Rice Creek Policy Document - Draft

Prepared for
City of Northfield

June 7, 2010

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1.0 Executive Summary

To be completed after draft is reviewed/public input provided.

2.0 Introduction and Purpose

The Rice Creek Policy Document sets the vision, policies, and proposed tasks for managing surface and ground water within the boundaries of the Rice Creek watershed. Rice Creek (also known as Spring Brook) contains brook trout and has been designated as a trout stream by the Minnesota Department of Natural Resources (DNR). Specifically, the DNR has designated that portion of Rice Creek within Sections 2-4 of Township 111 North, Range 20 West as a trout stream.

This document was prepared for the City of Northfield because the City may be annexing a portion of the Rice Creek watershed. The City of Northfield and Bridgewater Township have signed an agreement to allow the City of Northfield to annex portions of Bridgewater Township under certain conditions. Because of the special nature of trout streams, this policy document is not only meant to provide a basic understanding of coldwater streams (trout streams) and various protections tools, it is also intended to set a common foundation for Bridgewater Township, the City of Dundas, and other organizations in protecting Rice Creek.

Table 1 lists the stream length and watershed of Rice Creek by the local government unit. Figure 1 shows the Rice Creek watershed and existing and proposed community boundaries.

Table 1 Rice Creek Stream Length and Watershed (will verify/double check values before finalizing)

	Before Annexation				After Annexation			
	Area (sq. mi.)	Watershed Area (acres)	Length (ft)	Length (mi)	Area (sq. mi.)	Watershed Area (acres)	Length (ft)	Length (mi)
City of Northfield	0.0004	0.3	226	0.04	0.44	281.0	5,087	0.96
City of Dundas	0.15	93.4	0	0.00	0.15	93.4	0	0.00
Bridgewater Township	6.28	4,017.7	10829	2.05	5.84	3,737.0	5,968	1.13
Forest Township	0.03	17.7	0	0.00	0.03	17.7	0	0.00
Total	6.45	4,129.0	11,055	2.09	6.45	4,129.0	11,055	2.09
Note: Length is measured along the centerline of only the main channel, not the tributaries.								

3.0 Coldwater Stream Needs and Issues

Rice Creek is the home of naturally-reproducing brook trout.[1] Brook trout are often viewed as an indicator species of clean coldwater with good ecological integrity. The Minnesota Pollution Control Agency (MPCA) uses the brook trout and their need for cold, clear waters with silt-free bottoms, as a sign of good water quality. Brook trout are the only native species of trout in Minnesota streams and can tolerate only the cleanest and clearest water of the three species of trout in southeastern Minnesota.[2]

The DNR designates a stream as a trout stream if it currently has conditions to support trout, which includes an analysis of several factors including whether trout are present (although some streams can be designated trout streams without trout), water temperature, dissolved oxygen, habitat, and invertebrates. The DNR does not differentiate between trout streams and coldwater streams.

3.1 Coldwater Stream Needs

Trout need cold, clean, oxygenated water that is rich in aquatic life in order to survive and thrive. Their preferred habitat includes streams with gravel and rock/rubble bottoms, a variety of deep pools and shallow riffles, and overhead cover. Trout eat a wide variety of benthic invertebrates, primarily aquatic insects, but also crayfish, minnows and terrestrial insects that fall into the streams.

3.1.1 Cold Water

Water temperature is one of the most important factors in determining the health of a coldwater stream. Water temperature's relationship with dissolved oxygen (discussed in Section 3.1.2.1) influences living organisms. As the water gets warmer, an aquatic organism's metabolism speeds up, increasing its need for oxygen, but the warmer the water gets, the less oxygen it can hold. Aquatic organisms are adaptive to a variety of water temperatures, but each species has its own optimum for growth and reproduction. The optimum water temperature for brook trout is between 55 degrees

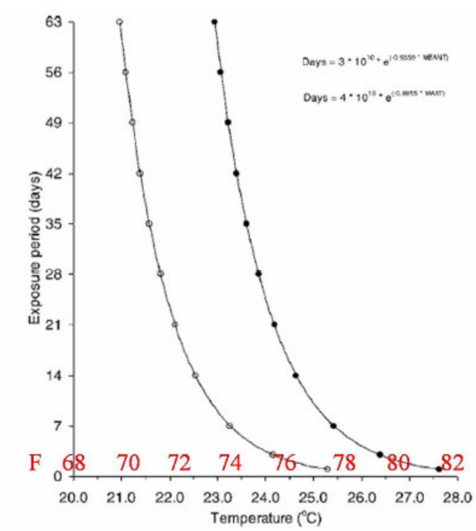

Figure 2. Estimates of the maximum daily mean temperatures (open circles) and the maximum daily maximum temperatures (closed circles) of brook and brown trout as functions of exposure period (Wehrley, 2007)

1 Personal communication with Jeff Weiss (Minnesota Department of Natural Resources) and Cathy Larson and Steve Albers (Bridgewater Township residents)

2 www.dnr.state.mn.us/fishing/trout_species.html

Fahrenheit and 65 degrees Fahrenheit[3]. As shown in Figure 2, once water temperatures exceed 68 degrees Fahrenheit, trout survival rapidly decreases.[4] Trout can tolerate brief periods of water temperatures up to 72 degrees Fahrenheit[5], but exposure to temperatures of 75 degrees Fahrenheit for only a few hours is usually lethal[6].

To achieve the optimum water temperature range for brook trout, the primary source of water in southern Minnesota's coldwater streams must be groundwater. Too much warm surface water inputs, generated from various sources including impervious surfaces, lakes and ponds, and inadequate shade, can warm the water in coldwater streams. Issues affecting cold water are discussed in Section 3.2.1.

3.1.2 Clean Water

Trout need oxygen to survive. Dissolved oxygen is a measure of the amount of oxygen that is dissolved in the water and available for aquatic organisms to use. The capacity for water to hold oxygen in dissolved form decreases as water temperature increases. Optimum oxygen levels for brook trout are not well documented but appear to be greater than or equal to 7 mg/l at water temperatures less than 59 degrees Fahrenheit and greater than or equal to 9 mg/l at water temperatures greater than or equal to 59 degrees Fahrenheit.[3] The MPCA has established a minimum of 7 mg/l as a daily minimum water quality standard for trout streams.

Water with a pH range generally between 6.5 and 8.0 (with a tolerance range of 5.0-9.5)[3] that is low in silt, suspended solids (optimum turbidity values approximately 0-30 Jackson Turbidity Units (JTUs), with a range of 0-130 JTUs)[3], numbers of bacteria, and concentrations of nitrogen and phosphorus are also desireable for coldwater streams. These parameters are disussed as issues in Section 3.2.2.

3.1.3 Habitat and Physical Characteristics

Brook trout appear to be opportunistic sight feeders, utilizing both bottom-dwelling and drifting aquatic macrinvertebrates and terrestrial insects. Such feeding habits make them particularly susceptible to even moderate turbidity levels, which can reduce their ability to locate food.[7] (See Section 3.2.2.4. for a discussion on turbidity.)

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3 Raleigh, R. F. 1982. Habitat suitability index models: brook trout. U.S. Department of the Interior, Fish and Wildlife Service, FWS/OBS-82/10.24

4 Wehrly, Kevin E., L. Wang and M. Mitro, "Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation" *Transactions of the American Fisheries Society* 2007, 136, 365-374.

5 Conservation Strategy Work Group, Eastern Brook Trout Joint Venture. December 2005. Conserving the Eastern Brook Trout: An Overview of Status, Threats, and Trends.

6 Flick, W. A. 1991. Brook trout. Pages 196-207 in J. Stohlz and J. Schnell, editors. The wildlife series: Trout. Stackpole Books. Harrisburg, Pennsylvania.

The Trout Unlimited publication, "A Guide to Native Trout Restoration: Science to Protect and Restore Coldwater Fisheries and their Habitats"[7] (this is from the CRWP report) identifies the following as healthy trout stream physical characteristics.

Characteristic	Description
Pools, Riffles, and Runs	Roughly equal numbers of pools, riffles, and runs should be present. Complex channels are preferred over simple, straight streams.
Large Wood	Downed trees and other large wood debris functions to create pools, store sediment, and act as a source of needed organic matter.
Riparian Vegetation	Adequate riparian vegetation is needed to shade streams, protect banks from severe erosion, and provide nutrients.
Deep Pools	Sufficient pools are necessary as thermal refuges and holding habitat.
Width to Depth Ratio	Generally, deeper and narrower streams provide better habitat than shallower, wider streams.
Bank Stability	Banks should be 80-90% stable. Some erosion is needed, but too much is detrimental.
Fine Sediments	Stream substrates should not exceed 20% fine materials (clay, silt, and sand) in riffles.
Flow Regime	Similar flow intensities and amounts to historical conditions are important. Baseflow is also important, but high flows may be required at certain times to scour pools and move sediment.

3.2 Coldwater Stream Issues

Coldwater streams can be negatively affected by several human activities. Reducing the amount of coldwater entering the stream, polluting the stream's water, changing a stream's hydrology, removing the riparian vegetative buffer, and removing the stream's inhabitants can have negatively consequences on the stream's health. Brook trout populations, if already stressed by issues such as warm water temperatures or overharvest are very susceptible to damage by the introduction of other fish species.

3.2.1 Issues Affecting Cold Water

As previously noted, the water source of most coldwater streams in Minnesota is groundwater. During the growing season, surface water runoff is warmer than groundwater. Groundwater in the region tends to be approximately 44 degrees Fahrenheit at 40 feet below the ground surface.

7 Williams, J.E., W. Colyer, N. Gillespie, A. Harig, D. DeGraaf, and J. McGurrin. 2006. *A guide to native trout restoration: science to protect and restore coldwater fishes and their habitats.* Trout Unlimited, Arlington, Virginia.

Excessive warm inputs from urban and agricultural runoff lead to thermal pollution of coldwater streams. Thermal pollution could also be caused by the lack of shading vegetation.

3.2.1.1 Reduction in Groundwater

Seeps and springs convey the cold groundwater to the ground surface. If the groundwater table drops because of climatic conditions, the lack of surface water replenishing it because of increased impervious surfaces and less infiltration, or from over-pumping, there will be less groundwater available to feed a coldwater stream. Less groundwater can lead to less water in the stream and warmer water temperatures; either of which can cause the stream's inhabitants to become stressed. For trout, the upwelling of groundwater within a stream's gravel beds is also critical for egg circulation and successful reproduction.

3.2.1.2 Land Cover and Surface Water Management

3.2.1.2.1 Impervious Surfaces

Research in recent years has consistently shown a strong relationship between the percentage of impervious cover in a watershed and the health of the receiving stream. Scientists generally agree that stream degradation consistently occurs at relatively low levels of imperviousness (10 - 15%) and where there is minimal or inadequate treatment of stormwater runoff. Increased impervious surfaces alter stream hydrology, resulting in lower flows during droughts and higher peak flows during floods. With advanced planning and identification of at-risk watersheds, total impervious cover can be reduced during development within a watershed and engineering steps taken to mitigate the impacts of added impervious cover with appropriate volume control and infiltration practices.[8]

3.2.1.2.2 Surface Water Management

Some stormwater management practices can cause more thermal pollution than others. For example, the water in wet detention stormwater ponds designed for rate control and water quality treatment heats up with sunlight and can become approximately the same temperature as the air. When a storm occurs, the heated water in the pond discharges into the coldwater stream. Therefore, many organizations who manage coldwater streams prohibit wet ponds as stormwater management features and instead require practices that will infiltrate or filter runoff.

When infiltration practices are used, consideration needs be given to the set-back distance from a coldwater stream. The City of Lakeville recognized this issue and commissioned a technical study[9] in 2000 to examine the temperature impact of a single infiltration pond versus its proximity to a trout stream. Although many assumptions were made in the modeling effort, including but not limited to precipitation amounts, infiltration rates, volume of water being infiltrated, temperature of water being infiltrated, and hydraulic conductivity of the groundwater, the modeling suggests some warming

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8 Kauffman, G. (2000). The role of impervious cover as a watershed-based zoning tool to protect water quality in the Christina River Basin of Delaware, Pennsylvania and Maryland. *Watershed Management Conference* (pp. 1-10). Water Environment Federation

9 Wilson, Greg. May 10, 2000. Barr Engineering Company memorandum to Tim Brown, Lakeville Joint EDC/EAC South Creek Subcommittee. Results of the Lakeville South Creek Study—FINAL.

downstream groundwater. The modeling indicated that groundwater temperatures may become elevated above ambient levels for large distances downgradient of a basin, with smaller temperature increases in the direction that is side-gradient to the groundwater flow. Over time, the model predicted continual warming of groundwater downgradient and sidegradient to the basin for approximately five years, until a steady-state condition was reached. In one scenario that was modeled, the ambient groundwater temperature at the pond increased by twelve degrees Fahrenheit. However, at a distance 300 feet downstream from the pond, all of the modeling scenarios predicted increases in the ambient groundwater temperature by less than three degrees Fahrenheit.

3.2.1.2.3 Shading

Canopy cover is important in maintaining shade for stream temperature control. Too much shade, however, can restrict plant growth in and along the banks of a stream. About 50-75% midday shade appears optimal for most small trout streams.[10]

3.2.2 Issues Affecting Clean Water

3.2.2.1 Dissolved Oxygen

Low dissolved oxygen concentrations can indicate an upstream discharge of oxygen-demanding substances, low stream velocities, or oxygen consumption by bottom sediments. Dissolved oxygen is consumed in large quantities by bacteria during the decomposition of organic materials. The organic matter may be of natural origin or may result from the addition of sewage, industrial waste, or stormwater runoff to the stream. Depression of dissolved oxygen can cause a shift from brook trout and invertebrate populations to undesirable fish and more tolerant invertebrate populations.

3.2.2.2 Siltation, Suspended Solids, and Turbidity

Siltation, suspended solids, and turbidity are related to each other. Siltation is the deposition of water-borne silt in a body of water. Suspended solids refers to small solid organic and inorganic particles which remain in suspension as a colloid or due to the motion of the water. Turbidity is the cloudiness or haziness of water caused by individual particles (suspended solids) that are generally invisible to the naked eye.

Streams can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the stream, very small particles will settle very slowly or not at all. These small solid particles cause the water to appear turbid.

High suspended solids concentrations tend to settle out in quiescent water, smothering organisms and interfering with the food web. Suspended solids may accumulate in the gills of fish. Therefore, high suspended solids concentrations may be injurious or toxic to fish.

The MPCA has not established a total suspended solids standard for trout streams.

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10 Raleigh, R.F. 1982. Habitat suitability index models: Brook trout. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.24. 42 pp.

In water quality monitoring, turbidity is a measure of the inability of a water sample to transmit light. The higher the turbidity, the less ability a water sample has to transmit light. Water of high turbidity has a murky appearance because it does not transmit light in straight lines, but rather scatters and absorbs the light. Turbidity can result from inorganic solids as well as from organic matter, such as plankton and other microscopic organisms. High turbidity can interfere with the growth and reproduction of aquatic organisms. The MPCA turbidity standard for Class 2A waters requires that turbidity not exceed 10 nephelometric turbidity units (NTU).

Siltation in streams typically occurs as a result of five major watershed factors: sheet erosion from agricultural practices on uplands, gully erosion, runoff from developments, construction site erosion in and near the stream, and bank erosion in the stream itself.

Siltation destroys trout spawning habitat. Brook trout spawn from October to December, congregating in shallow riffles over gravel and rubble bottoms. The female constructs a nest, or redd, by sweeping out a depression in the gravel with her anal and tail fins. Fertilized eggs settle to the bottom into crevices between the gravel and rubble. Siltation prevents the eggs from successfully developing because it reduces the available oxygen—smothering the eggs and embryos in the redd. Siltation also reduces the embryo's ability to escape the redd.

In addition, siltation can negatively affect the food source for trout by accumulating over materials needed to support the aquatic insects. Sediment also acts as an abrasive on small organisms, which reduces the food source of aquatic insects and in turn reduces the food source for trout. Finally, sedimentation leads to less riffle, pool, run habitat types.

3.2.2.3 pH

The hydrogen ion concentration is indicated by pH (pH = -log [H+]). It is measured on a scale of 1 to 14, with a pH of 7 indicating a neutral relationship between acidic and basic ions. pH values below 7 indicate increasingly acid properties, and pH values above 7 indicate increasingly basic properties. The pH of most natural waters is near neutrality and pH extremes at either end of the scale are rare due to the high buffering capacity of natural waters. A low pH can be caused by acidic discharges or by high concentrations of organic acids. Low pH can cause toxicity of aquatic life by releasing materials from sediments.

Acid rain from air pollution has resulted in pH levels too low to sustain brook trout in all but the highest headwaters in some Appalachian streams and creeks.[11] Brook trout populations across large parts of eastern Canada have been similarly challenged.

Water with a pH range generally between 6.5 and 8.0 is considered optimal for brook trout, but they can tolerant a range of 5.0-9.5[3]. The MPCA standard specifies a pH range from 6.5 to 8.5 for trout streams.

11 Camuto, Christopher. 1990. A Fly Fisherman's Blue Ridge, Henry Holt & Company.

3.2.2.4 Specific Conductance

Specific conductance is an indication of the amount of dissolved ionized minerals in water. Ionized minerals have the capacity to carry an electrical current, which can be measured. Specific conductance is a measurement of conductivity over a specific distance between electrodes. Therefore, a high specific conductance measurement is an indication that large quantities of dissolved ionized minerals are present in the stream. The concentration of dissolved ions in a stream frequently reflects the level of environmental impact to a watershed. Highly impacted systems frequently have high dissolved ion concentrations as a result of watershed discharges. Extremely high dissolved solids concentrations will affect aquatic life by upsetting the osmotic balance and inhibiting water absorption. In addition, specific dissolved ions may cause toxic effects. A low specific conductance measurement is an indication that dissolved ionized minerals are present in low quantities in a stream. Monitoring this parameter can be of use as a general indicator of changes in dissolved solids content over a period of time The MPCA has established a standard of a maximum of 1,000 umhos/cm at 25 degrees Celsius for specific conductance for trout streams.

Brook trout occur in waters with a wide range of alkalinity and specific conductance, although high alkalinity and high specific conductance usually increase brook trout production.[12]

3.2.2.5 Bacteria/E. coli

In addition to sediment, runoff can carry other pollutants with it, which can harm a coldwater stream. For example, Escherichia (E.) coli/fecal coliform can cause serious food poisoning in humans. High E. coli concentrations are typically mainly due to livestock manure, waterfowl and nonconforming separate sewage treatment systems, but tend to not impact trout directly. The MPCA standard for trout streams requires that E. coli not exceed 126 organisms per 100 milliliters.

3.2.2.6 Nitrogen

Nitrogen is a nutrient essential for the growth of organisms. Because of the high solubility of nitrogen, high nitrogen concentrations can indicate the presence of agriculture runoff, sanitary landfill leachate, municipal sewage, or stormwater runoff.

Nitrogen from fertilizer as well as from other sources can have a direct impact on the water quality of rivers and lakes. Nitrogen can move either through direct runoff, by means of erosion, via tile line drainage, subsurface flow, and shallow groundwater flow.

Relatively low concentrations of nitrates may be harmful to fish. Grabda et al.[13] reported that fry of rainbow trout, exposed to 5–6 mg nitrate nitrogen (NO3-N)/l for several days affected blood

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12 Raleigh, R.F. 1982. Habitat suitability index models: Brook trout. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.24. 42 pp.

13 Grabda, E., Einszporn-Orecka, T., Felinska, C., Zbanysek, R., 1974. Experimental methemoglobinemia in trout. Acta Ichthyol. Piscat. 4, 43–71.

chemistry and caused liver damage. Kincheloe et al. [14] concluded that a nitrate level as low as 2.0 mg NO3- N/l in surface waters of low total hardness (<40 mg calcium carbonate (CaCO3)/l) would be expected to limit survival of some salmonid fish populations because of impaired reproductive success.

Because excessive nitrate concentrations in water are typically the result of agriculture fertilizer use, better fertilizer management is needed to reduce nitrate concentrations. Some practices suggested by the Nitrogen Fertilizer Task Force[15] to prevent degradation of Minnesota water resources while maintaining farm profitability include:

- Adjusting nitrogen application rates according to soil organic matter content, previous crop, and manure application,
- Using a deep soil test to measure residual soil nitrate in the root zone,
- Using prudent manure management,
- Timing nitrogen application for better crop uptake

The MPCA has several standards for nitrogen levels in trout streams. Unionized ammonia concentrations must never exceed 16 ug/L, nitrate must not exceed 10 mg/L, nitrite must not exceed 1 mg/L, and nitrate + nitrite must not exceed 10 mg/L.

3.2.2.7 Phosphorus

Phosphorus is typically the limiting nutrient in Minnesota's waters for plant and algae growth. The primary natural sources of phosphorus to aquatic ecosystems are the slow dissolution of minerals in soil and decomposition of organic matter, such as leaf litter, although natural sources also include soil dusting and burning. Human activities, such as sewage (treated and untreated), septic tank leachate, fertilizer runoff, soil erosion, animal waste, and industrial discharges, have dramatically increased delivery of phosphorus to surface waters.

However, at least one study has shown that total phosphorus has positive effects on brook trout growth. The positive influence of total phosphorus may reflect increase food availability that subsequently enabled the brook trout to be in better condition before winter.[16]

The MPCA has not established a total phosphorus standard for trout streams.

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14 Kincheloe, J.W., Wedemeyer, G.A., Koch, D.L., 1979. Tolerance of developing salmonid eggs and fry to nitrate exposure. Bull. Environ. Contam. Toxicol. 23, 575–578.

15 The Nitrogen Fertilizer Task Force was established by the Legislature in the 1989 Comprehensive Groundwater Protection Act to "... study the effects and impact on water resources from nitrogen fertilizer use so that best management practices, a fertilizer management plan and nitrogen fertilizer use regulations can be developed."

16 Zorn, Troy G. and Andrew J. Nuhfer. May 3, 2007. Influences on Brown Trout and Brook Trout Population Dynamics in a Michigan River.

3.2.3 Issues Affecting Habitat and Physical Characteristics

As discussed in Section 3.2.2.2, siltation is a major issue for trout streams. In addition, reducing overhead cover along the stream margin can be a major factor limiting brook trout abundance[17]. Eliminating inputs of large woody debris into streams can have a negative effect on trout habitat by decreasing pool areas and volumes, increasing riffle lengths, and increasing vulnerability to predation[18]. In addition to impacts on stream temperatures, riparian cover, erosion, and siltation, any land use activity that removes vegetative cover, disturbs the soil mantle, reduces infiltration rates, decreases soil moisture storage, or increases overland flow has the potential to negatively affect streams by causing higher peak stream flows and more rapid attainment of peaks[19]. Stream manipulation (culverts, dams, etc.) can affect fish passage. Over-harvesting can decrease trout's ability to naturally reproduce.

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17 Enk, M. D. 1977. Instream overhead bank cover and trout abundance in two Michigan streams. M.S. Thesis, Michigan State University, East Lansing.

18 Hicks, B. J., J. D. Hall, P. A. Bisson, and J. R. Sedell. 1991. Responses of salmonid populations to habitat changes caused by timber harvests. Pages 483-518 in W. R. Meehan, ed. Influence of forest and rangeland

19 Hibbert, A. R. 1967. Forest treatment effects on water yield. Pages 527-543 in W.E. Supper and H.W. Lull, eds. Forest hydrology. Pergamon Press, Oxford.

4.0 Rice Creek Specific Issues

Because the majority of the Rice Creek watershed will remain outside of the City of Northfield's jurisdiction after the potential annexation, many of the issues identified in this document are inter-jurisdictional issues. If the City of Northfield annexes more of the Rice Creek watershed, it will need to work with landowners and other jurisdictions to address issues to protect and improve Rice Creek. The following section briefly discusses pollution and other issues with Rice Creek.

4.1 Cold Water

Monitoring Station	Temperature Data
S001-446 (upstream-most station at Cates Avenue)	Non-Winter Months in 1999, 2007-2008
S001-444 (at Decker Avenue)	Non-Winter Months in 1999-2009
S001-445 (downstream-most station at County 78/ Armstrong Road)	Non-Winter Months in 1999, 2001, 2002, 2006-2008

Based on information available from the Minnesota Pollution Control Agency (MPCA) and the Cannon River Watershed Partnership (CRWP), instantaneous temperature data has been collected at three stations in Rice Creek as shown in the table to the left. Figure 3 (to be created after receiving CWMP data) shows the monitoring locations. The reported data shows that the water temperature of Rice Creek has reached 74.73 degrees Fahrenheit at the farthest downstream station. At the Decker Avenue station, the data show occasional temperatures over 72 degrees Fahrenheit, with a report of 82 degrees Fahrenheit on August 4, 2002. (No data were collected at the other two stations that year so a comparison to this extremely high reported temperature cannot be done.) The maximum reported temperature at the farthest upstream (Cates Avenue) station was 79.74. During its continuous temperature monitoring in 2007-2008, the CRWP found that the daily temperature at the Cates Avenue station was almost always higher than that at the Armstrong Road station by a range of 0.5 to 6.0 degrees Fahrenheit. The CRWP found these results logical because the water flowing at the Cates Avenue station is from County Ditch 22 and drain tile, there is no tree cover along this area, there are springs between Cates Avenue and Decker Avenue that add cold water to the stream, and there are trees that provide shading in the downstream reaches of the stream. Need to create figures/charts after obtaining data

The data show that water temperatures higher than those preferred by brook trout occur several times during the summer and occasional lethal temperatures have been reported. However, Rice Creek's brook trout must have adapted to these higher temperatures and/or be finding refuge areas because the trout are surviving.

4.1.1 Groundwater

No data regarding the groundwatershed and the ratio of groundwater to surface water to Rice Creek appear to exist. Bedrock appears to be at least ten feet below the surface in the watershed.

4.1.2 Land Cover and Surface Water Management

Agriculture is currently the predominant land use in the Rice Creek watershed. Much of the watershed is used for row crops of corn and soybeans with two beef cattle feedlots/grazing operations located between Decker Avenue and Armstrong Road.[20]

4.1.2.1 Impervious Surfaces

While it is outside the scope of this project to determine the current and proposed percent of impervious surfaces within the Rice Creek watershed, it appears that the watershed currently has significantly less than 10% impervious coverage. Future development of the area being considered for annexation to Northfield appears to also keep the percentage of imperviousness in the watershed to less than 10%; however, individual drainage areas to the creek might have imperviousness coverage over 10%.

4.1.2.2 Surface Water Management

The City of Northfield has a stormwater management ordinance and is currently updating it. The City is also considering special provision for development within the Rice Creek watershed. Section 6.1.3 includes the stormwater management policies that the City is considering for the Rice Creek watershed.

4.1.2.3 Shading

Based on a review of aerial photographs, Rice Creek appears to be shaded by trees in most of the reach downstream from Cates Avenue. However, there appears to be very little tree canopy over the reach upstream of Cates Avenue and the tributary northwest of the Decker Avenue/100th Street East intersection, and the southern reach of the tributary southwest of the Decker Avenue/100th Street East intersection.

4.2 Clean Water

The water quality of Rice Creek is not as clean as required by the MPCA. While significant water quality issues have been documented through past monitoring efforts, Rice Creek's trout population is surviving. The following sections discuss various water quality issues at Rice Creek.

4.2.1 Dissolved Oxygen

No dissolved oxygen data were available from the MPCA or in the Cannon River Watershed Partnership's Rice Creek (Spring Brook) Water Quality Assessment Project Report August 2008.

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20 Rice Creek (Spring Brook) Water Quality Assessment Report, August 2008. Cannon River Watershed Partnership, Elizabeth Croteau-Kallestad.

4.2.2 Siltation, Suspended Solids, and Turbidity

Monitoring Station	Data (need to separate)
S001-446 (upstream-most station at Cates Avenue)	Transparency, tube with disk: 1999, 2006-2008; Total Suspended Solids: 2006-2008
S001-444 (at Decker Avenue)	Transparency, tube with disk: 1999-2008
S001-445 (downstream-most station at County 78/Armstrong Road)	Transparency, tube with disk: 1999, 2001-2002, 2006-2008; Total Suspended Solids: 2006-2008

Rice Creek is on the MPCA's draft 2010 impaired waters list for turbidity (e.g. suspended sediment) because its water exceeded the 10 NTU (Nephelometric Turbidity Units – the units of turbidity from a calibrated nephelometer) MPCA turbidity standard. May include figure(s).

