Rice Creek Assessment Project
Resources Investigation

Clean Water Partnership
Part 1 - Diagnostic Study

July 2013

Project Sponsor
Bridgewater Township (Rice County)

Contributing Co-Sponsors
Cannon River Watershed Partnership
St. Olaf College
Minnesota Department of Natural Resources- Fisheries
Trout Unlimited

Other Participating Sponsors
Rice County Soil and Water Conservation District
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency Citizen
Rice Creek Concerned Citizens Group

Prepared 7/13 by Cannon River Watershed Partnership
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EXECUTIVE SUMMARY

Rice Creek (also known as Spring Brook, HUC 07040002-557) is a stream of state and regional significance (Figure 1). It is the only designated trout stream in Rice County, Minnesota. Unlike the neighboring warm water streams of Health Creek and Wolf Creek, this stream does not flow through lakes but rather has significant groundwater inputs giving it colder temperatures. Naturally reproducing brook trout populations, such as those found in Rice Creek, are comparatively rare due to the sensitivity of this species to stream degradation. This stream has been used by the Minnesota Department of Natural Resources (MN DNR) as a source for brook trout stocking in the past. The watershed is a high priority for monitoring, implementation, and restoration due to its three impairment listings on the Minnesota 303(d) Impaired Waters List: turbidity, nitrates and E. coli bacteria. Rice Creek in turn contributes to impairments of the Cannon and Mississippi Rivers. In 2011 the Minnesota Pollution Control Agency (MPCA) conducted its Intensive Watershed Monitoring in the entire Cannon River watershed which included two sites in Rice Creek. Based on this work, the MPCA will recommend that a 1.9 mile reach of Rice Creek be listed as impaired for aquatic macroinvertebrates on the 2014 Impaired Waters List.

In November of 2009, the Rice Creek Concerned Citizens Group submitted a report and list of recommendations to Bridgewater Township to call for collaboration among stakeholders to improve and protect the brook trout community in Rice Creek (Appendix A). When Northfield made an annexation request in 2009, which was denied by Bridgewater Township in part because the City of Northfield did not have a stream protection ordinance in place, advocates of Rice Creek realized the urgency for action and partnered their efforts to improve, protect, and conserve Rice Creek.

Project Partners
Project participants consisted of local, regional, and state agencies including Bridgewater Township, Cannon River Watershed Partnership, St. Olaf College, Minnesota Department of Natural Resources, Trout Unlimited, Rice County Soil and Water Conservation District (SWCD), Rice County Planning and Zoning Department, Minnesota Pollution Control Agency, and the Rice Creek Concerned Citizens Group. In the second year of the project the Freshwater Society joined as a partner on outreach to farmers and landowners through their MN FarmWise project.

Diagnostic Study Results
During the study we collected water chemistry samples, stream flow, and water temperature and conductivity measurements. Stream habitat and width were assessed along with studying the brook trout and macroinvertebrates. One point of interest was to understand if the groundwater recharge to the stream was shallow or deep in origin.

Precipitation and weather in 2011 and 2012 deviated from normal in many months which complicated data collection and modeling for this project. The watershed experienced more extreme weather conditions with two years of mostly drought conditions punctuated by two flood events. Due to these conditions, sufficient flow data was not able to be collected to calculate loading results for the water chemistry samples collected. Additional flow measurements would be needed to develop the data set needed for load modeling.
We learned that nitrate-nitrogen (nitrate) concentrations are high during spring runoff and events as well as during base (low) flow conditions indicating subsurface inputs. Total suspended solids (TSS) and total phosphorus (TP) are event driven with concentrations far exceeding the proposed Class 2A TSS standard (10 mg/L) and TP of 0.15 mg/L. During base flow conditions TSS and TP are within desired ranges. Overall the stream habitat is fair with areas in need of improvement in terms of channel morphology, width and type of riparian vegetation. As we look toward restoration planning and projects, we wish to promote narrow and deeper channels. Use of a “soft armor” approach of deep-rooted grasses with less trees and a gentler 1:4 slope should be considered. Brook trout are present in the stream with an estimated population of 3,350 trout/mile. They are doing surprisingly well, but like their habitat there is room for improvement. The groundwater inputs to the system appear to be local, shallow and “young”; the estimated age based on tritium samples was 5 – 10 years old.

**Implementation Action Plan**
The five year implementation plan includes a mix of targeted Best Management Practices (BMPs) as well as outreach, behavior changes, and monitoring. As the watershed land use is 84% agricultural, BMPs are targeted to that sector to include nutrient management, conservation tillage, cover crops, controlled drainage, buffers and waterways, and wetland restoration.

**Water Quality and Habitat Goals**
The goals listed below are ones we hope to achieve in the short term (5-10 years) unless otherwise noted:

- Maintain and improve riparian corridor, including buffers, so that all MSHA scores are Fair or Good using the 2012 assessment as baseline (Figure 16).
- Reduce N concentration in the stream by 30%
  - Within 20 years stream N levels are at or below the Class 2A standard of 10 mg/L at all times.
  - Long term (30+ years) the N levels drop into the low single digits yielding additional benefits to aquatic life.
- Reduce peak flows/flooding by increasing water storage with wetlands, infiltration and controlled drainage.
- Maintain or reduce stream temperatures so that peak values do not exceed 68 degrees F along the trout stream portion of the system.
- Reduce TSS and TP input during high flows by 25%
  - 20 year goal of reducing TSS levels to proposed standard of 10 mg/L and TP goal of 0.15 mg/L.

While the stream is impaired for *E. coli* bacteria it is not often used for aquatic recreation which is the concern for this pollutant. As such while reducing *E. coli* levels is something to be addressed it is not one of the primary goals for this stream. We anticipate *E. coli* will be indirectly addressed by pursuing the goals above.
Priority Areas
Using the information gathered during the diagnostic phase we can prioritize some areas for implementation activities:

- Habitat improvements – Target existing MN DNR angler easement (TU project) as well as any areas with scores of “Fair” or less based on the 2012 MSHA assessment as noted in Figure 16. This is anticipated to help with stream temperature as well as in-stream food supply.
- Nitrate reductions – Land that drains to County Ditch 22 will be the priority for snow melt and spring runoff time as that section typically does not flow year round. The trout stream section and ditch at 100th Street East will be the areas of focus during the low flow times. Relevant data is found in Table 14 and Figures 26, 27, 37 & 38.
- Reducing peak flows – Land within County Ditch 22 drainage with potential for restorable wetlands (see Figure 10), as well as land throughout watershed with potential for controlled drainage and other water storage and infiltration options.
- Upland erosion – Any areas with 85% Stream Power Index (SPI) potential or greater will be ground-truthed and assessed for potential erosion control options to help reduce TSS and TP. Analysis is illustrated in Figures 24 and 25.

Additional work is needed by project partners in collaboration with landowners/operators to determine which projects can be implemented soon and which may have to wait or are not practical. The restoration and protection of this watershed must balance the needs of the stream and aquatic life, recreational aspirations, and the need for farmers in the watershed to earn a living. Bridgewater Township is committed to assisting in this effort as is Cannon River Watershed Partnership and St. Olaf College. The assistance of volunteers and the Rice Creek Concerned Citizens group in the diagnostic phase is evidence of community support. We have developed a valuable set of data and information that we can use to assess effectiveness of changes going forward. Several funding sources are available to support such efforts. The key piece, as in any watershed project, will be the needs, wants, and willingness of the landowners and operators to make the changes necessary to restore and protect the stream.
INTRODUCTION AND PROJECT BACKGROUND

Rice Creek (also known as Spring Brook) is a stream of state and regional significance (Figure 1). It is the only designated trout stream in Rice County, Minnesota. Unlike the neighboring warm water streams of Health Creek and Wolf Creek, this stream does not originate in a lake but rather has significant groundwater inputs giving it colder temperatures. Self-sustaining brook trout populations such as those found in Rice Creek are comparatively rare due to the sensitivity of this species to stream degradation. This stream has been used by the Minnesota Department of Natural Resources (MN DNR) as a source for brook trout stocking in the past. The watershed is a high priority for monitoring, implementation, and restoration due to its three impairment listings on the Minnesota 303(d) Impaired Waters List: turbidity, nitrates and E. coli bacteria. Rice Creek in turn contributes to impairments of the Cannon and Mississippi Rivers.

In 2011 the Minnesota Pollution Control Agency (MPCA) conducted its Intensive Watershed Monitoring in the entire Cannon River watershed which included two sites in Rice Creek. Based on this work, the MPCA will recommend that a 1.9 mile reach of Rice Creek be listed as impaired for aquatic macroinvertebrates on the 2014 Impaired Waters List.

Figure 1 – Map of Rice Creek watershed, project monitoring locations, stream classifications
Soils
Soils in this watershed (Figure 2) are till and modified till - chiefly loam, a little sandy loam; overlain, underlain, or mixed in places with minor sand and gravel (Geologic Atlas of Rice County, 1995).

Figure 2 – Soil Surface Texture map of Rice Creek Watershed
Geology
Most of the watershed is underlain by the Prairie du Chien and the St. Peter Sandstone and covered with till and modified till (Geologic Atlas of Rice County, 1995). The gravel in the watershed is almost certainly glacial in origin (Carrie Jennings, personal communication, May 2013).

In 1975 a gravel mine was proposed for the area near Armstrong Road. Different geologists had varying ideas about the sources of the springs in the creek and whether gravel mining would have affected them. One report stated that the Jordan aquifer – below the Prairie du Chien – was the source of the springs because the potentiometric surface of this aquifer was at the surface (the water was under pressure and could rise to the surface through artesian springs). Another report said that the source of the springs was likely sand and gravel inclusions in the Prairie du Chien. Although it did receive a conditional use permit, the gravel pit was not developed.

Slope
Most of the land in the watershed has slope of less than 6%, although some areas of greater slope are found (Figure 3).

![Figure 3 – Percent slope in the Rice Creek Watershed](image-url)
**Precipitation**

Historical precipitation data (Figure 4) was retrieved from the State Climatology Office – MN DNR Division of Ecological and Water Resources to better understand hydrology and its effects on water quality. This data indicates that normal precipitation in the watershed is between 32 – 33 inches per year.

![Normal Precipitation](image)

*Figure 4 - Normal precipitation from 1981-2010.*

**Land Use**

**Presettlement**

As can be seen in Figure 5, the vegetation in the Rice Creek watershed at Pre-settlement time was primarily Big Woods but there was a pocket of Wet Prairie. Oak Openings and Barrens as well as Aspen-Oak land and Prairie were located nearby, and it is likely that the land classification shifted back and forth over time (Brian Nerbonne, MN DNR, presentation to Rice Creek group, 2/8/2013). This information will be used as we look forward to potential restoration efforts.

![Presettlement Vegetation](image)
Current land use
At present, 84% (3,469 acres) of the watershed (Figure 6) is planted row crops (corn and soybeans). There are also two small beef cattle feedlot operations located between Decker Avenue and Armstrong Road. Other land uses in the watershed are as follows: range-6.6% (272 acres), urban-5.7% (235 acres), forest-3.6% (148 acres), and wetlands-0.1% (4 acres).

Urban expansion
A portion of the Rice Creek watershed, including a section where brook trout are present, is located within the urban expansion areas (Figure 7) of the cities of Northfield and Dundas. Currently there is no active development but it is likely that urban development will increase in the future. A timeline of past development proposals is listed below.
Figure 6 – Current land use in the Rice Creek watershed

Figure 7 – Urban expansion boundaries for Rice Creek watershed
Timeline of Development Plans and Actions

- 1975 - Gravel pit proposal put forward but dropped. Land purchased by private individual for farming.
- 1998 - Replacement of bridge at Decker Avenue and the railroad bridge at Armstrong Road due to flooding.
- 1998 - Bridgewater Township and the City of Northfield signed 20 -year annexation agreement.
- 1999 - Spring Brook Committee Report outlined possible watershed development/use scenarios. Based on this report, suggested resolution regarding stream protection was submitted to the City of Northfield but was never adopted.
- 2007 - Bridgewater Township adopts Comprehensive Planning and Zoning Ordinance.
- 2008 – City of Northfield changes land use to Industrial for future development.
- 2009 - A request was made to the City of Northfield by two landowners for a 450-acre area of land to be annexed into Northfield from Bridgewater Township.
- 2010 - The Economic Development Authority for the City of Northfield contracted with a consultant for development scenarios and public input is solicited.
- 2010 - City of Northfield works on developing a Rice Creek Policy document to be used as guidance for land use development ordinances and stream protection scenarios should annexation occur in the future. As of June 2013 the document still needs to be completed.
- 2012 – Culvert under Armstrong Road was found to be in need of replacement. Rice County Highway Department is planning to replace it in the fall of 2013.

Governance

Bridgewater Township has the planning and zoning authority to include: land use, septic systems, and shoreland ordinance enforcement. In addition, the Township maintains Township roads.

Rice County provides other services to include county highway maintenance and solid waste ordinance enforcement.

For the County Ditch 22 (Figure 1) section of the stream, the Rice County Board of Commissioners is the ditch authority and the Rice County Soil and Water Conservation District (SWCD) serves as the ditch inspector and contracts for maintenance. County Ditch 22 had benefits re-determined in 1985 but there is no record of purchase of land by the County for the one-rod buffer that is more typical with recent re-determination projects (personal communication, Rice County Auditor’s Office, July 1, 2013).

An angler easement, established in the 1970s, exists on a 3/4 stream mile stretch of the stream and crosses Decker Avenue; the easement extends 66 feet on each side of the stream (Figure 1). The purpose of the angler easement is “to permit the development of fish habitat, including tree planting, fencing, erosion control, installation of instream structures, posting of signs, and other such improvements as are deemed necessary;” and “to permit angling by the public.” (Minnesota
A small segment of the stream, from the Armstrong Road to the Cannon River, is within the City of Northfield. There is currently no land in the watershed that is within the boundaries of the City of Dunda. Urban expansion zones for both these cities do include land within the watershed.

**Ditch and Drainage History**

County Ditch 22 (the western half of the watershed) (Figure 1) was established in 1946 and originally had 767 benefitted acres. In 1985, the county redetermined benefits and it now benefits 2603 acres, most likely to added drainage in the area. The ditch is 18,100 feet in length and has an additional 3500 feet of subsurface drainage tile included as part of the system. For the most part, the banks are stable and covered in a dense sod (Steve Pahs, Rice SWCD Manager and Ditch Inspector, personal communication July 2010).

