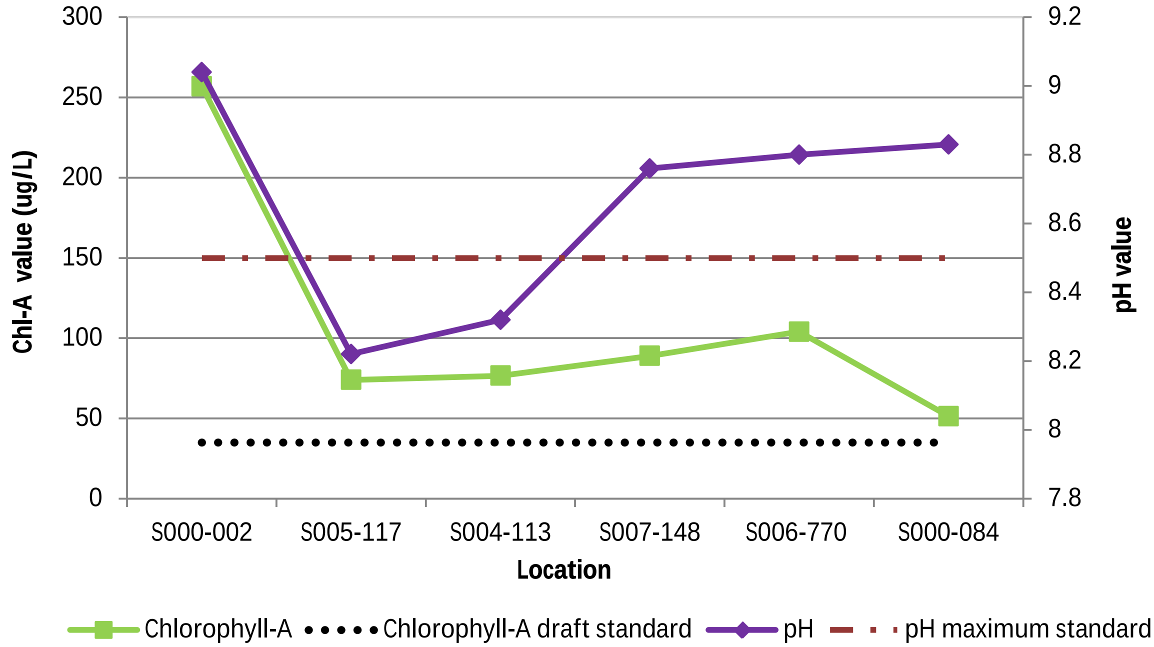



**Figure 19. Relationship between chlorophyll-a and pH on 7/20/12**

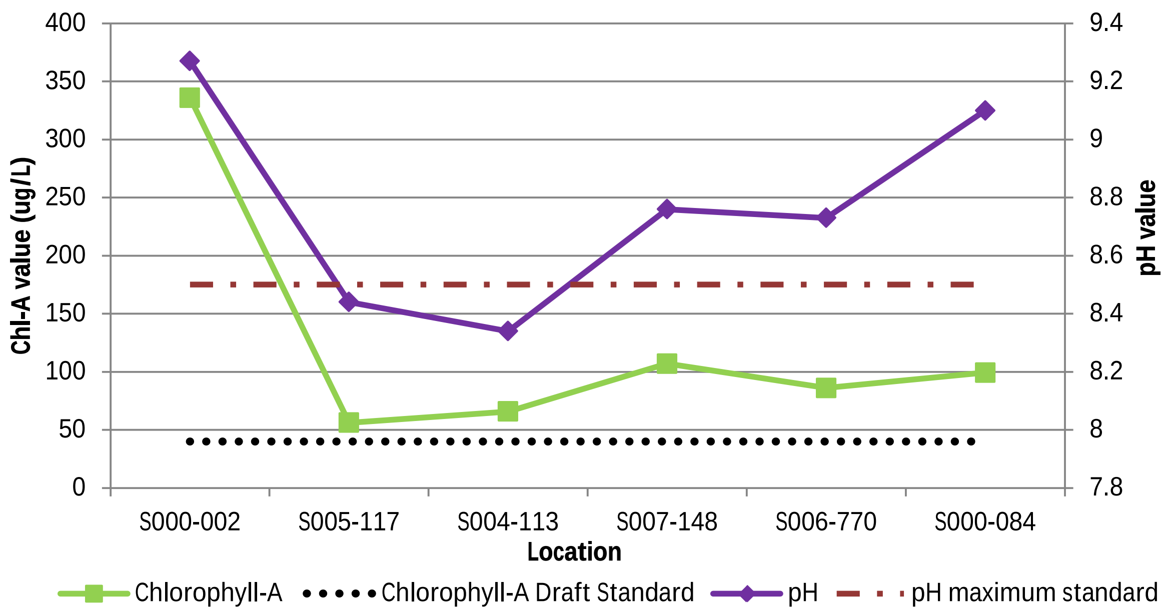



**Figure 20. Relationship between chlorophyll-a and pH on 8/9/12**

Given the high nutrient and chlorophyll-a values, it is not surprising that dense macrophyte growth is occuring on the Shell Rock River (Figures 21 and 22). Albert Lea Lake has high nutrient conecntrations, and in conjunction with the elevated nutrient effluent from Albert Lea WWTP algae and plant growth is excessive along the river. Tributaries and small inlets along the Shell Rock River are also adding to algal and plant growth in the stream (Figure 23).

**Figure 21. Algae on the Shell Rock River just downstream of the Albert Lea Lake dam (8/21/12)**

**Figure 22. Nutrient enrichment in the Shell Rock River upstream of Glenville (8/4/11)**

**Figure 23. Nutrient inputs to the Shell Rock River (8/4/11)**

## Biotic response

Sensitive individuals decrease with an increase in both phosphorus and nitrate concentrations. The sensitive individuals fish percentages in the river ranged from 0 to 6.15%. When compared to the entire Cedar River basin, the Shell Rock River has consistently high phosphorus values during biological sampling, all of which are higher than the proposed standard. Likewise the Shell Rock River has lower sensitive fish percentages than the average for the Cedar River basin (Figure 24).

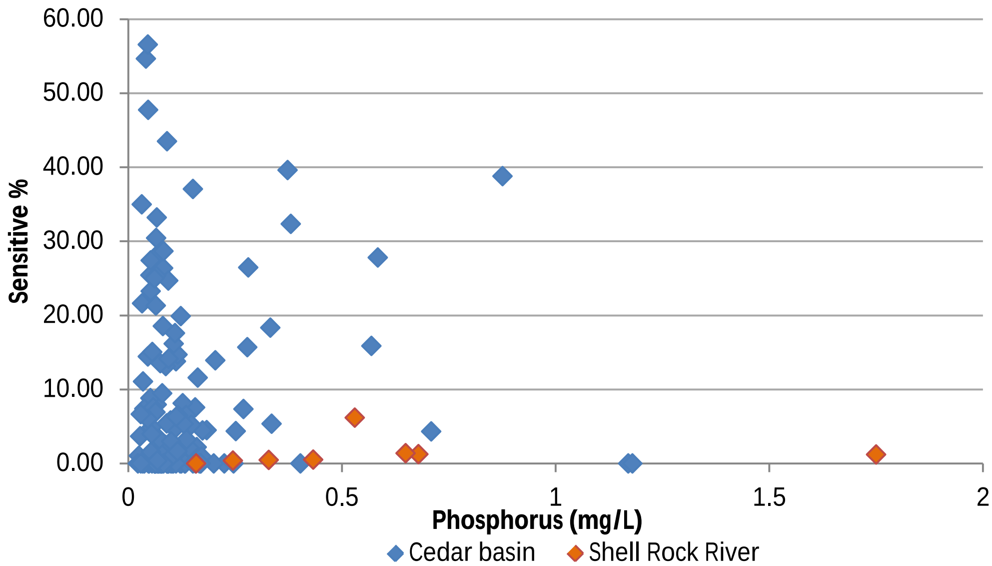



**Figure 24. Phosphorus concentrations at the time of fish sampling and percentage of sensitive fish**

The number of macroinvertebrate taxa are known to decrease with increased total phosphorus, as TP increases greater than approximately 0.130 mg/L, total taxa tend to fall below 32 in rivers (Heiskary, 2008). Only one visit on the Shell Rock River had more than 32 macroinvertebrate taxa collected, with the numbers ranging from 21 to 37 and averaging 26. Phosphorus is also positively correlated with the percentage of tolerant taxa for both fish and macroinvertebrates. Tolerant macroinvertebrate taxa ranged from 76.2% to 95% with the majority of sites comprised of over 90%. Fish tolerant taxa percentages ranged from 38 to 57%, averaging 45%. The intolerant percentage of individuals was 0 during seven of the macroinvertebrate samples, while the other two samples had percentages of 0.35 and 1.6.

Ephemeroptera, Plecoptera & Trichoptera (EPT) individual percentages show an inverse correlation with chlorophyll-a and DO flux values. The EPT percentages in the Shell Rock River were highest where the chlorophyll-a and DO flux values were lowest (Figure 25). Chlorophyll-a values also show a negative relationship with the number of macroinvertebrate taxa and sensitive fish. Average chlorophyll-a values from 2007-2012 is 60.77 µg/L, which is almost twice the proposed standard of 35.0 µg/L. As chlorophyll-a values increase over 20-30 µg/L, the percentage of sensitive fish make up less than 20% of the catch (Heiskary et al. 2013). The percentage of sensitive fish collected at sites on the Shell Rock River range from 0 to 6.15%. The lack of sensitive fish, macroinvertebrate taxa and intolerant macroinvertebrates, the dominance of tolerant species showing strong correlations with phosphorus and chlorophyll-a values, and the strong relationship between EPT percentages and chlorophyll-a values confirm that phosphorus and chlorophyll-a are main biological stressors to the Shell Rock River.