For impaired waterbodies, a total maximum daily load (TMDL) must be developed. A TMDL is a threshold calculation of the amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL establishes the pollutant loading capacity within a waterbody and develops an allocation scheme amongst the various contributors, which include point sources, non-point sources and natural background, as well as a margin of safety. As a part of the allocation scheme a waste load allocation (WLA) is developed to determine allowable pollutant loadings from individual point sources (including loads from storm sewer networks), and a load allocation (LA) establishes allowable pollutant loadings from non-point sources and natural background levels in a waterbody. The draft 2010 impaired water list indicates that the target start date for Rice Creek's turbidity TMDL is 2012.

Might need more discussion on past monitoring efforts and results.

4.2.3 pH

No pH data were available from the MPCA or in the Cannon River Watershed Partnership's Rice Creek (Spring Brook) Water Quality Assessment Project Report August 2008.

4.2.4 Specific Conductance

No specific conductance data were available from the MPCA or in the Cannon River Watershed Partnership's Rice Creek (Spring Brook) Water Quality Assessment Project Report August 2008.

4.2.5 Bacteria/E. Coli

Monitoring Station	Data	Data Range	Data Average
S001-446 (upper-most at Cates Avenue)	2007-2008	<1 -2419.6 MPN/100 ml	235
S001-444 (at Decker Avenue)	No data	NA	NA
S001-445 (lower-most at County 78/ Armstrong Road)	2007-2008	<1 - >2419.6 MPN/100 ml	505

Very high E. coli bacteria counts have been reported in water samples collected from Rice Creek. 2419.6 and greater than 2419.6 MPN/100 ml have been reported at the Cates Avenue and Armstrong Road stations, respectively. (May include figure.) The CRWP concluded that the higher counts at the Armstrong Road station were due to two feedlots between Decker Avenue and Armstrong Road. Rice Creek is on the MPCA's draft 2010 impaired waters list for Escherichia (E.) coli/fecal coliform because the bacteria counts are above 126 colony forming units (cfu)/100 ml. The MPCA's target start date for the E. coli TMDL is 2016, but the TMDL could be started earlier.

4.2.6 Nitrogen

Monitoring Station	Data	Data Range	Data Average
S001-446 (upper-most at Cates Avenue)	2008	<0.02-17.7 mg/l	11.1
S001-444 (at Decker Avenue)	2005-2008	3.94-12.5 mg/l	9.8
S001-445 (lower-most at County 78/ Armstrong Road)	2008	<0.02-16.6 mg/l	9.9

Rice Creek is on the MPCA's draft 2010 impaired waters list for nitrate because the creek's water has nitrate concentrations exceeding 10 mg/L. May include figure. The MPCA's target start date for the nitrate TMDL is 2010, but the nitrate TMDL will likely not start until 2011 at the earliest because the MPCA will likely conduct a watershed-wide TMDL on Rice Creek rather than have separate TDML studies for various parameters.

4.2.7 Phosphorus

Monitoring Station	Data
S001-446 (upper-most at Cates Avenue)	2006-2008
S001-444 (at Decker Avenue)	2005-2008
S001-445 (lower-most at County 78/ Armstrong Road)	2006-2008

Need to discuss.

4.3 Habitat and Physical Characteristics

Need to discuss with CRWP and summarize.

5.0 General Strategies for Managing Coldwater Streams

This section provides a summary of the protection tools that are most applicable to, or have/could have the most impact on, protecting Rice Creek.

5.1 Local Government Tools

Local governments (city, town, watershed organizations) have a variety of tools available to protect coldwater streams. Regulatory tools are typically applied at the time of development activity. Other land use planning tools are developed in anticipation of development and help guide the location and type of activity and inform the development of appropriate regulations.

5.1.1 Regulatory Tools

5.1.1.1 Permanent Post-Construction Stormwater Management Ordinance

Permanent post-construction stormwater management ordinances are regulations that address how stormwater runoff is permanently managed after construction and development activities are completed. Communities with trout streams within their jurisdiction typically regulate stormwater runoff for water quality, temperature, rate and volume. Regulations also address the amount of impervious surface allowed, flood management, as well as activities within floodplains, shorelines, and wetlands. Parameters and general standards of communities with trout streams within their jurisdictions also vary. Appendix A includes a summary of the regulated activities and standards from a sampling of local government units.

5.1.1.2 Erosion and Sediment Control Ordinance

Erosion and sediment control ordinances are regulations that concern management practices designed to control surface runoff and limit soil erosion during land disturbing and construction activities.

5.1.1.3 Environmental Overlay Districts

Environmental overlay districts are specific types of resource protection zones laid-over the base zoning district to protect a defined natural resource area with specific rules. The underlying use as defined by the base zoning district is still allowed in an appropriate form consistent with the overlay zone. A floodplain zoning district is an example of an overlay district.

5.1.1.4 Conservation Subdivision Design

Conservation subdivision design is a density neutral site design approach that clusters homes on smaller lots in order to protect natural resources, and create open space and greenway corridors. The use of conservation easements are often used to permanently protect the open space/resource areas.

5.1.1.5 Low Impact Development (LID)

While not necessarily a regulatory tool, LID is a stormwater management approach with a basic principle that is modeled after nature: manage rainfall at the source using distributed decentralized micro-scale controls. LID's goal is to mimic a site's pre-existing hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. With this approach overall runoff volume is reduced. Instead of conveying and treating stormwater in large, end-of-pipe facilities located at the bottom of drainage areas, LID addresses stormwater through a variety of smaller dispersed and aesthetically attractive techniques.

5.1.1.6 Buffer Ordinances

Buffer ordinances are an effective tool for the enhanced protection of woodlands, slopes, wetlands, and water courses. The concept is to protect natural resources, based on their inherent quality; the buffer width varies depending on the physical environment and goals. This tool helps to create a more ecologically stable system of natural resources that are less likely to be negatively affected by development.

5.1.1.7 Bonus/Incentive Zoning

Bonus zoning allows for additional development rights to be generated and used by the developer rather than purchased from another landowner. Incentive zones may establish a required set of conditions and an optional set of incentives that the developer may choose to meet in exchange for greater flexibility. For example, an incentive zoning law may allow a developer in a zone to build at a higher density than is normally allowed if the developer agrees to set aside more open space, create a greenway or ecological corridor or adopt certain energy saving or transportation measures.

5.1.1.8 Groundwater Management

The DNR regulates groundwater usage rate and volume as part of its charge to conserve and use the waters of the state. For example, suppliers of domestic water to more than 25 people, or applicants proposing a use that exceeds 10,000 gallons per day or 1,000,000 gallons per year must obtain a water appropriation permit from the DNR. Appropriation permits from the DNR are not required for domestic uses serving less than 25 persons for general residential purposes. The DNR is also responsible for mapping sensitive groundwater areas, conducting groundwater investigations, addressing well interference problems, and maintaining the observation well network.

Local jurisdictions will need to consider the groundwater impacts and effects on Rice Creek's base flow when locating future wells or planning increases in pumping volumes of existing wells. While developing more stringent groundwater appropriation rules than the DNR might be feasible depending on legal interpretations of Minnesota Statute and Minnesota Rule, enforcement of more stringent rules isn't very practical. However, the local jurisdictions might want to consider regulations prohibiting practices like open-ended geothermal systems which waste groundwater by using it and discharging it to the ground surface.

5.1.2 Land Use Planning and other Tools

5.1.2.1 Natural Resource Inventories and Plans

Inventories document the quantity, quality and location of natural resources important to a community. It is important to document these resources so they may be identified in plans and regulations intended to protect them. Resource plans identify strategies and tools for protecting and/or incorporating the resources into development activities in ways that protect the resources over the long-term.

5.1.2.2 Direct Purchase/Fee Simple Acquisition

A governmental jurisdiction or land trust purchases property when the parcel meets the long-term preservation objectives of the community and the parcel can be integrated into the larger parks, open space and trail system. With limited fiscal resources, direct purchase is typically considered only after other protection methods have proven to be unsuccessful.

5.1.2.3 Conservation or Preservation Easement

Conservation or preservation easements restrict development of land while permitting the landowner to retain ownership of the property. It is filed in the public records of the property and binds current and future property owners. The landowner may sell or donate the easement to a conservation organization, but it is not required. Where the easement is donated to a qualified charitable organization, a tax benefit may occur to the owner.

5.1.2.4 Purchase or Transfer of Development Rights

A local government, land trust, or other developer purchases the development rights to a property, while the landowner continues to maintain ownership. Once the rights are purchased, the land can only be used for a specified purpose other than development. The land would typically be protected under a subsequent conservation easement or other protection program. Transfer of development rights refers to protecting the natural values of one property by transferring or selling the right to develop that property to other properties within the city under strict guidelines. The property "receiving" the development rights may be developed at a higher density. Both of these approaches ensure that there is no economic harm to the landowner or developer and that the city retains its desired development density.

5.2 Agricultural Lands

Agricultural lands are typically exempt from stormwater ordinances. However, agencies such as the Natural Resources Conservation Service and the county Soil and Water Conservation District are usually available to work with landowners to help design, implement, and maintain stormwater practices on their land. Typical agricultural stormwater management practices include

- Filter strips
- Farm ponds (wet ponds should be discouraged in coldwater watersheds because of thermal affects; dry ponds should be encouraged)
- Strip cropping/contour farming

- Grassed waterways
- Diversion structure
- Crop residue management

As compared to urban development, the DNR views agriculture land use a temporary land use when managing trout stream watersheds.

5.3 Stream Use

Currently, there are DNR stream fishing easements in place along Rice Creek. Typically, the DNR plans parking and access so that streams are not negatively affected by overuse.

5.4 Monitoring

Collecting baseline data is important to understand the current health of Rice Creek. Future monitoring can then be used to determine if protection tools have been successful. Types of monitoring include water quality, water quantity, invertebrate, fish, and physical.

5.4.1 Water Quality and Quantity

Collecting discrete and continuous water quality data is useful. Typical parameters to monitor include

- Stage
- Discharge
- Precipitation
- pH
- Conductivity
- Temperature
- Dissolved Oxygen
- Total Solids
- Total Suspended Solids
- Volatile Suspended Solids
- Total Phosphorus
- Dissolved Phosphorus
- Total Nitrate Nitrogen
- Total Nitrogen
- Major Ions (hardness and alkalinity)

5.4.2 Biomonitoring

5.4.2.1 Invertebrates

While water samples provide an assessment of stream water quality at the time of sample collection, benthic invertebrates provide a long-term assessment of water quality. They live on the bottom and on the vegetation of a stream as long as water quality conditions permit. As attached organisms, benthic aquatic invertebrates are exposed to all the temporal variations in stream quality and "integrate" the quality of passing water. Each type of benthic invertebrate has a different tolerance for pollution; studying the numbers and types of benthic invertebrates can indicate pollution in a stream. When sufficient pollutants enter the stream to prevent their survival, they are eliminated. Monitoring the presence or absence of biological indicator organisms provides indirect evidence of the effects of transitory changes in stream water quality related to stormwater runoff.

Samples are typically collected from a riffle location with a D-frame aquatic net. The substrate is disturbed with the sampler's feet, allowing dislodged invertebrates to drift into the net downstream. Samplers also pass the D-frame net through debris and vegetation near the banks. Rocks are examined, too. All the invertebrate samples are preserved in 80 percent alcohol and later identified.

Once individual invertebrates are identified, a biotic index, such as the Hilsenhoff's Biotic Index is used to further analyze the data. The index uses invertebrate data to rank a stream according to its water quality. Water quality categories include excellent, very good, good, fair, poor, and very poor.

5.4.3.2 Fisheries

With the proper permits, routine fish shocking can be done to determine the type and quantity of fish within a stream. Like invertebrate data, fish data can be analyzed with a biotic index.

5.4.4 Habitat and Physical Characteristics

Physical monitoring to assess sedimentation sites and stream degradation, including the identification and progress of streambank and gully erosion sites, can be useful.

5.5 Education and Partnering with other Agencies and Individuals

Regulations cannot solve all coldwater stream issues. Sometimes public education is needed as well as work on private lands outside of regulation programs. For this type of work, partnering with another agency, such as the Soil and Water Conservation District, the DNR, and Trout Unlimited, can reduce the local jurisdiction's time commitment and costs and can improve the local jurisdiction's chances of obtaining grants.

6.0 Goals and Policies

Based on a review of the SWMP and the November 13, 2009 Rice Creek (Spring Brook) Concerned Citizens Group Report and Recommendations, the following Rice Creek watershed vision and strategies for the City of Northfield are suggested:

Vision	***The Rice Creek Watershed will be healthy and well functioning. The creek will not be degraded by surrounding land uses. Rice Creek will be fed by an adequate supply of clean, cold water and will provide quality habitat to support brook trout, an indicator of the stream and watershed's health.***
Strategies	*To conserve, protect, and improve the naturally reproducing brook trout community and habitat of Rice Creek by:* *A. Regulating activities to minimize negative impacts on Rice Creek* *B. Cooperating with other organizations to* *a. Promote open communication with the citizen base, business owners, developers, and pertinent governmental units* *b. Educate citizens, business owners, developers, and pertinent government units on issues affecting cold water habitat and means for improvement* *c. Collect data on the current physical, chemical, and biological health of Rice Creek and the effectiveness of protection efforts* *d. Implement public works projects and other prudent measures to correct problems* *e. Understand groundwater and septic system effects, encouraging positive behaviors, discouraging negative behaviors, and regulating where feasibility and necessary*

The following sections cover the goals and policies for land use planning, groundwater management, municipal stormwater management, and agricultural lands. Section 6.2 provides monitoring goals and a suggested program with protocols.

6.1 Regulation Goals and Policies

6.1.1 Land Use Planning

Goals:

- Rice Creek will be protected.
- Land uses will be planned and managed to avoid degradation of water quality.
- Critical habitats, such as unfragmented blocks of forest, will be preserved and future development will incorporate the preservation of native terrestrial plant communities, grasslands, and wildlife corridors.

Policies and Actions:

- Land use planning will guide high-impervious land uses away from Rice Creek.

- Through planning, total impervious cover will be reduced during development within the Rice Creek watershed and engineering steps will be taken to mitigate the impacts of added impervious cover with appropriate volume control and infiltration practices.
- When necessary and feasible, land use planning and zoning-type tools will be used to preserve undeveloped land, including:
    - Natural resource conservation plans,
    - Official maps,
    - Donated conservation easements,
    - Purchase of development rights,
    - Transfer of development rights (density transfer),
    - Land acquisition,
    - Overlay districts,
    - Conservation subdivision design (also known as clustering)

6.1.2 Groundwater Management

Goals:

- Groundwater will be uncontaminated, and there will be an adequate supply of groundwater to meet the ecological needs (base flow in Rice Creek) and social-economic demands (recreation, industry, personal consumption).
- Recharge areas will not receive contaminated water.
- Groundwater appropriations will not deplete stream flow.
- Additions of imperviousness will not negatively reduce groundwater recharge.

Policies and Actions:

- A groundwater management plan should be developed. Implementation of the plan should bring together neighboring surface water management entities to protect groundwater within and outside of the Rice Creek watershed.
- Research should continue to clearly identify the Rice Creek groundwatershed and significant recharge areas.
- Observation wells and other stations should be monitored.
- Sources of nitrate contamination should be identified.
- Septic systems should be up to code and owners should be informed about proper operation and maintenance.
- The DNR should continue its groundwater appropriations permitting program.

6.1.3 Municipal Stormwater Management

Goals:

- The water quality of Rice Creek will be maintained or improved.
- Temperature increases in Rice Creek will be prevented.
- Erosion will be prevented and steep slopes will be protected from disturbance.
- Contaminants such as sediment, nutrients, and chemicals will be kept out of Rice Creek.

- There will be minimal property damage or loss from flooding.

Policies and Actions:

- In preparing for the potential annexation of land within the Rice Creek watershed, the City of Northfield will prepare a stormwater management ordinance with post-construction performance standards that specifically address measures to protect Rice Creek as a viable trout habitat. These measures will include:
    - Requiring that runoff volume be controlled to the 2-year 24-hour design event (e.g. 2.8 inch event)
    - Requiring infiltration methods for water quality treatment and preventing thermal impacts (e.g. wet detention basins or ponds are not allowed)
    - Regulating the placement of stormwater treatment facilities through setbacks from Rice Creek
    - Establishing “presettlement” conditions as the standard for post development runoff rate control and volume control
    - Protecting existing vegetative buffers along Rice Creek
    - Requiring buffers around stormwater management facilities
    - Requiring minimum floor elevations to be no lower than two feet above the creek’s 100-year flood level
    - Encouraging low impact development practices
    - Applying the above policies to all subdivisions and projects requiring a site plan review
- The City of Northfield will continue to enforce its erosion control ordinance.
- The MPCA will continue to administer and enforce its NPDES Construction Stormwater Permit (e.g. for projects disturbing an acre or more of land).

The City of Northfield has already made significant progress in achieving these policies and actions including the development of a draft Stormwater Management ordinance in Appendix B. Details specific to development in the Rice Creek watershed are shown in italics in this appendix. Because Rice Creek will not be protected from development unless regulations are adopted, the City of Northfield suggests that all jurisdictions with development review and approval authority in the watershed adopt similar ordinances.

6.1.4 Agricultural Lands

Goal:

- Keep land in protection until municipal development occurs, yet protect Rice Creek

Policies and Actions:

The following policies will be considered and encouraged:

- Livestock will be kept out of creek and pastures will be set back at least 150 feet from the water (preferably 300 feet)
- Healthy, shady buffers will be created and/or maintained
- Invasive species, such as buckthorn and garlic mustard, will be encouraged to be removed from buffers
- Septic systems will be maintained and working properly and kept out of the creek's 100-year floodplain (preferably at least 300 feet back from the water's edge)
- Nitrogen will be managed by
  - Adjusting nitrogen application rates according to soil organic matter content, previous crop, and manure application,
  - Using a deep soil test to measure residual soil nitrate in the root zone,
  - Using prudent manure management,
  - Timing nitrogen application for better crop uptake
- Stream channel manipulation will be avoided (no crossings for farm and recreational vehicles)
- Drainage systems will be managed to avoid new drain tiles and investigations will be considered to determine the feasibility of eliminating existing tile lines
- Road/field crossings that obstruct fish passage will be removed
- Livestock management plans will be prepared and followed
- Livestock crossings and access to the creek will be prohibited Buffers and/or stormwater management facilities adjacent to paved and gravel roads will be created

6.1.5 Stream Use

Goal:

The public will be able to enjoy Rice Creek while keeping it healthy.

Policies and Actions:

- Work with DNR and landowners to limit over-fishing and other recreation activities that could harm the stream

6.2 Monitoring

Goal:

The existing and future health of Rice Creek will be monitored.

Policies and Actions:

- Stakeholders will develop, agree upon, and implement a monitoring plan

- Monitoring and data management protocols will be agreed upon and followed
- Monitoring results will be reported
- If or when the City of Northfield annexes part of the Rice Creek watershed, the City of Northfield will adopt and implement its own Rice Creek monitoring program in absence of a broader government unit

As land use changes occur and improvement projects are implemented, monitoring is needed to assess Rice Creek's condition. This information is critical for stakeholders to understand if the changes are affecting Rice Creek, to prioritize improvement projects, and to determine if adjustments in policies and methods are needed.

Likely prepare a map to summarize suggested monitoring locations and suggested types of monitoring.

6.2.1 Program Coordination

Regular, on-going coordination and oversight of the local partners is essential to a successful Rice Creek monitoring program. A program with many monitoring stations and partners must have oversight to ensure that the standardized monitoring and data management protocols are being followed; otherwise, each cooperator can quickly diverge into their own way of doing things. If this tendency to diverge were allowed to occur unchecked or unnoticed, then the integrity of the monitoring data would ultimately become compromised.

Additionally, since rainfall often occurs late at night, on weekends, or on holidays, the availability of a monitoring coordinator assures that the stations are still being managed remotely even during off duty hours. Opportunities to check the status of the stations, activate the automatic samplers, and capture event-generated composite samples are not missed simply because they occur when no one is at the office. Monitoring coordination also figures prominently when local cooperators are unable to address equipment failure or a need for station maintenance.

6.2.2 Reporting

Once the data are collected and analyzed, they should be reported. The report should contain a description of watershed land use and changes, annual hydrograph with rainfall and sampling information, summary of water chemistry information, annual loading information for suspended solids and nutrients, macroinvertebrate, and fisheries monitoring results and a comparison to water quality standards and habitat indices. Developing a consistent report format will make it easier to create each annual or biennial report.

6.2.1 Water Quality and Quantity

Appendix A contains the "Metropolitan Council Environmental Services Quality Assurance Program Plan: Stream Monitoring, Prepared by: Environmental Monitoring and Assessment Section Water Resource Assessment Section, December 2003." The sampling methods, field and sample custody documentation, field measurement procedures, laboratory analytical procedures, quality assurance procedures, data reporting should be considered for adoption.

The following water quantity and quality monitoring program is suggested:

- Continuous flow and temperature and water quality monitoring at mouth (current downstream station)
- Continuous flow and temperature and water quality monitoring at upstream end of potential Northfield annexation (continue Decker Avenue monitoring station or possibly move downstream slightly to match annexation boundary if access is available)
- Continuous flow and temperature and water quality monitoring at upstream end of stream (possibly at Cates Avenue station)
- See Table 2 for monitoring parameters and for field collection and laboratory analytical methods

Table 2. Field Collection and Laboratory Analytical Methods for Stream Monitoring Variables

Parameter	Field Sampling Method	Laboratory Analytical Method
Flow (Continuous)	Data logger – Continuous flow based on 15-minute stage measurements and a stage-discharge rating curve programmed into the data logger[21]	NA
Stage (Continuous)	Data logger – Continuous stage recorded at 15-minute intervals[21]	NA
Discharge	Instantaneous - Velocity Meter[21]	NA
Precipitation	Tipping-bucket rain gage[21]	NA
Temperature (Continuous)	Data logger – Continuous recorded at 15-minute intervals[21]	NA
Temperature (Instantaneous)	Temperature function of dissolved oxygen meter[21]	NA
pH	Portable pH meter[21]	NA
Dissolved Oxygen	Portable dissolved oxygen meter[21]	NA
Specific Conductance	Portable conductivity meter[21]	NA
Total Suspended Solids	Flow-weighted composite samples collected during storm events[21]	MCES 700.0.1[21]
Volatile Suspended Solids	Flow-weighted composite samples collected during storm events[21]	MCES 714.0.1[21]
Total Phosphorus (Unfiltered)	Flow-weighted composite samples collected during storm events[21]	MCES 502.1.2[21]
Dissolved Phosphorus (Filtered Ortho)	Flow-weighted composite samples collected during storm events[21]	MCES 502.1.2[21]
Nitrate Nitrogen (Unfiltered)	Flow-weighted composite samples collected during storm events[21]	MCES 529.0.3[21]
Nitrite Nitrogen (Unfiltered)	Flow-weighted composite samples collected during storm events[21]	MCES 529.0.3[21]
Total Kjeldahl Nitrogen (Unfiltered)	Flow-weighted composite samples collected during storm events[21]	MCES 502.1.2[21]
Total Hardness (Unfiltered)	Flow-weighted composite samples collected during storm events[21]	Standard Methods for the Examination of Water and Wastewater, 21st Edition, Method 2340C (EDTA Titration)[21,22]
Bicarbonate Alkalinity (Unfiltered)	Flow-weighted composite samples collected during storm events[21]	Standard Methods for the Examination of Water and Wastewater, 21st Edition, Method 2320 (Titration)[21,22]

21 Metropolitan Council Environmental Services Quality Assurance Program Plan: Stream Monitoring http://www.metrocouncil.org/environment/RiversLakes/streams/Streams%20Monitoring%20QAPP_Final.pdf

22 Eaton, Andrew (Editor), Lenore S. Clesceri (Editor), Eugene W. Rice (Editor), Arnold E. Greenberg (Editor), Mary Ann H. Franson (Editor). 2005. 21st Edition. Standard Methods for the Examination of Water and Wastewater: Centennial Edition. American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF). 1,368 pages.

6.2.1.1 Monitoring Tips

The following monitoring tips have been adopted from the document, "MCES and MSU-Mankato Water Monitoring Programs, In Support of the Interagency Water Monitoring Initiative, 2004 – 2005 Biennial Progress Report" by the Metropolitan Council.

6.2.1.1.1 Flow-weighted Composites and Grab Samples

Most nonpoint source pollution loading typically occurs during large, prolonged runoff events generated by snowmelt or heavy rainfall. If the monitoring stations are equipped with automated samplers, it is feasible to collect a flow-weighted composite sample that characterizes stream water quality for the entire duration of each runoff event. Grab samples alone do not characterize the water quality of a major runoff event as well as a composite sample of the entire event, because a single grab sample is reflective of the water quality at the time of its collection only, regardless of where it fits within the scope of the entire event.

Grab samples of runoff events are also more labor intensive and difficult to schedule, particularly in smaller streams with "flashy" flow regimes. Grab sampling depends upon field personnel to be available on short notice whenever a major runoff event occurs, which often is at night and/or on weekends. However, grab samples are an important part of the sampling protocol because they can readily characterize water quality under baseflow conditions. Grab samples collected monthly and interspersed between the major runoff events greatly improve the data distribution needed for reliably calculating estimates of the total sediment and nutrient loads for a watershed, on an annual or seasonal basis.

6.2.1.1.2 Planning

When equipment fails, automated collection of flow-weighted composites is usually no longer possible. The sampling protocols must switch to weekly grab samples until the situation is restored. Grab samples are labor intensive and do not characterize runoff events as well as composite samples. Until repairs are made, however, there is little alternative.

6.2.1.1.3 Heat Tape

(Is this an issue for Rice Creek?)

Minnesota winters are conducive to the formation of ice in streams and rivers. Heavy ice can easily destroy in-stream sensors, bubbler lines, transducers, sample intake lines, and temperature probes. To avoid this, monitoring stations should be equipped with heavy commercial braided heat tape that runs through the same buried conduit that houses the sample lines and signal wires for other in-stream probes. The heat tape terminates in the stream, and creates a small area where ice conditions cannot be sustained.

By using heat tape, all probes can remain installed in the stream throughout the year, and the sample intake lines are not compromised by ice. Continuous heat in the conduit cannot be sustained using only DC batteries as the power source. Rather, heat tape requires access to a constant AC power supply. If in-stream probes remain in place during the winter, stream flows can be captured during the first large snowmelt event, and composite samples can be obtained during this critical time period. These data are very important for accurate quantification of annual or seasonal pollutant loads. Monitoring stations powered only by heavy-duty marine batteries are typically unable to capture the spring snowmelt event, since the in-stream transducers and sample lines must be removed each fall to avoid ice damage. This equipment cannot be reinstalled until well after the spring snowmelt event is over, the ice is gone, and the water stage has returned to a level where it is safe to re-enter the stream to reinstall them.

6.2.1.1.4 Pests

Pests cause sampling problems. Monitoring shelters can become home to some type of pest, which, if persistent enough, can cause problems. Army ant and mice can cause problems with the sampling equipment. Flypaper materials and baits work to trap insects, such as ants. Hornet sprays can be used to deter wasps from using shelter masts or rain gages as supports for their nests. Mice can be managed with poisons, but use pipe sealer to close off the ends of the conduit inside the shelter. Also, cover the vent fan openings to the outside before winter begins.

6.2.1.1.5 Daily Data Downloading

Datalogger software has the capability to automatically download stored data on a schedule, independent of whether or not the station operator is present at the computer. A daily data download can always be conducted manually, but experience has found that the use of the automatic download feature is more efficient. Statistics displayed after each download can quickly alert the data owner if a potential problem exists at the station.

6.2.1.1.6 Data Management

As with planning to monitoring stations, installing equipment correctly, and adopting protocols for fieldwork, plans must be made to organize and manage the huge volume of data that each station generates. Both flow data and water quality data must be properly collected, managed, checked, edited, stored, and retrieved.

6.2.2 Biomonitoring (Invertebrates and Fisheries)

6.2.2.1 Initial Reconnaissance Procedures

The existing sites that have been biomonitored should be reviewed against the MPCA protocols (Appendix C). As indicated for the protocols for fish sampling, all station sampling sites need to be 35 times the mean stream width to capture a representative and repeatable sample of the fish community. If they are consistent with MPCA protocols, biannual fish sampling and annual invertebrate sampling and biotic index evaluations should be considered at the creek’s existing downstream station, the Decker Avenue station, and the upstream station.