Early aerial photography from 1938 (Figure 8a) indicates the presence of private ditch segments in the vicinity of what would become the terminus of County Ditch 22 (93.22762°W, 44.44532°N WGS 84 datum, decimal degrees). The evolution of County Ditch 22 since its completion in 1948 (Figure 8b), cleanout and extension in 1957 (Figure 8c) and informal extension in 1985 (Figure 8d) suggest continued input of agricultural waters over the last 75 years.

Connectivity between the ditch and stream system has been substantially altered in recent history leading to a complication of how to characterize the system, and what areas are bounded by what state statutes and rules. For example, MN DNR maps show stream designation for the entire waterway east of the intersection of Cates Avenue and 100th Street East; however, the initial County Ditch 22 terminus extended roughly 1254 feet to the NNE of that location.

Additional changes have occurred in the unnamed small tributary coming into Rice Creek from the south, just west of the intersection of 100th Street East and Decker Avenue (93.21407°W, 44.44229°N). An image from 1951 shows a highly channelized waterway (Figure 9a) and subsequent conversion of that entire waterway south of 100th Street East to a tile drainage system in two subsequent steps: half completed in 1961 (Figure 9b) and the other in 1972 (Figure 9c).

An interview with the landowner in 2012 indicated that these tile lines cut through springs/seeps in this region of the watershed, which explains the year-round flow from this system and it’s more constant temperature profile compared to the stream background. (Personal interview with Bruce Albers, July 2012)
Figure 8 - Aerial images reveal changes in Rice Creek/Spring Brook at intersection with County Ditch 22. Location is in SW ¼ of SE ¼ of Section 4, Township 111N, Range 20W (93.22762°W, 44.44532°N). Black arrows indicate County Ditch 22 termination point. a) 1938: upper right shows creek’s sinuosity with private ditch structures up gradient, b) 1951: ditch completed in 1948, c) 1964: county approved ditch extension associated with 1957 cleanout, d) 1991: unofficial 400+ ft extension of the ditch during 1985 cleanout.
Figure 9 - Aerial images reveal changes in southern tributary flowing into Rice Creek/Spring Brook. Location is in NW ¼ of Section 10, Township 111N, Range 20W (93.21407°W, 44.44229°N), just west of Decker Avenue and South of 100th Street East. a) 1951: tributary is an open drainage ditch, b) 1970: Black arrow indicates change from open drainage to buried tile drainage topped with grass swale in 1961, c) 1979: entire reach south of 100th Street East converted to tile drainage in 1972.

Community Water Supply
There is no municipal water supply in the Rice Creek watershed. All drinking water is supplied by private wells.

Point Sources of Pollution
There are no permitted point sources of pollution in the Rice Creek watershed. Although not considered point sources of pollution under the Federal Clean Water Act, there are agricultural drain tile outlets that discharge directly to the stream and many tile outlets in the County Ditch 22 section of the watershed.

Wastewater Treatment
All wastewater treatment in the Rice Creek watershed is handled through Individual Sewage Treatment Systems. Bridgewater Township did not have any record of any failing systems in this watershed.

Feedlots and Manure Management
There are two feedlots for beef cattle within the watershed between Armstrong Road and Decker Avenue. There is a dairy operation just outside the watershed boundaries on the south side of County Ditch 22. Feedlots that are located within 300 feet of the stream (shoreland zone) and have over ten animal units (AU) or greater are required to have a manure management plan. If the feedlot is outside the shoreland zone then the requirement is 50 AU or greater. The manure
management plan places restrictions on rate, timing, and location of manure application to the land. Figures 11 and 12 show areas where manure could be spread as part of existing manure management plans on file with Rice County (personal communication with Wade Schulz, Rice County Feedlot Officer, June 2013).

Previous Work
Prior to this project, some work had been done to evaluate the quality of the stream and encourage landowners to implement practices that would improve the stream. These projects are summarized here.

Spring Brook Committee (1997-1999)
CRWP began work regarding protection for Spring Brook in 1997 with assistance from the Legislative Commission on Minnesota Resources. A “Spring Brook Committee” of citizens, elected officials, and public and private agency personnel was formed and produced a preliminary report on the health of the stream and its watershed. Recommendations of that report included further water quality data collection as well as visions for the future and suggested ordinances for land use to protect the stream.

Citizen Stream Monitoring Program (CSMP) (1999-2012)
Volunteers through the MPCA CSMP program collected water quality information at three locations from 1999-2009. They evaluated transparency of the water and made observations regarding appearance and recreational suitability.

MPCA Macroinvertebrate Assessment - 2004
Rice Creek was sampled by MPCA biological monitoring staff just downstream of Decker Ave. in the summer of 2004. The resulting aquatic macroinvertebrate community data from this cold water stream was assessed using the Southern Coldwater Macroinvertebrate Index of Biological Integrity (M-IBI). This sample revealed the presence of a relatively simple community dominated by the amphipod genus *Gammarus* (likely *pseudolimnaeus*), the mayfly genus *Baetis* (likely species *tricaudatus*), the blackfly genus *Simulium*, and the snail genus *Physa*. A total of 21 macroinvertebrate taxa and one *Ephemeroptera, Plecoptera, Trichoptera (EPT)* taxa were collected predominantly from overhanging vegetation and undercut banks, as these were essentially the only habitat types present in the sample reach. Despite these relatively low numbers (compared to warm water streams) the M-IBI score of 48 was two points greater than the biological impairment criterion. Based solely on the 2004 sample, it appeared that the creek was supporting its aquatic life designated use at that time.

Rice Creek Water Quality Assessment Project (2006-2008) – funded through MN DNR grant
Temperature, flow, stage, and water chemistry data were collected at two locations (Cates Avenue and Armstrong Road). In-depth analysis of data was beyond the scope of this project; however, some commentaries were made when possible. Below is a summary of the information gathered from this project.
• Stream discharge measurements collected with a Pygmy meter and wading rod near Armstrong Road ranged from 0 to 115 cubic feet per second in 2007 and from 1.2 to 10.6 cubic feet per second in 2008.

• *Rice* Creek possible groundwater input sources were identified during a drought period in 2007 at latitude 44°26.861’/longitude -93°13.148’ and latitude 44°26.882’/longitude -93°13.220’.

• Median concentrations for Total Suspended Solids (TSS), Total Phosphorus (TP), and *E. coli* at both sites were within the typical eco-region range for streams. However, maximum TSS, TP, and *E. coli* concentrations at Armstrong Road in 2007 greatly exceeded the eco-region range as shown in Table 1.

• Median and maximum nitrate values in April through early June 2008 at both sites were greater than eco-region values as shown in Table 2.

• Stream samples from Cates Avenue and Armstrong Road had median and maximum nitrate concentrations that were much greater than the eco-region range. These water quality results were based on baseflow and event samples.

• Figure 10 shows possible areas where wetlands could be restored based on work done by the US Fish and Wildlife Service and Ducks Unlimited.

### Table 1 – Summary of Data from Grab Samples in 2007

<table>
<thead>
<tr>
<th>2007 Sample Summary</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>Average</th>
<th>Range</th>
<th># of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparency (cm)</td>
<td>6.5</td>
<td>8.7</td>
<td>&gt;60</td>
<td>&gt;60</td>
<td>58</td>
<td>&gt;60</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>123</td>
<td>40</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>TP (mg/L)</td>
<td>0.02</td>
<td>0.026</td>
<td>0.487</td>
<td>0.511</td>
<td>0.105</td>
<td>0.127</td>
</tr>
<tr>
<td><em>E. coli</em> (MPN/100 ml)</td>
<td>69.7</td>
<td>4.1</td>
<td>&gt;2419. 6</td>
<td>2419. 6</td>
<td>727</td>
<td>248.1</td>
</tr>
</tbody>
</table>

### Table 2 – Summary of Data from Grab Samples in 2008

<table>
<thead>
<tr>
<th>2008 Sample Summary</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>Average</th>
<th>Range</th>
<th># of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparency (cm)</td>
<td>17.2</td>
<td>16</td>
<td>&gt;100</td>
<td>&gt;100</td>
<td>97</td>
<td>&gt;100</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>49</td>
<td>25</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>TP (mg/L)</td>
<td>0.021</td>
<td>0.037</td>
<td>0.22</td>
<td>0.189</td>
<td>0.061</td>
<td>0.067</td>
</tr>
<tr>
<td><em>E. coli</em> (MPN/100 ml)</td>
<td>1</td>
<td>1</td>
<td>344.8</td>
<td>1299. 7</td>
<td>53.05</td>
<td>13.8</td>
</tr>
<tr>
<td>N+N (mg/L)</td>
<td>2.06</td>
<td>2.32</td>
<td>16.6</td>
<td>17.7</td>
<td>11.6</td>
<td>12.1</td>
</tr>
</tbody>
</table>
River Friendly Farmer Project (2007-2009)
CRWP supported farmers with funding and advice to encourage them to implement conservation projects on their land.

Agriculture Shoreland Management Project (2008-2010)
The Agriculture Shoreland Management Project (ASMP) was carried out to educate the public and local government throughout the Lower Mississippi River Basin about the need for shoreland protection through natural vegetation buffers and to identify areas that violate shoreline protection rules utilizing GIS mapping techniques. Results for the SE Minnesota region indicated 92,688 acres (36%) were forested; 54,756 acres (21%) were cropland; 39,475 acres (15%) were grassland; 23,288 acres (9%) were managed grassland; and 12,689 acres (5%) were impervious cover with grasses. Violations of the 50-foot buffer ordinance were documented for each county with violations ranging from 78 to 402 acres (2-9%). It is important to note that this mapping effort included identifying shoreline protection zone violations within the Rice Creek watershed.
**Bridgewater Township Stream Survey (2009-2010)**

In the spring of 2010 CRWP inventoried portions of the streams and public ditches in Bridgewater Township at the request of the Township Supervisors to help them get a better understanding of the conditions and features of these systems.

Findings from that survey indicate that overall County Ditch 22 is relatively featureless. It maintains a very pronounced “V” profile and is overgrown with thick vegetation on the banks and thick emergent vegetation in the stream channel. Tile outlets and culverts were frequent features; some culverts empty grassed waterways or other field drainage directly into the ditch.

Buffer size along the ditch was fairly consistent. On the southern side of the ditch, the buffer averaged approximately five meters in width (measured from the bank edge), while on the northern side of the ditch, the buffer averaged about 4.3 meters in width (measured from the bank edge). This is approximately a one-rod buffer, or 16.5 feet. The buffer ranged in width from a low of zero meters in width (directly east of the intersection of County Ditch 22 and Bachrach Avenue) to a high of 12 meters in width (near a connected grassed waterway); however, the averages listed above were far more common. Average depth where standing water was present was 0.29 meters in June 2010.

Artificial features included numerous tile outlets and several inlets. West of Bachrach Avenue on the northern side of the stream is a large tile water monitoring station, part of a local farmer’s bioreactor installation installed by the Minnesota Department of Agriculture (MDA). Further upstream from this station, flow from the upstream grassed waterway is channeled directly into an open tile intake (located in the channel) and apparently discharged 0.5 kilometers downstream through a tile outlet (also located in the channel); a visual inspection could not determine the reason for this.

Figures 11 and 12 show the locations of drain tile outlets and buffers that were determined through the stream survey and mapping projects. There are several tile inputs from Cates Avenue to Decker Avenue but those locations do not have GPS coordinates and so were not included in the map. Overall there is shorland buffer in place but there are areas where the buffer is not meeting the 50 foot requirement for agricultural shorland and area.
Figure 11 – Locations of tile outlets, buffers and potential manure application in eastern section of watershed (Cates Avenue to Armstrong Rd).
Figure 12 - Locations of tile outlets, buffers and potential manure application in western section of watershed (Start of County Ditch 22 to Cates Avenue).
Project Purpose
In November of 2009, the Rice Creek Concerned Citizens Group submitted a report and list of recommendations to Bridgewater Township to call for collaboration among stakeholders to improve and protect the brook trout community in Rice Creek (Appendix A). The document demonstrates support from local scientists, CRWP staff, a trout habitat specialist with the MN DNR, a former county ditch inspector, area farmers, members of the Northfield City Council and staff, Bridgewater Township Supervisors, habitat restoration agents, agricultural drainage experts and local citizens engaged in agricultural practices and water monitoring.

When Northfield made an annexation request in 2009, which was denied by Bridgewater Township in part because the City of Northfield did not have a stream protection ordinance in place, advocates of Rice Creek realized the urgency for action and partnered their efforts to improve, protect, and conserve Rice Creek.

Project Partners
Project participants consisted of local, regional, and state agencies including Bridgewater Township, Cannon River Watershed Partnership, St. Olaf College, Minnesota Department of Natural Resources, Trout Unlimited, Rice County Soil and Water Conservation District (SWCD), Rice County Planning and Zoning Department, Minnesota Pollution Control Agency, and the Rice Creek Concerned Citizens Group. In the second year of the project the Freshwater Society joined as a partner on outreach to farmers and landowners through their MN FarmWise project.

Other state and federal agencies, cities, and local groups were invited to participate in the public involvement portions of the project including water quality sampling, fish collection, temperature measurement, and other monitoring tasks.

Many volunteers contributed to the Rice Creek project. Local residents and students participated in the following activities:

- Conducted water quality monitoring as part of the MPCA’s Citizen Stream Monitoring Program
- Participated in nitrate surveys and brook trout surveys
- Built and installed monitoring stations
- Designed and installed signs at two stream access points to alert anglers to the trout study
- Photographed precipitation events and creek surveys
- Worked on outreach materials including website postings, presentation materials, fact sheets, and press releases (Appendix B).
- Presented project information to local groups
- Maintained the email distribution list and sent announcements

Volunteers enabled the partners to successfully complete many of the project objectives. Without their help, the project would have fallen far short of its goals. Volunteering was also an excellent and entertaining path for educating and involving the public.
Project Costs by Program Element

Project costs by program element are presented in table 3.

*Table 3 – Project costs*

<table>
<thead>
<tr>
<th>Element</th>
<th>Grant Cash</th>
<th>In Kind</th>
<th>Cash Match</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of Project Workplan</td>
<td>$2,400</td>
<td>$399.64</td>
<td>$3,500</td>
<td>$6,299.64</td>
</tr>
<tr>
<td>Watershed and Stream Characterization</td>
<td>$64,579.64</td>
<td>$34,737.77</td>
<td>$2,428.37</td>
<td>$104,174.15</td>
</tr>
<tr>
<td>Food Web Structure and Function</td>
<td>$9,644.00</td>
<td>$47,353.41</td>
<td>$0</td>
<td>$56,977.41</td>
</tr>
<tr>
<td>Public Outreach and Education</td>
<td>$3,103.25</td>
<td>$43,451.85</td>
<td>$0</td>
<td>$46,555.10</td>
</tr>
<tr>
<td>Model Development</td>
<td>$2240.00</td>
<td>$0</td>
<td>$0</td>
<td>$2240.00</td>
</tr>
<tr>
<td>Project Management</td>
<td>$13,442.35</td>
<td>$10,348.14</td>
<td>$1,000</td>
<td>$24,790.49</td>
</tr>
<tr>
<td>Development of Diagnostic Report and Implementation Plan</td>
<td>$14,787.66</td>
<td>43,738.53</td>
<td>$3,500</td>
<td>422,026.19</td>
</tr>
</tbody>
</table>
Project milestones that were proposed in the workplan along with status by end of the project are included in table 4.