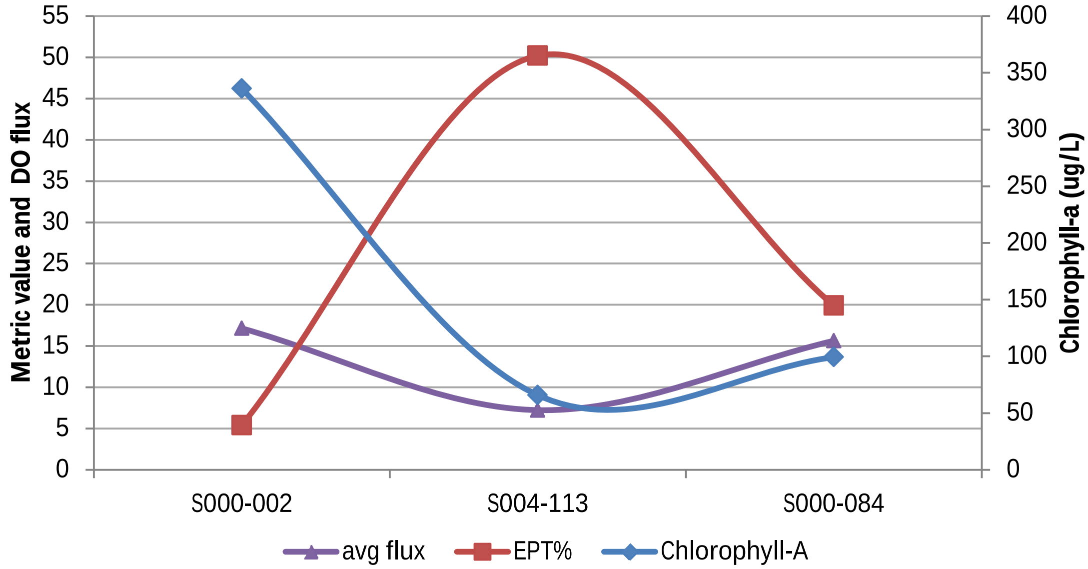



**Figure 25. Nutrients and EPT%**

## Candidate cause: pH

The Shell Rock River is impaired for pH. Values in the Shell Rock River from recent years were analyzed by month (Figure 26), and concentrations were highest during the month of August. This aligns with when phosphorus concentrations are also highest, which makes sense as eutrophication drives elevated pH values. The standard for pH in surface waters is a range of 6.5-8.5, values over 8.5 and large daily pH fluctuations are tied to nutrient enrichment. Fluctuations in pH similar to those with DO are due to photosynthesis and respiration. Values over 8.5 are common in the Shell Rock River watershed, getting as high as 9.6. Typical daily pH fluctuations are 0.2-0.3 (Heiskary et al., 2013). Fluctuations of pH in the Shell Rock River have been measured as high as 1.24. The high fluctuations reflect excessive in-stream primary production, as algae and aquatic plants drive up pH during the daytime.

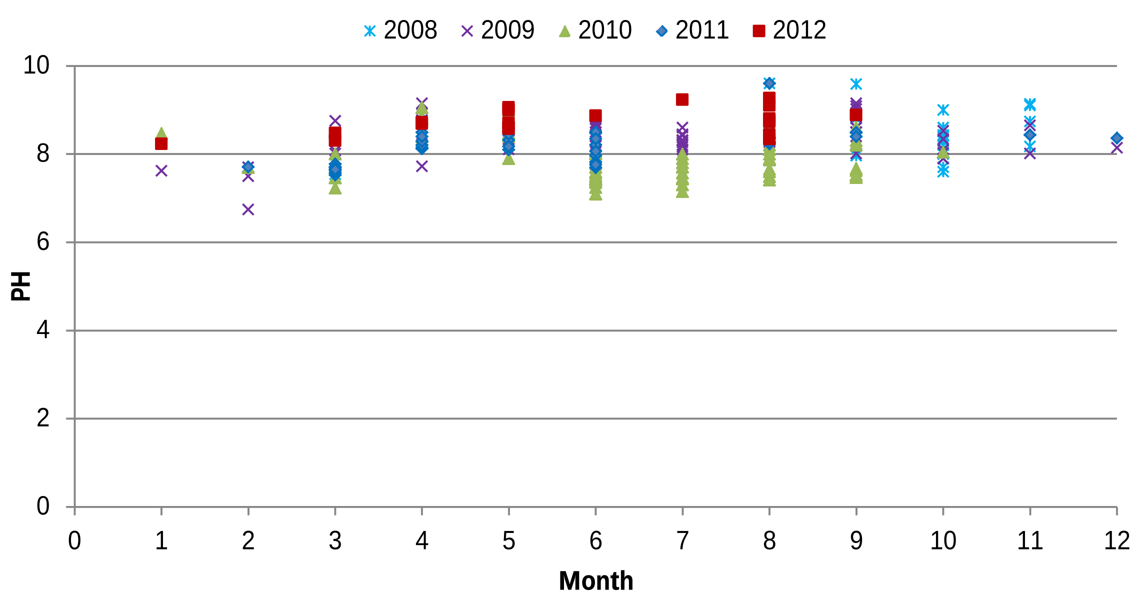



**Figure 26. pH values in the Shell Rock River 2009-2012**

## Biotic response

EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (CADDIS 2103). The fish samples on the Shell Rock River with pH values over 9.0 during biological sampling had the lowest number of yellow perch collected. The sites with recorded pH values over 9.0 had an average of 27.3 yellow perch collected, while those sites with pH values less than 9.0 averaged 125.2 yellow perch collected. Levels of pH between 9.5 and 10 causes reduced emergence of some stoneflies. Each of the nine macroinvertebrate samples collected on the Shell Rock River had stonefly percentages of zero, but the lack of presence of stoneflies could also be caused by low DO values. It is difficult to pinpoint pH as a stressor separate from eutrophication effects, but the lack of stoneflies on the Shell Rock River and correlation with yellow perch and pH values indicates that pH may be a contributing stressor.

# Candidate cause: Dissolved oxygen

Continuous DO data were collected at three locations along the Shell Rock River from August 9 to August 21, 2012 (Figure 27). All three locations had values that dipped below the standard of 5.0 mg/L, and all three locations had daily fluxes that were above the proposed south regional standard of 4.5 mg/L (Figure 28). DO flux values between 2.0 to 4.0 are typical in a 24-hour period (Heiskary et al, 2010). Daily DO fluctuations are a measure of stress on the aquatic community. Algal respiration and photosynthesis are considered the primary drivers of daily flux in DO, and high daily fluctuations of DO are connected to nutrient concentrations. The high phosphorus values are fueling photosynthesis and algal respiration, which in turn are effecting the daily oxygen production and oxygen demand, as seen by fluctuations as high as 20.89 mg/L in a single day. A difference of 20.36 mg/L during one day is extremely high, and completely out of the norm for healthy stream systems.

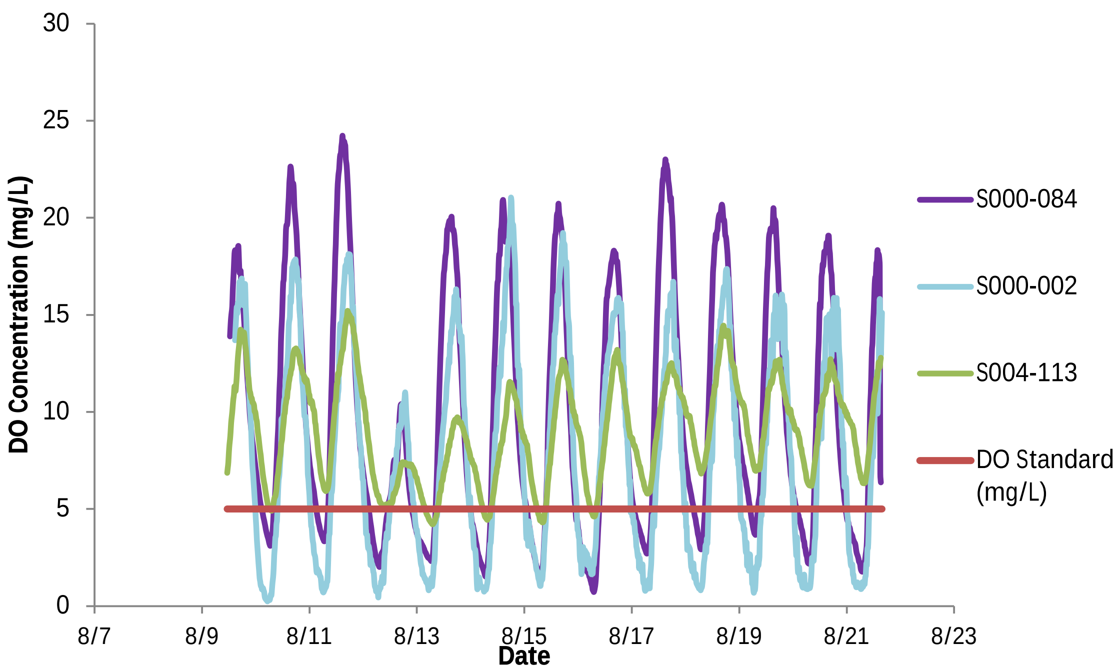



**Figure 27. Continuous DO in 2012**

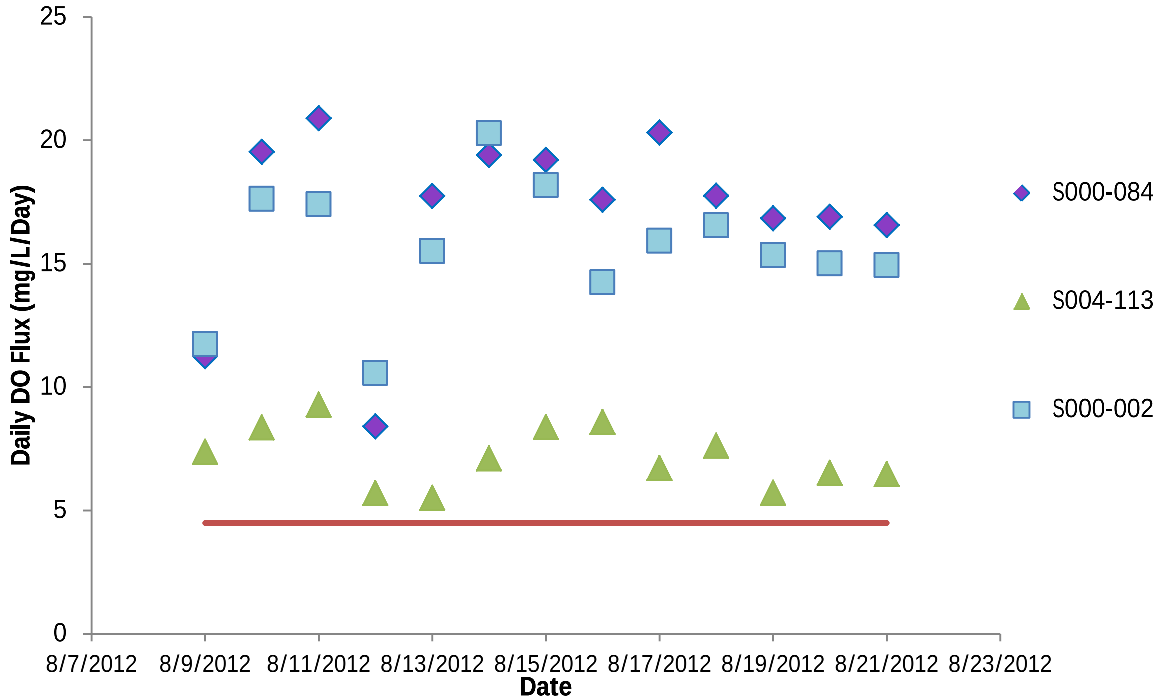



**Figure 28. Daily DO fluctuations**

## Biotic response

Low DO values correspond with increased tolerant species and decreased sensitive species. This was observed in the Shell Rock River, where there were a high percentage of tolerant fish taxa, ranging from 33.21 to 91.29, with an average of 57.41%, and low sensitive fish taxa which range from 0 to 4 species. Total taxa richness has been shown to decrease with an increase in DO flux, phosphorus, and chlorophyll-a. The metric value needed to meet the threshold for these sites is 4.68, and 6 of the 7 sites fail to meet this value for macroinvertebrate taxa richness, with values ranging from 0 to 5.3 (Figure 9). Tolerant macroinvertebrate taxa ranged from 76.2% to 95% with the majority of the sites comprised of over 90% tolerant taxa. A decrease in EPT communities is also correlated with low DO values and high DO flux, and the site with the highest DO flux and lowest minimum values (Station 04CD037) has a low EPT value of 5.4% individuals. Station 04CD017 which has lower DO flux and fewer DO standard violations had a community comprised of 50% EPT taxa.