6.2.2.2 Fish Sampling

Appendix D includes the MPCA’s protocols for fish community sampling. As indicated, sampling must be conducted during the daylight hours between mid-June and mid-September when the stream is at or near baseflow conditions. For wadeable streams, fish community sampling is conducted in conjunction with physical habitat assessment protocols (see Appendix F). Fish sampling should be conducted before the physical habitat assessment so as not to disturb the fish community prior to sampling. Fish less than 25 millimeters in total length are not counted as part of the catch. Fish survey results are recorded on data sheets. The MPCA protocol includes sample data sheets and guidelines for filling out the data sheets.

6.2.2.3 Macroinvertebrate Sampling

Appendix E includes the MPCA's protocols for macroinvertebrate sampling. Sampling includes using D-frame dipnets with 500 micron mesh nets.

6.2.4 Habitat and Physical Characteristics

Appendix F contains the MPCA's protocols for stream habitat assessments, which is a qualitative assessment of stream physical and habitat conditions. In addition to the MPCA's assessment method, the Rosgen Level III tool could be used every five to ten years to assess the stream's morphology and changes in stream physical parameters. After the first habitat assessment and Rosgen Level III tool assessment, a more specific monitoring plan can be developed and implemented.

6.3 Education and Cooperation with Other Agencies and Individuals Policies and Actions

Because the City of Northfield does not and will not have jurisdiction over the entire surface watershed and groundwatershed of Rice Creek, the various stakeholders (including, but not limited to landowners, business owners, Northfield, Dundas, Bridgewater Township, Forest Township, Rice Creek Concerned Citizens, Cannon River Watershed Partnership, Rice County, Rice County Soil and Water Conservation District, Metropolitan Council, St. Olaf College, Carlton College, University of Minnesota Extension, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, and Trout Unlimited) will need to cooperate and collaborate to successfully manage Rice Creek.

Stakeholders will:

- work together to conduct monitoring,
- work together to conduct education,
- contact individual property owners within the Rice Creek watershed and offer advice on implementing Rice Creek protection and improvement measures, and
- work with others to implement projects to implement projects and work with individuals to implement projects, through an incentive program.

Need to discuss implementation after public input.

Appendices

Appendix A

Summary of Regulated Activities and Standards from a Sampling of Local Government Units

Regulated Activities

Table A-1 summarizes the activities that require stormwater management by a sampling of area organizations with jurisdiction over trout stream watersheds.

Table A-1. Activities Requiring Stormwater Permits by Area Local Government Units[23]

General Activity	**Permit Triggers of Area Local Government Units with Trout Streams**				
	Browns Creek Watershed District	**City of River Falls**	**Valley Branch Watershed District**	**Vermillion River Joint Powers Organization**	**City of Winona**
Disturbing Land	5,000 square feet or more within the surface water contributing area of a groundwater-dependent natural resource Movement of more than 50 cubic yards of earth or removal of vegetative cover on 5,000 square feet or more of land	Any land development or land disturbing activity of any size, with several exemptions	One acre or more	One acre or more outside of the Shoreland District or 10,000 square feet or more or 100 linear feet or more of shoreline in a Shoreline District	Greater than 4000 square feet for commercial and industrial land uses and one acre or more for residential uses, and excavation or fill of greater than 1,000 cubic yards of material
Subdivisions	Residential subdivision or development of four or more lots		All subdivisions, plats, and developments		Subdivisions that create more than four lots or require drives or road improvements
Creating impervious surfaces	5,000 square feet or more of additional impervious surface appurtenant to existing non-residential development		6,000 square feet or more of new impervious		

23 Summaries have not been reviewed and verified by each organization.

General Activity	Permit Triggers of Area Local Government Units with Trout Streams				
	Browns Creek Watershed District	**City of River Falls**	**Valley Branch Watershed District**	**Vermillion River Joint Powers Organization**	**City of Winona**
	Road, bikeway, sidewalk or other linear impervious surface of one acre or more Non-residential development creating impervious surface that, in the aggregate, exceeds either one acre or 5% of a site Redevelopmen t on a site of five acres or more, where pervious surface is disturbed and final impervious surface, in the aggregate, exceeds one acre or 5% of a site				
Floodplain Work	Alterations or fill below the 100-year flood elevation of any waterbody		All work below a 100-year flood level of a water	Alter or fill land, or build a structure or infrastructure below the 100-year critical flood elevation of any major waterway, public waters, public waters wetland, or other wetland	

General Activity	Permit Triggers of Area Local Government Units with Trout Streams				
	Browns Creek Watershed District	**City of River Falls**	**Valley Branch Watershed District**	**Vermillion River Joint Powers Organization**	**City of Winona**
Wetland/ Shoreline/ Streamline Work	Disturbance of the natural shoreline or streambank partially or wholly below the ordinary high water mark of a waterbody		Any work within a wetland	Any work within a wetland	Any work, including cutting vegetation, grading or filling, installing and maintaining water supply and wastewater systems, or subdivision within a shoreland
Miscellaneous			Lake augmentation projects Projects that will discharge municipal or industrial water or wastewater to a surface water drainage system	Activities that alter artificially drain surface water, or obstruct or divert the natural flow of runoff	

Specific Parameters and Standards

Table A-2 summarizes various parameters regulated by a sampling of area organizations with jurisdiction over trout stream watersheds.

Table A-2. Parameters and General Standards of Area Local Government Units[24]

Parameters	**Standards of Area Local Government Units with Trout Streams**				
	Browns Creek Watershed District	**City of River Falls**	**Valley Branch Watershed District**	**Vermillion River Joint Powers Organization**	**City of Winona**
Stormwater Runoff Rate Control	No increase from pre-settlement rates for the 2, 10-, and 100-year 24-hour events	No increase from existing rates for the 1.5-, 2-, 10-, and 100-year rainfall events	No increase from existing rates for the 2, 10-, and 100-year 24-hour events and 10-day 100-year snowmelt event	No increase from existing runoff rates for the 1-year and 10-year critical duration storm events (also 100-year event, but implemented by cities)	No change in the runoff rate from the 1-year, and 2-year, 10-year, and 100-year 24-hour precipitation events from existing conditions
Stormwater Runoff Volume Control and Quality Treatment	<u>Trout stream watersheds:</u> No increase for the 2-year 24-hour event from pre-settlement conditions <u>Landlocked basins:</u> No increase for the 5-year 24-hour event from pre-settlement conditions	No increase for the 1.5-year rainfall event Prior to infiltration, reduce the TSS load by 85% for new development and 40% for redevelopment	Dependent on location: • <u>Non-trout stream:</u> No increase for the 1-inch 24-hour event and treat ½ inch off impervious surfaces • <u>Trout stream watersheds:</u> No increase for the 2-year 24-hour event and treat 1 inch off impervious	No increase for 2-year 24-hour storm above pre-development conditions. Credits given for rooftop disconnections, disconnected impervious surfaces, buffers, grassed channels, soil amendments, forest/prairie restorations, natural area conservation, green rooftop, permeable paver/pavement, and irrigation	No change in the runoff volume from the 1-year, and 2-year, 24-hour precipitation events from existing conditions

24 Summaries have not been reviewed and verified by each organization.

Parameters	Standards of Area Local Government Units with Trout Streams				
	Browns Creek Watershed District	**City of River Falls**	**Valley Branch Watershed District**	**Vermillion River Joint Powers Organization**	**City of Winona**
			surfaces	reuse.	
Erosion and Sediment Control	Standards similar to those required by other agencies	Standards similar to those required by other agencies	Standards similar to those required by other agencies	Standards similar to those required by other agencies	Standards similar to those required by other agencies
Wetland Management	Hydrologic standards	No standards found	Wetland Conservation Act requirements and hydrologic standards	Wetland Conservation Act requirements	Wetland Conservation Act requirements
Vegetative Buffers	Varies by resource, 100 feet for Brown's Creek (trout stream)	No standards found	Varies by resource: • 100 foot minimum for Valley Creek (trout stream portion) • 50 feet for other streams (and intermittent reaches of Valley Creek)	150 foot average and 100 foot minimum for trout stream designated area, less for other areas	100 foot minimum stream buffer

Appendix B

Proposed City of Northfield Stormwater Ordinance

Definitions

Applicant. A property owner or agent of a property owner who has filed an application for a stormwater management plan.

Best Management Practice (BMP). A stormwater practice that will be operational after the construction phase of a project and that is designed to become a permanent part of the stie for the purposes of managing stormwater runoff. Examples of BMPs can be found in; *Protecting Water Quality in Urban Areas*, Minnesota Pollution Control Agency 2000; *Minnesota Urban Small Sites BMP Manual,* Metropolitan Council 2001; *State of Minnesota Stormwater Manual*, MPCA 2005.

Buffer. An area of land at or near a streambank, wetland, or waterbody that has intrinsic water quality value due to the ecological and biological processes it performs or is otherwise sensitive to changes which may result in significant degradation to water quality.

Dedication. The deliberate appropriation of property by its owner for general public use.

Drainageway. A natural or artificial watercourse with a definite bed and banks that conducts continuously or periodically flowing water.

Detention. The temporary storage of stormwater runoff in a stormwater BMP with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

Easement. A legal right granted by a landowner to a grantee allowing the use of private land for conveyance or treatment of stormwater funoff and access to stormwater practices.

Fee in Lieu Contribution. A payment of money in place of meeting all or part of the stormwater performance standards required by this ordinance.

Impaired Waters. Those streams, rivers, and lakes that currently do no meet their designated use classification and associated water quality standards under the Clean Water Act.

Impervious Cover. Those surfaces that cannot effectively infiltrate rainfall (e.g., building rooftops, pavement, sidewalks, driveways, etc.)

Infiltration. The process of percolating stormwater into the subsoil.

Infiltration Facility. Any structure designed to infiltrate retained water to the subsurface. These facilities may be above grade or below grade.

Landowner. The legal owner of land, including those holding the right to purchase or lease the land, or any other person holding proprietary rights in the land.

Maintenance Agreement. A legally recorded document that acts as a property deed restriction, and that provides for long-term maintenance of stormwater BMPs or practices.

Municipal Separate Storm Sewer System (MS4). Publicly-owned facilities by which stormwater is collected and/or conveyed, including but not limited to any roads with drainage systems, municipal streets, gutters, curbs, catch basins, inlets, piped storm drains, pumping facilities, retention and detention basins, natural and human-made or altered drainageways, reservoirs, and other drainage structures.

National Pollutant Discharge Elimination System (NPDES) Stormwater Discharge Permit. A permit issued by the EPA or by a state under authority delegated pursuant to 33 USC § 1342(b), that authorizes the discharge of pollutants to waters of the State, whether the permit is applicable on an individual, group, or general area-wide basis.

New Development. Any land development that occurs on previously undeveloped land or land used for agricultural uses.

Non-Stormwater Discharge. Any discharge to the storm drain system that is not composed entirely of stormwater.

Non-Structural Practice. A stormwater control and treatment technique that uses natural processes, restoration, or enhancement of natural systems, or design approaches to control runoff and/or reduce pollutants levels. Such measures are used in lieu or or to supplement structural practices on a land development site. Non-structural measures include, but are not limited to : minimization and/or disconnection of impervous surfaces; development design that reduces the rate and volume of runoff; restoration or enhancement of natural areas such as riparian area, wetlands, and forest; and on-lot practices such as rain barrels, cisterns, and vegetated area that intercept roof and driveway runoff.

Nonpoint source Pollution. Pollution from any source other than from any discernible, confined, and discrete conveyances, and shall include, but not be limited to, pollutants from agricultural, mining, construction, subsurface disposal and urban runoff sources.

Off-Site Facility. A stormwater BMP located outside the subject property boundary described in the stormwater management plan.

On-Site Facility. A stormwater BMP located within the subject property boundary described in the stormwater management plan.

Owner. Includes fee owner, contract purchaser, and lessee for whom construction is being undertaken.

Redevelopment/expansion. Land development that occurs within designated areas based on local land use where the surrounding area is generally developed, and where the site is either vacant or has previously been used or developed.

Regional Facility. Stormwater BMPs designed to control and treate stormwater runoff from multiple properties or a particular land use district, and where the or developers of the individual properties may participate in the provision of land, financing, design, construction, and/or maintenance of the facility.

Responsible Party. Any individual, partnership, co-partnership, firm, company, association, or any other legal entity; or their legal representatives, agents, or assigns that is name on a stormwater maintenance agreement as responsible for long-term operation and maintenance of one or more stormwater BMPS.

Stop Work Order. An order issued by the city that requires that all construction activity on a site be stopped.

Stormwater Management. The use of structural or non-structural practices that are designed to reduce stormwater funoff pollutant loads, discharge volumes, peak flow discharge rates and detrimental changes in stream temperature that affect water quality and habitat.

Stormwater Runoff. Flow on the surface of the ground, resulting from precipitation.

Structural Practice. An engineered physical device designed and constructed to trap or filter pollutants from runoff, or reduce runoff velocities.

Water Resources. Water resources include ground water, surface water bodies (rivers, creeks, wetlands) and their riparian buffers, and stormwater management facilities and their established vegetative buffers.

City of Northfield

Stormwater Ordinance – Draft (June 7, 2010)

To be included in the City Code of Ordinances, Chapter 22, division 2 – Stormwater Management

Note: Performance standards and requirements that specifically pertain to the Rice Creek Subwatershed are written in italics.

DIVISION 2. – STORMWATER MANAGEMENT

Section xx-xxx. – Purpose, scope and definitions

(a) Purpose. The purpose of this division is to minimize negative impacts of stormwater runoff pollution on the city's water resources by regulating development activities and by assuring long-term effectiveness of existing and future stormwater management facilities on public and private property. This division sets forth rules and regulations to manage the stormwater runoff and establishes procedures for the development and approval of a stormwater management plan. This division is adopted pursuant to the authorization contained in Minnesota Statutes Chapter 103B and 462, and Minnesota Rules Chapter 7090.

(b) Applicability. A stormwater management plan meeting the standards and procedures established herein shall be submitted as part of an application for any Site Plan Review or Plat.

(c) Exceptions. A Stormwater Management Plan is not required for the following:

(1) Any part of a subdivision if a preliminary plat for the subdivision has been approved by the City Council on or before the effective date of this Article.

(2) Any site plans approved on or before the effective date of this Article.

(3) A lot for which a building permit has been approved on or before the effective date of this Article.

(4) Emergency work to preserve life, limb, or property.

(d) NPDES Construction Stormwater Permit. All stormwater management plans must comply with the most recent NPDES permit requirements as administered under the Minnesota NPDES General Stormwater Permit for Construction Activity, Permit Number MN R100001 and all subsequent revisions, except where more specific requirements are contained herein.

(e) TMDL Allocation Plans. All stormwater management plans must be in compliance with TMDL allocation plans, and other special plans as shall be adopted and amended from time to time.

(f) Compliance with city plans and permits. All stormwater management plans must be prepared in accordance with the city's Surface Water Management Plan (SWMP), Greenway System Action Plan and the city's current NPDES MS4 Permit.

(g) The city may waive requirements of this ordinance upon making a finding that compliance with the requirements will involve an unnecessary hardship and the waiver of such requirements will not adversely affect the standards and requirements set forth in this ordinance. The city may require, as a condition of the waiver, such dedication (e.g. land, easement, etc.), construction, or fee in lieu of construction as a contribution to off-site facilities, as may be necessary to adequately meet said standards and requirements.

(h) Definitions. (see separate document)

Section xx-xxx. – Application, review and approval process

(a) No building permit, grading permit, erosion and sediment control permit, site plan approval or subdivision approval shall be issued until the city has approved a required stormwater management plan. A stormwater management plan application shall be made on a form provided by the city and shall include all accompanying documents required by the city. Approval of a stormwater management plan does not exempt the applicant from the requirements and permitting authority of other agencies having jurisdiction over the work performed nor from other permitting processes required by the city. The process and requirements for approval of a stormwater management plan are specified below:

(1) Site Plan.

a. Application. The submittal requirements listed herein shall be submitted with an application for a site plan review.

b. Stormwater management plan. The plan shall be prepared by a licensed professional engineer or other professional acceptable to the city.

c. Application fee. A fee shall be paid by the applicant. The fee shall cover the costs of application review and all routine inspections for monitoring compliance and enforcement. Any inspections and administration of the application triggered by a correction notice are not included in this fee. The amount of the fee shall be set by city council resolution from time to time.

d. Escrow deposit or financial security. The city shall require financial security in such form and amounts as deemed necessary to assure that the work, if not completed in accordance with the reviewed plans and specifications, will be corrected to eliminate conditions posing a danger to public health, safety and welfare, adjacent property and the environment. The security shall be in the form of a surety bond, cash bond, or an irrevocable letter of credit. The financial security must be in place prior to any work. The amount of financial security required will be calculated based on the work detailed in the plans and specifications. The city may require a portion of the security to be provided as a cash escrow based on the proposed work. The applicant may be required to maintain the escrow at a minimum amount set by the city.

e. Application review. The city's development review committee shall review the application for completeness and compliance with standards as part of the site plan review. City staff may request changes or additional information from the applicant.

f. Reviewed plans. If the plans meet the performance standards and requirements of this Ordinance, the city shall endorse in writing or stamp on the plans "Reviewed." However, construction activities may begin only upon approval of the site plan review application. Such reviewed plans shall not be changed or deviated from by the applicant without authorization from the city. One set of reviewed plans shall be returned to the applicant, and that set shall be kept on the site of project site at all times during which the authorized work is in progress.

(2) Platted development.

a. Application. The submittal requirements listed herein shall be submitted with applications for preliminary and final plat.

b. Stormwater management plan. The plan shall be prepared by a licensed professional engineer or other professional acceptable to the city.

c. Application fee. A fee shall be paid by the applicant. The fee shall cover application review and all routine inspections for monitoring compliance and enforcement. Any inspections and administration of the application triggered by a correction notice are not included in this fee. The amount of the fee shall be set by city council resolution from time to time.

d. Escrow deposit or financial security. The city shall require financial security in such form and amounts as deemed necessary to assure that he work, if not completed in accordance with the reviewed plans and specifications, will be corrected to eliminate conditions posing a danger to public health, safety and welfare, adjacent property and the environment. The security shall be in the form of a surety bond, cash bond, or an irrevocable letter of credit. The financial security must be in place prior to any work. The amount of financial security required will be calculated based on the work detailed in the plans and specifications. The city may require a portion of the security to be provided as a cash escrow based on the proposed work. The applicant may be required to maintain the escrow at a minimum amount set by the city.

e. Application review. The city's development review committee shall review the application for completeness and compliance with standards as part of preliminary and final plat review. City staff may request changes or additional information from the applicant.

f. Reviewed plans. If the plans meet the performance standards and requirements of this Ordinance, the city shall endorse in writing or stamp on the plans "Reviewed" at time of final plat review. However, construction activities may begin only upon approval of the final plat application. Such reviewed plans shall not be changed or deviated from by the applicant without authorization from the city. One set of reviewed plans shall be returned to the applicant, and that set shall be kept on the project site at all times during which the authorized work is in progress.

Section xx-xxx. – Post-Construction Performance Standards for Stormwater Management

(a) <u>Water Quality Criteria</u>

(1) Best management practices shall be implemented that reduce the total suspended solids load by ninety (90) percent, and the phosphorus load by sixty (60) percent from the runoff generated by the 2-year, 24-hour event for the developed site as a whole, as compared to no runoff management controls. These standards may be met through the runoff volume

reduction criteria below (subsection (c) of this section). If the criteria are met through ponding, the following guidelines for the design of wet detention basins shall be followed:

a. A permanent pool ("dead storage") volume below the principal spillway (normal outlet) which shall be greater than or equal to the runoff from a 2.5-inch storm over the entire contributing drainage area assuming full development.

b. A permanent pool average depth (basin volume/basin area) which shall be $\geq$ 4 feet, with a maximum depth of $\leq$ 10 feet.

c. Basin side slopes above the normal water level should be no steeper than 3:1, and preferably flatter. A basin shelf with a minimum width of 10 feet and 1 foot deep below the normal water level is recommended to enhance wildlife habitat, reduce potential safety hazards, and improve access for long-term maintenance.

d. The pond should be wedge shaped with the inlet at the narrowest end and the outlet at the widest end. A length to width ration of 3:1 or greater shall be used whenever possible. Distance between outfalls and outlets should be maximized.

e. Skimmers or other similar devices are required on pond outlets. Designs shall provide for skimmers that extend a minimum of 4 inches below the water surface and minimize the velocities of water passing under the skimmer to less than 0.5 feet per second for the 1-year 24-hour event.

f. Side slopes shall be seeded with native seed mix appropriate to the site conditions. Upland buffers on side slopes are required. Buffers shall include a mixture of deciduous and coniferous shrubs and include access for pond maintenance. Trees are encouraged as part of the upland buffer. Buffers shall be designed to provide maintenance access to the facility.

g. The applicant shall provide the city with a two year warranty on all vegetation to ensure plant establishment and survival.

h. Pond designs that incorporate filtered bottom withdrawal, vegetated swale discharges, or constructed wetland treatment cells to limit temperature increases are encouraged.

i. Pond designs that incorporate tree shading to limit future temperature increases are encouraged.

(2) Infiltration/filtration methods, described under runoff volume control are the preferred approach to satisfying the water quality treatment requirements in all areas of the city where practical and subject to the limitations of (c) (4) below. *Infiltration/filtration methods described under runoff volume control are the required approach to satisfying the water quality treatment requirements in areas that drain to Rice Creek and its tributaries*.

(3) For all projects, street catch basins must have a three (3) foot sump.

(b) Runoff Rate Control Criteria

(1) Expansion/redevelopment projects. For the 2-year, 10-year, and 100-year 24-hour SCS Type II storm events and the 100-year 10-day snowmelt event (Table 1), the proposed post development runoff rate must not exceed the existing conditions runoff rate at all points leaving the site. The city may reduce or waive the need for expanded on-site improvements if downstream facilities can accommodate the additional rate increase. In flood prone areas and landlocked subwatersheds, greater restrictions may apply. Pervious curve numbers shown in Table 3 shall be used for existing and new turf grass.

(2) *All new development in the City and any development in the Rice Creek Subwatershed. For the 2-year, 10-year and 100-year 24-hour SCS Type II storm events and the 100-year 10-day snowmelt event (Table 1), the proposed post development runoff rate must not exceed the rate for pre-settlement conditions. Pre-settlement conditions shall be defined as the estimated land cover in the area before European settlement as determined by historic topographic and photographic data. Runoff curve numbers shown in Table 2 shall be used for determining presettlement conditions. In flood prone areas and landlocked subwatersheds, greater restrictions may apply. Pervious curve numbers shown in Table 3 shall be used for existing and new turf grass.*

Table 1.Precipitation for different storm events

SCS Type II 24-hour storm event	**Precipitation**
1-Year	2.3 inches
2-Year	2.8 inches
10-Year	4.25 inches
100-Year	6.1 inches
SCS Type II 10-day snow melt	
100- year 10-day snow melt	7.05 inches

Table 2. Runoff curve numbers for pre-settlement "Prairie" conditions

Hydrologic Soil group	A	B	C	D
Runoff Curve Number	30	58	71	78

Table3: SCS Pervious Curve Numbers for Turf Grass

Hydrologic Soil group	A	B	C	D
Runoff Curve Number	61*	61	74	77

*Curve number of 61 is used for both A and B soils to reflect the standard landscaping practice of placing loamy soils on top of compacted subgrade in preparation for the placement of turf grass.

(4) The stormwater system must be designed to provide discharge capacity or level of service for the following system components. The city may allow variance to these standards if regional ponding systems are located downstream.

Local storm sewer – 5-year event
Trunk storm sewer – 10-year event
Storm ponds, pipe and drainageways connecting ponds, and open channels – 100-year event.

(5) For stormwater collection systems not designed to meet rate control standards (e.g. catch basins), a clogging factor of 50% will be used to size intake structures

(6) No orifice having a diameter less than eight inches is allowed in the design of rate control structures within the city. If a structure having an opening less than 8 inches is required to meet rate control requirements, the required rate control for a site will be increased to allow a rate consistent with an opening of this size.

(7) An emergency spillway or outlet from ponding areas shall be installed at a minimum of one foot below the lowest building opening and shall be designed to have a capacity to overflow water at an elevation below the lowest building opening at a rate not less than three times the 100-year peak discharge rate from the basin or the anticipated 100-year peak inflow rate to the basin, whichever is higher. A narrative shall be submitted describing the secondary flow paths for events larger than the 100-year event.

(c) Runoff Volume Control Criteria

(1) New development and expansion/redevelopment projects. Projects must infiltrate the first 0.75 inches of runoff from impervious surfaces.

(2) *Rice Creek subwatershed. For the 2-year 24-hour SCS Type II event (Table 1), the proposed post development runoff volume must not exceed the presettlement conditions runoff volume at all points where runoff leaves the site. Infiltration/filtration basins must be setback at least 300 feet from the centerline of Rice Creek to minimize thermal impacts to groundwater and Rice Creek.*

(3) When designing infiltration for volume control, on-site testing and detailed analyses are strongly encouraged to determine the infiltration rates of the proposed infiltration facility. Documented site-specific infiltration or hydraulic conductivity measurements completed by a licensed soil scientist or engineer is required for all regional infiltration facilities, which are defined as infiltration facilities with proposed drainage areas greater than two acres or with proposed drainage areas with 0.7 acres or more of impervious surfaces. In the absence of a detailed analysis, the saturated infiltration rates listed in Table 4 must be used A soil boring with blow counts is required at the location of a proposed regional infiltration facility. The soil boring is required to go to depth of at least five feet below the proposed bottom of the infiltration facility. If bedrock is suspected, the soil boring must go to a depth of at least ten feet below the proposed bottom of the infiltration facility. The soils must be classified using the Unified Soil Classification system. The least permeable soil horizon will dictate the infiltration rate. *Infiltration practices shall be designed to infiltrate the required runoff volume within 24 hours within the Rice Creek Subwatershed and* 72 hours for any development elsewhere in the City.

Table 4.Hydrologic soil groups and saturated infiltration rate

Hydrologic Soil group	A	B	C	D
Saturated infiltration rate (inches per hour)	0.50	0.25	0.10*	0.01*

* Infiltration is not allowed in C and D soils without soil corrections

(4) The following standards apply to infiltration facilities or practices:

a. Pretreatment of stormwater runoff is required to protect the infiltration systems from clogging with sediment and to protect ground water quality.

b. Must conform to the minimum setbacks required by the Minnesota Department of Health

c. Cannot be used within fifty feet (50') of a municipal, community, or private well unless specifically allowed by an approved wellhead protection plan.

d. Cannot be used on areas with less than three feet (3') vertical separation from the bottom of the infiltration system and the seasonal high water table or bedrock, or 10 feet where fractured bedrock is present.

e. Cannot be used for runoff from fueling and vehicle maintenance areas and industrial areas with exposed materials posing contamination risk.

f. Cannot be used in type C and D soils without soil corrections.

(5) Where achieving volume control standards through infiltration is not possible due to site limitations (see immediately preceding subsection), or where space limits opportunities for site redevelopment and expansion, the city may reduce and/or waive volume control standards. In considering reducing or waiving volume control requirements, the following will be considered in order of decreasing preference:

a. Modifications to the site design to incorporate additional LID or "better site design" practices as described in the Minnesota Stormwater Manual, to the extent practical.

b. Use of filtration practices.

c. Opportunities for storage and reuse of water on-site.

d. Contribution of a fee in lieu of on-site volume control measures (SWAC). Fee is contributed towards achievement of the volume control requirement through an off-site city-owned and managed facility.

(d) General Performance Standards

(1) All stormwater treatment must be designed to address the actual amount of impervious surface or the following impervious surface coverage amounts for the entire development site, whichever is higher.

a. Residential lots (1 or 2 dwelling units) – 40%

b. Commercial and Industrial lots – 85%

c. *All plats in the Rice Creek Watershed – 65%*

(2) Unless superseded by the City's requirements, stormwater management practices shall be designed according to the most current technology as reflected in the MPCA publication "Minnesota Stormwater Manual," as supplemented and amended from time to time.

(3) All structural or engineered stormwater treatment facilities shall be located in an outlot or in a drainage and utility easement dedicated to the city. Facilities may be located within the right of way at the city's discretion. Access of sufficient size shall be provided to each treatment facility to perform maintenance activities identified in the maintenance plan.