Table 4 – Project Milestones

<table>
<thead>
<tr>
<th>Planned Activity</th>
<th>Time Frame</th>
<th>Responsibility</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective 1: Work plan development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of project work plan</td>
<td>January-March, 2011</td>
<td>CRWP and all other project sponsors</td>
<td>Completed as scheduled</td>
</tr>
<tr>
<td>Objective 2: Watershed and Stream characterization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collection and review existing GIS data</td>
<td>January-April, 2011</td>
<td>CRWP</td>
<td>Completed as scheduled. GIS data was shared between CRWP, St. Olaf and Rice County</td>
</tr>
<tr>
<td>Train citizen stream volunteers</td>
<td>March, 2011/2012</td>
<td>CRWP, St. Olaf College</td>
<td>Most stream monitoring was conducted by staff and faculty</td>
</tr>
<tr>
<td>Stream water quality monitoring</td>
<td>March-September, 2011/2012</td>
<td>CRWP</td>
<td>Completed as scheduled. Drought and spring flooding caused for fewer samples to be collected than originally planned</td>
</tr>
<tr>
<td>Geomorphic assessment</td>
<td>April-September 2011</td>
<td>CRWP, St. Olaf College</td>
<td>St. Olaf collected stream width information. Some bank erosion collected as part of habitat assessment.</td>
</tr>
<tr>
<td>Habitat assessment</td>
<td>April &amp; September, 2011/2012</td>
<td>CRWP, St. Olaf College</td>
<td>Completed August 2011 and October 2012</td>
</tr>
<tr>
<td>Existing channel erosion surveys</td>
<td>April, 2011/2012</td>
<td>CRWP, St. Olaf College</td>
<td>Limited erosion estimates made as part of MSHA surveys.</td>
</tr>
<tr>
<td>Rice Creek stream longitudinal profiling (Conductivity/temperature)</td>
<td>May &amp; September 2011/2012</td>
<td>St. Olaf College</td>
<td>Completed as scheduled. Nitrate and calcium longitudinal profiles were also conducted</td>
</tr>
<tr>
<td>Objective 3: Food web structure and development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish and macroinvertebrate collection</td>
<td>May-August, 2011/2012</td>
<td>St. Olaf College, MPCA</td>
<td>Feb – Aug 2011</td>
</tr>
<tr>
<td>Identify macroinvertebrate to family</td>
<td>May-August, 2011/2012</td>
<td>St. Olaf College, MPCA</td>
<td>MPCA 2011 Oct 2012 St. Olaf student</td>
</tr>
<tr>
<td>Conduct sample preparation for stable isotope analysis</td>
<td>August-December, 2011/2012</td>
<td>St. Olaf College</td>
<td>Completed as scheduled in 2011 only due to staff changes.</td>
</tr>
<tr>
<td>Analyze samples for carbon and nitrogen isotopes</td>
<td>August-December, 2011/2012</td>
<td>St. Olaf College</td>
<td>Completed 2011 only due to staff changes.</td>
</tr>
<tr>
<td>Objective 4: Public outreach and education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project meetings</td>
<td>April 2011/2012</td>
<td>CRWP</td>
<td>Completed as scheduled</td>
</tr>
<tr>
<td>Post website project updates and newsletter articles</td>
<td>April 2011-June 2013</td>
<td>CRWP</td>
<td>Completed as scheduled</td>
</tr>
<tr>
<td>Local Government involvement at Bridgewater Township board meetings</td>
<td>January 2012, May 2013</td>
<td>CRWP, St. Olaf College, Bridgewater Township</td>
<td>Completed as scheduled</td>
</tr>
<tr>
<td>Final public project meeting</td>
<td>May-June 2013</td>
<td>CRWP</td>
<td>Completed June 4, 2013</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective 5: Model development</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUX modeling: stream seasonal and annual loads</td>
</tr>
<tr>
<td>Complete a stage/stream discharge relationship</td>
</tr>
<tr>
<td>Data analysis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective 6: Project Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of project budgeting, invoicing, reporting, and tracking methods</td>
</tr>
<tr>
<td>In-kind tracking for project sponsors/participants</td>
</tr>
<tr>
<td>Project management meetings</td>
</tr>
<tr>
<td>Submit metadata to EQuIS database</td>
</tr>
<tr>
<td>Project reporting</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective 7: Implementation plan development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assess project area data</td>
</tr>
<tr>
<td>Determine watershed area goals</td>
</tr>
<tr>
<td>Establish implementation tasks</td>
</tr>
<tr>
<td>Identify BMPs for priority management areas</td>
</tr>
<tr>
<td>Estimate implementation costs</td>
</tr>
</tbody>
</table>
METHODS

Water Quality & Flow Monitoring
Stream monitoring stations were installed at four locations (Armstrong Rd, Decker Ave, 100th St. East, 100th St. West) within the Rice Creek watershed to cover the two main tributaries and two key locations on the main stream channel (Figure 1). The stations were operated from snowmelt through the end of October in 2011 and 2012. Water chemistry samples, as described in Table 5, were collected for Total Suspended Solids (TSS), Total Phosphorus (TP), Nitrogen, Nitrate+Nitrite (nitrate), Total Kjeldahl Nitrogen (TKN), E. coli bacteria, and turbidity. In addition to chemistry samples, transparency measurements were taken using a transparency tube (2011) and a Secchi tube (2012).

Table 5 – Description of Water Chemistry Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphorus (TP)</td>
<td>Represents dissolved phosphorus and phosphorus attached to particles (often soil) in water</td>
<td>EPA 365.3</td>
</tr>
<tr>
<td>Nitrate-nitrogen (Nitrate)</td>
<td>Nitrate-nitrogen refers to either a measured mass of nitrite and nitrate forms of nitrogen (NO₂ + NO₃), as nitrite mass is typically negligible and close to zero. For this report nitrate will be synonymous with nitrate-nitrogen.</td>
<td>EPA 353.2</td>
</tr>
<tr>
<td>Total Kjenldahl Nitrogen (TKN)</td>
<td>Includes ammonia-N and organic-N.</td>
<td>EPA 351.2</td>
</tr>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td>The most common measure of solids in water.</td>
<td>SM 2540 D</td>
</tr>
<tr>
<td>Turbidity</td>
<td>A measure of light scattering properties of suspended materials; more light scattering materials the less transparent the water.</td>
<td>EPA 180.1</td>
</tr>
<tr>
<td>Transparency</td>
<td>The depth to which light penetrates the water column.</td>
<td>Field measurement using transparency and secchi tube</td>
</tr>
<tr>
<td>E. coli bacteria</td>
<td>An indicator of possible sewage or animal waste contamination</td>
<td>SM* 2223 B–97 (Colilert)</td>
</tr>
</tbody>
</table>
Each station was composed of a wooden box with a 6712 portable automated sampler (Teledyne Isco) powered by a 12v DC battery and a 10w regulated solar panel. A 750 area velocity module (Teledyne Isco) was used in conjunction with each automated sampler to continuously record level (stage), velocity, and calculated discharge in 15 minute intervals. Flow data and sample data were downloaded regularly to a field laptop computer. More information on equipment set up, water chemistry sample data and flow data are provided in Appendix D.

As a result of a June 2012 flood event, three of the four monitoring stations (all but the Decker Avenue site) were washed into the stream or Cannon River. After the flood waters receded, two of the stations were recovered. After discussion with the project team, including MPCA staff, it was decided to reinstall the site at 100th St. E and continue the Decker Avenue site with continuous monitoring equipment. Grab samples were collected for the rest of the season at Armstrong Road and 100th St. West.

Laboratory analysis was completed by RMB Laboratories, Inc., a certified laboratory in Detroit Lakes, Minnesota, with methods used noted in Table 5. Standard operating procedures for the collection of these samples and environmental data are given in the MPCA (2006) Water Quality Programs Sampling and Monitoring Standard Operating Procedures (SOP) manual, and the project’s Quality Assurance Protection Plan (QAPP).

In addition to automated flow measurements recorded by the ISCO units, manual stream measurements were collected under a variety of flow regimes at each of the four monitoring stations. During each stream-gauging event, a tapedown distance measurement was taken to measure the distance from the bridge or culvert to the surface of the water. Velocity was measured at 0.5ft intervals using a wading road, AquaCalc and pygmy or Price type AA meter.

**Load Calculations**

FLUX is an interactive program designed for use in estimating the loadings of nutrients or other water quality components passing a tributary sampling station over a given period of time. These estimates can be used in formulating reservoir nutrient balances over annual or seasonal averaging periods appropriate for application of empirical eutrophication models. ([http://cfpub.epa.gov/crem/knowledge_base/crem_report.cfm?deid=74894](http://cfpub.epa.gov/crem/knowledge_base/crem_report.cfm?deid=74894)). The plan for this project was to use the FLUX32 version of the model to calculate pollutant loading.

**Longitudinal Monitoring**

On two occasions (May and August 2012), longitudinal surveys were conducted in order to gain a better understanding of nitrate and calcium at a particular point in time along the entire designated trout stream. Several volunteers were stationed along the creek with instructions to collect grab samples within a tight window of time, about 20 minutes. Samples were then sent to RMB Laboratories for analysis.

**Tritium**

Three sites were sampled for tritium on October 8, 2012: the monitoring station at Armstrong Road, a deep hole about 85 meters downstream of the Decker Avenue bridge and the tile outlet at 100th St. East. This sampling was carried out to assist in dating the groundwater and helping determine if recharge was moving from a shallow or deeper groundwater source. Samples were collected in a 1L HDPE plastic bottle, filled to the top with no head space, and air tight to
prevent evaporation. Specific Conductance (µS/cm) and pH were also measured using a field Hach meter (HACH HQ40d multi) at the time of sample collection.

Samples were shipped to the University of Waterloo Environmental Isotope Laboratory for enriched tritium (E³H) analysis, a liquid scintillation counting method with a detection limit of ±0.8 TU.

**Stream Temperature and Conductivity**

Stream temperatures were determined by continuous monitoring as well as spot monitoring with hand held devices. Over the study period four continuous temperature stations were installed, three during the first year and a fourth in the second year. Data loggers (Onset HOBO Water Temperature Pro v2, U22-001) were set to record stream temperatures at 15-minute intervals to the nearest 0.02 °C. Units were affixed by heavy duty wire or zip ties to concrete blocks positioned in the middle of the stream channel. Accuracy of these units is 0.2 °C. Sensor position was adjusted to read temperature approximately five centimeters from the stream bed. The first three stations, shown in Table 6 and Figure 1, span a range of riparian habitat and represent significant zones in the reach. The Armstrong Road station (S001-445) essentially serves as the *de facto* mouth of the stream; the drainage of the entire watershed passes through this point. After passing under Armstrong Road in an elevated culvert, there is not much connectivity with the remaining 100 meter link to the Cannon River. The Spring Brook Forest station sits inside the riparian forest zone of the stream, near the eastern edge of the trout fishing easement. It permits one to contrast the two grassland stations and this different riparian cover. The third station, named Decker Down (04LM077), sits ~65 meters downstream of the junction point for two branches of the creek. This station serves to examine thermal inputs from the upgradient components of the stream system and establish what water temperatures are entering parts of the stream with higher trout densities. The final station, added in 2012, monitors water temperature from a buried agricultural drainage system which was installed during the 1960s and 1970s. What was a natural tributary to Rice Creek was converted to channeled, agricultural ditch beginning in 1946. The logger and block were positioned in the upstream drainage outflow box and situated on the west side of the culvert passing under 100th Street East so that the logger would record the average temperature of water flowing past. The underground flow in this system should reflect a smaller diurnal temperature variation throughout the seasons. Spot monitoring of stream conductivity and temperatures were conducted using a handheld YSI Model 30 Salinity, Conductivity and Temperature System.
Table 6 - Stream Temperature Stations on Rice Creek

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Coordinates</th>
<th>EQuIS Station ID</th>
<th>Dominant Vegetation</th>
<th>Installation Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong Road</td>
<td>N44.444820°</td>
<td>S001-445</td>
<td>Grassland/Pasture</td>
<td>13 Apr 2011</td>
</tr>
<tr>
<td></td>
<td>W93.191740°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. WGS 84 datum, decimal degrees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring Brook Forest</td>
<td>N44.44426°</td>
<td>S001-444</td>
<td>Riparian Forest</td>
<td>13 Apr 2011</td>
</tr>
<tr>
<td></td>
<td>W93.20684°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decker Down</td>
<td>N44.44583°</td>
<td>04LM077</td>
<td>Grassland</td>
<td>13 Apr 2011</td>
</tr>
<tr>
<td></td>
<td>W93.21053°</td>
<td>S001-444</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100th Street East</td>
<td>N44.44303°</td>
<td>S006-843</td>
<td>Shrubs/Ag Field</td>
<td>12 Jun 2012</td>
</tr>
<tr>
<td></td>
<td>W93.21407°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Centerline Stream Temperature Method

A centerline stream walk was used to probe for possible cold water input sources into the Rice Creek system. Small, accurate, water resistant, rapid response temperature loggers (Dallas Thermochron DS1922L-F5 iButtons) were used to record stream temperature to the nearest 0.0625 °C every six seconds. On-board memory storage allowed more than 5 hours of data collection time once the loggers initiated. Six iButtons were bundled into a 12 cm x 12 cm nylon mesh basket (1.5 mm mesh spacing) and the basket was closed by weaving a narrow gauge wire through the nylon mesh. Duct tape was then placed over the closed end of the bag to serve as a secondary seal and to prevent the nylon mesh from catching stream debris. As shown in Figure 13 the mesh bag was affixed by narrow gauge wire to the eyelet on the bottom of a 1.2 m, 2.5 cm diameter painted wood rod. The rods allow the baskets to be dragged just off the bottom of the stream bed. GPS track logs were recorded with Garmin GPS-76S handheld units. All signals (fixed-temperature stations, centerline-walk temperatures and the six iButtons) would be merged into one data set and processed. Processing would attempt to match GPS position with stream centerline temperatures, and the background stream temperature would be subtracted from the centerline data. Due to time and availability, centerline walks did not occur until early October 2012. Ideally the walks would have happened during a warm day in late summer/early fall to promote sensing greater temperature differentials.