Longitudinally from upstream to downstream along the Shell Rock River, the early morning DO tolerance indicator values (TIV) for fish at the seven Shell Rock River sites show highly tolerant fish communities (Figure 29). All of the fish data collected in the Cedar basin, which is comprised of the Cedar and Shell Rock watersheds, were placed into quartiles (i.e. 0-25%; 25-50%;51-75%; and 76-100%) depending on their tolerance to low DO values, and then the number of fish in each quartile was added together for each site. The majority of the fish collected at the Shell Rock River sites are comprised of species in the first and second quartiles (low early morning DO tolerance). As DO flux increases above 4.0 mg/L per day, the sensitive fish population falls to less than 10% (Heiskary, 2008). Sensitive fish individuals ranged from 0 to 6.15% on the Shell Rock River. Based on the preponderance of low DO tolerant fish and the lack of sensitive fish and macroinvertebrate taxa, DO is determined to be a main stressor.

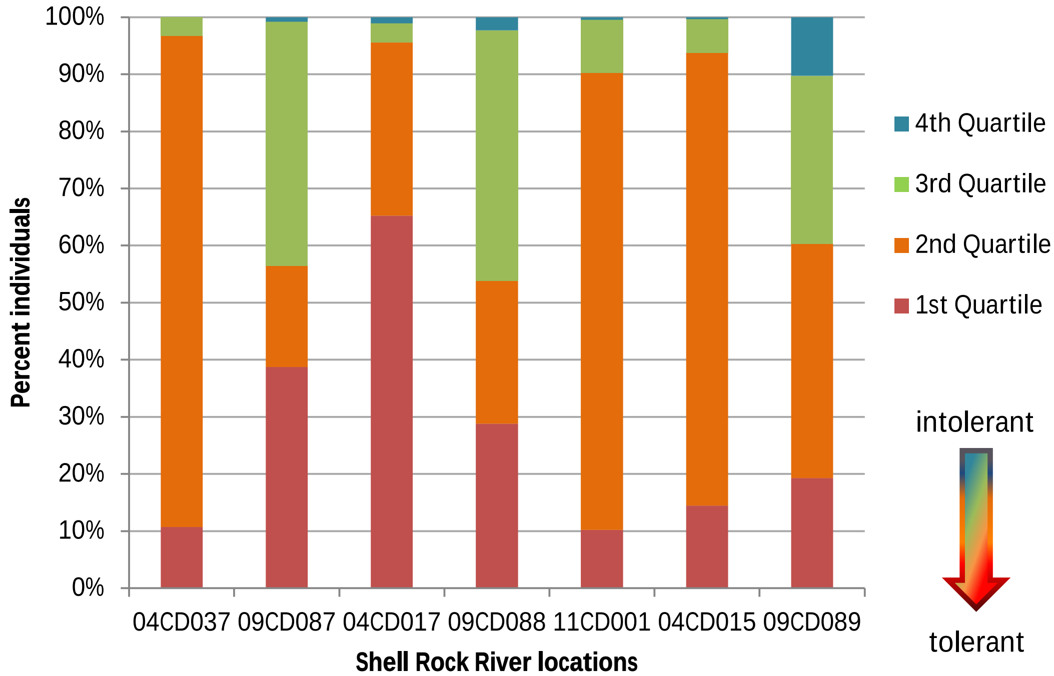



**Figure 29. The percentage of fish individuals by tolerance quartile on the Shell Rock River**

## Candidate cause: Ionic strength

Specific conductance values in the watershed are highest on the Shell Rock River. The highest specific conductance concentrations in the river have been recorded in the late summer and fall, corresponding with low flow conditions. The ecoregion norm for the Western Corn Belt Plain (based on the 75$^{th}$ percentile of annual specific conductance values) is 820 (McCollor et. al, 1993). There are large differences in specific conductance values in the Shell Rock River between the Albert Lea dam and the city of Glenville. Like nitrate and phosphorus values, specific conductance values are highest at station S005-117. There are a number of outputs between these two locations; the Albert Lea WWTP, a gravel pit outflow, and an ethanol plant. The values steadily decrease downstream as shown in the two longitudinal surveys during 2012 (Figure 30). As seen in the continuous data (Figure 31), at Station S004-113 located in Glenville, all readings are over 1,000 uS/cm and often over 1,400 uS/cm. This is not surprising when looking at the effluent numbers out of the Albert Lea WWTP, which in 2012 were often over 2,000 uS/cm. The ions with the highest concentrations in the WWTP discharge are chloride and sodium. The effluent levels of chloride were generally exceeding the water quality standard of 230 mg/L. Based on a failed chronic Whole Effluent Toxicity (WET) test at the WWTP in May of 2012, an intensive Toxicity Reduction Evaluation is currently underway; this project will be considering sources of chloride and other ions measured by conductivity.

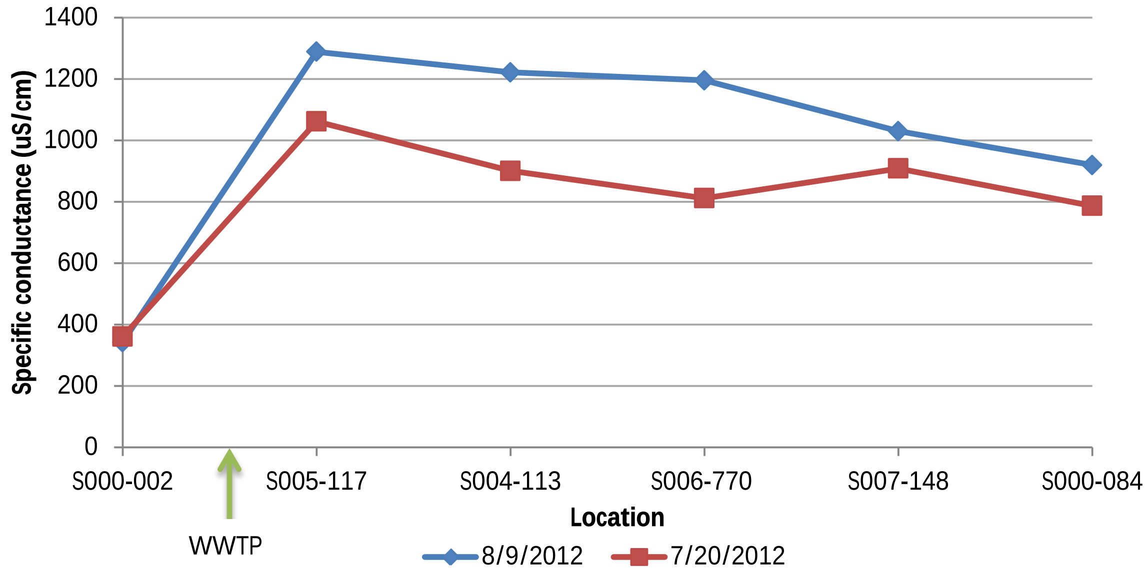



**Figure 30. Longitudinal conductivity**

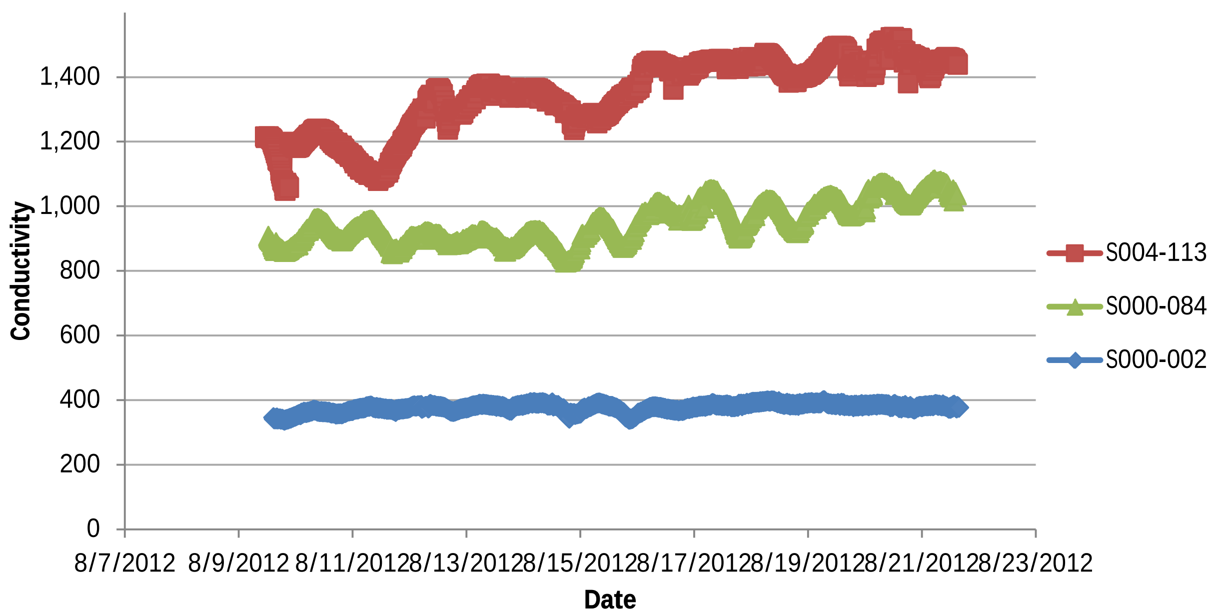



**Figure 31. Continuous specific conductance data**

## Biotic response

Biological effects of conductivity are hard to quantify. Increased ionic strength can cause an increase in ion tolerant taxa and an increase in ion tolerant life stages, causing fish and invert impairments, but it is difficult to separate this effect from other stressors. As salinity increases, macroinvertebrate taxa richness has been found to decrease (Piscart et al., 2005). Piscart et al. also found a decrease in ephemeroptera abundance as salinity increased. Echols et. al (2009) also found a reduction in EPT abundance as conductivity values increased. A study of Minnesota biological data and stressor linkages found that sites with conductivities higher than 1,000 µS/cm rarely meet the biological thresholds for general use streams (MBI, 2012). A statewide review of specific conductance values and macroinvertebrate taxa richness showed a wedge shaped relationship (Figure 32). The three Shell Rock River sampling visits with the lowest specific conductance values had the highest macroinvertebrate taxa counts. The site just below the Albert Lea Lake dam effluent and the site furthest downstream near the Iowa border had two of the highest ephemeroptera percentages (2.8 and 4.5). These sites had lower continuous specific conductance values than the site below the WWTP, where the ephemeroptera percentages were 0 and 0.7 on two different dates. Taxa count also is related to other stressors, so ionic strength could be contributing to this decline along with other stressors. The macroinvertebrate taxa richness could also be affected by the elevated nutrient levels and high DO fluxes. The high concentration of ions, as measured by specific conductance, is a possible stressor to the biological communities, especially considering the stress they are experiencing from high nutrient levels.