(4) All applicants shall submit as-built plans for all structural or engineered facilities at project completion. The plans must show the final design specifications for all facilities. Plans must certify that the facilities meet the performance standards and be signed by a registered professional engineer.

(5) Stormwater management plans must show construction staging and specifically address measures to preserve the infiltration capacity of proposed infiltration facilities to ensure that the performance of such facilities are not impaired at the conclusion of construction. Plans shall also demonstrate methods of staging construction to minimize soil compaction of landscaped areas during construction. Soil testing and decompaction may be required if site construction activities negatively impact soil permeability.

(6) A planted vegetated buffer width of 50 feet shall be established and maintained around all wetlands, stormwater ponds and infiltration/filtration facilities. Buffers shall be measured perpendicular from the high water level of a constructed facility or the delineated wetland edge, and shall be provided and maintained at all times. Monuments/signs shall be located to delineate the buffer. The monuments/signs should be placed at an interval of approximately 100 feet and at locations where the buffer line deviates by more than 30 degrees. The signs should conform to local standards and be at least four feet high, made of non-degradable material, and minimally contain the words: Buffer – Do Not Mow or Fill. Contact City of Northfield for Further Information

Section xx-xxx. – Flood Control

(a) The lowest floor elevation of any structure shall be at least two feet above the elevation of the highest known historic high groundwater elevations.

(b) The lowest floor elevation of any structure shall be at least two feet above the 100-year surface water flood elevation for the area

(c) Delineation of the 100-year flood is required in all areas mapped as "A" on the FEMA Flood Insurance Rate Map.

Section xx-xxx. – Shoreland Areas

(a) The following standards apply to development in shoreland areas as defined by the Shoreland Overlay District:

(1) For any project, runoff from parking areas with 10 or more spaces or in excess of 3,000 square feet must meet the water quality criteria of Section xx.xxx subsection (a) (page 6). Treatment of runoff through volume reduction and infiltration practices is encouraged.

(2) *For any new development or redevelopment/expansion project an undisturbed vegetative buffer of not less than 50 feet from the water body shall be maintained. For projects adjacent to the Cannon River, an undisturbed vegetative buffer of not less than 100 feet shall be maintained and for projects adjacent to Rice Creek, an undisturbed vegetative buffer of not less than 300 feet shall be maintained.* Buffers shall be measured perpendicular from the edge of water on each side of the water body and shall be provided and maintained at all times for all permitted activities adjacent to the water body. Within the undisturbed buffer, vegetation shall not be cultivated, cropped, pastured, mowed, fertilized, subject to the placement of mulch or yard waste, or otherwise disturbed, except for periodic cutting or burning that promotes the health of the buffer, actions to address disease or invasive species, mowing for purposes of public safety, temporary disturbance for placement or repair of buried utilities, or other actions to maintain or improve buffer quality, each as approved by the City or when implemented pursuant to a written agreement executed with the City. No new private structure or impervious surface shall be placed within a buffer. No fill, debris or other material shall be excavated from or placed within a buffer. Exceptions for areas such as water crossings, limited water access and restoration of the buffer are allowed if the exceptions are documented in the stormwater management plan application. Replacement of existing impervious surface within the buffer is allowed.

Section xx-xxx. – Low Impact Development

(a) Low impact development (LID) practices are preferred for all projects to the greatest extent reasonable, subject to the limitations described in Section xx.xxx subsection (c) (4).The city encourages the following LID or better site design practices as described in the Minnesota Stormwater Manual where they do not conflict with the requirements of this ordinance

(1) Better site design practices:
a. Natural area conservation
b. Site restoration to prairie or forest
c. Stream and shoreline buffers
d. Disconnection of impervious cover
e. Roof top disconnection
f. Use of grass channels for conveyance
g. Reduction of impervious surfaces
h. Use of trees to shade impervious surfaces

(2) Engineered or structural practices
a. Bioretention
b. Infiltration
c. Filtration

Section xx-xxx. – Maintenance Agreement and Maintenance Plan for Private Stormwater Management Facilities

(a) During the application process, the applicant and the City shall determine which party will be responsible for stormwater facility ownership and long term maintenance responsibilities.

(b) If the applicant is determined to have ownership and maintenance responsibilities, the applicant and city shall enter into an Agreement that documents all responsibilities for operation and maintenance of all stormwater practices. Such responsibility shall be documented in a maintenance plan and executed through an Agreement. The Agreement shall be executed and recorded with the parcel.

(c) The stormwater maintenance agreement shall be in a form approved by the city, and shall, at a minimum:

(1) Designate the owner or other responsible party which shall be permanently responsible for maintenance of the structural or nonstructural measures.

(2) Pass responsibility for such maintenance to successors in title.

(3) Grant the city and its representatives the right of entry for the purposes of inspecting all stormwater measures at reasonable times and in a reasonable manner. This includes the right to enter a property when the city has a reasonable basis to believe that a violation of this Ordinance or maintenance agreement is occurring or has occurred and to enter when necessary for abatement of a public nuisance or correction and enforcement of a violation of this Ordinance or agreement.

(4) Allow the city to repair and maintain the facility, if after proper and reasonable notice by the city to the owner of the facility. The Agreement shall permit the city to certify the costs of the maintenance/correction to the taxes for the subject property.

(5) Include a maintenance plan that contains, but is not limited to the following:

a. Identification of all structural stormwater practices.

b. A schedule for regular inspection, monitoring, and maintenance for each practice. Monitoring shall verify whether or not the practice is functioning as designed and may include, but is not limited to quality, temperature, and quantity of runoff.

c. Identification of the responsible party for conducting the inspection, monitoring and maintenance for each practice.

(6) Identify a schedule and format for reporting compliance with the maintenance plan to the city.

Section xx.xxx. – Application submittal requirements

(a) Project narrative describing stormwater management objectives, site conditions and how the proposed practices will address objectives and the requirements of this ordinance.

(b) Plans showing predevelopment and post development conditions

(c) All calculations demonstrating compliance with the requirements of this ordinance

(d) All other data, plans, and figures required by the city (see checklist provided by the City).

Section xx.xxx – Enforcement by legal or administrative action

(a) Any action or inaction which violates the provisions of the Ordinance, the requirements of an approved stormwater management plan, and/or the requirements of a development agreement shall be a misdemeanor, and each day during which any violation is committed, continued or permitted, shall constitute a separate offense.

(b) Violation of any provisions of this division may be enforced by civil action including an action for injunctive relief and by any administrative penalties approved by the city.

Appendix C

Metropolitan Council Environmental Services Quality Assurance Program Plan: Stream Monitoring

Metropolitan Council Environmental Services

Quality Assurance Program Plan: Stream Monitoring

Prepared by:

Environmental Monitoring and Assessment Section
Water Resource Assessment Section

December 2003

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1 INTRODUCTION

1.1 MCES STREAM MONITORING PROGRAM BACKGROUND AND PURPOSE

Stormwater runoff in both urban and rural areas carries nonpoint source pollutants from diverse and widely scattered sources to Metropolitan Area streams and rivers. Stream monitoring is conducted to determine the extent of nonpoint source pollutant loading from tributaries to the Mississippi, Minnesota, and St. Croix Rivers, to provide the information necessary for development of target pollutant loads for these tributary watersheds, and to evaluate the effectiveness of watershed best management practices for reducing nonpoint source pollution and improving water quality in streams and rivers. Automated measurements of water stage, in conjunction with site-specific rating curves, are used to estimate flow rates in all streams. During runoff events, automated water samples and occasional grab samples are obtained for laboratory analysis of a variety of nonpoint source pollutants. During baseflow conditions, grab samples are obtained for laboratory analysis of water quality variables. The stream monitoring program is comprised of several sub-programs as described below.

1.1.1 Streams – Nonpoint Source Pollution Monitoring Program

The nonpoint source pollution monitoring program has been in place since 1989 in the Metropolitan Area. The purpose of the program is to collect data to assess nonpoint source pollution impacts in the Lower Minnesota River Watershed. The Lower Minnesota River has exceeded state water quality standards, resulting in a wasteload allocation that affects MCES operation of the Seneca and Blue Lake Wastewater Treatment Plants. The nonpoint source pollution monitoring sites were originally established in response to the water quality problems in the Minnesota River and the wasteload allocation. The data are also used to evaluate current watershed conditions, to aid Council staff in the development of target pollution loads for the watersheds in the metropolitan area, and to measure progress toward meeting the target pollution loads. The sampling program includes baseflow sampling and storm (runoff) event sampling at six sites located on Lower Minnesota River tributaries and one site located on the Minnesota River mainstem at Jordan. Event-based sampling is conducted during the March – November period and baseflow sampling is conducted year round. Water samples are analyzed for conventional and toxic pollutants. Precipitation, temperature, conductivity, and streamflow information are also collected at these sites.

1.1.2 Streams – Mankato Area Monitoring Program

The Mankato Area monitoring program has been in place since 1999. The purpose of the program is to collect data to assess nonpoint source pollution impacts on the Minnesota River Basin outside the Metropolitan Area. This program is supported with funding provided by the Minnesota Legislature, via the Minnesota Pollution Control Agency (MPCA). Streams and rivers in the Minnesota River Basin near Mankato, MN are monitored as part of this program. Six monitoring stations are located on the Minnesota, Le Sueur, and Blue Earth Rivers, as well as on two small streams. Data are collected to characterize nonpoint sources of suspended sediments, nutrients, mercury, PCB, and other pollutants, to document water quality trends, and to assess potential reductions of mercury and PCB concentrations to achieve a "fishable condition" in the Minnesota River Basin. The sampling program includes baseflow sampling and storm (runoff) event sampling. Event-based sampling is conducted during the March – November period and baseflow sampling is conducted year round. Water samples are analyzed for conventional, toxic, and organic pollutants. Precipitation, temperature, conductivity, and streamflow information are also collected at these sites.

1.1.3 Streams – Watershed Outlet Monitoring Program

The watershed outlet monitoring program (WOMP) has been in place in the Metropolitan Area since 1995. The purpose of the program is to collect data to assess nonpoint source pollution impacts on Metropolitan Area watersheds. The data are used to evaluate current watershed conditions, to develop the Council's target pollution loads for Metropolitan Area watersheds, and to measure progress toward achieving the target pollution loads. This program is supported in part with funding provided by the Minnesota Legislature, via the MPCA. WOMP monitoring is conducted by watershed management organizations, watershed districts, soil and water conservation districts, and other government agencies, through a cooperative cost-share arrangement with the Metropolitan Council. The sampling program includes baseflow and storm (runoff) event sampling at 17 Metropolitan Area stream sites. Event-based monitoring is conducted during the March – November period and baseflow sampling is conducted year round. Water samples are analyzed for conventional and toxic pollutants. Precipitation, temperature, conductivity, and streamflow information are also collected at these sites.

1.2 RELATIONSHIP OF QAPP TO OTHER GUIDANCE DOCUMENTS

This Quality Assurance Program Plan (QAPP) is one of a number of documents that guide the monitoring activities of the MCES Stream Monitoring Program. The primary goal of this document is to define the data quality assurance goals and the quality assurance procedures that are applicable to this stream monitoring program. This QAPP also provides an overview of the program design, including monitoring parameters and sampling locations. This document also summarizes sampling methods, analytical procedures, and data review protocols. Specific details of procedures for sampling, field analysis, laboratory analysis, and data review are covered by a series of Standard Operating Procedure (SOP) documents included as appendices to this QAPP.

2 PROGRAM ORGANIZATION AND RESPONSIBILITY

2.1 OVERVIEW

This stream monitoring program is administered by the Metropolitan Council Environmental Services (MCES). There are three business units in the Environmental Quality Assurance Department that have some role in the program. These business units include Environmental Monitoring and Assessment (EMA), Laboratory Services, and Water Resource Assessment (WRA). The managers from each of these business units report to the Assistant General Manager of the Environmental Quality Assurance Department. An organization chart of these relationships is shown in Figure 2.1. In addition, the Metropolitan Council's Information Systems Department provides technical services relating to database management and application development in support of this monitoring program. Key team members and their responsibilities are identified in Table 2.1.

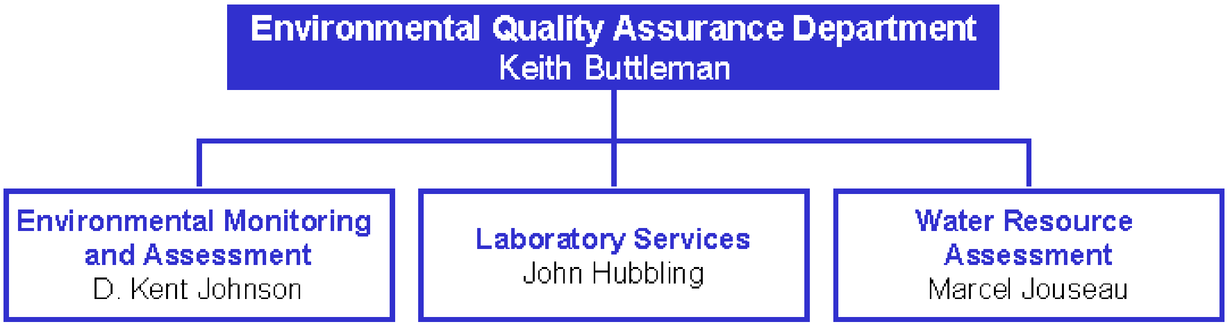

Figure 2.1. MCES Business Units Involved with the Stream Monitoring Program

Table 2.1 Roles and Responsibilities of MCES Staff Involved with the Stream Monitoring Program

Member	Business Unit	Responsibility
Kent Johnson	Environmental Monitoring and Assessment	Business Unit Manager
Tim Pattock	Environmental Monitoring and Assessment	NPS Monitoring
Mike Ahlf	Environmental Monitoring and Assessment	NPS Monitoring
Heather Offerman	Environmental Monitoring and Assessment	Mankato Area Monitoring
Cassie Champion	Environmental Monitoring and Assessment	WOMP Coordinator
Leigh Harrod	Environmental Monitoring and Assessment	WOMP Coordinator
John Hubbling	Laboratory Services	Business Unit Manager
Lam Sanouvong	Laboratory Services	Laboratory QA Officer
Marcel Jouseau	Water Resource Assessment	Business Unit Manager
Terrie O'Dea	Water Resource Assessment	Water Quality DB Administrator
Steve Kloiber	Water Resource Assessment	EIMS Administrator

2.2 *ENVIRONMENTAL MONITORING AND ASSESSMENT*

The Environmental Monitoring and Assessment (EMA) business unit is responsible for coordinating and conducting field operations for the stream monitoring program. Staff in this unit have the primary responsibility for siting new monitoring stations and providing technical specifications for the instrumentation, shelter, and other monitoring equipment. In addition, depending upon the specific sub-program, EMA staff may be fully responsible for operating and maintaining a station, or they may be responsible for overseeing a local cooperator who operates the station and providing additional technical assistance and maintenance support.

The stream sites in the Nonpoint Source Pollution Monitoring Program (described in Section 1.1.1) and the Mankato Area Monitoring Program (described in Section 1.1.2) are entirely maintained and operated by the EMA business unit. EMA staff routinely visit these sites to collect samples and make in-situ field measurements. EMA staff are also responsible for maintaining the on-site equipment. Routine maintenance and operation of stream sites in the Watershed Outlet Monitoring Program (described in Section 1.1.3) is provided by a local cooperating agency (typically a watershed district, county, or other local governmental unit). For sites in this program, EMA staff (WOMP Coordinators) are responsible for training and coordinating monitoring activities with the local cooperators. EMA staff also provide technical support and assistance on an as needed basis for sites in the Watershed Outlet Monitoring Program.

In addition to monitoring, EMA staff are responsible for reviewing all stream data for quality assurance. The data review responsibilities and procedures are summarized in Section 9.1 of this QAPP and more detail is provided in the data review SOP. EMA staff also have some responsibility for analysis and interpretation of the stream data.

2.3 *LOCAL COOPERATORS*

Local WOMP cooperators ensure that monitoring equipment is in working order, collect samples at these sites, and make in-situ field measurements according to procedures specified by the terms of a contractual agreement with MCES. The local cooperators are also responsible for basic routine maintenance of the sites.

2.4 *LABORATORY SERVICES*

The Laboratory Services business unit is primarily responsible for analyzing stream samples for the water quality variables requested by EMA staff, and reporting the analytical data to the EMA business unit via the Laboratory Information Management System (LIMS). The laboratory receives the stream samples from the field staff (EMA staff and the local cooperators), logs all samples into LIMS, and stores the samples until analysis. The laboratory is also responsible for ensuring that QA/QC procedures are in place for all laboratory functions. Details regarding laboratory QA/QC procedures are contained in the laboratory's Quality Assurance Management Plan.

2.5 *WATER RESOURCE ASSESSMENT*

The Water Resource Assessment (WRA) business unit is responsible for analysis and interpretation of the stream data. WRA is one of the primary end-users of the data generated from the stream monitoring program. This unit is also responsible for environmental data management and assessment. The stream data are a required part of the Council's Target Pollutant Load (TPL) project, which is managed by WRA. The goal of the TPL project is to develop target pollutant loads for Metropolitan Area watersheds, to reduce water quality impacts due to nonpoint source pollution, to help achieve federal and state water quality standards, and to help reduce unnecessary investments in advanced wastewater treatment. Stream water quality data are needed to establish baseline conditions and to calibrate watershed models, which can then be used to evaluate alternative management strategies to achieve the target pollutant load limits. The WRA business unit is also responsible for managing the Water Quality Database and the Environment Information Management System (EIMS), the two data systems which handle the data from the stream monitoring program as well as data from other programs. Given these roles, WRA also has the responsibility to provide feedback and technical advice on improving the monitoring program, developing and implementing quality assurance procedures, and maintaining sound data management practices.

3 MONITORING PROGRAM DESCRIPTION

3.1 *STUDY AREA*

This program monitors water quality and quantity of streams tributary to three large Minnesota rivers: 1) the Mississippi River, 2) the Minnesota River, and 3) the St. Croix River. Monitoring of these large rivers is conducted under a different MCES program and is covered by a separate QAPP. The extent of the study area covered by the stream monitoring program includes much of central Minnesota, with most sites located in the seven-county Metropolitan Area. This area straddles two ecoregions: the North Central Hardwood Forest and the Western Cornbelt Plains. About half the land within the Metropolitan Area is agricultural or undeveloped, while the remaining half is predominantly urban. In the Mankato Area, land cover is predominantly agricultural with scattered rural centers. Over 90 percent of the original wetland acreage in the Minnesota River Basin has been drained for agricultural production.

The landscape of the region is heavily influenced by its glacial origins and is characterized by glacial landforms, such as moraines and outwash plains, that result in topography that ranges from nearly level to gently rolling hills. Portions of the region have more relief and numerous kettle lakes, while other parts have low hills and outwash plains with relatively few shallow lakes.

3.2 *SITE SELECTION / PROGRAM DESIGN*

The number of sites in the MCES stream monitoring program has varied over the years, as dictated by management objectives and the availability of funding. As of 2003, the stream monitoring program includes 28 active sites and four historical sites that are no longer in the program (Figure 3.1). Monitoring sites have been selected based upon a number of criteria that have varied slightly over the years.

Generally, monitoring sites are located near the mouths of streams tributary to the three major rivers (Mississippi, Minnesota, and St. Croix). Physical considerations for monitoring site selection include accessibility, hydraulic conditions, watershed size, and land use. With regard to site accessibility, sites should be near a road, and many of the sites are located near bridge crossings. Proximity to utility (electrical and telephone) service is an additional key factor. Hydraulic considerations are also important. Sites need to be placed far enough upstream to avoid tailwater conditions from the Mississippi, Minnesota, and St. Croix Rivers, when these rivers are at flood stage. Some sites are situated to take advantage of existing hydraulic control structures, but site selection should avoid localized tailwater conditions caused by downstream constrictions. Consideration is also given to the size of the tributary watershed, with greater weight being given to larger watersheds. However, the tributary watersheds do cover a broad range of size, from 3.4 square miles (Eagle Creek) to 2,620 square miles (Crow River). The watersheds of the streams in this program also span a range of land cover, from predominantly agricultural to predominantly urban. If a monitoring site is located on private property, landowner permission is obtained via a written agreement. An additional important criterion for WOMP site selection is the presence of an interested local cooperating agency. WOMP requires a trained local cooperator to provide most of the labor for operating a site. The program also requires a partial funding match from the local cooperating agency. Table 3.1 lists all past and present stream monitoring sites by sub-program and provides some basic physical characteristics of these sites.

Figure 3.1. Location of MCES Stream Monitoring Sites

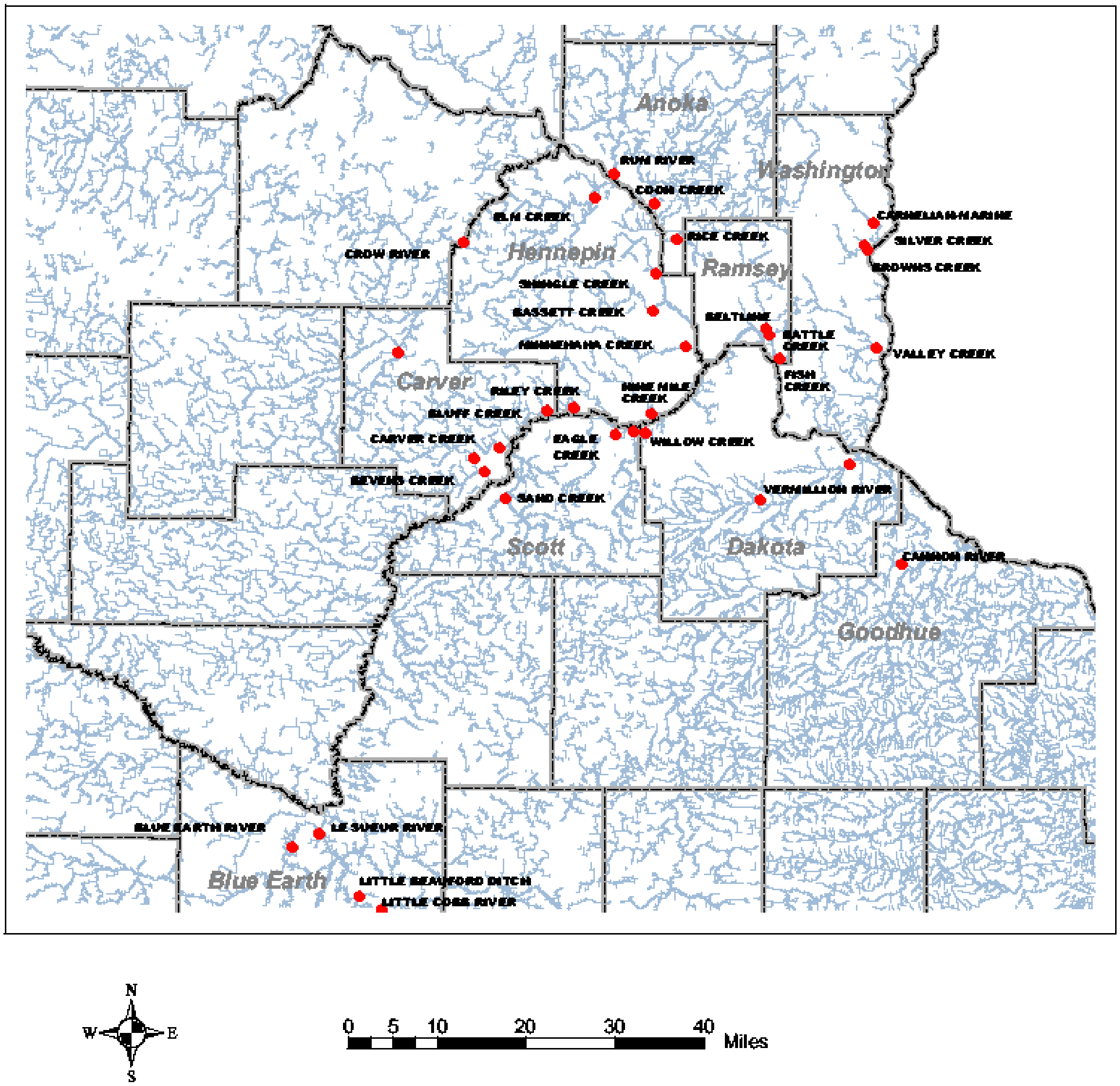

Table 3.1 MCES Stream Monitoring Sites

Monitoring Site	Major Basin	Dominant Land Use	Year Initiated	Watershed Size ($miles^2$)
Beauford Ditch	Minnesota - Middle	Agricultural	1999	7.0
Blue Earth River	Minnesota - Middle	Agricultural	1999	1550
LeSueur River	Minnesota - Middle	Agricultural	1999	1100
Little Cobb River	Minnesota - Middle	Agricultural	1999	130
Bevens Creek - Lower	Minnesota - Lower	Agricultural	1989	131
Bevens Creek - Upper	Minnesota - Lower	Agricultural	1992	90.2
Bluff Creek	Minnesota - Lower	Rural/Transitional	1990	8.9
Carver Creek	Minnesota - Lower	Agricultural	1989	83.5
Credit River	Minnesota - Lower	Rural/Transitional	1989	51.4
Eagle Creek	Minnesota - Lower	Urban/Transitional	1999	3.4
Nine Mile Creek	Minnesota - Lower	Urban	1989	38.3
Riley Creek	Minnesota - Lower	Rural/Transitional	1999	13.1
Sand Creek	Minnesota - Lower	Agricultural	1989	255
Willow Creek	Minnesota - Lower	Urban	1999	10.2
Battle Creek	Mississippi - Lower	Urban	1996	11.4
Beltline Interceptor	Mississippi - Lower	Urban	1995	28.0
Cannon River	Mississippi - Lower	Agricultural	1999	1340
Fish Creek	Mississippi - Lower	Urban/Transitional	1995	5.1
Vermillion River	Mississippi - Lower	Agricultural	1995	327
Bassett Creek	Mississippi - Upper	Urban	2000	42.8
Coon Creek	Mississippi - Upper	Rural/Transitional	Discontinued	91.1
Crow River	Mississippi - Upper	Agricultural	1999	2620
Crow River - South Fork	Mississippi - Upper	Agricultural	2001	1137
Elm Creek	Mississippi - Upper	Urban/Transitional	Discontinued	106
Minnehaha Creek	Mississippi - Upper	Urban/Transitional	1999	181
Rice Creek	Mississippi - Upper	Urban/Transitional	Discontinued	180
Rum River	Mississippi - Upper	Rural	1996	1552
Shingle Creek	Mississippi - Upper	Urban	Discontinued	41.6
Browns Creek	St. Croix	Rural/Transitional	1998	34.1
Carnelian-Marine Outlet	St. Croix	Rural/Transitional	1995	30.0
Silver Creek	St. Croix	Mixed/Transitional	1998	7.6
Valley Creek	St. Croix	Mixed/Transitional	1999	62.1

3.3 *Monitoring Variables and Frequency*

Streams in this program are monitored for a variety of water quality variables (Table 3.2). These variables are not always analyzed at all sites on every sampling occasion. The variables and frequency of analysis depend upon the sample condition (such as holding time requirements and available sample volume) and water quality concerns for a given stream.