Figure 13. iButtons bundled in nylon mesh bags and readied for stream temperature measurements.
Watershed Assessment

Habitat Assessment
An assessment of the aquatic habitat was conducted at 101 points along the designated trout stream in 2011 and again in 2012 using the MPCA Stream Habitat Assessment (MSHA) protocol. This protocol was designed to provide an empirical evaluation of stream habitat characteristics that are important to fish communities and other aquatic life. The MSHA incorporates measures of watershed land use, riparian quality, bank erosion, substrate type and quality, in-stream cover, and several characteristics of channel morphology. The MSHA assessment worksheet is based on a scale of 0 to 100 ranging from very poor (<30), poor (30-44), fair (45-59), good (60-74), and excellent (75-100).

Stream Width
The mean stream width of Rice Creek was determined by segmenting the entire trout habitat into three smaller reach sections. The down gradient reach (1) is bounded by Armstrong Road on the east and Decker Avenue on the west. One of the two up-gradient reaches reflect the main stream channel (2) bounded by the Nichol Property on the west and Decker Avenue on the east. The last up gradient reach (3) is the drainage coming into the system from the south, flowing under a culvert located just to the west of Decker Avenue and passing under 100th Street East. Each reach was divided into a series of existing and new stations, ten in total, such that stream width could be measured moving upstream from the station coordinates. Typically the station transects measured approximately 100 meters. The wetted width of the stream channel was measured to the nearest hundredth of a meter at 8-10 meter transect intervals during the third week of July 2012. Since Rice Creek is a low gradient stream, the wetted width is the defined portion of the stream channel, and it does not include adjacent wetlands and areas of emergent vegetation.

Brook trout Surveys
Trout were sampled on approximately 10 occasions from April through October 2011 and on two occasions in July 2012. Sampling stations are listed in Table 7. Seines were used to collect trout early in the season (April – July) and permitted more effective capture of young of the year. A Smith-Root LR-24 backpack electrofisher with one anode and dip net was used to collect trout later in the season using pulsed direct currents. In April through June 2011 captured trout that were more than 110 mm total length were measured to the nearest millimeter, sexed by external identification (if possible), and tagged with a Biomark HPT12, 12.5 mm, 134.2 kHz, passive integrated transponder (PIT). Tags were inserted into the body cavity and 500 individuals received tags. After tagging, trout were released back into the pool from which they were captured. Trout were resampled using backpack electrofishing during July – November 2011 and again in July 2012. Tags were read with a Biomark 601 handheld reader. Figure 1 shows the site locations.
Table 7. Primary Rice Creek Trout Sampling Stations

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Coordinates</th>
<th>Dominant Vegetation</th>
<th>EQuIS Station ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong Fish</td>
<td>N44.44597° W93.19577°</td>
<td>Riparian Forest</td>
<td>11LM099</td>
</tr>
<tr>
<td>Spring Brook Forest</td>
<td>N44.44426° W93.20684°</td>
<td>Riparian Forest</td>
<td>n/a</td>
</tr>
<tr>
<td>Decker Down</td>
<td>N44.44583° W93.21053°</td>
<td>Grassland</td>
<td>04LM077</td>
</tr>
<tr>
<td>Armstrong Road</td>
<td>N44.444820° W93.191740°</td>
<td>Pasture/Grassland</td>
<td>S001-444</td>
</tr>
<tr>
<td>Decker Up</td>
<td>N44.44687° W93.21339°</td>
<td>Grassland</td>
<td>n/a</td>
</tr>
</tbody>
</table>

a. WGS 84 datum, decimal degrees

Food Web Isotope Analysis
Tissue samples for stable isotope analysis were taken from selected individuals by clipping a sliver from the lower caudal fin (unless it was a recapture in which case the upper caudal or the dorsal fin was clipped). A subsample of fish was sacrificed and a sample of muscle tissue was taken for comparison of muscle isotopes and fin clip isotopes. Fin clips were preserved in a freezer. Small subsamples of trout at each site, usually three, were sedated with sodium bicarbonate and gut contents were collected via gastric lavage. Stomach contents were preserved in 70% ethanol and identified in the laboratory under a dissecting microscope.

Stable isotope analyses were run on the Delta V Advantage Isotope Ratio Mass Spectrometer coupled with a Costech Elemental analyzer and TC/EA at St. Olaf College.

All trout fin clips and trout muscle tissue were oven-dried at 55°C for at least 36 hours and ground to a fine powder using mortar and pestle. For δD analysis, approximately 2.5mg of each sample was weighed into a silver capsule and allowed to equilibrate with local water vapor for greater than 96 hours. Samples were calibrated against VSMOW SLAP2 GI water standards. Apple leaves were calibrated against these water standards and used as internal laboratory standards to monitor precision and accuracy. Approximately 0.7 mg of each sample was weighed into tin capsules for carbon and nitrogen isotope analyses, which were performed on the same sample. We used Glutamic acid 40 and Glutamic acid 41 as standards calibrated against VPDB (Vienna Pee Dee Belemite) for carbon and air for nitrogen.

Macroinvertebrates
As part of the MPCA Intensive Watershed Monitoring (IWM) effort for the Cannon River Watershed a 1.9 mile reach between two sites (Decker Downstream and Spring Brook Forest) were sampled in 2011. Figure 1 shows the sampling locations.

Aquatic macroinvertebrates were sampled following MPCA protocols (EMAP-SOP4, Rev. 0). At each station, the two to three most dominant habitat types observed (e.g., rock, woody debris, bank, overhanging vegetation, and instream vegetation) were sampled with a Dipnet in
proportion of availability for a total of 20 habitat samples. Composited samples were preserved and sent to a lab where the specimens were identified to the lowest taxonomic level resolvable. Streams were classified based on drainage area size and stream type (e.g., glide-pool and riffle-run) and MIBI scores were calculated using metrics developed specifically for each stream class.

Fish samples were also collected as part of this sampling following MPCA protocols.

**GIS Terrain Analysis**
A terrain analysis was performed, by Joel Nelson of the University of Minnesota, for the Rice Creek watershed using the 1m dataset. Individual quarter-quarter quadrangle section tiles were downloaded and merged together as points. These points were assembled and interpolated by the ArcGIS 10.1 tool TOPOGRID. TOPOGRID utilizes spot elevation data, and in this instance, a stream burn layer which was modified from the MN DNR 24K streams layer and heads-up digitized for sections where the data was incorrect. Pit or sink-filled versions and non-pit-filled versions were used to interpolate a hydrologically-conditioned DEM with the aid of the TOPOGRID command and the above mentioned layers. Several other programs besides ArcGIS 10.1, including SAGA GIS, TauDEM, and Whitebox GAT, were used to calculate a host of terrain attributes.

**Tillage Survey**
In November 2012, a tillage survey was conducted to obtain up-to-date information on farming practices in the watershed. The survey was conducted by driving around the watershed with an experienced, local farmer and making best estimates of the type of tillage practice.

**RESULTS and DISCUSSION**

**Weather Conditions**
Precipitation and weather in 2011 and 2012 deviated from normal in many months which complicated data collection and modeling for this project. The watershed experienced seesawing weather conditions with two years of mostly drought conditions punctuated by two flood events. These issues will be addressed later in the report.

A summary of these two summers is provided in Table 8, and Figure 14 shows the precipitation departure in 2011.
The first half of 2011 saw temperatures that were one to nearly two and a half degrees cooler than normal in southeast Minnesota. July and October were notably above average with 4.7 and 4.6 degrees above average, respectively. Precipitation was near or above average for most of the year with more than an inch more rainfall than normal in April, June, and July. Departures below average occurred in August through October with August having the greatest disparity of 2.63 inches. July 2011 ranked among the ten warmest Julys in Minnesota's modern record. The remainder of the year was warm and dry as the U. S. Drought Monitor, released on October 27, depicted nearly every county in Minnesota as experiencing some level of drought. The month of September saw the second driest September on record, going back to 1882.

In 2012 there was limited snowmelt due to a dry winter. Spring precipitation was close to normal with the exception of May and June which had more rain. Large areas in southern Minnesota received three or more inches of rain from May 4 through May 6. On May 23 and 24, over four inches of rain fell in some southern and eastern Minnesota communities. A large rain event on June 14 dropped six to eight inches on portions of Rice, Dakota, and Goodhue Counties. The axis of the heaviest rainfall totals aligned nearly perfectly with the axis of the Cannon River watershed, amplifying the river flooding. Average totals during the second half of the year were lower than normal with September being much drier than normal.
Table 8. Monthly average precipitation for Southeast Minnesota and departure from normal in 2011 and 2012.

<table>
<thead>
<tr>
<th>Month</th>
<th>2011 Average Precipitation (inches)</th>
<th>2011 Departure from Normal (inches)</th>
<th>2012 Average Precipitation (inches)</th>
<th>2012 Departure from Normal (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.73</td>
<td>-0.29</td>
<td>0.68</td>
<td>-0.25</td>
</tr>
<tr>
<td>February</td>
<td>1.12</td>
<td>0.30</td>
<td>1.59</td>
<td>0.67</td>
</tr>
<tr>
<td>March</td>
<td>2.82</td>
<td>0.88</td>
<td>1.68</td>
<td>-0.26</td>
</tr>
<tr>
<td>April</td>
<td>4.72</td>
<td>1.63</td>
<td>2.9</td>
<td>-0.15</td>
</tr>
<tr>
<td>May</td>
<td>3.83</td>
<td>0.16</td>
<td>5.23</td>
<td>1.5</td>
</tr>
<tr>
<td>June</td>
<td>5.22</td>
<td>1.04</td>
<td>6.2</td>
<td>1.69*</td>
</tr>
<tr>
<td>July</td>
<td>5.88</td>
<td>1.43</td>
<td>3.32</td>
<td>-0.96</td>
</tr>
<tr>
<td>August</td>
<td>1.71</td>
<td>-2.63</td>
<td>2.89</td>
<td>-1.63</td>
</tr>
<tr>
<td>September</td>
<td>1.98</td>
<td>-1.44</td>
<td>1.13</td>
<td>-2.47</td>
</tr>
<tr>
<td>October</td>
<td>0.92</td>
<td>-1.35</td>
<td>2.37</td>
<td>0</td>
</tr>
<tr>
<td>November</td>
<td>0.61</td>
<td>-1.48</td>
<td>0.65</td>
<td>-1.35</td>
</tr>
<tr>
<td>December</td>
<td>1.17</td>
<td>0.08</td>
<td>1.5</td>
<td>0.27</td>
</tr>
</tbody>
</table>

*There was a single 8” rain event in June that resulted in this above average result

Flow

Stage (level) and discharge (flow) were measured from 7 – 13 times (Table 9) at each of the four monitoring stations. Typically, low stage is accompanied by low discharge and the alternate is also true, higher stage dictates higher discharge. Measuring these two parameters under a variety of flow regimes and plotting them on a graph provides a stage-discharge relationship that can be used to determine the rate at which a packet of water is moving through the stream at any level (stage). Understanding discharge is important for predicting flood conditions. It is also useful for calculating pollutant loads using FLUX software.

Automated area-velocity flow meters helped to collect continuous flow data in 15-minute intervals. Channel dimensions were carefully measured and programmed into the logger, which calculated the flow based on geometric equations and the input parameters; however, natural streams rarely fit perfectly into the geometric algorithms that the logger employs. For this reason, manual discharge measurements, collected at a variety of flow regimes, help to field check the logger discharge dataset. Manual and logger discharge data, when used in tandem, provide an accurate, continuous record of flow.

This project period fell during two consecutive drought years in which a couple of very large rain events occurred. The data record for 2011 and 2012 on Rice Creek contains mostly low flows with some mid-range flow, but very few high flows. Ideally, 12-15 manual measurements would be collected at each of the stations across a variety of flow regimes to build a reliable stage-discharge relationship. Pollutants such as TP and TSS tend to increase with flow, while nitrate...
tends to decrease as flow increases. In order to use FLUX software to confidently calculate annual mass loading, more high flow data are required. Table 9 summarizes the manual discharge data that was collected during the project period at each site. Flow data are provided on a disc as part of Appendix D.

Table 9. Summary of manual gaging using wading rod

<table>
<thead>
<tr>
<th>Monitoring Site</th>
<th>Sample Size</th>
<th>Range of discharge (cfs)</th>
<th>Range of stage (ft)</th>
<th>R² coefficient</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong Road (S001-445)</td>
<td>13</td>
<td>&lt;1.0 - 16.6</td>
<td>0.45</td>
<td>0.7454</td>
<td>Measured about 50 ft upstream of 9ft round pipe. Medium vegetation control.</td>
</tr>
<tr>
<td>Decker Avenue (S001-444)</td>
<td>8</td>
<td>&lt;1.0 - 8.5</td>
<td>0.98</td>
<td>0.933</td>
<td>Measured 10 ft downstream of bridge. Often stagnant beginning in mid-summer. Medium tree debris control.</td>
</tr>
<tr>
<td>100th St. East (S006-842)</td>
<td>9</td>
<td>&lt;1.0 - &lt;1.0</td>
<td>0.23</td>
<td>0.7485</td>
<td>Measured in 9 ft round pipe. Very flashy here, difficult to catch higher flows. Constant tile/spring flow and event surges. Due to tile input, this reach was very flashy. Clear channel control.</td>
</tr>
<tr>
<td>100th St. West @ Cates (S006-843)</td>
<td>7</td>
<td>2.0 - 6.0</td>
<td>0.62</td>
<td>0.7561</td>
<td>Measured 5 ft upstream of culvert. This section of the stream typically went dry in mid August.</td>
</tr>
</tbody>
</table>

Two drought years, dry stream reaches, flooding, and natural variability in channel dimensions posed some challenges; however, a strong relationship is achievable with more data. A more comprehensive set of flow measurements, particularly at high flow, is needed to confidently calculate TP, TSS and nitrate pollutant loads for Rice Creek.

Habitat Assessment

Two habitat assessments were completed in consecutive years, segregated by a major flooding event (June 2012). This provided an opportunity to see how the flood impacted the habitat quality of the stream.

In 2011 the habitat assessment results (Figure 15) shows that west (upstream) of Decker Avenue had mostly fair to poor scores with a scattering of good scores. Downstream (East) of Decker Avenue had slightly higher scores with mostly fair to good scores and several excellent scores with several poor and one very poor score in the section between Armstrong and Decker where cows graze along the stream. The average score was 52.
The 2012 habitat assessment (Figure 16) shows a more gradual increase in habitat quality from upstream sites to the outlet to the Cannon River. The average score was 56.