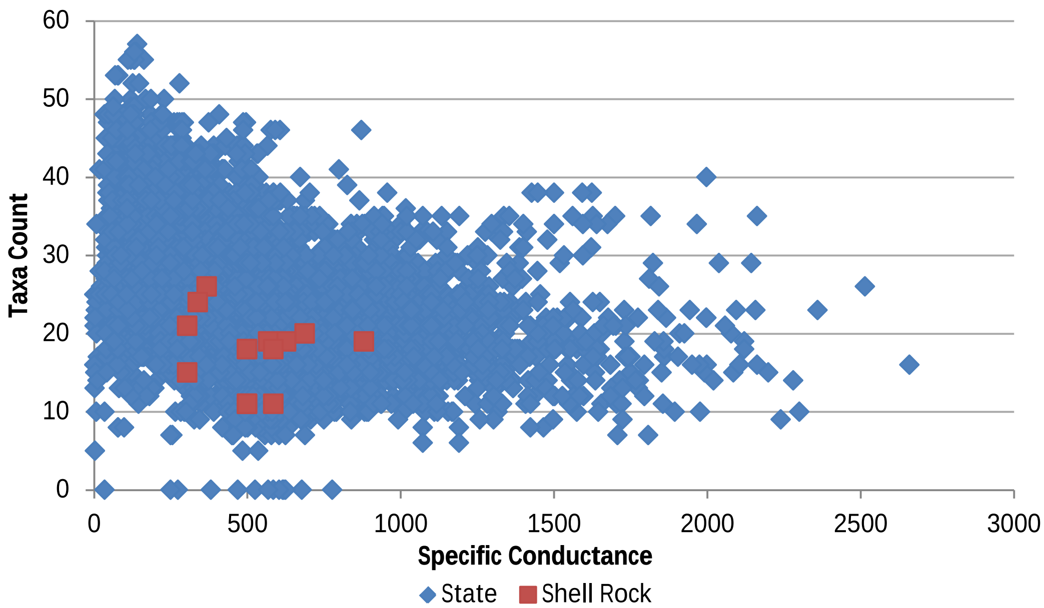



**Figure 32. Specific conductance at the time of fish sampling and macroinvertebrate taxa count**

# Candidate cause: Habitat

Habitat availability is lacking in the Shell Rock River; the Minnesota Stream Habitat Assessment (MSHA) scores taken during biological sampling are low at all sampling sites. Severe embeddedness and lack of riffles were the main contributors to the low scores, and there was a resulting lack of simple lithophilic spawners throughout the stream. The channel morphology scores in the Shell Rock River ranged from 13 to 17. The channel morphology scores were low due to lack of riffles, a lack of depth variability, lack of channel development, and lack of velocity types. A more diverse flow has a positive relationship with sensitive species, which were not present in the Shell Rock River.

The river does have good floodplain connections. The Shell Rock River is a C5-, with a high width-to depth ratio (wide and shallow). C channels have well developed floodplains, are sinuous and low gradient with characteristic point bars within the active channel (Rosgen, 1996). The 5 refers to the dominant substrate, which is sand in this case. C5c- are streams with gradients less than 0.0001. Increasing stream channel width decreases stream power (EPA, 2012), reducing the ability of the stream available to move sediment. As a result, the stream has aggraded leaving little pool refuge for fish.

Cobble and gravel presence also has a positive relationship with a higher fish IBI. There was some gravel present at sites on the river, but on average gravel was greater than 50% embedded and was 100% embedded at some sites. There is a high bedload present, but not enough stream power to move the sediment, which results in the fine sediment accumulation observed. The average sediment size (D50) at station 11CD001 is 0.29 mm, which is a medium sand substrate. The reach is comprised of 35% silt, 32% sand, and 33% gravel. There are some areas of exposed gravel as described above, but most of the reach was embedded gravel with a silt or sand layered on top of the gravel (Figure 33). In the pools, 70% of the substrate was comprised of silt. Measurements with a copper rod averaged 16.85 cm of fine sediment layered on coarser substrate; with measurements up to 39 cm.

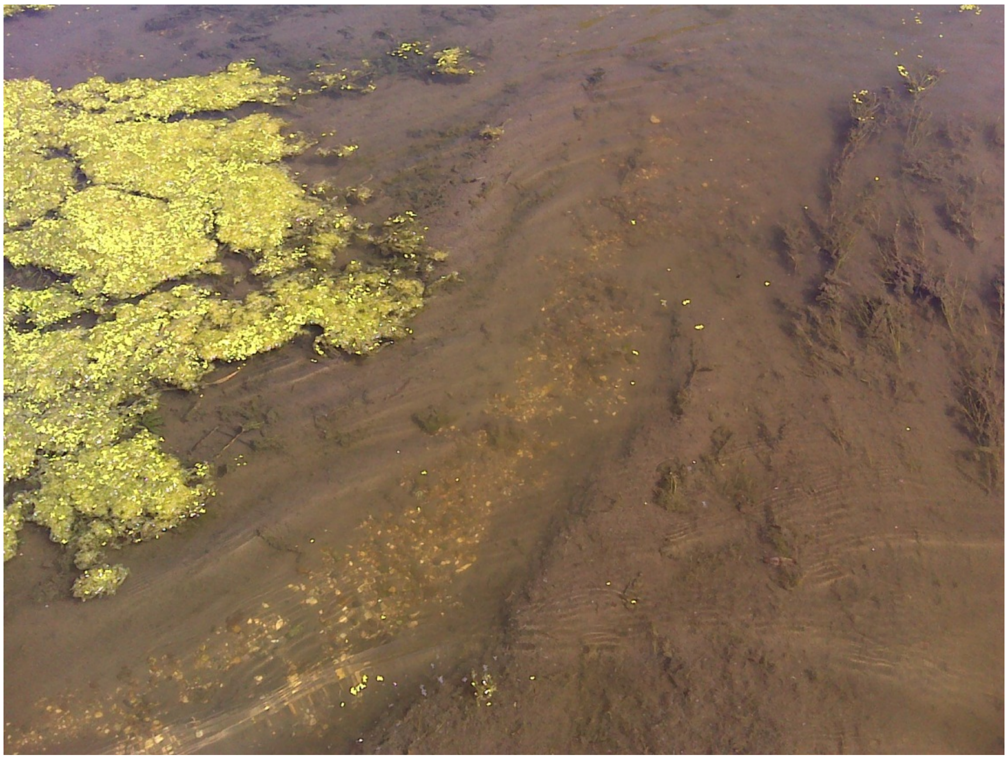


**Figure 33. Sediment in the Shell Rock River (8/21/12)**

## Biotic response

Where full qualitative habitat information is available at biological sampling sites, there is a clear relationship between recorded depth of fines and the resulting percentage of simple lithophilic spawners collected (Figure 34). This relationship is mirrored by the macroinvertebrate community, where the number of clinger taxa decreases with the increase in percent fines (Figure 35). The percentage of fines ranges from 73 to 84%, which is a significant amount of fine sediments. In comparison, the Pomme de Terre River which is also a large low gradient system and is also impaired for biology has a range of percent fines from 7.69 to 69%. The lack of a diversity of habitat types and the presence of fine sediments in the stream bed seems to be impacting the biological community resulting in a lack of lithophilic spawners, an increase in climber taxa and a decrease in clinger taxa. Bedded sediment should be considered as a contributing stressor to both the fish and macroinvertebrate communities. Sediment influences need to be addressed to prevent further filling in of pool and riffle areas.