Table 3.2 MCES Stream Monitoring Variables

Aluminum, Filtered	Conductivity[1]	pH[2]
Aluminum, Unfiltered	Copper, Filtered	Pheophytin-a
Ammonia Nitrogen, Unfiltered	Copper, Unfiltered	Potassium, Unfiltered
Bicarbonate Alkalinity, Unfiltered	Dissolved Oxygen	Precipitation[1]
BOD 5-day, Unfiltered	Fecal Coliform Bacteria	Sodium, Unfiltered
BOD Ultimate, Unfiltered	Flow[1]	Stage[1]
Cadmium, Filtered	Hardness, Unfiltered	Sulfate, Unfiltered
Cadmium, Unfiltered	Iron, Unfiltered	Temperature[1]
Calcium, Unfiltered	Lead, Filtered	Total Alkalinity, Unfiltered
Carbonate Alkalinity, Unfiltered	Lead, Unfiltered	Total Dissolved Solids
CBOD 5-day, Unfiltered	Magnesium, Unfiltered	Total Kjeldahl Nitrogen, Unfiltered
CBOD Ultimate, Unfiltered	Manganese, Filtered	Total Kjeldahl Nitrogen, Filtered
Chloride, Unfiltered	Manganese, Unfiltered	Total Organic Carbon, Unfiltered
Chlorophyll-a, Pheo-Corrected	Mercury, Methyl	Total Phosphorus, Filtered
Chlorophyll-a Trichromatic Uncorr.	Mercury, Unfiltered	Total Phosphorus, Unfiltered
Chlorophyll-b	Nickel, Filtered	Total Suspended Solids
Chlorophyll-c	Nickel, Unfiltered	Turbidity[2]
Chromium, Filtered	Nitrate N, Unfiltered	Volatile Suspended Solids
Chromium, Unfiltered	Nitrite N, Unfiltered	Zinc, Filtered
COD, Filtered	Ortho Phosphate, Filtered	Zinc, Unfiltered
COD, Unfiltered	Ortho Phosphate, Unfiltered	

[1]Continuous and routine in-situ measurements
[2]Laboratory and in-situ measurements

Stream samples are collected on a regular basis during baseflow conditions. In the winter, monthly grab samples are obtained if ice conditions allow. In the spring, summer, and fall, baseflow grab sampling frequency may increase to twice per month. Depending on specific site conditions, additional grab samples might be obtained to help further characterize water quality.

In addition to the baseflow grab samples, flow-weighted composite samples are collected by the automatic samplers during all storm runoff events in the open-water (ice-free) season. About 10-15 storm events per year are characterized via composite sampling, although this number can vary depending upon rainfall frequency and distribution.

Each monitoring station is equipped with a datalogger that continuously records water stage and flow, conductivity, and temperature at 15-minute intervals during the open-water season. Precipitation (rainfall) is measured in 0.01-inch increments via a tipping-bucket rain gauge. The open-water season varies from site-to-site and year-to-year, but a typical operational period is from mid-March through the end of November. Typical minimum sampling frequency is summarized in Table 3.3.

Table 3.3 MCES Stream Monitoring Frequency

Sample Type	Typical Minimum Frequency
Grab	12 samples / year
Composite	10 - 15 samples / year
Continuous[1]	24,960 records for each variable

[1] 260 days of operation times 96 records per day.

4 QUALITY ASSURANCE OBJECTIVES

The data collected through the MCES stream monitoring program are intended to meet the data quality assurance (QA) objectives outlined in this section. This section provides overall QA goals for precision, accuracy, representativeness, completeness, comparability, and analytical sensitivity.

4.1 PRECISION AND VARIABILITY

Precision is a measure of agreement of repeated measurements for a given sample. Precision can also be described in relationship to its opposite, variability. Laboratory precision goals are established by the Laboratory Services business unit for each analytical variable and for each sample matrix. Laboratory precision is determined by replicate analyses on a single sample.

Total variability, which combines laboratory variability and field variability, is determined by analysis of replicate samples. Because total variability includes variability of both the laboratory and field procedures, it will always be larger than laboratory variability. Thus the total precision goals, as measured by relative percent difference between replicate samples, are larger than the laboratory precision goals. Total precision goals have not been established for this program, and the collection of field replicate samples (for either grab or composite samples) is not routinely performed as a part of the stream monitoring program.

4.2 ACCURACY AND BIAS

Accuracy is a measure of agreement between an observed value and the accepted reference value or true value. Conversely, bias is the deviation of the observed value from the true or accepted value. Bias may enter the monitoring program in several ways, with one of the most common ways being sample contamination. MCES seeks to minimize bias, especially systematic bias in the data collected through the stream monitoring program. Laboratory accuracy goals are established by the Laboratory Services business unit for each analytical variable and for each sample matrix. Laboratory accuracy is determined by analysis of standard reference samples, spiked samples, and/or matrix-spiked samples, as well as by instrument and method blank samples.

Field accuracy is assessed using trip and equipment blank samples. Trip blank samples (sometimes called bottle blanks) involve collecting a sample of the water source (typically distilled water from the MCES laboratory) used for decontaminating equipment and sample bottles. These samples are used to assess possible contamination in the water source as well as possible contamination contributed via the sample bottle preparation process.

Equipment blank samples involve processing distilled water throughout the entire sample collection routine, as outlined in Section 5 of this QAPP and detailed in the field standard operating procedures (SOPs). The field equipment used to collect water quality samples may become contaminated through the course of sampling if the equipment is not properly cleaned, rinsed, and handled between sampling events. Equipment blanks can be used to assess possible contamination of the equipment used for water quality sample collection. Presently, trip blank samples and equipment blank samples are not routinely part of the stream monitoring program.

4.3 REPRESENTATIVENESS

Representativeness is the degree to which a sample or analytical result accurately represents a population characteristic, a process, or an environmental condition of interest. To evaluate representativeness, the relevant population of interest must first be defined. Then representativeness is mostly a function of where and when a sample is collected. For example, dissolved oxygen concentrations in rivers and streams typically exhibit a well-known diurnal cycle. If one is interested in evaluating the mean and variability of dissolved oxygen concentrations to which stream biota are exposed, measurements must be obtained at different times throughout the day. Measurements made only at noon would provide an unrepresentative sample of dissolved oxygen concentrations. The primary goal of the stream monitoring program is to be able to accurately assess watershed pollutant loads.

Pollutant concentrations and loads in streams vary spatially, temporally, and with flow. Macro-scale spatial representativeness is assured by monitoring multiple watersheds with varying land use compositions. Meso-scale spatial representativeness is assured by locating the monitoring stations near the mouths of the streams, to measure pollutant loading from as large a portion of the watershed as possible. By locating the stations near the outlets, subwatershed scale variabilities are integrated into a single overall pollutant load estimate. Micro-scale representativeness is assured by collecting water quality samples and making in-situ measurements from the well-mixed, central area of the stream.

To assure representativeness with respect to time and flow, sample collection is distributed across the year and across the range of flow conditions. The monthly collection of grab samples serves two purposes. First, it ensures that sampling is conducted throughout the year. Second, because most grab sampling is conducted at baseflow conditions, it also ensures that the lower end of the flow range is adequately represented. The collection of composite samples during storm (runoff) events ensures that medium to high flow conditions are represented in the sampling program during the open-water season (mid-March through November). Dataloggers are programmed to trigger flow-weighted composite sample collection during all storm (runoff) events each year. About 10-15 storm event composite samples are obtained per year, but this number varies based upon site and climate conditions. Overall, this sampling design for the stream monitoring program is essentially a stratified sampling scheme conducted at near regular intervals throughout the year, with the sampling effort stratified by flow conditions. As such, for most applications, the continuously recorded flow data are critical for weighting the stratified data in a representative manner.

4.4 COMPLETENESS

The data completeness goal can be expressed as the percent of valid data collected as compared to the total amount of data that were expected. Numerous events can reduce data completeness for a monitoring project, including sample container breakage, inability to safely access a sampling location under certain conditions, failure of automatic monitoring and sampling equipment, and failure of laboratory equipment. The typical minimum frequency of sample collection and measurement is outlined in Section 3.3 of this QAPP. Typically, at least 12 grab samples and 10-15 flow-weighted composite samples should be collected each year at each monitoring station. In addition, the continuously recorded data should be collected at 15-minute intervals throughout the open-water season, resulting in about 24,960 observations for each continuously recorded variable each year (based on 260 days of open-water operation). The annual goal for this program is 90% completeness or better for each monitoring variable.

4.5 COMPARABILITY

Data comparability is the degree to which one data set can be compared to another. MCES strives for internally comparable data by using consistent field and laboratory methods for all sites throughout the stream monitoring program, and by maintaining consistent methods over time, except where improvements are required for data quality.

When method changes are proposed, these changes will be evaluated and documented before being implemented, thereby allowing adequate study to ensure data comparability over time. In addition, MCES ensures internal and external data comparability by employing industry-accepted standard methods where applicable. See the field and laboratory SOPs for details on the methods used by MCES and the original source methods.

4.6 ANALYTICAL SENSITIVITY

Analytical sensitivity is the lowest concentration of a variable that can be reliably measured in a given sample. To ensure that analytical data are useful, the lowest reporting limit (LRL) for a given analyte should be either well below the lowest expected ambient environmental concentrations or below any applicable regulatory action levels. Although the LRL can vary from sample to sample due to matrix interferences and other analytical issues, under most conditions the LRL is fixed for a given analytical method. The routine LRLs for water quality variables analyzed for this program are listed in Table 4.1.

Table 4.1 Lowest Reporting Limits (LRLs) for MCES Stream Monitoring Variables

Laboratory Variable	LRL	Units	Laboratory Variable	LRL	Units
Aluminum, Filtered	3	ug/L	Magnesium, Unfiltered	10	ug/l
Aluminum, Unfiltered	3	ug/L	Manganese, Filtered	0.1	ug/L
Ammonia Nitrogen, Unfiltered	20	ug/L	Manganese, Unfiltered	0.1	ug/L
Bicarbonate Alkalinity, Unfiltered			Mercury, Methyl	0.03	ng/L
BOD 5-day, Unfiltered	1	mg/L	Mercury, Unfiltered	0.06	ng/L
BOD Ultimate, Unfiltered	1	mg/L	Nickel, Filtered	0.09	ug/L
Cadmium, Filtered	0.04	ug/L	Nickel, Unfiltered	0.09	ug/L
Cadmium, Unfiltered	0.04	ug/L	Nitrate N, Unfiltered	50	ug/L
Calcium, Unfiltered			Nitrite N, Unfiltered	30	ug/L
Carbonate Alkalinity, Unfiltered			Ortho Phosphate, Filtered	5	ug/L
CBOD 5-day, Unfiltered	1	mg/L	Ortho Phosphate, Unfiltered	5	ug/L
CBOD Ultimate, Unfiltered	1	mg/L	pH	0.1	pH unit
Chloride, Unfiltered	2	mg/L	Pheophytin-a	1	ug/L
Chlorophyll-a, Pheo-Corrected	1	ug/L	Potassium, Unfiltered	10	ug/L
Chlorophyll-a, Trichromatic Uncorr.	1	ug/L	Sodium, Unfiltered	20	ug/L
Chlorophyll-b	1	ug/L	Sulfate, Unfiltered	1	mg/L
Chlorophyll-c	1	ug/L	Total Alkalinity, Unfiltered		
Chromium, Filtered	0.2	ug/L	Total Dissolved Solids	1	mg/L
Chromium, Unfiltered	0.2	ug/L	Total Kjeldahl Nitrogen, Filtered	0.2	mg/L
COD, Filtered	5	mg/L	Total Kjeldahl Nitrogen, Unfiltered	0.2	mg/L
COD, Unfiltered	5	mg/L	Total Organic Carbon, Unfiltered	1	mg/L
Copper, Filtered	0.5	ug/L	Total Phosphorus, Filtered	10	ug/L
Copper, Unfiltered	0.5	ug/L	Total Phosphorus, Unfiltered	10	ug/L
Dissolved Oxygen	.05	mg/L	Total Suspended Solids	1	mg/L
Fecal Coliform Bacteria	1	Col/100 ml	Turbidity	0.5	NTU
Hardness, Unfiltered			Volatile Suspended Solids	1	mg/L
Iron, Unfiltered	6	ug/L	Zinc, Filtered	0.4	ug/L
Lead, Filtered	0.07	ug/L	Zinc, Unfiltered	0.4	ug/L
Lead, Unfiltered	0.07	ug/L			

5 SAMPLING METHODS

The MCES stream monitoring program collects two different types of samples: instantaneous grab samples and flow-weighted composite samples. Grab samples are generally collected during baseflow conditions and composite samples are generally collected during storm (runoff) events. Grab samples may also be collected during storm events, especially if an automatic sampler is not functioning. The procedures and equipment used for collecting these samples are outlined below. Additional details can be found in the field SOPs.

5.1 SAMPLING PROCEDURES

5.1.1 Grab Sampling Procedures

To ensure representativeness, grab samples are generally collected from the stream thalweg, where water is well mixed. Four different methods are used for grab sample collection. The method used for any particular sample depends on several factors, including flow rate, stream depth, stream width, and accessibility. However, the overriding factor is safety of the sampling crew.

Regardless of collection method, the grab sample is stored and transported in a clean, labeled one-gallon container. Half-gallon and 2-gallon containers may also be acceptable, depending on the type and number of water quality variables to be analyzed. The container should be rinsed twice with sample water before the sample is collected. For each rinsing, the container should be partially filled, capped, and shaken; then the rinsate should be discarded. When sampling, enough volume should be collected to fill the one-gallon container, with the exception of a 1-inch headspace. The sample bottle is capped, stored in a cooler with ice packs, and transported to the MCES laboratory within 48 hours.

The four variations of the grab sampling method are described below.

5.1.1.1 Wading and Hand Collection

If the stream is safe to wade, the person collecting the sample wades to the center of the stream with a sample bottle. The sample collector should face upstream, taking care to ensure that any stream bottom debris disturbed by wading does not contaminate the sample. After the sample container is rinsed twice with site water, the bottle cap is removed and the sample bottle is inverted and dipped below the surface, then turned upright to collect the sample while holding the bottle about 1 foot below the water surface.

5.1.1.2 Reach Pole Collection

When wading conditions are not safe in smaller streams, a grab sample may be collected using a reach pole. In this case, the sample bottle is fitted into a wire cage attached to the end of a long, telescoping reach pole. After the sample container is rinsed twice with site water, the bottle cap is removed and the sample bottle is inverted and dipped below the surface, then turned upright to collect the sample while holding the bottle about 1 foot below the water surface.

5.1.1.3 Bridge and Rope Collection

For larger rivers where the sampling station is adjacent to a bridge, a grab sample may be collected using a Labline Polypro® (or equivalent) sampler lowered from the bridge deck near the river thalweg. The Labline sampler is lowered to the river surface and plunged into the water to an approximate depth of 1 meter below the water surface. The sampler is then raised to the bridge deck, and the grab sample is poured into the sample container. In this variation, both the Labline sampler and the sample bottle should be rinsed twice with site water before collection of the final sample, as described above.

5.1.1.4 Autosampler Pump Collection

If it is not possible to use one of the other three grab sampling methods, the pump from the automatic sampler can be used to collect a grab sample. The autosampler should be programmed to rinse and purge the intake line before the sample is collected. Once this has been done, the sample container is rinsed twice and the final sample is collected via the autosampler pump.

5.1.2 Flow-Weighted Composite Sampling Procedure

Flow-weighted composite samples are collected by the automatic samplers during storm runoff events. Samples are collected by the automatic sampler on an equal-flow increment (EFI) basis. With EFI sampling, the datalogger is programmed to trigger the autosampler to collect discrete sub-samples representing equal volumes of stream flow. For example, an autosampler may be programmed to collect a sub-sample for every 100,000 cubic feet of stream discharge. If a storm runoff event had a total of 1,000,000 cubic feet of discharge, the autosampler would collect 10 discrete sub-samples. The discrete sub-samples can be collected in separate 1000-ml plastic containers in the automatic sampler during the runoff event, then mixed thoroughly and combined into a 5-gallon plastic container, to create a composite sample. As an alternative, a composite sample can be directly created by placing a 5-gallon glass container in the automatic sampler to receive all of the discrete flow-weighted sub-samples collected during the runoff event. The composite sample is placed in a cooler with ice and transported to the MCES laboratory, for analysis within 48 hours. Details for operation of the automatic sampler and sample compositing are covered in the field SOPs.

5.2 FIELD EQUIPMENT USED

5.2.1 Grab Sampling Equipment

The following equipment is used for collecting grab samples. The exact equipment will vary slightly, depending upon the specific protocol for each of the four possible grab sampling methods.

- Chest or Hip Waders
- Personal Flotation Device
- Clean, Labeled One-Gallon Sample Bottle (Half-Gallon or Two-Gallon may be used at times)
- Telescoping Reach Pole
- Labline Polypro® Sampler with 50-Foot Nylon Rope
- Automatic Sampler (either Sigma® or ISCO®)
- Polypropylene Sample Tubing
- Cooler and Ice

5.2.2 Composite Sampling Equipment

The following equipment is used for collecting flow-weighted composite samples.

- 24 Clean, 1000-ml Plastic Sample Bottles
- Clean, Labeled Five-Gallon Composite Sample Bottle
- Automatic Sampler (either Sigma® or ISCO®)
- Polypropylene Sample Tubing
- Campbell CR10X Datalogger
- Cooler and Ice

5.3 SAMPLE BOTTLE PREPARATION AND EQUIPMENT CLEANING

5.3.1 Grab Sample Bottles and Equipment Cleaning

Grab samples are typically collected and transported to the MCES laboratory in 1-gallon polypropylene sample bottles. Half-gallon or 2-gallon polypropylene sample bottles may be used on occasion, depending on the type and number of water quality variables to be analyzed. These bottles are dedicated for use by EMA staff for river, stream, and lake monitoring. The decontamination procedure for these sample bottles includes brushing out the interior of the bottle with soapy water, placing the bottle in an automatic dishwasher for a 5-minute wash with Dry Contrad®, a 7-minute rinse with laboratory water, and a 2-minute rinse with distilled water, placing the bottle in a hot air dryer until dry, capping the bottle, and delivering the bottle to the EMA storage area in the laboratory. In addition, as noted in the grab sampling procedure (Section 5.1.1) the sample container is twice rinsed with sample water in the field, before the final sample is collected. Samples for fecal coliform bacteria analysis are collected in sterile, 18-ounce Whirl-Pak® bags. The Labline Polypro® Sampler is cleaned by brushing out the interior with soapy water, then thoroughly rinsing with distilled water. The sampler is twice rinsed with sample water in the field, before the final sample is collected.

5.3.2 Composite Sample Bottles and Equipment Cleaning

The flow-weighted composite sampling procedure is described in Section 5.1.2. The sample bottles needed for this procedure include 1000-ml polypropylene automatic sampler bottles, rectangular 5-gallon polypropylene “composite” sample bottles, and round 5-gallon glass “composite” sample bottles. The decontamination procedure for these sample bottles is the same as that for the grab sample bottles, as described in Section 5.3.1. When the 1000-ml autosampler bottles are emptied in the field to form a composite sample, these bottles are decontaminated by rinsing with distilled water from the MCES laboratory. The autosampler bottles are then placed back in the automatic sampler for collection of the next runoff event sample. The internal polypropylene autosampler tubing and the external polypropylene sample line are not routinely decontaminated during the monitoring season. However, the automatic sampler is programmed to purge the sample line prior to the collection of each sub-sample.

6 FIELD AND SAMPLE CUSTODY DOCUMENTATION

Information on field conditions, such as the weather, deviations from written procedures, operating condition of the equipment, and other unusual occurrences, may be critical for interpreting the resulting data. It is also important to be able to trace the path of a sample from collection in the field through laboratory analysis, to be able to address issues such mistaken sample identity. Therefore, adequate field documentation is an essential quality assurance element of any montoring program. This section describes the documentation requirements for the MCES stream monitoring program.

6.1 *FIELD DATA SHEETS*

Field data sheets are the primary method for documenting most field activities associated with the MCES stream monitoring program. Presently, each of the three MCES stream monitoring programs described in this QAPP use slightly different sheets (Appendix A). These sheets are primarily used to record field measurements and document information regarding all sampling events. They include the monitoring site location, date, time, and field crew names. These sheets also serve as the initial record of any field measurements and weather conditions at the time of sampling. Space is provided on the sheets to record any other field notes or observations. In addition, these sheets serve as the analytical request that is provided to the MCES laboratory when samples are submitted to the login bench. These sheets must be filled out by MCES field staff or by the local cooperators and submitted with the samples to the MCES laboratory. Samples without field sheets are not accepted. Once the laboratory login bench has logged a sample into the laboratory information management system (LIMS), the accompanying field sheet is transferred to the appropriate MCES stream monitoring coordinator for the given site (Table 2.1). The responsible stream monitoring coordinator also logs field data and sample identification information into the water quality database (WQDB).

6.2 *FIELD NOTES*

As noted above, the field data sheets are the primary means of recording field information. However, field notebooks are occasionally used to supplement the field data sheets. When this occurs, MCES field staff and local cooperators record field notes in Rite-in-Rain© notebooks, using indelible ink. Field notebooks are primarily used to document visits to the monitoring site, including equipment checks and site maintenance.

6.3 *SAMPLE LABELING*

All sample containers must have sample labels attached and completely filled out. Sample containers without labels or with missing label information are not accepted by the MCES laboratory. At a minimum, the sample label must include the river/stream code (or name), the river mile, the date, and the time of sample collection.

6.4 *SAMPLE SHIPPING*

All samples are packed in ice-filled coolers for transport to the MCES laboratory. If temporary storage is required before transport to the laboratory, the sample is kept in cool, dark storage (either an ice-filled cooler or a refrigerator). After collection, samples are generally transported to the MCES laboratory within 24 hours. For samples that do not meet this requirement, analyses with short holding times (such as BOD, fecal coliform, and ortho-phosphorus) are deleted from the analytical request.

6.5 *Sample Chain-of-Custody Procedure*

A formal chain-of-custody procedure is not used for the MCES stream monitoring program. Sample custody can be documented by the field data sheets and the LIMS record. The field data sheets indicate the location, date, and time of sample collection, as well as the staff who collected the sample. MCES staff and the local cooperators are generally responsible for transporting samples to the MCES laboratory. No record is kept when another party (such as a courier service) transports a sample to the MCES laboratory. However, when a courier service is used, samples are shipped in a sealed cooler. The LIMS record notes the date and time when the sample is logged in by the MCES laboratory. The time of sample receipt by the laboratory is not noted, but samples are logged in within 24 hours of receipt.

7 FIELD MEASUREMENT PROCEDURES

7.1 *Permanent In-Situ Monitoring Equipment*

The typical stream monitoring station is designed to continuously monitor stage, flow, temperature, and conductivity at 15-minute intervals. Precipitation (rainfall) is measured in 0.01-inch increments via a tipping-bucket rain gauge. The standard equipment layout is:

- A walk-in shelter equipped with AC power, a phone line, and modem for data transmission.
- A tipping-bucket rain gauge for collection of rainfall data, in 0.01-inch increments. The rain gauge is situated at a location that is free from overhanging vegetation.
- A stage reference guide, usually a staff gauge or a wire weight gauge.
- A stage measurement device, usually a bubbler/pressure transducer system. Stations without this system are equipped with an ultrasonic sensor or a shaft encoder.
- A Sigma® or ISCO® automatic sampler, with either 24 1000-ml sample bottles or 1 5-gallon composite sample bottle. At monitoring stations where extended hydrographs and sampling times are possible after storm events, a refrigerated automatic sampler is used to maintain sample integrity.
- A conduit which runs from the shelter to the stream. The conduit contains autosampler tubing, heat tape, a temperature/conductivity probe, and a bubbler line. The end of the conduit is securely anchored to a solid surface (typically a fence post) in the stream, at a representative monitoring location. The remainder of the conduit, between the shelter and the stream, is typically buried or covered with rip-rap.
- A Campbell CR10X datalogger, which activates/deactivates the automatic sampler and writes a data record every fifteen minutes for stage, flow, temperature, and conductivity, and at 0.01-inch increments for rainfall.

7.1.1 Permanent In-Situ Monitoring Equipment: Operation and Calibration

7.1.1.1 Stage

Measurements of water stage (level) are recorded at 15-minute intervals by the Campbell CR10X datalogger. Water stage measurements are typically made using a bubbler/pressure transducer system, but an ultrasonic sensor or a shaft encoder is used as some stations.

The bubbler/pressure transducer system detects water stage by using a pressure transducer to measure the pressure needed to force a gas (air or nitrogen) bubble from the end of the submerged bubbler line. The higher the water stage, the greater the pressure necessary to force a gas bubble out of the bubbler line. The gas source (either a compressed nitrogen gas cylinder or an air pump) is located in the monitoring shelter, along with the pressure transducer. The bubbler line extends from the shelter to the stream (or stilling well), through a conduit. The end of the bubbler line is securely mounted in a fixed position under the water surface. The bubbling rate, controlled by a needle valve in the shelter, is typically set at one to three bubbles per second.

The ultrasonic sensor detects water stage by emitting an acoustic pulse and measuring the travel time to the water surface and back. The ultrasonic sensor is installed in a fixed position above the water surface, typically on the underside of a bridge or culvert.

The shaft encoder, typically located in a stilling well, employs a float and counter-weight system supported above the water surface by a chain draped over a wheel mounted on a movable shaft. The encoder outputs a digital pulse per unit angle of rotation of the wheel on its shaft, thereby sensing whether the water level under the float is rising or falling, and by how much.

The instrument stage measurement is also manually calibrated by comparing it against the stage reference guide (usually a fixed staff gauge or wire weight gauge). If the instrument stage measurement and the reference stage measurement differ by more than 0.05 foot, then the instrument stage measurement is re-calibrated to equal the reference stage measurement. An exception to this procedure occurs if there is reason to believe that the reference stage has been altered (i.e. the staff gauge has been moved).

7.1.1.2 Flow

Stream flow is recorded at 15-minute intervals by the Campbell CR10X datalogger, based upon the 15-minute stage measurements and a stage-discharge rating curve that is programmed into the datalogger. The rating curve is developed by fitting a curve to paired in-stream measurements of stage and flow, under a variety of flow conditions. The rating curve flow measurements are described in Section 7.2.1.5.

7.1.1.3 Temperature

Measurements of water temperature are recorded at 15-minute intervals by the Campbell CR10X datalogger. A temperature probe, connected to the datalogger, extends from the shelter to the stream (or stilling well), through a conduit. A thermistor at the end of the temperature probe is encapsulated in a protective housing. Thermistors are thermally sensitive resistors that exhibit a large change in electrical resistance with a small change in temperature. Temperature measurements are manually calibrated by comparing the instrument measurement to a manual field temperature measurement obtained with an independently-calibrated portable meter or thermometer. See Section 7.2.1.3 for information on manual field measurement of water temperature.

7.1.1.4 Conductivity

Conductivity is the inverse of electrical resistance. In water, conductivity is related to ionic strength, or the amount of ions in solution, including calcium, magnesium, sodium, potassium, chloride, sulfate and others. Measurements of water conductivity are recorded at 15-minute intervals by the Campbell CR10X datalogger. A conductivity probe, connected to the datalogger, extends from the shelter to the stream (or stilling well), through a conduit. The end of the conductivity probe consists of two or more metal plates separated by a gap through which water can flow. An electrical voltage is then applied across the plates and the resulting electrical resistance is measured. Conductivity measurements are manually calibrated by comparing the instrument measurement to a manual field conductivity measurement obtained with an independently-calibrated conductivity meter. If an adjustment is needed, the conductivity probe is assigned an appropriate offset (via the datalogger keypad) to match the conductivity meter measurement. See Section 7.2.1.4 for information on manual field measurement of conductivity.

7.1.2 Permanent In-Situ Monitoring Equipment: Maintenance

Routine maintenance is performed on the permanent in-situ equipment at each monitoring station at least once a month. This maintenance includes the following:

- Clean any debris from the rain gauge (every visit),
- Clean the staff gauge,
- Compare instrument stage with reference stage and recalibrate if needed (every visit),
- Compare the instrument temperature with manual field temperature and recalibrate if needed,
- Clean the conductivity probe,
- Compare the instrument conductivity with manual field conductivity and recalibrate if needed,
- Remove any debris from the ends of the conduit and bubbler and sampler lines (when stage conditions permit),
- Inspect the bubbler and sampler lines (when stage conditions permit),
- Check for leaks in the bubbler and sampler lines,
- Purge the bubbler and sampler lines to ensure that they are not plugged,
- Replace the bubbler and sampler lines if cracked, broken, or worn,
- Check nitrogen tank pressure and replace the tank if nearly empty,
- Check for loose wires, and
- Check the dessicant indicators and replace if needed (when color changes from blue to pink).

7.2 PORTABLE MONITORING EQUIPMENT

Portable monitoring equipment is routinely used to collect additional stream monitoring data, including dissolved oxygen concentration, pH, temperature, conductivity, and stream flow. The portable equipment is also used to calibrate the permanent in-situ equipment in the monitoring stations. The portable field monitoring equipment used in this program is listed in Table 7.1.