Over the two-year survey, many sites improved significantly, particularly just east of Decker Avenue and halfway between Decker Avenue and Armstrong Road as can be seen in Figure 17. Alternatively, several sites saw a significant decrease in habitat score: just west of Decker Avenue and before the outlet to the Cannon River. The differences between the two years show that areas with higher scores had degraded while areas with lower scores had improved, as if habitat quality shifted downstream. As a result of the June 2012 rain event, the bedload material had moved downstream. In areas where sediment was cleared, the habitat assessment score had improved. Sites with higher scores were also the result of increased vegetative cover over the instream zone. Further downstream where the suspended material had slowed and deposited, habitat assessment scores were lower. Data also showed that areas with lower scores also had increased bank erosion, pooling, and decreased channel stability compared to the previous year, which was most likely a result of the June 2012 flood event.
Figure 16 – Habitat assessment 2012
In addition to surveying the habitat in Rice Creek, we wanted to learn more about how others had carried out stream restorations in similar settings. We invited Dr. Michael Osterholm to give a presentation on trout stream restoration. Dr. Osterholm has successfully restored three trout streams on his farm in Allamakee County, Iowa, which is located in the Driftless area. The Driftless area is a geographic area in the Upper Midwest that was untouched by the most recent glaciation and includes a portion of southeastern Minnesota. Its original vegetation was mostly tall-grass prairie and oak savanna (grasslands with scattered oaks). Rice Creek is located in the area targeted by Trout Unlimited’s Driftless Area Restoration Effort, and its watershed was covered by oak-aspen savannas (likely alternating with prairie) and wet prairies before European settlement. Following are highlights from his presentation:

- No “cookie cutter” approach applies to every trout stream. What works in the northeastern states or even eastern Wisconsin may not work in Rice Creek. You need to adopt and adapt techniques that work for your specific stream and geographic area.

- Dr. Osterholm started restoring trout streams on his farm using the traditional approach of “hard armoring.” In this approach, you armor or stabilize stream banks using hard materials.
such as rocks and concrete and build artificial structures for trout habitat (for example, “lunker bunkers” for the trout to hide and hunt for prey). This approach was costly and subject to damage during floods.

- He later adopted an “evolving soft armor” approach. Following are the basic building steps:
  - Apply to cold-water streams in the Driftless or similar areas
  - Remove trees a minimum of 60 feet from the stream bank; focus effort on this zone
  - Grade stream banks to a 1:4 slope
  - Plant with a cover crop and tall-grass prairie mix heavy on grasses and sedges
  - Continue to apply as an ever-evolving science and practice

- The soft armor approach costs less to implement and maintain:
  - Costs $4-11 per stream foot to construct compared to $25-45 per foot for hard armoring
  - Does not require volunteer labor, while hard armoring often does
  - Costs $1-2 for maintenance during initial 2-4 years
  - Creates a stream that is resilient to floods, reducing maintenance costs
  - Requires less maintenance: prairie burning and brush cutting

- The soft armor approach has the following restoration impacts:
  - Stabilizes stream banks and decreases bank erosion
  - Improves the substrate by reducing siltation and increasing the amount of boulders, cobble and gravel
  - Naturally creates features preferred by trout such as deep pools (without excavation), rocky riffles (without dumping rock), and “hides” of undercut banks (without concrete bunkers)
  - Increases trout numbers (for example, from roughly 1500 to nearly 4000 per mile in his streams)
  - Creates a habitat that deters invasive species (that is, desirable prairie plants outcompete noxious plants)
  - Cools water by covering exposed banks and shading open water with tall grasses

- Trees are the “number one enemy” to trout streams in the Driftless area:
  - Trees result in less recharge to ground water and more runoff to streams than prairies or oak savannas.
  - Trees provide little undergrowth and roots to stabilize banks, so they result in more bank erosion. One cubic yard of tall-grass prairie contains 25 miles of roots and root hairs.
  - Reed canary grass is another “enemy” due to its shallow roots. It should be aggressively removed.
• While watershed-wide improvement is ideal, restoring even “one mile at a time” can make a big difference to trout and other cold-water populations.

We will use the information learned from this presentation to inform restoration work on Rice Creek. The Twin Cities Chapter of Trout Unlimited plans to do a restoration project to improve habitat on the trout stream easement section of the stream beginning in the summer of 2013. This should help to address some of the degraded areas on the east side of Decker Avenue.

**Stream Width Data**
The Rice Creek system is a highly wadeable stream as shown by the mean stream width data in Tables 10 and 11. On average, the stream width is approximately 3.2 ± 1.2 meters, narrowing in some stations to just over a meter in width and expanding in others to nearly six meters. As expected the width of the stream increased as one moved down gradient. Furthermore the data suggested the adjacent land use has an influence on stream width. Across the entire system and within reach 1, there were statistically significant differences in the stream width between grassland and riparian forest regimes. The grasslands yielded a stream width significantly narrower than the forested zones. This observation is consistent with that reported by Trimble (1997) and subsequent studies involving southeast Minnesota trout streams (Blann 2002; Vondracek 2005). As we look toward restoration planning and projects, we wish to promote narrow and deeper channels; use of a “soft armor” approach of deep-rooted grasses with less trees should be considered.

**Table 10. Mean Stream Width for Rice Creek and Reach Segments**

<table>
<thead>
<tr>
<th>Reach Descriptor</th>
<th>MSW (m)</th>
<th>Stdev (m)</th>
<th>Msmts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Creek (entire)</td>
<td>3.16</td>
<td>1.2</td>
<td>99</td>
</tr>
<tr>
<td>Reach 1</td>
<td>3.98</td>
<td>1.8</td>
<td>50</td>
</tr>
<tr>
<td>Reach 2</td>
<td>3.14</td>
<td>0.9</td>
<td>30</td>
</tr>
<tr>
<td>Reach 3</td>
<td>1.67</td>
<td>0.7</td>
<td>19</td>
</tr>
<tr>
<td>Reach 1 grasslands$^a$</td>
<td>2.43</td>
<td>0.6</td>
<td>20</td>
</tr>
<tr>
<td>Reach 1 forest$^a$</td>
<td>5.02</td>
<td>1.5</td>
<td>30</td>
</tr>
<tr>
<td>Grasslands$^b$</td>
<td>2.63</td>
<td>0.7</td>
<td>30</td>
</tr>
<tr>
<td>Forest$^b$</td>
<td>4.27</td>
<td>1.6</td>
<td>51</td>
</tr>
</tbody>
</table>

a. Habitat comparisons in reach 1; variances and means are statistically different at alpha = 0.05
b. Habitat comparisons across all reaches; variances and means are statistically different at alpha = 0.05
Table 11. Mean Stream Width *and Station Locations for Rice Creek Reach Segments*

<table>
<thead>
<tr>
<th>Reach</th>
<th>Station Name</th>
<th>Coordinates</th>
<th>Mean Stream Width (m)</th>
<th>Std Dev (m)</th>
<th>Dominant Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Armstrong Road</td>
<td>N44.444820° W93.191740°</td>
<td>2.43</td>
<td>0.57</td>
<td>Grassland/Pasture</td>
</tr>
<tr>
<td>1</td>
<td>Armstrong Fish</td>
<td>N44.44597° W93.19577°</td>
<td>5.78</td>
<td>2.05</td>
<td>Riparian Forest</td>
</tr>
<tr>
<td>1</td>
<td>Prawer Forest</td>
<td>N44.44534° W93.20154°</td>
<td>4.51</td>
<td>0.99</td>
<td>Riparian Forest</td>
</tr>
<tr>
<td>1</td>
<td>Spring Brook Forest</td>
<td>N44.44426° W93.20684°</td>
<td>4.54</td>
<td>0.77</td>
<td>Riparian Forest</td>
</tr>
<tr>
<td>1</td>
<td>Decker Down</td>
<td>N44.44583° W93.21053°</td>
<td>2.41</td>
<td>0.68</td>
<td>Grassland</td>
</tr>
<tr>
<td>2</td>
<td>Decker Up</td>
<td>N44.44687° W93.21339°</td>
<td>3.02</td>
<td>0.62</td>
<td>Grassland</td>
</tr>
<tr>
<td>2</td>
<td>West Nichols</td>
<td>N44.44658° W93.22363°</td>
<td>2.79</td>
<td>0.60</td>
<td>Riparian Forest</td>
</tr>
<tr>
<td>2</td>
<td>East Nichols</td>
<td>N44.44740° W93.22159°</td>
<td>3.58</td>
<td>1.06</td>
<td>Riparian Forest</td>
</tr>
<tr>
<td>3</td>
<td>Lower 100th Street</td>
<td>N44.44512° W93.21219°</td>
<td>1.13</td>
<td>0.17</td>
<td>Grassland/ Shrubs</td>
</tr>
<tr>
<td>3</td>
<td>100th Street East</td>
<td>N44.44303° W93.21407°</td>
<td>2.28</td>
<td>0.45</td>
<td>Shrubs</td>
</tr>
</tbody>
</table>
Brook trout Data & Discussion
The ability to tag 500 brook trout in Rice Creek suggests that these fish are quite common in this stream system. A vast majority of these fish were captured and tagged at the stations listed in Table 7, the first three stations yielded high numbers during the sampling period. In late spring and early summer young of the year numbers were high in the pasture area just west of Armstrong Road (S001-445), and as the summer progressed young of the year captures moved further upstream. During each capture period fish were measured for length.

Two major flood events occurred near and during the study period, which may impact trout numbers. Major rains in the Cannon River Watershed yielded substantial flooding of Rice Creek and the local community in late September 2010. Again in mid June 2012, heavy rains over a short time led to severe flooding in the Rice Creek system.

Figure 18 and Table 12 shows the length distribution of *Salvelinus fontinalis* (brook trout) in Rice Creek across three survey years, two during this study and one historic time point.

### Table 12. Presence and Length Distribution of Salvelinus fontinalis in Rice Creek

<table>
<thead>
<tr>
<th>Reach Descriptor</th>
<th>2011&lt;sup&gt;a&lt;/sup&gt;</th>
<th>2011&lt;sup&gt;b&lt;/sup&gt;</th>
<th>2012&lt;sup&gt;c&lt;/sup&gt;</th>
<th>1972&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean length (cm)</td>
<td>18.8</td>
<td>15.7</td>
<td>18.3</td>
<td></td>
</tr>
<tr>
<td>Median (cm)</td>
<td>18.6</td>
<td>15.2</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Std dev (cm)</td>
<td>3.9</td>
<td>3.5</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Young of Year</td>
<td>55</td>
<td>58</td>
<td>189</td>
<td></td>
</tr>
<tr>
<td>Total sampled</td>
<td>525</td>
<td>167</td>
<td>196</td>
<td>119</td>
</tr>
<tr>
<td>Total recaptured</td>
<td>n/a</td>
<td>32</td>
<td>8</td>
<td>n/a</td>
</tr>
</tbody>
</table>

<sup>a</sup> Individuals sampled and tagged April – July 2011  
<sup>b</sup> Individuals sampled October 2011 in 0.25 miles of reach; 3 fish showed scars but no tag  
<sup>c</sup> Individuals sampled July 2012  
<sup>d</sup> Individuals sampled 07 June 1972 and mean estimated from frequency distribution.

Using length as a rough proxy for age, one observes a distinct shift in age class between the two study years. In 2011 a fair number of fish are likely two or more years of age (≥ 20 cm), and many fewer occur in this region of the distribution in 2012. Similarly the mean and median both show a 3 cm decrease in length during 2012 compared to the year prior, likely favoring an age class of 1 year. One possible explanation for this observation might be the major flood events associated with the study period. Flooding in September 2010 likely improved spawning habitat in the system by cleaning out areas used for reds (areas where trout lay eggs), leading to a successful 2011 young-of-year class which would then be of measurable size, as year 1 fish, in the 2012 sampling period. This would serve as a plausible explanation for the much lower recapture rate in 2012, where a large class of untagged fish entered the measurable population. The team also obtained an early survey of brook trout from 1972 and computed the rough mean length of the measured population in that study based on the size distribution report. Figure 18 shows the size distribution in 1972 is consistent with that observed in 2011.
Figure 18. Length distribution of Salvelinus fontinalis in Rice Creek across three survey years. Mean length shifts from nearly 19 cm in 2011 (n=525) to approximately 16 cm in 2012 (n=196). The 1972 (n=119) and 2011 length distributions closely mirror one another.

Our recapture studies from October 2011 did not yield large numbers of tagged fish. We suspect some tags were lost and observed a few fish with injection scars but no tag. This is consistent with Dieterman & Hoxmeier (2009), and we would recommend future studies use insertion into the dorsal musculature. Of those recaptured, we did a rough estimate of population. We compared the number of tags deployed to the average recapture rate (21%) then extrapolated to a population size based on how much of the stream was sampled and locations of viable habitat for brook trout. Depending on habitat lengths, we estimate the fish population in the neighborhood of 2000-2500 individuals. We estimate that this is roughly 3,350 trout/mile although this estimate may be on the high side. Only three of the 32 trout were recaptured in a location different from the tagging area. Two of those three had traveled more than a few hundred meters upstream or downstream. The observation that brook trout generally reside in a narrow stream distance of habitat is consistent with that reported by Hoxmeier and Dieterman (2013), and references therein.

According to Hoxmeier and Dieterman (2013) there is little consensus as to what season is limiting survival for stream trout and they suggest survival may be dependent on conditions during each season rather than a specific time period. Waters (1999) reports that brook trout
survival appears to be driven by flood events, especially severe flooding; however, brook trout have also been shown to recover quickly from flood events by increasing recruitment (Smith & Atkinson, 1999). Our own study results are consistent with these interpretations.

In addition to the trout work conducted by St. Olaf College the MPCA collected samples at two sites on Rice Creek as part of a larger sampling of 71 total stations of southern, coldwater streams. At the site upstream of Armstrong Road (11LM099) they collected 290 brook trout for 175 meters sampled (1.7 fish/m). Compared to other streams with approximately comparable size, the number of trout collected at this site was the highest number/station and 3rd highest number/meter. At the station upstream of Decker Avenue (04LM077) they collected 50 brook trout for 158 meters (0.3 fish/m). If the two stations were averaged the stream would be the sixth highest in number. Based on this information the brook trout collected at Rice Creek are more abundant than most of the smaller southern coldwater streams in the state (Brenda Asmus, MPCA, personal communication, May 20, 2013).