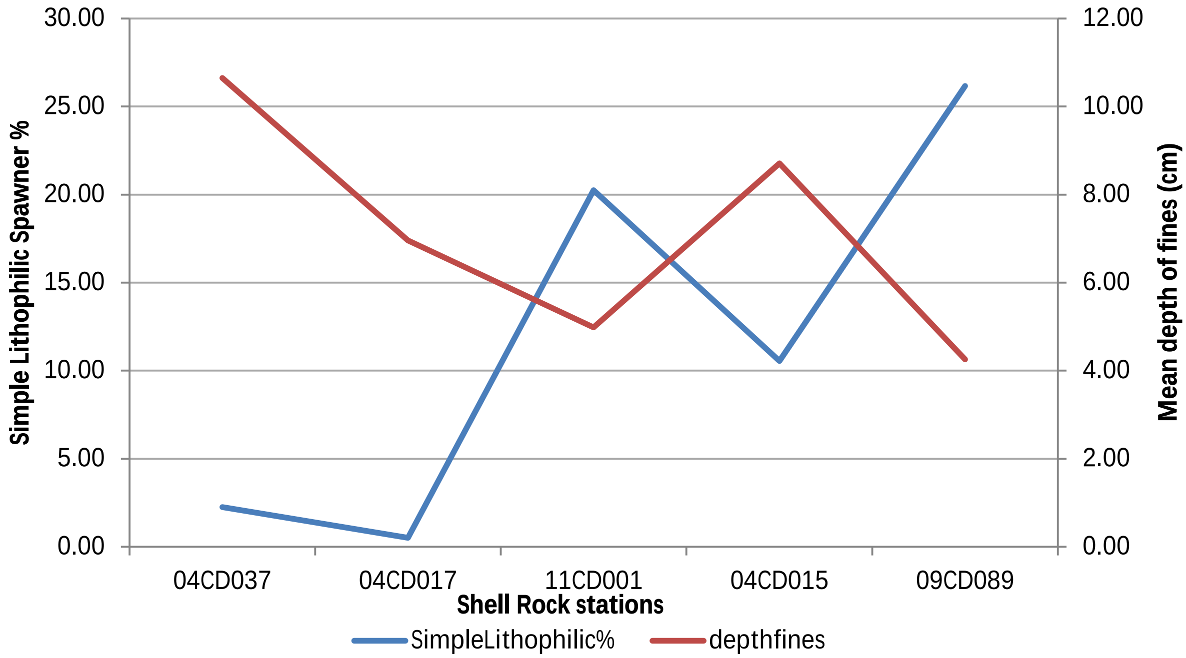



**Figure 34. Depth of fines and lithophilic spawners**

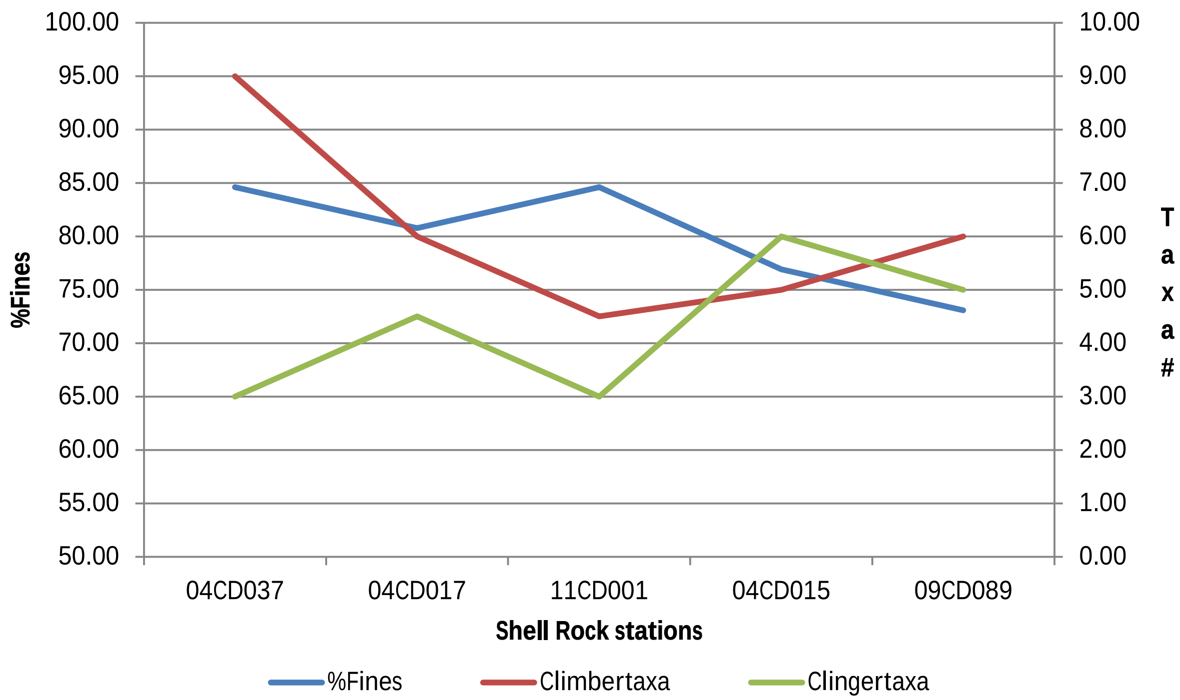



**Figure 35. Macroinvertebrate metrics and fines**

## Candidate cause: Suspended sediment

The Shell Rock River is impaired for turbidity. TSS values are highest in the watershed on the main-stem Shell Rock River, Shoff Creek, and the unnamed tributary from Goose Lake. TSS values from the Shell Rock River in recent years were analyzed by month (Figure 36). Values are highest in May, with values up to 130 mg/L. The proposed standard for TSS for the southern region of the state is 65 mg/L.

Secchi tube readings were taken longitudinally on both July 20 and August 9, 2012 (Figure 37), with higher clarity in the August readings. There was 0.75 inches of rain in the days preceding the July 20 sample which likely accounts for the lower clarity readings on that day. A transparency tube reading of 20 cm has been shown to be equivalent to the turbidity standard of 25 NTUs. On July 20, three sites were above and three were below, all but one of the six readings was above 20 cm on August 9.

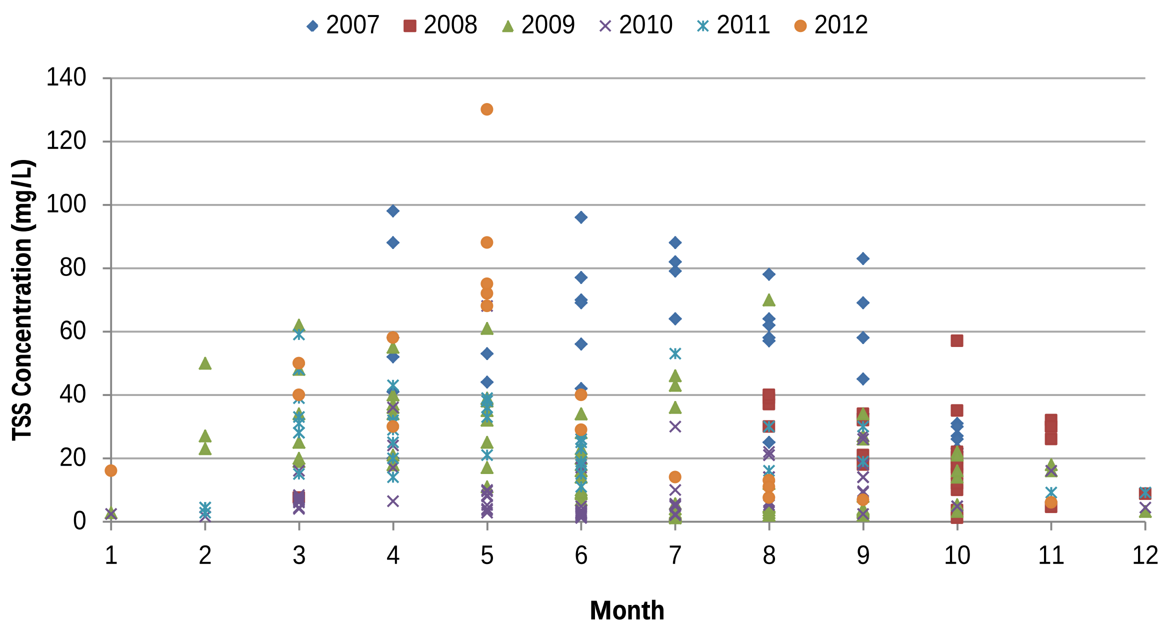



**Figure 36. TSS concentrations on the Shell Rock River**

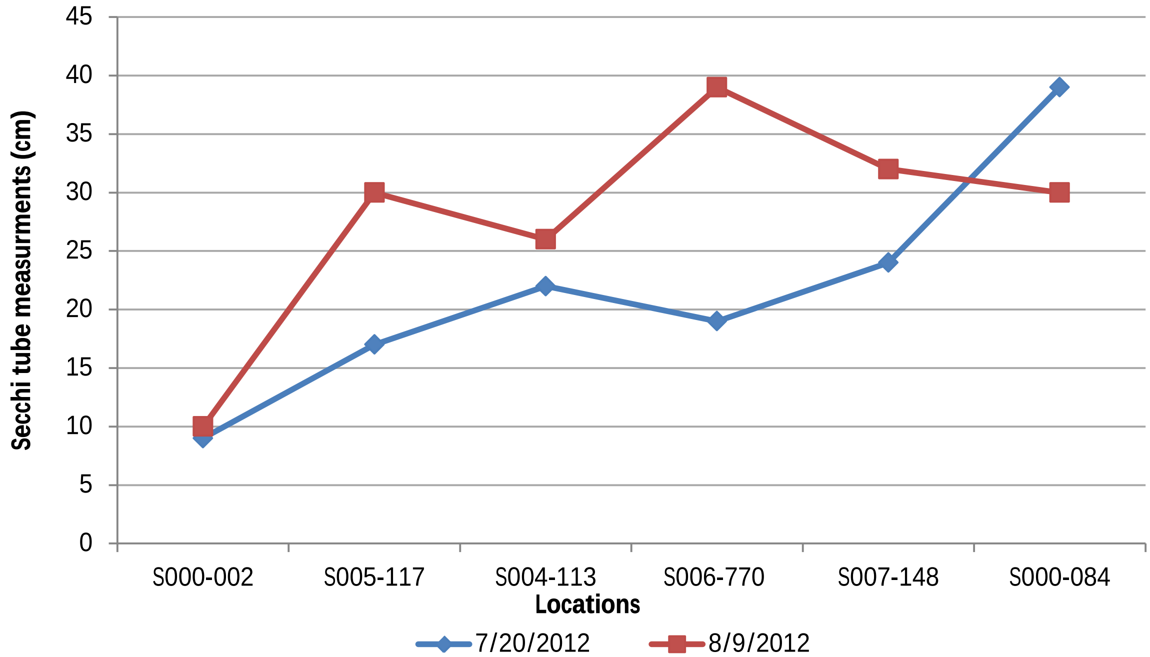



**Figure 37. Clarity readings on the Shell Rock River**

Both organic solids (TSVS) and inorganic solids (TSS) are present in the river with prominence depending on site location. Just below the Albert Lea Lake dam at S000-002, TSVS makes up more than 60% of the suspended solid concentrations on average, which correlates with the highest chlorophyll-a values. Further downstream, the percentage of organic solids was just over 40% on average, and inorganic solids make up the majority of the suspended solids (Figure 38). Both organic and inorganic solid contributions need to be addressed.

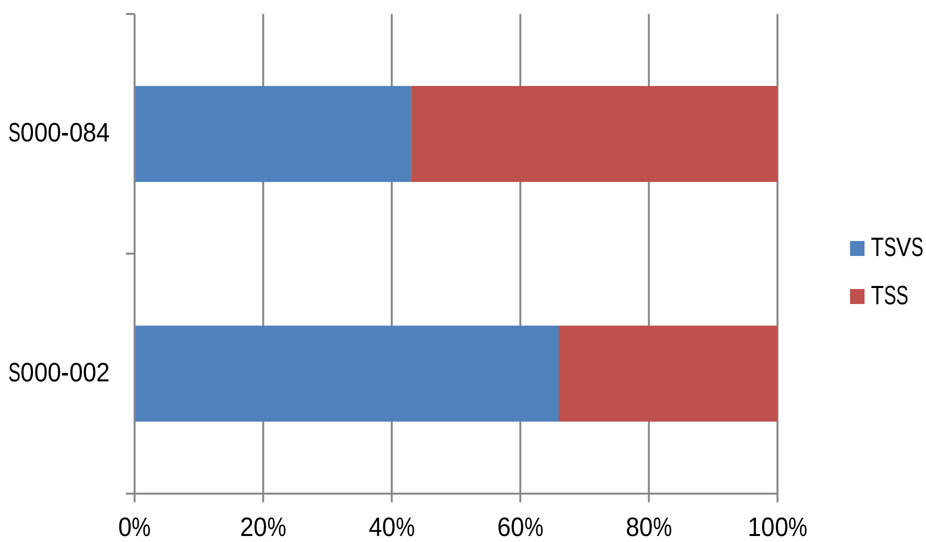



**Figure 38. Organic vs. inorganic sediment percentages**

Visible evidence of bank erosion exists along the banks of the Shell Rock River (Figure 39 and 40). This is likely a source of the inorganic suspended solids. The eutrophication of the upstream lakes and the nutrient loads to the Shell Rock River are contributing to the suspended organic solids present in the river.

**Figure 39. Stream bank erosion (8-4-11)**

**Figure 40. Fence posts that have fallen into the river from losing surrounding soil (8-4-11).**

## Biotic response

Herbivore species of fish decrease as TSS values increase. The individual herbivore percentages on the Shell Rock River are low, ranging from 0 to 5.38, and averaging 0.74. The number of macroinvertebrate taxa collected that are intolerant to TSS was 0 at 5 of the sites sampled on the Shell Rock River while only one taxa intolerant to TSS was collected at the other two sites (Figure 41). This is a strong indicator that TSS is affecting the macroinvertebrate community.

TSS can also affect both the number and growth of smallmouth bass. During the eight biological samples taken on the Shell Rock River, only four smallmouth bass were surveyed. The number of tolerant fish and macroinvertebrate species increases with an increase in suspended sediment while taxa richness decreases. As discussed in previous sections, tolerant macroinvertebrates and fish were high and macroinvertebrate taxa richness was low on the Shell Rock River. The low numbers of herbivores, small mouth bass, and TSS intolerant taxa points to suspended sediments being a main stressor to the river.