Table 7.1 MCES Portable Stream Monitoring Equipment

Variable	Equipment Used
Dissolved Oxygen	YSI 650/6820 Multiparameter Meter
Dissolved Oxygen	YSI 85 Multiparameter Meter
pH	YSI 650/6820 Multiparameter Meter
pH	Hanna pHep Meter
Temperature	YSI 650/6820 Multiparameter Meter
Temperature	YSI 85 Multiparameter Meter
Temperature	Fisher Scientific Digital Thermometer
Conductivity	Oakton C 100, 300, 440 Meter
Conductivity	YSI 650/6820 Multiparameter Meter
Conductivity	YSI 85 Multiparameter Meter
Flow	Dye Drip Pump and Fluorometer
Flow / Velocity	Marsh-McBirney Velocity Meter
Flow / Velocity	SonTek Acoustic Doppler Velocity meter
Flow / Velocity	Acoustic Doppler Current Profiler (ADCP)
Flow/ Velocity	USGS Price Meter and Aqua Calc 5000
Flow/ Velocity	Gurley Velocity Meter
Transparency	Transparency Tube

The purpose of complementing the MCES stream monitoring program with portable monitoring equipment is four-fold. First, portable monitoring equipment can be used to obtain stream information that is not ordinarily obtained via permanent in-situ monitoring equipment or laboratory analysis. Examples include dissolved oxygen and transparency tube measurements. Second, measurements of flow (or discharge) are paired with stage measurements to develop a rating curve for each monitoring site, which is used to calculate continuous flow from the continuous stage measurements. Third, portable equipment measurements can be compared to corresponding measurements from the permanent in-situ equipment. Because the portable equipment can be independently calibrated, these comparisons can provide the basis for identifying instrument drift and other possible malfunctions in the permanently installed equipment. Fourth, field measurements made via portable equipment can be compared to corresponding laboratory measurements to identify possible problems with the use of the field equipment or possible changes in water chemistry resulting from sample storage or handling.

7.2.1 Portable Monitoring Equipment: Operation, Calibration, and Maintenance

7.2.1.1 Dissolved Oxygen

Field dissolved oxygen (DO) measurements are made using a portable DO meter. Field staff typically wade into the stream, place the DO probe directly into a well-mixed area of the stream, read the result from the meter, and record the result on the field data sheet. If it is not possible to wade into the stream due to safety considerations, a grab sample may be collected using one of the alternative methods described in Section 5.1.1, and the DO measurement is made on the grab sample. DO measurements are often obtained at select stream monitoring stations in conjunction with the collection of grab and composite samples. Dissolved oxygen is measured with a membrane-covered sensor, which detects the electrical current associated with the reduction of oxygen as it diffuses through a Teflon® membrane. The electrical current associated with this process is proportional to the amount of oxygen present in the solution outside the membrane (YSI 6820 operations manual).

Before each field trip, the portable DO meter is air-calibrated in the MCES laboratory, using local barometric pressure and air temperature, according to the procedure recommended by the instrument manufacturer. At the conclusion of each field trip, upon returning to the MCES lab building, an end-of-day DO measurement is made in laboratory water and recorded. The DO meter is then re-calibrated, and a new DO measurement is made in the same water and recorded, to document any meter drift that may have occurred during the course of the monitoring day.

Maintenance of the DO probe requires changing the potassium chloride (KCL) electrolyte solution and Teflon membrane as recommended by the instrument manufacturer. The KCL solution and membrane should be changed when bubbles are present under the membrane, when dried electrolyte is visible on the membrane/O-ring, or if the meter exhibits unstable measurements. The silver electrodes beneath the probe membrane should be resurfaced if they become black in color, as directed by the instrument manufacturer (YSI 6820 operations manual).

7.2.1.2 pH

Field pH measurements are made using a portable pH meter. Field staff typically wade into the stream, place the pH probe directly into a well-mixed area of the stream, read the result from the meter, and record the result on the field data sheet. If it is not possible to wade into the stream due to safety considerations, a grab sample may be collected using one of the alternative methods described in Section 5.1.1, and the pH measurement is made on the grab sample.

Before each field trip, the portable pH meter is calibrated in the MCES laboratory, using the two-point calibration procedure recommended by the instrument manufacturer. At the conclusion of each field trip, upon returning to the MCES laboratory, the pH meter calibration should be verified by measuring the pH of a known reference sample.

Cleaning of the pH probe is required whenever deposits or contaminants are apparent, or when the response of the probe becomes slow (YSI 6820 operations manual).

7.2.1.3 Temperature

Field temperature measurements are made using the temperature function of the dissolved oxygen meter, pH meter, or conductivity meter. Field staff typically wade into the stream, place the temperature probe directly into a well-mixed area of the stream, read the result from the meter, and record the result on the field data sheet. If it is not possible to wade into the stream due to safety considerations, a grab sample may be collected using one of the alternative methods described in Section 5.1.1, and the temperature measurement is made on the grab sample. The temperature sensors in the dissolved oxygen, pH, and conductivity meters are factory-calibrated, but should be checked for accuracy on an annual basis, using a certified NBS thermometer.

7.2.1.4 Conductivity

Field conductivity measurements are made using a portable conductivity meter. Field staff typically wade into the stream, place the conductivity probe directly into a well-mixed area of the stream, read the result from the meter, and record the result on the field data sheet. If it is not possible to wade into the stream due to safety considerations, a grab sample may be collected using one of the alternative methods described in Section 5.1.1, and the conductivity measurement is made on the grab sample.

Before each field trip, the portable conductivity meter is calibrated in the MCES laboratory, using the one-point calibration procedure recommended by the instrument manufacturer. At the conclusion of each field trip, upon returning to the MCES laboratory, the conductivity meter calibration should be verified by measuring the conductivity of a known reference sample.

The openings in the conductivity probe that allow water access to the conductivity electrodes must be cleaned regularly using a small brush (YSI 6820 operations manual).

7.2.1.5 Stream Flow

Stream flow (discharge) measurements paired with stream stage measurements are critical for establishing a reliable and accurate stage-discharge rating curve at each stream monitoring station. The rating curve is programmed into the Campbell CR10X datalogger to produce a continuous time-series of flow data from the record of continuous stage measurements at each station, obtained via the permanent in-situ monitoring equipment (bubbler/pressure transducer, ultrasonic sensor, or shaft encoder).

Velocity (or current) meters, such as the Marsh-McBirney Meter, Son Tek Meter, USGS Price Meter, and Gurley Meter, are used to measure water velocity at a specific point in the stream channel. Stream flow (discharge) can be calculated by making regularly spaced velocity measurements across a stream or river transect, coupled with measurements of the cross-sectional stream channel geometry at the same transect locations. The current meters are factory-calibrated. Presently, the accuracy of these velocity meters is not verified on a routine basis for the MCES stream monitoring program.

An estimate of stream flow is obtained in the following manner. Velocity meters are only used when conditions allow wading across the entire stream channel. A measuring tapeline is extended perpendicularly across the stream channel from bank to bank, at a suitable location. The width of the stream channel is divided up into ten equal intervals (typically 1-3 feet). Each of these intervals represents an idealized trapezoidal panel. A graduated wading rod is used to measure the stream depth at the mid-point of each panel. For panels with a water depth greater than 30 inches, the velocity is measured at 20% and 80% of the water depth, along a vertical line at the mid-point of the panel. These two velocity measurements are averaged to determine an average velocity for the panel. If the water depth is less than 30 inches, the velocity is measured at 60% of the water depth, along a vertical line at the mid-point of the panel. This single velocity measurement is used as the average velocity for the panel. The flow for each panel is derived by multiplying the average velocity for that panel by the area of the panel (determined from the depth and width of the panel). The flows for all the panels are then summed to arrive at the total stream flow.

Instantaneous stream flow measurements over a wide range of flow conditions are paired with concurrent measurements of stream stage and plotted on a chart for each stream monitoring station. The flow and stage data are reviewed and a rating curve is fit to the data according to the MCES SOP, which is based on USGS methodology. Rating curve measurements should be regularly obtained at each monitoring station throughout the year, to ensure that the rating curve has not changed, or to establish a new rating curve if stream channel morphology changes.

7.2.1.6 Transparency

Transparency, a measure of water quality, is an indicator of water clarity or the ability to transmit light. Transparency can be measured with a transparency tube, a graduated, clear plastic, 60 or 100 cm-long tube with a black and white Secchi-type disk on the bottom. Transparency tube data provides information on the clarity of stream water, indicating how much sediment, algae, and other particulate materials are suspended in the water. To obtain a transparency tube measurement, a grab sample is collected from a well-mixed stream location, using one of the alternative methods described in Section 5.1.1. The transparency tube is filled with water from the grab sample. While viewing the transparency tube from the top, water is slowly released from a valve and spigot near the bottom, until the black and white Secchi disk on the bottom of the tube first becomes visible. Water depth in the tube is recorded to the nearest 0.1 cm. A bit more water is then released from the tube until the Secchi disk is clearly visible. Water depth in the tube is again recorded to the nearest 0.1 cm. The two water depth measurements are averaged to provide the final transparency tube measurement. While making transparency tube measurements, avoid direct sunlight and do not wear sunglasses. Keep the transparency tube clean and free from scratches.

8 LABORATORY ANALYTICAL PROCEDURES

All laboratory analyses for the MCES stream monitoring program are performed by the MCES laboratory, located at 2400 Childs Road, St. Paul, Minnesota 55106. The MCES laboratory is certified under the State of Minnesota laboratory certification program. The Minnesota Department of Health, which is the certifying agency for Minnesota, has assigned the MCES laboratory a certification number of 027-123-172. An overview of laboratory procedures, processes, and its quality assurance program are provided in the laboratory QA manual (Appendix B). The analytical methods and their SOP reference numbers for the MCES stream monitoring program are listed in Table 8.1. The detection limits for these methods are previously noted in Table 4.1.

Table 8.1 MCES Laboratory Analytical Methods for Stream Monitoring Variables

Laboratory Variable	MCES Method	Certified Reference	Laboratory Variable	MCES Method	Certified Reference
Aluminum, Filtered	MCES 550.1.2	EPA 200.8	Magnesium, Unfiltered	MCES 550.1.2	EPA 200.8
Aluminum, Unfiltered	MCES 550.1.2	EPA 200.8	Manganese, Filtered	MCES 550.1.2	EPA 200.8
Ammonia Nitrogen, Unfiltered	MCES 501.0.2	EPA 350.1	Manganese, Unfiltered	MCES 550.1.2	EPA 200.8
Bicarbonate Alkalinity, Unfiltered	NA	NA (Titration)	Mercury, Methyl	MCES 548.5.1	EPA 245.1
BOD 5-day, Unfiltered	MCES 300.0.1	SMEWW 507	Mercury, Unfiltered	MCES 548.5.1	EPA 245.1
BOD Ultimate, Unfiltered	MCES 324.0.0	SMEWW 507	Nickel, Filtered	MCES 550.1.2	EPA 200.8
Cadmium, Filtered	MCES 550.1.2	EPA 200.8	Nickel, Unfiltered	MCES 550.1.2	EPA 200.8
Cadmium, Unfiltered	MCES 550.1.2	EPA 200.8	Nitrate Nitrogen, Unfiltered	MCES 529.0.3	EPA 353.1
Calcium, Unfiltered	MCES 550.1.2	EPA 200.8	Nitrite Nitrogen, Unfiltered	MCES 529.0.3	EPA 353.1
Carbonate Alkalinity, Unfiltered	NA	NA (Titration)	Ortho Phosphate, Filtered	MCES 502.1.2	EPA 351.2 EPA 365.4
CBOD 5-day, Unfiltered	MCES 300.0.1	SMEWW 507	Ortho Phosphate, Unfiltered	MCES 502.1.2	EPA 351.2 EPA 365.4
CBOD Ultimate, Unfiltered	MCES 324.0.0	SMEWW 507	pH	NA	NA (Probe)
Chloride, Unfiltered	MCES 608.1.1	EPA 325.2	Pheophytin-a	MCES 802.0.3	ASTM D3731-87
Chlorophyll-a, Pheo-Corrected	MCES 802.0.3	ASTM D3731-87	Potassium, Unfiltered	MCES 550.1.2	EPA 200.8
Chlorophyll-a Trichromatic Uncorrected	MCES 802.0.3	ASTM D3731-87	Sodium, Unfiltered	MCES 550.1.2	EPA 200.8
Chlorophyll-b	MCES 802.0.3	ASTM D3731-87	Sulfate (SO4), Unfiltered	NA	NA (Turbidimetric)
Chlorophyll-c	MCES 802.0.3	ASTM D3731-87	Total Alkalinity, Unfiltered	NA	NA (Titration)
Chromium, Filtered	MCES 550.1.2	EPA 200.8	Total Dissolved Solids	MCES 716.0.0	SMEWW 2540C
Chromium, Unfiltered	MCES 550.1.2	EPA 200.8	Total Kjeldahl Nitrogen, Filtered	MCES 502.1.2	EPA 351.2 EPA 365.4
COD, Filtered	MCES 609.0.2	EPA 410.4	Total Kjeldahl Nitrogen, Unfiltered	MCES 502.1.2	EPA 351.2 EPA 365.4
COD, Unfiltered	MCES 609.0.2	EPA 410.4	Total Organic Carbon, Unfiltered	NA	NA
Copper, Filtered	MCES 550.1.2	EPA 200.8	Total Phosphorus, Filtered	MCES 502.1.2	EPA 351.2 EPA 365.4
Copper, Unfiltered	MCES 550.1.2	EPA 200.8	Total Phosphorus, Unfiltered	MCES 502.1.2	EPA 351.2 EPA 365.4
Dissolved Oxygen	MCES 301.0.0	ASTM D888-92A	Turbidity	MCES 320.0.0	SMEWW 2130 B
Fecal Coliform Bacteria	MCES 302.0.0	NA (Membrane Filtration)	Total Suspended Solids	MCES 700.0.1	SMEWW 2540D
Hardness, Unfiltered	NA	NA (EDTA Titration)	Volatile Suspended Solids	MCES 714.0.1	USGS 1-3767-78
Iron, Unfiltered	MCES 550.1.2	EPA 200.8	Zinc, Filtered	MCES 550.1.2	EPA 200.8
Lead, Filtered	MCES 550.1.2	EPA 200.8	Zinc, Unfiltered	MCES 550.1.2	EPA 200.8
Lead, Unfiltered	MCES 550.1.2	EPA 200.8			

9 QUALITY ASSURANCE PROCEDURES

All environmental measurement data collected through the MCES stream monitoring program are reviewed by MCES staff for quality before reporting and release of the data through the Metropolitan Council's Environmental Data Warehouse (EDW). This section provides an overview of the data review and procedural review procedures for this program.

9.1 DATA REVIEW AND VALIDATION

The EMA business unit has developed a Water Quality Data Review Procedures Manual (Appendix C). This manual contains a SOP for reviewing and approving field data prior to transfer to the EDW. SOPs for reviewing and approving laboratory data, continuous monitoring data, and biological data are under development. The review process for these other data types will be similar to that for field data review. The field data review process consists of the following steps:

- Proof-reading data for typos and transcription errors,
- Reviewing and charting QC data (e.g. calibration data, blanks, etc.),
- Reviewing field notes for potential problems and deviations from written SOPs, and
- Providing a final review and validation of intermediate QC results.

9.2 QUALITY ASSURANCE AUDITS AND REPORTING

The EMA Manager or designee shall periodically review the procedures used by the MCES stream monitoring program. This shall include a review to ensure that written procedures remain consistent, clear, and current. QA audits shall also include ride-along assessments to ensure that field staff are following written procedures, that deviations from written SOPs are documented, and that field documentation is generally complete. Furthermore, QA audits shall also include a periodic review of the QA flags assigned to data through the review process described in Section 9.1. Finally, data will be reviewed for patterns that may indicate possible problems with the monitoring procedures, or suggest monitoring gaps.

The results of these audits shall be reported in writing to the EMA Manager or designee for any necessary corrective action.

9.3 CORRECTIVE ACTION

The EMA Manager or designee shall keep a log of any issues identified through the QA audit reports described in Section 9.2, as well as the corrective action taken to address these issues. Possible problems requiring corrective action include:

- Sample contamination,
- Equipment malfunction, and
- Non-compliance with quality control systems.

Any non-conformance with the established quality control procedures outlined in the QAPP shall be identified and corrected. The EMA Manager or designee shall issue a corrective action memorandum for each non-conformance condition and resolution.

10 DATA REPORTING

10.1 AUTOMATED, ELECTRONIC DATA REPORTING

Reporting of data for the MCES stream monitoring program is addressed primarily through automated electronic transmission.

For laboratory samples, the sample ID information is logged into the Laboratory Information Management System (LIMS) and the Water Quality Database (WQDB). When laboratory analytical results become available after laboratory review and approval, the data are automatically transferred from LIMS to the WQDB. EMA staff review and approve these data in the WQDB, after which the data are automatically transmitted to the Environmental Data Warehouse (EDW). The data contained in EDW are available to all Metropolitan Council staff via the Council's intranet.

Field data are directly entered into the WQDB by EMA staff at the same time the sample ID information is entered. Once the field data have been reviewed and approved by EMA staff, the data are automatically transmitted to the EDW and become accessible to all Council staff.

Continuous monitoring data are initially stored by dataloggers, then are transferred daily via modem from the dataloggers to the WQDB, by an automated dial-up program. The data are then reviewed and approved by EMA staff. Once this occurs, these data are also automatically transferred to the EDW.

10.2 ANNUAL ASSESSMENT REPORT

Data collected through the MCES stream monitoring program are compiled and assessed in an annual stream monitoring assessment report. This report summarizes the monitoring activities for each year, presents the results for all the monitoring sites, and provides interpretive assessment of the monitoring results.

Appendix D

Reconnaissance Procedures for Initial Visit to Stream Monitoring Sites

RECONNAISSANCE PROCEDURES FOR INITIAL VISIT TO STREAM MONITORING SITES

I. PURPOSE

To describe the methods used by the Minnesota Pollution Control Agency's (MPCA) Biological Monitoring Program to determine the location of stream monitoring sites for the purpose of assessing water quality and developing biological criteria.

II. SCOPE/LIMITATIONS

This procedure applies to all initial site visits for which an integrated assessment of water quality is to be conducted. An integrated assessment involves the collection of biological (fish and macroinvertebrate communities), physical habitat, and chemical information to assess stream condition. Reconnaissance procedures must be implemented before any sampling can be conducted.

III. GENERAL INFORMATION

Sites may be selected for assessment for a number of reasons including: 1) sites randomly selected for condition monitoring as part of the Environmental Monitoring and Assessment Program (EMAP), 2) sites selected for the development and calibration of biological criteria, and 3) sites selected to evaluate a suspected source of pollution. Although the reasons for monitoring a particular site vary, the reconnaissance procedures described in this document apply to all monitoring sites unless otherwise noted.

IV. REQUIREMENTS

A. Qualifications of crew leaders: The crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in aquatic biology or closely related specialization. Field crew leaders should also possess excellent map reading skills and a demonstrated proficiency in the use of a GPS (Global Positioning System) receiver and orienteering compass.

B. Qualifications of field technicians/student interns: A field technician/student intern must have at least one year of college education and coursework in environmental and/or biological science.

C. General qualifications: All personnel conducting this procedure must have the ability to perform rigorous physical activity. It is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a sampling site.

V. RESPONSIBILITIES

A. Field crew leader: Implement the procedures outlined in the action steps and ensure that the data generated meets the standards and objectives of the Biological Monitoring Program.

B. Technicians/interns: Implement the procedures outlined in the action steps, including maintenance and stocking of equipment, data collection and recording.

VI. QUALITY ASSURANCE AND QUALITY CONTROL

Compliance with this procedure will be maintained through annual internal reviews. Technical personnel will conduct periodic self-checks by comparing their results with other trained personnel. Calibration and maintenance of equipment will be conducted according to the guidelines specified in the manufacturer's manuals.

In addition to adhering to the specific requirements of this protocol and any supplementary site specific procedures, the minimum QA/QC requirements for this activity are as follows:

A. Control of deviations: Deviation shall be sufficiently documented to allow repetition of the activity as performed.

B. QC samples: Quality control samples are not required for this procedure.

C. Verification: The field crew leader will conduct periodic reviews of field personnel to ensure that technical personnel are following procedures in accordance with this SOP.

VII. TRAINING

A. All inexperienced personnel will receive instruction from a trainer designated by the program manager. Major revisions in this protocol require that all personnel be re-trained in the revised protocol by an authorized trainer.

B. The field crew leader will provide instruction in the field and administer a field test to ensure personnel can execute this procedure.

VIII. ACTION STEPS

A. Equipment List: Verify that all necessary items are present before commencement of this procedure (Table 1).

B. Method: Depending on the type of site being sampled (random, biocriteria development, etc.); reconnaissance activities may begin with the collection of preliminary information in the office or take place entirely in the field.

1) Latitude and longitude coordinates (x-site) are provided by EPA, Corvallis for all randomly selected condition monitoring sites (EMAP). A stream information sheet is supplied for each site which contains locational information and a stream trace, making it possible to determine the approximate location of the site on a USGS 7.5” topographic map and the state DeLorme atlas. Record the site location on the topographic map and make a copy of the appropriate section. Also record the location on the state atlas to aid in vehicular navigation to the site.

   It is often advantageous to begin landowner determination prior to site reconnaissance. County Platte maps, courthouse records, and the internet can be used to determine ownership and provide contact information for landowners. If a site is accessible only via private land, it is essential to obtain access permission from the landowner before visiting the site. Under no circumstances should field personnel knowingly trespass on private property to access a sampling site. For each site an information packet is compiled containing the **Stream Verification Form** (see below), the stream information sheet provided by EPA, the topographic map copy, and any additional maps that may be useful (Platte map, aerial photos, land use coverage, etc.)

   Consult the state atlas, topographic map, Platte map, aerial photos, etc. to navigate as close as possible to the site by vehicle. Navigate from the vehicle to the target location (x-site), as identified on the EMAP stream information sheet, utilizing available maps, a compass, and a GPS receiver (consult GPS manual for operating instructions). In remote areas, it is recommended that a GPS waypoint be taken at the vehicle to aid in returning from the site. Considerable effort should be expended to identify and record an access route that minimizes access problems for sampling crews returning at a later date.

2) For targeted sites (i.e. latitude and longitude are unknown prior to initial site reconnaissance) it is up to the investigator to determine what, if any, preliminary information should be obtained before field reconnaissance activities are conducted. It is often beneficial to gather information about the stream and its watershed (e.g. reference condition, above or below point sources, and watershed land use) to help achieve the monitoring objectives. Prior to field reconnaissance activities there may be many candidate sites considered for sampling, however, completion of the **Stream Verification Form** is necessary only for those sites that meet the monitoring objectives and are determined *sampleable*.

While selection of the sampling reach and determination of the x-site are at the discretion of the principal investigator, it is important to consider local influences that may affect the fish or macroinvertebrate community. Unless your objective is to evaluate a specific local influence, an effort should be made to avoid sampling within 1 mile of a lake, dam, or stream confluence that is three or more stream orders larger. Establishing sampling reaches under bridges, through culverts, or within their associated scour holes should also be avoided.

For all sites the station length is 35 times the mean stream width, which is based on the distance necessary to capture a representative and repeatable sample of the fish community (following: Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management. 16:241-256.). This approach provides progressively longer stations with increasing stream size.

The information obtained during initial site reconnaissance is recorded on the **Stream Verification Form**. A copy is attached and guidelines for filling out this data sheet are described in the following pages.

C. Stream Verification Form

This form provides locational, stream status, and reach length information. The form is completed after location or determination of the x-site. For sites in which a predetermined latitude and longitude is not provided, it will be necessary for the investigator to determine the x-site. Record the following information in the space provided:

C.1. Stream Documentation

1) *Field Number* – A seven-digit code that uniquely identifies the station. The first two digits identify the year of sampling, the second two identify the major river basin, and the last three are numerically assigned in sequential order (example 02UM001). Assign the station an appropriate field number. For EMAP sites the last three digits should correspond to the sequential number provided by EPA for each site.

2) *Date* – The date initial site reconnaissance is conducted in month/day/year format (MM/DD/YY).

3) *Stream Name* – The name of the stream as shown on the most recent USGS 7.5" topographic map. Include all parts of the name (i.e. "North Branch", "Creek", "River", "Ditch", etc.).

4) *Project* – The purpose behind sampling of the site (i.e. "Phase I", "TMDL", "EMAP", etc.).

5) *Crew* – The personnel who conducted the reconnaissance procedures.

6) *Invasive Presence* – The invasive species that are known to be present in the area, based on DNR map coverage. Species specific measures to prevent spreading invasives between sites should be taken.

7) *GPS File Name* – The unique identifier of a rover file assigned by the GPS unit. When the x-site is located, a GPS file is taken to document the location. The unit will assign an eight-digit code consisting of a file prefix, date stamp, and time stamp that uniquely identifies the file. Consult the GPS user's manual for additional guidance on GPS operation.

8) *GPS Date* – The date that the final GPS file is taken in month/day/year format (MM/DD/YY).

9) *GPS Time* – The time of day (24-hour clock) that the GPS file is taken.

10) *Latitude* – The angular distance north or south of the equator. Record the latitude of the x-site as displayed on the GPS receiver in degrees, minutes, seconds format.

11) *Longitude* – The angular distance east or west of the prime meridian. Record the longitude of the x-site as displayed on the GPS receiver in degrees, minutes, seconds format.

12) *Type of GPS Fix* – The position mode (3D or 2D) of the GPS file recording. The default and recommended position mode is 3D. The option you choose affects the number of satellites needed to calculate a position. The 3D mode requires more satellites and thus, is considered more accurate. A file should be recorded in 2D only when a 3D position is unattainable.

13) *Logger Serial Number* – The serial number of the temperature logger if one is placed at the site.

14) *Temp Logger Latitude* – Record the latitude of the temperature logger placement as displayed on the GPS receiver in degrees, minutes, seconds format.

15) *Temp Logger Longitude* – Record the longitude of the temperature logger placement as displayed on the GPS receiver in degrees, minutes, seconds format.

16) *Coldwater Stream* – A site is considered a coldwater stream if the reach is on a DNR designated trout stream. This box should be checked to indicate that a temperature logger should be placed at the site.

17) *Logger Description* – If a temperature logging device is placed at the site, describe in detail the location of the logger.

C.2. <u>Stream Status</u>: A determination of the stations sampleability. Determine if the station is *sampleable* or *non-sampleable* for biological monitoring; check the box that best describes the status of the station.

1) *Sampleable* – A site is considered *sampleable* if it has a defined stream channel and at least 50% of the sampling reach contains water. All targeted sites (i.e. non-random) should be regarded as *sampleable*. Indicate if the stream is perennial or intermittent in nature.

   Perennial: A stream that flows continuously throughout the year.

   Intermittent: Flow of water is not continual at the site but the stream channel is defined and greater than 50% of the sampling reach contains water.

   Other: If a site is determined to be *sampleable* for a reason other than one of those described above, note and explain in the comments.

2) *Non-Sampleable* – For EMAP sites there are circumstances that would cause field personnel to reject a site for assessment. Reasons for declaring a site *non-sampleable* include:

   No Channel or Waterbody Present: Examination of the x-site revealed no waterbody or stream channel.

   Impounded: The stream is submerged under a lake or pond due to man-made or natural (e.g. beaver dam) impoundments. An impounded site can be declared *sampleable* if it maintains a defined channel and more than half of the reach can be effectively sampled for fish.

   Wetland: The site contains water but does not have a definable stream channel. In cases in which riparian wetland vegetation surrounds a defined stream channel, classify the site as *sampleable* and restrict sampling to the defined channel.

   Insufficient Flow: A discernible stream channel is present but less than half of the sampling reach contains water. If the channel is completely dry, note in comments.

   Access Permission Denied: The field crew is denied permission to access the site by the landowner.

   Inaccessible: The site cannot be sampled safely or effectively because it is not possible to access the site with the necessary sampling gear or the nature of the stream makes it unsafe to sample (e.g. rapids or waterfalls).

Other: If a site is determined to be *non-sampleable* for a reason other than one of those described above, note and explain in the comments.

3) *Gear Type* – Determine the type of electrofishing gear that will most effectively sample the fish community given the width, depth, and accessibility of the stream, and check the appropriate box. The MPCA's Biological Monitoring Program utilizes four electrofishing gear types. General guidelines for determining the appropriate gear type are as follows:

   Backpack: Generally used in small, wadeable streams (typically < 8 m MSW and < 50 mi^2 drainage area).