**Brook trout Genetics**

According to local lore the brook trout occupying Rice Creek (a.k.a. Spring Brook) were stocked sometime in the late 1800s or early 1900s by a local landowner, W. F. Schilling. Some years later, after fish stocks were depleted, another story has a farmhand making a trip to western Wisconsin in the 1920s or 1930s to add another supply of fish to the system. Early genetic work by the MN DNR showed the brook trout in Rice Creek to be genetically unique compared to some known stocks in southeast Minnesota. As a consequence, the MN DNR Fisheries transferred fish from Rice Creek to stock other streams in the region, namely, Bullard Creek, Deering Valley Creek, Miller Valley Creek and Trout Valley Creek (Hoxmeier, Dieterman and Miller, 2012). Additionally a brook trout strain, MNWILD, was created by crossing trout from Rice Creek with those from Coolridge Creek.

As genetic analysis progressed, the MN DNR ascertained that the brook trout in Rice Creek were unique; however, they were more closely related to species strains from New England fisheries than from remnant Driftless region populations. Figure 19, taken from Hoximeier et al. (2012) shows this genetic character in the form of a radial tree diagram. The circled labels on the figure are two different sets of genetic samples obtained from Rice Creek fish in 1999 and again in 2001. The gray lines are associated with stocks with origins outside southeast Minnesota, and the dark lines reflect genetic profiles associated with remnant Driftless region populations. As you follow the radius toward the center, you observe genetic connectivity to streams known to be stocked with Rice Creek fish. The next nearest links connect to a fish strain from Wisconsin (Parfrey’s Glen, Lower Wisconsin River with no known stocking records from 1972-2006) and a neighboring branch featuring fish traced to New England hatcheries in Maine (ASN) and Rome, New York (ROME). While this result does not confirm local lore, it does indicate that the brook trout in Rice Creek are not native to this region and were likely part of frequent formal and informal fish stocking activities.

Most importantly, these fish are a viable, naturally reproducing population that has adapted to this particular system and has been shown to successfully adapt to other suitable habitats in the region.
Figure 19. Radial tree diagram showing the genetic similarity among brook trout populations in southeastern Minnesota streams and known hatchery strains (n = 102). Circled labels are two cohort samples from Rice Creek (Spring Brook). The heavy lines reflect genetic profiles associated with remnant driftless region populations. Gray lines are associated with stocks with origins outside southeast Minnesota. Figure from Hoxmeier R.J.H.; Dieterman, D.J.; Miller, L.M. 2012.
Food Web Isotope Analysis
Because terrestrial and aquatic sources of organic material differ in their isotopic composition, the ratio of certain isotopes found in brook trout tissue can be used to determine if the brook trout’s diet is more autochthonous (aquatically sourced) or allochthonous (terrestrially sourced) at different points in space and time. Terrestrial inputs can provide as much as half the annual energy budget for fish and research suggests that riparian habitat plays a role in determining the distribution of fish species as a result of the contribution of terrestrial inputs. Understanding sources of nutrients to brook trout helps us to understand how and where they obtain the energy needed to grow and reproduce and also how to manage resources to ensure that brook trout populations are sustainable. Two sites (Figure 20) were sampled in 2011 to help us understand the sources of nutrients for this stream.

Figure 20 – Two study sites: for food web isotopes Decker Down (DD) and Spring Brook Forested (SBF).

Isotopes of carbon, nitrogen and hydrogen were looked at. Based on the isotope analysis the food web appears to have a strong dependence on allochthonous (terrestrial) inputs. This is indicated by the higher levels of C13 found in trout and in two of the three invertebrate species. Amphipods (scuds), which are a common food for trout, consume coarse organic matter much of which is coming from terrestrial sources. Scuds can be thought of as the “meat and potatoes” for trout (http://www.flyfishersrepublic.com/entomology/freshwater-shrimp/, accessed May 17, 2013). They were the most consistent invertebrates found which is also consistent with MPCA sampling in 2011.

As a consequence, maintenance and improvements in the terrestrial habitats adjacent to the stream are of high priority. This ensures continued supply of terrestrial food sources to the cold water stream system. There also appeared to be a slight divergence in trout feeding habits between forested and grassy stretches of the stream during the summer with significant differences between sites in two of the three isotope values measured for each sampling date in June and July.
It is likely that fish rely on the most abundant species in the stream, and a single source may only subsidize the fish for a short period of time. These small shifts would not appear in the time-integrated isotope values but are nevertheless important in terms of understanding how fish obtain energy.

A more detailed report of the isotope work can be found in the paper by Herron- Sweet, Jackson and Schmidt, 2012, found in Appendix D.

**Macroinvertebrates & Fish (MPCA IWM – 2011)**

The 2011 sample at Decker Avenue produced only 15 unique macroinvertebrate taxa and two EPT taxa, and was dominated by the same four genera as was 2004 sample. The 2011 M-IBI score was 10 points lower than the 2004 sample as a result of slightly lower scores for several metrics including the Hilsenhoff Biotic Index, the proportion of collector-filterer feeders, and the proportion of very tolerant taxa. Based on the more recent data set, it appears as though this stream is not supporting its aquatic life use.

At the site downstream from Decker Avenue, there were more habitat types including rock, woody debris, overhanging vegetation, undercut banks, and aquatic macrophytes. This station was above the biological impairment threshold with an M-IBI score of 56 and had a total of 27 unique taxa. The macroinvertebrate community still had comparable abundances of the four genera listed above but with significantly more of the caddisfly species *Brachycentris occidentalis*, a species considered to be of intermediate sensitivity to anthropogenic disturbance. The community at this station also differed from the upstream location in that it had some additional tolerant taxa present such as the mayfly genus *Caenis*, hydropsychid caddisfly genera *Hydropsyche* and *Ceratopsyche*, and oligochaete worms.

Examination of field notes and site photos indicated that the influx of tolerant taxa may be in response to excess nutrients (excessive algal growth was noted and photographed at this location), habitat degradation (severe bank erosion noted and evident on the site photos), and possibly toxic concentrations of nitrate (stream is already impaired in this regard; drinking water designated use). Despite meeting the M-IBI criteria at the downstream station, the overall assessment decision for Rice Creek was that it is not fully supporting aquatic life for a coldwater stream and is therefore to be recommended for an impairment listing for this use.

In addition to the macroinvertebrates samples, the MPCA also collected fish samples in 2004 and 2011 at the site just downstream of Decker Avenue and at Armstrong Road in 2011 as part of the Fish IBI portion of their intensive watershed monitoring effort. The results are provided in Table 13. The Fish IBI threshold is 45 with a confidence limit of +/- 13. The Decker Avenue site had an FIBI score of 80 (excellent) in 2004 and 68 (good) in 2011. The Armstrong Road site had an FIBI score of 65 (good) in 2011.

Per Brenda Asmus of the MPCA, many age classes were represented and many young-of-year were present in good numbers at both stations indicating a healthy naturally reproducing population of brook trout. Some observations include a shift in the aquatic food base between EPT taxa in the spring to *Gammarus* or *Hyella* species in fall. In stream filamentous algae may indicate a potential nutrient issue. Nitrogen was high (10 to 16 mg/L) as well as phosphorus. This
stream should be considered for additional protections given the rare naturally reproducing brook trout community. The MPCA recommends classifying the stream as full-support for aquatic life for fish at this time.

Table 13 – Fish Sampling Data from the MPCA

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>CommonName</th>
<th>Number</th>
<th>LengthMin</th>
<th>LengthMax</th>
</tr>
</thead>
<tbody>
<tr>
<td>04lm077</td>
<td>7/12/2004</td>
<td>Brook trout</td>
<td>38</td>
<td>64</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blacknose Dace</td>
<td>5</td>
<td>72</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Johnny Darter</td>
<td>2</td>
<td>45</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brook Stickleback</td>
<td>1</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>04lm077</td>
<td>6/14/2011</td>
<td>Brook trout</td>
<td>50</td>
<td>139</td>
<td>303</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Johnny Darter</td>
<td>10</td>
<td>45</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brook Stickleback</td>
<td>9</td>
<td>39</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Creek Chub</td>
<td>6</td>
<td>90</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green Sunfish</td>
<td>1</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>11lm099</td>
<td>6/14/2011</td>
<td>Brook trout</td>
<td>290</td>
<td>35</td>
<td>303</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Creek Chub</td>
<td>4</td>
<td>124</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Johnny Darter</td>
<td>3</td>
<td>36</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White Sucker</td>
<td>3</td>
<td>162</td>
<td>208</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Black Bullhead</td>
<td>1</td>
<td>108</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Green Sunfish</td>
<td>1</td>
<td>55</td>
<td>5</td>
</tr>
</tbody>
</table>

Tillage Survey

A tillage survey from 2007 (Figure 21) showed that most of the watershed was “ripped” (a method of tillage that is similar to chisel plowing) with untilled fields being the second most common tillage practice. There were also a fair amount of moldboard plowing and some patches of hay fields. There were a few small, scattered patches of land that were Reinvest in Minnesota (RIM) lands, Christmas trees, pasture, and wetland.
Since 2007, there have been some noticeable shifts in tillage practices (Figure 22). In the eastern half of the watershed, many fields changed from untilled to “ripped”. In the western part of the watershed, we observed a new tile line being laid that will drain water to County Ditch 22 at the time of our 2012 survey. Some nutrient applications including anhydrous ammonia and pumped manure were also observed during the survey.

Although there is still room for improvement, the watershed has seen some land use changes that benefit water quality. There appears to be less moldboard plowing with just one small field still using this practice. Moldboard plowing lifts and turns the soil over; making it more susceptible to erosion compared to other more sustainable tillage practices. Secondly, another section of RIM land has been added just east of Decker Avenue. The RIM program is designed to acquire and protect critical habitat. Thirdly, a parcel just west of Decker Avenue is dominated by restored prairie. The deep-rooted grasses of the prairie help to anchor soil and increase infiltration.

Figure 21 – 2007 Tillage Survey
Figure 22 – 2012 Tillage Survey

Analysis of Terrain Using GIS
Terrain Analysis of highly-accurate LiDAR elevation data was utilized to help give us a better understanding of areas with the most potential for erosion and sediment delivery to the stream. Stream Power Index (SPI), catchment area, slope, and curvature amongst other attributes were examined to target areas with high erosion potential that are connected to the stream or ditch via surface water flow. Where these areas intersected, entire catchments that delivered surface-flow to a single point on the stream were identified and described as upslope areas of interest.

Aerial photography was used as a base-layer, and combinations of Stream Power Index (SPI) values above the 85th percentile and flow accumulation were used. Of particular interest, were locations in the landscape where channelized flow breached the delineated streams as verified by CRWP staff. These areas, especially when connected via high SPI signatures (all areas ended up containing SPI values above the 98th percentile), defined the boundaries of the upslope areas of interest. Acres were calculated for each polygon to better assess total upslope contributing area to these points. Figure 23 shows a map of these connected surface drainage areas broken in categories by acres. There are 172 acres that fit this category. Figure 24 is an example of a close up of this information for one specific upslope area.
These data provide highly-detailed spatial and quantitative characterizations of surface topography, and are to be used for better understanding the surface hydrology and landscape processes which are dependent upon this topography. The upslope contributing areas delineated provide a framework for locating and statistically characterizing the highest likelihood areas of surface erosion and deposit into the ditch/stream network. All upslope contributing areas delineated contain at least some SPI signatures higher than the 98th percentile for the entire watershed.

Figure 23 – Upslope areas with high erosion potential connected to surface drainage.
Figure 24 – Example close up of upslope area with high potential for surface erosion and connection to surface drainage.

**Water Chemistry**

Water chemistry samples were collected at four sites, as previously described. Due to issues with rain events over weekends and shipping issues that cause *E. coli* and turbidity to exceed hold times for analysis the decision was made to stop sampling those parameters after 2011.

When looking at water sample results we need compare them to existing and proposed water quality standards in Minnesota if available. For Class 2A waters, the nitrate standard is 10 mg/L. There is currently no standard for TKN. The MPCA is proposing a new standard for TSS which will be 10 mg/L for Class 2A waters. A condition of this standard is that TSS samples may exceed the standard ten percent of samples taken from April – September. The standard for *E. coli* is 126 colony forming units (cfu/L) as a chronic standard and 1260 cfu/L as an acute standard. There is currently no stream standard for TP. The MPCA is proposing a river nutrient standard comprised of both TP values and response variable thresholds to include chlorophyll-a, the presence of periphyton, and swings in dissolved oxygen and biological oxygen demand. Rice Creek is on the border of the Central and Southern region for the TP standard which ranges from 0.100 -0.150 mg/L. Rice Creek does not typically grow phytoplankton and will most likely not exceed the chlorophyll-a however we have seen instances of periphyton growth.
Results from water chemistry samples are presented in Table 14, displayed graphically in Figures 25 – 37 and the data set is included in Appendix D. For the box plots the solid lines indicate the median, upper and lower bounds (75th and 25th percentiles) and the whisker caps indicate the 10th and 90th percentiles. The circles represent outlier values.

*Table 14 - Results from water chemistry sampling in 2011 and 2012*

<table>
<thead>
<tr>
<th>Location</th>
<th>TP (mg/L)</th>
<th>N+N (mg/L)</th>
<th>TKN (mg/L)</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>100th St. West @ Cates Ave.</strong></td>
<td>0.034</td>
<td>2.16</td>
<td>0.547</td>
<td>1</td>
</tr>
<tr>
<td>Min</td>
<td>0.034</td>
<td>2.16</td>
<td>0.547</td>
<td>1</td>
</tr>
<tr>
<td>Avg Events</td>
<td>0.338</td>
<td>11.73</td>
<td>1.44</td>
<td>155.82</td>
</tr>
<tr>
<td>Avg Base Flow</td>
<td>0.065</td>
<td>11.9</td>
<td>0.575</td>
<td>3.33</td>
</tr>
<tr>
<td>Max</td>
<td>1.11</td>
<td>26.5</td>
<td>5.48</td>
<td>1336</td>
</tr>
<tr>
<td><strong>Number of samples collected (2011-2012)</strong></td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>TP (mg/L)</th>
<th>N+N (mg/L)</th>
<th>TKN (mg/L)</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>100th St. East</strong></td>
<td>0.029</td>
<td>1.83</td>
<td>&lt;0.3</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Min</td>
<td>0.029</td>
<td>1.83</td>
<td>&lt;0.3</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Avg Events</td>
<td>0.356</td>
<td>8.96</td>
<td>2.03</td>
<td>240.89</td>
</tr>
<tr>
<td>Avg Base Flow</td>
<td>0.043</td>
<td>10.96</td>
<td>0.381</td>
<td>17.33</td>
</tr>
<tr>
<td>Max</td>
<td>1.05</td>
<td>15.6</td>
<td>11.3</td>
<td>2616</td>
</tr>
<tr>
<td><strong>Number of samples collected (2011-2012)</strong></td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>TP (mg/L)</th>
<th>N+N (mg/L)</th>
<th>TKN (mg/L)</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decker Avenue</strong></td>
<td>0.034</td>
<td>4.3</td>
<td>&lt;0.3</td>
<td>3</td>
</tr>
<tr>
<td>Min</td>
<td>0.034</td>
<td>4.3</td>
<td>&lt;0.3</td>
<td>3</td>
</tr>
<tr>
<td>Avg Events</td>
<td>0.456</td>
<td>15.01</td>
<td>2.33</td>
<td>240.8</td>
</tr>
<tr>
<td>Avg Base Flow</td>
<td>0.072</td>
<td>11.7</td>
<td>0.495</td>
<td>9.33</td>
</tr>
<tr>
<td>Max</td>
<td>1.56</td>
<td>70.8</td>
<td>8.4</td>
<td>1056</td>
</tr>
<tr>
<td><strong>Number of samples collected (2011-2012)</strong></td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>
As expected we see TP and TSS levels increase during storm events exceeding the proposed TSS standard many times over. At baseflow the TSS levels are close to the standard. TP shows a similar pattern and is actually below eco-region values at baseflow (Figures 25-28). As TP is often bound to soil particles reducing TSS should reduce TP as well. With some work to reduce the impacts of erosive conditions at high flows achieving the TSS standard should be attainable.