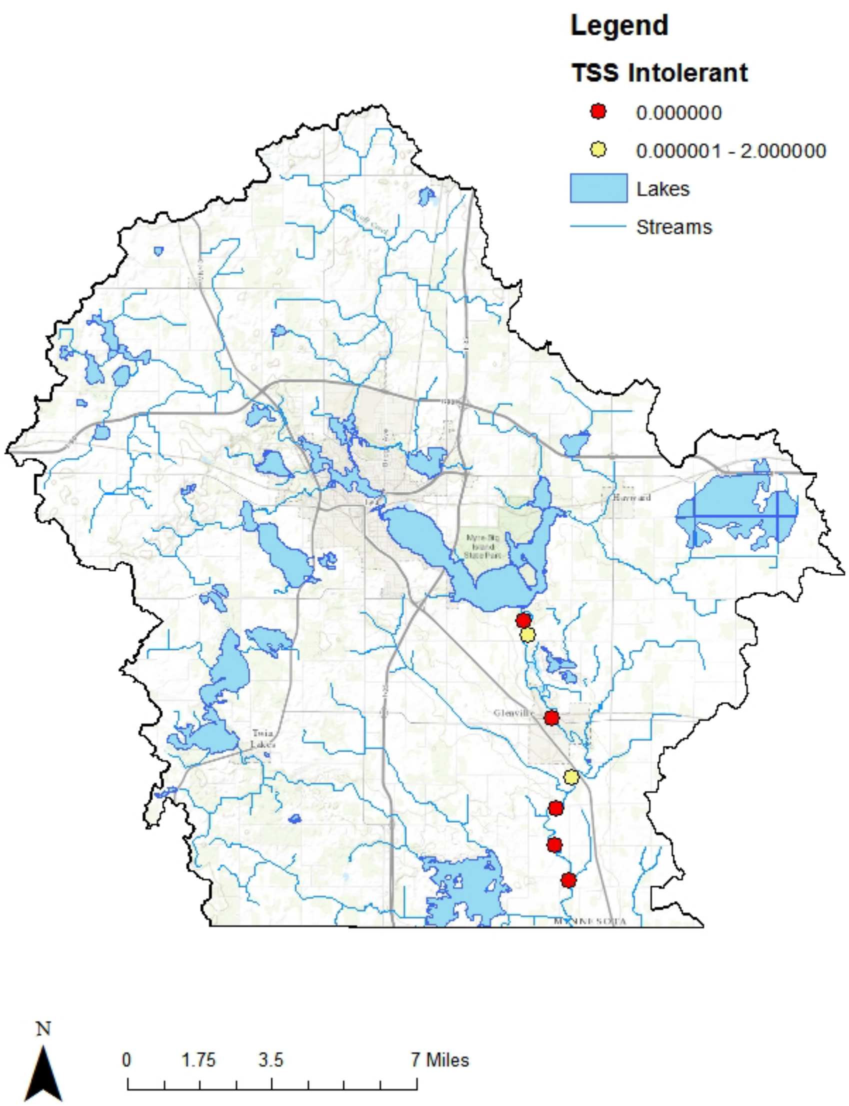



**Figure 41. Macroinvertebrate taxa intolerant to TSS on the Shell Rock River**

## Candidate cause: Flow

The Albert Lea Lake dam impacts downstream flow on the Shell Rock River. The extent of the impact is unknown as continuous flow data is not available at this location. During 2012, visible flow coming over the Albert Lea Lake dam was very minimal (Figure 42). Flow increases downstream due to the Albert Lea Lake WWTP discharge below the dam and tributaries below Glenville, but the biological communities between the lake outlet and the inputs are vulnerable during low flow periods. Connectivity between the lake and river is affected during these low flow periods.

**Figure 42. Albert Lea Lake dam (8-9-12)**

### Biotic response

Macroinvertebrate swimmers are shown to increase at low flow, and looking at the results from the seven samples shows no difference in individual swimmer percentages between upstream and downstream of the inflow of water from the WWTP. A Pennsylvania study (Hutchinson, 2012) found fish riffle associate species to be the most sensitive to low flow conditions. Station 04CD037, the one site sampled upstream of the Albert Lea WWTP had only 1 riffle dwelling species sampled, while downstream the number of species ranged from 2 to 4 and averaged 3.14. While not a large difference, the low flow conditions upstream of the inputs could be contributing to the impaired fish community at this location. Low flow in the upstream section of the river does not seem to be a main stressor to the system, but low flow conditions can have an effect on the river when pool space is already at a minimum. The low flow conditions concentrate sediment and nutrient loads, in turn effecting DO levels, which could be indirectly affecting the biological community.

## Candidate cause: Temperature

Temperatures in the Shell Rock River can get very high during the summer months, especially in July (Figure 43). These elevated water temperatures are affecting the high DO levels recorded, as water can hold less DO at warmer temperatures. The nature of the wide, shallow conditions of the stream is conducive to increased temperatures. Two longitudinal surveys in 2012 show the temperatures highest below the Albert Lea dam, which correlates with the lowest flow and the highest chlorophyll-a concentrations (Figure 44). The continuous temperature readings along the river in 2012 show the section below the Albert Lea Lake dam getting above 30 degrees Celsius ($^{o}$C) numerous times during two weeks (Figure 45). The continuous data were similar at all three sites: below the Albert Lea Lake dam, in Glenville, and near Gordonsville.