   Stream-shocker: Used in larger, wadeable streams and rivers (typically > 8 m MSW and 50-500 mi^2 drainage area). The stream-shocker is a towable unit that can effectively sample larger streams because it has additional power capabilities and employs two anodes, thus increasing the electrified zone. When stream-shocker access is too difficult or the site is a wide, shallow riffle it may be necessary to sample larger streams utilizing two backpack electrofishers simultaneously.

   Mini-boom: Used in non-wadeable streams and rivers that are either too small or that do not afford the access necessary to utilize a boom-shocker. The mini-boom electrofisher is a jon-boat that is light enough to be portaged, yet provides a stable work platform.

   Boom-shocker: Used in large rivers with available boat ramps.

4) *Comments* – Record any additional information about the station in the space provided, such as the reason the site is unsampleable or comments about gear type.

C.3. <u>Stream Reach Determination</u>: To obtain the reach length multiply the mean stream width (MSW) by 35, round to the nearest meter. Divide by 2 to determine the distance to proceed upstream and downstream from the x-site. The x-site will serve as the mid-point of the sampling reach. The minimum and maximum reach length is 150 m and 500 m, respectively.

Mark the reach with flagging at the x-site, downstream end, and upstream end of the station. It is important that the flagging be visible from as great a distance as possible. It is preferable to tie the flagging on nearby vegetation as high as possible to ensure that high water conditions do not wash it away. Write on the flagging in permanent marker which reach boundary is being marked.

For EMAP sites there are some circumstances that would require "sliding" the stream reach around features we do not wish to sample across. Do not advance upstream into a lower order stream or downstream into a higher order stream when laying out the stream reach. Similarly, do not proceed if you encounter a lake, impoundment, or wetland while establishing the reach. If such a confluence is reached, note the distance and flag the confluence as the reach end. Compensate for the loss of reach length by moving ("sliding") the other end of the reach an equivalent distance away from the x-site. Do not slide the reach to avoid man-made features such as bridges, culverts, rip-rap, or channelization. If more than 50% of the original reach cannot be sampled, the station is *non-sampleable*.

1) *Mean Stream Width* – The average stream width (m) used to determine the reach length of the sampling site. Determine the MSW by measuring with a tape measure the wetted width of the stream channel at the x-site and a minimum of three other representative cross sections, such as a riffle, run, and pool. Average the measurements and record to the nearest half-meter. If initial site reconnaissance is conducted during high water conditions, it may be necessary to "adjust" the MSW downward to account for the narrower stream widths that would be encountered while sampling. To the degree possible, the reach length should be 35 times the normal summer base flow MSW.

2) *Upstream Length* – The length, measured to the nearest half meter, of the upstream portion of the sampling reach. From the x-site, measure the appropriate distance upstream with a tape measure, avoid rounding off bends or diverging too far from the stream channel.

3) *Downstream Length* – The length, measured to the nearest half meter, of the downstream portion of the sampling reach. From the x-site, measure the appropriate distance downstream with a tape measure, avoid rounding off bends or diverging too far from the stream channel.

4) *Total Length* – The length (m) of the sampling reach. To obtain, add the upstream and downstream lengths.

5) *Length Accuracy* – Record the accuracy of the total reach length. If the reach was measured in the stream or in the immediate riparian zone and incorporates all bends, the reach length is accurate. If the stream reach was measured away from the immediate riparian zone and does not incorporate all bends, the reach length is not accurate, and the stream should be remeasured during sampling.

C.4. <u>Directions to Stream Site</u>: Provide a comprehensive description of your access route to guide sampling crews returning at a later date. Include county, Atlas page, driving instructions, where to park and access, major landmarks, trail info, etc. It is critical that the reconnaissance crew does a thorough job identifying and documenting the easiest access route to the site in order to minimize the difficulty experienced by the sampling crews.

C.5. <u>Landowner Information</u>: Provide pertinent landowner information including landowner name and phone number, and the address if the landowner is interested in a fish list, or if providing the address will make the site easier to find. Include the County Plat page number

C.6. <u>Flagging Information</u>: Record information about flagging placement. Flags should be placed at the downstream, mid-point, and upstream sections of the reach in an area that will be visible throughout the summer. Mark the flags with the appropriate section of the reach. Describe in detail the location of the flagging tape including what side of the bank the flagging is on, what the flagging is tied to, etc.

Table 1. Equipment List – This table identifies all equipment needed in order to implement the initial site reconnaissance procedure as described.

Stream information sheet – for location of x-site, provided by EPA (needed only for EMAP sites)

1:24,000 USGS topographical maps – for navigation to and from the sampling site

County Platte maps – for determining land ownership

Aerial photographs – for navigation to and from the sampling site

DeLorme atlas – for vehicular navigation to and from the sampling site

Stream Verification Form – for recording initial site reconnaissance information

Measuring tape (m) – for measuring distances

GPS receiver – to locate and document sampling location

Compass – for navigation to and from the sampling site

Flagging – to mark the boundaries of the sampling reach

Pencil – for filling out forms

Permanent marker – to label flagging

Clipboard – to store forms/maps and record data

Waders – because it may be necessary to enter the stream during site reconnaissance

Cellular telephone – to contact landowners, to communicate between field crews, and for safety

STREAM VERIFICATION FORM

MPCA (Revised Feb 2009)

STREAM DOCUMENTATION

Field Number:	Date of Visit (mm/dd/yy):
Stream Name:	Project:
Crew:	Invasive Presence:

GPS File Name	GPS Date	GPS Time

Coordinates	Latitude	Longitude	Type of GPS
Field GPS:	_____._______________	_____._______________	☐ 2D ☐ 3D
Logger Serial #	**Temp Logger Latitude**	**Temp Logger Longitude**	**Coldwater**
	_____._______________	_____._______________	☐

Logger Description:

STREAM STATUS

Sampleable

☐ Perennial – (flowing water / defined channel)
☐ Intermittent – (dry spots along reach)
☐ Other (explain in comments)

Gear Type

☐ Backpack ☐ Stream Shocker
☐ Mini-boom ☐ Boom Shocker

Non-Sampleable (no sample taken)

☐ No Channel or Waterbody Present
☐ Impounded (underneath lake/pond)
☐ Impounded (beaver dam)
☐ Wetland (no definable channel)
☐ Insufficient Flow (<50% of reach has water)
☐ Access Permission Denied
☐ Inaccessible (unable to sample)
☐ Other (explain in comments)

Comments:

STREAM REACH DETERMINATION

Mean Stream Width (m)	Upstream Length (m)	Downstream Length (m)	Total Length (m)	Length Accuracy
				☐ Yes ☐ No, remeasure

DIRECTIONS TO STREAM SITE

LANDOWNER INFORMATION

FLAGGING INFORMATION

Appendix E

Fish Community Sampling Protocol for Stream Monitoring Sites

FISH COMMUNITY SAMPLING PROTOCOL FOR STREAM MONITORING SITES

I. PURPOSE

To describe the methods used by the Minnesota Pollution Control Agency's (MPCA) Biological Monitoring Program to collect fish community information at stream monitoring sites for the purpose of assessing water quality and developing biological criteria.

II. SCOPE/LIMITATIONS

This procedure applies to all monitoring sites for which an integrated assessment of water quality is to be conducted. An integrated assessment involves the collection of biological (fish and macroinvertebrate communities), physical habitat, and chemical information to assess stream condition.

III. GENERAL INFORMATION

Sites may be selected for assessment for a number of reasons including: 1) sites randomly selected for condition monitoring as part of the Environmental Monitoring and Assessment Program (EMAP), 2) sites selected for the development and calibration of biological criteria, and 3) sites selected to evaluate a suspected source of pollution. Although the reasons for monitoring a site vary, the fish community sampling protocol described in this document applies to all monitoring sites unless otherwise noted.

IV. REQUIREMENTS

A. Qualifications of crew leaders: The crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in aquatic biology or closely related specialization. He or she must have a minimum of six months field experience in fish community sampling methodology and fish taxonomy. Field crew leaders should also possess excellent map reading skills and a demonstrated proficiency in the use of a GPS (Global Positioning System) receiver and orienteering compass.

B. Qualifications of field technicians/interns: A field technician/intern must have at least one year of college education and coursework in environmental and/or biological science.

C. General qualifications: All personnel conducting this procedure must have the ability to perform rigorous physical activity. It is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a sampling site

V. RESPONSIBILITIES

A. Field crew leader: Implement the procedures outlined in the action steps and ensure that the data generated meets the standards and objectives of the Biological Monitoring Program.

B. Technicians/interns: Implement the procedures outlined in the action steps, including maintenance and stocking of equipment, data collection and recording.

VI. QUALITY ASSURANCE AND QUALITY CONTROL

Compliance with this procedure will be maintained through annual internal reviews. Technical personnel will conduct periodic self-checks by comparing their results with other trained personnel. Calibration and maintenance of equipment will be conducted according to the guidelines specified in the manufacturer's manuals.

In addition to adhering to the specific requirements of this sampling protocol and any supplementary site specific procedures, the minimum QA/QC requirements for this activity are as follows:

A. Control of deviations: Deviation shall be sufficiently documented to allow repetition of the activity as performed.

B. QC samples: Ten percent of sites sampled in any given year are re-sampled as a means of determining sampling error and temporal variability.

C. Verification: The field crew leader will conduct periodic reviews of field personnel to ensure that technical personnel are following procedures in accordance with this SOP.

VII. TRAINING

A. All inexperienced personnel will receive instruction from a trainer designated by the program manager. Major revisions in this protocol require that all personnel be re-trained in the revised protocol by experienced personnel.

B. The field crew leader will provide instruction in the field and administer a field test to ensure personnel can execute this procedure.

VIII. ACTION STEPS

A. Equipment list: Verify that all necessary items are present before commencement of this procedure (Table 1).

B. Data collection method: The location and length of the sampling reach is determined during site reconnaissance (see SOP--"***Reconnaissance Procedures for Initial Visit to Stream Monitoring Sites***"). The reach length, 35 times the mean stream width (MSW), is based on the distance necessary to capture a representative and repeatable sample of the fish community within a stream segment (following: Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management. 16:241-256.). Sampling is conducted during daylight hours within the summer index period of mid-June through mid-September. Sampling should occur when streams are at or near base-flow because flood or drought events can have a profound effect on fish community structure and sampling efficiency.

For wadeable streams, fish community sampling is conducted in conjunction with the physical habitat assessment protocol (see SOP--"***Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites***"). Fish sampling should be conducted before the physical habitat assessment so as not to disturb the fish community prior to sampling. Sample all habitat types available to fish within the reach in the approximate proportion that they occur. An effort is made to collect all fish observed. Fish < 25 mm in total length are not counted as part of the catch.

All fish that are alive after processing should be immediately returned to the stream, unless they are needed as voucher specimens. Considerable effort should be expended to minimize handling mortality, such as using a live well, quickly sorting fish into numerous wet containers, and replacing their water supply.

Fish survey results are recorded on the **Fish Survey Record** data sheet. A copy is attached and guidelines for filling out this data sheet are described in the following pages.

C. Fish Survey Record Data Sheet

This data sheet summarizes the location, sampling characteristics, and fish community composition of the sampling site. The variables recorded are as follows:

C.1. Location and Sampling Characteristics

1) *Field Number* – A seven-digit code that uniquely identifies the station. The first two digits identify the year of sampling, the second two identify the major river basin, and the last three are numerically assigned in sequential order (example 02UM001).

2) *Date* – The date fish sampling is conducted in month/day/year format (MM/DD/YY).

3) *Stream Name* – The name of the stream as shown on the most recent USGS 7.5" topographic map. Include all parts of the name (i.e. "North Branch", "Creek", "River", "Ditch", etc.).

4) *County* – The county in which the station is located.

5) *Location* – A general description of where the sampling station is located. Usually includes the nearest road crossing and town. For example, "0.5 mi. downstream of C.R. 30, 4 mi. SW of Northome".

6) *Crew* – The personnel who conducted fish community sampling.

7) *Gear Type* – The specific type of electrofisher utilized for fish collection. The MPCA's Biological Monitoring Program utilizes four electrofishing gear types. Care is taken to select the gear type that will most effectively sample the fish community. Gear selection is dictated by stream width, depth, and accessibility. General guidelines for determining the appropriate gear type and their use are as follows:

   Backpack: Generally used in small, wadeable streams (typically < 8 m MSW and < 50 mi^2 drainage area). A single electrofishing run is conducted in an upstream direction. In very small streams (<2 m wide) it is possible to sample most of the available habitat but in larger streams it is often necessary to meander between habitat types. Two personnel are necessary; one to carry the unit and operate the anode and another to collect the fish. Make sure to indicate the type of backpack used on the **Fish Survey Record**.

   Stream-shocker: Used in larger, wadeable streams and rivers (typically > 8 m MSW and 50-500 mi^2 drainage area). The stream-shocker is a towable unit that can effectively sample larger streams because it has additional power capabilities and employs two anodes, thus increasing the electrified zone. Five personnel are required for operation, one to control the electrofisher, two to direct the anodes, and two to net fish. A single electrofishing run is conducted in an upstream direction weaving between habitat types. When stream-shocker access is too difficult or the site is a wide, shallow riffle it may be necessary to sample larger streams utilizing two backpack electrofishers simultaneously.

   Mini-boom: Used in non-wadeable streams and rivers that are either too small or that do not afford the access necessary to utilize a boom-shocker. The mini-boom electrofisher is a jon-boat that is light enough to be portaged, yet provides a stable work platform. Personnel consist of one person to operate the boat, monitor the control box, and ensure the safety of a single fish collector on the bow. A single electrofishing run is conducted in a downstream direction weaving between habitat types.

   Boom-shocker: Used in large, accessible rivers. Three electrofishing runs are made in a downstream direction, one each along the right bank, left bank, and mid-channel. Personnel consist of one person to drive the boat, monitor the control box, and ensure the safety of the two fish collectors on the bow.

8) *Channel Position* – If the site is sampled with a boom-shocker, circle the appropriate channel position of the electrofishing run (determined while facing downstream); right bank, left bank, or mid-channel. A separate **Fish Survey Record** data sheet is used for each of the three runs.

9) *Distance* – The length of stream sampled for fish, measured to the nearest meter following the center of the stream channel. If the entire reach is electrofished, the distance sampled for fish is the same as the *station length* recorded on the **Visit Summary** data sheet (see SOP--"***Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites***"). In the event the entire station cannot be electrofished, measure the portion of the reach that was not sampled and subtract this distance from the

station length to calculate the distance sampled for fish. Possible explanations include the occurrence of a culvert or beaver impoundment within the reach.

10) *Time Fished* – The number of seconds electrofished. Reset the timer on the electrofisher before each sampling event.

11) *Identified By* – The person(s) who field identified the fish collected, must meet the minimum requirements of a field crew leader described previously.

C.2. Fish Community Composition

1) *Species* – The common name of each fish species collected during the electrofishing run. If a fish cannot be identified to species with certainty, identify to the lowest possible taxon (e.g. to genus) and voucher for later lab identification.

2) *Length Range* – The minimum and maximum length for each fish species collected (fish < 25 mm are excluded). Measure to the nearest millimeter using Maximum Total Length protocol: the distance from the anterior-most part of the fish to the posterior-most tip of the caudal fin while it is being compressed. If only one individual of a fish species is captured, record the length as both the minimum and maximum total length.

3) *Weight* – The total wet weight of each fish species collected. Together, weigh all individuals of the same species to the nearest 0.5 gram. Multiple batch weights may be necessary if scale capacity is exceeded; these can be recorded on the back of the data sheet in the space provided. Only species totals should be recorded here.

4) *No.* – The total number of individuals of each fish species.

5) *Anomalies* – Record the total number and type of anomalies observed on all individuals of a fish species. Recognized anomalies and their codes are located on the bottom of the **Fish Survey Record** data sheet.

6) *Voucher* – The number of specimens of each fish species retained for verification and deposition in the Minnesota Bell Museum of Natural History. For fish that are identified with certainty to species level, several individuals of each species should be preserved in 10% formalin solution (37% formaldehyde:water) in the "A- jar". For each species of fish, document the number of individuals preserved in this data field. The person recording the fish information is in charge of the voucher bottle, and specimens will only be added to the voucher bottle upon the recorder's approval, to ensure accuracy of numbers,.

   All fish that could not be identified to the species level should be preserved in a separate container (B-jar) in 10% formalin solution. Record the number preserved.

   Voucher containers should be labeled externally and internally. On the outside of the jar write the field number, sampling date, and jar identification (A or B) with a permanent marker. Place a label inside each jar identifying the field number, sampling date, stream name, jar identification, county, gear type, and collectors. Write this information on an index weight label in pencil or a solvent proof marker. If an "A" and "B" jar are used, tape them together.

   For specimens that are too large to preserve, a photograph may be taken to serve as a voucher. Place a card with the site field number and sampling date visibly into the picture frame with the fish positioned in a manner that allows key characteristics to be identified.

C.3. Individual or Batch Measurements: Often times it is necessary to weigh large fish individually or conduct multiple batch weights for a species of fish, these measurements can be recorded in this section of the data sheet. The data fields are the same as those described above. After fish processing is complete, combine the information for fish of the same species so that only species totals are recorded in the previous section.

Table 1. Equipment List – This table identifies all equipment needed in the field in order to implement the sampling protocol as described.

Electrofisher – for sampling the fish community, use appropriate gear type
(includes control box, generator, anode(s), and cathode)

Nets – for collection of fish; 1/8" mesh, fiberglass handles

Rubber gloves – for safety during electrofishing; electrically rated

Holding tank – for holding fish during electrofishing; of sufficient size to minimize stress

Wet containers – for holding fish during processing; of sufficient size and number to minimize stress

Balance or spring scales – for weighing fish

Measuring board – for measuring total length of fish

Waders – for safety during electrofishing

Polarized sunglasses – for aid in capturing fish

Clipboard – to store forms and record data

Forms – for recording data

Pencil – for filling out forms

Permanent marker – for labeling voucher bottle

Taxonomic key – to assist in identifying fish

Voucher bottle – for storing preserved specimens

Formalin – for preserving voucher specimens

Labels – to label voucher jars

Camera – to document fish species collected that are too large to preserve

FISH SURVEY RECORD MPCA

Field Number:	Date (mm/dd/yy):
Stream Name:	County:
Location:	Crew:

Gear Type: (circle one) Backpack* Stream-Shocker Boom-Shocker Mini-Boom

*Type of Backpack: (circle one) Generator LR-24 Halltech

Channel Position: (circle one if boom-shocking site) Right Bank Mid-Channel Left Bank

Distance (m):	Time Fished (sec):	Identified By:

Species (common name)	**Length Range (mm)**	**Weight (g)**	**Number**	**Anomalies**	**Voucher**
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					

Anomalies: A-anchor worm; B-black spot; C-leeches; D-deformities; E-eroded fins; F-fungus; G-yellow grub; L-lesions; N-blind; P=parasites; PL-parasite lesion; Y-popeye; S-emaciated; W-swirled scales; T-tumors; Z-other. (Heavy (H) or Light (L) code may be combined with above codes.)

(Cont.)

Species (common name)	Length Range (mm)	Weight (g)	Number	Anomalies	Voucher
28.					
29.					
30.					
31.					
32.					
33.					
34.					
35.					
36.					
37.					

INDIVIDUAL OR BATCH MEASUREMENTS

Species (common name)	Length Range (mm)	Weight (g)	Number	Anomalies	Voucher
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					

Appendix F

Invertebrate Sampling Procedures

Subject: Invertebrate Sampling Procedures

I. PURPOSE

To describe methods used in the collection of stream invertebrates for the purpose of developing biological criteria used in assessing water quality.

II. REFERENCES

A. Source Documents

U.S. Environmental Protection Agency (USEPA). 1994. Environmental Monitoring and Assessment Program - Surface Waters and Region 3 Regional Environmental Monitoring and Assessment Program: 1994 pilot field operations and methods manual for streams. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory. Cincinnati, OH. EPA/620/5-94/004.

Barbour, M. T., J. Gerritsen, and J. S. White. 1996. Development of the Stream Condition Index (SCI) for Florida. Florida Department of Environmental Protection, Tallahassee, Florida. 105 pp.

B. Other References

U.S. Environmental Protection Agency (USEPA). 1996. Biological Criteria: Technical Guidance for Streams and Small Rivers. Revised Edition. Office of Water, Washington DC. EPA/822/B-96/001.

U.S. Environmental Protection Agency (USEPA). 1997. Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers (Draft). Office of Water, Washington D.C. EPA/841/D-97/002.

III. SCOPE/LIMITATIONS

This procedure applies to all site visits in which stream invertebrates are to be collected for the development of biological criteria and/or the assessment of water quality.

IV. DEFINITIONS

Integrated monitoring A stream monitoring technique to assess water quality using chemical, biological and physical indicators.

Environmental Monitoring and Assessment Program (EMAP): U.S. Environmental Protection Agency program designed to determine the status, extent, changes, and trends in the condition of our national ecological resources on regional and national scales.

Biological Criteria: Narrative expressions or numerical values that describe the reference biological integrity of a specified habitat. Biological criteria are the benchmarks for judging the condition of aquatic communities.

Qualitative Multihabitat Sample (QMH): A method of sampling invertebrates which involves sampling a variety of invertebrate habitats, including the following substrata: rocky substrates, vegetation, undercut banks, snags, leafpacks, and soft sediment.

V. GENERAL INFORMATION

The methods described herein are to be applied to all wadeable streams included in the MPCA's integrated stream condition monitoring program. This document is not meant to be used by itself, consult one of the documents indicated in the box below if any of the described situations apply. For most efficient use of time and resources, crew leaders must be in constant communication with crews sampling for fish, preventing duplication of effort. It must be understood that this method is not to be applied to streams sampled for fish that are not wadeable.

Data generated from samples collected using the described method can be used for any of the following reasons: 1) Development of regional biological criteria, 2) Calibration of biological criteria, 3) Ambient water quality assessment, 4) Water quality assessment of sites suspected of a having a problematic source of pollution.

NOTE

SOP1 - Site Reconnaissance: A site reconnaissance should be done by the first crew to visit a site. After the initial recon has been done, no more are required. One must be done before any sampling can take place.

SOP2 - Chemical Assessment: A chemical assessment should be done by the first crew to visit a site following a site reconnaissance. These procedures can be completed during a single site visit.

VI. REQUIREMENTS

SOP3 - Habitat Assessment: A habitat assessment should be done during the same visit as the chemical assessment. If a habitat assessment is to be done during the same visit as an invertebrate collection, the invertebrate collection should be done first.

A. Qualifications of Crew Leaders
A crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in biology with an aquatic entomology, invertebrate, zoology, fisheries, or closely related specialization. Additionally, they must have at least 6 months experience working under a macroinvertebrate biologist in the areas of invertebrate sampling methodology and taxonomy.

B. Qualifications of field technicians/interns
A field technician/intern must have at least one year of college education and had coursework in environmental and/or biological science.

C. General Qualifications
All personnel conducting this procedure must have excellent map reading skills and a demonstrated proficiency in the use of a GPS receiver and an orienteering compass. Because sites may be located miles from the nearest vehicle assessable road, it is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a site. Personnel conducting this procedure must have the physical ability to accomplish this.

VII. RESPONSIBILITIES

A. Field Crew Leader
Ensures that data generated using this procedure meet the standards and objectives of the integrated condition monitoring program. Carries out the procedures outlined in the action steps.

B. Technical personnel
Carries out the procedures outlined in the action steps, including maintenance and stocking of equipment, date collection and recording.

VII. QUALITY ASSURANCE AND QUALITY CONTROL

Compliance with this procedure will be maintained through annual internal reviews. Technical personnel will conduct periodic self-checks by comparing their results with other trained personnel. Calibration and maintenance of equipment will be conducted according to the guidelines specified in the manufacturer manuals.

VII. QUALITY ASSURANCE AND QUALITY CONTROL (continued)

In addition to adhering to the specific requirements of this sampling protocol and any supplementary site specific procedures, the QA/QC requirements for this protocol are as follows:

A. Control of Deviations
Deviations from the procedure shall be sufficiently documented to allow repetition of the activity as actually performed.

B. QC Samples
Ten percent of all sites sampled on any given year are resampled as a means of determing sampling error.

C. Verification
The field crew leader will conduct periodic reviews of field personnel to ensure that technical personnel are following the procedures according to this SOP.

IX. TRAINING

A. All personnel will receive training annually from a trainer designated by the program manager. Major revisions in this procedure will require that all personnel be retrained in the revised procedure by an authorized trainer.

B. Training activities will include instruction in the field as well as a field test to ensure that personnel can implement this procedure.

X. ACTION STEPS

A. Equipment List

Ensure that all of the following items are presents before implementing this procedure:

Two D-frame dipnets with 500 micron mesh nets, preferably Wildco, turtox design
Two sieve buckets with 500 micron sieves
Stream Invertebrate Visit Form
Stream verification form, previously completed with attached copies of 1:24,000 USGS topographical map
Minnesota Atlas and Gazateer (Delorme)
Pencils
Permanent/Alcohol proof markers

A. Equipment List (continued)

Labeling tape
Invertebrate sample identification labels
100% reagent alcohol, enough to preserve one days worth of samples, ca. 1 gallon/site
Waterproof notebook
Chest-high waders
Rain-gear
Jars or bottles in which sample is to be preserved; preferably non-breakable synthetic, minimum 1 litre capacity
Box or crate to store sample bottles
Canoe
Backpack

B. Method

The multihabitat method entails collecting a composite sample from up to five different habitat types. The goal of this method is to get a sample representative of the invertebrate community of a particular sampling reach, it is also to collect and process that sample in a time and cost effective manner. For that reason the habitats described below are relatively non-specific, being chosen to represent broad categories rather than microhabitats. Every broad category includes numerous microhabitats, some of which will not be sampled. It is to the discretion of the sampler which microhabitats are to be sampled. As a general rule, sample in manner that reflects the most common microhabitat of any given broad habitat category. The habitats to be sampled include:

Hard bottom (riffle/cobble/boulder)
This category is intended to cover all hard, rocky substrates, not just riffles. Runs and wadable pools often have suitable "hard" substrates, and should not be excluded from sampling. The surfaces of large boulders and areas of flat, exposed bedrock are generally quite unproductive, avoid including these habitats in the sampling area if possible. This is a general rule, if a particular stream has productive exposed bedrock, or boulder surfaces, those habitats should be considered sampleable.

Aquatic Macrophytes (submerged/emergent vegetation)
Any vegetation found at or below the water surface should be considered in this category. Emergent vegetation is included because all emergent plants have stems that extend below the water surface, serving as suitable substrate for macroinvertebrates. Do not sample the emergent portion of any plant.

B. <u>Method</u> (continued)

Undercut Banks (undercut banks/overhanging veg)

This category is meant to cover in-bank or near-bank habitats, shaded areas away from the main channel that typically are buffered from high water velocities.

Snags (snags/rootwads)

Snags include any piece of large woody debris found in the stream channel. Logs, tree trunks, entire trees, tree branches, large pieces of bark, and dense accumulations of twigs should all be considered snags. Rootwads are masses of roots extending from the stream bank.

Leaf Packs

Leaf packs are dense accumulations of leaves typically present in the early spring and late fall They are found in deposition zones, generally near stream banks, around logjams, or in current breaks behind large boulders.

Sampling consists of dividing 20 sampling efforts equally among the dominant, productive habitats present in the reach. If 2 habitats are present, each habitat should receive 10 sampling efforts. If 3 habitats are present, the two most dominant habitats should receive 7 jabs, the third should receive 6 jabs. If a productive habitat is present in a reach but not in great enough abundance to receive an equal proportion of sampling efforts, it should be thoroughly sampled and the remaining samples should be divided among the remaining habitat types present.

A sample effort is defined as taking a single dip or sweep in a common habitat. A sweep is taken by placing the D-net on the substrate and disturbing the area directly in front of the net opening equal to the net width, ca. 1ft^2. The net should be swept several times over the same area to ensure that an adequate sample is collected. Each effort should cover approximately .09m^2 of substrate. Total area sampled is ca. 1.8m^2.

Once a site reach has been found or newly established, invertebrate sampling should follow. If a habitat assessment and chemical analysis is to be done it should follow invertebrate sampling.