![Average Total Phosphorus Events Vs. Baseflow](image-url)

*Figure 25 – Total phosphorus averages of event and baseflow samples 2011 and 2012.*
Figure 26 – Boxplots of total phosphorus event and baseflow samples 2011 and 2012.

Figure 27 – Total Suspended Solids averages of event and baseflow samples 2011 and 2012.
High nitrate levels are noted in the spring because of fertilizer application and bare ground. Plants haven’t come up yet and nitrate leaching occurs through soil as well as direct transport through subsurface drainage. During the remainder of the year, and unlike TP and TSS, nitrate concentrations remain elevated at base (low) flow likely due to inputs from subsurface drainage (Figures 29 and 30). The data are consistent with past sampling in this watershed and other areas of the larger Cannon River watershed. Figure 31 highlights that nitrate concentrations stay at or around 8 – 12 mg/L through the May – September timeframe.

In a recent study conducted by the MPCA (Watkins, 2011) of 100 trout streams in southeast Minnesota, a relationship between row crop land use and nitrate-nitrogen concentration in the stream at baseflow was developed. Rice Creek was included in this study. Results indicate that nitrate-nitrogen concentrations are directly related to the percentage of row crop in the watershed (r-squared = 0.68). A linear regression showed a slope of 0.16, suggesting that the average baseflow nitrate-nitrogen concentration in the trout stream watersheds of southeast Minnesota can be approximated by multiplying a watershed’s row crop percentage by 0.16. Figure 32 provides an illustration of this data. Multiplying the 84% land in row crops in the Rice Creek watershed by 0.16 we get a result of 13.44 which is close to the averages of our nitrate samples.

*Figure 28- Boxplots of total suspended solids event and baseflow samples 2011 and 2012.*
Figure 29 – Nitrate averages of event and baseflow samples 2011 and 2012.

Figure 30 – Boxplots of Nitrate event and baseflow samples 2011 and 2012.
Figure 31 – Baseflow nitrate concentrations from 2012 by month
The total amount of nitrogen in water is usually considered to be the sum of the TKN and nitrate+nitrite nitrogen concentrations. TKN concentrations may be used in project analyses; however, it is more commonly used as an intermediate value to calculate the concentrations of other forms of nitrogen (MPCA, 2013). TKN concentrations are dependent on biological activity and the sources of the pollution. In some situations TKN may be higher than nitrate indicating more organic N presence. Based on our results more of the total nitrogen was of the dissolved form (nitrate) than TKN which matched expectations and is consistent with other southern Minnesota streams. Figures 33 and 34 show TKN values during events and baseflows for 2011 and 2012. TKN is typically an indicator of sewage or manure contamination. Seeing more nitrate than TKN indicates that most of the nitrogen in Rice Creek of the dissolved form loaded via leaching and tile drainage.
Figure 33 - Total Kjeldahl Nitrogen (ammonia and organic nitrogen) averages of event and baseflow samples 2011 and 2012.

Figure 34 - Boxplots of Total Kjeldahl Nitrogen (ammonia and organic nitrogen) event and baseflow samples 2011 and 2012.
Samples were collected in 2011 for *E. coli* bacteria and turbidity, but due to compositing of samples from weekend rain events and travel time to laboratory, many of the samples were past the acceptable 24-hour hold time. Most *E. coli* samples exceeded the chronic standard and two exceeded the acute standard at the Armstrong Road site during a July 2011 storm event. Figure 35 shows average results per site. High levels of coliform bacteria continue to be found across the southeast Minnesota region.

Transparency measurements were collected in 2012 that serve as a surrogate for turbidity. Average values are displayed in Figure 36. A transparency value of 100 cm is the best and zero is the worst. As we saw with TSS, transparency samples under baseflow conditions are good but during events they drop and are below the desired levels.

![Rice Creek Watershed 2012: Average Transparency by Site](image)

*Figure 35 – Transparency averages of event and baseflow samples 2012.*
Figure 36 – Average E. coli results from 2011

Load Estimates
Lack of flow measurements in the high range resulted in insufficient data to carry out FLUX modeling as planned or calculate loading for nitrate, total phosphorus and total suspended solids. However, for both the drinking water assessment and consideration of potential nitrate toxicity to aquatic organisms, low flow (or baseflow) is the critical condition and thus the context within which nitrate is examined in Rice Creek.

Figure 37 below indicates that during typical baseflow the nitrate concentration at Armstrong Road is approximately 10 mg/l (Table 15). This value is similar to baseflow values collected in previous sampling years. Rice Creek is unusual in that it is a trout stream that receives significant volume from agricultural drain tiles (see Figure 11). While nitrate concentrations in most southeast Minnesota trout streams are often diluted by runoff events, Rice Creek’s concentration often rises with flow after water carries nitrate down into tiles and out into the surface water. Similar graphical displays for TP and TSS are not provided as they are present predominantly at high flow conditions where good flow data is lacking.
Table 15- Approximated baseflow nitrate details at Armstrong Road.

<table>
<thead>
<tr>
<th>Stream Baseflow</th>
<th>Nitrate Concentration</th>
<th>Daily Load (24 hours of baseflow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 cubic feet per second</td>
<td>10 mg/l</td>
<td>48.9 kg/day</td>
</tr>
</tbody>
</table>

Figure 37 – Example of typical baseflow nitrate concentrations

Longitudinal Monitoring
A longitudinal survey sampling for nitrate was conducted in May and again in August of 2012 for two reasons, 1) to better understand how the concentration of nitrate changed along the stream and 2) to pinpoint groundwater influences.

In May, nitrate levels (Figure 38) were almost double the Class 2A standard of 10 mg/L with the highest level near the intersection of 100th St. and Cates Avenue and decreasing downstream. A couple days prior, a significant rain event caused flow levels to rise. This sampling event occurred at the end of the hydrograph as levels were still receding and tile lines were draining. According to Randall and Mulla (2001) this subsurface drainage and baseflow can be a much larger source of nitrate than surface runoff as nitrate is leached from the soil profile.
In August 2012 (Figure 39), nitrate levels were much lower. The water level was extremely low during sampling and the input from upstream of Cates Avenue was essential nonexistent. The ditch portion often runs dry at the end of summer in this stretch. Nitrate increases as we move downstream due to subsurface loading from other tributaries but the major contributor (agriculture drainage into County Ditch 22) is no longer present. Additional nitrates may be being added to the stream from tile lines between Cates and Decker Avenue. In addition to the inputs from County Ditch 22, the south tributary at 100th St and Decker Avenue seems to be a significant contributor to high nitrate values. Feedlot runoff is a factor between Decker Avenue and Armstrong Road. Nitrate transport through tile drainage causes high concentrations even when the hydrograph is flat.
Longitudinal calcium concentrations were measured to identify groundwater input (Figure 40). Groundwater has a unique chemical signature that differs from surface water; it tends to have higher concentrations of calcium, magnesium, sulfur and iron. Iron precipitation is another indicator of groundwater input (this phenomenon was observed near Armstrong Rd in April). Since the Prairie du Chien aquifer has higher calcium concentrations than surface water, a longitudinal survey of the calcium concentration along the creek could provide information as to inputs.

The calcium values along the creek did not appear to change significantly. The data do not appear to indicate a significant deep groundwater source, although many other lines of evidence as described in this report suggest a shallow source that seeps in at many indistinguishable sites.
Tritium

Tritium ($^3$H) is a radioactive isotope of hydrogen with a half life of 12.4 years and is naturally occurring in the environment at levels of 2-8 tritium units (TU). Tritium atoms combine with oxygen and form water, which then falls to the earth as precipitation. In the early 1950s, nuclear weapons testing had increased atmospheric tritium by two to three orders of magnitude, peaking in 1963. Upon signing of the Atmospheric Test Ban Treaty, atmospheric tritium has steadily declined to current levels between 12 and 15 TU. Although the nuclear-weapons-testing era ended decades ago, tritium concentrations serve as a useful tool in age dating because groundwater concentrations of tritium are a reflection of the atmospheric concentration when the water was last in contact with the atmosphere. Table 16 provides information for distinguishing the age of water based on tritium levels (Motzer, 2007).
Table 16 – Tritium level ranges and interpretation

<table>
<thead>
<tr>
<th>Tritium (TU)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.8</td>
<td>Submodern water (prior to 1950s)</td>
</tr>
<tr>
<td>0.8 to 4</td>
<td>Mix of submodern and modern water</td>
</tr>
<tr>
<td>5 to 14</td>
<td>Modern water (&lt;5 to 10 years)</td>
</tr>
<tr>
<td>15-30</td>
<td>Some bomb tritium</td>
</tr>
<tr>
<td>&gt;30</td>
<td>Recharge occurred in the 1960s and 1970s</td>
</tr>
</tbody>
</table>

Three sites were sampled in October for tritium as listed in Table 17: Armstrong Road, a deep hole downstream of the Decker Avenue Bridge, and the tile outlet at 100th St. East (Figure 1). All three sites were similar in their TU, pH, and specific conductance. Based on the criteria in Table 16, tritium levels in the Rice Creek samples indicate modern water that is less than five to 10 years old.

Table 17 Tritium sampling results October 2012

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>Tritium (TU)</th>
<th>± 1σ</th>
<th>pH</th>
<th>Specific Conductance (µS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong Road</td>
<td>5.1</td>
<td>0.6</td>
<td>7.69</td>
<td>686</td>
</tr>
<tr>
<td>Decker deep</td>
<td>6.0</td>
<td>0.6</td>
<td>7.65</td>
<td>672</td>
</tr>
<tr>
<td>100th East tile</td>
<td>5.7</td>
<td>0.6</td>
<td>7.12</td>
<td>682</td>
</tr>
</tbody>
</table>

Stream Temperature and Conductivity

Figures 41 and 42 show the stream temperatures continuously measured in Rice Creek across four monitoring stations. In 2011 three monitoring stations were installed and used to probe stream temperatures associated with different riparian habitat and stream segment. A fourth station was added to monitor the temperature coming out of a long stretch of buried agricultural drainage that historically was a tributary of Rice Creek. The three stations along the stream channel all exhibit the same daily trends and roughly similar magnitude of change - water temperatures increase during the day and fall at night. In addition to closely matching diurnal temperature changes, all three stations reveal summer temperatures frequently exceed upper thermal preference (18.8 °C, 66 °F) for Brook trout (Blann, 2002). Figure 43 shows the extent to which the daily maximum temperature equaled or exceeded the thermal preference of brook trout at the Armstrong Road (S001-445) station during June and July in both 2011 and 2012. In 2011 the daily maximum temperatures equaled or exceeded 18.8 °C about one-third of the time during those two summer months. The next summer saw a dramatic shift in the exceedence, increasing to two-thirds of the time. This reveals the strong connection of this stream system to the seasonal summer weather patterns. A very hot June and July 2012 led to high temperatures in the stream.
Figure 41 - Temperature variation at three monitoring stations in Rice Creek during 2011. Stations closely match one another throughout seasonal change and summer temperatures frequently exceed upper thermal preferences of the trout (19 °C, 66 °F).

Figure 42 - Temperature variation at four monitoring stations in Rice Creek during 2012. Stations, except buried drainage line (green line), closely match one another throughout seasonal change and summer temperatures frequently exceed upper thermal preferences of the trout (19 °C, 66 °F).
The importance of avoiding overland, surface flow into the stream is highlighted by the station at 100th Street East (S006-843). This station sits at the outflow of a buried agricultural drainage that historically was a tributary of Rice Creek. According to the local landowner who installed this drainage/swale system, tile lines were laid into springs/seeps upstream from this station. This is consistent with the observation that water flows at the station year-round. As you can see from Figure 42, the water temperature emanating from this buried pipe exhibits lower temperatures than the other stations throughout the summer and then cools more slowly as the seasons change into fall and winter. The daily fluctuation in temperatures is not as large as the stream system, being dampened by the thermal characteristics associated with underground flow and surrounding soil temperatures. On occasion, we observe rapid increases in output temperatures in this system. Those temperature increases are associated with major 2012 rain events, especially the mid-June deluge (8+ inches over 2 days) and 2.3 inches overnight on 23/24 July 2012. In each of these instances, the event generated overland flow through the grassed swale on top of the buried drainage line. The thermal energy from the surfaces are quickly exchanged with the water and directly transferred into the stream system. Other stations show a similar trend, but the daily variation in temperatures at those stations partially obscures the strength of the signal associated with the thermal inputs. It should be noted that in some cases the swale does its job by slowing water and capturing sediment. During the 14 June 2012 event, the overland flow contributed substantial sediment to the system. The 23/24 July 2012 event revealed a thermal input but secchi tube readings show quick improvement in the clarity of the surface flow (68 cm on 24 July and 120+ cm on 26 July). In comparison the Decker Down station (04LM077) had secchi tube readings on the two days of 17 cm and 75 cm, respectively). These data underscore the importance of allowing precipitation to infiltrate to maintaining stream temperatures as well as minimizing erosion or sediment inputs from the surrounding landscape.
In order to get a sense of the thermal fluctuations in Rice Creek relative to other southeast Minnesota trout streams, we make use of the work reported by Hoxmeier, et al (2012). Figure 44 plots the mean daily water temperature for six trout streams in southeastern Minnesota from April 2008 through September 2009. While this is not the same season or the raw temperature values, it is a useful comparison to place Rice Creek in context. If one focuses on the summer months in the plot shown and estimates the means during that same time period, the mean temperatures for Rice Creek are around 18 °C (65 °F). This places Rice Creek at the warmest summer stream temperatures relative to the comparison group. Even more interesting is the differences in those six trout streams. Some have a daily summer mean temperature just above 10 °C (~low 50’s °F). Those streams also exhibit a warmer daily average temperature during the winter months, approximately 5 °C (~low 40’s °F). Rice Creek, like a few other streams sees much lower average winter temperatures (~1°C, 34 °F). The combination of strong coupling to summer and winter air temperatures suggest that the groundwater input into the Rice Creek system is either not very large in volume or not coming from deep aquifers.