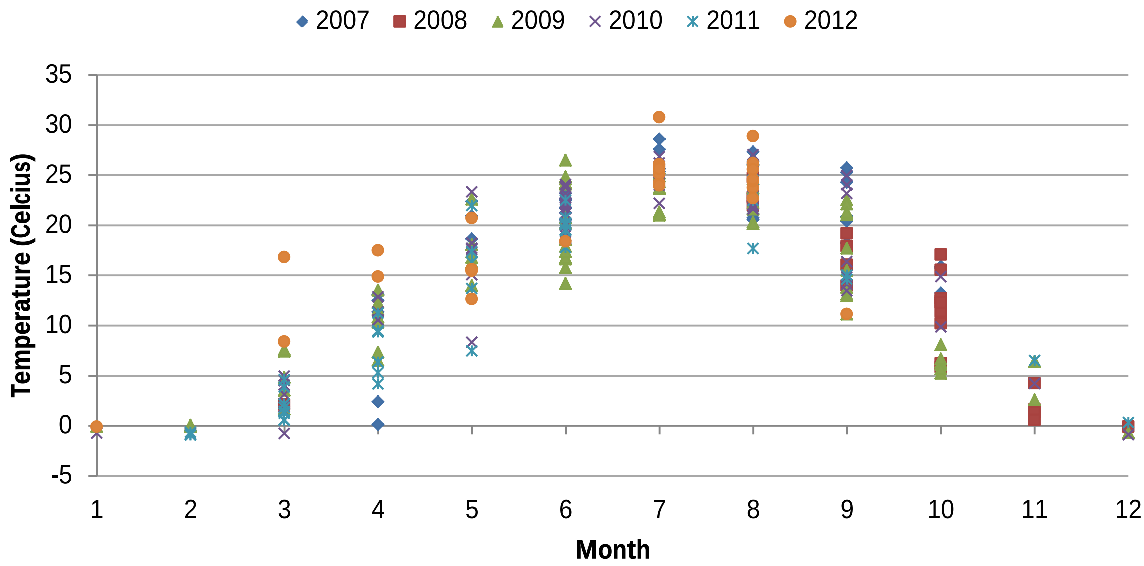



**Figure 43. Temperature in the Shell Rock River 2007-2012**

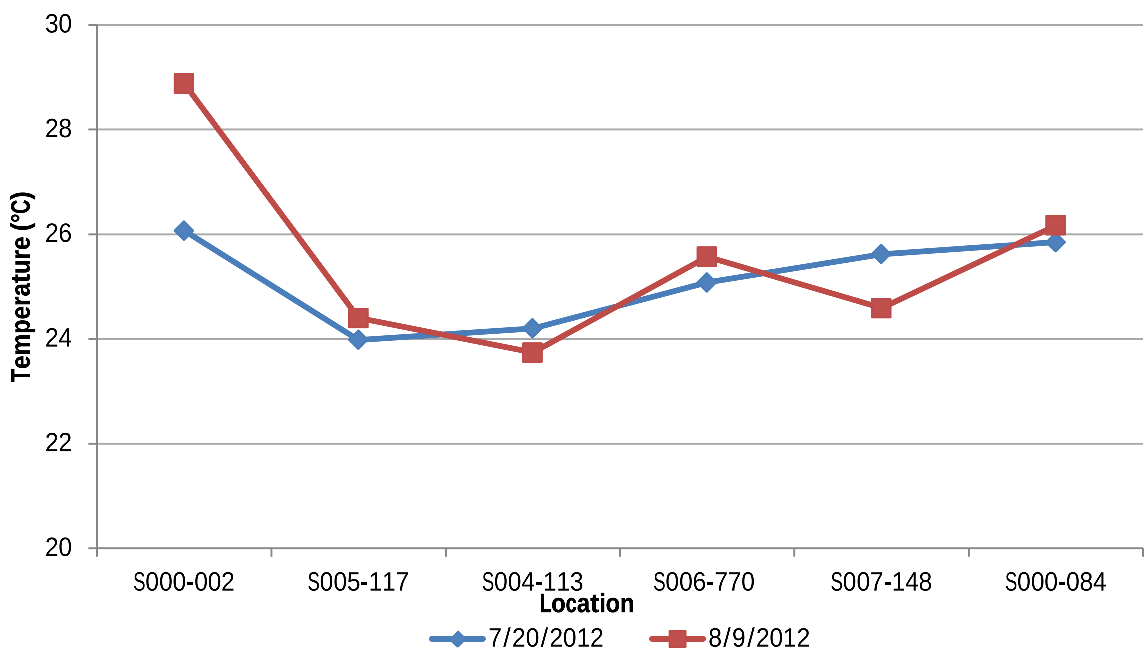



**Figure 44. Longitudinal temperature in the Shell Rock**

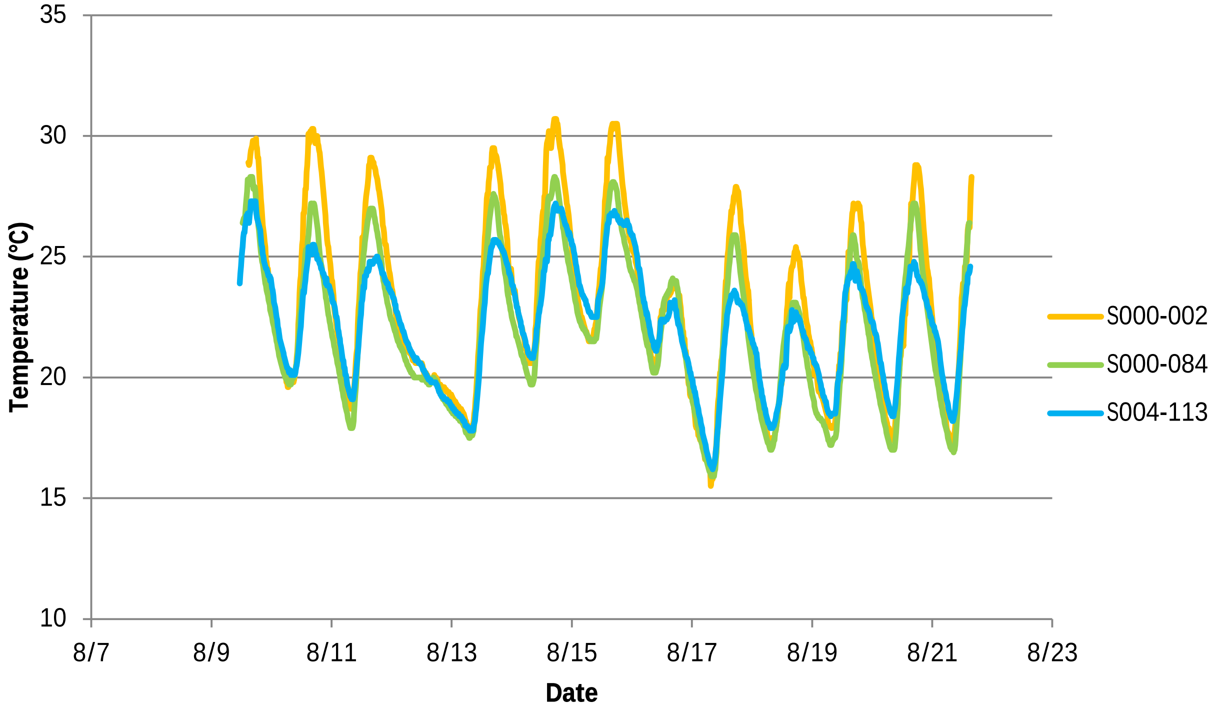



**Figure 45. Continuous temperature data in 2012**

## Biotic response

Effects on aquatic communities in warm-water systems are not as clear as is in cold-water systems. CADDIS (2012) describes changes in growth and thermal stress, and impaired fish and macroinvertebrate assemblages. A publication by EPA (1986) shows a maximum weekly temperature of 28 degrees °C for optimum white sucker growth and 29 degrees °C for optimum smallmouth bass growth. The weekly average recorded in August of 2012 was 24 degrees °C, while temperature gets up to 30.71 °C at times during the two week study period. In a study in the Minnesota River basin, Feist and Niemela (2005) found significant relationships between increased temperatures and temperature fluctuations and a decrease in top carnivores and sucker species and an increase in the number of minnow species. The continuous temperature data collected in 2012 was similar at all three locations with the highest temperatures and highest temperature fluctuations in one day recorded at Station S000-002. The number of minnow species collected was lowest at Stations 04CD037 and 09CD087 located downstream of the Albert Lea Lake dam where the temperatures and temperature fluctuations were highest. The number of minnows collected was highest at station S000-084. Station S000-084 had the second highest temperatures and temperature fluctuations recorded, but if temperature was a main factor, high number of minnow species would also be expected downstream of the dam. Carnivores were highest at the warmest sites, when they would be expected to decrease. Sucker species were low throughout the stream which could be tied to temperature. Sucker species numbers were low, but carnivores and minnows did not react as expected. Temperature may be having an effect but is likely not a main stressor, rather an indirect stressor to the other primary stressors it is affecting like DO.

## Strength of evidence

The evidence of each potential stressor, and the quantity and quality of each type of evidence is evaluated. The consistency and credibility of the evidence is also evaluated. The Shell Rock River was scored and summarized in Table 4. For more information on scoring, see EPA's CADDIS Summary Table of Scores key in Appendix C.

**Table 4. Weight of evidence for potential stressors in the Shell Rock River**

| | Evidence using data from the Shell Rock River | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Types of Evidence** | | **Scores** | | | | | | | | |
| | **Low Dissolved Oxygen** | **Pesticides** | **Nitrogen** | **Ionic Strength** | **Habitat** | **Temperature** | **Phosphorus** | **Flow** | **pH** | **TSS** |
| **Spatial/temporal co-occurrence** | + | 0 | + | + | + | 0 | + | 0 | + | + |
| **Temporal sequence** | + | 0 | + | + | + | 0 | + | 0 | + | + |
| **Field evidence of stressor-response** | ++ | 0 | ++ | + | ++ | - | ++ | 0 | + | + |
| **Causal pathway** | ++ | 0 | + | + | + | + | ++ | + | + | + |
| **Evidence of exposure, biological mechanism** | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| **Field experiments /manipulation of exposure** | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| **Laboratory analysis of site media** | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| **Verified or tested predictions** | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| **Symptoms** | D | 0 | + | + | + | 0 | D | 0 | + | + |
| | Evidence using data from other systems | | | | | | | | | |
| **Mechanistically plausible cause** | + | 0 | + | + | + | + | + | + | + | + |
| **Stressor-response in other lab studies** | ++ | + | + | + | NE | + | + | NE | + | + |
| **Stressor-response in other field studies** | ++ | + | + | + | + | + | + | + | + | + |
| **Stressor-response in ecological models** | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| **Manipulation experiments at other sites** | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| **Analogous stressors** | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| | Multiple lines of evidence | | | | | | | | | |
| **Consistency of evidence** | +++ | 0 | +++ | + | +++ | 0 | +++ | 0 | + | + |
| **Explanatory power of evidence** | ++ | 0 | ++ | ++ | ++ | 0 | ++ | 0 | 0 | ++ |

## Summaries and recommendations

The fish and macroinvertebrate communities in the Shell Rock River are reflective of the effects of multiple stressors. The prominent stressors are the elevated nitrate, phosphorus, pH and chlorophyll-a levels and resulting DO fluctuations. Areas of intense macrophytes and algae growth are present throughout the river. While phosphorus values were highest downstream of the Albert Lea WWTP (up to 5.4 mg/L), the values coming out of the lake were close to exceeding the proposed standard (0.140 mg/L on 8/9/12). Nutrient loading can create an increase in phytoplankton (measured as sestonic chlorophyll); along with the contributing factors of temperature, light, and residence time (Heiskary et al., 2013). Ideal conditions for nutrient enrichment exist in the Shell Rock River; a low gradient stream with little shade, elevated temperatures and high nutrient loads. Phosphorus, chlorophyll-a, and DO flux values are all above the proposed water quality standards, and pH values exceed the standard. The Albert Lea Lake TMDL is in progress and will contain a nutrient reduction plan for the lake. Intercepting and removing nutrient inputs as much as possible should be pursued throughout the entire watershed.

DO values routinely fall below 5.0 mg/L and have been measured as low as 0.36 mg/L below the Albert Lea Lake dam. DO values have been elevated as high as 24.23 mg/L near Gordonsville (Station S000-084). The extreme low and high conditions, along with the vast differences in one day are extremely stressful to the biological communities. There is a clear relationship between the nutrient values and DO conditions. Nutrient reductions are necessary to improve the DO conditions in the Shell Rock River. While temperature does not appear to be a direct stressor to the biological communities, it is impacting DO concentrations in the river.

Phosphorus, nitrate, and specific conductance values sharply increase between the Albert Lea WWTP and the city of Glenville. Records from the WWTP confirm this with the high nitrate, phosphorus, and specific conductance values in their discharges. The gravel pit outflow and the ethanol plant may also contribute to these concentrations. The effects of ionic strength are not as strong as for other stressors, but since the Shell Rock River biotic communities are already experiencing a lot of stress, decreasing the ions comprising the high specific conductance values would be beneficial. The macroinvertebrate taxa richness was highest upstream of the WWTP, was at the lowest levels in Glenville, and then slowly rebound near the border. This could be due to numerous stressors, but the inputs between Albert Lea Lake and Glenville should be addressed. An intensive Toxicity Reduction Evaluation is currently underway to address a failed chronic WET test at the Albert Lea WWTP.

Bedded sediment is affecting the habitat availability, and the undercutting of stream-banks is contributing to the influx of fine sediment. The suspended sediment and bedded sediment are closely tied and need to be addressed together. The aquatic communities would benefit from a decrease in fine sediment, especially since the high width to depth nature of the stream makes it very difficult for the stream to move the sediment once it has been deposited. As would be expected, suspended sediment concentrations are highest after rain events; protection of the eroding banks that are causing both suspended and bedded sediment is needed.

During dry summer conditions, very little flow comes over the Albert Lea Lake dam, leading to increased sediment concentrations, nutrient loads and temperatures. Increased temperatures and nutrient levels in turn affect the DO concentrations. A more consistent flow from Albert Lea Lake to the Shell Rock River is important, especially during periods of low precipitation. Ideally, Albert Lea Lake could flow into the Shell Rock River without the presence of a dam.

Temperature, flow, and specific conductance values are having indirect effects on the biological communities of the Shell Rock River. Nutrients (nitrate, phosphorus, pH, and chlorophyll-a), DO, and sediments (both inorganic and organic suspended and bedded) are the main stressors to both communities and should be the primary focus of restoration efforts in the watershed. Secondarily, the indirect stressors of flow, temperature, and specific conductance should be addressed.

# Bancroft Creek

The macroinvertebrate impairments on Bancroft Creek were deferred due to the majority of the stream channel being modified. However some of the chemistry data are summarized below because of the importance of this sub-watershed. The biological and water chemistry sampling locations are below (Figure 46).

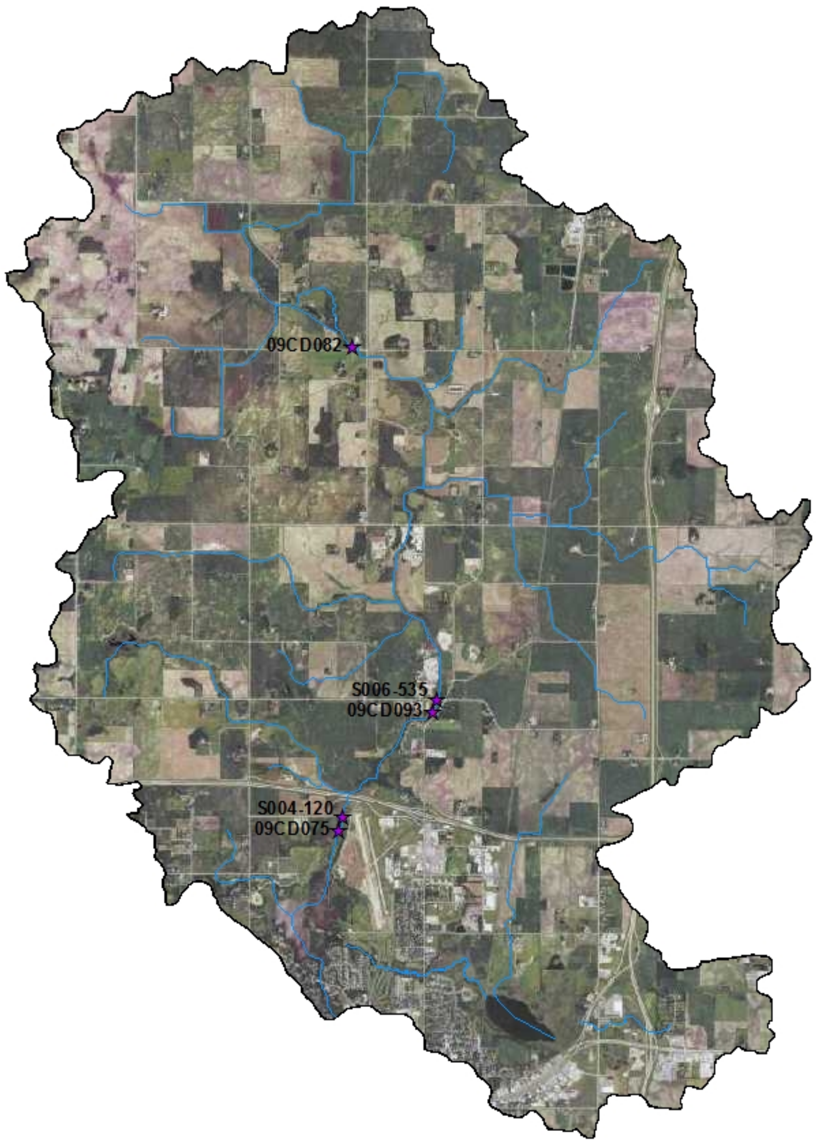



**Figure 46. Aerial map of Bancroft Creek**

Continuous DO data from Bancroft Creek in 2011 (Figure 47) shows a daily drop below the DO standard of 5.0 mg/L, with all of the daily flux values at or over the proposed standard of 4.5 mg/L (Figure 48). The daily flux values range as much as 9.84 mg/L in one day, which is more than twice the proposed standard.