NOTE
Before leaving the vehicle be sure that the following equipment is brought to the site: two d-frame dipnets, one (or two) sieve buckets, habitat partition form, site file, compass, GPS receiver, backpack filled with sample bottles (optional), alcohol (optional)

B. Method (continued)

1. Before sampling can begin, the Crew Leader and field tech must determine which habitats are present in the reach. This should be a cooperative effort. This is done by walking the length of the stream and determining which productive habitats dominate the stream reach. A site visit form should be filled out during this process. Ideally the stream should be viewed from the top of the stream bank, but this is generally the exception rather than the rule. For this reason, great care must be taken to walk gingerly along the stream edge, or any streamside exposed areas. If this is not possible, stay to one side of the stream so as to disturb as little substrate as possible.

> NOTE
>
> Since sampling should be conducted in a downstream to upstream fashion, it will save time to start the initial visual inspection of the stream from the upstream end of the sampling reach, and walk downstream. This will allow you to start sampling at the down stream end of the reach as soon the inspection is completed.

It is difficult to estimate total stream coverage of certain habitats due to their linear or three dimensional natures. Undercut banks and overhanging vegetation appear linear, snags are three dimensional, as are vegetation mats, and emergent vegetation. For these reasons best professional judgment must be used to determine what level of effort is adequate to equal one “sample effort” for any given substrate. Keep in mind that this method is considered semiquantitative, rulers and grids are not necessary to effectively implement this procedure. Following are some suggestions as to how approach each habitat for the perspective of

Hard bottom: Riffles are basically two dimensional areas, and should be thought of as such when trying to determine how dominant the riffle habitat is in a stream. It must be kept in mind that the riffle is likely to be the most productive and diverse habitat in the reach, relatively speaking. The field personnel must not get overzealous, the purpose of this method is to get a representative sample. The temptation will undoubtedly exist to spend all day in the riffle areas, this must be avoided. Sampling in this habitat type is relatively simple. The D-net should be place firmly, and squarely on the substrate downstream of the area to be sampled. If the water is shallow enough, the area directly in front of the net should be disturbed with the hands, taking care to wash large rock off directly into the net. If the water

is too deep for this, kicking the substrate in front of the net is adequate. Watch for stoneflies trying to crawl out of the net!

Vegetation: Aquatic vegetation is either completely submerged, mostly submerged and partially floating on the waters surface, or partially submerged and mostly extended above the waters surface. Things like Potamageton sp., coontail, and milfoil tend to clump and float at the waters surface. These types of plants should be sampled with an upward sweep of the net. If the net fills with weeds, the weeds should be hand washed vigorously or jostled in the net for a few moments and then discarded. Emergent plants such as reed canary grass and various plants in the rush family, should be sampled with horizontal and vertical sweeps of the net until it is felt that the area being swept has been adequately sampled. Plants like floating bur reed, and water celery tend to float in long strands with the current. They can be floating on the surface of completely submerged. These plants should be sample as emergent plants with horizontal and vertical sweeps in a downstream to upstream motion.

Undercut banks/ Overhanging Vegetation: Undercut banks and overhanging vegetation follow the line of the stream bank. Undercut banks can vary in how undercut they are. An additional problem is that many banks appear undercut, but when investigated prove not to be. For these reasons banks should be prodded to determine how deeply they are undercut. Overhanging vegetation should be treated the same way. Sampling should consist of upward thrusts of the net, beating the undercut portion of the bank or the overhanging vegetation, so as to dislodge any clinging organisms.

Snags: Snags and rootwads can be large or small, long or wide, simple or twisted masses of logs or twigs that don't have any consistent shape. Best professional judgment must be used to determine what a "sampling effort" is. Approximating the amount of sampleable surface area is a sensible method with larger tree trunks or branches. Where as masses of smaller branches and twigs must be given a best guess. Given their variable nature, there is not one best method for sampling snags. Using something like a toilet brush works well for large pieces of wood, whereas kicking and beating with the net works best for masses of smaller branches. The person taking the sample must determine the best method for each particular situation.

B. <u>Method</u> (continued)

Leaf packs: Leaf packs are simple, but messy to sample. One square foot of leaf pack surface area that has two cubic feet of leaf underneath should be sampled near the surface. Whereas a shallow leafpack can be sampled in it's entirety. Sweeping to the bottom of every leafpack could create a disproportionately large amount of sample volume being collected for relatively small sample area. In most situations leaf packs will not be dominate enough to be included in a sample. If leaf packs are sampled, it is suggested that time be spent streamside washing invertebrates off of leaves and discarding the leaves, as a leaf pack sample can easily become overwhelmingly large.

2. After the number of productive, sampleable habitats have been determined, the sampling team should proceed in a downstream to upstream manner, sampling the various habitats present.

NOTE

In order to get complete samples, the contents of the D-net should be emptied into a sieve bucket frequently. This prevents the back flow of water resulting from a clogged net. In larger streams it is convenient for each sampler to have a sieve bucket. This allows samplers to sample independent of each other, avoiding frequent stream crossings which can alter the stream bed.

NOTE

While sampling it may become necessary to clean the sample of muddy, fine sediment. This can be done by filling the sieve bucket with clean water and allowing the resulting mucky water to drain. Care must be taken not twist and turn the bucket to much, this creates a washing machine action which separates insects from their delicate parts quite effectively.

B. Method (continued)

3. Once sampling is complete the sample material should be preserved as quickly as possible. Transfer the sample material from the sieve bucket to the sample containers. Fill sample containers to the top with 100% reagent alcohol. Be sure to thoroughly clean the bucket as well as sampling nets of all invertebrates. The use of forceps might be necessary to dislodge some of the smaller organisms.

4. With labeling tape, label the outside of the container with field number, date, site name, initials of those who collected samples, and number of containers, i.e 1 of 3, and Place a properly filled out sample label in each sample container.

XI. REQUIRED RECORDS

Stream Invertebrate Visit Form

A. The Stream Invertebrate Visit Form should be filled out during the streamside survey, or notes should be taken on field note books and transferred to visit form. This information will be placed in the biological database.

Quantitative Riffle Sample (optional):

These samples are being taken by the MPCA as a means to determining the best method for sampling streams with dominant riffle/run features.

If a riffle is present in the sampling reach, or in close proximity to the reach, a riffle sample should be taken. This should be a “quality” riffle, that is, a riffle that consists of gravel and/or cobble of varying sizes, and has adequate flow for sampling. The flow should be fast enough to wash dislodged organisms into the sampling net.

Three quantitative riffle samples should be taken. They do not need to be side by side. They should be spread throughout the riffle area.

Appendix G

MPCA Stream Habitat Assessment (MSHA) Protocol for Stream Monitoring Sites

MPCA STREAM HABITAT ASSESSMENT (MSHA) PROTOCOL FOR STREAM MONITORING SITES

I. PURPOSE

To describe the methods used by the Minnesota Pollution Control Agency's (MPCA) Biological Monitoring Program to collect qualitative physical habitat information at stream monitoring sites for the purpose of assessing water quality and developing biological criteria.

II. SCOPE/LIMITATIONS

This procedure applies to all river and stream monitoring sites for which an integrated assessment of water quality is to be conducted. An integrated assessment involves the collection of biological (fish and macroinvertebrate communities), physical habitat, and chemical information to assess stream condition.

III. GENERAL INFORMATION

Sites may be selected for assessment for a number of reasons including: 1) sites randomly selected for condition monitoring as part of the Environmental Monitoring and Assessment Program (EMAP), 2) sites selected for the development and calibration of biological criteria, and 3) sites selected to evaluate a suspected source of pollution. Although the reasons for monitoring a site vary, the MSHA protocol described in this document applies to all monitoring sites unless otherwise noted.

IV. REQUIREMENTS

A. Qualifications of crew leaders: The crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in aquatic biology or closely related specialization. He or she must have a minimum of six months field experience in physical habitat sampling methodology. Field crew leaders should also possess excellent map reading skills and a demonstrated proficiency in the use of a GPS (Global Positioning System) receiver and orienteering compass.

B. Qualifications of field technicians/interns: A field technician/intern must have at least one year of college education and coursework in environmental and/or biological science.

C. General qualifications: All personnel conducting this procedure must have the ability to perform rigorous physical activity. It is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a sampling site.

V. RESPONSIBILITIES

A. Field crew leader: Implement the procedures outlined in the action steps and ensure that the data generated meets the standards and objectives of the Biological Monitoring Program.

B. Technicians/interns: Implement the procedures outlined in the action steps, including maintenance and stocking of equipment, data collection and recording.

VI. QUALITY ASSURANCE AND QUALITY CONTROL

Compliance with this procedure will be maintained through annual internal reviews. Technical personnel will conduct periodic self-checks by comparing their results with other trained personnel.

In addition to adhering to the specific requirements of this sampling protocol and any supplementary site specific procedures, the minimum QA/QC requirements for this activity are as follows:

A. Control of deviations: Deviation shall be sufficiently documented to allow repetition of the activity as performed.

B. QC samples: Ten percent of sites sampled in any given year are resampled as a means of determining sampling error and temporal variability.

C. Verification: The field crew leader will conduct periodic reviews of field personnel to ensure that technical personnel are following procedures in accordance with this SOP.

VII. TRAINING

A. All inexperienced personnel will receive instruction from a trainer designated by the program manager. Major revisions in this protocol require that all personnel be re-trained in the revised protocol by experienced personnel.

B. The field crew leader will provide instruction in the field and administer a field test to ensure personnel can execute this procedure.

VIII. ACTION STEPS

A. Equipment list: Verify that either a form and pencil, or a field computer is present before commencement of this procedure.

B. Data collection method: The location and length of the sampling reach is determined during site reconnaissance (see SOP--"***Reconnaissance Procedures for Initial Visit to Stream Monitoring Sites***"). Unless otherwise instructed, observations of physical habitat characteristics should be limited to the sampling reach. Sampling is conducted during daylight hours within the summer index period of mid-June through mid-September. Sampling should occur when streams are at or near base-flow. The habitat evaluation is conducted immediately after fish sampling in order to provide the evaluator a perspective of the fish habitat within the reach.

Habitat characteristics are recorded using a qualitative, observation based method (modified from: Rankin 1989. The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application. Ohio EPA, Division of Water Quality Planning and Assessment, Ecological Analysis Section, Columbus, Ohio.). The Ohio QHEI is a physical habitat index designed to provide an empirical evaluation of the lotic macrohabitat characteristics that are important to fish communities and which are generally important to other aquatic life. Although similar to the Ohio QHEI, the MSHA has been modified to more adequately assess important characteristics influencing Minnesota streams. The MSHA incorporates measures of watershed land use, riparian quality, bank erosion, substrate type and quality, instream cover, and several characteristics of channel morphology.

Observations are recorded on the **MPCA Stream Habitat Assessment Worksheet**. A copy is attached and guidelines for filling out this data sheet are described in the following pages.

C. MPCA Stream Habitat Assessment Data Sheet

This data sheet describes the presence and abundance of instream and riparian characteristics within the sampling reach. The variables recorded are as follows:

C.1. Stream Documentation

A) *Stream* – The name of the stream as shown on the most recent USGS 7.5" topographic map. Include all parts of the name (i.e. South Branch Wild Rice River).

B) *County* – The county in which the station is located.

C) Date – The date habitat sampling is conducted in month/day/year format (MM/DD/YY).

D) Field Number – A seven-digit code that uniquely identifies the station. The first two digits identify the year of sampling, the second two identify the major river basin, and the last three are numerically assigned in sequential order (example: 02UM001).

E) Person Scoring – The personnel completing the MSHA. This person(s) should have walked or boated the entire stream reach paying particular attention to habitat features.

F) Site Location – A general description of where the sampling station is located. Usually includes the nearest road crossing and town. For example, "0.5 mi. downstream of C.R. 30, 4 mi. SW of Northome".

C.2. Surrounding Land Use: Record the predominant land use on each bank within approximately 2 to 3 square miles, not just the surrounding area of the site. The emphasis should be on upstream land use. Check either the most predominant land use, or choose two and average the scores. A land use or aerial map can be used for this assessment if available. Land use categories are as follows:

Forest, Wetland, Prairie, Shrub: Land that is dominated by trees, low-lying areas saturated with water, grasses and forbs, or woody vegetation less than 3 m. in height.

Old Field/Hay Field: Land that is used for agricultural purposes other than row crops or pasture.

Fenced Pasture: Land that is regularly grazed by livestock, but is fenced to prevent livestock from entering streams.

Conservation Tillage, No Till: Land that is currently in agricultural production, but retains the vegetative material from the previous year's crop to protect the soil.

Residential/Park: Land that has been modified for residential use (i.e. backyards, city parks).

Urban/Industrial: Land that has been modified for commercial or industrial use (i.e. parking lots, malls).

Open Pasture: Land that is regularly grazed by livestock, but is not fenced to prevent livestock from entering streams.

Row Crop: Land that is currently in intensive agricultural production, and doesn't use any conservation tactics (i.e. corn, soybeans, beets, potatoes).

C.3. Riparian Zone (Check the most appropriate category for each bank)

A) Riparian Width – Estimate the width of the undisturbed vegetative zone adjacent to the stream. Beneficial vegetation types include stable grasses, trees, and shrubs with low runoff potential. Disturbed vegetation is not included in the riparian width (i.e. mowed grass).

B) Bank Erosion – Estimate the percentage of the stream bank that is actively eroding. To be considered as erosion, the banks must be actively eroding through break down, soil sloughing, or false banks. False banks are natural banks that have been cut back, usually by livestock trampling.

C) Shade – Estimate the percentage of overhead canopy cover that is shading the stream channel. Professional judgment may be required to rate stream shading characteristics in larger streams and rivers as 100% shade cover would not be expected in these systems even in the absence of disturbance. The general intent of the rating is to evaluate the condition of stream canopy characteristics.

C.4. Instream Zone

A) Substrate – Document the two predominant substrate types for each channel type present within the reach. One substrate type may be recorded where > 80% of the channel is dominated by a single substrate type. For each channel type present within the reach, estimate the percent of the stream channel represented by that channel type. The percentages should add up to 100. For example, if the majority of your reach was a run, with a few pools and one riffle, the percentage could be 75% run, 20% pool, and 5% riffle. The definitions for each channel and substrate type are as follows:

Channel Types

Pool: Water is slow and generally deeper than a riffle or run. Water surface is smooth, no turbulence. A general rule that can be used to distinguish a pool from a run or riffle is if two or more of the following conditions apply; the stream channel is wider, deeper, or slower than average.

Riffle: Higher gradient areas where the water is fast and turbulent, water depths are relatively shallow, and substrates are typically coarse. Water surface is visibly broken.

Run: The water may be moderately fast to slow but the water surface typically appears smooth with little or no surface turbulence. Generally, runs are deeper than a riffle and shallower than a pool.

Glide: Similar to a run, but where there is no visible flow and the channel is too shallow for a pool. Examples include a channelized stream with a uniform depth and flow. This term should not be used in conjunction with pools, riffles, and runs in a natural stream setting.

Substrate Types

Boulder: Large rocks ranging from 250 mm to 4000 mm in diameter (basketball to car size).

Cobble: Rocks ranging in diameter from 64 mm to 250 mm (tennisball to basketball).

Gravel: Rocks varying in diameter from 2 mm to 64 mm (BB to tennisball).

Sand: Inorganic material that is visible as particles and feels gritty between the fingers, 0.06 to 2.0 mm in size.

Clay: Very fine inorganic material. Individual particles are not visible or are barely visible to the naked eye. Will support a person's weight and retains its shape when compacted.

Bedrock: A solid slab of rock, > 4000 mm in length (larger than a car).

Silt: Fine inorganic material that is typically dark brown in color. Feels greasy between fingers and does not retain its shape when compacted into a ball. A person's weight will not be supported if the stream bottom consists of silt.

Muck: A fine layer of black completely decomposed vegetative organic matter.

Detritus: Decaying organic material such as macrophytes, leaves, finer woody debris, etc. that may appear similar to silt when very fine.

Sludge: A thick layer of organic matter of animal or human origin, often originating from wastewater.

B) *Embeddedness* – Indicate the percentage to which coarse substrates are surrounded by or covered with fine sediments throughout the reach. Coarse substrates consist of gravel, cobble, and boulders. An embeddedness rating of 0% corresponds to very little or no fine sediments surrounding coarse substrates. Course substrate material completely surrounded and covered with sediment is considered 100% embedded. If course substrates are not present in the reach, check "no course substrate".

C) *Substrate Types* – Record the number of substrate types present within the reach, either less than or equal to 4, or greater then 4.

D) *Water Color* – Record the predominant color of the water by checking the appropriate category. Definitions are as follows:

Clear: Water is transparent, and objects are clearly visible underwater.

Stained: Water is colored due to minerals in the water, but objects are still visible.

Turbid: Water is colored and not transparent; brown due to silt, green due to algae, or other.

E) *Cover Type* – Indicate the types of cover available to fish within the reach (check all that apply). Cover for fish consists of objects or features dense enough to provide complete or partial shelter from the stream current or concealment from predators or prey. In order to be considered cover, the water depth must be at least 10 cm where the cover type occurs. Definitions are as follows:

Undercut Banks: Stream banks where the stream channel has cut underneath the bank. The bank could overhang the water surface when water levels are low. The undercut bank must overhang (horizontally) the wetted stream channel a minimum of 15 cm and the bottom of the undercut bank must be no more than 15 cm above the water level in order to be considered cover for fish.

Overhanging Vegetation: Terrestrial vegetation overhanging the wetted stream channel. Vegetation must be no more than 15 cm above the water level to be considered cover for fish.

Deep Pools: Area where the channel is particularly deep, often near a bend.

Logs or Woody Debris: Logs, branches, or aggregations of smaller pieces of wood in contact with or submerged in water.

Boulders: Large rocks as described under *Substrate Types.*

Rootwads: Aggregation of tree roots that extend into the stream.

Emergent Macrophytes: Vascular plants that typically have a significant portion of their biomass above the water surface. Examples include *Typha, Scirpus,* and *Zizania*.

Floating Leaf Macrophytes: Vascular plants with a significant amount of their biomass floating on the water in the form of leaves and flowers. Examples include duckweed and water lily.

Submergent Macrophytes: Vascular plants that have all of their biomass (except flowers) at or below the surface of the water. Examples include *Vallisneria*, *Elodea*, *Potamogeton*, *Nymphaea* and *Ceratophyllum*.

F) *Cover Amount* – Estimate the total percentage of fish cover within the reach. If the channel is completely filled with aquatic vegetation, check the “choking vegetation only” option.

C.5. <u>Channel Morphology (Check the most appropriate category for each)</u>

A) *Depth Variability* – The difference in thalweg depth between the shallowest stream cross section and the deepest stream cross section. The thalweg depth is the deepest point along a stream cross section. Indicate the degree to which the thalweg depths vary within the stream reach.

B) *Channel Stability* – The ability of a stream channel to maintain its bed and banks, without eroding or moving particles downstream. A riffle that forms diagonally across the channel and has a high amount of fine substrates that change location is indicative of an unstable stream bed. Channelized streams often have high bank stability but low bed stability as the substrate is typically comprised of fine materials that are susceptible to moving downstream. Ratings are as follows:

High: Channel with stable banks and substrates, little or no erosion of the banks, and little or no bedload within the stream. Artificial channels (i.e. concrete) exhibit a high degree of stability even though they typically have a negative effect on biological communities.

Moderate/High: Channel has the ability to maintain stable riffle, run, and pool characteristics. A minor amount of bank erosion and/or bedload is present.

Moderate: Channel that exhibits some instability, characterized by erosion, bedload, or shows the effects of wide fluctuations in water level.

Low: Channels that have a high degree of bedload and severely eroding banks. A homogenous stream bed characterized by shifting sand substrates has low stability.

C) *Velocity Types* – Indicate which flow types are present within the reach (check all that apply). The definitions are as follows:

Torrential: Extremely turbulent and fast flow; water surface is broken, usually limited to gorges and dam spillways.

Fast: Mostly non-turbulent flow with small standing waves in riffle-run areas, water surface may be partially broken.

Moderate: Non-turbulent flow that is detectable (i.e. floating objects are visibly moved downstream).

Slow: Water flow is detectable, but barely perceptible.

Eddies: Areas of circular motion within the current, usually formed in pools immediately downstream of riffles/runs.

Interstitial: Water flow that infiltrates a streambed, and moves through gravel substrates in riffle-run areas.

Intermittent: No flow is present, with standing pools separated by dry reaches.

D) *Sinuosity* – Indicate the degree to which the stream meanders. Sinuosity is defined as the ratio of stream channel distance to straight line distance between two points on a stream. For wide streams or rivers it may be necessary to consider a longer stream reach, as the true meander cycle is often not adequately represented in these systems within the sampling reach. Ratings are as follows:

Excellent: Streams exhibiting a high degree of meandering. Presence of 2 or more well defined bends (deep areas outside and shallow areas on the inside of the bend).

Good: Stream with more than 2 bends, with at least one well defined bend.

Fair: Channel with 1 or 2 poorly defined outside bends, or slight meandering within a modified reach.

Poor: Straight channel with no bends in the reach. Channelized streams or ditches are often rated as poor.

E) *Pool Width/Riffle Width* – Indicate the ratio of pool width to riffle width within the reach. If there is no riffle at the site select “no riffle”.

F) *Channel Development* – Indicate the complexity of the stream channel or the degree to which the stream has developed different channel types, creating sequences of riffles, runs, and pools. In small streams, riffles, runs, and pools must occur more than once within the sampling reach. The ratings of channel development are as follows:

Excellent: Well defined riffles present with gravel, cobble, or boulder substrates; pools vary in depth, and there is a clear transition between pools, riffles, and runs. Multiple sequences of riffles, runs, and pools are present within the reach.

Good: Riffles, runs, and pools are all present, but with less frequency, and are less distinct. Riffles have large substrates (gravel, rubble, or boulder), and pools have variation in depth.

Fair: Riffles are absent or poorly developed (shallow with sand and fine gravel substrates). Some deeper pools may exist, but transitions are generally not abrupt.

Poor: Riffles are absent; pools if present are shallow or lack variation in depth. Channelized streams generally have poor channel development.

G) Present Water Level – An estimation of water level as it relates to summer base flow expectations. In most streams, the "normal" water level can be determined with relative ease by observing channel characteristics.

D. Scoring the MSHA

Following are instructions on how to score the completed MSHA form. The maximum score is 100.

D.1. Surrounding Land Use: Average the scores of the two banks. For example, if residential/park was the land use selected on the left bank, and forest, wetland, prairie, shrub was selected on the right bank, then the land use score would be (2+5)/2=3.5. In the case of two land uses selected for one bank, the two scores are averaged together, and then averaged with the score of the other bank. The maximum land use score is 5.

D.2. Riparian Zone: Average the scores of the two banks for Riparian Width, Bank Erosion, and Shade; then add the three scores. For example, if moderate riparian width (3) was chosen for the left bank and very narrow (1) on the right bank; little bank erosion (4) on the left bank, and moderate (3) on the right bank; heavy shade (5) on the left bank, and substantial (4) on the right bank; the riparian zone score would be: [(3+1)/2] + [(4+3)/2] + [(5+4)/2] = 10. The maximum riparian score is 15.

D.3. Instream Zone

A) Substrate, Embeddedness, and Substrate Types – Add the scores of substrate, embeddedness, and substrate type. The substrate score is calculated by adding the two substrate scores for each channel type, multiplying by the percentage of the channel type, and adding the scores for each channel type present. If only one substrate type is chosen because it makes up more than 80% of the channel type, multiply the one substrate score by 2 before multiplying it by the percentage of the channel type. The maximum substrate score is 27.

B) Cover Type and Cover Amount – Add the scores of cover type and cover amount. The cover score can range from 1 to 8. The highest macrophyte score is 1, even if all three macrophyte types are present. The maximum cover score is 17.

D.4. Channel Morphology: Add the scores of Depth Variability, Channel Stability, Velocity Types, Sinuosity, Pool Width/Riffle Width, and Channel Development. The maximum channel morphology score is 36.

D.5. Total Score: Add the Surrounding Land Use, Riparian Zone, Instream Zone, and Channel Morphology scores together to get the total MSHA score for the site.

MPCA STREAM HABITAT ASSESSMENT

(revised 3-07)

1. Stream Documentation

Stream ______________________________

County ______________________ Date ______________

Field Number ______________ Person Scoring ______________

Site Location ______________________________

MSHA SCORE ☐ Max = 100

2. Surrounding Land Use (check the most predominant or check two and average scores) [L=left bank/R =right bank, facing downstream]

L	R			L	R		
☐	☐	Forest, Wetland, Prairie, Shrub	[5]	☐	☐	Residential/Park	[2]
☐	☐	Old Field/Hay Field	[3]	☐	☐	Urban/Industrial	[0]
☐	☐	Fenced Pasture	[2]	☐	☐	Open Pasture	[0]
☐	☐	Conservation Tillage, No Till	[2]	☐	☐	Row Crop	[0]

Land Use ☐ Max=5

3. Riparian Zone (check the most predominant)

A. Riparian Width

L	R			
☐	☐	Extensive	> 300'	[5]
☐	☐	Wide	150'-300'	[4]
☐	☐	Moderate	30'-150'	[3]
☐	☐	Narrow	15'-30'	[2]
☐	☐	Very Narrow	3'-15'	[1]
☐	☐	None		[0]

B. Bank Erosion

L	R			
☐	☐	None		[5]
☐	☐	Little	5-25%	[4]
☐	☐	Moderate	25-50%	[3]
☐	☐	Heavy	50-75%	[1]
☐	☐	Severe	75-100%	[0]

C. Shade

L	R			
☐	☐	Heavy	>75%	[5]
☐	☐	Substantial	50-75%	[4]
☐	☐	Moderate	25-50%	[2]
☐	☐	Light	5-25%	[1]
☐	☐	None		[0]

Riparian ☐ Max=15

4. Instream Zone

A. Substrate (check two for each channel type)

	Boulder [10]	Cobble [9]	Gravel [8]	Sand [7]	Clay [5]	Bedrock [5]	Silt [2]	Muck [1]	Detritus [1]	Sludge [0]	Channel Type %
Pool	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	______
Riffle	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	______
Run	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	______
Glide	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	______

B. Embeddedness

- ☐ None [5]
- ☐ Light 25-50% [3]
- ☐ Moderate 50-75% [1]
- ☐ Severe 75-100% [-1]
- ☐ No coarse substrate [0]

C. Substrate Types

- ☐ >4 [2]
- ☐ <=4 [0]

D. Water Color

- ☐ Clear
- ☐ Stained

Turbid

- ☐ Brown
- ☐ Green
- ☐ Other

Substrate ☐ Max=27

E. Cover Type (check all that apply)

- ☐ Undercut Banks [1]
- ☐ Overhanging Vegetation [1]
- ☐ Deep Pools [1]
- ☐ Logs or Woody Debris [1]
- ☐ Boulders [1]
- ☐ Rootwads [1]
- ☐ Macrophytes: [1]
  - ☐ Emergent
  - ☐ Floating Leaf
  - ☐ Submergent

F. Cover Amount (check one)

- ☐ Extensive >50% [10]
- ☐ Moderate 25-50% [7]
- ☐ Sparse 5-25% [3]
- ☐ Nearly Absent [0]
- ☐ Choking Vegetation only [-1]

Cover ☐ Max=17

5. Channel Morphology

A. Depth Variability

- ☐ Greatest Depth >4X Shallow Depth [6]
- ☐ Greatest Depth 2-4X Shallow Depth [3]
- ☐ Greatest Depth <2X Shallow Depth [0]

B. Channel Stability

- ☐ High [9]
- ☐ Moderate/High [6]
- ☐ Moderate [3]
- ☐ Low [0]

C. Velocity Types (check all that apply)

- ☐ Torrential [-1]
- ☐ Fast [1]
- ☐ Moderate [1]
- ☐ Slow [1]
- ☐ Eddies [1]
- ☐ Intermittent [-2]
- ☐ Interstitial [-1]

D. Sinuosity

- ☐ Excellent [6]
- ☐ Good [4]
- ☐ Fair [2]
- ☐ Poor [0]

E. Pool Width/Riffle Width

- ☐ Pool Width > Riffle Width [2]
- ☐ Pool Width = Riffle Width [1]
- ☐ Pool Width < Riffle Width [0]
- ☐ No Riffle [0]

F. Channel Development

- ☐ Excellent [9]
- ☐ Good [6]
- ☐ Fair [3]
- ☐ Poor [0]

G. Present Water Level

- ☐ Flood
- ☐ High
- ☐ Normal
- ☐ Low
- ☐ Interstitial

Channel Morphology ☐ Max=36