In addition to temperature measurements a series of conductivity measurements were used to explore potential ground water inputs. We would expect inputs or contributions from deep aquifers, with higher dissolved mineral content, to be detected by increased conductivity as well as decreases in temperature. A subset of conductivity data is exhibited in Figure 45; conductivity at the four stations is remarkably consistent. Between rain events the conductivity of the stream generally is in the range of 670 -740 μS cm. Roughly one to four days after a modest rain event, such as 24 July 2012 or 29 Oct 2012, the stream conductivity drops by roughly 200 μS cm. Water sitting in a surface pool embedded in the grassed swale just upstream of station S006-843 was observed to have a field conductivity measurement of 354 μS cm; whereas, water collected from rainfall as measured at the cistern at St. Olaf College has extremely low conductivity (< 20 μS cm). This suggests the stream may be obtaining a substantial amount of water from shallow groundwater as well as from overland flow during events of substantive scale.
Figure 44 - Mean daily water temperature for six trout streams in southeastern Minnesota from April 2008 through September 2009. Coolridge Creek, Trout Brook, and Trout Valley Creek had missing data during parts of the study. Rice Creek shows even greater upper temperature exceedences than these six streams, suggesting the importance of local groundwater sources and to mitigating thermal inputs. From Hoxmeier, et al, 2012.

Figure 45. Stream conductivity at the four temperature monitoring stations in Rice Creek. (L-R): Armstrong Road (S001-445); Spring Brook Forest; Decker Down (04LM077) and 100th Street East (S006-843). Observed decreases in conductivity correlated with recent precipitation events.
Additional conductivity and temperature measurements were made in the segments of the stream known to hold substantial numbers of trout during the summer months. Data were collected 20 meters up and downstream of three biological stations (11LM099, 04LM077, and Spring Brook Forest) and in cross-section. Around each station we did not detect any substantive change in stream temperature or conductivity that was different from the background signal in the stream. There was only one exception to this. We observed a few, very localized fresh water seeps in the area of biological station 04LM077. Figure 46 shows the exact locations of the seeps in the pool near a willow tree; depth of the pool varied between 30 and 90 cm. The background stream temperature and conductivity at this location was 21.0 °C and 671 μS cm, respectively. The upstream seep exhibited a temperature of 10.2 °C and a fluctuating conductivity between 730-760 μS cm. Moving the handheld meter 10 cm any direction resulted in both temperature and conductivity returning to the stream baseline and quickly stabilizing. The second seep, located adjacent to the willow tree trunk, resulted in a water temperature of 13.4 °C and a stable conductivity at 748 μS cm. Topographically, this area appears to be the bottom of the “bowl” of the surrounding landscape. A majority of the surrounding watershed likely drains to this location.

Stream temperatures and conductivity measurements suggest that this stream is not fed by substantial amounts of deep aquifer groundwater. Changes in conductivity at two seep locations, while different from the stream background, were not of substantial magnitude (≥ 1000 μS cm), to indicate contributions from deep groundwater. More likely is the supply of shallow groundwater to the stream by diffuse and dispersed seeps along the stream gradient.
Figure 46. Seep locations shown by white arrows at Decker Down (04LM077) station. *The background stream temperature and conductivity at this location was 21.0 °C and 671 mS cm, respectively. Measured temperatures at the two seeps are 10.2 °C and 13.4 °C, upstream to downstream respectively. Conductivity values sit in the range between 730-760 mS cm – fluctuating substantially at the upstream locale and stabilizing at 748 mS cm downstream.*

An attempt was made to conduct a centerline walk of the stream, logging temperature with a series of iButtons and position with handheld GPS. Ideally the walk would have taken place in summer during a hot day so as to maximize potential to thermally differentiate groundwater inputs from the stream background. Staff time and weather forced the date to occur in early October. The results of the centerline walk are not suitable for a multitude of reasons, foremost is the lack of GPS position data density along the reach segment between Decker Avenue and Armstrong Road. Additionally the thermal variation between background flow and stream temperature was not as sufficient to probe water inputs in a reliable fashion. A small team plans to pursue this work outside the grant-funded window and will be reporting back when the data are collected.

Further work with stream temperatures was undertaken to explore the issues of diurnal variation. Daily temperature variation can be another source of stress to cold-water-stream biota, especially when diurnal changes are more than 5 °C. Representative diurnal temperature variation in Rice
Creek is shown in Figures 48-49. During the first 14 months of our study we plotted the daily temperature variation from loggers at our first three stations. The most downstream station immediately stands out from the other two logging stations in this analysis. Figures 47 and 48 shows Armstrong Road (S001-445) having a larger diurnal variation during the summer months of 2011 and in the late summer/early fall of 2012. We suspect the riparian habitat is a major player in this temperature variation. In this portion of the reach, ground cover is pasture grasses, regularly grazed by cattle. This yields very little shading for the stream system and dark colored banks which are ideally suited to absorb solar energy and re-radiate it back into the stream system. This trend continues when we calculate the distribution of the diurnal temperature changes for a full year of observations (April 2011-April 2012). We observe a 0.5 °C positive shift in the distribution of mean daily temperatures for the Armstrong Road station compared to the upstream grassland and forested stations.

The data are consistent with observations by Blann (2002) regarding riparian buffer type and water temperatures in Driftless region trout streams. The diurnal variation, shown in Figure 37, further illustrates the importance of water infiltration to temperature. The buried agricultural drainage system that outputs at 100th St. East (S006-843) shows less than 0.5 °C diurnal temperature change.

![Figure 47. Daily temperature change at three monitoring stations in Rice Creek during Apr 2011 – Jun 2012. Note the higher daily temperature differential in the lower reach in the 2011 summer months compared to the upstream stations](image-url)
Figure 48. Daily temperature change in each of the four monitoring stations. Outfall of buried agriculture drainage line at 100th St East shows minimum variation, whereas S001-445 shows highest variation as seasons transition from summer to fall.

Figure 49. Frequency distribution of daily temperature change at three monitoring stations in Rice Creek for full year (Apr 2011-Apr 2012). Downstream station (meanD = 2.95) is nearly 0.5 degrees warmer in temperature changes compared to the two upstream stations (meanD = 2.55 and 2.54)
CONCLUSIONS
Through this project we have increased our knowledge of the watershed, groundwater, the stream and habitat it provides, the brook trout and macroinvertebrate populations, and areas where landowners and local units of government have interest in taking actions to protect and improve the stream.

In the workplan for the project we listed the following goals:

- Characterize stream sediment, nutrient and *E. coli* bacteria concentrations, loads, and their effect on the Rice Creek system.
- Determine groundwater sources and high stream temperature priority areas within the stream.
- Determine macroinvertebrate and fish population distribution within Rice Creek Watershed.
- Evaluate the ecological health of the Rice Creek system.

Overall these goals were met with the exception of loading calculations due to limited high flow data.

We have learned or confirmed the following:

- The hydrology (flow) of the system has been greatly influenced by land use and drainage. It is a flashy system where flooding has been common. There is need for storage and slowing of the flow to reduce channel scouring during rain events.
- Nitrate levels are high and are influenced by land use practices and subsurface drainage. High levels of nitrates can adversely affect the aquatic life.
- Flooding/heavy rain events are driving TSS and TP inputs.
- The fish are doing alright but there is room for improvement of population and habitat.
- The macroinvertebrates are marginal and need to be improved.
- Water temperature is on the borderline with brook trout needs and attention must be paid to keep it from increasing. It is influenced by shallow groundwater recharge.

Table 18 provides a summary of our findings and outlines suggestions for implementation. More discussion on next steps is included in the Implementation section that follows in this report.
**Table 18 - Summary of Findings**

**Rice Creek Project 2011-2013 Summary of Findings**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
<th>Findings</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trout population</td>
<td>Dependent on size of stream, competitors, major events, habitat availability and suitable food sources.</td>
<td>Estimate between 2,000-2,500 trout or roughly 3,350 trout/mile. Typical for a stream of this size with rather narrow riparian zone and inputs from drainage systems. Average size was 6-7 inches, a good breeding size. Size distribution changes with major events.</td>
<td>With habitat enhancements, including buffers and water quality improvements, may see populations expand. This may also yield greater numbers of fish above 10 inches (25 cm) as they represent an age &gt; 2 years.</td>
</tr>
<tr>
<td>Habitat assessment</td>
<td>Provides overview of stream and riparian characteristics, including bank stability/erosion. Good to Excellent scores are highly desired.</td>
<td>Average scoring is “Fair” for both 2011 and 2012 (52 and 56 out of 100, respectively). Multiple areas of poor and very poor scores. Habitat changes (for better or worse) are often driven by episodic flooding events.</td>
<td>Target zones rated poor and fairly poor for improvement efforts. Apply soft armoring approach to at least 60-ft corridor: grade to 1:4 slope and establish tall grass prairie or oak savanna.</td>
</tr>
<tr>
<td>Water quantity</td>
<td>Cool, pollutant-free water is critical to spawning juvenile rearing and adult resting habitat for many fish species.</td>
<td>Source water is likely local groundwater recharge from small, dispersed seeps. Area east of Decker Ave is important source area. County Ditch 22 experiences intermittent flow. Swale/ditch located south of 100th St and between Cates and Decker Avenues flows year-round.</td>
<td>Protect area east of Decker Avenue as ground-water source possibly with easements or land use ordinances. Karst provides challenges due to interconnectedness and ability for rapid spread of contaminated waters. Target watershed-wide infiltration of the 2-year 24-hour rainfall event (2.8 inches)*.</td>
</tr>
<tr>
<td>Water quality - Temperature</td>
<td>Generally, &lt; 16 °C (60.8 °F) is needed for spawning, and &lt; 18 °C (64.4 °F) for rearing. Sufficient deep pools are necessary as thermal refuges and holding habitat for many fish species.</td>
<td>Upper thermal preference frequently exceeded during summer months, especially in downstream areas west of Armstrong road.</td>
<td>Use riparian vegetation and managed grazing to establish and/or increase shading. As urbanization occurs, target infiltration of the 2- year 24-hour rainfall event (2.8 inches).</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Description</td>
<td>Findings</td>
<td>Implementation</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Water quality – Nitrate Nitrogen | At concentrations above the state standard (10 mg/L), nitrates in drinking water (trout streams are protected as drinking water sources) can affect human health. There is growing evidence that nitrates at lower concentrations affect the health of aquatic organisms. | Frequently fails to meet state standards at all flow regimes. Intermittent flows do disconnect input zones, especially County Ditch 22 during drought cycles.                                                   | • On-farm reductions via changes in nutrient management practices.  
• In-system bioreactors  
• Wetland restoration (with consideration of stream temperatures)  
• Controlled drainage in tile lines.  
• Cover crops |
| Water quality-Phosphorus       | High levels of phosphorus and nitrogen can cause excess growth of algae in downstream waters (e.g. Byllesby Reservoir, Lake Pepin and beyond), which in turn can increase turbidity and decrease oxygen levels. | Phosphorus concentrations exceeded state eco-region goals during rain events.                                                                                                                                 | Phosphorus is delivered to the stream primarily on soil particles. See controls for total suspended solids below.                                   |
| Water quality – Total suspended solids | Clear waters are required for trout streams; promotes ability to capture prey and to maintain areas for reproduction. Stream substrates should not exceed 20% fine materials (clay, silt and sand) in riffles. | Failed to meet state standards during rain events and snow melt but close to proposed 10 mg/L standard at baseflow. Coupled to total phosphorus as well.                                                    | • Expand shoreland buffers, using perennial cover and managed grazing systems  
• Employ effective conservation tillage practices  
• Employ cover crops  
• Stabilize stream banks with native grasses (soft armor approach) |
<p>| Flow regime                    | The hydrograph is similar in intensity and flow amounts to historical conditions. Minimum flows are important but high flows may be required at certain times to dig pools and move sediment. | Two years of low precipitation interspersed with major flood events. Stream is very flashy (that is, it rapidly rises in response to rain events). Need more high flow data to create good rating curve. | Reduce peak flows with more infiltration and drainage controls.                                                                                             |</p>
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
<th>Findings</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian zone – Food web</td>
<td>Adequate riparian vegetation is needed to provide food sources/nutrients.</td>
<td>Trout forage on both aquatic (in-stream) and terrestrial (riparian) invertebrates.</td>
<td>Improve riparian habitat with native prairie vegetation to ensure resilient and diverse food sources. Expand width for higher quality habitat corridor: 300 feet is best; however, any expansion would help.</td>
</tr>
<tr>
<td>Riparian zone – Stream width-to-depth ratio</td>
<td>Generally, deeper and narrower streams provide better habitat than shallower, wider streams.</td>
<td>The grasslands yielded a stream width significantly narrower than the forested zones. This is consistent with other studies in the Driftless region and points to soft armor rehabilitation strategies.</td>
<td>Implement rotational grazing, grazing exclusion zones, and savanna type transitional habitat. Encourage diversity in livestock operations. Place high priority on protecting deep pools (cold-water refuges) and known spawning areas possibly with easements or land use ordinances.</td>
</tr>
</tbody>
</table>

*Northfield, Minnesota, Code of Ordinances >> PART II - NORTHFIELD CODE >> Chapter 22 - ENVIRONMENT >> ARTICLE VI. - SURFACE WATER MANAGEMENT >> DIVISION 2. - STORMWATER MANAGEMENT – Ord No. 911, 9-17-2010. See Sec. 22-302 (b)(2) and (c)(2) for Rice Creek specific pieces.  
http://library.municode.com/HTML/13439/level4/PTIINOCO_CH22EN_ARTVISUWAMA_DIV2STMA.html
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City of Northfield, 2010, Ordinance Number 911. Chapter 22, Article VI. Surface Water Management, Division 2. – Stormwater Management, Section 22-302, part c, subpart 2.


Minnesota Department of Natural Resources. “DNR Trout Stream Easements: answers to questions landowners frequently ask”, St. Paul, Minnesota, 2003