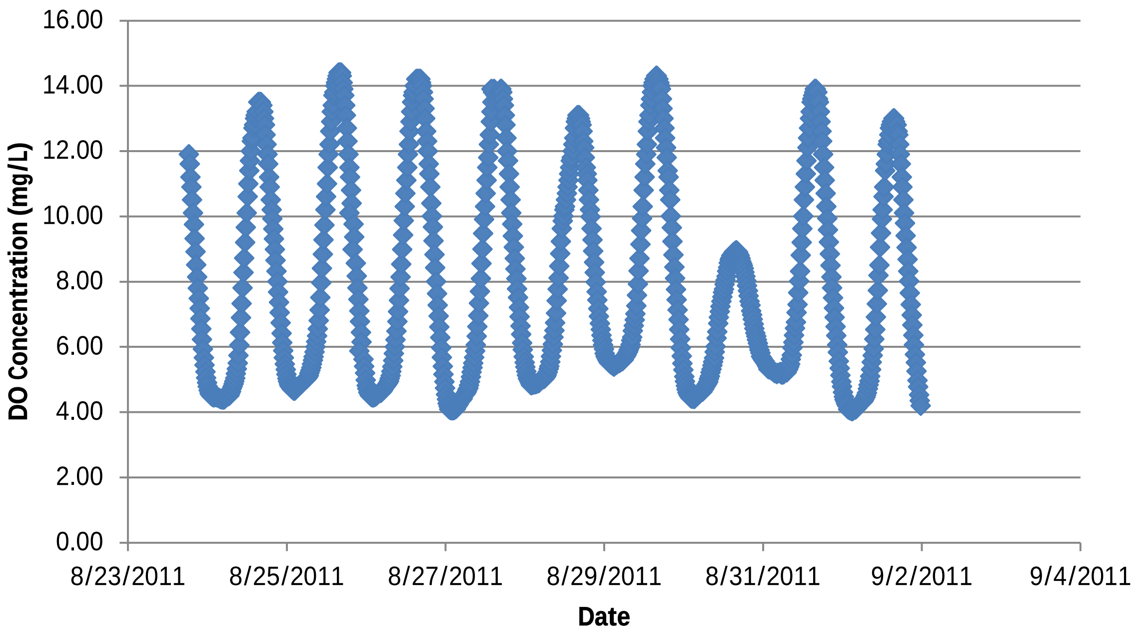



**Figure 47. Bancroft Creek continuous DO data**

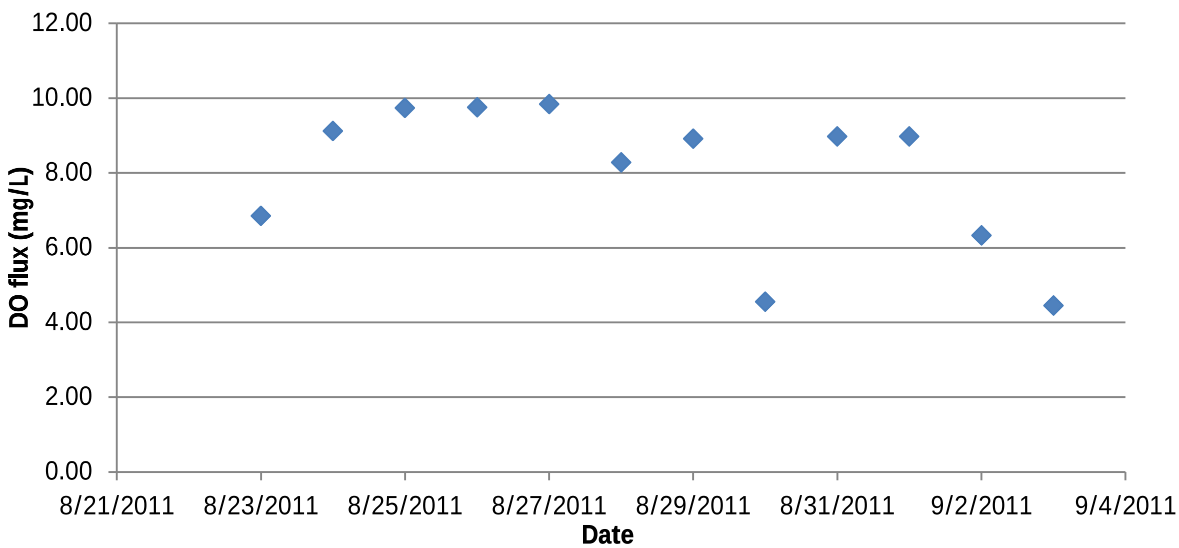



**Figure 48. Daily DO fluctuations**

Nitrate values coming from tile lines into Bancroft Creek were recorded at 15.0 mg/L after rain events, and were reflected in the creek itself with values of 12.0 and 13.0 mg/L downstream. There are recorded values of nitrogen of 23.0 mg/L after a rain event of 2.5 inches. A value of 11.0 mg/L of nitrate was recorded coming out of tile line CD 76, and a value of 15.0 mg/L out of a tile line into CD 63. Even though there is a nice buffer along this channelized reach, the flows coming through this ditch have too much force for the channel banks to handle, causing erosion (Figures 49 and 50).

**Figure 49. Stream-bank erosion (6/23/11)**

**Figure 50. Erosion (6/23/11)**

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# Appendix A. Metric fact sheets applicable to the Shell Rock River

## Fish Class 2-southern streams

| MetricName | Category | Response | Metric_Desc_tech |
|---|---|---|---|
| BenInsect-TolTXPct | trophic | positive | Relative abundance (%) of taxa that are benthic insectivores (excludes tolerant species) |
| DetNWQTXPct | trophic | negative | Relative abundance (%) of taxa that are detritivorous |
| MA<2Pct | reproductive | negative | Relative abundance (%) of early-maturing individuals (female mature age <=2 years) |
| SensitiveTXPct | tolerance | positive | Relative abundance (%) of taxa that are sensitive |
| SLvd | life history | negative | Taxa richness of short-lived species |
| TolTXPct | tolerance | negative | Relative abundance (%) of taxa that are tolerant |
| TolPct | tolerance | negative | Relative abundance (%) of individuals that are tolerant |
| DomTwoPct | dominance | negative | Combined relative abundance of two most abundant taxa |
| FishDELTPct | tolerance | negative | Relative abundance (%) of individuals with Deformities, Eroded fins, Lesions, or Tumors |

## Macroinvertebrate Class 6 –southern forest streams (glide/pool habitats)

| Metric Name | Category | Response | Metric Description |
|---|---|---|---|
| *ClingerCh* | Habitat | Decrease | Taxa richness of clinger taxa |
| *Collector-filtererPct* | Trophic | Decrease | Relative abundance (%) of collector-filterer individuals in a subsample |
| *DomFiveChPct* | Composition | Increase | Relative abundance (%) of dominant five taxa in subsample (chironomid genera treated individually) |
| *HBI_MN* | Tolerance | Increase | A measure of pollution based on tolerance values assigned to each individual taxon, developed by Chirhart |
| *Intolerant2Ch* | Tolerance | Decrease | Taxa richness of macromacroinvertebrates with tolerance values less than or equal to 2, using MN TVs |
| *POET* | Richness | Decrease | Taxa richness of Plecoptera, Odonata, Ephemeroptera, & Trichoptera (baetid taxa treated as one taxon) |
| *PredatorCh* | Trophic | Decrease | Taxa richness of predators |
| *TaxaCountAllChir* | Richness | Decrease | Total taxa richness of macromacroinvertebrates |
| *TrichopteraChTxPct* | Composition | Decrease | Relative percentage of taxa belonging to Trichoptera |
| *TrichwoHydroPct* | Composition | Decrease | Relative abundance (%) of non-hydropsychid Trichoptera individuals in subsample |

# Appendix B. Shell Rock River primary stressors

| Stressors | Shell Rock River |
|---|---|
| Ammonia | No |
| Chloride | Possible |
| Chlorophyll-a | Yes |
| Connectivity | Limited data |
| Dissolved Oxygen | Yes |
| Habitat | Yes |
| Ionic strength | Possible |
| Low flow | Possible |
| Nitrate | Yes |
| Parasitism | Not likely |
| Predation | Limited data |
| Pesticides | Inconclusive |
| pH | Yes |
| Phosphorus | Yes |
| Physical crushing and trampling | No |
| Temperature | Possible |
| TSS | Yes |
| TSVS | Possible |

## Appendix C.1 - Values used to score evidence in the stressor identification process developed by EPA

| Rank | Meaning | Caveat |
|---|---|---|
| **+++** | *Convincingly supports* | *but other possible factors* |
| **++** | *Strongly supports* | *but potential confounding factors* |
| **+** | *Some support* | *but association is not necessarily causal* |
| **0** | *Neither supports nor weakens* | *(ambiguous evidence)* |
| **-** | *Somewhat weakens support* | *but association does not necessarily reject as a cause* |
| **--** | *Strongly weakens* | *but exposure or mechanism possible missed* |
| **---** | *Convincingly weakens* | *but other possible factors* |
| **R** | *Refutes* | *findings refute the case unequivocally* |
| **NE** | *No evidence available* | |
| **NA** | *Evidence not applicable* | |
| **D** | *Evidence is diagnostic of cause* | |

## Appendix C.2 - Strength of evidence scores for various types of evidence used in stressor identification analysis

| Types of Evidence | Possible values, high to low |
|---|---|
| | |
| ***Evidence using data from case*** | |
| Spatial / temporal co-occurrence | +, 0, ---, R |
| Evidence of exposure, biological mechanism | ++, +, 0, --, R |
| Causal pathway | ++, +, 0, -, --- |
| Field evidence of stressor-response | ++, +, 0, -, -- |
| Field experiments / manipulation of exposure | +++, 0, ---, R |
| Laboratory analysis of site media | ++, +, 0, - |
| Temporal sequence | +, 0, ---, R |
| Verified or tested predictions | +++, +, 0, -, ---, R |
| Symptoms | D, +, 0, ---, R |
| ***Evidence using data from other systems*** | |
| Mechanistically plausible cause | +, 0, -- |
| Stressor-response relationships in other field studies | ++, +, 0, -, -- |
| Stressor-response relationships in other lab studies | ++, +, 0, -, -- |
| Stressor-response relationships in ecological models | +, 0, - |
| Manipulation of exposure experiments at other sites | +++, +, 0, -- |
| Analogous stressors | ++, +, -, -- |
| ***Multiple lines of evidence*** | |
| Consistency of evidence | +++, +, 0, -, -- |
| Explanatory power of evidence | ++, 0, - |